The effects of vocal loading and steam inhalation

on acoustic, aerodynamic and self-perceived voice measures in adults

Monica Gerosa

ABSTRACT

Background

Vocal fatigue is one of the most frequent underlying symptoms of many vocal health conditions. A variety of vocal loading tasks (VLTs) have been developed for research purposes to induce the laryngeal system to experience the symptom of vocal fatigue through high vocal demands. Previous works attempted to devise optimal VLTs with discrepancies between findings. Other studies tested the effects of systemic and surface hydration on voice measures and the effectiveness of rehydration interventions in restoring the detrimental effects of vocal fatigue. However, the available evidence concerning rehydration's effects on voice is inconclusive and lacks indications for clinicians regarding hydration schedules and recommended tools.

Aims

This research aims to investigate the effectiveness of a bespoke 20-minute VLT in inducing changes in acoustic, aerodynamic and self-perceived voice measures in vocally healthy adults. It also aims to determine the effects of 10-minutes steam inhalation and its potential effectiveness in reversing the detrimental effects of the VLT.

Methods & Procedures

A one-group pretest-posttest study design was conducted. Twelve vocally healthy adults (19-34 years) performed a 20-minute reading VLT with higher vocal intensity (70-85 dB), a prosodic voice effect and a forward head position. The VLT was followed by 10-minutes of steam inhalation with a common basin of boiling water and a towel to contain the steam. Sessions were held remotely using Zoom. The same outcome measures were collected at baseline, immediately after VLT and immediately after steam inhalation. Outcome measures involved acoustic parameters (F_0, intensity, jitter, shimmer, noise-to-harmonics ratio, cepstral peak prominence), the aerodynamic measure of maximum phonation time, vocal tract discomfort and reported sensations of effort and fatigue.

Results

Following the VLT, a statistically significant increase in vocal tract discomfort (number of sensations and severity), effort and fatigue was detected. Each of these measures decreased significantly after steam inhalation and showed no statistical difference between post-steaming and baseline. No significant effects for either the VLT or the steam inhalation were observed for acoustic or aerodynamic measures.

Conclusion

The bespoke VLT negatively affected self-perceived measures of vocal tract discomfort, effort and fatigue. 10-minutes of steam inhalation performed with a common basin of boiling water, displayed positive effects on self-perceived measures, reversing the detrimental effects of the VLT. Conversely, either the VLT and the steam inhalation did not affect voice quality, significantly altering acoustic and aerodynamic measures. This research suggests the relevant role of self-perceived measures in the characterisation of vocal fatigue following VLT. It informs clinicians regarding the effectiveness of steam inhalation as a simple and low-cost tool to be recommended to enhance the recovering of the perceived adverse effects of vocal fatigue. Future research including a control group will be needed to establish the superiority of this strategy over simple voice rest.

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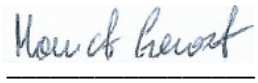
Declaration

I hereby declare that this is entirely my own work and that it has not been submitted as an exercise for a degree at this or any other University. I agree that the Department of Clinical Speech and Language Studies may lend or copy this dissertation upon request.



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List of Abbreviations

VLT: Vocal loading task

PTP: Phonation threshold pressure

F_0: Fundamental frequency

PPE: Perceived phonatory effort

NHR: Noise-to-harmonics ratio

CPP: Cepstral peak prominence

SLT: Speech and language therapist

VH: Vocal hygiene

MPT: Maximum phonation time

SOVTE: Semi-occluded vocal tract exercises

PIL: Participant information leaflet

PI: Principal investigator

DPIA: Data protection impact assessment

SPL: Sound pressure level

IQR: Interquartile range

RCT: Randomized controlled study

Chapter 1 – Literature Review

1.1 Introduction

The current study investigated the effects of vocal loading and steam inhalation on acoustic, aerodynamic and self-perceived voice measures in adults. The first chapter reports the literature on vocal fatigue, hydration and the evidence of the effects of rehydration on vocal fatigue. Lastly, the aims and research questions are stated.

1.2 Voice and vocal fatigue

1.2.1 Voice production

Voice production is an essential tool for humans, being a medium of oral communication (Tiwari & Tiwari, 2012). It involves the coordination of respiration and phonation with the combination of resonance and speech articulation (Boone et al., 2020). Traditionally, the processes of vocal fold vibration and voice production have been explained through the myoelastic-aerodynamic theory (Švec et al., 2021), the Bernoulli effect and the Body/Cover theory (Schwartz, 2004). A "normal voice" is widely identified by: i) normal voice quality, ii) appropriate voice to age, sex, cultural group, iii) free of pathology, iv) supports self-expression and self-satisfaction with voice (Boone et al., 2020).

A voice disorder and dysphonia are identified by the lack of one or more of these features. Moreover, several symptoms might be signs of a voice disorder. According to Roy et al. (2004), vocal fatigue and voice-related discomforts are considered signs of a voice disorder.

1.2.2 Vocal fatigue and vocal loading

Vocal fatigue is one of the most frequent underlying symptoms of many vocal health conditions (Gotaas & Starr, 1993; Hunter & Banks, 2017). It is defined as "a set of self-perceived vocal symptoms, as well as physiologic adaptations following extensive vocalizing" (Hunter et al., 2020, p. 6). Vocal fatigue is perceived as an increased sense of vocal effort. It typically increases with voice use, with peaks at the end of the day or during periods of high-vocal demand (e.g. prolonged speaking). It subsides with voice rest (Hunter, 2020; Solomon, 2008).

Vocal fatigue is a phenomenon frequently reported by clinicians who work with individuals with voice disorders (Nanjundeswaran et al., 2015). It can occur in the absence of dysphonia. Vocal

fatigue may represent a risk factor for the development of a voice disorder. Indeed, persistent vocal fatigue together with high vocal demands or maladaptive behaviours might lead in the long term to changes in the vocal fold mucosa, which may result in a voice impairment (Mathieson, 2001).

Since vocal fatigue can be present despite a normal-sounding voice and a healthy larynx, laryngoscopic findings as well as auditory-perceptual and acoustic measures have historically struggled to diagnose vocal fatigue. Vocal fatigue has been clinically identified by symptoms. Table 1.1 reports the typical clinical symptoms and features of vocal fatigue (Abou-Rafée et al., 2019; Hunter et al., 2020; Solomon, 2008).

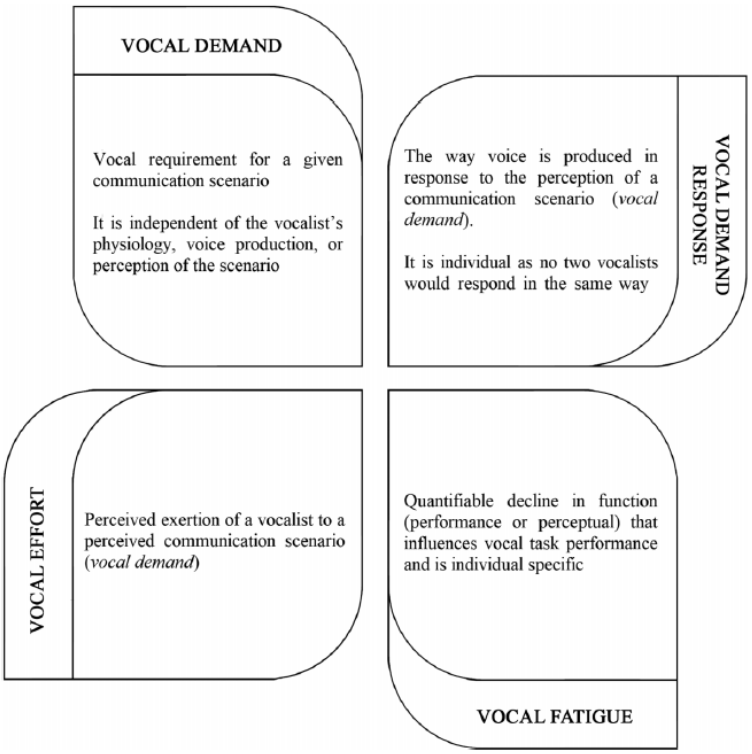
Table 1.1 Vocal fatigue symptoms

Vocal fatigue symptoms (Abou-Rafée et al., 2019; Hunter et al., 2020; Solomon, 2008)
- Increased vocal effort
- Increased vocal discomfort, throat pain
- Neck and shoulder tension
- Reduced control of voice flexibility, monotone voice
- Reduced vocal projection or power, weak voice
- Reduced control of voice quality, poor vocal quality
- Increase in symptom severity across the speaking day
- Improvements with vocal rest

Over the last two decades, vocal fatigue has been the focus of an increasing number of studies, which has led however to a variety of terms (Hunter, 2020). In a consensus description recently published by Hunter et al. (2020), experts analysed 971 publications pertinent to the topic and proposed a new terminology identifying the key terms of i) vocal demand, ii) vocal demand response, iii) vocal effort, iv) vocal fatigue. The definitions as reported by Hunter et al. (2020) are outlined in Figure 1.1.

Vocal fatigue is a challenging area in voice research that is attracting a widespread interest to the point that the Voice Foundation in 2020 titled its last international Voice Symposium as “Vocal fatigue: is it worth the effort?”. Despite research interest, there is still a considerable controversy surrounding the nature and the effects of vocal fatigue that needs to be addressed (Hunter, 2020; Nanjundeswaran, 2020; Solomon, 2020).

Figure 1.1: Terminology introduced by Hunter et al. (2020).



Solomon (2020) differentiated vocal fatigue into three dimensions based on the potential factors and mechanisms that contribute to the symptom of vocal fatigue. These are: mucosal, muscular and mental fatigue.

The mucosal (or non-muscular) dimension is the documented tissue fatigue response to external stress. Increased mucosal tissue viscosity was reported at high-pitch phonation (Titze, 1994). Moreover, a computational model highlighted how different layers like the vocal fold cover and ligament may react differently when subjected to a stress (Hunter et al., 2014). Other researchers investigated the tissues changes in the vocal fold cover looking at phonation threshold pressure (PTP) in conjunction with vocal fatigue. PTP is defined as "the minimum subglottal pressure required to initiate vocal fold oscillation" (Mathieson, 2001, p. 460). Studies showed that talking for 2 hours increased the PTP of participants (Solomon & DiMattia, 2000; Solomon et al., 2003).

Muscular (peripheral) fatigue concerns intrinsic laryngeal muscles and respiratory muscles. Claassen and Werner (1992) tested the larynges of eleven laryngectomized patients. The authors showed that the majority of intrinsic laryngeal muscle fibers were nonfatigable (type I, 55%) or fatigue resistant (type IIa, 38%) while only a minimum of fibers were fatigable (type IIb, 7%). Additionally, the respiratory muscles appeared fatigue resistant. Indeed, diaphragmatic fatigue was observed only after whole body endurance exercise at high intensity (Dempsey & Babcock, 1995).

Lastly, mental (central) fatigue refers to the perceived sense of effort, phonatory effort and respiratory effort. Studies reported that high vocally demanding tasks can increase mental fatigue (Hunter et al., 2020; Supinski et al., 1987).

Therefore, prolonged highly vocally demanding activities lead to vocal fatigue that may be observed with mucosal laryngeal tissue changes or mental fatigue. Conversely, a muscular fatigue is less likely to be observed.

1.2.3 Vocal loading tasks

To investigate vocal fatigue, researchers have developed a variety of vocal loading tasks (VLTs). A VLT is an activity that involves, for instance, prolonged or loud phonation. VLTs have been implemented and tested on healthy speakers for research purposes with the principle of inducing the laryngeal system to experience the symptom of vocal fatigue through high vocal demands (Nanjundeswaran, 2020). Therefore, vocally healthy individuals temporarily mimic voice difficulties that are subsequently assessed by researchers giving insights into the features of vocal fatigue. The long-term aim of VLTs is to develop a clinical tool to recognise individuals who are at risk of developing a voice disorder. VLTs have also been implemented to assess the effectiveness of interventions on a vocally fatigued voice (Fujiki & Sivasankar, 2017).

Previous studies attempted to devise an optimal VLT. A wide variety of VLTs has been developed that, together with other methodological differences (e.g. varied participants and outcome measures), led to mixed findings with reference to their effectiveness (Welham & Maclagan, 2003).

The variety of results from VLTs is due to the manipulation of intrinsic, extrinsic and individual factors (Fujiki & Sivasankar, 2017; Nanjundeswaran, 2020). These are outlined in Figure 1.2.

Figure 1.2: Vocal loading factors (Fujiki & Sivasankar, 2017; Nanjundeswaran, 2020)

Intrinsic factors	Extrinsic factors	Individual factors
•Type of task •Duration •Intensity (e.g. conversational, loud voice) •Use of a non-habitual voice (e.g. pressed voice)	•Presence of an ambient/ backround noise (e.g. multi-babble noise) •Room acoustics	•Personal features of participants (e.g. age, sex) •Profession •Vocal training

Historically, studies focused on duration as a main vocal loading factor (Remacle et al., 2012). An inconsistency in the length of time can be observed throughout the literature. VLTs vary from a duration of 3-10 minutes (Hanschmann et al., 2011; Whitling et al., 2015) to 1-2 hours or more (Kelchner et al., 2006; Solomon & DiMattia, 2000; Stemple et al., 1995; Vilkman et al., 1999). In some studies, participants could terminate the task if they developed fatigue or discomfort (Boominathan et al., 2010), whereas in others the duration was fixed for all participants. Lastly, VLTs were often completed in one session, however some studies implemented the procedure across multiple sessions (Vilkman et al., 1999; Vintturi et al., 2001).

An inconsistency between the type of task is also observed with VLTs that differed in frequency and intensity requirements and that varied between a reading task (Stemple et al., 1995), vowel sequence repetition task (Enflo et al., 2013) and singing task (Yiu & Chan, 2003).

Few studies suggested a relationship between postural deviations, vocal effort and voice parameters (Gilman & Johns, 2017; Giovanni et al., 2008; Kooijman et al., 2005; Lagier et al., 2010). Kooijman et al. (2005) observed a correlation between muscular tension, body posture and either voice handicap and voice quality in a sample of twenty-five female teachers. Gilman and Johns (2017) developed a VLT where individuals were asked to sustain the vowel /a/ in six postures that differed for head position and stance. Results showed greater significant differences in the self-perceived phonatory effort for the exaggerated forward and back head positions both in sitting and standing positions.

Environmental factors like different ambient noises were tested as contributory factors to vocal fatigue (Södersten et al., 2005). Researchers exploited the Lombard effect which states that voice intensity increases in the presence of background noise (Egan, 1971).

With reference to individual factors, it is understandable that features like participants' profession and their vocal training level might affect vocal fatigue. These individuals might require different VLTs to elicit vocal fatigue. For instance, VLTs were tested in teachers, who are at high risk of developing voice disorders given their daily vocal demands (De Bodt et al., 1998; Remacle et al., 2012). Similarly, studies on trained and untrained singers were conducted (Gelfer et al., 1991; Onofre et al., 2021). Recently, Onofre et al. (2021) published a study on twenty-one trained female choir singers, observing them for signs of vocal fatigue after a 60-minute VLT. In a previous work, Gelfer et al. (1991) compared the effects of 1-hour of loud reading on trained and untrained female singers. Data showed that acoustic measures (fundamental frequency - F_0, jitter, signal-to-noise ratio) of untrained participants appeared more negatively affected by the VLT.

Research findings overall recommend duration and additional variables like intensity and vocal quality as effective loading factors (Fujiki & Sivasankar, 2017; Remacle et al., 2012). When increased vocal intensity is the sole component of a VLT, a longer duration is required, often making VLTs impractical for research and clinical settings. Other researchers attempted to shorten the duration but had difficulties in detecting significant effects (Buekers, 1998; Whitling et al., 2015). For shorter VLTs, effects were mainly identified in self-perceived measures like ratings of the perceived phonatory effort (PPE) (Fujiki & Sivasankar, 2017). This result might indicate that mental fatigue could be detected before a mucosal fatigue.

The work of Fujiki et al. (2017) stands out for its methodology. The authors successfully developed a short duration VLT. This comprised a 30-minute reading task, alternating low-pitch and high-pitch pressed vocal qualities, and in the presence of ambient noise. The authors detected significant effects on acoustic and self-perceived measures. However, the reduced sample size (sixteen vocally healthy speakers) threats the validity of the study. Overall, this work highlights the importance of combining different factors to design an effective short VLT.

1.2.4 Sensitivity of outcome measures for vocal fatigue

Despite the influence of different VLT designs, higher sensitivity in detecting the effects of vocal fatigue have been observed within aerodynamic and self-perceived measures compared to acoustic parameters (Nanjundeswaran, 2020). PTP, as an aerodynamic parameter, showed a higher consistency in findings than other voice measures with changes observed even after short VLTs (Fujiki & Sivasankar, 2017). Indeed, Sivasankar and Erickson-Levendoski (2012) detected PTP changes after a 15-minute reading task combined with oral breathing.

Conversely, findings from acoustic measures are more inconclusive given also the variety of acoustic parameters tested. F0, intensity, jitter, shimmer have been captured but a disagreement is reported partly as a consequence of the implementation of different VLTs (Boominathan et al., 2010; Buekers, 1998; Fujiki & Sivasankar, 2017). Few studies tested cepstral peak prominence (CPP) and found mixed results, highlighting the importance of further studies (Fujiki & Sivasankar, 2017). Significant modifications of CPP were not observed on connected speech following a VLT of 30 sustained vowels (Gorham-Rowan et al., 2016) and after 45-minutes loud reading using a child-like speech characterised by high pitch (Sundarrajan et al., 2017). Conversely, Fujiki et al. (2017) detected a significant decrease in CPP on soft phonation after a 30-minute reading VLT with altered voice quality.

As for auditory-perceptual outcomes, measures were seen to be less sensitive overall compared to self-reported measures (Fujiki & Sivasankar, 2017; Nanjundeswaran, 2020). It must be considered

that given the subjective nature of auditory-perceptual measures and other methodological factors like raters' training and blinding, mixed findings are perhaps unsurprising.

Therefore, the implementation of an effective, practical, short-duration VLT should be kept as a goal for researchers together with the use of several outcomes to measure voice and vocal tract changes multidimensionally. Given the inconsistency of findings, additional data is required to better understand the sensitivity of measures in detecting the subtle effects of vocal fatigue.

1.3 Hygienic voice therapy

Hygienic voice therapy is a voice therapy approach widely used by speech and language therapists (SLTs). Its purpose is to identify and modify factors that may contribute to phonotrauma, as well as to modify vocal behaviour and promote vocal well-being (Alves et al., 2019; Behlau & Oliveira, 2009; Van Houtte et al., 2011). Vocal hygiene (VH) is relevant both for the prevention and treatment of voice disorders. Individuals with dysphonia usually have a less robust laryngeal system because of a potentially impaired anatomy and physiology which predispose them to major risks of harm from vocal abuse and misuse. Promoting vocal health is also crucial to facilitate vocal recovery (Boone et al., 2020; Schwartz, 2004).

The effectiveness of VH has been well documented, with greater benefits observed in combination with a direct voice therapy (Faham et al., 2016; Gillivan-Murphy et al., 2006; Pasa et al., 2007; Roy et al., 2001). VH increased voice care knowledge (Porcaro et al., 2019) and was positively correlated with the Voice Handicap Index, showing decreased scores post-intervention, indicating improvement (Pasa et al., 2007). Moreover, Fu et al. (2015) observed increased physiological, perceptual and acoustic measures after a combination of hygienic and direct treatments in a sample of fifty-three women with bilateral vocal nodules. The evidence, therefore, recommends VH as a preventive strategy or a management technique for voice disorders that should be integrated into a wider comprehensive treatment plan (Behlau & Oliveira, 2009; Fu et al., 2015).

A hygienic voice program includes several practices and recommendations that can be grouped into the components of vocal health, vocal abuse and vocal misuse (Schwartz, 2004). It is the role of clinicians to tailor the vocal hygiene program considering the patient's profile. The reasons for the inclusion of recommendations should always be discussed with the client (Mathieson, 2001). Table 1.2 summarises the most common VH advice used in clinical practice and for research purposes.

Table 1.2: Vocal Hygiene recommendations (Behlau & Oliveira, 2009; Roy et al., 2001; Schwartz, 2004)

Vocal health	• Lifestyle changes: reduce/eliminate tobacco, alcohol, recreational drugs, water and caffeine consumptions which might affect voice production. • Adequate environmental humidity, systemic and superficial hydration • Dietary modifications are recommended for patients with gastroesophageal reflux disease (GERD) • Reduction/elimination of environmental factors which might contribute to vocal issues: airborne irritants, chemical irritants, dust, exposure to allergens, acoustic properties of the room (e.g. background noise)
Vocal abuse	Reduction/ elimination of harmful vocal habits: • Excess loudness • Excessive and prolonged voice use • Misaligned postures which might affect voice production • Phonotraumatic events, yelling, shouting, whispering • Non-speech behaviours: throat-clearing, coughing, imitation of sounds • Voice use during physical exercises (e.g. grunting during sport activities) • Reduce the total amount of voice use introducing vocal rests.
Vocal misuse	Modifications regarding improper voice use: • Speaking/singing with a non-appropriate pitch or loudness • Talking with a low-pitched voice (e.g. glottal fry) • Inadequate use of breath support

Even though a growing number of studies have been conducted to explore the effects of hygienic voice therapy, data are still inconclusive (Behlau & Oliveira, 2009). The positive effects of VH programmes have been documented, but the efficacy of individual recommendations have usually not been tested in isolation, or limited data are reported to support them.

1.4 The role of hydration

Improving hydration is one of the most common interventions recommended by SLTs to enhance VH. Nonetheless, it has been historically based on anecdotal reports of its general benefits on voice (Sivasankar & Leydon, 2010). The underlying principle is that frequent hydration of the vocal folds contributes to the maintenance of regular phonation and prevents the occurrence of vocal fold lesions (Alves et al., 2019).

Adequate body hydration is a vital need for human beings since water is the main body constituent (approximately 63.3% of body mass) and contributes to the optimal function of several body systems (Armstrong, 2007; Jéquier & Constant, 2010). While approaching this broad topic, many variables need to be defined. Hydration is defined as "the current state of water balance within an individual" (Hartley & Thibeault, 2014, p. 2). This definition refers firstly to the total body water which varies according to water intake and losses. Water balance is reported to be maintained within 0.2% over a 24-h period under usual conditions of temperature and activity levels (Jéquier & Constant, 2010). The three major sources of water inputs in percentages are food ingestion (~30%), fluid ingestion (~60%) and tissue catabolism (~10%). The levels of hydration within the human body can be assessed and termed as appropriate (euhydration), reduced (hypohydration, dehydration) or excessively increased (hyperhydration). Given the documented effects of dehydration, later discussed (§1.4.1), euhydration is commonly recommended and desirable (Armstrong, 2007).

Concerning vocal fold hydration, different terms have been identified. Indeed, hydration or dehydration procedures might be considered as systemic or surface depending on whether they affect the whole body or just the vocal tract (Sivasankar & Leydon, 2010). Over the last two decades, several researchers have investigated the relationship between hydration and voice. Nevertheless, data are heterogeneous and controversies are reported regarding the contribution of each subtype of hydration. Lastly, specific hydration schedules with indications of effective tools, durations and repetitions still need to be defined (Alves et al., 2019; Behlau & Oliveira, 2009; Leydon et al., 2010).

1.4.1 Dehydration

Dehydration is defined as "the process of uncompensated water loss via urine, sweat, feces and respiratory vapor" (Armstrong, 2007, p. 3).

The detrimental effects of dehydration on the physiology and biomechanical properties of the vocal folds have been documented (Sivasankar & Leydon, 2010). The sol layer, that together with the deeper gel layer constitutes the mucosal surface layer of vocal folds, is sensitive to hydration changes. If the gel layer has the function of protecting the airway, the aqueous sol layer has a purely biomechanical function. It contributes to the viscoelasticity of the mucosal layer, thus being a relevant factor for optimal voice production (Tanner et al., 2007).

A study conducted in a canine model showed that dehydration leads to increased stiffness and viscosity of the vocal folds (Chan & Tayama, 2002). Dehydration challenges increase tissue viscosity and reduce mucosal mobility causing alterations in the movement of the vocal folds. This is reflected in additional perturbations in the acoustic signal, with effects on voice quality (Alves et al., 2019). Furthermore, during phonation fluids are pushed away from the area of contact,

increasing the risk of phonotrauma (Alves et al., 2019). Insufficiently lubricated vocal folds are more likely to become irritated in the presence of repeated collisions or phonotraumatic events. Subsequently, maladaptive behaviours like throat clearing can be introduced in response to sensations of discomfort, worsening the irritation (Franca & Simpson, 2009).

Several techniques were introduced in clinical studies to induce systemic or surface dehydration like oral breathing, low environmental humidity, inhalation of dehydrating agents and diuretics. Other studies implemented VLTs to replicate dehydrating conditions associated with prolonged talking.

A number of clinical studies have explored the effects of dehydration on voice quality, acoustic measures, phonatory efficiency and vocal effort (Leydon et al., 2009; Sivasankar & Leydon, 2010). Overall, systemic dehydration (fasting / non-ingestion of fluids) significantly affected acoustic measures (NHR, jitter, shimmer), aerodynamic measures (s/z ratio), phonatory effort and voice quality (increased hoarseness). Similarly, surface dehydration induced with oral breathing showed significant detrimental effects on acoustic measures (NHR, jitter, shimmer) and perceived phonatory effort (PPE) (Alves et al., 2019).

Adverse effects on the subglottic pressure were documented by Verdolini-Marston et al. (1990), who showed an increased PTP consequent to dehydration from diuretics. Analogously, Sivasankar and Erickson-Levendoski (2012) observed an increased PTP after obligatory mouth breathing during a loud reading VLT in vocally healthy adults.

Lastly, the effects of oral breathing versus nasal breathing were explored, showing differences between the two modalities with an increased PTP following oral breathing (Sivasankar & Fisher, 2002, 2003).

1.4.2 Systemic hydration

Systemic hydration refers to the general body hydration, usually achieved with daily fluid intake, that keeps the body tissues healthy. It is considered the simplest and most cost-effective form of hydration. Recommendations typically include approximately eight 8 oz water glasses per day (64 fl oz total) (Hartley & Thibeault, 2014).

Systemic hydration enhances the production of a thin, non-viscous mucosal layer that leads to the lubrification of vocal folds, ideally restoring an optimal vocal fold movement (Franca & Simpson, 2009). The study of Chan and Tayama (2002) on excised canine larynges showed that dehydration increased vocal fold stiffness and viscosity, while the same parameters were significantly reduced after systemic rehydration, supporting the important biomechanical effects of hydration.

In a clinical study conducted on female singing students, van Wyk et al. (2017) tested the effects of systemic hydration versus systemic dehydration after 2-hour singing rehearsal. Results showed positive effects on jitter and maximum frequency in the hydrated experimental group as well as an increased maximum phonation time (MPT) and greater s/z ratio compared to the control group (low hydration mode). Additionally, the grade of voice quality rated with the GRBAS scale (Hirano, 1981) was seen to be statistically significantly worse with systemic dehydration.

The systematic review by Alves et al. (2019) reports significant effects after water ingestion for acoustic measures (jitter, shimmer, maximum frequency) with a greater sensitivity compared to other measures. Significant effects are also reported for MPT as an aerodynamic measure, which can be explained by reduced subglottic pressure facilitated by moist vocal folds.

1.4.3 Surface hydration

Surface hydration (also called superficial or topical hydration) refers to a direct lubrification of the epithelial surface of the vocal folds (Sivasankar & Leydon, 2010). With systemic hydration, the process of homeostasis has to take place across a 24-h period and an equal hydration status might not be reached in all body tissues at the same time (Franca & Simpson, 2009). Conversely, the inhalation of warm steam through the oral/nasal cavities directly increases the moisture of vocal folds, affecting its viscoelastic properties. Therefore, in principle, the effects of systemic hydration on vocal folds are not as targeted as the effects conveyed by superficial hydration.

For this reason, SLTs and other professionals (e.g. vocal coaches) often recommend surface hydration to improve voice quality. It can be achieved through steam inhalation or nebulization of different substances (water, isotonic saline, hypertonic saline, mannitol). Additionally, an increasing number of devices have been developed and advertised in particular among intensive and professional voice users also with preventive aims. Common practices for surface inhalation include commercial humidifiers and nebulizers, facial steamers, steam inhalation from a basin of boiling water, breathing through a wet gauze and breathing steam during a warm daily shower. However, there is a lack of clinical studies validating clinical recommendations (Sivasankar & Leydon, 2010).

Mahalingam and Boominathan (2016) investigated the effects of 3 minutes of steam inhalation through a facial steamer after mouth breathing in forty-five vocally healthy females. All the acoustic parameters tested (jitter, shimmer, HNR) were negatively affected following mouth breathing and subsequently significantly improved after rehydration. No significant differences were observed between the baseline measures and the post steam inhalation measures supporting the important role of steam inhalation in restoring voice quality-related acoustic measures to normal ranges.

Effects of surface hydration on acoustic measures are also reported by Santana et al. (2017) who asked participants to perform 10 minutes of oral breathing, in order to desiccate the vocal tract achieving homogeneous baselines, and consequently to inhale a saline solution (NaCl 0.9%) for 5 minutes using a nebulizer. The intervention was performed every day over a 4-week period and outcome measures were obtained one week before and one week after the intervention. Data showed a significant increase in F_0 post-intervention that might be linked with quicker vibrations of vocal folds enhanced by the increased moisture of the vocal tract.

Other studies tested nebulised sterile water and other nebulised treatments (isotonic saline, hypertonic saline) after oral breathing. Even though positive trends have been found, no treatment significantly reversed the negative effects of desiccation on PTP (Tanner et al., 2016; Tanner et al., 2007). Nonetheless, PTP seems to be task-dependent and affected by pitch levels (Keltz & McHenry, 2020; Roy et al., 2003). Additionally, self-reported sensations of effort and dryness were seen to decrease with the nebulised saline treatment (Tanner et al., 2016).

Regarding environmental humidity, avoiding low humidity environments and increasing the ambient humidity is generally recommended considering the negative effects of superficial dehydration on voice (Alves et al., 2019). Sivasankar and Erickson (2009) conducted a study with female smokers and non-smoker controls who were asked to perform nasal and oral breathing challenges in either low ambient humidity (20% ± 5%) or moderate ambient humidity (55% ± 5%) environments. Both the subject group and the type of humidity did not show significant effects on PTP which significantly increased following the breathing challenge. Perhaps higher levels of environmental humidity might be required to attenuate the detrimental effects of dehydration.

Keltz and McHenry (2020) tested the effects of different vocal warm-up strategies on PTP. The strategies involved: 3 minutes of steam inhalation, 3 minutes of semi-occluded vocal tract exercises (SOVTE), steam inhalation combined with SOVTE. Improvements in vocal efficiency with a decreased PTP were mainly seen for steam inhalation (isolated or combined with SOVTE). However, patterns of increased and decreased PTP depending on the participant were observed for all the strategies. The work of Keltz and McHenry (2020) suggests that clinicians should recommend steam inhalation and carefully consider the client's profile before recommending strategies.

Recently, Borragan et al. (2021) investigated the effects of 10 minutes of nasal breathing through a damp gauze combined with vocal warm-up exercises in a sample of sixty-one adults. Results showed significant changes in the glottic closure, the amplitude of the mucosal wave, the maximum opening of the glottic space, the shimmer, and the B of GRBAS in the gauze group that performed nasal breathing and vocal warm-up exercises. Nonetheless, outcome measures did not include self-perceived sensations of vocal tract discomfort.

1.5 Vocal fatigue and hydration

Systemic and surface hydration have been also investigated in conjunction with vocal fatigue. Instead of testing rehydration after dehydration challenges, researchers tested rehydration after VLTs. The underlying principle is that highly intensive vocal demands can increase the viscosity and stiffness of vocal folds, making them susceptible to dehydration (Alves et al., 2019; Fujiki et al., 2017; Solomon, 2008). Indeed, viscoelastic properties affect the vibration of the vocal folds and are influenced by hydration levels (Chan & Tayama, 2002; Santana et al., 2017; Solomon, 2008).

Researchers have been interested in assessing the potential role of hydration in restoring the adverse effects of VLTs, informing clinicians about the usefulness of recommending re-hydration after vocally demanding activities. While the effects of vocal fatigue or hydration have been individually documented (§1.3, §1.4), the relationship between these two domains has been poorly explored (Fujiki et al., 2017).

Yiu and Chan (2003), tested systemic hydration and vocal fatigue in twenty amateur singers. Participants who were given both systemic hydration and vocal rest during a singing VLT were able to sing significantly longer than those without hydration, but no significant effects on acoustic measures were detected.

Vintturi et al. (2001) tested the effects of a 45-minute reading VLT. Data showed no effects of either low or high ambient humidity on vocal loading. Nevertheless, this study suffers from several pitfalls. The study manipulated multiple other factors introducing potential confounding variables. Indeed, authors exposed participants to eight different conditions (10 participants for each condition) combining the low and high ambient humidity with two loudness levels required during VLT, and a sitting versus standing posture during VLT. The authors also did not control for hydration levels, for instance through blood plasma concentrations or bioelectrical impedance analysis, or at least asking participants to avoid any fluid ingestion before the experiment to achieve homogeneous baselines. Lastly, a multidimensional voice assessment was not performed. Outcome measures mainly included time-domain parameters of the glottal flow.

In a more recent study, Fujiki et al. (2017) tested environmental humidity in conjunction with a 30-minute VLT in sixteen vocally healthy adults. Participants were exposed either to low (22% - 28%) or moderate (52% - 65%) ambient humidity for 20 minutes before the VLT. Multiple outcomes measures were assessed. Data showed that even if the VLT successfully produced effects on acoustic and self-perceived voice measures, no major differences in the magnitude of the detrimental effects were observed for the two ambient conditions. However, as previously supported by Sivasankar and Erickson (2009), it should also be considered that rehydration

treatments that do not maximise exposure to high humidity levels (80%-100%) may not be successful as a consequence of the robustness of vocally healthy larynges. Perhaps, a surface hydration achieved with steam inhalation, compared to an environmental humidifier, might induce a more directed lubrification of the vocal fold mucosa.

1.6 The purpose of this research

A growing body of literature has investigated vocal loading as well as the effects of hydration on several voice measures. Nonetheless, results are often inconclusive and strictly task-dependent. Heterogenous methodologies that involve different inclusion/exclusion criteria, different study designs and pre-session instructions as well as the use of different equipment and outcome measures; make findings difficult to compare.

Vocal fatigue is undoubtedly a complex multifactorial phenomenon widely experienced, often the core of the current scientific debate. Many attempts have been made to implement effective VLTs in research settings. This research aims to investigate whether a practical and short 20-minute VLT, designed by combining multiple loading factors affects acoustic, aerodynamic and self-perceived voice measures. Thus, it extends the knowledge of vocal fatigue on vocally healthy adults.

Regarding hydration, overall positive effects were found for systemic and surface hydration although mixed findings have been recorded (Alves et al., 2019). Only a limited number of studies have explored the role of rehydration in restoring the detrimental effects of vocal fatigue. This research seeks to expand current knowledge by investigating the interaction between vocal fatigue and surface hydration achieved with 10 minutes of steam inhalation performed with a basin of boiling water and a towel to contain the steam. This may inform clinicians about including steam inhalation in vocal hygiene programmes providing details regarding equipment and duration to recommend during home-practice. The research may also inform about the implementation of steam inhalation as a cool-down strategy to recommend after vocally demanding activities to restore the effects of vocal fatigue.

1.7 Aims

The first aim of this study is to investigate the effectiveness of a Vocal Loading Task (VLT) in inducing changes in voice outcome measures in adults.

The second aim is to investigate the effects of steam inhalation in adults and its potential effectiveness in restoring the adverse effects of a VLT.

1.8 Research questions

To address the research aims, three research questions are stated:

1) Is there a difference in voice outcome measures between baseline measures and post VLT measures in adults?

This research question will identify whether the bespoke VLT designed for this study produced aberrant voice quality or vocal tract symptoms. If successful, this has the advantage of providing standardised and shorter VLT than others published in the literature.

2) Is there a difference in voice outcome measures between pre and post steam inhalation measures in adults?

This research question explores the effects of the steam inhalation procedure implemented for this study on voice quality and self-perceived sensations. It will inform clinicians regarding the potential benefits of steam inhalation achieved with a common basin of boiling water.

3) Is there a difference in voice outcome measures between baseline measures and post steam inhalation measures in adults?

This last research question will investigate the effectiveness of steam inhalation in recovering the potential detrimental effects induced by the VLT. If effective, no differences between baseline and post rehydration measures will be detected thus informing regarding the role of steam inhalation in restoring the adverse effect of vocal fatigue.

1.9 Summary

Throughout this chapter, three main themes were explored: vocal fatigue, hydration, vocal fatigue in conjunction with hydration. Lastly, aims and research question were stated. The next chapter will discuss the methodology adopted in this research.

Chapter 2 – Methodology

2.1 Introduction

This chapter reports the research methodology adopted in the current study. It provides also ethical considerations and discusses the validity and reliability of this work.

2.2 Ethics

The present research was submitted for ethical approval as a joint project with another MSc. student. The recruitment of participants and the data collection were performed by the principal investigator (PI) and by the co-investigator, whereas different data analyses were performed.

Ethical approval was obtained from the School of Linguistic, Speech & Communication Sciences, Trinity College Dublin on 19.02.21 (Appendix I). The ethical principles of respect for persons, autonomy, justice, beneficence and non-maleficence were considered in the current project (Beauchamp & Childress, 2019).

2.2.1 Respect for persons and autonomy

By upkeeping the principles of respect for persons and autonomy, the researcher has "to disclose information, to ensure understanding and voluntariness and to foster adequate decision making" (Beauchamp & Childress, 2019, p. 80). Those principles have been adhered to by providing participants with the consent form and the participant information leaflet (PIL) (Appendices II, III). The PIL contained detailed information about the project's aims, procedures, data handling and potential risks. Contact details of the PI, co-investigator and the supervisor of the study were included. Queries related to the study were directly answered by the investigators. After a three-day period to freely consider the research, written consent was obtained. Withdrawing from the study was possible at any time.

Participants were informed that their confidentiality was kept by using only institutional email accounts for correspondence, Zoom as a secure platform (Zoom Video Communications Inc., 2016) and Microsoft OneDrive (Microsoft Corporation, 2007) as a storage platform. No session was recorded. Regarding data storage, all identifiable data (name, voice samples, consent forms) were password protected and encrypted in a Zip file, stored in Microsoft OneDrive, accessible only to the investigators. The data retention period was seven years according to ethics committee

recommendations. Considering the fully online nature of this study, a Data Protection Impact Assessment (DPIA) was conducted indicating a low risk level (Appendix IV).

2.2.2 Principles of justice, beneficence and non-maleficence

To ensure the principle of justice, all eligible participants were enrolled in the study. Procedures were equally administered ensuring fairness and equality.

Regarding the principles of beneficence and non-maleficence, the researcher has to minimise potential risks and increase possible benefits for participants (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979). Considering the ongoing global pandemic, participant protection was ensured by collecting data online.

VLTs are designed to stress the laryngeal system and adverse effects might occur. Increased tension due to a muscular fatigue, or laryngeal mucosal damage may result (Solomon, 2008). This might seem at odds with the principle of non-maleficence. The VLT used in this study was however designed on the basis of existing literature not to be harmful to individuals. Moreover, VLTs are comparable in their execution to vocal function exercises. These are a widely used evidence-based therapeutic approach that add a demand to the laryngeal system in order "to strengthen and rebalance the laryngeal musculature" (Bane et al., 2019, p. 2; Stemple et al., 1994). Therefore, it was hypothesized that VLTs would not generate long-term detrimental effects.

To ensure no long-term consequences from the VLT, a comprehensive understanding of the correct procedure was facilitated by sending an instructional video in advance, performing a VLT trial and reviewing the full procedure with participants. To prevent potential adverse effects from VLTs, participants were given a set of post-session vocal hygiene recommendations to promote relaxation and a vocal well-being (Appendix V). Lastly, participants were invited to contact the investigators in case they were concerned with their voice or in case of long-term adverse effects. A voice assessment session was scheduled with participants if needed.

2.3 Participant characteristics

2.3.1 Inclusion and exclusion criteria

This study recruited adults with no known voice disorders. A set of sample criteria were carefully defined to control for possible confounding factors and were confirmed before scheduling sessions with participants (Table 2.1). Exclusion criteria were also designed to avoid recruiting participants at potential risk of harm from VLT (e.g. smokers).

Table 2.1: Inclusion and exclusion criteria

Inclusion criteria	**Rationale**
Age: adults aged 18-60	Individuals younger than 18 years were excluded considering the significant influence of childhood and adolescence on voice measures (McAllister & Sjölander, 2013). Adults older than 60 years may present presbyphonia and presbyacousis (Angerstein, 2018).
Exclusion criteria	**Rationale**
History of voice pathology, self-reported voice problems, voice therapy	These parameters identify individuals with voice disorder whereas the current research focused on vocally healthy individuals
Professional voice users: trained singers only	Trained singers were seen not to be sensitive to VLTs (Gelfer et al., 1991).
Smokers	Cigarette smoking is a risk factor for the development of voice disorders, like Reinke's Oedema (Tavaluc & Tan-Geller, 2019). Smokers can be at greater risk of vocal harm from VLTs.
Taking medications on a regular basis at the time of the study, except for birth pill control	Medications can affect hydration status and cause symptoms of dryness, vocal fatigue (Bock, 2019; Nemr et al., 2018; Walter & Lenz, 2011), while contraceptive pills do not affect voice as fluctuations in sex hormones might do (Giersch et al., 2020; Lã & Polo, 2020; Pavela Banai, 2017). People who take regular medications are possibly at risk of harm from VLTs.
Respiratory problems: upper/ lower respiratory tract infection, asthma at the time of data collection	Those participants can be at greater risk of harm from VLTs.
Allergy at the time of data collection	Allergy can affect phonation (Spantideas et al., 2019). Those participants can be at risk of harm from VLTs.
Flu at the time of data collection	Those participants can be at risk of harm from VLTs
Self-reported hearing loss	Hearing loss affects the ability to control the loudness during VLTs

2.3.2 Recruitment

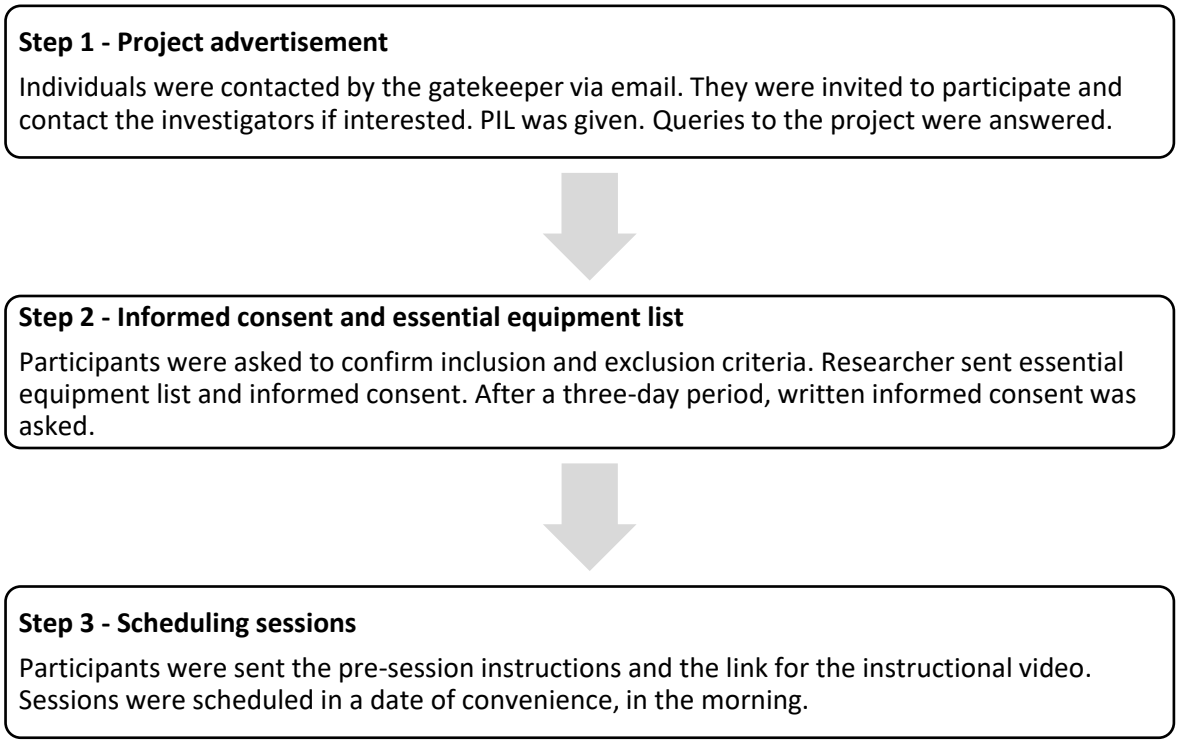
The project was advertised to undergraduate and postgraduate students of the Department of Clinical Speech and Language Studies of Trinity College Dublin. The departmental Executive Officer acted as the gatekeeper sending an email to prospective participants on behalf of the investigators. The email included the PIL and the inclusion/exclusion criteria (Appendix VI). Prospective participants were offered the possibility of a Zoom call to explain further details of the project and answer any queries.

The investigators replied to interested participants asking them to confirm population criteria, sent an essential equipment list. After a three-day period, written informed consent was asked. Sessions were scheduled for a date of their convenience in the morning so that external vocal demands were less likely to have occurred. Pre-session instructions further explained (§2.5.1) were sent to participants.

Additionally, an instructional video showing all the experimental procedures demonstrated by the investigators was filmed specifically for this research, uploaded as unlisted YouTube Video and the link was sent to participants to prepare individuals to the session. The video can be viewed at the following link: https://youtu.be/DAY8e13K9l4.

The overall recruitment process is summarised in Figure 2.1.

Figure 2.1: Recruitment process



2.3.3 Sampling method

A convenience sampling strategy, a form of non-probability sampling, was chosen for this project. Within a self-selected sampling strategy, prospective participants placed themselves into the sample of the target population (Passer, 2014). A convenience sample was deemed suitable considering its large use in health research and the limited available time for recruitment (Bowling, 2014).

2.3.4 Sample size estimation

The total sample size of an experiment can be calculated combining the effect size, *P value* and power, chosen accordingly to the nature of the study (Cadeddu et al., 2008). A sample size calculation was conducted with G*Power 3.1 software (Faul et al., 2007). Although a power level of 0.80 is commonly used in research, the power of this study was set to 0.90, reducing the probability of a type II error (β=10%). A medium effect size of 0.25 was chosen based on Cohen's f measure. The total sample size was n=36. Details on the sample size calculation are listed below (Table 2.2).

Table 2.2: Sample size calculation

Statistical test	ANOVA: Repeated measures, within factors
Effect size f	0.25
α error probability	0.05
Power	0.90
Number of groups	1
Number of measurements	3
Correlation among repeated measures	0.5
Nonsphericity correction	1
Total sample size	**36**

2.4 Materials & methods

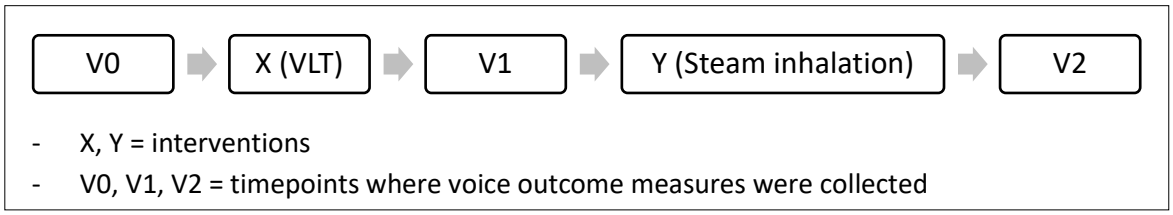
2.4.1 Research design

To address the research questions, a quantitative methodological approach was chosen since it permits descriptive and inferential statistics to be determined from the collected numerical data (Passer, 2014). A systematic or scoping review was discarded since the project's aim is to assess new instruments and previous reviews already exist.

A quasi-experimental prospective study, a one-group pretest-posttest design was the most appropriate design since it measures within-subject changes in outcome measures following interventions. However, it "lacks key aspects of experimental control" (Passer, 2014, p. 302) reducing the internal validity of the study. The lack of a control group for practical reasons made it more difficult to infer causality between variables. Indeed, natural changes could potentially be responsible for effects. That threat was counterbalanced with a robust design that minimised confounding factors.

The study was divided into three data collection timepoints: baseline (V0), after VLT (V1), after steam inhalation (V2). The same outcome measures in the same sequence were collected at each of these time points to capture changes in voice. A diagram of the one-group pretest-posttest design of Campbell et al. (1963) is applied to this research (Figure 2.2).

Figure 2.2: One-group pretest-posttest study design



This research was an exploratory study where interventions (VLT, steam inhalation) were specifically designed and tested. As such, research hypotheses were not formulated, but rather research questions were stated (§1.8).

2.4.2 Dependent and independent variables

Experimental study designs aim to assess causality between dependent and independent variables (Bowling, 2014). In this study, the dependent variables are represented by voice outcome measures.

PTP is an aerodynamic measure that refers to "the minimum subglottal pressure required to initiate vocal fold oscillation" (Fisher & Swank, 1997, p. 1). Self-perceived outcomes have traditionally involved self-evaluation questionnaires to measure the impact of voice issues on individuals (Behlau et al., 2017). According to the literature, PTP and self-perceived measures are sensitive outcomes for vocal fatigue. A disagreement exists for acoustic measures (F_0, intensity, jitter, shimmer, NHR). Only a few studies captured CPP with mixed results (Fujiki & Sivasankar, 2017). Regarding hydration, acoustic measures were mainly used in previous works (Alves et al., 2019).

Therefore acoustic, aerodynamic and self-perceived measures were chosen as outcome measures. Acknowledging the sensitivity of PTP and its impracticability for this project, MPT was chosen as an alternative aerodynamic measure.

Concerning self-perceived measures, this study adopted a modified version of the Vocal Tract Discomfort Scale (VTDS) which is designed to evaluate "the severity and frequency of an individual's throat discomfort" (Mathieson et al., 2009, p. 2). The VTDS is commonly used with clients who experience vocal tract discomfort that often accompanies muscle tension dysphonia (Mathieson et al., 2009). Individuals are asked to rate the severity and frequency of eight sensations from 0 (least) to 6 (most). For this study, a modified version was developed including only a rating of the severity

of the listed sensations whereas the frequency was excluded since it was non-relevant. To capture a wider range of sensations, participants were offered the opportunity to specify other sensations and their severity. Moreover, two additional rating scales on effort and fatigue were included to quantify the experience of participants on these qualitative descriptors from 0 (least) to 10 (most). The modified VTDS and the rating scales of effort and fatigue were then implemented on Qualtrics (SAP, Walldorf) to permit online administration (Appendix VII).

Independent and dependent variables of the present research are reported in Figure 2.3.

Figure 2.3: Independent and dependent variables

Independent variables	**Dependent variables**	
• Time – V0 • Time – V1 • Time – V2	Acoustic measures:	• Fundamental frequency (F_0) • Intensity (dB) • Jitter • Shimmer • NHR • CPP
	Aerodynamic measures:	• Maximum phonation time (MPT)
	Self- perceived measures:	• Scores on modified VTDS (Mathieson et al., 2009) • Rating scales of effort and fatigue

2.4.3 Research instruments and equipment

Data collection was conducted remotely by the PI and co-investigator, both qualified SLTs, following practice sessions and a protocol to ensure a consistency between investigators. Individuals were monitored for the whole procedure. Outcome measures were collected during the session. In particular, acoustic and aerodynamic measures were recorded during the session by participants with their smartphones, sent to the PI and subsequently analysed. With the onset of the COVID-19 pandemic, telepractice and remote recordings have become accessible and reliable alternatives to in-person voice assessment techniques (Schneider et al., 2021). Grillo et al. (2016) confirmed that performing remote recordings with different smartphones does not significantly affect acoustic analysis. Recordings in an uncompressed file format (.wav) were required since audio compression might affect acoustic measures (Cavalcanti et al., 2021).

The free of charge App “Voice Recorder” was suggested either for android (j labs, 2020) and iOS (TapMedia Ltd, 2020) smartphones since it allowed to record voice samples in the appropriate format.

Figure 2.4: Screenshots of *Voice Recorder & Audio Editor* app for android (j labs, 2020) and iOS (TapMedia Ltd, 2020) smartphones.

Android – j labs *iOS – TapMedia Ltd*

Before the session, participants were provided with an essential equipment list (Figure 2.5).

Figure 2.5: Essential equipment list

Essential equipment list
This is the essential equipment you will use during the session: • Laptop or computer with microphone available • Create a Zoom account ready to be used • Smartphone (charged) • Download the app “Voice Recorder” (j labs on Android or TapMedia Ltd on iOS) which is free of charge. This will be used to record your voice in an uncompressed format (.wav) to ensure the quality of audio. • Download the App “Decibel X” (SkyPaw Co. Ltd, 2020), which is free of charge and available for iOS and Android. This will be used to monitor your loudness. • Ruler (30 cm) to measure distances • Basin and a towel for the steam inhalation • Water and kettle/pot to boil water available

The sound pressure level (SPL) meter App “Decibel X” (SkyPaw Co. Ltd, 2020) was used during the VLT further explained (§2.5.2). The app was chosen as it is available on Android and Apple devices, improving instrumental reliability. During the experimental procedure, individuals were asked to monitor their loudness by checking the red number showed in Figure 2.6 which reported dB SPL.

Figure 2.6: Screenshot of the App *Decibel X:dB Sound Level Meter* (SkyPaw Co. Ltd, 2020)

Furthermore, no requirements for the shape or dimension of the basin were given, increasing ecological validity, since these will vary amongst households.

The research instruments used by the investigators are presented in Figure 2.7.

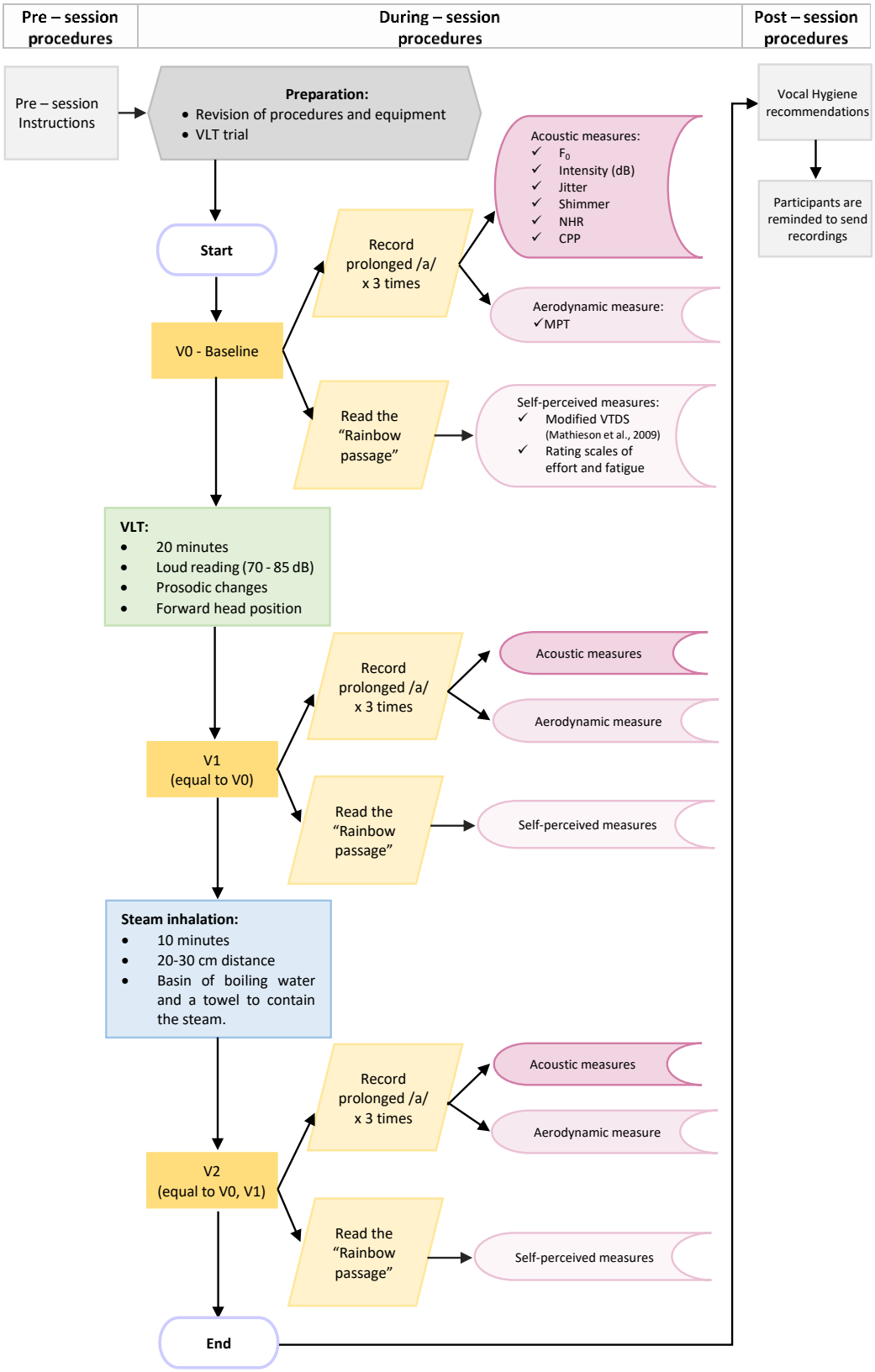
Figure 2.7: Research instruments

Research instruments
• Modified version of the VTDS (Mathieson et al., 2009) • Qualtrics (SAP, Walldorf) used to administer modified VTDS • The Chronicles of Narnia ebook (Lewis, 2004) for VLT. • The “Rainbow Passage”, to capture voice samples at V0, V1, V2 • Stopwatch • Zoom as a platform to arrange sessions and carry out data collection • Praat version 6.1.29 (Boersma & Weenink, 2020) for acoustic analysis • Microsoft Excel for data collection • IBM SPSS Statistics Version 26.0 (IBM Corporation, Armonk) for statistical analyses • HP laptop with Windows 10 Home

2.5 Procedures

Pre-session, during session and post-session procedures were carefully defined and equally applied to participants. These are outlined in the flowchart below (Figure 2.8).

Figure 2.8: Flowchart of the study procedures



2.5.1 Pre-session procedures

Pre-session instructions were designed to control for possible confounding factors (Figure 2.9). Sessions were arranged for mornings to minimise the risk that voices were already fatigued. Participants were asked to be awake for at least one hour to ensure they were in the appropriate physical conditions to perform the VLT without causing damage. Participants were asked to avoid hot showers, foods or drinks before the session since differing surface and systemic hydration could have influenced the baseline. Individuals were also recommended to use a quiet room for the session to reduce background noises. Indeed, room acoustics and background noises might affect voice parameters even more than the type of microphone used for recordings (Bottalico et al., 2020).

Figure 2.9: Pre-session instructions

Pre-session instructions
• Avoid vocally harmful behaviours (e.g. long periods of shouting, singing or projecting your voice) in the 24h before the session. • Be up from bed for at least 1 h with minimal voice use since then. • Avoid hot shower or bath before the session. • Avoid foods or drinks before the session. • Use a quiet room for the session so that recordings will not be affected by background noises

2.5.2 During session procedures

At the beginning of the session, all the essential equipment and procedures were revised. A short VLT trial was conducted to assess the participant's understanding of the task. During the session, the investigators shared their computer screen as needed, for example to display reading passages.

Initially, participants were asked to confirm their identity and provide their age. The same outcome measures using the same procedures and sequences were collected at V0, V1, V2. Participants were asked to record the following tasks at 4 cm distance from the smartphone in an uncompressed format (Cavalcanti et al., 2021; Grillo et al., 2016):

- Take a deep breath and produce a sustained /a/ for as long as possible in a comfortable voice. Three trials were conducted, the longest one was used for aerodynamic and acoustic analyses according to Mathieson (2001).
- Read naturally the "Rainbow passage" on the screen and rate the modified VTDS and the rating scales of effort and fatigue.

Figure 2.10: Screenshot of the instructional video showing the recording of voice samples

After baseline measures, the VLT took place. The VLT was designed with the goals of being as short as possible in duration and non-traumatic to avoid participant burden. It was designed to be challenging to induce vocal fatigue, well-controlled to avoid potential confounders and easily replicable to increase the external validity of the procedure. To shorten the duration, multiple loading factors were manipulated based on previous works. Higher vocal intensity, a prosodic voice effect and altered head posture were chosen as the most appropriate (Gilman & Johns, 2017; Remacle et al., 2012). The VLT consisted of reading loudly and with emphasis "The Chronicles of Narnia" (Lewis, 2004) for 20 minutes with an exaggerated forward head position (Figure 2.11). To convey a prosodic voice effect, participants were invited to perform as if they were reading the book to a child adding inflections with their voice.

Figure 2.11: Screenshot of the instructional video showing the VLT

Alternative methods were also evaluated. Adding background noise to increase the intensity of participants exploiting the Lombard effect was discarded because it was not feasible online (Whitling et al., 2015). Instead, an SPL meter app helped participants maintain a loudness range of 70 - 85 dB. That range was chosen to ensure loud voice, but prevent participants from using extreme loudness and risking vocal harm given that precise instrumental sensitivity was not known. At the end of every page, the investigator reminded participants to check their loudness. Moreover, the strategies of asking participants to use an altered pitch (Buekers, 1998) or a pressed voice (Fujiki et al., 2017) were discarded considering the potential inconsistency of participant responses. Those methods, mainly based on modelling, were difficult to implement, which might affect reliability. Instead a prosodic voice effect represented a more natural demand for participants. Regarding the exaggerated forward head position, it was seen to significantly affect the self-perception of phonatory effort (Gilman & Johns, 2017). It requires only a minimum of coaching. Lastly, an inconsistency in length of time of VLTs has been documented in the literature (§1.2.4). Considering the aimed goals of the present VLT, based on the 30-minutes VLT of Fujiki et al. (2017), the duration was shortened and kept to 20 minutes given that additional loading factors were introduced.

The conceptual framework concerning vocal fatigue provided by Hunter et al. (2020) (§1.2.2) is applied to the present research as followed:

- Vocal demand: The vocal requirement generated by the VLT.
- Vocal demand response: The voice features (loudness, pitch) modulated in response to the VLT.
- Vocal effort: The participant's perception of the effort associated with voice production during the VLT.
- Vocal fatigue: The result of the vocal effort. The participant's voice might get fatigued in response to the VLT.

Immediately after VLT, the same baseline measures procedures (V0) were repeated (V1). Participants were then asked to boil some water for the next phase.

For the steam inhalation phase, participants were asked to do a 10-minutes steam inhalation over a basin of boiling water at a distance range of 20-30 cm, measured with a ruler (Figure 2.12). To maximise the effects of steam inhalation, participants were asked to breathe in through both their oral and nasal cavities simultaneously, ensure water was boiling or at least producing steam, and a towel was worn over the head to contain the steam.

Figure 2.12: Screenshot of the instructional video showing the steam inhalation intervention

Lastly, immediately after the steam inhalation, outcome measures were collected (V2) identically to V0 and V1.

The instructions provided during the experimental phase are reported below (Table 2.3) thus ensuring consistency between the investigators.

Table 2.3: During session instructions for participants

Outcome measures V0, V1, V2	Remember to sit in a comfortable position. Open the Recorder app and select the *.wav* format. Measure 4 cm distance from the smartphone to your mouth. While recording, produce a sustained /a/ for as long as possible with a comfortable voice. Then press save and rename the file with your code participant number followed by the number of the recording. Let's do it three times.
	Read the "Rainbow passage" shared on the screen as naturally as possible. Rate the sensations that you are experiencing on the shared scale on the screen.
VLT	Open your smartphone and the Decibel X app. Place the smartphone on the laptop. With a forward head position, read loudly with emphasis the book until I stop you. Imagine reading it to a child. Check to have a loudness of 70-85 dB using the app. At the end of every page I will remind you to check your loudness saying "check your loudness". Keep on reading until I will stop you
Steam inhalation	Take the laptop and move to the kitchen or bring the basin of boiling water next to you. Take the kettle or the pot and check that the water is still boiling or steaming. If it is not, put it boiling some minutes more. Pour the water into the basin. Sit in a comfortable position. Measure 20-30 cm distance from the water. Put the head under a towel. Breathe at a natural pace into the oral-nasal cavity at that distance, until I stop you.

2.5.3 Post-session procedures

After the session, participants were provided with a document with evidence-based vocal hygiene recommendations to prevent potential vocal fatigue (Mathieson, 2001) (Appendix V). Finally, individuals were reminded to send recordings and were advised to contact the researchers if they had any voice problems afterwards.

2.6 Validity

2.6.1 Internal validity

Internal validity is the confidence in which a study demonstrates that one variable truly produced an effect on another variable without the obtrusion of external factors (Bowling, 2014; Passer, 2014). Although acknowledging the quasi-experimental nature of this study with a lack of a control group, the rigorous study design with multiple outcome measures ensured internal validity. Indeed, the designed set of inclusion/exclusion criteria and pre-session instructions minimised confounding factors.

Nonetheless, given the necessarily remote nature of the study, environmental humidity was not controlled. Opening windows to normalise humidity between participants was discarded due to the multiple geographical locations of individuals. Female sex hormone fluctuations weren't controlled. Literature shows that hormones might influence hydration and voice function (Giersch et al., 2020; Pavela Banai, 2017). However, controlling for menstrual cycle among women was not feasible since it would have not allowed the recruitment of the expected sample size. It should be considered that sex hormones might affect only some outcome measures, like F_0 (Lã & Polo, 2020), with a potential small magnitude not relevant to the analyses.

An evaluation of potential internal validity threats identified in the literature (Bowling, 2014; Higgins et al., 2019; Passer, 2014) within the measures taken to minimise risks is provided below (Table 2.4).

Table 2.4: Potential internal validity threats

Potential internal validity threats	
Maturation	Outcome measures were collected immediately after VLT or steam inhalation. The risk that the passage of time affected measures was therefore minimised.

Testing	Outcome measure procedures were chosen as short, minimally burdensome, easily applicable and consistent for participants. It was reduced the possibility that the collection of baseline outcomes could lead to testing effects that might affect the further steps of the experimental procedure.
Instrumentation	Same outcome measures in the same sequence were collected at V0, V1, V2. However, given the remoteness nature of the study, a variety of equipment between participants existed. Consistency of the equipment of the researcher was observed throughout data collection.
Attrition	Procedures involved only the minimum essential steps. A detailed session protocol ensured a less time-consuming procedure, reducing the risk of subject loss during the study.
Selection	The current study included only one group of participants. The same procedures were conducted with all individuals. Therefore, selection, social interaction and regression to the mean would not be potential threats to the internal validity.
Social interaction	
Regression to the mean	
Mortality	This internal validity threat is not applicable to the current project

2.6.2 External validity

External validity is related to the generalisability of findings, across different populations and settings (Bowling, 2014). In particular, ecological validity refers to the generalisability of findings from the research context to a natural setting (Passer, 2014). The online nature of this study with the use of different types of basins improved ecological validity since usually vocal hygiene practices do not involve specific types of basins. The main limitation to the generalisability of findings was the task dependency of results. Indeed, the VLT and steam inhalation procedures were specially designed for this research.

Threats to external validity identified in the literature (Bowling, 2014; Higgins et al., 2019; Passer, 2014) and relevant to the current project are provided in Table 2.5.

Table 2.5: Potential external validity threats

Potential external validity threats	
Sampling bias	Considering the inclusion/exclusion criteria of this project, the final sample was expected to be representative of vocally healthy adults aged between 18 and 60 years. However, considering that the research was advertised through undergraduate and postgraduate students of the Department of Clinical Speech and Language Studies of Trinity College Dublin, the final sample was likely to be clustered in age and sex.

Experimenter effect	The study procedures and the protocol for the investigator were rigorously defined to reduce the potential influence of the researcher on outcome measures. The investigators performed a training period that further enhanced the consistency between the researchers.
Hawthorne effect	Participants were not blinded to study procedures. The self-reported measures of participants taken after VLT and after steam inhalation might be altered due to a Hawthorne effect.
Testing effect	Outcome measures procedures were chosen as short, not stressful, easily applicable and consistent. Therefore, it was reduced the potential influence of the procedures on the tested interventions.
Situation effect	A rigorous control for confounding factors was conducted. However, specific features of the study (e.g. the morning time for data collection) might reduce the generalisability of the results.

2.7 Reliability

Reliability refers to the consistency of measurements. It relates to the degree to which the same experiment generates equal results even in different circumstances (Roberts & Priest, 2006). The reliability estimates, typically described in health research (Kimberlin & Winterstein, 2008; Passer, 2014) are reported below (Table 2.6).

Table 2.6: Reliability estimates

Inter-rater reliability	Stability of ratings among different investigators, also called interobserver agreement.
Intra-rater reliability	Stability of ratings among repeated measurements conducted by a single investigator
Test-retest reliability	Stability of ratings when a measure is repeated with the same instrument, under equivalent test conditions.

In this study, the use of the same procedures with every participant enhanced reliability. However, variability of research instruments (participants' mobile devices) existed leading to a potential threat to the intra-rater and test-retest reliability of findings. No potential threats to inter-rater reliability occurred in this study since only objective measures were used.

2.8 Data Analysis

All the participants' data were collected in an Excel spreadsheet that included the participant ID number, age, sex and all the outcome measures taken. Data were traceable to its origin thanks to a code key that ensured participants' right to withdraw at any time. The code key was password protected, encrypted and stored in Microsoft OneDrive. Data analyses were conducted with IBM SPSS Statistics version 26.0 (IBM Corporation, Armonk).

Descriptive statistics summarised the sample's data. Appropriate measures of central tendency and spread were calculated for age, sex and dependent variables. In particular, the median and the interquartile range (IQR) were chosen since they are less sensitive to extreme values and therefore more appropriate considering the reduced sample size of this study (Passer, 2014).

To answer the research questions, inferential statistical analyses were run. Statistical significance was $\alpha \leq 0.05$. All test assumptions were met unless stated.

One-way repeated measure ANOVA was planned to test the effects of interventions on voice measures. Nevertheless, the test assumption concerning the approximate normality distribution of the dependent variables in the related groups could not be fully satisfied. The normality of data was assessed visually and with the Shapiro-Wilk test which revealed a statistically significant non-normal distribution in at least one group for the following variables: F_0 (V0), shimmer (V0), jitter (V0), NHR (V0, V1, V2), total score (V0, V2), effort (V2). Table 2.7 reports a summary of the Shapiro-Wilk test for normality.

Table 2.7: Summary of the Shapiro-Wilk test for normality. Significant results are in bold.

Variables	V0	V1	V2
F_0 (Hz)	***p* = .018**	*p* = .573	*p* = .818
Intensity (dB)	*p* = .772	*p* = .646	*p* = .577
Shimmer (%)	***p* = .001**	*p* = .715	*p* = .275
Jitter (%)	***p* < .001**	*p* = .134	*p* = .082
NHR	***p* < .001**	***p* = .001**	***p* < .001**
CPP	*p* = .115	*p* = .249	*p* = .803
MPT (s)	*p* = .936	*p* = .576	*p* = .199
Total score	***p* = .008**	*p* = .217	***p* < .001**
Total severity	*p* = .537	*p* = .087	*p* = .551
Fatigue	*p* = .329	*p* = .172	*p* = .212
Effort	*p* = .056	*p* = .163	***p* = .031**

Considering also the small sample size (n=12), and therefore a reduced overall statistical power, the Friedman test was performed as non-parametric alternative. Appropriate statistical hypotheses are stated (Figure 2.13).

Figure 2.13: Statistical hypotheses of the Friedman test

Null hypothesis (H_0): there is no statistically significant difference in median values of the depend variable tested at V0, V1 and V2 in any of the related groups.

Alternative Hypothesis (H_1): there is a statistically significant difference in at least one pair of the related groups for the dependent variable tested at V0, V1 and V2.

The Kendall's W test value was adopted as effect size estimation (Tomczak & Tomczak, 2014) and interpreted following Cohen's guidelines of 0.1 as small effect, 0.3 as medium effect and above 0.5 as large effect (Cohen, 1988).

The Wilcoxon signed-rank test was then conducted for post hoc analyses. The assumption concerning the shape of the distribution of differences between the two related groups was visually assessed. When the distribution was non symmetrical, the Sign test was conducted on paired observations. A Bonferroni correction (α = .017) was applied.

2.9 Summary

This chapter reported the methodology adopted to answer the stated research questions. The following chapter presents the findings of this study.

Chapter 3 – Results

3.1 Introduction

The study investigated the effects of a VLT and subsequent steam inhalation on acoustic, aerodynamic and self-perceived voice measures in adults. It also aimed to evaluate the effectiveness of steam inhalation in restoring the potential adverse effects of VLT. In this chapter the results of the analyses conducted following the stated methodology (§2.9), are reported.

3.2 Participation rate

Overall, a total of *n*=12 eligible participants were involved in this study. Although the period of recruitment and data collection lasted for two months, the estimated sample size of 36 participants was not achieved. During the data collection, no withdrawals or exclusions of participants occurred. All the intended data were collected for all participants with no missing values.

3.3 Participant's demographics

12 participants (11 females, 1 male) with a median age of 24.5, an IQR of 6 and a range of 19-34 years old were recruited from the department of Clinical Speech and Language Studies of Trinity College Dublin. Figures 3.1 and 3.2 represent the age and sex distributions. As noted, the sample is clustered in age and sex. Indeed, only one male was recruited.

Figure 3.1: *Age* distribution

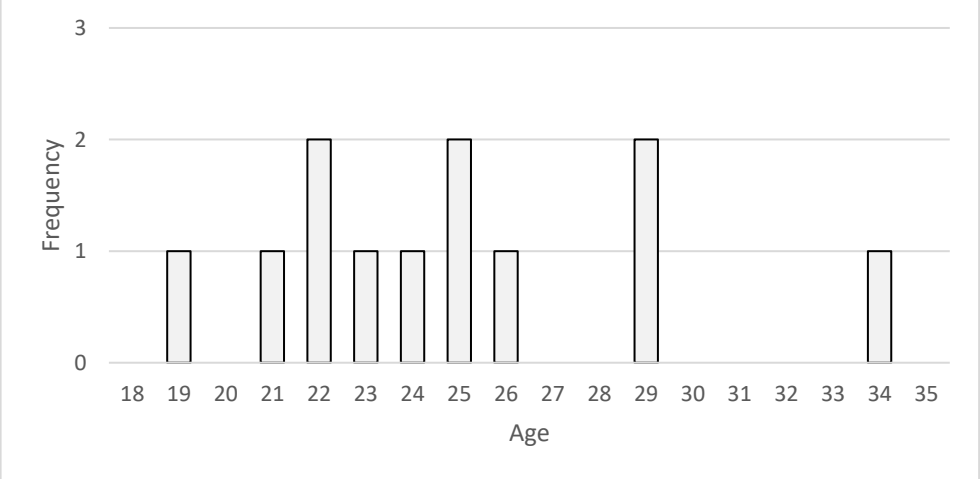
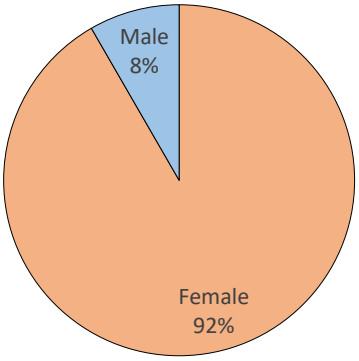


Figure 3.2: *Sex* distribution; n=12



3.4 Effects on acoustic measures

The acoustic analyses performed with Praat version 6.1.29 (Boersma & Weenink, 2020) using standard settings obtained the acoustic parameters of mean fundamental frequency (F_0), mean intensity, shimmer, jitter, NHR, CPP. Descriptive statistics for measures at baseline (V0), post VLT (V1) and post steam inhalation (V2) are reported in Table 3.1.

Table 3.1: Descriptive statistics for acoustic measures; n=12

Variables	Median	IQR	Min	Max	Range
F_0 (Hz)					
V0	235.35	37.686	127.71	260.11	132.40
V1	238.63	72.95	110.83	326.40	215.57
V2	238.17	53.37	120.56	314.18	193.62
Intensity (dB)					
V0	75.62	5.570	70.42	80.98	10.56
V1	75.89	4.42	70.00	81.80	11.79
V2	76.50	4.42	68.23	81.24	13.01
Shimmer (%)					
V0	2.27	1.212	1.11	8.58	7.46
V1	2.49	2.05	0.76	4.88	4.11
V2	2.41	1.93	1.30	4.22	2.92
Jitter (%)					
V0	0.289	0.150	0.157	4.201	4.044
V1	0.353	0.243	0.117	0.869	0.752
V2	0.394	0.180	0.255	0.787	0.532
NHR					
V0	0.006970	0.004966	0.002408	0.369028	0.366620
V1	0.006492	0.014958	0.001562	0.053686	0.052124
V2	0.008016	0.006286	0.004096	0.052784	0.048688
CPP					
V0	16.35	3.89	13.37	19.19	5.82
V1	16.89	4.47	12.88	19.47	6.59
V2	16.42	4.87	12.02	20.38	8.36

Data analyses revealed the presence of two statistical outliers. Participant 7 differed for F_0, shimmer, jitter, NHR. However, given that participant 7 was the only male in the data set, a sex-related phenomenon was likely to be responsible for the different measures. Owing to the smaller sample size, analyses could be easily affected by extreme values. For this reason, the inferential statistical analyses of acoustic measures were performed both on whole group and female data only. The results of both sets of data analysis agreed in terms of statistical significance. Therefore, considering the outcome measures of participant 7 were a genuine reflection of male sex, his data were included for analysis. Participant 4 was also a statistical outlier in terms of shimmer and NHR. These were likely a true reflection of the variability of the physiological characteristics involved in the study. In the absence of any rationale for exclusion, and since this participant's data did not adversely affect inferential statistical analysis, her data were also included.

Grouped boxplots were performed for each measure to visualise the distribution of variables across the three groups. Since participant 7 was an outlier, his data were not displayed in the charts given the high discrepancies compared to the female data. Grouped boxplots of F_0, shimmer, jitter, NHR reported female data only.

For all the acoustic measures the high range and the high spread of data make it overall difficult to assess the presence of trends in these variables across groups.

As noted in Figure 3.3 and Table 3.1, the median F_0 remained constant throughout the groups. This is consistent with the Friedman test that revealed no statistically significant difference between the three groups ($\chi^2(2) = 0.500$, $p = .779$, $W = .021$). Therefore, the null hypothesis was retained. Additionally, a higher variability of F_0 at V1 is visualised in Figures 3.3 and 3.4.

Figure 3.3*: F_0* grouped box-plot for female data

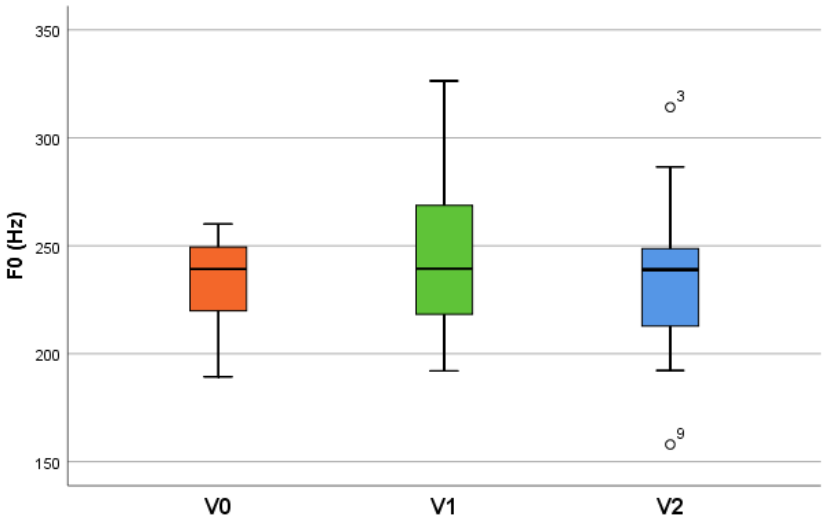
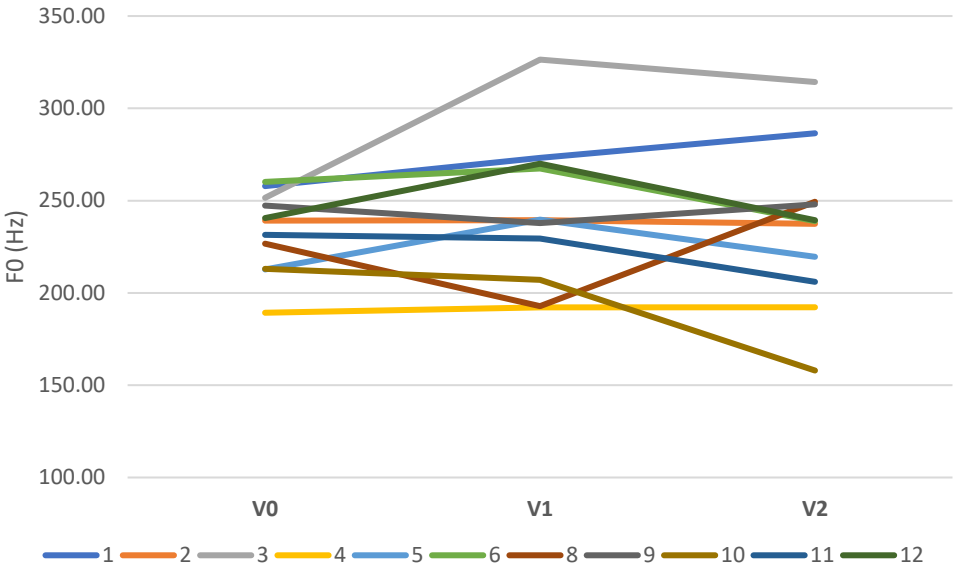
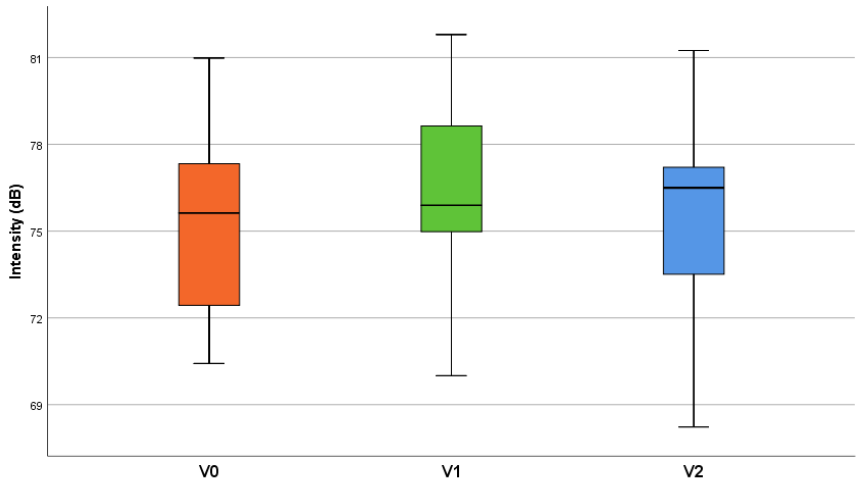


Figure 3.4: Line chart showing the variation of F_0 across groups for female data



As noted in Figure 3.5 and similar to F_0, the median value of intensity remained constant throughout the groups accordingly to the Friedman test that revealed no statistically significant difference ($\chi^2(2) = 3.167$, $p = .205$, $W = .132$). Thus, the null hypothesis was retained.

Figure 3.5: *Intensity* grouped box-plot



Concerning jitter and shimmer, both the parameters appeared to slightly increase over the three groups. Nevertheless, the spread of data makes comparison hard (Figures 3.6, 3.7). Differences for measures across groups were not statistically significant according to the Friedman test for jitter ($\chi^2(2) = 1.167$, $p = .558$, $W = .049$) or shimmer ($\chi^2(2) = 0.667$, $p = .717$, $W = .028$). The null hypotheses were therefore retained.

Figure 3.6: *Jitter* grouped box-plot for female data

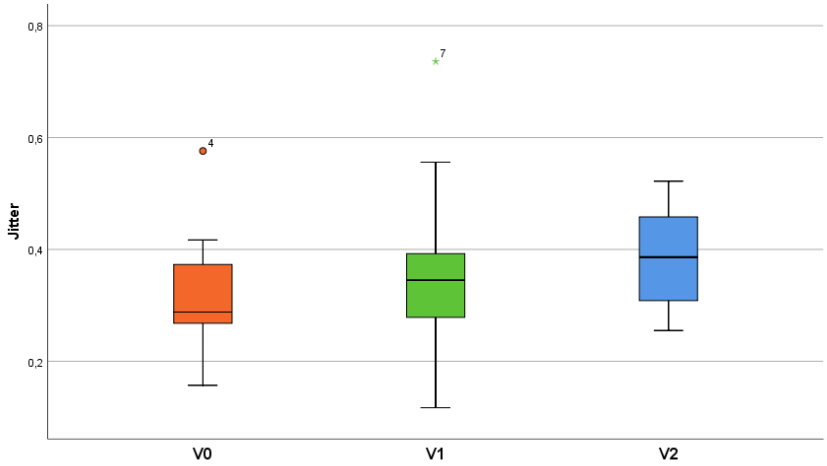
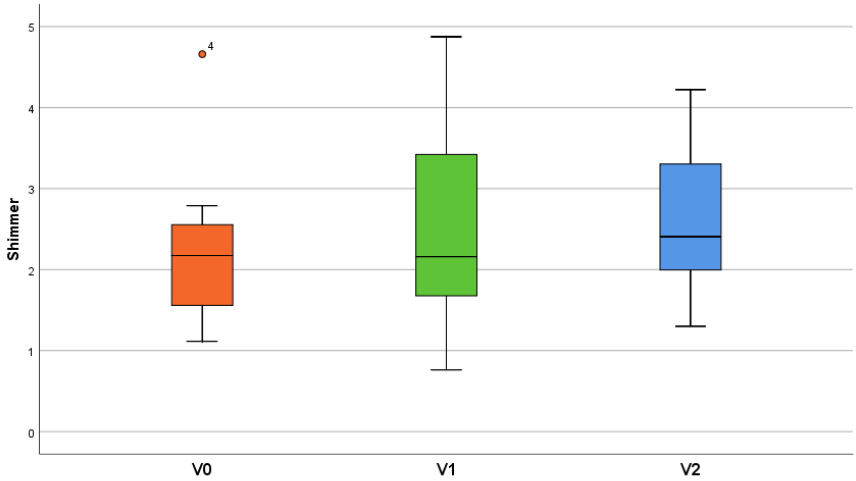


Figure 3.7: *Shimmer* grouped box-plot for female data



Overall trends for NHR and CPP over the three groups cannot be assessed given the higher IQR (Figures 3.8, 3.10). This is consistent with the Friedman test that detected no statistically significant differences between V0, V1, V2 either for NHR ($\chi^2(2) = 0.500$, $p = .779$, $W = .021$) or CPP ($\chi^2(2) = 0.667$, $p = .717$, $W = .028$). The statistical hypotheses were retained. Despite the lack of statistical significance, data showed a higher IQR for NHR in V1 than in V0 and V2 (Figures 3.8, 3.9).

Figure 3.8: *NHR* grouped box-plot for female data

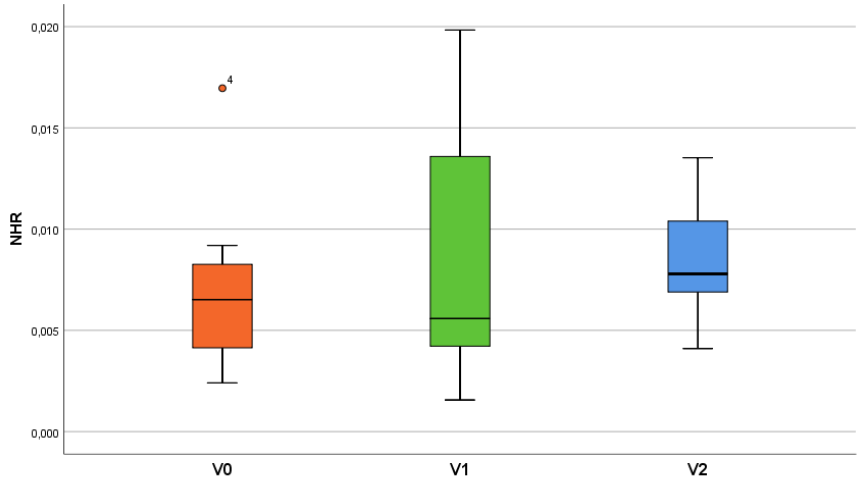


Figure 3.9: Line chart showing the variation of *NHR* across data points for female data

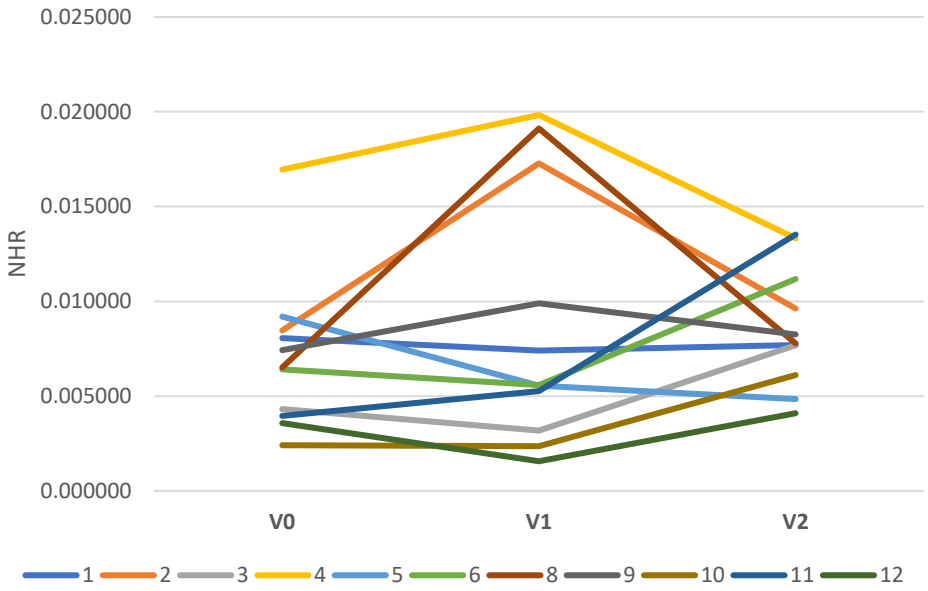
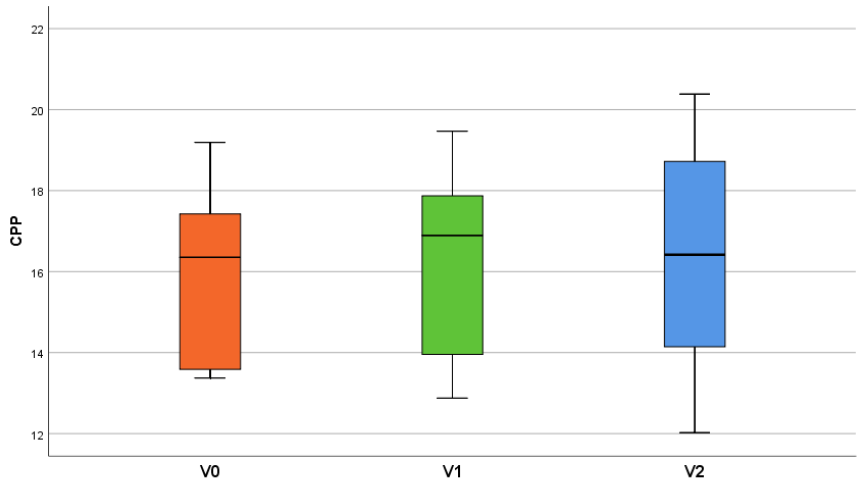


Figure 3.10: *CPP* grouped box-plot



3.5 Effects on aerodynamic measures

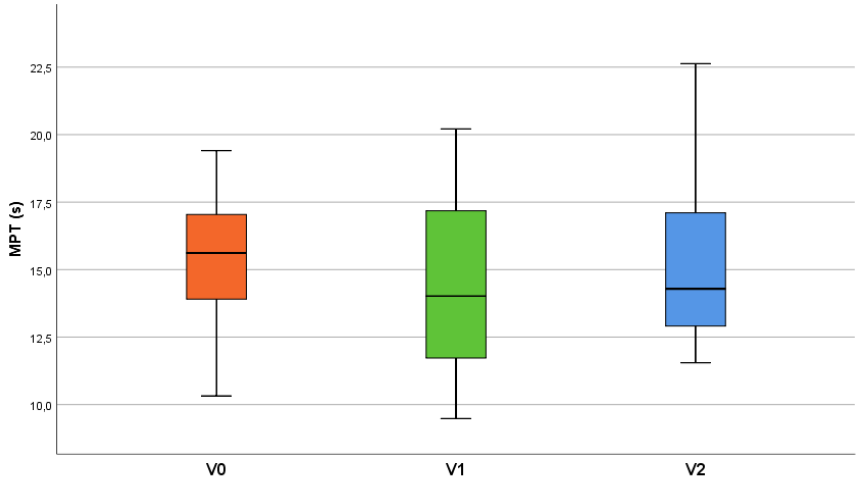
Descriptive statistics for MPT at V0, V1 and V2 are reported in Table 3.2.

Table 3.2: Descriptive statistics for acoustic and aerodynamic voice measures; n=12

Variable	Median	IQR	Min	Max	Range
MPT (s)					
V0	15.62	3.38	10.32	19.41	9.09
V1	14.02	6.06	9.48	20.21	10.73
V2	14.29	4.29	11.55	22.63	11.08

Despite the wide range, the median value of MPT decreased from V0 to V1 and did not increase to baseline from V1 to V2 (Figure 3.11). Differences across groups were not statistically significant according to the Friedman test ($\chi^2(2) = 4.167$, $p = .125$, $W = .174$). Therefore, the null hypothesis was retained.

Figure 3.11: *MPT* grouped box-plot

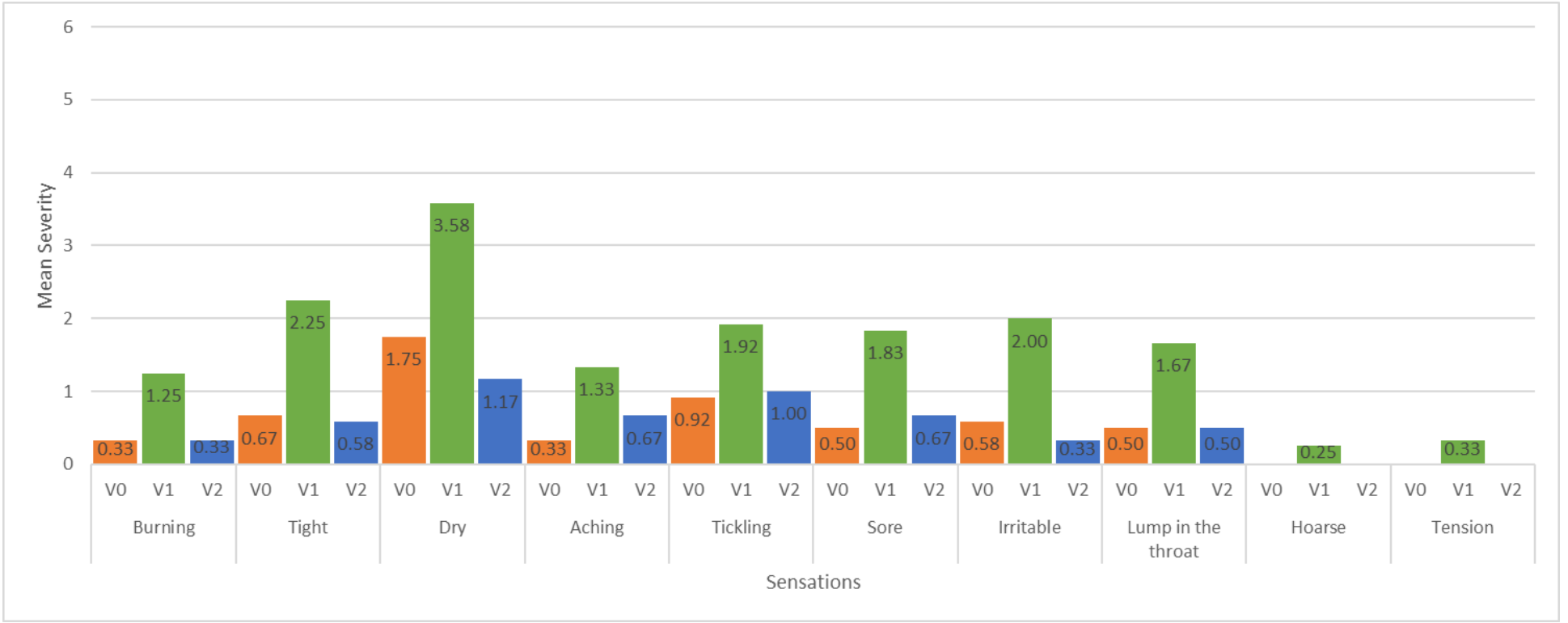


3.6 Effects on self-perceived measures

3.6.1 VTDS

Descriptive statistics were performed for self-perceived measures. Figure 3.12 displays mean severity ratings for the sensations of the VTDS across the three groups. Mean values were reported instead of median values, since they better described data highlighting the presence of additional sensations in V1. Indeed, at V1 after the VLT "hoarse" and "tension" were reported by participants as additional sensations not captured by the assessment instrument. No additional sensations were reported at V0 or V2. Overall, the severity of sensations increased in V1 after VLT and decreased in V2 after steam inhalation with a final severity rating equal or even lower than the baseline V0.

Figure 3.12: Mean severity of the sensations of the *VTDS* for V0, V1 and V2



Two additional variables were calculated for every participant:

- Total score: sum of the severity of all the sensations reported
- Total sensations: total number of sensations experienced

Descriptive statistics for these variables are displayed in Table 3.3.

Table 3.3: Descriptive statistics for the variables *Total score* and *Total sensations*; n=12

Variables	Median	IQR	Min	Max	Range
Total score					
V0	3.00	7	0	21	21
V1	15.50	11	4	38	34
V2	3.00	3	0	27	27
Total sensations					
V0	2.50	3	0	8	8
V1	6.50	3	4	8	4
V2	3.00	3	0	8	8

Data analysis for the total severity score reported the presence of three outliers. However, they were a genuine reflection of participants' performances and therefore were not treated as statistical outliers (Figure 3.13).

Despite the variability between participants, the median values of total score increased in V1 after VLT and decreased in V2 after steam inhalation reaching the baseline V0 (Figure 3.13). These differences were statistically significant according to the Friedman test ($\chi^2(2) = 17.911$, $p < .001$, $W = .746$). Therefore, the null hypothesis was rejected. Post hoc analyses were conducted applying the Bonferroni correction ($\alpha = .017$). The pairwise comparison performed with Wilcoxon Signed-Rank Test detected a statistically significant increase in the overall perceived severity (total score) in V1 after VLT compared to the baseline V0 ($Z = -2.936$, $p = .003$). Moreover, there was a statistically significant reduction of the total score in V2 after steam inhalation compared to V1 ($Z = -3.063$, $p = .002$). Given the non-symmetrical shape of the distribution of the difference between V2 and V0 (Figure 3.14), the Sign test was performed revealing a non-significant difference between V2 and V0 ($p = .754$).

Figure 3.13: *Total score* grouped box-plot

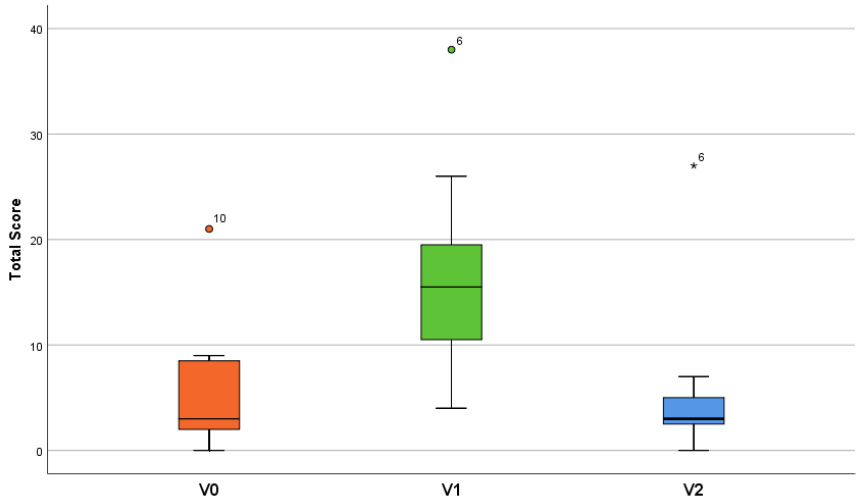
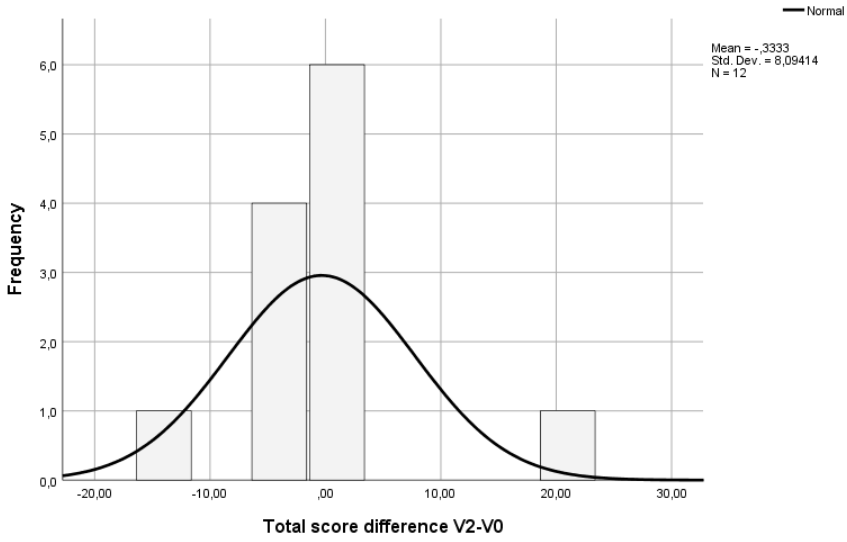
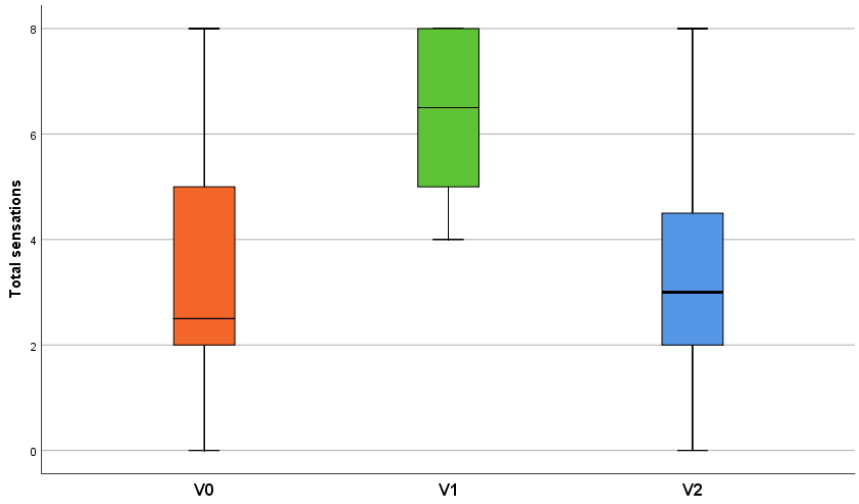


Figure 3.14: Histogram of the difference of the variable *Total score* between V2 and V0



Concerning the total number of sensations, the median value increased in V1 and decreased in V2 reaching the baseline V0 (Figure 3.15). These differences were statistically significant according to the Friedman test ($\chi^2(2) = 15.050$, $p = .001$, $W = .627$) and the null hypothesis was rejected. Pairwise comparisons performed with the Wilcoxon Signed-Rank Test detected a statistically significant increase in the sensations reported in V1 compared to V0 ($Z = -2.858$, $p = .004$) and a statistically significant reduction in V2 compared to V1 ($Z = -2.969$, $p = .003$). Finally, a non- significant difference was assessed between V0 and V2 ($Z = -0.108$, $p = .914$).

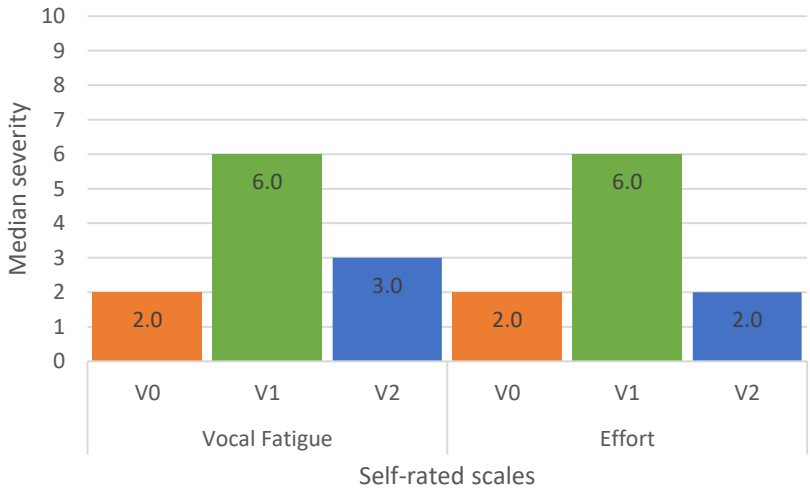
Figure 3.15: *Total sensations* grouped box-plot



3.6.2 Vocal fatigue and effort

Concerning the self-rated scales of fatigue and effort, analyses revealed the presence of outliers although these were not considered as statistical outliers but instead as realistic extreme values. Figure 3.16 displays the median severity of the self-rated scales.

Figure 3.16: Median severity of self-rated scales of *Vocal fatigue* and *effort*



Analyses showed an equivalent trend to the previously reported self-perceived variables. The median severity of the ordinal variables increased at V1 and declined to baseline values at V2 (Figure 3.16). The Friedman test revealed a statistically significant difference both for fatigue ($\chi^2(2) = 19.447$, $p < .001$, $W = .810$) and effort ($\chi^2(2) = 19.478$, $p < .001$, $W = .812$). Therefore the null hypotheses were rejected.

Regarding the fatigue scale, given the non-symmetrical shape of the distribution of the difference between V1 and V0 (Figure 3.17), the pairwise comparison with the Sign test was performed

showing a statistically significant increase in fatigue in V1 after the VLT ($p < .001$). Further post hoc analyses with Wilcoxon Signed-Rank Test detected a statistically significant reduction in the perceived fatigue at V2 compared to V1 (Z = -3.089, p = .002) and non-statistically significant difference between V2 and V0 (Z = -1.811, p = .070).

Similarly, pairwise comparisons for the effort scale with the Wilcoxon Signed-Rank Test detected a statistically significant increase in effort at V1 compared to V0 (Z = -3.074, p = .002) and a statistically significant reduction in V2 compared to V1 (Z = -3.070, p = .002). For the related groups V2-V0, considering the non-symmetrical shape of the distribution of the difference (Figure 3.18), the Sign test was performed revealing a non-statistically significant difference in the perceived effort between V2 and V0 (p = .344).

Figure 3.17: Histogram of the difference of the variable *Vocal Fatigue* between V1 and V0

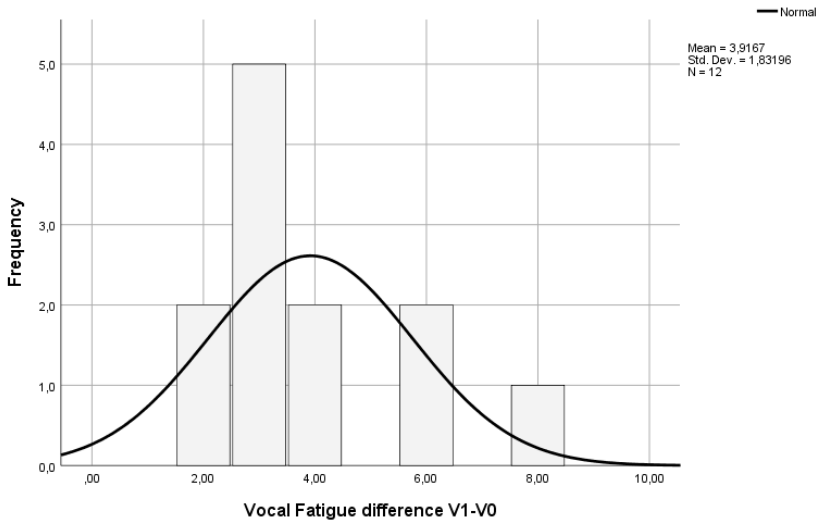
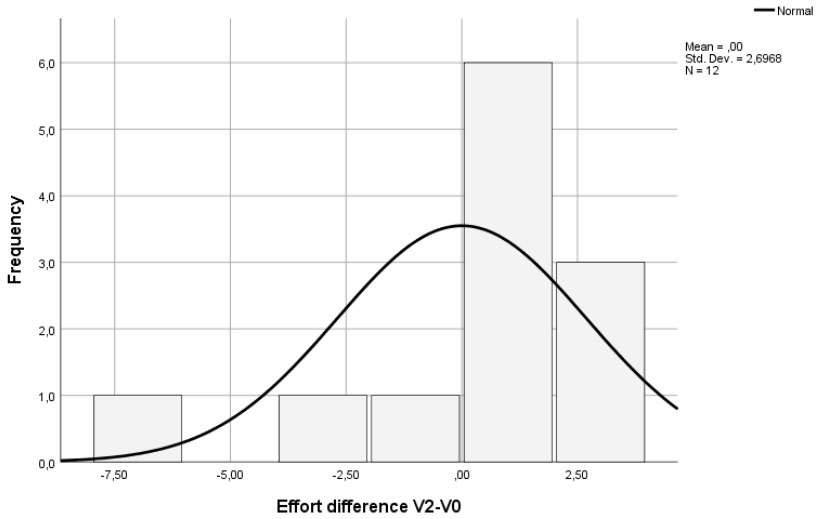


Figure 3.18: Histogram of the difference of the variable *effor*t between V2 and V0



3.7 Summary

In this chapter the results of data analyses were provided. These enabled to answer the three stated research questions as followed:

Research question 1) Is there a difference in voice outcome measures between baseline measures and post VLT measures in adults?

Significant effects following the designed VLT were detected for all the self-perceived variables but not for acoustic or aerodynamic measures. A reduction of MPT after VLT was noted although it was not statistically significant.

Research question 2) Is there a difference in voice outcome measures between pre and post steam inhalation measures in adults?

Following the steam inhalation procedure significant effects were detected for self-perceived measures when compared to post VLT measures. No significant differences were detected for acoustic and aerodynamic measures.

Research question 3) Is there a difference in voice outcome measures between baseline measures and post steam inhalation measures in adults?

Overall, no significant differences were assessed between the baseline and post steam inhalation outcome measures.

The discussion and the interpretation of these findings are presented in the following chapter.

Chapter 4 – Discussion

4.1 Introduction

The present study investigated the effects of a VLT and then steam inhalation on voice outcome measures. The key findings answered the aims and the research questions. In this chapter, the main results are discussed and an interpretation of findings in the context of existing literature is provided for vocal fatigue and then steam inhalation. Lastly, the implications for clinical practice, strengths, limitations and future research directions are discussed.

It is noted that the current results are only partially comparable to previous findings. Indeed, the implementation of different VLTs and hydration procedures across studies often makes studies difficult to compare (§1.2, §1.4). Results are also partially comparable due to other methodological discrepancies like the implementation of different outcome measures or eligibility criteria for the population.

4.2 Vocal fatigue and VLT

The first aim and research question of this project investigated the effectiveness of a 20-minute VLT in inducing changes in voice outcome measures in adults. Overall, the VLT induced statistically significant changes in the self-perceived measures with an increased number of sensations reported on the VTDS, increased overall severity of sensations, and higher perceived vocal fatigue and effort compared to baseline. Conversely, the acoustic measures were not significantly affected. A reduction of MPT after VLT was noted, although not statistically significant. With reference to F_0 and NHR, the high range observed after the VLT compared to the other timepoints might suggest an effect of the VLT on these outcome measures. However wider ranges might also simply reflect intra-individual variations or be the effect of the test-retest reliability.

To explore vocal fatigue, a 20-minute VLT was designed combining the loading factors of high vocal intensity (70-85 dB), a prosodic voice effect and an exaggerated forward head position. Results suggested that the VLT successfully induced vocal tract discomfort, effort and fatigue with large effect sizes ($W > 0.5$), according to Cohen's interpretation guidelines (Cohen, 1988). Conversely the VLT did not induce an aberrant voice quality considering that no statistically significant differences were detected for acoustic and aerodynamic measures. The reduced statistical power, caused by the small sample size, might have increased the likelihood of a type II error for acoustic and aerodynamic measures. Indeed a reduction of MPT after VLT was noted when observing the descriptive statistics. Perhaps a bigger sample size and an increased statistical power could lead to

a statistically significant difference. On the other hand, these results could be a genuine reflection of a physiological phenomenon involved in voice production. Findings suggested that perhaps the VLT might affect self-reported sensations first and potentially later affect acoustic measures.

Tables 4.1 and 4.2 show the acoustic and aerodynamic values obtained in this research and the available normative values (Goy et al., 2013; Murton et al., 2020). Given the reduced sample size, the median and the IQR were chosen as descriptive measures for the current data since they are less sensitive to extreme values. It is observed that all the values throughout this project at V0, V1, V2 remained close to threshold and normative values. When the median values provided in Table 4.1 are compared to normative values, these appear close to the mean with no standard scores greater than two standard deviations from the mean. This comparison suggests that baseline values at V0 correctly described vocally healthy participants in accordance with the eligibility criteria of this project. It also shows that the VLT did not induce an abnormal voice quality characterised by acoustic and aerodynamic parameters within the dysphonic range.

Table 4.1: Comparison between the present female outcome measures of F_0, intensity, shimmer, jitter, NHR, MPT and the female normative values provided by Goy et al. (2013)

	Values obtained in this research n = 11 , Females (19-34 years old)		**Normative values (Goy et al., 2013) Females (18-28 years old)**
Variables	**Median**	**IQR**	**Mean (SD)**
F_0 (Hz)			
V0	239.23	38.479	
V1	239.42	62.86	251 (28)
V2	238.92	43.366	
Intensity (dB)			
V0	76.08	6.24	
V1	76.33	5.19	74.7 (3.9)
V2	76.67	5.14	
Shimmer (%)			
V0	2.17	1.10	
V1	2.16	1.95	2.36 (0.91)
V2	2.41	1.57	
Jitter (%)			
V0	0.289	0.148	
V1	0.345	0.127	0.37 (0.25)
V2	0.386	0.156	
NHR			
V0	0.006514	0.004510	
V1	0.005582	0.014096	0.007 (0.010)
V2	0.007787	0.005067	
MPT (s)			
V0	15.76	3.63	
V1	14.17	6.67	15.1 (4.4)
V2	14.71	4.26	

Table 4.2: Comparison between the present outcome measure CPP and the threshold value provided by Murton et al. (2020).

	Values obtained in this research n = 12		Threshold value (Murton et al., 2020)
Variables	**Median**	**IQR**	
CPP			
V0	16.35	3.89	
V1	16.89	4.47	14.45
V2	16.42	4.87	

Methodological issues have to be considered when interpreting findings. The nature of the VLT and the data collection procedures could logically have affected results. Outcome measures were collected immediately after the VLT, thus reducing maturation as a threat to internal validity and the possibility that vocal rest might have reduced the observable effects of vocal fatigue. The use of the uncompressed format for recordings increased the audio quality ensuring more reliable acoustic analyses. Moreover, strategies to enhance the correct implementation of the VLT were introduced. These involved the monitoring of participants over Zoom, the use of the Decibel X app (SkyPaw Co. Ltd, 2020) to check for the loudness range (70-85 dB), instructional videos and a VLT trial before the experimental phase. However, it was not possible to fully monitor participants for the loudness and the forward head position because of the remote nature of the study. As such, it could be that the vocal demand was lower than expected or at least that it was sufficient to have affected self-perceived measures, but not tiring enough to induce changes in acoustic and aerodynamic measures. Other factors like being generally healthy and younger as well as being SLTs and perhaps more knowledgeable about voice use and used to using the voice for a long period of time might also have made participants more fatigue resistant.

Acoustic measures tested in previous studies demonstrated varying sensitivity in detecting the effects induced by VLT (Fujiki & Sivasankar, 2017). Concerning F_0 the findings of this research aligns with studies that did not detect significant changes following VLT (De Bodt et al., 1998; Gorham-Rowan et al., 2016; Neils & Yairi, 1987) but differs from other studies that detected a significant increase in F_0 (Boominathan et al., 2010; Fujiki et al., 2017; Laukkanen et al., 2004; Remacle et al., 2012; Stemple et al., 1995; Vilkman et al., 1999; Vintturi et al., 2001). However, the majority of VLTs that induced significant changes in F_0 lasted on average 2 hours (Fujiki & Sivasankar, 2017). Only Fujiki et al. (2017) detected a significant increase in F_0 after a 30-minute reading VLT with altered voice quality. Considering the presence of other loading factors (high vocal intensity, prosodic voice effect, forward head position), perhaps increasing the VLT from twenty to thirty minutes as in Fujiki

et al. (2017) or forty-five minutes as in Laukkanen et al. (2004) may have induced observable changes in the acoustic and aerodynamic measures. A longer duration was not originally adopted since the goals involved developing an effective VLT as short as possible in duration and non-traumatic to avoid participant burden.

Results concerning intensity (dB) are partially comparable with the previous studies due to the different acoustic analyses performed. Indeed this study investigated the mean intensity (dB) whereas other authors measured the intensity range, the lowest and the highest intensity. In line with this study, Yiu and Chan (2003) did not detect significant changes in the mean, maximum and minimum loudness of phonetograms following a minimum of 95 minutes of karaoke singing. Also De Bodt et al. (1998) did not detect changes for habitual intensity and intensity range after 20-minutes of loud reading. Conversely, the mean intensity of untrained subjects following 1-hour reading significantly increased (Gelfer et al., 1991). Similarly, Remacle et al. (2012) observed a statistically significant rise of the lowest intensity after two 2-hours sessions of oral reading whereas the highest intensity remained unvaried. The implementation of different VLTs might be responsible for the discrepancies between studies.

Concerning the perturbation measure jitter, the present results aligned with previous works that did not detect changes in jitter following two 2-hours sessions of oral reading (Remacle et al., 2012), nor 25 minutes of vowel production (Verstraete et al., 1993). Other authors detected modifications with a decrease after 2 hours of loud reading (Stemple et al., 1995) or an increase after a maximum of 1 hour of loud reading in both untrained speakers and trained singers (Boominathan et al., 2010; Gelfer et al., 1991) as well as after a minimum of 95 minutes of karaoke singing (Yiu & Chan, 2003). Regarding shimmer, findings aligned with previous studies that did not observe significant changes following 25 minutes of vowel production (Verstraete et al., 1993) or 1 hour reading in trained singers (Gelfer et al., 1991), whereas differ from researches that detected significant changes following 2-hours reading (Remacle et al., 2012) and 1-hour reading (Boominathan et al., 2010). Overall, the present findings matched the limited sensitivity of perturbation measures (jitter, shimmer) to laryngeal changes occurred following VLTs suggested in the literature review of Fujiki and Sivasankar (2017).

The lack of significant changes for NHR after VLT agreed with studies that implemented a 30-minutes VLT (Buekers, 1998) and 3 repetitions of a loud vowel VLT (Gorham-Rowan et al., 2016). Conversely, a significant increase in NHR values was detected by Boominathan et al. (2010) following a maximum of 1 hour of loud reading. Perhaps the longer duration of the VLT could be responsible for the discrepancy with the present findings.

Lastly, no significant changes were detected for CPP in this study similarly to Gorham-Rowan et al. (2016) that did not observe modifications in CPP on phonation at comfortable loudness after a VLT of 30 sustained vowels. Conversely, Fujiki et al. (2017) detected a significant decrease of CPP on soft phonation after a 30-minute reading VLT with altered voice quality. This difference could be explained by the different task adopted to collect CPP (comfortable loudness or soft phonation).

Concerning aerodynamic measures, only a few studies previously investigated MPT while the majority adopted PTP. The current findings are in line with studies that did not detect significant changes in MPT after 2-hour reading VLT in females (Stemple et al., 1995) or males (Kelchner et al., 2006). By contrast, a significant increase was detected by Remacle et al. (2012) following 2-hour VLT. As suggested by the authors, an adaptation of the laryngeal system or a training effect following 2-hour VLT could be responsible for this modification. Considering the documented higher sensitivity of PTP for vocal fatigue (Fujiki & Sivasankar, 2017), including PTP as outcome measure might have given further insights into the effects of VLT on aerodynamic measures. It was not adopted due to the complexity of the procedure and the impracticability for remote data collection. Conversely, one strength of this research is that it provided results concerning MPT which is an easier and more commonly used aerodynamic measure in clinical practice.

With regard to self-reported measures, the significant increase detected in this study is consistent with previous works that investigated the effects induced by several VLTs (Fujiki et al., 2017; Gorham-Rowan et al., 2016; Kelchner et al., 2006; Laukkanen et al., 2004; Remacle et al., 2012; Stemple et al., 1995; Whitling et al., 2015; Yiu & Chan, 2003). Nevertheless, researchers adopted a variety of different instruments to assess the self-reported experience of participants. Unlike the majority of the aforementioned studies, this research investigated the severity of several sensations included in the VTDS (Mathieson et al., 2009) and allowed participants to include additional features. The adopted methodology is more robust than previous works who used single-dimensional analogue scales like for instance Gorham-Rowan et al. (2016) who collected subjective ratings only of muscle soreness. However, a potentially poor internal consistency of the adopted modified VTDS might have affected the validity of the research. Moreover, the validity could have been threatened by a detection bias due to the lack of blinding of individuals to the study procedures. For instance, participants might have expected a benefit from steam inhalation and rated accordingly. Nevertheless, the blinding of individuals was unachievable in this study design.

Considering the theoretical framework of vocal fatigue provided by Solomon (2020), the overall findings of this study are consistent with the hypotheses that high vocally demanding activities lead to mental fatigue (self-perceived sensations of fatigue) and perhaps muscle fatigue. Conversely, the mucosal fatigue that might affect acoustic and aerodynamic measures was not observed. However,

as previously mentioned, this could be due to study limitations or perhaps be a genuine reflection of vocal fatigue. Indeed the mucosal dimension might be affected by more intensive VLTs.

4.3 Steam inhalation

The second aim of this research was to investigate the effects of 10 minutes of steam inhalation in adults and its potential effectiveness in restoring the adverse effects of a VLT.

In particular, the second research question asked whether there was a difference in voice outcome measures between pre and post steam inhalation measures. With reference to acoustic and aerodynamic measures, no differences were found. On the other hand, self-perceived measures were significantly affected with a large effect size indicating that participants reported benefits after 10 minutes of steam inhalation in terms of vocal tract discomfort (severity and number of sensations reported), effort and vocal fatigue.

The third research question examined whether there was a difference in outcome measures between baseline and post steam inhalation, thus investigating the effectiveness of rehydration in restoring the adverse effects of VLT. Once more, acoustic and aerodynamic measures were not significantly affected. These are not unexpected findings considering that these measures were not statistically significantly affected by the VLT either. Concerning the self-perceived measures, no differences were found. Considering that these measures were negatively affected by the VLT, findings suggested that steam inhalation not only positively affected the reported discomforts, effort and fatigue but even successfully restored these measures to baseline levels. Perhaps steam inhalation could be an effective strategy to recover voice measures when these have deteriorated. Nevertheless, because of a lack of a control group, vocal rest could have also been responsible for the noted benefits. Further studies addressing this limitation are therefore encouraged.

The results obtained for hydration are partially comparable to previous findings. Since this study investigated steam inhalation following a VLT, the findings are also dependent on the VLT. However, only few studies explored the effects of surface hydration in conjunction with vocal fatigue (§1.5). Moreover, studies varied for the equipment implemented. For instance, Borragan et al. (2021), observed significant changes in voice parameters following nasal breathing through a damp gauze in combination with vocal warm-up exercises. Needless to say, the methodology adopted was highly different from this study. The current results are compared below with studies that performed surface hydration. Nonetheless, the effectiveness of steam inhalation performed with a common basin of boiling water and a towel to contain the steam had not yet been investigated.

In the work of Mahalingam and Boominathan (2016), the acoustic parameters tested (jitter, shimmer, NHR) significantly improved and restored to baseline levels after 3 minutes of steam inhalation achieved with a facial steamer. The authors induced surface dehydration asking participants to perform on average 10 minutes of mouth breathing before the steam inhalation phase. Conversely, this research implemented a VLT with an attempt to increase the viscosity of vocal folds inducing vocal fatigue. Therefore if the hydration tool implemented is similar to the present study, the absence of the VLT make findings hardly comparable. By contrast, Vintturi et al. (2001) did not observe significant effects when exposing participants to low versus high environmental humidity during a 45-minute reading VLT. However, acoustic, aerodynamic or self-perceived measures were not collected and participants were exposed to multiple conditions (humidity levels, loudness levels, sitting versus standing posture). Additionally, systemic hydration was not controlled at the baseline level which represents a confounding factor. In this research individuals were asked to avoid hot showers, foods or drinks before the session.

Fujiki et al. (2017), investigated vocal fatigue and surface hydration with no significant results concerning the effects of hydration on outcome measures (F_0, CPP, perceived phonatory effort, perceived tiredness). Participants were exposed to low and high ambient humidity for 20 minutes before performing a 30-minute VLT. These findings are in contrast with the present research that detected significant effects for surface hydration on self-perceived ratings which, similarly to Fujiki et al. (2017), were negatively affected by the 20-minute VLT. This difference might be due to the different hydration tool and procedure. In this research, steam inhalation was performed after the VLT and not before as in the mentioned study. Moreover, as suggested by the authors, the moderate ambient humidity implemented was not sufficient to attenuate the effects of the VLT. In this study, perhaps 10-minutes of steam inhalation induced higher levels of surface hydration. To further maximise the effects of rehydration, participants were asked to inhale air through both the oral and nasal cavity at 20-30 cm distance using a towel to contain the steam.

4.4 Implications for clinical practice

The present findings have the potential to influence clinical practice. Concerning the external validity of the study, results are mainly generalisable to young females (19-36 years old). However, the small sample size represents a threat to the validity of the study. Results are partially generalisable to voice clients in particular to the ones that experience vocal fatigue and muscle tension dysphonia characterised by vocal tract discomfort. Further research utilising this study's methods within the clinical population of subjects with dysphonia is needed.

Concerning vocal fatigue, this study evinced that 20-minute VLT affected self-perceived measures. These measures could be symptoms of vocal fatigue and might precede an abnormal voice quality detected with traditional acoustic and aerodynamic measures. This research informs clinicians that vocal tract discomfort sensations and altered levels of fatigue and effort could be precipitating signs of dysphonia, even before acoustic correlates appear.

The current study also provides clinically relevant results concerning steam inhalation that was implemented accordingly to the common clinical practice of clinicians. The vocal tract discomfort and perceptions of effort and fatigue experienced post-VLT improved after 10-minutes of steam inhalation. This hygienic voice therapy can be recommended to individuals who experience vocal fatigue as a cool-down strategy to be performed after high intensive vocally demanding activities. However, future studies including a control group will be needed to establish the superiority of this strategy over simple voice rest. The clinical implications of this study are even higher considering that steam inhalation was achieved with basins of boiling water and a towel, which are very common tools and easily accessible differently from other surface hydration tools on the market. The fact that the basins of boiling water were not standardised between participants, maximised the ecological validity. Therefore 10-minutes of steam inhalation performed at 20-30 cm distance could be an effective strategy to restore the self-reported sensations of vocal fatigue. This study provides information concerning the effectiveness of steam inhalation which has been often based on anecdotal reports and provides hydration schedules that often lack in clinical practice. These are relevant for SLTs that will recommend rehydration (e.g. 10 minutes, 20-30 cm distance).

Finally, as a methodological consideration, the current research showed that a rigorous remote approach for data collection can be a valid alternative to the traditional face to face approach during the Covid-19 pandemic to ensure the safety of participants. Undoubtedly, it requires strict control to reduce potential confounding factors nevertheless it has the key advantage that it enhances the ecological validity since participants are observed in their natural context.

4.5 Strengths and limitations

The strengths of this research have been outlined throughout the previous chapters. The research aimed to contribute to clinical practice and to the scientific debate surrounding vocal fatigue and hydration. The close relation with clinical practice and the high ecological validity, represent significant strengths. Other strengths involved a robust design and a rigorous control of the experimental procedure adopted to minimised possible confounding factors. A carefully attention to treatment fidelity was observed during the sessions with participants. Treatment fidelity is defined as “the extent to which the intervention was delivered as planned” (Higgins et al., 2019, p.

119). It is a core aspect of research methodology since it ensures that changes in outcomes are not due to the implementation or measurement but changes are due to the intervention itself (Cattaneo et al., 2021). Table 4.3 provides further details concerning the strength of this research.

Table 4.3: Strengths of the current research

Strengths
• Pre-session instructions were designed to control for possible confounding factors (e.g. avoid vocally harmful behaviours, avoid hot showers, avoid foods/drinks). • Inclusion and exclusion criteria were carefully defined to control for possible confounding factors as well as to avoid recruiting participants at potential risk of harm from VLT. For instance, confounding variables were represented by medications, professional singers and self-reported hearing loss. These were set as exclusion criteria. • The VLT was carefully designed according to the literature combining different loading factors (high vocal intensity, prosodic voice effect, exaggerated forward head position). • The steam inhalation procedure was designed according to the literature and the common practices of clinicians. The equipment needed for the steam inhalation procedure (basin, towel to contain the steam) involved low-cost and easily accessible tools. • The study procedures were rigorously defined to reduce the potential influence of the researcher on outcome measures. The same procedures were conducted with all individuals. The investigators followed a protocol and performed a training period to enhance the consistency between the researchers. • Strategies to enhance the correct implementation of the VLT and the steam inhalation procedure were adopted: - Instructional videos sent prior to the session - Participants were monitored over zoom for the entire session - VLT trial at the beginning of the session - Use of Decibel X app (SkyPaw Co. Ltd, 2020) to monitor the loudness of participants - Participants were systematically reminded to check their loudness. • Consistent procedure for the remote recording of voice samples: - Use of an uncompressed format (.wav format) for recordings to increase the audio quality ensuring more reliable acoustic analyses. - 4 cm distance from the smartphone to the mouth - Use of a quiet room to reduce background noises. • Multiple outcome measures were chosen according to the literature. Outcome measure procedures were chosen as short, easily applicable and consistent for participants. • Outcome measures were collected immediately after VLT and the steam inhalation, reducing maturation as a threat to internal validity. • The research investigated the severity of several sensations included in the VTDS (Mathieson et al., 2009). Participants were also allowed to include additional features. • A consistency of the equipment of the researcher was observed throughout data collection. • Overall attention to treatment fidelity. • High ecological validity: - Given the online nature of the study, participants were observed in their natural context. - The use of different types of basins increased the ecological validity of the study.

Acknowledging that no research lacks weaknesses, the limitations of this research are reported and discussed below. The major limitation consisted of the small sample size recruited. Due to time constraints, only 12 participants were recruited although the sample size intended by power analyses would have involved 36 subjects. Therefore the likelihood of a type II error was increased. The findings reported are preliminary and the data will be reanalysed after continuing to recruit and having increased the sample size of the research. A balanced percentage of the recruited males and females would have avoided a potential sex effect on vocal loading and hydration. This aspect was considered performing double data analyses when appropriate.

Other limitations involved the pre-session procedure. In this study, women were not controlled for the menstrual cycle. This is relevant since sex steroid hormones across the menstrual cycle alter voice function and voice measures (e.g. F_0) and might influence the overall hydration status representing a confounding factor (Giersch et al., 2020; Lã & Polo, 2020; Pavela Banai, 2017). Recruiting females during the follicular phase, where the levels of hormones are lower, would have enabled controlling for the hormonal effects on the voice. Additionally, sessions were scheduled in the morning and participants were asked to avoid foods/drinks and vocally abusive behaviours before the experiment to minimise confounding for vocal fatigue and systemic hydration. The hydration status could have been objectively measured through blood plasma concentrations or bioelectrical impedance analysis (Kavouras, 2002; Ward, 2019). Nevertheless, it was not performed due to the complexity of the procedure and requirements that the procedures be conducted remotely due to the global pandemic.

Concerning the remote approach for data collection, which maximised the overall ecological validity, it also threatens the rigour of the experimental procedure. The loudness level during the VLT was controlled by asking participants to monitor themselves using the Decibel X app (SkyPaw Co. Ltd, 2020). To increase the reliability of the procedure, the PI reminded participants to check their loudness at the end of every page during the VLT. However, the use of voice dosimeters or the direct monitoring of loudness performed by the PI using a SPL meter would have provided non-invasive and more reliable strategies to ensure the appropriate vocal demand (Manfredi & Dejonckere, 2016). The remote nature of the study indeed threatened the overall reliability of the study. Participants were asked to use a quiet room for the session to reduce the presence of background noises. Nonetheless, the use of an appropriate acoustical clinical space would have increased the quality of recordings and the reliability of analyses (Bottalico et al., 2020). Additionally, even if the same procedure was rigorously adopted with every participant, a variability in the equipment existed because of the remote nature of the study.

Moreover, environmental humidity was not controlled and might constitute a confounding factor. Opening windows to enhance equal humidity was considered and discarded due to the multiple

geographical locations of participants. With a face to face procedure, the environmental humidity could have been controlled with an hygrometer and with the consistent use of the same clinic room.

Concerning outcome measures, the inclusion of PTP as an aerodynamic measure would have provided further insights into the effects of VLT and steam inhalation considering the higher sensitivity of PTP observed in previous studies (§1.2.4, §1.4).

A risk of bias appraisal is conducted following the domains reported in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019) and reported below (Table 4.4)

Table 4.4: Risk of bias appraisal

Risk of bias	**Appraisal**
Selection bias	The non-probability sampling strategy might have led to the exclusion of some individuals. With a convenience sampling strategy, students of the Department of Clinical Speech and Language Studies of Trinity College Dublin were involved.
Performance bias	Only one group of participants was involved in this study. Systematic differences between groups that would have led to a performance bias were not present.
Detection bias	The lack of blinding of participants potentially led to a detection bias with reference to self-reported outcome measures. The lack of blinding of investigators at V0, V1, V2 did not affect voice measures since only objective measures (acoustic and aerodynamic parameters) were collected. Investigators followed a protocol delivering the same instructions and collecting the same measures in the same sequence, thus minimising systematic differences between participants.
Attrition bias	No withdrawals, exclusions of participants or missing data occurred.
Reporting bias	Results were reported accordingly with raw data and p-values for all the adopted outcome measures.

4.6 Future research

Further research on the field should be focused on the clinical population of subjects with dysphonia. Although VLTs are designed to replicate conditions similar to that of dysphonia, research validity would improve if dysphonic individuals were recruited in the first instance. The laryngeal system of subjects with dysphonia might be characterised by different vocal demand responses and therefore different vocal effort and vocal fatigue. This recruitment of dysphonic individuals was not considered for the present study but was unachievable due to the current global pandemic.

Furthermore, it would be interesting to compare the effects of vocal rest and different surface hydration devices (e.g. common basin of boiling water, wet gauze, facial steamer). Perhaps an RCT

study design with multiple groups or using one group longitudinally would allow researchers to measure and compare the effects of different tools.

Lastly, further research should be focused on the different effects of euhydration versus hyperhydration. High vocal demands increase the viscosity of vocal folds making them susceptible to dehydration therefore the following rehydration procedure might act to restore the hydration status to its appropriate baseline levels (euhydration). It would also be interesting to explore the effects of hyperhydration. For instance, comparing different durations of hydration schedules (e.g. 5, 10, 20 minutes) could establish the magnitude of the effects of longer and shorter procedures.

4.7 Conclusion

The present research investigated the effectiveness of a 20-minutes VLT in inducing changes in acoustic, aerodynamic and self-perceived voice measures in vocally healthy adults. It also aimed to evaluate the effects of 10-minutes of steam inhalation and its potential effectiveness in restoring the adverse effects of the VLT.

The current results demonstrated that the VLT designed for this research negatively affected self-perceived measures (vocal tract discomfort, perceived effort and fatigue). Following 10-minutes of steam inhalation performed with a basin of boiling water and a towel to contain the steam, ratings significantly improved and restored to baseline levels. Conversely, either the VLT and the steam inhalation did not affect voice quality, significantly altering acoustic and aerodynamic measures.

The present research suggests the relevant role of self-perceived measures in the characterisation of vocal fatigue induced with a short VLT. This research informs clinicians regarding the effectiveness of steam inhalation as a simple and low-cost tool to be recommended to enhance the recovering of the self-perceived adverse effects of vocal fatigue.

References

Abou-Rafée, M., Zambon, F., Badaró, F., & Behlau, M. (2019). Vocal fatigue in dysphonic teachers who seek treatment. *Codas, 31*(3), e20180120. https://doi.org/10.1590/2317-1782/20182018120

Alves, M., Krüger, E., Pillay, B., van Lierde, K., & van der Linde, J. (2019). The Effect of Hydration on Voice Quality in Adults: A Systematic Review. *Journal of Voice, 33*(1), 125.e113-125.e128. https://doi.org/10.1016/j.jvoice.2017.10.001

Angerstein, W. (2018). Vocal Changes and Laryngeal Modifications in the Elderly (Presbyphonia and Presbylarynx). *Laryngorhinootologie, 97*(11), 772-776. https://doi.org/10.1055/a-0652-6758

Armstrong, L. E. (2007). Assessing hydration status: the elusive gold standard. *Journal of the American College of Nutrition, 26*(5 Suppl), 575s-584s. https://doi.org/10.1080/07315724.2007.10719661

Bane, M., Angadi, V., Dressler, E., Andreatta, R., & Stemple, J. (2019). Vocal function exercises for normal voice: The effects of varying dosage. *International Journal of Speech-Language Pathology, 21*(1), 37-45. https://doi.org/10.1080/17549507.2017.1373858

Beauchamp, T. L., & Childress, J. F. (2019). *Principles of Biomedical Ethics* (8th ed.). Oxford University Press.

Behlau, M., & Oliveira, G. (2009). Vocal hygiene for the voice professional. *Current Opinion Otolaryngology & Head and Neck Surgery, 17*(3), 149-154. https://doi.org/10.1097/MOO.0b013e32832af105

Behlau, M., Zambon, F., Moreti, F., Oliveira, G., & de Barros Couto, E., Jr. (2017). Voice Self-assessment Protocols: Different Trends Among Organic and Behavioral Dysphonias. *Journal of Voice, 31*(1), 112.e113-112.e127. https://doi.org/10.1016/j.jvoice.2016.03.014

Bock, J. M. (2019). Medications and Vocal Function. *Otolaryngologic Clinics of North America, 52*(4), 693-702. https://doi.org/10.1016/j.otc.2019.03.013

Boersma, Paul & Weenink, David (2020). *Praat: doing phonetics by computer* (Version 6.1.29) [Computer software]. https://www.praat.org

Boominathan, P., Anitha, R., Shenbagavalli, M., & Dinesh, G. (2010). Voice characteristics and recovery patterns in indian adult males after vocal loading. *Journal of the All India Institute of Speech & Hearing, 29*(2), 220-231.

Boone, D. R., McFarlane, S. C., Berg, S. L. V., & Zraick, R. I. (2020). *The Voice and Voice Therapy* (10th ed.). Pearson.

Borragan, M., Mediavilla, B. G., Legina, M. A., Fernandez, M. J. G., Strangis, D., Fantini, M., Maccarini, A. R., & Torre, A. B. (2021). Nasal Breathing Through a Damp Gauze Enhances Surface Hydration of the Vocal Folds and Optimizes Vocal Function. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.06.023

Bottalico, P., Codino, J., Cantor-Cutiva, L. C., Marks, K., Nudelman, C. J., Skeffington, J., Shrivastav, R., Jackson-Menaldi, M. C., Hunter, E. J., & Rubin, A. D. (2020). Reproducibility of Voice Parameters: The Effect of Room Acoustics and Microphones. *Journal of Voice, 34*(3), 320-334. https://doi.org/10.1016/j.jvoice.2018.10.016

Bowling, A. (2014). *Research methods in health: investigating health and health services* (4th ed.). Open University Press.

Buekers, R. (1998). Are voice endurance tests able to assess vocal fatigue? *Clinical Otolaryngology & Allied Sciences, 23*(6), 533-538. https://doi.org/10.1046/j.1365-2273.1998.2360533.x

Cadeddu, M., Farrokhyar, F., Thoma, A., Haines, T., Garnett, A., & Goldsmith, C. H. (2008). Users' guide to the surgical literature: how to assess power and sample size. Laparoscopic vs open appendectomy. *Canadian Journal of Surgery, 51*(6), 476-482.

Campbell, D. T., Stanley, J. C., & Gage, N. L. (1963). *Experimental and quasi-experimental designs for research*. Houghton, Mifflin and Company.

Cattaneo, C., Flynn, É., & Walshe, M. (2021). Fidelity in Behavioral Interventions for Oropharyngeal Dysphagia in Parkinson's Disease: A Systematic Review. *Dysphagia*. https://doi.org/10.1007/s00455-021-10279-3

Cavalcanti, J. C., Englert, M., Oliveira, M., & Constantini, A. C. (2021). Microphone and Audio Compression Effects on Acoustic Voice Analysis: A Pilot Study. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2020.12.005

Chan, R. W., & Tayama, N. (2002). Biomechanical effects of hydration in vocal fold tissues. *Otolaryngology & Head and Neck Surgery, 126*(5), 528-537. https://doi.org/10.1067/mhn.2002.124936

Claassen, H., & Werner, J. A. (1992). Fiber differentiation of the human laryngeal muscles using the inhibition reactivation myofibrillar ATPase technique. *Anatomy and Embryology, 186*(4), 341-346. https://doi.org/10.1007/bf00185983

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Academic Press.

De Bodt, M. S., Wuyts, F. L., Van de Heyning, P. H., Lambrechts, L., & Vanden Abeele, D. (1998). Predicting vocal outcome by means of a vocal endurance test: a 5-year follow-up study in female teachers. *Laryngoscope, 108*(9), 1363-1367. https://doi.org/10.1097/00005537-199809000-00020

Dempsey, J. A., & Babcock, M. A. (1995). An integrative view of limitations to muscular performance. *Advances in Experimental Medicine and Biology, 384*, 393-399. https://doi.org/10.1007/978-1-4899-1016-5_31

Egan, J. J. (1971). The Lombard reflex. Historical perspective. *Archives of Otolaryngology - Head and Neck Surgery, 94*(4), 310-312. https://doi.org/10.1001/archotol.1971.00770070502004

Enflo, L., Sundberg, J., & McAllister, A. (2013). Collision and phonation threshold pressures before and after loud, prolonged vocalization in trained and untrained voices. *Journal of Voice, 27*(5), 527-530. https://doi.org/10.1016/j.jvoice.2013.03.008

Faham, M., Ahmadi, A., Drinnan, M., Saadatmand, N., Fatahi, E., & Jalalipour, M. (2016). The Effects of a Voice Education Program on VHI Scores of Elementary School Teachers. *Journal of Voice, 30*(6), 755.e751-755.e711. https://doi.org/10.1016/j.jvoice.2015.09.009

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191. https://doi.org/10.3758/BF03193146

Fisher, K. V., & Swank, P. R. (1997). Estimating phonation threshold pressure. *Journal of Speech, Language, and Hearing Research, 40*(5), 1122-1129. https://doi.org/10.1044/jslhr.4005.1122

Franca, M. C., & Simpson, K. O. (2009). Effects of Hydration on Voice Acoustics. *Contemporary Issues in Communication Science and Disorders, 36*(Fall), 142-148. https://doi.org/10.1044/cicsd_36_F_142

Fu, S., Theodoros, D. G., & Ward, E. C. (2015). Intensive versus traditional voice therapy for vocal nodules: perceptual, physiological, acoustic and aerodynamic changes. *Journal of Voice, 29*(2), 260.e231-244. https://doi.org/10.1016/j.jvoice.2014.06.005

Fujiki, R. B., Chapleau, A., Sundarrajan, A., McKenna, V., & Sivasankar, M. P. (2017). The Interaction of Surface Hydration and Vocal Loading on Voice Measures. *Journal of Voice, 31*(2), 211-217. https://doi.org/10.1016/j.jvoice.2016.07.005

Fujiki, R. B., & Sivasankar, M. P. (2017). A Review of Vocal Loading Tasks in the Voice Literature. *Journal of Voice, 31*(3), 388.e333-388.e339. https://doi.org/10.1016/j.jvoice.2016.09.019

Gelfer, M. P., Andrews, M. L., & Schmidt, C. P. (1991). Effects of prolonged loud reading on selected measures of vocal function in trained and untrained singers. *Journal of Voice, 5*(2), 158-167. https://doi.org/10.1016/S0892-1997(05)80179-1

Giersch, G. E. W., Charkoudian, N., Stearns, R. L., & Casa, D. J. (2020). Fluid Balance and Hydration Considerations for Women: Review and Future Directions. *Sports Medicine, 50*(2), 253-261. https://doi.org/10.1007/s40279-019-01206-6

Gillivan-Murphy, P., Drinnan, M. J., O'Dwyer, T. P., Ridha, H., & Carding, P. (2006). The effectiveness of a voice treatment approach for teachers with self-reported voice problems. *Journal of Voice, 20*(3), 423-431. https://doi.org/10.1016/j.jvoice.2005.08.002

Gilman, M., & Johns, M. M. (2017). The Effect of Head Position and/or Stance on the Self-perception of Phonatory Effort. *Journal of Voice, 31*(1), 131.e131-131.e134. https://doi.org/10.1016/j.jvoice.2015.11.024

Giovanni, A., Akl, L., & Ouaknine, M. (2008). Postural Dynamics and Vocal Effort: Preliminary Experimental Analysis. *Folia Phoniatrica et Logopaedica, 60*(2), 80-85. https://doi.org/10.1159/000114649

Gorham-Rowan, M., Berndt, A., Carter, M., & Morris, R. (2016). The Effect of a Vocal Loading Task on Vocal Function Before and After 24 Hours of Thickened Liquid Use. *Journal of Speech Pathology & Therapy, 1*(1). https://doi.org/10.4172/2472-5005.1000103

Gotaas, C., & Starr, C. D. (1993). Vocal fatigue among teachers. *Folia Phoniatrica et Logopaedica, 45*(3), 120-129. https://doi.org/10.1159/000266237

Goy, H., Fernandes, D. N., Pichora-Fuller, M. K., & van Lieshout, P. (2013). Normative voice data for younger and older adults. *Journal of Voice, 27*(5), 545-555. https://doi.org/10.1016/j.jvoice.2013.03.002

Grillo, E. U., Brosious, J. N., Sorrell, S. L., & Anand, S. (2016). Influence of Smartphones and Software on Acoustic Voice Measures. *International Journal of Telerehabilitation, 8*(2), 9-14. https://doi.org/10.5195/ijt.2016.6202

Hanschmann, H., Gaipl, C., & Berger, R. (2011). Preliminary results of a computer-assisted vocal load test with 10-min test duration. *European Archives of Oto-Rhino-Laryngology, 268*(2), 309-313. https://doi.org/10.1007/s00405-010-1428-3

Hartley, N. A., & Thibeault, S. L. (2014). Systemic hydration: relating science to clinical practice in vocal health. *Journal of Voice, 28*(5), 652.e651-652.e620. https://doi.org/10.1016/j.jvoice.2014.01.007

Higgins, J. P., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2019). *Cochrane handbook for systematic reviews of interventions* (2nd ed.). John Wiley & Sons.

Hirano, M. (1981). *Clinical Examination of Voice*. Springer-Verlag.

Hunter, E. (2020, May 27-31). *Redefining Vocal Fatigue* Vocal fatigue: is it worth the effort?, Virtual Voice Symposium. https://voicefoundation.org/virtual-voice/special-session/

Hunter, E. J., & Banks, R. E. (2017). Gender Differences in the Reporting of Vocal Fatigue in Teachers as Quantified by the Vocal Fatigue Index. *Annals of Otology, Rhinology, and Laryngology, 126*(12), 813-818. https://doi.org/10.1177/0003489417738788

Hunter, E. J., Cantor-Cutiva, L. C., van Leer, E., van Mersbergen, M., Nanjundeswaran, C. D., Bottalico, P., Sandage, M. J., & Whitling, S. (2020). Toward a Consensus Description of Vocal Effort, Vocal Load, Vocal Loading, and Vocal Fatigue. *Journal of Speech, Language, and Hearing Research, 63*(2), 509-532. https://doi.org/10.1044/2019_jslhr-19-00057

Hunter, E. J., Siegmund, T., & Chan, R. W. (2014). Strain modulations as a mechanism to reduce stress relaxation in laryngeal tissues. *PLoS One, 9*(3), e90762. https://doi.org/10.1371/journal.pone.0090762

j labs (2020). *Voice Recorder & Audio Editor* (Version 3.5.1) [Mobile App]. https://play.google.com/store/apps/details?id=me.jlabs.voicerecorder&hl=en&gl=US

Jéquier, E., & Constant, F. (2010). Water as an essential nutrient: the physiological basis of hydration. *European Journal of Clinical Nutrition, 64*(2), 115-123. https://doi.org/10.1038/ejcn.2009.111

Kavouras, S. A. (2002). Assessing hydration status. *Current Opinion in Clinical Nutrition & Metabolic Care, 5*(5), 519-524. https://doi.org/10.1097/00075197-200209000-00010

Kelchner, L. N., Toner, M. M., & Lee, L. (2006). Effects of Prolonged Loud Reading on Normal Adolescent Male Voices. *Language, Speech, and Hearing Services in Schools, 37*(2), 96-103. https://doi.org/10.1044/0161-1461(2006/012)

Keltz, A., & McHenry, M. (2020). Steam and/or Semi-occluded Vocal Tract Exercise as Morning Vocal Warm-up Strategy. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2020.08.037

Kimberlin, C. L., & Winterstein, A. G. (2008). Validity and reliability of measurement instruments used in research. *American Journal of Health-System Pharmacy, 65*(23), 2276-2284. https://doi.org/10.2146/ajhp070364

Kooijman, P. G. C., de Jong, F. I. C. R. S., Oudes, M. J., Huinck, W., van Acht, H., & Graamans, K. (2005). Muscular Tension and Body Posture in Relation to Voice Handicap and Voice Quality in Teachers with Persistent Voice Complaints. *Folia Phoniatrica et Logopaedica, 57*(3), 134-147. https://doi.org/10.1159/000084134

Lã, F. M. B., & Polo, N. (2020). Fundamental Frequency Variations Across the Menstrual Cycle and the Use of an Oral Contraceptive Pill. *Journal of Speech, Language, and Hearing Research, 63*(4), 1033-1043. https://doi.org/10.1044/2020_jslhr-19-00277

Lagier, A., Vaugoyeau, M., Ghio, A., Legou, T., Giovanni, A., & Assaiante, C. (2010). Coordination between Posture and Phonation in Vocal Effort Behavior. *Folia Phoniatrica et Logopaedica, 62*(4), 195-202. https://doi.org/10.1159/000314264

Laukkanen, A. M., Järvinen, K., Artkoski, M., Waaramaa-Mäki-Kulmala, T., Kankare, E., Sippola, S., Syrjä, T., & Salo, A. (2004). Changes in Voice and Subjective Sensations during a 45-min Vocal Loading Test in Female Subjects with Vocal Training. *Folia Phoniatrica et Logopaedica, 56*(6), 335-346. https://doi.org/10.1159/000081081

Lewis, C. S. (2004). *The Chronicles of Narnia*. Harpercollins.

Leydon, C., Sivasankar, M., Falciglia, D. L., Atkins, C., & Fisher, K. V. (2009). Vocal fold surface hydration: a review. *Journal of Voice, 23*(6), 658-665. https://doi.org/10.1016/j.jvoice.2008.03.010

Leydon, C., Wroblewski, M., Eichorn, N., & Sivasankar, M. (2010). A meta-analysis of outcomes of hydration intervention on phonation threshold pressure. *Journal of Voice, 24*(6), 637-643. https://doi.org/10.1016/j.jvoice.2009.06.001

Mahalingam, S., & Boominathan, P. (2016). Effects of steam inhalation on voice quality-related acoustic measures. *The Laryngoscope, 126*(10), 2305-2309. https://doi.org/10.1002/lary.25933

Manfredi, C., & Dejonckere, P. H. (2016). Voice dosimetry and monitoring, with emphasis on professional voice diseases: Critical review and framework for future research. *Logopedics Phoniatrics Vocology, 41*(2), 49-65. https://doi.org/10.3109/14015439.2014.970228

Mathieson, L. (2001). *Greene and Mathieson's the Voice and Its Disorders*. John Wiley & Sons.

Mathieson, L., Hirani, S. P., Epstein, R., Baken, R. J., Wood, G., & Rubin, J. S. (2009). Laryngeal manual therapy: a preliminary study to examine its treatment effects in the management of muscle tension dysphonia. *Journal of Voice, 23*(3), 353-366. https://doi.org/10.1016/j.jvoice.2007.10.002

McAllister, A., & Sjölander, P. (2013). Children's voice and voice disorders. *Seminars in Speech and Language, 34*(2), 71-79. https://doi.org/10.1055/s-0033-1342978

Murton, O., Hillman, R., & Mehta, D. (2020). Cepstral Peak Prominence Values for Clinical Voice Evaluation. *American Journal of Speech-Language Pathology, 29*(3), 1596-1607. https://doi.org/10.1044/2020_ajslp-20-00001

Nanjundeswaran, C. (2020, May 27-31). *Measuring and Monitoring the Complex Nature of Vocal Fatigue* Vocal Fatigue: is it worth the effort?, Virtual Voice Symposium. https://voicefoundation.org/virtual-voice/special-session/

Nanjundeswaran, C., Jacobson, B. H., Gartner-Schmidt, J., & Verdolini Abbott, K. (2015). Vocal Fatigue Index (VFI): Development and Validation. *Journal of Voice, 29*(4), 433-440. https://doi.org/10.1016/j.jvoice.2014.09.012

National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. (1979). *The Belmont report: Ethical principles and guidelines for the protection of human subjects of research*. https://www.hhs.gov/ohrp/regulations-and-policy/belmont-report/read-the-belmont-report/index.html

Neils, L. R., & Yairi, E. (1987). Effects of speaking in noise on vocal fatigue and vocal recovery. *Folia Phoniatrica et Logopaedica, 39*(2), 104-112. https://doi.org/10.1159/000265846

Nemr, K., Di Carlos Silva, A., Rodrigues, D. A., & Zenari, M. S. (2018). Medications and Adverse Voice Effects. *Journal of Voice, 32*(4), 515.e529-515.e539. https://doi.org/10.1016/j.jvoice.2017.07.009

Onofre, F., Ricz, H., de Almeida Prado, Y., Rojas, G. V. E., Garcia, D. M., & Aguiar-Ricz, L. (2021). Vocal resistance among choir singers. *European Archives of Oto-Rhino-Laryngology, 278*(1), 159-165. https://doi.org/10.1007/s00405-020-06238-7

Pasa, G., Oates, J., & Dacakis, G. (2007). The relative effectiveness of vocal hygiene training and vocal function exercises in preventing voice disorders in primary school teachers. *Logopedics Phoniatrics Vocology, 32*(3), 128-140. https://doi.org/10.1080/14015430701207774

Passer, M. W. (2014). *Research methods : concepts and connections*. New York: Worth Publishers.

Pavela Banai, I. (2017). Voice in different phases of menstrual cycle among naturally cycling women and users of hormonal contraceptives. *PLoS One, 12*(8), e0183462. https://doi.org/10.1371/journal.pone.0183462

Remacle, A., Finck, C., Roche, A., & Morsomme, D. (2012). Vocal impact of a prolonged reading task at two intensity levels: objective measurements and subjective self-ratings. *Journal of Voice, 26*(4), e177-186. https://doi.org/10.1016/j.jvoice.2011.07.016

Roberts, P., & Priest, H. (2006). Reliability and validity in research. *Nursing Standard, 20*(44), 41-45. https://doi.org/10.7748/ns2006.07.20.44.41.c6560

Roy, N., Gray, S. D., Simon, M., Dove, H., Corbin-Lewis, K., & Stemple, J. C. (2001). An evaluation of the effects of two treatment approaches for teachers with voice disorders: a prospective randomized clinical trial. *Journal of Speech, Language, and Hearing Research, 44*(2), 286-296. https://doi.org/10.1044/1092-4388(2001/023)

Roy, N., Merrill, R. M., Thibeault, S., Parsa, R. A., Gray, S. D., & Smith, E. M. (2004). Prevalence of voice disorders in teachers and the general population. *Journal of Speech, Language, and Hearing Research, 47*(2), 281-293. https://doi.org/10.1044/1092-4388(2004/023)

Roy, N., Tanner, K., Gray, S. D., Blomgren, M., & Fisher, K. V. (2003). An evaluation of the effects of three laryngeal lubricants on phonation threshold pressure (PTP). *Journal of Voice, 17*(3), 331-342. https://doi.org/10.1067/s0892-1997(03)00078-x

Santana, É. R., Masson, M. L. V., & Araújo, T. M. (2017). The Effect of Surface Hydration on Teachers' Voice Quality: An Intervention Study. *Journal of Voice, 31*(3), 383.e385-383.e311. https://doi.org/10.1016/j.jvoice.2016.08.019

Schneider, S. L., Habich, L., Weston, Z. M., & Rosen, C. A. (2021). Observations and Considerations for Implementing Remote Acoustic Voice Recording and Analysis in Clinical Practice. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.06.011

Schwartz, S. K. (2004). *The Source for Voice Disorders: Adolescent & Adult*. LinguiSystems.

Sivasankar, M., & Erickson, E. (2009). Short-duration accelerated breathing challenges affect phonation. *Laryngoscope, 119*(8), 1658-1663. https://doi.org/10.1002/lary.20530

Sivasankar, M., & Fisher, K. V. (2002). Oral breathing increases Pth and vocal effort by superficial drying of vocal fold mucosa. *Journal of Voice, 16*(2), 172-181. https://doi.org/10.1016/s0892-1997(02)00087-5

Sivasankar, M., & Fisher, K. V. (2003). Oral breathing challenge in participants with vocal attrition. *Journal of Speech, Language, and Hearing Research, 46*(6), 1416-1427. https://doi.org/10.1044/1092-4388(2003/110)

Sivasankar, M., & Leydon, C. (2010). The role of hydration in vocal fold physiology. *Current Opinion Otolaryngology & Head and Neck Surgery, 18*(3), 171-175. https://doi.org/10.1097/MOO.0b013e3283393784

Sivasankar, M. P., & Erickson-Levendoski, E. (2012). Influence of obligatory mouth breathing, during realistic activities, on voice measures. *Journal of Voice, 26*(6), 813.e819-813. https://doi.org/10.1016/j.jvoice.2012.03.007

SkyPaw Co. Ltd. (2020). *Decibel X:dB Sound Level Meter* (Version 9.1.0) [Mobile App]. https://play.google.com/store/apps/details?id=com.skypaw.decibel&hl=en&gl=US

Södersten, M., Ternström, S., & Bohman, M. (2005). Loud speech in realistic environmental noise: phonetogram data, perceptual voice quality, subjective ratings, and gender differences in healthy speakers. *Journal of Voice, 19*(1), 29-46. https://doi.org/10.1016/j.jvoice.2004.05.002

Solomon, N. P. (2008). Vocal fatigue and its relation to vocal hyperfunction *International Journal of Speech-Language Pathology, 10*(4), 254-266. https://doi.org/10.1080/14417040701730990

Solomon, N. P. (2020, May 27-31). *The Three MS of Vocal Fatigue: Mucosal, Muscular, and Mental* Vocal Fatigue: is it worth the effort, Virtual Voice symposium. https://voicefoundation.org/virtual-voice/special-session/

Solomon, N. P., & DiMattia, M. S. (2000). Effects of a vocally fatiguing task and systemic hydration on phonation threshold pressure. *Journal of Voice, 14*(3), 341-362. https://doi.org/10.1016/s0892-1997(00)80080-6

Solomon, N. P., Glaze, L. E., Arnold, R. R., & van Mersbergen, M. (2003). Effects of a vocally fatiguing task and systemic hydration on men's voices. *Journal of Voice, 17*(1), 31-46. https://doi.org/10.1016/s0892-1997(03)00029-8

Spantideas, N., Bougea, A., Drosou, E., & Assimakopoulos, D. (2019). The Role of Allergy in Phonation. *Journal of Voice, 33*(5), 811.e819-811.e827. https://doi.org/10.1016/j.jvoice.2018.02.016

Stemple, J. C., Lee, L., D'Amico, B., & Pickup, B. (1994). Efficacy of vocal function exercises as a method of improving voice production. *Journal of Voice, 8*(3), 271-278. https://doi.org/10.1016/s0892-1997(05)80299-1

Stemple, J. C., Stanley, J., & Lee, L. (1995). Objective measures of voice production in normal subjects following prolonged voice use. *Journal of Voice, 9*(2), 127-133. https://doi.org/10.1016/s0892-1997(05)80245-0

Sundarrajan, A., Fujiki, R. B., Loerch, S. E., Venkatraman, A., & Sivasankar, M. P. (2017). Vocal Loading and Environmental Humidity Effects in Older Adults. *Journal of Voice, 31*(6), 707-713. https://doi.org/10.1016/j.jvoice.2017.02.002

Supinski, G. S., Clary, S. J., Bark, H., & Kelsen, S. G. (1987). Effect of inspiratory muscle fatigue on perception of effort during loaded breathing. *Journal of Applied Physiology, 62*(1), 300-307. https://doi.org/10.1152/jappl.1987.62.1.300

Švec, J. G., Schutte, H. K., Chen, C. J., & Titze, I. R. (2021). Integrative Insights into the Myoelastic-Aerodynamic Theory and Acoustics of Phonation. Scientific Tribute to Donald G. Miller. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.01.023

Tanner, K., Fujiki, R. B., Dromey, C., Merrill, R. M., Robb, W., Kendall, K. A., Hopkin, J. A., Channell, R. W., & Sivasankar, M. P. (2016). Laryngeal Desiccation Challenge and Nebulized Isotonic Saline in Healthy Male Singers and Nonsingers: Effects on Acoustic, Aerodynamic, and Self-Perceived Effort and Dryness Measures. *Journal of Voice, 30*(6), 670-676. https://doi.org/10.1016/j.jvoice.2015.08.016

Tanner, K., Roy, N., Merrill, R. M., & Elstad, M. (2007). The effects of three nebulized osmotic agents in the dry larynx. *Journal of Speech, Language, and Hearing Research, 50*(3), 635-646. https://doi.org/10.1044/1092-4388(2007/045)

TapMedia Ltd (2020). *Voice Recorder & Audio Editor* (Version 4.3) [Mobile App]. https://apps.apple.com/us/app/voice-recorder-audio-editor/id685310398

Tavaluc, R., & Tan-Geller, M. (2019). Reinke's Edema. *Otolaryngologic Clinics of North America, 52*(4), 627-635. https://doi.org/10.1016/j.otc.2019.03.006

Titze, I. R. (1994). Mechanical stress in phonation. *Journal of Voice, 8*(2), 99-105. https://doi.org/10.1016/s0892-1997(05)80302-9

Tiwari, M., & Tiwari, M. (2012). Voice - How humans communicate? *Journal of natural science, biology, and medicine, 3*(1), 3-11. https://doi.org/10.4103/0976-9668.95933

Tomczak, M., & Tomczak, E. (2014). The need to report effect size estimates revisited. An overview of some recommended measures of effect size. *Trends in Sport Sciences, 21*(1), 19-25.

Van Houtte, E., Van Lierde, K., & Claeys, S. (2011). Pathophysiology and treatment of muscle tension dysphonia: a review of the current knowledge. *Journal of Voice, 25*(2), 202-207. https://doi.org/10.1016/j.jvoice.2009.10.009

van Wyk, L., Cloete, M., Hattingh, D., van der Linde, J., & Geertsema, S. (2017). The Effect of Hydration on the Voice Quality of Future Professional Vocal Performers. *Journal of Voice, 31*(1), 111.e129-111.e136. https://doi.org/10.1016/j.jvoice.2016.01.002

Verdolini-Marston, K., Titze, I. R., & Druker, D. G. (1990). Changes in phonation threshold pressure with induced conditions of hydration. *Journal of Voice, 4*(2), 142-151. https://doi.org/10.1016/S0892-1997(05)80139-0

Verstraete, J., Forrez, G., Mertens, P., & Debruyne, F. (1993). The effect of sustained phonation at high and low pitch on vocal jitter and shimmer. *Folia Phoniatrica et Logopaedica, 45*(5), 223-228. https://doi.org/10.1159/000266266

Vilkman, E., Lauri, E. R., Alku, P., Sala, E., & Sihvo, M. (1999). Effects of prolonged oral reading on F0, SPL, subglottal pressure and amplitude characteristics of glottal flow waveforms. *Journal of Voice, 13*(2), 303-312. https://doi.org/10.1016/s0892-1997(99)80036-8

Vintturi, J., Alku, P., Lauri, E. R., Sala, E., Sihvo, M., & Vilkman, E. (2001). The effects of post-loading rest on acoustic parameters with special reference to gender and ergonomic factors. *Folia Phoniatrica et Logopaedica, 53*(6), 338-350. https://doi.org/10.1159/000052687

Walter, A. N., & Lenz, T. L. (2011). Hydration and Medication Use. *American Journal of Lifestyle Medicine, 5*(4), 332-335. https://doi.org/10.1177/1559827611401203

Ward, L. C. (2019). Bioelectrical impedance analysis for body composition assessment: reflections on accuracy, clinical utility, and standardisation. *European Journal of Clinical Nutrition, 73*(2), 194-199. https://doi.org/10.1038/s41430-018-0335-3

Welham, N. V., & Maclagan, M. A. (2003). Vocal fatigue: current knowledge and future directions. *Journal of Voice, 17*(1), 21-30. https://doi.org/10.1016/s0892-1997(03)00033-x

Whitling, S., Rydell, R., & Lyberg Åhlander, V. (2015). Design of a clinical vocal loading test with long-time measurement of voice. *Journal of Voice, 29*(2), 261.e213-227. https://doi.org/10.1016/j.jvoice.2014.07.012

Yiu, E. M., & Chan, R. M. (2003). Effect of hydration and vocal rest on the vocal fatigue in amateur karaoke singers. *Journal of Voice, 17*(2), 216-227. https://doi.org/10.1016/s0892-1997(03)00038-9

Zoom Video Communications Inc. (2016). *Security guide. Zoom Video Communications Inc*. https://zoom.us/docs/doc/Zoom-Security-White-Paper.pdf

Appendices

Appendix I – Ethical approval

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Application	Academic Year 2020/21
Applicant Code	HT22
Applicant/Supervisor Name	Monica Gerosa, Blessy Sabu / Dr Ciarán Kenny
Title of Research	The effects of vocal loading and steam inhalation on voice measures in adults.
Date of this letter	19/02/2021

Dear Monica and Blessy,

Your amended submission (dated 19/02/2021) for ethical approval for the research project above was considered by the Research Ethics Committee, School of Linguistic, Speech and Communication Sciences, Trinity College Dublin and has been approved in full.

Please note:
(i) On completion of research projects, applicants should complete the *End of Project Report Form* (which can be found at: https://www.tcd.ie/slscs/research/ethics/) and submit one electronic copy (to slscs@tcd.ie)
(ii) The REC requests, in particular, that you attend to your commitments regarding the storage and destruction of data arising from this research, in keeping with REC policy and General Data Protection Regulation (GDPR) guidelines.

We wish you every luck with your research.

Best wishes,

Ciarán Kenny

Dr Ciarán Kenny
Chair, Research Ethics Committee
School of Linguistic, Speech and Communication Sciences

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Appendix II – Consent form

TRINITY COLLEGE DUBLIN

SCHOOL OF LINGUISTIC, SPEECH AND COMMUNICATION SCIENCES

CONSENT FORM

"The effects of vocal loading and steam inhalation
on acoustic, aerodynamic, self-perceived and subjective voice measures in adults."

Participant code for study: __

There are two sections in this form. Each section has a statement and asks you to initial if you agree. The end of this form is for the researchers to complete.

Please ask any questions you may have when reading each of the statements. Thank you for participating.
Please Initial the box if you agree with the statement. Please feel free to ask questions if there is something you do not understand.

General	Tick box
I confirm I have read and understood the Information Leaflet for the above study. The information has been fully explained to me and I have been able to ask questions, all of which have been answered to my satisfaction.	
I understand that this study **is entirely voluntary, and if I decide that I do not want to take part, I can stop taking part in this study at any time without giving a reason.** I understand that deciding not to take part will not affect my current or future studies or career.	
I understand that all information will be kept private and confidential and that my name will not be disclosed.	
I understand that I will not be paid for taking part in this study	
I agree to take part in this research study having been fully informed of the risks, benefits, and alternatives which are set out in full in the information leaflet which I have been provided with.	
I agree to being contacted by researchers by Monica Gerosa – gerosam@tcd.ie, Blessy Reachal Sabu – sabub@tcd.ie as part of this research study	

Data processing	Tick box
I understand that there are **no direct benefits to me** from participating in this study. I understand that **results from the analysis of my personal information will not be given to me unless I request it.**	
I understand that I can stop taking part in this study at any time without giving a reason and this will not affect my future studies or career.	
I agree to being contacted by researchers by Monica Gerosa – gerosam@tcd.ie, Blessy Reachal Sabu – sabub@tcd.ie as part of this research study	

Signature of the research participant

.....

Participant Name (Block Capitals) Participants Signature Date

I, the undersigned, have taken the time to fully explain to the above patient the nature and purpose of this study in a way that they could understand. I have explained the risks and possible benefits involved. I have invited them to ask questions on any aspect of the study that concerned them.

I have given a copy of the information leaflet and consent form to the participant with contacts of the study Team

Researcher name: Monica Gerosa, Blessy Reachal Sabu

Title and qualifications: MSc. Students – Clinical Speech & Language studies

Signature: 

Date

Appendix III – Participant Information Leaflet (PIL)

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

TRINITY COLLEGE DUBLIN

SCHOOL OF LINGUISTIC, SPEECH AND COMMUNICATION

Participant Information Leaflet

"The effects of vocal loading and steam inhalation
on acoustic, aerodynamic, self-perceived and subjective voice measures in adults."

Principal Investigators	Monica Gerosa, Msc. Student – gerosam@tcd.ie Blessy Reachal Sabu, MSc. Students – sabub@tcd.ie
Supervisor	Dr. Ciarán Kenny - ciaran.kenny@tcd.ie
Data Controller	Trinity College Dublin
Data Protection Officer	Data Protection Officer Secretary's Office Trinity College Dublin Dublin 2

You are being invited to take part in a research study that is being done by Monica Gerosa and Blessy Reachal Sabu. The project will be conducted online.

Before you decide whether or not you wish to take part, please read this information sheet carefully.

You should understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. You may wish to discuss it with others. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

Why is this study being done?

We are doing this study to investigate the effects of vocal loading and steam inhalation on voice in adults. This project is being carried out as part of our MSc programme (Clinical Speech & Language Studies).

Why have I been invited to take part?

You have been invited to take part because you might be a healthy individual with no known voice disorder. We aim to have 128 people involved in this study.

Do I have to take part? Can I withdraw?

You don't have to take part in this study. *It is up to you to decide whether or not to take part.* If you decide not to take part it won't affect your current or future studies or career.

You can change your mind about taking part in the study and opt out at any time even if the study has started and even if we have already collected data from you. If you decide to opt out, it won't affect your current or future studies or career. You don't have to give a reason for not taking part or for opting out. If you wish to opt out at any time, please contact Monica Gerosa, Msc. Student – gerosam@tcd.ie and/or Blessy Reachal Sabu, MSc. Student – sabub@tcd.ie who will be able to organise this for you.

What happened if I change my mind?

You can change your mind at any time by contacting Monica Gerosa, Msc. Student – gerosam@tcd.ie; Blessy Reachal Sabu, MSc. Student – sabub@tcd.ie.

If you choose not to continue to take part, this will not affect your life in any way. If you wish, you can ask for your data to be destroyed. If you request this, we will destroy all data that are still in our possession. We will no longer use or share your data for research from this point onwards. However, it will not be possible to destroy data already used in the production of published results.

Why will happen to me if I decide to take part? What will I need to do?

This study will take place online via Zoom, in the morning at a date of your convenience. Study procedures will be completed in one sitting and will last approximately 1 hour.

A list of pre-session instructions will be sent via email to you before the experimental procedure. These will include:

- Avoid vocally harmful behaviours (e.g. long periods of shouting, singing or projecting your voice) in the 24h before the session
- Be up from bed for at least 1 h with minimal voice use since then
- Avoid hot shower or bath before the session
- Avoid foods or drinks before the session

This is the essential equipment you will need to use during the session:

- Laptop or computer with microphone available
- Create a Zoom account ready to be used
- Smartphone (charged)
- Download the App "Voice Recorder" (j labs on Android or TapMedia Ltd on iOS) which is free of charge. This will be used to record your voice in an uncompressed format (.wav) to ensure the quality of audio.
- Download the App "Decibel X" (SkyPaw Co. Ltd, 2020), which is free of charge and available for iOS and Android. This will be used to monitor your loudness.
- Ruler (30 cm) to measure distances
- Basin and a towel for the steam inhalation
- Water and kettle/pot to boil water available

The study procedure involves the following steps:

- **Step 1**: The first step involves the baseline measurements. You will be asked to record with your smartphone a prolonged "ahh" three times (4 cm distance from the microphone). Then you will be asked to read a passage shared on the screen and then rate your throat sensations, effort and fatigue on a scale.
- **Step 2**: After that, a Vocal Loading Task will take place. This means you will be asked to read loudly and with emphasis a portion of the book "The Chronicles of Narnia" for 20 minutes with a forward head position. While you do this, you will have the app "Decibel X" (SkyPaw Co. Ltd, 2020) turned on. This will help you maintain a loudness range of 70-85 dB, which is needed for the task.
- **Step 3:** The researcher will ask you to repeat the same measurements conducted in step 1.
- **Step 4:** You will be asked to do the steam inhalation. You will need to take a basin of boiling water, put your head under a towel at 20-30 distance from the basin. Then you will be asked to breathe at a natural pace through your mouth and nose for 10 minutes.
- **Step 5:** Lastly, the same measurements of step 1 will be repeated

After the session, you will be asked to send us the voice recordings via email or to upload them in a secure one drive folder. We will give you instructions on how to do this. Those recordings will be analysed and perceptually judged by the principal investigators and the supervisor of the study to evaluate the effects of the vocal loading task and steam inhalation on your voice.

If you agree to participate, you will be sent links to step-by-step instructional videos about the study procedures.

Are there any benefits to taking part in this research

Taking part in this study will not directly benefit you. It will improve scientific awareness about the effects of excessive voice use. Your data and information may help us to better understand the effects of vocal loading and steam inhalation on voice. This research will help understand how patients may be assessed and treated in the future.

Are there any risks to me or others if I take part? What will happen if something goes wrong?

The vocal loading (loud reading) task is designed to stress your voice box, making you experience vocal fatigue. You may feel a temporary strain or fatigue after participating, but this will usually resolve by the next day. There are no long-term risks or consequences involved in this procedure. You will be sent instructional videos in advance and we will do a trial before the session to ensure a better understanding of the process to minimise the risk of anything going wrong.

After the session, you will be given a document with some vocal care advice. These will encourage your voice box to relax, reducing potential strain.

If you have any concerns about your voice after the study, you are invited to contact the principal investigators Monica Gerosa, MSc. Student – gerosam@tcd.ie; Blessy Reachal Sabu, MSc. Student – sabub@tcd.ie or the supervisor Dr. Ciarán Kenny - ciaran.kenny@tcd.ie. They will arrange to follow up with you to manage this if necessary. Any such follow up will be at no cost to you.

Will I be told the results of any assessments performed as part of this study that relate to me?

Great care will be taken to ensure the confidentiality of all data and the risk to participants of a breach of confidentiality is considered very low. You will not be provided with the results of this research but at any point in time you have the right to ask to view your data. If so, you can contact the principal investigators Monica Gerosa, MSc. Student – gerosam@tcd.ie; Blessy Reachal Sabu, MSc. Student – sabub@tcd.ie. or the supervisor Dr. Ciarán Kenny - ciaran.kenny@tcd.ie. They will arrange access to your assessment findings for you.

How will my data be used?

Data from this research project may be published in future in scientific journals. You will not be able to be identified in any reports or publications. The original recording and all copies will be available only to the investigators running this study and will not be shared with anybody else.

What information about me (personal data) will be used as part of this study?
Will my medical records be accessed?

During data collection, the following personal data will be obtained:

- Participant name for identification.
- Age and sex for the description of the sample of participants.
- Written consent for the legal basis for processing
- Audio recordings for analysing the voice measures

Your consent form and any audio files collected from you will be stored in a password encrypted file in a secure folder on Microsoft OneDrive, owned by Trinity College Dublin and managed by the research supervisor. A password encrypted Excel spreadsheet will also be stored in this folder and will match your name with a unique ID number. Your ID number will be used instead of your name for research purposes to maintain your confidentiality.

All the personal data that we collect about you during the course of the research will be kept strictly confidential and will only be accessible to the principal investigators and the supervisor of the study. All of your personal data will be stored in Ireland. Trinity College Dublin will be the data controller of the study.

Data that can identify you will be kept for 7 years. After this time period your data will be destroyed by the supervisor of the study.

Will my personal data be kept confidential? How will my data be kept safe?

Your privacy is important to us. We take many steps to make sure that we protect your confidentiality and keep your data safe. Here are some examples of how we do this:
Any information or data which is obtained during this research which identifies you will be treated confidentially. All the data collected will be stored on the researcher's laptop in an encrypted and password protected file. The data will then be made anonymous so as to hide your identity. All original files will be encrypted and transferred to a secure folder in the Trinity College Dublin computer network. Any files containing identifiable information will then be deleted off the laptop, so that only data coded with your unique ID number remains. All files will be accessible only by the principal investigators and the supervisor of the study.

All individual researchers involved in this project have been trained in data protection laws and are bound by professional code to maintain confidentiality.

What is the lawful basis to use my personal data?

A data protection impact assessment has been carried out indicating a **low** risk level.

What are my rights?

According to data protection legislation, we are required to inform you of the legal basis for using your personal data. The tasks we are performing are on the basis of your explicit consent.

You are entitled to:

- The right to access to your data and receive a copy of it
- The right to have your data transferred to another organisation or 'data controller'.
- The right to restrict or object to processing of your data
- The right to object to any further processing of the information we hold about you (except where it is de-identified)
- The right to have inaccurate information about you corrected or deleted
- The right to request deletion of your data

By law you can exercise these rights in relation to your personal data, unless the request would make it impossible or very difficult to conduct the research. You can exercise these rights by contacting the principal investigators Monica Gerosa, MSc. Student – gerosam@tcd.ie; Blessy Reachal Sabu, MSc. Student – sabub@tcd.ie or the supervisor Dr. Ciarán Kenny - ciaran.kenny@tcd.ie or the Trinity College Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie Website: www.tcd.ie/privacy

Has this study been approved by a research ethics committee?

Yes, this study has been approved in full by the Research Ethics Committee of the School of Linguistic, Speech & Communication Sciences, Trinity College Dublin on 19/02/2021.

Who is organising and funding this study

No funding was obtained for the study.

Is there any payment for taking part? Will it cost me anything if I agree to take part?

No, you will not be paid to participate in this study.

Who should I contact for information or complaints?

If you have any concerns or questions, you can contact:

- Principal Investigators: Monica Gerosa – gerosam@tcd.ie; Blessy Reachal Sabu – sabub@tcd.ie.
- Supervisor: Dr. Ciarán Kenny - ciaran.kenny@tcd.ie
- Data Protection Officer, Trinity College Dublin: Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie Website: www.tcd.ie/privacy Under GDPR, if you are not satisfied with how your data is being processed, you have the right to lodge a complaint with the Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2, Ireland. Website: www.dataprotection.ie

Will I be contacted again?

If you would like to participate, you can contact us and we will provide you with the consent form.

You will be given a copy of this information leaflet and the signed Consent Form to keep. If you consent, we will contact you to arrange a session for study procedure.

Thank you for taking the time to read this leaflet.

Appendix IV – Data protection impact assessment approval

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

15/02/2021

Study Title: The effects of Vocal loading and steam inhalation on voice measures in adults

Dear Monica

I have reviewed the Data Protection Impact Assessment ('DPIA') and supporting documentation (Information Leaflet, Consent Form) in respect of this research study and am satisfied that the intended processing of personal data for the purposes of the study as described therein is in compliance with data protection legislation, specifically the EU General Data Protection Regulation 2016 ('GDPR'), Data Protection Acts 1988-2018 and Health Research Regulations 2018 and that the risk associated with processing is **LOW**.

Please note that the completion of a DPIA is not a one-time exercise, but a continual process. If at any stage there are changes to the processing envisaged by this assessment please contact me.

Be advised that the Trinity College Data Protection Office may carry out a review to assess if the processing is being performed in accordance with the information provided.

I wish you the very best of luck with your research.

Sincerely,

Data Protection Officer
Secretary's Office,
Trinity College Dublin,
Dublin 2, Ireland.

Appendix V – Vocal hygiene recommendations

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Voice care advice

Thank you for taking part in this study.

After this session, you may experience a temporary vocal strain or fatigue that should disappear by the next day. Below are some tips for taking care of your voice during the remainder of the day:

- Avoid shouting, whispering or singing during the day which could cause you fatigue in your voice further.
- Drink plenty of water. Keep your water bottle near you. It will help remind you to drink water during the day.
- Avoid dusty and dry environments.
- Avoid talking excessively and over background noises.
- Avoid drinking alcohol and smoking for the remainder of the day.
- If at all you start experiencing tiredness in your voice, take voice rest if possible and avoid speaking for a while. It will allow your voice to recover.

If you have any concerns about your voice after the study procedures you are free to contact the principal investigators or the supervisor. The contact details are provided below:

Principal Investigators:Monica Gerosa - gerosam@tcd.ie

Blessy Reachal Sabu - sabub@tcd.ie

Supervisor: Dr. Ciaran Kenny - ciaran.kenny@tcd.ie

Appendix VI – Email to participants

Dear undergraduate and postgraduate students,

We are emailing you to invite you to participate in our research project. The topic of our research is "The effects of vocal loading and steam inhalation of voice in adults". It involves taking some voice recordings, using your voice intensively to make it tired, then inhaling some steam to see if this will relieve your throat. We are looking for individuals who:

- Are between the age of 18-60 years old
- Have no history of voice pathology, voice complaints and have done any voice therapy
- Are not professional singers
- Are non-smokers
- Have no known hearing loss
- Do not take medications on a regular basis (with the exception of the contraceptive pill)

Moreover, on the day of the procedures, the individuals should not have the complaints listed below:

- Must have no respiratory problems (respiratory tract infection or asthma)
- Active allergic reaction at the time of data collection (e.g. hayfever)
- Flu at the time of data collection

The project will take place online and we will ask you to do a particular activity with your voice. If you are interested in participating in our research, please read the attached Participant Information Leaflet (PIL) to find out more about our project.

If you have any queries with respect to our project, you can contact any of the investigators for the study and if you would like, we can arrange a video conference call to explain our research to you in more detail.

Co-investigators: Monica Gerosa - gerosam@tcd.ie

Blessy Reachal Sabu - sabub@tcd.ie

Alternatively, you can contact our supervisor if needed,

Supervisor: Dr. Ciaran Kenny - ciaran.kenny@tcd.ie

Thank you for your time and we hope that you will be interested in participating in this study.

Best Regards,

Monica Gerosa & Blessy Reachal Sabu

MSc Students

Department of Clinical Speech and Language Studies

Appendix VII – Modified VTDS and rating scales of effort and fatigue implemented on Qualtrics (SAP, Walldorf)

Participant Number

Outcome measure phase:

V0 - Baseline measure

V1 - Post VLT

V2 - Post Steam inhalation

Indicate the severity of the following sensations that you may feel in your throat

	None 0	1	Mild 2	3	Moderate 4	5	Extreme 6
Burning	○	○	○	○	○	○	○
Tight	○	○	○	○	○	○	○
Dry	○	○	○	○	○	○	○
Aching	○	○	○	○	○	○	○
Tickling	○	○	○	○	○	○	○
Sore	○	○	○	○	○	○	○
Irritable	○	○	○	○	○	○	○
Lump in the throat	○	○	○	○	○	○	○

If other, please specify (sensation, severity)

Please indicate your level of fatigue:

0 1 2 3 4 5 6 7 8 9 10

Fatigue

Please indicate your level of effort:

0 1 2 3 4 5 6 7 8 9 10

Effort