# The effect of superficial hydration, with or without systemic hydration, on voice quality in female professional singers

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A dissertation submitted in fulfillment of the requirements for the degree MA Speech-Language Pathology in the Department of Speech-Language Pathology and Audiology at the University of Pretoria, Faculty of Humanities

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*"Those who wish to sing, will always find a song."*

- Swedish Proverb

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*"Walk with Me and work with Me - watch how I do it. Learn the unforced rhythms of grace. I won't lay anything heavy or ill-fitting on you"* **(**Hebrews 11:29)

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## List of Abbreviations

| | |
|---|---|
| **CSL** | Computerized speech laboratory |
| **DSI** | Dysphonia severity index |
| **ENT** | Ear-, nose and throat specialist (otorhinolaryngology) |
| **GERD** | Gastroesophageal reflux disease |
| **GRBASI** | Grade (voice disorder), roughness, breathiness, asthenia, strain and instability |
| **IS** | Isotonic Saline |
| **MDVP** | Multi-dimensional voice program |
| **MPT** | Maximum phonation time |
| **PPE** | Perceived phonatory effort |
| **PTP** | Phonation threshold pressure |
| **PVU** | Professional voice user |
| **VFI** | Vocal fatigue index |
| **VRP** | Voice range profile |

## Formatting

APA referencing style was used in this dissertation
Vancouver referencing style was used in Chapter 3 according to the journal specification.

**Abstract: Objective.** Professional voice users exhibit the highest prevalence of voice disorders due to high vocal demands. Education and implementation of counter measures such as preventative vocal hygiene, is therefore vitally important. The aim of this study was to describe the effect of superficial hydration, with or without systemic hydration, on the vocal quality of female professional singers.

**Methods.** A within-subject, experimental, pre-test post-test research design was implemented. The study replicated the protocol, as executed by Van Wyk et al. (2016). This study however added the experimental conditions of superficial hydration and combined superficial and systemic hydration and their effects on voice quality in female professional singers, between the ages of 18 – 32 years. Participants also completed the Vocal Fatigue Index (VFI). Pre- and post-test perceptual and acoustic voice assessments were conducted on two occasions (1) a control test with no applied hydration and (2) an experimental test where participants were randomly divided into a superfical hydration group or a combined systemic and superficial hydration group. Therefore, each participant acted as their own control.

**Results**. When comparing pre- and post-test results, a statistically significant increase in maximum phonation time (MPT) values were obtained for the hypo hydrated (p=0.015) and superficial hydration (p=0.004) condition. Furthermore, a significant increase in frequency (Hz) min (p=0.019) within the hypo hydrated condition was also observed. With the combined hydration condition, a significant increase was observed in the intensity (dB) min (p=0.010) and $F_0$(Hz) min (p=0.002) scores. Between-group, post-test comparison outcomes revealed that where superficial hydration was applied mean shimmer % (p=0.016), MPT (sec) (p=0.003), and dysphonia severity index (DSI) (p=0.020) scores increased significantly and a significant reduction in mean intensity (dB) max (p=0.049) and intensity (dB) min (p=0.018) was observed.

**Conclusion**. This study indicated that the use of superficial hydration had positive outcomes on the perceptual parameters of voice quality and symptoms of vocal fatigue in female professional singers. Hydration can therefore be seen as an effective preventative measure in vocal hygiene programs.

**Key Words:** Female Professional Singers; Phonotrauma; Superficial Hydration; Vocal Fatigue; Systemic Hydration; Vocal Hygiene.

# Chapter 1

# Introduction

## 1.1. Chapter aim and outline:

This chapter aims to provide the reader with background as well as current trends in literature on the effect of superficial and systemic hydration on vocal quality in singers. The rationale and problem statement, the research questions and terminology as used in the dissertation are subsequently justified.

## 1.2. Background to the study:

The human voice plays a vital role in effective communication. The significance of voice is even more evident when used as an occupational instrument (Franca & Simpson, 2009). An increase in occupations that rely on the voice as a professional tool has been noted in the past decade (Datta, 2013). Approximately one-third of the modern working population depend on voice production to execute their occupational tasks (Warhurst et al., 2012). Professional voice users (PVUs) rely on their voices as their 'primary tool of trade', yet they exhibit the highest prevalence of voice disorders due to high vocal demands (Warhurst et al., 2012; Wingate, Brown, Shrivastav, Davenport, Sapienza, et al., 2007). Singers, teachers, lawyers, consultants, salespersons, clergymen, call centre operators, healthcare providers and ministers of religious groups are all PVUs (Lerner, Paskhover, Acton, & Young, 2013; Przysiezny, Tironi, & Przysiezny, 2015).

PVUs' voices need to remain clear and stable throughout the working day (Hazlett, Duffy, & Moorhead, 2011). These persons are however often exposed to a number of internal and external risk factors that may affect their vocal health. Internal risk factors include talking loudly or yelling over distances, long periods of voice use, lack of vocal health awareness and stress. External risk factors are environmental factors that negatively influence the vocal mechanism such as suboptimal room acoustics, background noise and vocal fold irritants such as dust or decreased humidification (Munier & Kinsella, 2008; Niebudek-Bogusz, Kotyło, Politański, & Sliwińska-Kowalska, 2008). PVUs are often exposed to high vocal demand, which may negatively affect pitch, loudness, quality and flexibility of the voice and in turn affect their occupational performance and future career (Hazlett, Duffy, & Moorhead, 2009). The prevalence of voice disorders in PVUs are increasing due to frequent exposure to these risk factors (Thomas, Kooijman, Donders, Cremers, & De Jong, 2007). As a result, renewed focus has been placed on voice management and vocal health of PVUs (Van Lierde, Evelien, Wuyts, & De Ley, 2010).

Singers are a group of PVUs prone to voice disorders, as singing critically depends on the functional voice (Franca & Wagner, 2015). Singing is a complex task and thus professional singers are set apart from other voice professions by requiring extensive vocal training to reach the highest levels of performance (Behlau & Oliveira, 2009). Training demands are high, as vocal mastery includes having a healthy, functional, and aesthetically acceptable voice (Timmermans, Vanderwegen, & De Bodt, 2005).

Due to high vocal demands singers need to consciously protect their voices from excessive use, but often fail to do so (Franca & Wagner, 2015). Singers regularly use their voices without adequate rest, in unfavourable environments, in an effortful manner, and do not allow sufficient time to recover after illnesses (Timmermans et al., 2005). As a result, singers are vulnerable to develop cumulative symptoms of vocal fatigue, a condition associated with excessive voice demands (Carroll et al., 2006). Vocal fatigue involves an increase in effortful phonation as a result of a decrease in phonation abilities (Solomon, 2008). The sensation of chronic voice tiredness is a symptom of vocal fatigue and is associated with straining the larynx. The effect of vocal fatigue will progress with unremitting vocal demands and commonly accumulate over time (Braun-Janzen & Zeine Manitoba, 2009; Timmermans et al., 2005). Symptoms include restricted intensity and frequency ranges that are perceived as a change in voice quality (Hillman & Mehta, 2011). Voice changes may be physically and psychologically debilitating for the singer, as it may affect their ability to work (Cohen et al., 2007). It is therefore imperative that singers are trained in vocal health and employ preventative strategies to maintain a healthy and efficient vocal mechanism.

In an effort to prevent vocal fatigue and voice problems, vocal health is emphasized in professional voice training (Haben, 2012; Ruben, 2014). Vocal exercises and indirect strategies such as relaxation, breathing techniques, and vocal hygiene programmes may be employed in the training of singers (Rodríguez-Parraa, Adrián, & Casado, 2011). The conditioning of certain muscle groups in athletes is as important as vocal exercise to the vocalist. If an athlete does not sufficiently train before a race, they are at risk of sustaining an injury. Similarly, inadequate practice, rehearsal and vocal training can result in vocal abuse and misuse (Heman-Ackah, Sataloff, Hawkshaw, & Divi, 2008). It is therefore recommended that preventative strategies, such as vocal hygiene programmes, are used to lower the risk of voice disorders in the PVU (Williams & Carding, 2005).

Hydration is another important factor that is frequently considered in vocal hygiene programs. However, the effect of hydration on voice quality has been understated and the results from application thereof remains unclear (Behlau & Oliveira, 2009). When the PVU does not hydrate adequately, dehydration leads to the mucous layer on the vocal folds becoming thick and viscous, simultaneously increasing the weight and dryness of the vocal folds, impeding smooth vibratory patterns, and elevating vulnerability to vocal injury (Sivasankar & Leydon, 2010). Lubricated vocal fold mucosa necessitates less subglottic air pressure compared to when the vocal mechanism is dry, thus sufficient surface hydration is essential to optimal vocal fold oscillation. The minimum subglottic air pressure required to activate vocal fold oscillation is termed phonation threshold pressure (Titze, 1994). It is well known that decreased PTP reflects a reduced amount of effort and stress placed on the vocal mechanism (Verdolini-Marston, Titze, & Druker, 1990).

Now that the importance of vocal fold surface fluid consisting of layers of water and mucus that act to protect the mucosa and allow for efficient oscillation (Labiris & Dolovich, 2003; Leydon, Sivasankar, Falciglia, Atkins, & Fisher, 2009; Sivasankar & Fisher, 2007; Widdicombe, Bastacky, Wu, & Lee, 1997). Regrettably we must also acknowledge, that there are numerous environmental and behavioural sources of dehydration of the vocal mechanism. Exposure to dry air (desiccation), trans oral breathing, poor oral intake of liquids, as well as vocal use factors may all cumulatively contribute to dehydration (Hemler, Wieneke, & Dejonckere, 1997; Sivasankar & Fisher, 2003; Sivasankar & Fisher, 2002; Solomon & Dimattia, 2000; Solomon, Glaze, Arnold, & Van Mersbergen, 2003). In a recent systematic review, it was determined that when the vocal folds become desiccated due to insufficient systemic hydration, adverse effects on noise-to-harmonics ratio (NHR), shimmer, jitter, frequency, and the s/z ratio can be seen. In turn, water intake led to substantial improvements in shimmer, jitter, frequency, and maximum phonation time (Alves, Krüger, Pillay, Lierde, & Linde, 2017). Thus, it is emphasized that hydration of the vocal folds is essential to optimal functioning of the voice (Fujiki, 2014).

Former studies have reported that males and females may differ in the effects of surface tissue dehydration. Sivasankar and Erickson (2008) observed no substantial differences whilst comparing males with normal voices to those with vocal fatigue after a 25-minute oral desiccation challenge. Several factors suggest that the effect of laryngeal desiccation challenges and subsequent hydration treatments differ between males and females. A lesser incidence of male vocal disorders proposes that the male vocal apparatus may be more resistant to poor conditions of functioning, such as dehydration. This is likely due to puberty, wherein length, thickness and mass of the male vocal folds increase, thus causing the male vocal mechanism to be less susceptible to environmental factors (Titze, 1994). It is also possible that males and females differ in biochemical properties of the vocal fold surface and/or viscoelastic properties of the vocal folds (Sivasankar, Erickson, Schneider, & Hawes, 2008). Male vocal folds present with significantly higher levels of collagen when compared to their female counterparts, allowing the male vocal mechanism to achieve increased levels of stiffness while requiring decreased elongation (Fujiki, 2014). A chemical reason exists explaining why males may not respond similarly to females when exposed to a desiccation challenge (Fujiki, 2014). The development of vocal tissue is assisted by the presence of Hyaluronic acid (HA), a chemical found throughout the body, but more specifically where shock absorption occurs (Fujiki, 2014). A stable distribution of HA can be found in the male vocal apparatus, whereas lower levels of the chemical are found on the surface lamina in the female vocal mechanism, putting them at higher risk for phonotrauma (Ward, Thibeault, Gray & Al, 2002).

Regardless of the differences between the male and female vocal mechanism, the presence of fluid in multiple water compartments within the human body, continuously regulate hydration of the vocal folds. The concept of hydration is generally understood as either systemic (intracellular water) or superficial (water being present in the vocal fold mucosa) and clinical voice management aims to improve both in order to attain optimal vocal efficiency (Sivasankar & Leydon, 2010). Systemic hydration is when water is consumed orally and absorbed at cellular level. The internal vasculature of the vocal folds, regulate the fluid composition, whereas superficial hydration is reliant on the humidity of inhaled air (Leydon et al., 2009). Superficial hydration of the vocal mucosa and laryngeal epithelia is achieved through ion transport channels that control trans-epithelial water fluxes. This sustains the fluid layer necessary for local lubrication and optimal vocal fold vibratory patterns (Leydon et al., 2009). Maintaining adequate vocal fold hydration also protects epithelial cells against inhaled bacteria and irritants (Erickson-Levendoski, Leydon, & Thibeault, 2014). Both systemic and superficial hydration have been used with the over-arching goal of improving voce production (Hartley & Thibeault, 2014; Verdolini et al., 2002). Although both biological hydration mechanisms are believed to maintain vocal fold vibration and optimal voice quality, the exact processes responsible for their joint influence are not fully comprehended (Tanner et al., 2010).

The application of superficial hydration through the use of nebulizers, humidifiers, and steam inhalation, has been common practice as a means to maintain optimal voice quality by several professional voice users over the years (Tanner et al., 2010). However, the topic of vocal fold hydration remains controversial (Hartley & Thibeault, 2014). The suggested gold standard for hydration status differs from one source to another. Still, clinicians have been known to routinely advise increased oral intake of water or the limitation of diuretic substances, most commonly, alcoholic and caffeinated beverages. However, in a recent study it was found that caffeine consumption does not adversely affect voice production, contrary to popular belief (Alves et al., 2017). Clinicians recommend the application of humidification and/or steam inhalation to inhibit vocal fold drying (Sivasankar & Leydon, 2010). Despite the fact that these recommendations have grown popular amongst professional voice users, the validity and underlying mechanisms contributing to maintaining adequate vocal fold hydration are in question (Roy, Tanner, Gray, Blomgren, & Fisher, 2003; Tanner, Roy, Merrill, & Elstad, 2007; Tanner et al., 2010). Thus, the validity of these clinical recommendations must be questioned and substantiated by current evidence-based research.

### 1.3 Literature overview on the effect of superficial hydration on vocal quality in singers:

Although many studies have investigated the outcome of superficial hydration in various vocal measures, few have examined its effects in singers. Three studies who have considered professional singers, typically used phonation threshold pressure (PTP), perceived phonatory effort (PPE) and pulmonary effort necessary to initiate and sustain oscillation as outcome measures (Franca & Simpson, 2013; Fujiki et al., 2014; Levendoski, Sundarrajan, & Sivasankar, 2014; Leydon, Sivasankar, Falciglia, Atkins, & Fisher, 2009; Plexico, Sandage, & Faver, 2011; Robb, 2014; Tanner, Roy, Merrill, & Elstad, 2007; Witt, Taylor, Regner, & Jiang, 2011).

In a study examining the effects of nebulized isotonic saline versus sterile water on self-PPE and PTP following a surface laryngeal dehydration challenge in classically trained singers. Thirty-four sopranos were exposed to dry air (relative humidity < 1%) trans-orally for 15 min, thereafter 3mL of either isotonic saline or sterile water was nebulized. After nebulization, the singers reported sustained increased vocal effort 2 hours after desiccation in the sterile water and control condition. Yet, for the isotonic saline condition PPE returned to baseline. The measure of PTP yielded no statistically significant changes subsequent to laryngeal desiccation, however the isotonic saline scores remained below baseline nearly 2 hours post-nebulization. As seen in many other studies, the correlation between PPE and PTP were not significant. Thus, isotonic saline, when compared to sterile water, showed potential in remediating self-perceived effects following laryngeal desiccation (Tanner et al., 2010).

Another study investigated the outcome of laryngeal desiccation and whether altered doses of nebulized isotonic saline would affect voice production in trained male singers. In a within-subject, double-blind investigation, 10 male singers (ages 18 to 24) were exposed to a laryngeal desiccation lasting 30 minutes, where after either 3 mL or 9 mL of isotonic saline was nebulized on two consecutive weeks. Samples of PTP, PPE, and self-perceived mouth and throat dryness were taken during pre-desiccation, post-desiccation, and at 5, 35, and 65 minutes post-nebulization. Although no differences in PTP could be observed post-desiccation or nebulization, PPE did however increase significantly post laryngeal desiccation and then decreased towards baseline after nebulization. It was also determined that the dosage of isotonic saline presented did not yield significant differences (Fujiki, 2014).

Lastly and most recently, a study explored the effects of laryngeal desiccation and nebulized isotonic saline on voice production in 10 young, healthy male singers compared to 10 of their age-matched non-singer peers. Following a laryngeal desiccation challenge in which participants breathed medical grade dry air (<1% relative humidity) trans-orally for 30 minutes participants were nebulized with either 3 mL or 9 mL of isotonic saline (0.9% Na+Cl). PPE and dryness measures worsened (increased) post-desiccation challenge and improved (decreased) post nebulization ($P < 0.05$). Again it was observed that no consistent changes were observed for PTP over time. In the study singers presented with significantly lower vocal effort when compared to non-singers. Therefore, vocally healthy, young men may experience less physiologic alterations in voice production when exposed to laryngeal desiccation and nebulized saline treatments. It should however be noted that self-reported PPE increases associated with laryngeal dryness may improve with nebulizing treatments (Tanner et al., 2016).

## 1.4 Rationale

Recent literature has identified a need for research exploring the relationship between hydration and phonation (Alves et al., 2017). Evidence suggests that if both systemic and superficial hydration levels are increased it is possible that voice production may benefit. Despite this emerging knowledge, strong evidence for positive outcomes of superficial hydration treatments are lacking (Sivasankar & Leydon, 2010). Studies on PVU with vocal training, such as singers, are often overlooked (Van Wyk, Cloete, Hattingh, Van Der Linde, & Geertsema, 2017). Therefore, more scientific knowledge is required to improve the performance as well as the occupational health of this group. It is also imperative to gain better insight on the use of systemic and superficial hydration in vocal hygiene programs (Van Wyk et al., 2017). It is hypothesized that an increase in superficial hydration will improve the perceptual and acoustic characteristics of the female professional voice, and more so with accompanied systemic hydration. In light of the information provided thus far, the following research questions are posed:

1. What is the effect of superficial hydration, with or without systemic hydration, on vocal quality in female professional singers?
2. What is the effect of superficial hydration on perceived vocal fatigue (VFI) in female professional singers?

## 1.5 Concluding statement

This chapter shows that out of many past speculated notions of hydration that may have appeared theoretically plausible, only a limited amount of studies reported on the positive effects of hydration on voice quality (Franca & Simpson, 2009). However, in recent years renewed attention has been placed on vocal fold hydration. Numerous studies aimed to determine the influence of hydration on the functioning of the vocal folds (Franca & Simpson, 2009; Franca & Simpson, 2011, 2013; Hamdan, Sibai, & Rameh, 2007; Sandage, Connor, & Pascoe, 2013; Tanner et al., 2007). Conversely, opposing findings have been reported. There is a definitive effect of dehydration on various aspects of voice acoustics shown, yet contradictory or simply non-significant changes are present on the effects of rehydration (Franca & Simpson, 2009; Franca & Simpson, 2013; Hamdan et al., 2007; Tanner et al., 2015, 2007, 2010; Van Wyk et al., 2017). Prior studies have mainly concentrated on the effect of hydration on PTP and PPE and not on the acoustic parameters of the voice or voice quality (Roy et al., 2003). Thus, it is of vital importance to determine if an increased superficial hydration is justified as an approach to improving vocal quality in female professional singers, as well as in vocal hygiene recommendations for the prevention and intervention of voice disorders.

### 1.6 Terminology as used in the dissertation

Frequency: This term refers to the frequency at which the vocal folds are vibrating and is perceived as vocal pitch (Titze, 1994).

Fundamental frequency: This term refers to the lowest tone of harmonics heard in voice production known as the habitual frequency (Hz) (Raphael, Borden, & Harris, 2007).

Intensity**:** This term refers to variable force used to pass air from the lungs through the vibrating larynx and is perceived as vocal loudness (Titze, 1994).

Laryngeal desiccation challenge**:** This term refers to a task that causes the vocal mechanism to lose moisture such as mouth breathing, talking for extended periods of time, singing etc. (Tanner et al., 2016).

Perceived phonatory effort (PPE)**:** This term refers to the perceived amount of effort needed to produce voicing experienced by the speaker (Chang & Karnell, 2004).

Phonation**:** This term refers to voice production through vocal fold vibration caused by airflow from the lungs (Titze, 1994).

Phonation threshold pressure (PTP)**:** This term refers to the minimum amount of subglottic pressure required to initiate and sustain vocal fold oscillation (Titze, 1994).

Phonotrauma/ Vocal abuse and misuse**:** This term refers vocal behaviours that are extended, effortful, and maladaptive, usually being excessively loud or aggressive voice use, sharp glottal attack, inappropriate technique for voice or singing, and aggressive laryngeal vegetative manoeuvres. These behaviours can often lead to traumatic injury to the vocal fold (Ferrand, 2012).

Superficial hydration**:** This term refers to hydration of the vocal mucosa and laryngeal epithelia is achieved through ion transport channels that control trans-epithelial water fluxes. This sustains the fluid layer necessary for local lubrication and optimal vocal fold vibratory patterns (Leydon et al., 2009).

Systemic hydration**:** This term refers to when water is consumed orally and absorbed at cellular level. The internal vasculature of the vocal folds regulate the fluid composition (Leydon et al., 2009).

Voice disorders**:** This term refers to the vocal folds not vibrating in a normal pattern when air is forced through the larynx causing voice production to be abnormal. This is caused by a structural, physiological, functional or psychological reason (Ferrand, 2012).

Vocal fatigue**:** This term refers a decrease in phonatory abilities due to increased effortful phonation (Solomon, 2008).

Vocal hygiene**:** This term refers to a therapeutic tool including the modification of vocal habits and the implementation of principles to facilitate improved vocal health (Ferrand, 2012).

Vocal loading**:** This term refers to the demands that voice use needs place on the voice organ (Vilkman, 2004).

# Chapter 2

# Method

## 2.1 Chapter aim and outline:

This chapter aims to explain the methods of the study. The study replicated a previously published protocol, with additions. These additions included the experimental conditions of superficial hydration and combined superficial and systemic hydration and their effects on voice quality in female professional singers. Participants also completed the Vocal Fatigue Index (VFI) in addition to the voice protocol. Participant selection, experimental procedures and testing, data analysis as well as proposed contribution are explicated.

## 2.2 Research Aim

The aim of this study was to describe the effect of superficial hydration, with or without systemic hydration, on the vocal quality and perceived vocal fatigue of female professional singers.

## 2.3 Research Design

A within-subject, experimental, two group comparative, pre-test post-test research design was applied where each participant acted as their own control. The study replicated the protocol, as executed by Van Wyk et al. (2016) with some additions. These additions included the experimental conditions of superficial hydration and combined superficial and systemic hydration and their effects on voice quality in female professional singers. Participants also completed the Vocal Fatigue Index (VFI) in addition to the voice protocol.

## 2.4 Setting

The participants' singing rehearsals, control and experimental conditions as well as the perceptual and instrumental voice assessment conducted by the researcher took place at the Voice Laboratory in the Department of Speech-Language Pathology and Audiology at the University of Pretoria.

## 2.5 Participants

A sample of 24 adults was purposively selected for the study. Inclusion criteria were as follows: 1) participants had to be females, 2) participants had to be between the ages of 18–32 years, 3) participants were required to be enrolled in singing as a study area at the Department of Music at the University of Pretoria, either on undergraduate or postgraduate university level or be receiving professional training and 4) participants provided informed consent for their participation.

Limiting the gender of the participants allowed for the elimination of confounding variables related to gender-based differences in fundamental frequencies of voice range profiles (VRPs). The use of a homogeneous population promoted external validity and therefore trustworthiness of research outcomes. The dysphonia severity index (DSI) is significantly influenced by an increase in age, therefore the maximum age was set at 32 years (Hakkesteegt, Brocaar, & Wieringa, 2010). This also ensured a uniform assessment procedure throughout the study.

Exclusion criteria included: 1) a history of voice disorders as diagnosed by an otolaryngologist (ENT), because predetermined voice pathology would have influenced the perceptual and acoustic results. 2) The presence of current infection or disease that may affect vocal fold functioning such as laryngitis, upper respiratory tract infection, colds, or flu. Factors that may have influenced voice quality such as allergies, gastroesophageal reflux disease (GERD), sinusitis, and so forth, were not regarded as exclusion criteria, but were taken into consideration.

Participants' smoking habits were also considered, as a significant reduction of the DSI has previously been observed in female smokers. A decrease in fundamental frequency and a reduced MPT are often observed in smokers and should therefore be taken into consideration (Awan, 2011).

## 2.6 Ethical Considerations

*Ethical clearance and permission to conduct research*

Permission was obtained from the Head of the Music Department and the Director of Student Affairs at the University of Pretoria to identify and invite participants who met the inclusion criteria to participate in the study. Ethical clearance was obtained from the Research and Ethics Committee of the Faculty of Humanities, University of Pretoria prior to data collection (GW20180103HS).

*Autonomy and informed consent*

Participants were given an informed consent letter in which all the relevant information regarding the proposed study was made available. Participants were notified that they had the right to terminate their participation at any time.

*Beneficence*

Participants were informed about possible benefits of participating in the study. All participants received guidance in vocal hygiene practices and environmental modifications to prevent voice disorders, focusing on hydration of the vocal mechanism. In addition, assessment and identification of vocal pathology resulted in the necessary referrals for appropriate intervention.

*Non-maleficence*

Research participants were not subjected to physical or psychological injury, stress or embarrassment. Participants were respected at all times. A qualified trained speech-language therapist collected the data at the UP voice laboratory.

*Confidentiality*

Confidentiality measures were employed in the study. Participants remained anonymous, as the researcher assigned a numerical code to each participant. Furthermore, no identifying information was documented which ensured maintenance of confidentiality.

## 2.7 Voice Assessment Protocol

*Background Information Questionnaire*

A case history questionnaire was completed by each participant. This allowed the researcher to obtain a comprehensive voice history by taking each participant's age, level of voice training, general heath (reflux and allergies), medical history, and vocal habits (smoking, alcohol consumption, and vocal abuse) into account.

*Perceptual voice assessment*

The perceptual analysis of voice was conducted within the sound proof Voice laboratory at the Department of Speech-Language Pathology and Audiology. The GRBASI 4-point Rating Scale (Yamauchi, Imaizumi, Maruyama, & Haji, 2010) was used to rate the perceptual quality of the participant's voices as they read the phonetically balanced rainbow passage (Fairbanks, 1960), and sang 5 repetitions of the C Major five finger scale. Each participant's voice was audio recorded (MP3 format) using the Ashampoo Music Studio 5 Voice Recording Software. The recorder was held at a fixed distance of 30 cm from the mouth to obtain the most consistent results across different participants and to obtain optimal quality recordings (Timmermans, De Bodt, Wuyts, & Van De Heyning, 2004; Van Lierde, Bonte, Baudonck, Van Cauwenberge, & De Leenheer, 2008). A small listeners' panel of five qualified speech-language therapists was used to score the perceptual data. A previous study on the reliability in perceptual analysis of voice quality, found that even when a small number of listeners are used, inter-rater reliability remains high (Bele, 2005). All listeners were experienced to ensure reliable data (Howard & Lohmander, 2011). The voice recordings were presented in random order to eliminate bias. Each member of the panel of listeners gave a rating for each component of the GRBASI scale and consensus was be reached by majority vote for each component. Thus, the use of an uneven number of listeners eliminated the possibility of a split-vote. The reliability and objectivity of the perceptual measures were increased due to the listeners' panel being blind to which recordings are from which conditions (experimental or control). The listeners panel scoring occurred on the same day in a quiet environment.

Table 2.1: GRBASI 4-point Rating Scale (Yamauchi et al., 2010)

| Perceptual Quality | | Description | Scoring |
|---|---|---|---|
| G | Grade | Degree of hoarseness of the voice/ voice disorder | 0= Normal<br>1= Slight<br>2= Moderate<br>3= Severe |
| R | Roughness | Impression of irregularity of vocal fold movement | |
| B | Breathiness | Degree of escaping air heard | |
| A | Asthenia | Degree of weakness | |
| S | Strain | Degree of strain | |
| I | Instability | Changes in voice quality over time | |

*Acoustic voice assessment*

The acoustic data were gathered by means of the Computerized Speech Lab (CSL) 4300 hardware system. The CSL includes the Multi-Dimensional Voice Program (MDVP) by Kay Elemetrics, designed to calculate, analyse, and graphically display numerous voice parameters recorded during sustained phonation.

Table 2.2: Acoustic Voice Parameters

| Voice Parameter | Description | Norms |
|---|---|---|
| Maximum Phonation Time (MPT) | The longest possible phonation of the /a/ sound after maximum inspiration (Maslan, Leng, Rees, Blalock, & Butler, 2011). | 21.34 sec |
| Jitter (%) | Defined by variation in frequency (number of cycles per unit of successive cycles) (Titze, 1994). | ≤ 1.04% |
| Shimmer (%) | Defined as short-term, cycle-to-cycle variability in vocal fold vibration amplitude (Titze, 1994). | ≤ 3.81% |
| Fundamental Frequency ($F_0$) | The lowest tone of harmonics heard in voice production known as the habitual frequency (Hz) (Raphael et al., 2007). | 155-334Hz |

The CSL also includes the voice range profile measurement (VRP/ phonetogram) which is used to graphically compare the vocal intensity range and the fundamental frequency. These various voice parameters were used to calculate the participants voice quality with the Dysphonia Severity Index (DSI) (Van Wyk et al., 2017). It is known that multi-parametric measures are more suitable for evaluation of voice quality than single measures. The DSI is a multi-parametric instrument designed to obtain an objective measurement of perceived vocal quality in quantitative format. The following set of voice measurements was taken into consideration when calculating the DSI (as per the equation below); maximum phonation time (MPT in seconds), highest frequency ($F_0$ high in Hz), lowest intensity (I—low in dB), and jitter (%) (KayPENTAX, 2008).

DSI= 0.13 x MPT(s) + 0.0053 x $F_0$- High (Hz) – 0.26 x I-Low (dB) – 1.18 x Jitter (%) + 12.4

*Self-rating scale*

Participants were also asked to complete the vocal fatigue index (VFI) (Nanjundeswaran, Jacobson, & Gartner-Schmidt, 2015) twice for comparison of self-perceived vocal fatigue. Participants completed the VFI after control and experimental conditions. This nineteen-question scaled index aimed to reliably identify and quantify vocal fatigue in the participants. This also allowed the study to discriminate between participants with dysphonia and participants with typical phonation (or phonation within normal limits). Participants rated 19 voice statements (e.g. “My voice feels tired when I talk more”) according to how applicable they were to them and their voice. Ratings were from 0-4, 0 being “never” and 4 being “always”. Three factors were examined relating to vocal fatigue due to questions being separately aimed at 1. Tiredness of voice, 2. Physical discomfort and, 3. Improvement of symptoms with rest. A higher score for factors 1 and 2 indicated increased vocal fatigue. Inversely, an higher score for factor 3 indicated decreased vocal fatigue (Nanjundeswaran et al., 2015).

## 2.8 Control Conditions

The participants were required to refrain from alcoholic and carbonated drinks twelve hours prior to both data collection sessions. They were however allowed to eat their regular breakfast, but not within two hours prior to testing (Van Wyk et al., 2017). Participants who were in the control group on a given day were not allowed to ingest any fluids two hours prior to singing, nor during the two-hour rehearsal. Participants were asked sign an adherence letter before testing to measure consistency of adherence to the stipulated conditions to ensure fidelity.

## 2.9 Experimental Conditions

*Systemic hydration schedule*

The systemic hydration schedule used in the study was followed by the participants in the combined superficial and systemic hydration experimental group. Similar to control conditions, participants were required to refrain from alcoholic and carbonated beverages twelve hours prior to singing. They were however allowed to eat their regular breakfast, but not within two hours prior to singing (Van Wyk et al., 2017). In the schedule, it was stipulated that the participants were only allowed to drink water 60 minutes prior to singing. This is based on a pharmacokinetic analysis where it has been reported that complete absorption of water in the plasma and blood cells occurs within 75–120 minutes after ingestion (Péronnet et al., 2012). Participants were required to drink 500 mL of water during the one-hour rehearsal, focusing on drinking approximately 250 mL/30 minutes of singing. This notion is supported by previous research that reported significant improvement in voice parameters when ingesting water during rehearsal (Yiu & Chan, 2003).

*Superficial hydration schedule*

The Superficial hydration schedule used in the study was followed by the participants in both experimental groups. This was implemented through each of the participants receiving 3mL of nebulized isotonic saline (0.9% NaCl) before, in a five-minute break in the middle of as well as after the one hour signing rehearsal. Isotonic saline (IS) was used as it was suggested in a study that compared with sterile water, nebulized IS showed promise as an effective way to remediate the adverse, self-perceived effects of laryngeal desiccation (Tanner et al., 2010). It is therefore possible that trans-epithelial water flux across the vocal fold epithelia could change if the concentration level of the hypertonic agent were changed. While the mechanics of this phenomenon are largely unknown, it could be that the hyperosmolarity of the liquid on the laryngeal epithelia would result in increased trans-epithelial water fluxes that improve vocal fold surface fluid properties. This could in turn result in increased airway and laryngeal hydration, improved mucociliary clearance and increased laryngeal and vocal fold health (Erickson-Levendoski, Leydon, et al., 2014). The nebulizer used for this study was a CA-MI Flo Eolo Nebulizer. This is a piston compressor nebulizer designed for nebulization therapy. The Eolo operating pressure is 1.1 Bar 16 psi 110 kPa, the maximum air flow is 51/min. Standard infection control procedures were implemented, as each participant received their own mask and tubing that remained sealed until use.

## 2.10 Procedure

Ethical clearance was obtained from the Research and Ethics Committee of the Faculty of Humanities, University of Pretoria prior to data collection (GW20180103HS). Music lecturers were contacted regarding the potential participation of lectured singing students. Participants were approached by the researcher following permission from the University of Pretoria (UP) during the period of December 2017 to February 2018. All students participated on a voluntarily basis after informed consent was obtained. Upon written consent from participants, a case history questionnaire was provided and completed to gather the participants' voice histories regarding age, level of voice training, general heath (reflux and allergies), medical history, and vocal habits (smoking, alcohol consumption, and vocal abuse).

All assessments were conducted by the researcher at the Voice Laboratory at the University of Pretoria. Pre- and post-test assessments were conducted for each participant in control (hypo hydration) and experimental (either superficial hydration only or superficial and systemic hydration) conditions. During the pre-test, perceptual and acoustic voice parameters were measured. The participants were required to carry out a 1-hour routine singing rehearsal and immediately thereafter, the post-test was conducted. The average rehearsal times were used to determine the singing duration used in the study.

## 2.11 Data Processing and Analysis

The statistical software programme SPSS was used in all data analyses. Since the sample size was less than 50, the Shapiro-Wilk's statistic was used instead of the Kolmogorov-Smirnov statistic in order to test for normality. If the p-value (significance level (Sig.)) is greater than 0.05, then normality is assumed. Since the p-values of many of the variables are less than 0.05 normality cannot be assumed. Thus, nonparametric methods were used in this study.

For continuous variables, the Wilcoxon signed-rank tests were used to determine statistically significant differences for related samples. For example, it was used for the comparisons between pre-test and post-test for a specific group. For continuous variables, the Mann-Whitney U test was used to determine statistically significant differences for independent samples. For example, it was used for the superficial hydration only group and combined hydration group comparisons. For frequencies (counts) the Fisher's Exact tests were used in order to determine whether the frequencies differed statistically significantly from each other.

## 2.12 Reliability and Validity

Validity is the degree to which a tool measures what it was intended to (Leedy & Ormrod, 2014). The validity of the data gathered was increased by using highly calibrated instrumentation within a soundproof voice laboratory. Within this research study, both content and criterion validity measures were implemented by using validated and standardized measurement tools (for example, GRBASI and VFI). The GRBASI perceptual tool is widely recognised and deemed reliable, validated in various languages, in multiple settings, when compared against similar tools (De Bodt, Wuyts, Van De Heynin, & Croux, 1997; Dejonckere, Obbens, De Moor, & Wieneke, 1993; Hirano, Hibi, & Terasawa, 1986; Yu, Ouaknine, Revis, & Giovanni, 2001). A cross-check method was used to compare the case history questionnaire, VFI self-rating scale and, perceptual and acoustic measures to see if any correlations were present in the results obtained. The researcher made use of a listeners' panel of qualified speech therapists to achieve consensus for the GRBASI scale and to simultaneously ensure inter-rater validity measures.

Reliability is the capacity of a tool to produce measurements that are exact and consistent in multiple replications (Leedy & Ormrod, 2014). Calibrated instrumentation, and the above-mentioned validated and standardized tools ensured reliability in this study. The reliability and objectivity measures were increased due to the listeners' panel being blinded. Furthermore, the researcher and listeners panel are trained in the field of voice disorders.

# Chapter 3

## The effect of superficial hydration, with or without systemic hydration, on voice quality in female professional singers

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**Abstract**

**Summary: Objective.** The aim of this study was to describe the effect of superficial hydration, with or without systemic hydration, on the vocal quality of female professional singers. Professional voice users exhibit the highest prevalence of voice disorders due to high vocal demands. Previous studies have mainly focused on phonatory threshold pressure (PTP) and perceived phonatory effort (PPE) when superficial hydration was applied to singers. Thus, the current study focused on vocal quality changes by examining acoustic, perceptual measures and symptoms of vocal fatigue.

**Study design.**
A within-subject, experimental, two group comparative, pre-test post-test research design was applied where professional singers between the ages of 18-32 acted as their own control.

**Methods.** The study replicated the protocol, as executed by Van Wyk et al., (2016) with some additions. These additions included the experimental conditions of superficial hydration and combined superficial and systemic hydration and their effects on voice quality in female professional singers. Participants also completed the Vocal

Fatigue Index (VFI) in addition to the voice protocol. Pre- and post-test perceptual and acoustic voice assessments were conducted for each participant on two occasions (1) a control test with no applied hydration and (2) an experimental test where participants were randomly divided into a superfical hydration group or a combined systemic and superficial hydration group.

**Results**. When comparing pre- and post-test results a statistically significant increase in MPT values were obtained for the hypo hydrated (p=0.015) and superficial hydration (p=0.004) condition. Furthermore, a significant increase in frequency min (Hz) (p=0.019) within the hypo hydrated condition was also observed. Within the combined hydration condition, a significant increase was observed in the intensity (dB) min (p=0.010) and $F_0$(Hz) min (p=0.002) scores. Between-group, post-test comparison outcomes revealed that where superficial hydration was applied mean shimmer % (p=0.016), MPT (sec) (p=0.003), and dysphonia severity index (DSI) (p=0.020) scores increased significantly and a significant reduction in mean intensity (dB) max (p=0.049) and intensity (dB) min (p=0.018) was observed.

**Conclusion**. In this study, it was confirmed that the use of superficial hydration had positive outcomes on the perceptual parameters of voice quality and symptoms of vocal fatigue in female professional singers. Mixed results were however found regarding the acoustic parameters of voice. The positive results obtained pertaining to perceptual voice quality and vocal fatigue, can be used as a potential preventative measure in vocal hygiene programs.

**Key Words:** Female Professional Singers; Phonotrauma; Superficial Hydration; Vocal Fatigue; Systemic Hydration; Vocal Hygiene.

### 1.1 Introduction

The human voice plays a vital role in effective communication. The significance of voice is even more evident when used as an occupational instrument (1). Professional voice users (PVUs) rely on their voices as their 'primary tool of trade' (2,3). Yet, they exhibit the highest prevalence of voice disorders due to excessive vocal demands (2,4,5). PVUs' depend on their voices to remain clear and stable throughout the working day (6), although they are often exposed to a number of internal (loud talking, yelling, continuous voice use, stress, lack of vocal health awareness) and external (suboptimal room acoustics; background noise, vocal fold irritants) risk factors that may affect their vocal health (7). Due to this increased exposure, the prevalence of voice disorders in the PVUs are increasing (8). As a result, renewed focus has been placed on voice management and vocal health of the PVU (9).

The professional singer is set apart from other voice professions as they require extensive vocal training to reach the highest levels of performance (10). The conditioning of certain muscle groups in athletes is equally important as vocal exercise to the vocalist. If an athlete does not sufficiently train before a race, they are at risk of sustaining an injury. Similarly, inadequate practice, rehearsal and vocal training can result in vocal abuse and misuse (11). Despite high vocal demands, singers often fail to consciously protect their voices (12).

Singers regularly use their voices without adequate rest, in unfavourable environments, in an effortful manner, and do not allow sufficient time to recover after illnesses (13). Singers are vulnerable to develop cumulative symptoms of vocal fatigue, resulting in an increase in effortful phonation due to a decrease in phonation abilities (14). The sensation of chronic voice tiredness is a symptom of vocal fatigue and is associated with straining the larynx. Symptoms include restricted intensity and frequency ranges that are perceived as a change in voice quality (15). It is therefore imperative that singers are trained in vocal hygiene to maintain healthy and efficient vocal mechanisms (16–18). Without appropriate vocal hygiene training, singers are at risk of cumulative phonotrauma which, if unrelenting, will lead to voice disorders or vocal fold pathologies (19)**.** Singers with voice disorders may experience hoarseness, asthenia, variation in fundamental frequency, decreased volume and projection, low resistance when speaking, decreased vocal efficiency and vocal fatigue (20). Such voice change may be physically and psychologically debilitating for the singer, as it may affect their ability to work (21). It is thus recommended that preventative strategies, such as vocal hygiene programmes, are used to lower the risk of voice disorders in the PVU (22). Often the most prescribed method of improving vocal hygiene is by increasing hydration levels (23). Despite the fact that hydration has always been considered in vocal hygiene programs, the effect of hydration on voice quality has been understated (10).

The presence of fluid in multiple water compartments within the body, continuously regulate hydration of the vocal folds. The concept of hydration is generally understood as either systemic (intracellular water) or superficial (water being present in the vocal fold mucosa) and clinical voice management aims to improve both in order to attain optimal vocal efficiency (24). Systemic hydration is when water is consumed orally and absorbed at cellular level. The internal vasculature of the vocal folds, regulate the fluid composition, whereas superficial hydration is reliant on the humidity of inhaled air (25). Superficial hydration of the vocal mucosa and laryngeal epithelia is achieved through ion transport channels that control trans-epithelial water fluxes. This sustains the fluid layer necessary for local lubrication and optimal vocal fold vibratory patterns (25). Maintaining adequate vocal fold hydration also protects epithelial cells against inhaled bacteria and irritants (26). Although both biological hydration mechanisms are believed to maintain vocal fold vibration and optimal voice quality, the exact processes responsible for their joint influence are not fully understood (27).

When professional singers do not hydrate adequately, dehydration leads to the mucus layer on the vocal folds becoming thick and viscous, simultaneously increasing the weight and dryness of the vocal folds, impeding smooth vibratory patterns, and elevating vulnerability to vocal injury (28). Lubricated vocal fold mucosa necessitates less subglottic air pressure compared to when the vocal mechanism is dry, thus sufficient surface hydration is essential to optimal vocal fold oscillation. The minimum subglottic air pressure required to activate vocal fold oscillation is termed phonation threshold pressure (PTP) (29). It is widely understood that decreased PTP reflects a reduced amount of effort and stress placed on the vocal mechanism (30). In a recent systematic review, it was determined that when the vocal folds become desiccated due to insufficient systemic hydration, adverse effects on noise-to-harmonics ratio (NHR), shimmer, jitter, frequency, and the s/z ratio can be seen. In turn, water intake led to substantial improvements in shimmer, jitter, frequency, and maximum phonation time (31).

The application of superficial hydration through the use of nebulizers, humidifiers, and steam inhalation, has been common practice as a means to maintain optimal voice quality over the years (27). Clinicians recommend the application of nebulization, humidification and/or steam inhalation to inhibit vocal fold drying (24). Despite the fact that these recommendations have grown popular amongst professional voice users, the underlying mechanisms contributing to maintaining adequate vocal fold hydration are in question (27,32,33). Thus, the validity of these clinical recommendations must be questioned and substantiated by current evidence-based research.

Although many studies have scrutinized the outcome of superficial hydration in various vocal measures, few have examined its effects in singers. Three previous studies aimed to determine the influence of superficial hydration on the functioning of the vocal folds in singers (27,34,35). Conversely, opposing findings have been reported. There is a definitive effect of dehydration on various aspects of voice acoustics shown; yet contradictory or simply non-significant changes are present on the effects of rehydration (1,27,33,36–38). Prior studies have mainly concentrated on the effect of hydration on PTP and PPE and not on the acoustic parameters of the voice or voice quality (32). Thus, it is of vital importance to determine if increased superficial hydration is justified as an approach to improving vocal quality in female professional singers, as well as in vocal hygiene recommendations for the prevention and intervention of voice disorders.

Evidence suggests that if both systemic and superficial hydration levels are increased it is possible that voice production may benefit. Despite this emerging knowledge, strong evidence for positive outcomes of superficial hydration treatments are lacking (28). Studies on PVU with vocal training, such as singers, are often overlooked (38). It must also be noted that previous research has mostly focused on male singers and have neglected superficial hydration outcomes in females, the population who are more vulnerable to the effects of dehydration on the vocal folds. Therefore, more scientific knowledge is required to improve the performance as well as the occupational health of this group (39). It is also imperative to gain better insight into the use of systemic and superficial hydration in vocal hygiene programs (38). It is hypothesized that an increase in superficial hydration will significantly improve the perceptual and acoustic characteristics of the female professional voice, and more so with accompanied systemic hydration. In light of the information provided thus far, the following research questions are posed:

1. What is the effect of superficial hydration, with or without systemic hydration, on vocal quality in female professional singers?
2. What is the effect of superficial hydration on perceived vocal fatigue (VF) in female professional singers?

## 1.2 Method

### 1.2.1 Aim

The aim of this study was to describe the effect of superficial hydration, with or without systemic hydration, on the vocal quality and perceived vocal fatigue of female professional singers.

### 1.2.2 Research design

A within-subject, experimental, two group comparative, pre-test post-test research design was applied where professional singers between the ages of 18-32 acted as their own control.

### 1.2.3 Participants

A purposive sample of 24 females with an average age of 21.38 years (*SD*=2.60), enrolled for singing at, or alumni from the Department of Music, University of Pretoria, were selected to take part in the study. Limiting the gender of the participants will allow for the elimination of confounding variables related to gender-based differences in fundamental frequencies of voice range profiles (VRPs). The dysphonia severity index (DSI) is significantly influenced by an increase in age; therefore, a maximum age of 32 years was set (40). The use of a homogeneous population promotes external validity and therefore trustworthiness of research outcomes.

Only singers who were not diagnosed with previous voice disorders by an otolaryngologist (ENT) or current infection or disease affecting vocal fold functioning were included, as these would have influenced perceptual and acoustic results. Factors that may have influenced voice quality such as allergies, gastroesophageal reflux disease (GERD), sinusitis, and so forth, were not regarded as exclusion criteria, but were taken into consideration. Seven participants (29.2%) reported having an allergy; namely anaesthesia, pet hair, dust, peanuts, caffeine and/or codeine. Six participants (25.0%) reported gastroesophageal reflux disease (GERD), five (20.8%) reported sinusitis and eleven (45.8%) were on prescribed medication. It was also considered that three participants (12.5%) were smokers. A significant reduction of the DSI and fundamental frequency and a reduced MPT has previously been observed in female smokers, and should therefore be taken into consideration (41).

Participants were randomly assigned to two experimental groups of 12 (superficial hydration only n=12 and superficial and systemic hydration combined n=12) and acted as their own control (hypo hydration n=24).

### 1.2.4 Control and experimental conditions

#### 1.2.4.1 Control conditions (hypo hydration)

The participants were required to refrain from alcoholic and carbonated drinks twelve hours prior to testing. They were allowed to eat their regular breakfast, but not within 2 hours prior to testing (38). Those who were in the control group on a given day were not allowed to ingest any fluids two hours prior to singing, nor during the two-hour rehearsal. Participants were asked to sign an adherence letter before testing to measure consistency of adherence to the stipulated conditions to ensure fidelity.

#### 1.2.4.2 Experimental conditions

##### *1.2.4.2.1 Systemic hydration schedule*

The systemic hydration schedule used in the study was followed by the participants in the combined superficial and systemic hydration experimental group. Similar to control conditions, participants were required to refrain from alcoholic and carbonated drinks twelve hours prior to singing. They were allowed to eat their regular breakfast, but not within 2 hours prior to singing (38). Founded on a pharmacokinetic analysis where it has been reported that complete absorption of water in the plasma and blood cells occurs within 75–120 minutes after ingestion (42). In the schedule, it was stipulated that the participants were only allowed to commence drinking water 30 minutes prior to singing. They were required to drink 500 mL of water during the 1-hour rehearsal, focusing on drinking approximately 250 mL/30 minutes of singing. This notion is supported by previous research that reported significant improvement in voice parameters when ingesting water during rehearsal (43).

*1.2.4.2.2 Superficial hydration schedule*

The superficial hydration schedule used in the study was followed by the participants in both experimental groups.  This was implemented through each of the participants receiving 3mL of nebulized isotonic saline (a salt solution that has the same osmotic pressure as bodily fluids) (0.9% NaCl) before, in a 5-minute break in the middle of as well as after the 1-hour signing rehearsal. The nebulizer used for this study was a CA-MI Flo Eolo Nebulizer This is a piston compressor nebulizer designed for nebulization therapy. The Eolo operating pressure is 1.1 Bar 16 psi 110 kPa, the maximum airflow is 51/min. Standard infection control procedures were implemented through each participant receiving their own mask and tubing that remained sealed until use.

**1.2.5 Voice assessment protocol**

A case history questionnaire was provided and completed to best gather the participant's voice histories regarding the information including age, level of voice training, general heath (reflux and allergies), medical history, and vocal habits (smoking, alcohol consumption, and vocal abuse).

Participants were also asked to complete the vocal fatigue index (VFI) (44) twice for comparison of self-perceived vocal fatigue. Participants completed the VFI after control and experimental conditions. This index aimed to reliably identify those suffering from vocal fatigue. The VFI is a nineteen-question scale used to quantify the amount of vocal fatigue suffered by a given individual and discriminate between those with dysphonia and those without.  Participants rated 19 voice statements (e.g. "My voice feels tired when I talk more") according to how applicable they were to them and their voice. Ratings were from 0-4, 0 being never and 4 being always. Three factors were examined relating to vocal fatigue due to questions being separately aimed at 1. Tiredness of voice 2. Physical discomfort and 3. Improvement of symptoms with rest. With factors 1 and 2 increased vocal fatigue was indicated by a higher score. Inversely, with factor 3 an increased score indicated decreased vocal fatigue (44).

Perceptual and acoustic voice parameters were measured in both pre- and post-test assessments. A pre-test was conducted after which participants were required to carry out a 1-hour routine singing rehearsal and immediately thereafter, the post-test was conducted.

All perceptual analysis of voice was conducted within a sound proof voice laboratory by the researcher. The GRBASI 4-point Rating (45) was used to rate the perceptual quality of the participant's voices as they read the phonetically balanced rainbow passage (46), and sang 5 repetitions of the C Major five finger scale. Audio recordings of the voices of each participant were made using the Ashampoo Music Studio 5 Voice Recording Software, recording in MP3 format. The recorder was held at a fixed distance of 30 cm from the mouth to obtain the most consistent results across different participants and to obtain optimal quality recordings (9,47). A listeners panel of five qualified speech-language therapists was used to score the perceptual data as a previous study on the reliability in perceptual analysis of voice quality, found that even when a small number of listeners are used, inter-rater reliability remains high (48). The voice recordings were presented in random order to remove bias. Each member of the panel of listeners gave a rating for each component of the GRBASI scale and consensus was be reached by majority vote for each component. Thus, the use of an uneven number of listeners eliminated the possibility of a split-vote. Due to the listeners panel being blind to which recordings are from which group of experimental or control conditions this increased the objectivity and reliability of the perceptual measures. Majority consensus was reached through independent scoring in a quiet room, of all 96 samples, in one session.

The maximum phonation time (MPT) of all participants was taken using the steady state vowel /a/ after maximum inspiration and the best time over three repetitions were recorded. MPT was considered normal when greater than or equal to 7.98 seconds (49).

Multidimensional voice program analysis (MDVP) and the voice range profile (VRP) of the computerized speech lab (CSL) (MODEL 4105B; KayPENTAX) was conducted on all the participants in a sound-proof voice laboratory. Acoustic analysis of the voice was accomplished using a microphone set at 10cm away from the mouth. The MDVP was used to evaluate the jitter (*jitt %)*, shimmer (*shim %)*, fundamental frequency variation (v$F_0$) and noise-to-harmonics ratios (NHR) of each participant. The VRP depicted the participant's minimum and maximum volume and pitch capacities across their vocal range.

The dysphonia severity index (DSI), a multi-parametric tool, was employed to generate an objective vocal quality score based on acoustic results (40). A score was then generated using the maximum phonation time (MPT in seconds), highest frequency (Hz), lowest intensity (dB) and jitter (%). The following set of voice measurements was taken into consideration when calculating the DSI (as per the equation below); maximum phonation time (MPT in seconds), highest frequency ($F_0$($F_0$high in Hz), lowest intensity (I—low in dB), and jitter (%) (KayPENTAX, 2008).

DSI= 0.13 x MPT(s) + 0.0053 x $F_0$(- High (Hz) – 0.26 x I-Low (dB) – 1.18 x Jitter (%) + 12.4

Adult norms indicate that a DSI of >0 as normal and a DSI of <0 to -5 as either mild, moderately or severely dysphonic. These norms were used as a guideline (50).

### 1.2.6 Data analysis

Data were analysed by using formulas in Excel, from which all statistics were obtained. Statistical software (SPSS) was used in all analyses. Since the sample size was less than 50, the Shapiro-Wilk's statistic was used instead of the Kolmogorov-Smirnov statistic in order to test for normality. If the p-value (significance level (Sig.)) is greater than 0.05, then normality is assumed. Since many of the p-values are less than 0.05, for many of the variables considered in this study, normality cannot be assumed for all variables. Thus, nonparametric methods were used in this study. For continuous variables, the Wilcoxon signed-rank tests were used to determine statistically significant differences for related samples, for example, it was used for the post-test comparisons between control and experimental conditions. For continuous variables, the Mann-Whitney U test were used to determine statistically significant differences for independent samples, for example, it was used for the superficial hydration only group and combined hydration group comparisons. For frequencies (counts) the Fisher's Exact tests were used in order to determine whether the frequencies differed statistically significantly from each other.

## 1.3 Results

Table 3.1 Frequency Distribution of GRBASI scores

| (Control n=24, Superficial n=12 & Combined n=12) | | | | | |
|---|---|---|---|---|---|
| GRBASI | Condition | | Normal (Score=1) | Slight (Score=2) | Moderate (Score=3) |
| Grade of Voice Disorder | Hypo hydration | Pre-test | 83% (n=20) | 17% (n=4) | 0% (n=0) |
| | | Post-test | 50% (n=12) | 46% (n=11) | 4% (n=1) |
| | | p-value | 0.030* | 0.060 | 1.000 |
| | Superficial Hydration | Pre-test | 75% (n=9) | 25% (n=3) | 0% (n=0) |
| | | Post-test | 75% (n=9) | 25% (n=3) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |
| | Combined Hydration | Pre-test | 58% (n=7) | 33% (n=4) | 8% (n=1) |
| | | Post-test | 50% (n=6) | 50% (n=6) | 0% (n=0) |
| | | p-value | 1.000 | 0.680 | 1.000 |
| Roughness | Hypo hydration | Pre-test | 92% (n=22) | 8% (n=2) | 0% (n=0) |
| | | Post-test | 63% (n=15) | 37% (n=9) | 0% (n=0) |
| | | p-value | 0.036* | 0.036* | - |
| | Superficial Hydration | Pre-test | 58% (n=7) | 42% (n=5) | 0% (n=0) |
| | | Post-test | 67% (n=8) | 33% (n=4) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |
| | Combined Hydration | Pre-test | 75% (n=9) | 17% (n=2) | 8% (n=1) |
| | | Post-test | 67% (n=8) | 33% (n=4) | 0% (n=0) |
| | | p-value | 1.000 | 0.640 | 1.000 |
| Breathiness | Hypo hydration | Pre-test | 83% (n=20) | 17% (n=4) | 0% (n=0) |
| | | Post-test | 83% (n=20) | 17% (n=4) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |
| | Superficial Hydration | Pre-test | 75% (n=9) | 25% (n=3) | 0% (n=0) |
| | | Post-test | 100% (n=12) | 0% (n=0) | 0% (n=0) |
| | | p-value | 0.217 | 0.217 | - |
| | Combined Hydration | Pre-test | 50% (n=6) | 50% (n=6) | 0% (n=0) |
| | | Post-test | 100% (n=12) | 0% (n=0) | 0% (n=0) |
| | | p-value | 0.014* | 0.014* | - |
| Asthenia | Hypo hydration | Pre-test | 96% (n=23) | 4% (n=1) | 0% (n=0) |
| | | Post-test | 83% (n=20) | 13% (n=3) | 4% (n=1) |
| | | p-value | 0.348 | 0.609 | 1.000 |
| | Superficial Hydration | Pre-test | 83% (n=10) | 17% (n=2) | 0% (n=0) |
| | | Post-test | 83% (n=10) | 17% (n=2) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |
| | Combined Hydration | Pre-test | 92% (n=11) | 8% (n=1) | 0% (n=0) |
| | | Post-test | 92% (n=11) | 8% (n=1) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |
| Strain | Hypo hydration | Pre-test | 96% (n=23) | 4% (n=1) | 0% (n=0) |
| | | Post-test | 88% (n=21) | 8% (n=2) | 4% (n=1) |
| | | p-value | 0.609 | 1.000 | 1.000 |
| | Superficial Hydration | Pre-test | 100% (n=12) | 0% (n=0) | 0% (n=0) |
| | | Post-test | 100% (n=12) | 0% (n=0) | 0% (n=0) |
| | | p-value | 1.000 | - | - |
| | Combined Hydration | Pre-test | 92% (n=11) | 8% (n=1) | 0% (n=0) |
| | | Post-test | 83% (n=10) | 17% (n=2) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |
| Instability | Hypo hydration | Pre-test | 92% (n=22) | 8% (n=2) | 0% (n=0) |
| | | Post-test | 92% (n=22) | 4% (n=1) | 4% (n=1) |
| | | p-value | 1.000 | 1.000 | 1.000 |
| | Superficial Hydration | Pre-test | 75% (n=9) | 25% (n=3) | 0% (n=0) |
| | | Post-test | 92% (n=11) | 8% (n=1) | 0% (n=0) |
| | | p-value | 0.590 | 0.590 | - |
| | Combined Hydration | Pre-test | 75% (n=9) | 25% (n=3) | 0% (n=0) |
| | | Post-test | 83% (n=10) | 17% (n=2) | 0% (n=0) |
| | | p-value | 1.000 | 1.000 | - |

**Significance level: $p < 0.05$*

Participants reported that on average they rehearse 10 hours (*SD*= 5.51) a week and the majority of (87.5%, n=21) of participants reported a negative change in their voices after rehearsals; namely breathiness (n=6), painful voice production (n=2), grade of voice disorder (n=12), roughness (n=5), loss of voice (n=3), generally softer voice (n=7) or weaker voice on certain pitch levels (n=5).

In Table 1, the Fisher's Exact tests were used in order to determine whether the frequencies differed statistically significantly from each other. Only the frequencies and the p-values are presented for brevity. If the p-value is less than 0.05, there is a statistically significant difference in the frequencies. The only significant perceptual differences (Table 1) observed between the pre- and post-test results were in the hypo hydrated, and combined hydration conditions. In the hypo hydration group G (grade of voice disorder) was significantly increased (p=0.030) as eleven participants (46%; n=11) present with slight, and one participant (4%; n=1) with moderate G (grade of voice disorder) at post-test. Similarly, R (roughness) also significantly increased in the hypo hydration condition (p=0.036) as 92% (n= 22) of the participants roughness levels were perceived as normal at pre-test and 37% of participants (n=9) present with slight roughness at post-test. In the combined hydration group B (breathiness) was significantly decreased (p=0.014) as half of the participants (50%; n=6) presented with slight breathiness at pre-test and all of the participants (100%; n=12) were scored as "normal" at post-test.

When comparing the change between pre- and post-test of MPT of both hypo hydration and superficial hydration conditions, using the Wilcoxon signed-rank tests, a significant increase in duration was noted in both conditions (p=0.015 and p=0.004, respectively) (Table 2). Significant increases between the pre- and post-test within the hypo hydrated condition was also observed in frequency min (Hz) (p=0.019) (Table 2). When comparing pre- and post-test results within the combined hydration condition, significant differences were observed in the intensity (dB) min (p=0.010) and $F_0$(Hz) min (p=0.002) as both increased from pre- to post-test (Table 2).

For the between-group comparisons, Mann-Whitney tests were run. There is no table for the pre-test results, as there were no significant differences between the groups pre-test. Between-group, post-test comparisons, using the Mann-Whitney tests, (Table 3) revealed significant differences between control group and superficial hydration groups only. Outcomes show that where superficial hydration was applied mean shimmer % (p=0.016), MPT (sec) (p=0.003), and dysphonia severity index (DSI) (p=0.020) scores increased significantly (Table 3). A significant reduction in mean intensity (dB) max (p=0.049) and intensity (dB) min (p=0.018) was observed, (Table 3). No significant differences were found between the control group and combined hydration group or when comparing the two experimental conditions, superficial and combined hydration.

Table 3.2 Acoustic Parameter Outcomes and Pre-test -Post-test Comparisons

| (Control n=24, Superficial n=12 & Combined n=12) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hypo hydration | | | Superficial Hydration | | | Combined Hydration | | |
| | Pre-test | Post-test | | Pre-test | Post-test | | Pre-test | Post-test | |
| Acoustic Parameters | Mean (SD) | Mean (SD) | p-value | Mean (SD) | Mean (SD) | p-value | Mean (SD) | Mean (SD) | p-value |
| Jitter% | 0.93 (0.77) | 0.79 (0.59) | 0.219 | 1.07 (0.75) | 0.90 (0.66) | 0.583 | 0.87 (0.42) | 0.59 (0.39) | 0.060 |
| Shimmer% | 3.86 (2.02) | 3.29 (1.84) | 0.253 | 3.74 (1.30) | 4.73 (2.52) | 0.182 | 3.30 (1.52) | 3.13 (1.59) | 0.583 |
| $F_0$ (Hz) | 2.47 (3.89) | 1.21 (0.72) | 0.157 | 2.05 (2.20) | 3.42 (8.30) | 0.388 | 1.28 (0.65) | 3.59 (8.51) | 0.480 |
| MPT (sec) | 14.92 (4.38) | 15.88 (3.96) | 0.015* | 15.00 (3.72) | 18.83 (5.67) | 0.004* | 15.75 (2.77) | 17.42 (4.48) | 0.065 |
| Frequency (Hz) Max | 938.85 (173.54) | 945.32 (221.03) | 0.986 | 924.42 (212.43) | 993.64 (279.19) | 0.721 | 948.29 (117.86) | 1077.37 (241.09) | 0.286 |
| Frequency (Hz) Min | 138.02 (33.70) | 157.20 (37.59) | 0.019* | 151.35 (17.69) | 163.17 (34.95) | 0.374 | 141.86 (42.35) | 153.46 (44.18) | 0.456 |
| Intensity (dB) Max | 103.42 (5.81) | 104.63 (5.17) | 0.302 | 100.42 (6.23) | 100.67 (7.61) | 0.953 | 103.50 (5.71) | 103.17 (7.44) | 0.475 |
| Intensity (dB) Min | 57.63 (6.53) | 60.04 (4.90) | 0.152 | 57.67 (3.92) | 58.50 (4.74) | 0.623 | 56.17 (4.71) | 59.33 (5.25) | 0.010* |
| $F_0$ (Hz) Max | 827.34 (150.55) | 768.57 (178.19) | 0.194 | 858.72 (209.92) | 839.25 (200.64) | 0.182 | 791.09 (130.45) | 804.02 (180.43) | 0.433 |
| $F_0$ (Hz) Min | 185.69 (101.04) | 188.53 (74.57) | 0.415 | 216.36 (77.35) | 217.91 (105.96) | 0.814 | 188.55 (107.02) | 213.93 (95.62) | 0.002* |
| DSI | 3.11 (1.69) | 2.89 (2.24) | 0.558 | 3.09 (2.10) | 3.96 (2.17) | 0.308 | 3.82 (1.32) | 4.30 (2.64) | 0.609 |

**Significance level: p < 0.05*

The Vocal Fatigue Index outcomes (Table 4) show that the mean values of perceived vocal fatigue Factors 1 and 2 decreased insignificantly with superficial hydration compared to control condition, indicating slightly reduced vocal fatigue in the forms of tiredness of voice and physical discomfort when superficial hydration is introduced. Both factor 1 (p=0.044) and 2 (p=0.029) were however, significantly decreased in the combined hydration group when compared to the control condition. It must also be noted that when comparing the experimental conditions for Factor 1, the combined hydration group had significantly (p=0.016) decreased perceived vocal fatigue when compared to superficial hydration group.

Table 3.3 Acoustic Parameter Between-Group Post-test Comparisons

| (Control n=24, Superficial n=12 & Combined n=12) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control vs. Superficial | | | Control vs. Combined | | | Superficial vs. Combined | | |
| Acoustic Parameters | Mean (SD) | Mean (SD) | p-value | Mean (SD) | Mean (SD) | p-value | Mean (SD) | Mean (SD) | p-value |
| Jitter% | 0.79 (0.59) | 0.90 (0.66) | 0.733 | 0.79 (0.59) | 0.59 (0.39) | 1.000 | 0.90 (0.66) | 0.59 (0.39) | 0.141 |
| Shimmer% | 3.29 (1.84) | 4.73 (2.52) | 0.016* | 3.29 (1.84) | 3.13 (1.59) | 0.718 | 4.73 (2.52) | 3.13 (1.59) | 0.053 |
| $F_0$ (Hz) | 1.21 (0.72) | 3.42 (8.30) | 0.622 | 1.21 (0.72) | 3.59 (8.51) | 0.520 | 3.42 (8.30) | 3.59 (8.51) | 0.623 |
| MPT (sec) | 15.88 (3.96) | 18.83 (5.67) | 0.003* | 15.88 (3.96) | 17.42 (4.48) | 0.094 | 18.83 (5.67) | 17.42 (4.48) | 0.977 |
| Frequency (Hz) Max | 945.32 (221.03) | 993.64 (279.19) | 0.123 | 945.32 (221.03) | 1077.37 (241.09) | 0.652 | 993.64 (279.19) | 1077.37 (241.09) | 0.369 |
| Frequency (Hz) Min | 157.20 (37.59) | 163.17 (34.95) | 0.240 | 157.20 (37.59) | 153.46 (44.18) | 0.557 | 163.17 (34.95) | 153.46 (44.18) | 0.467 |
| Intensity (dB) Max | 104.63 (5.17) | 100.67 (7.61) | 0.049* | 104.63 (5.17) | 103.17 (7.44) | 0.291 | 100.67 (7.61) | 103.17 (7.44) | 0.247 |
| Intensity (dB) Min | 60.04 (4.90) | 58.50 (4.74) | 0.018* | 60.04 (4.90) | 59.33 (5.25) | 0.898 | 58.50 (4.74) | 59.33 (5.25) | 0.772 |
| $F_0$ (Hz) Max | 768.57 (178.19) | 839.25 (200.64) | 0.496 | 768.57 (178.19) | 804.02 (180.43) | 0.765 | 839.25 (200.64) | 804.02 (180.43) | 0.908 |
| $F_0$ (Hz) Min | 188.53 (74.57) | 217.91 (105.96) | 0.569 | 188.53 (74.57) | 213.93 (95.62) | 0.359 | 217.91 (105.96) | 213.93 (95.62) | 0.620 |
| DSI | 3.11 (1.69) | 3.96 (2.17) | 0.020* | 3.11 (1.69) | 4.30 (2.64) | 0.782 | 3.96 (2.17) | 4.30 (2.64) | 0.817 |

*Significance level: $p < 0.05$*

Table 3.4 Outcomes and Comparisons for Individual Factors on the VFI for Hypo hydrated, Superficial Hydration and Combined Hydration

| (Control n=24, Superficial n=12& Combined n=12) | | | |
|---|---|---|---|
| | Mean (SD) | | |
| Condition | Factor 1. Tiredness of voice | Factor 2Physical discomfort | Factor 3Improvement of symptoms with rest |
| Hypo hydration | 21.83 (9.13) | 7.5 (4.49) | 9.62 (1.68) |
| Superficial Hydration | 21.58 (8.96) | 7.4 (4.54) | 10.25 (1.35) |
| Combined Hydration | 11.75 (9.31) | 4.25 (4.11) | 10.75 (1.48) |
| Between group comparison | p-value | | |
| Control vs. Superficial Hydration | 0.773 | 0.890 | 0.697 |
| Control vs. Combined Hydration | 0.044* | 0.029* | 0.129 |
| Superficial vs. Combined Hydration | 0.016* | 0.065 | 0.428 |

*Significance level: $p < 0.05$*

## 1.4 Discussion

This study examined the effect of superficial hydration, with or without systemic hydration, on voice quality in a population (n= 24) of female professional singers. For perceptual analysis, the grade of voice disorder and roughness indicated that lack of hydration had a significant effect on voice quality (p=0.030 and p=0.036, respectively). Half (n=12) of the participants were identified with a perceptually increased grade of voice disorder after the singing rehearsal in the hypo hydrated condition. Increased perceptual roughness was also present in 46% (n=11) of participants after vocal performance in hypo hydration. This deterioration in perceptual voice quality may be an indication of vocal fatigue (43). Similar findings were reported in a previous study on Indian men where no hydration was provided. An increase in grade of voice disorder was noted on the GRBAS scale following an oral reading vocal loading task (VLT) (51). In contrast, another study examining the effects of vocal load without hydration on perceptual quality of voice in vocally healthy females documented a significant decrease in breathiness observed, suggesting an improvement of voice subsequent to loading regardless of applied hydration (52).

It was also found, that perceptual breathiness was significantly reduced (p=0.014) in all (n=24) participants in the combined hydration group where both superficial hydration and systemic hydration was applied. This serves to question whether the positive change in decreased breathiness seen in the current study is due to the applied hydration or simply caused by the vocal loading task itself, a 1 hour classical signing rehearsal. In a recent study examining the effect of systemic hydration on the vocal quality of future professional vocal performers GRBASI scores revealed a statistically significant increase (p=0.046) for the grade of voice disorder measure in the hypo hydrated group in comparison to the hydrated group (38). Conversely, no detectable auditory perceptual differences in voice quality were previously reported, between systemically hydrated and hypo hydrated conditions, when 20 untrained singers were subjected to extended karaoke singing (43). The perceptual results obtained in the current study support the hypothesis that increased hydration, in the form of both superficial and systemic hydration combined, decreased perceptual breathiness in the performing singer. Inadequate hydration may conversely lead to increased perceptual grade of voice disorder and roughness in vocal quality.

It is possible that the effect of vocal fatigue contributed to the following changes in acoustic parameters; A significant increase in Frequency Min (p=0.019) in hypo hydration from pre-test to post-test indicates a reduction in the singer’s ability to reach lower notes and therefore a deterioration of vocal range when the vocalist is inadequately hydrated. Average Intensity (dB) Min and $F_0$ (Hz) Min also increased significantly in the combined hydrated condition from pre-test to post-test (10.1% and 00.0% respectively). The percentage change for Intensity (dB) Min and $F_0$ (Hz) Min increased with 5.6% and 23.0%, respectively. As previously seen in the hypo hydration condition pre- to post-test comparisons, this indicates a significant reduction in the range of both loudness and pitch. In the PVU, frequency and intensity changes are an essential variables in order to identify early vocal fatigue (53) as this may indicate a deterioration in elasticity and viscosity of the vocal fold mechanism (39). When singers attempt to reach their highest and lowest frequencies or intensities, prime elasticity is necessary in order to reach notes without strain. The increase in intensity (dB) min and $F_0$ (Hz) min for the combined hydration condition clinically manifested as a smaller voice range, with decreased loudness projection which is undesirable for the singer's performance. In previous research on hydration and vocal quality, frequency (Hz), intensity (dB) and $F_0$ (Hz) did not reveal significant changes; however, in a single study on systemic hydration and habitual pitch in females, a significant deterioration in $F_0$ (Hz) was found after fasting (54). Values remained within normal limits despite the decrease seen. Similar to the current study, in the application of superficial hydration on teachers, a statistically significant increase was previously found in $F_0$ (Hz) for the /a:/ vowel (p=0.036) (4). This increase was recognised as the vocal folds possibly became lighter and thus were able to oscillate more efficiently when well lubricated (4). It is possible that there is comparable causation for the increase in $F_0$ (Hz) min seen presently.

Conceivably, vocal fatigue also contributed to significantly increased mean Shimmer (p=0.016) scores as well as a significant reduction in mean Intensity (dB) Max (p=0.049) scores obtained when comparing the experimental and control condition post-test results where superficial hydration was applied. It was expected that shimmer, would improve in the superficial hydration condition, as with increased hydration levels in previous studies (1). In contrast, shimmer values, significantly worsened (p=0.016) within this condition, thus the cycle-to-cycle variation in amplitude increased with superficial hydration. Similarly, a previous study found a statistically significant decrease (p=<0.050) in shimmer in the hypo hydrated condition, revealing an inverse positive effect of a hypo hydrated condition. Unlike the current study, following the ingestion of fluids, a statistically significant (p=<0.05) decrease in shimmer results was however reported (54). Previous studies have nevertheless, reported that jitter is recognised as a more accurate indication of perturbation in synthesized speech signals when compared to shimmer, and should thus be interpreted with caution (55).

From the acoustic results a significant increase in MPT (sec) (p=0.015) was observed in the hypo hydrated condition from pre-test to post-test (10.1% and 00.0% respectively). Even though the outcome of improved MPT in hypo hydration does not support the hypothesis, it points to the possibility of a warm-up effect present. Research has previously yielded evidence on this effect in literature on speech-language pathologists and young choir girls (56). This phenomena caused an improvement in vocal quality after 30 minutes of vocal stretches and exercises. Beneficial outcomes due to vocal warm-up for the acoustic analysis of have previously been present in both singers and non-singers (57). Another study observed the vocal warm-up effect when employed in young choir girls, indicating increased glottal closure and positive fine-tuning of the vocal folds position (58).

One must however consider the positive change seen MPT (sec) in both the superficial hydration condition from pre-test to post-test as well as when comparing the experimental and control condition post-test results show that where superficial hydration was applied mean significant positive increase in MPT (sec) was observed, (p=0.004) and (p=0.003) respectively. In previous studies mixed or non-significant results were reported for the effect of dehydration on MPT, specifically when fasting (54,59). Yet, one study focusing on the effects of systemic hydration found a statistically significant increase in MPT for sounds /a/ (*p*= 0.012) and /s/ (*p*= 0.024) after hydration (38). This increased in MPT may be due to nimble, pliable and therefore easily vibrated vocal folds requiring reduced subglottic pressure needed in order to vibrate for lengthier periods. Thus, the results found for the MPT outcomes of the current study further support the hypothesis of the benefits of hydration (38). Dysphonia Severity Index (DSI) (p=0.020) scores also increased significantly whereas Intensity (dB) Min (p=0.018) significantly reduced when comparing the experimental and control condition post-test results of the superficial hydration group. A previous study only reporting on the effects of systemic hydration and hypo hydration on the Dysphonia Severity Index yielded no significant results (38). Superficial hydration can alternatively be seen to significantly improve overall acoustic vocal quality via increased DSI scores (p=0.020). For a PVU who depends on optimal voice quality, any improvement thereof contributes to enhancing in the overall professional vocal performance. Improvement may be perceptual, regarding decreased grade of voice disorder, roughness and breathiness present in the voice when performing. Longer maximum phonation time (MPT), the ability to produce softer voice (Intensity Min) and most importantly overall improved voice quality (DSI) is also vital improvement observed, depending on the individual. Improvement can also be considered as consistent decreased perceived vocal fatigue in the singer when increased superficial and combined hydration is employed.

The vocal fatigue index yielded outcomes that were most consistently aligned with the proposed hypothesis. As self-perceived tiredness of voice and physical discomfort, decreased slightly, improvement of symptoms with rest, increased slightly with applied superficial hydration and again continued to do so more significantly with added systemic hydration schedule, indicating reduced perceived vocal fatigue when improvement of symptoms of rest are supported by adequate hydration. Both tiredness of voice (p=0.044) and physical discomfort (p=0.029) were, significantly decreased by combined hydration when compared to the control condition. It must also be noted that when comparing the experimental conditions, combined hydration significantly (p=0.016) decreased vocal fatigue compared to superficial hydration. A previous study aimed to determine the amount of singing required to experience perceived vocal fatigue in untrained amateur karaoke singers, found that when provide with regular but brief systemic hydration and vocal rests amateur karaoke singers sang significantly longer before vocal fatigue was reported (mean 101.93 minutes) than the group without taking water or rests (mean 85.48 minutes) (43). Another study examined the effect of a laryngeal desiccation challenge and subsequent nebulized isotonic saline in trained male singers and non-singers. Demonstrating an increase after laryngeal desiccation and decrease after nebulized saline treatment in all self-perceived measures of vocal effort (35).

Although mixed results on acoustic parameters must be considered, from the results, it is inferred that superficial hydration has a positive effect on various acoustic and perceptual parameters of voice quality as well as vocal fatigue in the female professional singer. Vocal hygiene programs can benefit from this clinically relevant data by providing a cost-effective and efficient method to improve voice perceptual quality and decreased perceived vocal fatigue. Optimal vibration of the vocal folds is permitted when one makes use of adequate superficial and systemic hydration, this in turn increases ease of phonation, allowing a performance to be as effortless as possible. Singers are then free to focus on performance value, without additional anxiety caused by the perceptual voice quality or vocal fatigue.

### 1.4.1 Limitations and recommendations

There are several potential limitations to the current study that warrant mention. First, the sample included in this study was a small group of young, vocally healthy, female singers (n=24). It may be that age, vocal health and hygiene, and/or vocal training influence susceptibility to laryngeal dehydration, and it is therefore recommended that future research should be conducted on a larger sample (60). Second, VFI ratings may have been influenced by participants' expectation that treatment would improve vocal hydration and decrease vocal effort. The examiner did their best to prevent bias during experimental procedures, but it is possible that a bias did exist. One must also always consider the possible presence of the placebo effect (61). Due to the VFI rating being done by the participants, they may have been biased to give improved ratings when receiving hydration compared to hypo hydration merely due to previous education and pre-existing notions on hydration within vocal hygiene in their studies as professional singers.

### 1.4.2 Conclusion

Many clinicians advocate for increased hydration as an important component of vocal hygiene. However, on the topic of applied superficial hydration through nebulization, a greater evidence base is required to determine the exact relationship with, and effect on with voice quality, and substantiate the clinical application thereof. In this study, it was confirmed that the use of superficial hydration had positive outcomes on the perceptual parameters of voice quality and vocal fatigue in female professional singers. Mixed results were however found regarding the acoustic parameters of voice. The positive results obtained pertaining to perceptual voice quality and vocal fatigue supports the use of hydration as a preventative measure that should be included in vocal hygiene programs. This application of systemic and superficial hydration may assist female professional singers who rely heavily on not only voice production but optimal vocal quality, as the primary tool for occupational success.

### 1.4.3 Funding Sources

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### 1.4.4 Disclosure Statement

The authors have no conflicts of interest to declare.

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# Chapter 4

# Discussion and Conclusion

## 4.1 Chapter aim and outline:

The aim of this chapter is to provide an overview and critically discuss the research findings. An evaluation of the research project, the clinical implications of the findings, as well as recommendations for future research opportunities is also presented.

## 4.2 Discussion

In summary, it was found that dehydration; caused by a one-hour classical singing rehearsal in hypo-hydration, lead to the following vocal changes in female professional singers. Perceptually, grade of voice disorder and roughness significantly increased (p=0.030 and p=0.036, respectively). Whereas acoustically, a significant increase in Frequency Min (p=0.019) and MPT (p=0.015) from pre-test to post-test was observed. Thus, participants' voices were perceptually more dysphonic to the trained ear. Lower notes were harder to reach therefore a reduced vocal range is observed when the vocalist is inadequately hydrated. Though the singers could sustain notes for longer regarding MPT (p=0.015), the vocal quality of the note was compromised through grade of voice disorder and roughness (p=0.030 and p=0.036).

The unexpected improvement in MPT in hypo hydration may be due to a warm-up effect. Research has previously yielded evidence on this effect in speech-language pathologists and young choir girls (Van Lierde, Evelien, Baudonck, Claeys, & De Bodt, 2011). This phenomena caused an improvement in vocal quality after 30 minutes of vocal stretches and exercises. Beneficial outcomes due to vocal warm-up for the acoustic analysis have previously been seen in both singers and non-singers (Amir et al., 2005). Another study observed the vocal warm-up effect when employed in young choir girls, indicating increased glottal closure and positive fine-tuning of the vocal folds position (Falcao, Masson, Oliveira, & Behlau, 2014).

When hydration was applied by means of a nebulized isotonic saline, a water drinking schedule or both, the following vocal changes were observed in female professional singers. Perceptually, breathiness was significantly reduced (p=0.014) in all (n=24) participants in the combined hydration group, where both superficial hydration and systemic hydration was applied. In contrast, another study examining the effects of vocal load without hydration on perceptual quality of voice in vocally healthy females documented a significant decrease in breathiness observed, suggesting an improvement of voice subsequent to loading regardless of applied hydration (Remacle et al., 2014). This serves to question whether the positive change in decreased breathiness seen in the current study is due to the applied hydration or simply caused by the vocal loading task itself and possible warm-up effect.

Acoustically, Average Intensity (dB) min and $F_0$ (Hz) Min also increased significantly in the combined hydrated condition from pre-test to post-test (p=0.019 and p=0.010 respectively). An increase in mean Shimmer (p=0.016) as well as a significant reduction in mean Intensity (dB) Max (p=0.049) was observed when comparing the experimental and control condition post-test results where superficial hydration was applied. The increase in intensity (dB) min and $F_0$ (Hz) min for the combined hydration condition clinically manifested as a smaller voice range, with decreased loudness projection which is undesirable for the singer's performance. Additionally, increased cycle-to-cycle variation in amplitude and decreased range of loudness was observed where superficial hydration was employed. When singers attempt to reach their highest and lowest frequencies or intensities, prime elasticity is necessary in order to reach notes without strain. In the PVU, frequency and intensity changes are essential variables in order to identify early vocal fatigue (Leydon et al., 2018) as this may indicate a deterioration in elasticity and viscosity of the vocal fold mechanism (Welham & Maclagan, 2003). It is therefore essential to consider how vocal fatigue remains an unavoidable counter variable when attempting to improve the vocal quality of a female professional singer.

Where superficial hydration was applied a significant positive increase in MPT (sec) was observed in pre-test to post-test (p=0.004) as well as when comparing the experimental and control condition post-test results (p=0.003). This increase in MPT may be due to nimble, pliable and therefore easily vibrated vocal folds requiring reduced subglottic pressure needed in order to vibrate for lengthier periods. Thus, the results found for the MPT outcomes of the current study further support the hypothesis of the benefits of hydration (Van Wyk et al., 2017). Intensity (dB) Min (p=0.018) significantly reduced when comparing the experimental and control condition post-test results of the superficial hydration group, indicative of larger range of volume levels when singing. Most importantly, Dysphonia Severity Index (DSI) (p=0.020) scores also increased significantly when comparing the experimental and control condition post-test results of the superficial hydration group. Hence, superficial hydration resulted in significantly decreased dysphonia scores in the female professional singer.

The vocal fatigue index yielded outcomes that were most consistently aligned with the proposed hypothesis. As self-perceived tiredness of voice and physical discomfort decreased slightly, improvement of symptoms with rest, increased slightly with applied superficial hydration. This was observed more significantly with added systemic hydration schedule, indicating reduced perceived vocal fatigue when improvement of symptoms of rest is supported by adequate hydration. Both tiredness of voice (p=0.044) and physical discomfort (p=0.029) were, significantly decreased by combined hydration when compared to the control condition. It should also be noted that when comparing the experimental conditions, combined hydration significantly (p=0.016) decreased vocal fatigue compared to superficial hydration. The researcher did their best to prevent bias during experimental procedures, but it is possible that a bias did exist. One must also always consider the possible presence of the placebo effect (Moerman, 2002). Due to the VFI rating being done by the participants, they may have been biased to give improved ratings when receiving hydration compared to hypo hydration merely due to previous education and pre-existing notions on hydration within vocal hygiene in their studies as professional singers. A previous study aimed to determine the amount of singing required to experience perceived vocal fatigue in untrained amateur karaoke singers. The results showed that when the participants were provided with regular but brief systemic hydration and vocal rests, amateur karaoke singers sang significantly longer before vocal fatigue was reported (mean 101.93 minutes) than the control group that did not consume water or rest (mean 85.48 minutes) (Yiu & Chan, 2003).

### 4.2.1 Clinical Implications

Superficial hydration has be seen to significantly enhance acoustic vocal quality via positively increased DSI scores (p=0.020). For a PVU who depends on optimal voice quality, any improvement thereof contributes to benefit the overall professional vocal performance. Enhancement may be perceptual, regarding decreased grade of voice disorder, roughness and breathiness present in the voice when performing. Longer maximum phonation time (MPT), the ability to produce softer voice (Intensity Min) and most importantly overall better voice quality (DSI) is also vital improvement observed, depending on the individual. Positive voice change is also observed as perceived vocal fatigue consistently decreases in the singer when increased superficial and combined hydration is employed.

Although mixed results on acoustic parameters were obtained in this study, it is inferred that superficial hydration has a positive effect on various acoustic and perceptual parameters of voice quality as well as vocal fatigue in the female professional singer. Vocal hygiene programs can benefit from this clinically relevant data by providing a cost-effective and efficient method to improve voice perceptual quality and decreased perceived vocal fatigue. Optimal vibration of the vocal folds is permitted when one makes use of adequate superficial and systemic hydration; this in turn increases ease of phonation, allowing a performance to be as effortless as possible. Singers are then free to focus on performance value, without additional anxiety caused by the perceptual voice quality or vocal fatigue.

*Practical tips for the female vocalist on preventative vocal hygiene measures:*

As observed in the current study, various means of hydration are key factors when it comes to optimization of the female singing voice. One must however consider all internal and external variables that influence vocal quality. From the present findings and previous literature the following hydration and dehydration related vocal hygiene measures are recommended as part of a vocal hygiene approach:

- Try and drink 8-10 glasses of water per day to maintain adequate systemic/internal hydration (Verdolini-Marston et al., 1990),

- When rehearsing, intermittently sip water in short breaks as much as you can, instead of only drinking before or after rehearsal. The combination of short breaks and water drinking throughout your rehearsal times can curb the effects of vocal fatigue (Yiu & Chan, 2003),
- Employ the use of a nebulizer in order to hydrate the vocal mucosa superficially/externally and enhance perceptual vocal quality and decrease vocal fatigue. 3mL of nebulized isotonic saline (a salt solution that has the same osmotic pressure as bodily fluids) (0.9% NaCl) can be used before, after and in breaks of rehearsals. It must be noted that the amount used (3mL) does not influence the vocal quality outcome. Thus, nebulizing 9mL will provide the same outcome on vocal quality and vocal fatigue as 3mL (Fujiki, 2014),
- A facial steamer can be used to practice short periods (3 min) of steam inhalation as this can improve vocal quality (Mahalingam & Boominathan, 2016),
- Humidifiers can be used to alter environmental low-level humidity contributing to dehydration and counter vocal loading. However, it is important to note that moderate humidity levels will only provide limited effect on vocal production. Humidifiers must therefore increase humidity to a high level (100%) before it will be useful in decreasing the negative effects of vocal loading (Fujiki, Chapleau, Sundarrajan, & Mckenna, 2018; Sivasankar & Erickson, 2009),
- Avoidance of allergens and irritants is recommended but it is important to remember that by maintaining adequate vocal fold hydration you will simultaneously protect epithelial cells against inhaled bacteria and irritants (Erickson-Levendoski, Leydon, & Thibeault, 2014),
- Avoid the following; fasting where fluid intake is limited, oral and accelerated breathing, extensive, loud speaking or reading, whispering, exercise, diuretic substances and medications and smoking as this will contribute to dehydration and thus affect vocal quality. It is advisable to compile lists of diuretic foods, drinks and medications for your own consideration and diet (Awan, 2011; Hamdan et al., 2007; Sivasankar & Erickson-Levendoski, 2012; Sivasankar & Erickson, 2009). Contrary to popular belief, caffeine is allowed in moderation as a conservative amount will not negatively affect voice production (Alves et al., 2017).

- Voice use factors: avoid voice use when ill, excessive talking, crying, screaming, unconventional voicing, and throat-clearing. Make use of voice rest and reduction programs (Van der Merwe, 2004), vocal warm-up and cool-down exercises to safe guard your voice from vocal abuse, misuse and avoidable fatigue (Behlau & Oliveira, 2009).

*Clinical tips for the speech-language pathologist- assessing & treating a PVU:*

- Make use of "*Practical Tips for the Female Vocalist on Preventative Vocal Hygiene Measures"* when counselling the PVU. It is vital for clinicians to carry-over the importance of these recommendations in a way our clients understand as literature shows that even musical performers with voice complaints, do not adequately comply to or regard preventive voice care as a priority (Behlau & Oliveira, 2009),
- Previous studies show that the GRBASI 4-point rating scale is most in-line with perceptual vocal qualities and thus, the preferred tool to use when assessing perceptual vocal characteristics of the PVU (Bele, 2005),
- Perceived vocal fatigue is a very important physiological, but also psychological variable to assess and treat when dealing with a PVU. By considering its impact on the PVU, you can address the client's needs more holistically by employing and educating them on counter measures (Erickson-Levendoski, Sundarrajan, & Sivasankar, 2014).

### 4.2.2 Strengths, limitations and recommendations

Mentionable strengths of this study are as follows; the reliability and validity measures taken to ensure the standard of data collected. The use of calibrated instrumentation, validated and standardized tools, a blinded listeners' panel trained in the field of voice disorders ensured reliability and validity in this study. The use of a previously executed protocol (Van Wyk et al., 2017) with additions allowed the researcher to add to existing body of research but with a new perspective of superficial hydration and vocal fatigue. The study also serves to create awareness regarding hydration and vocal hygiene among PVUs. The scarcity in research regarding superficial hydration in singers, consequently results in inadequate awareness of the appropriate management and vocal hygiene for a population who are at risk of phonotrauma, cumulative effects of vocal fatigue and later, vocal fold pathologies as a result. With the positive effects of superficial hydration on the perceptual parameters and vocal fatigue observed in this study, similar hydration schedules can be employed in vocal hygiene programs and increased education and advocacy can be fostered amongst professional singers in order to prevent voice disorders as well as concomitant laryngeal pathology from developing.

There are several potential limitations to the current study which warrant mention. First, the sample included in this study was a small group of young, vocally healthy, female singers (n=24). It may be that age, vocal health, and/or vocal training influence susceptibility to laryngeal dehydration, and it is therefore recommended that future research should be conducted on a larger sample (Franca, 2006). Second, VFI ratings may have been influenced by participants' expectation that treatment would improve vocal hydration and decrease vocal effort. The researcher did their best to prevent bias during experimental procedures, but it is possible that a bias did exist. One must also always consider the possible presence of the placebo effect (Moerman, 2002). Due to the VFI rating being done by the participants, they may have been biased to give improved ratings when receiving hydration compared to hypo hydration merely due to previous education and pre-existing notions on hydration within vocal hygiene in their studies as professional singers.

Third, it is recommended that future research studies consider a variety of occupational groups that may benefit from the results. Additionally, for future research on the effect of superficial hydration on voice quality, it is recommended that participants all follow a similar warm-up program (30 minutes of vocal stretches and exercises) before testing in all conditions to eliminate the possible voice quality changes as a result of the warm-up effect (Amir et al., 2005). Although all participants were asked to perform a short vocal exercise in the current protocol before pre-test, this is not sufficient to eliminate the influence of possible warm up effect. Lastly, superficial as well as systemic hydration are complex variables to control due to differences in bodily fluid balance from participant to participant. Although measures were in place to control the intake of fluids and food before testing, it may be possible that more rigorous control over this variable could allow for more reliable research outcomes (Timmermans et al., 2002). The amount and duration of nebulized isotonic saline needed to alter superficial hydration is poorly defined in literature (Valtin, 2002; Verdolini et al., 2002). Future research should focus on hydration schedules of differing durations and doses and compare these results. Control measures for time, voice rest, warm-up, cool-down and vocal training should also be considered. Despite its limitations, this study is the one of the few examining nebulized isotonic saline treatment as superficial hydration in female professional singers. It will serve as a basis for future research in this area.

### 4.2.3 Conclusion

Many clinicians advocate for increased hydration as an important component of vocal hygiene. However, on the topic of applied superficial hydration through nebulization, a greater evidence base is required to determine the exact relationship with, and effect on with voice quality, as well as substantiate the clinical application thereof. In this study, it was confirmed that the use of superficial hydration had positive outcomes on the perceptual parameters of voice quality and vocal fatigue in female professional singers. Mixed results were however found regarding the acoustic parameters of voice thus, the hypothesis cannot be accepted or rejected. The negative results obtained in hypo hydration as well as, the positive results pertaining to perceptual voice quality and vocal fatigue supports the use of hydration as a preventative measure that should be included in vocal hygiene programs. This application of systemic and superficial hydration may assist female professional singers who rely heavily on not only voice production, but optimal vocal quality, as the primary tool for occupational success.

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# 6. Appendices

## Appendix A: Ethical Application

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Research Ethics Committee

28 February 2018

Dear Ms van Zyl

| | |
|---|---|
| **Project:** | **The effect of superficial hydration, with and without, systematic hydration on voice quality in professional female singers** |
| **Researcher:** | **R van Zyl** |
| **Supervisor:** | **Dr J van der Linde** |
| **Department:** | **Speech-Language Pathology and Audiology** |
| **Reference Number:** | **13206258 (GW20180103HS)** |

Thank you for your response to the Committee's letter of 20 February 2018.

I am pleased to inform you that the above application was **approved** by the **Research Ethics Committee** at an ad hoc held on 28 February. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely

**Prof Maxi Schoeman**
**Deputy Dean: Postgraduate Studies and Ethics**
**Faculty of Humanities**
**UNIVERSITY OF PRETORIA**
**e-mail: tracey.andrew@up.ac.za**

cc: Dr J van der Linde (Suoervisor and HoD)

## Appendix B: Participant and Informed Consent Letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

**Faculty of Humanities**
Department of Speech-Language Pathology and Audiology

March 2018

Dear Participant

**PARTICIPATION IN A POSTGRADUATE RESEARCH PROJECT.**

**Study title:**
The effect of superficial hydration, with or without systemic hydration, on the voice quality of female professional singers

**Introduction:**
As a Speech-Language Pathology Master's degree student, I am conducting a research project in the field of Voice.

**The aim of the study:**
Due to the voice being an occupational instrument, a singer's professional and vocational success relies heavily on optimal voice quality. Even though vocal hygiene education is an important aspect that forms part of singing students' training, the role of hydration and the different methods of keeping the vocal mechanism hydrated are overlooked at times. This research aims to evaluate the effect of superficial hydration, with or without systemic hydration, on singers' vocal quality, hereby contributing to the body of research in the field of Speech-Language Pathology, specifically Voice in professional singers.

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Hatfield 0028, South Africa
Tel +27 (0)12 420 2355 (x2948)
Email jeannie.vanderlinde@up.ac.za
www.up.ac.za

**Fakulteit Geesteswetenskappe**
Departement Spraak-Taalpatologie en Oudiologie
**Lefapha la Bomotho**
Kgoro ya Phatholotši ya Polelo-Maleme le Go kwa

**Participants:**
You are invited to participate in this research study that requires the participation of female undergraduate, postgraduate or alumni vocal students between the ages of 18 and 32. In order to participate you must be enrolled in or have completed the BA Music program at the University of Pretoria with singing as first or second instrument, in any genre. Regrettably, if you have a current diagnosis of a voice disorder by an Ear-Nose and Throat Specialist you will not be able to participate as this will affect the data collected.

**Procedures:**
This study involves a voice assessment before and after a routine singing rehearsal, where you will be subjected to different vocal fold hydration techniques. Superficial hydration used in the study will be through receiving 4mL of nebulized isotonic saline before, in a 10-minute break in the middle of, as well as after the 1-hour signing rehearsal. Concerning the water intake schedule, you will be required to refrain from alcoholic and carbonated drinks twelve hours prior to singing. You will however, be allowed to eat your regular breakfast, but not within 2 hours prior to singing. In the schedule, it will be stipulated that you are only allowed to drink water 30 minutes prior to singing and will be required to drink 500 mL of water during the hour rehearsal, focusing on drinking approximately 250 mL every 30 minutes of singing. The researcher will test the quality of your voice perceptually and acoustically before the 1-hour rehearsal of a singing piece of your own choice. Hereafter, your voice will be tested again with the same measures for the sake of comparison. The testing involves simple vocalizations, brief reading and singing. You will also be required to complete two questionnaires on your perceived vocal fatigue, vocal health habits and any personal history that could possibly influence the study outcomes.

**Ethical Approval:**
The research is subject to ethical clearance from the Research and Ethics Committee of the Faculty of Humanities, as well as the permission of the Director of Student Affairs at the University of Pretoria.

**Risks involved in participating in this study:**
No risks are involved in this study for participants.

**Your rights as a participant in this study:**
Your participation would purely be on a voluntary basis and if at any time, you wish to withdraw, you may do so without any negative consequences. All the data collected will be kept confidential and only the researcher and supervisors of the study will have access to the information. Data in this study will be stored on the University of Pretoria's databases and in hardcopy format in the Department of Communication Pathology and Audiology for archiving and possible future research and teaching. Steps will be taken to protect your identity and personal information. Each participant will receive a participant

number in order to maintain anonymity and no identifying information will be captured by the researcher. Results will be published or presented in a manner in which participants remain unidentifiable.

**Compensation:**
Your participation is entirely voluntary and therefore participants will not be compensated. You may benefit from your participation in this research by learning how to optimally hydrate your singing voice through hydration schedule and superficial hydration practices and therefore optimize your voice quality and vocal performance.

Questions about the study can be directed to my academic supervisor, Dr J. Van Der Linde, at the Department of Speech-Language Pathology and Audiology via email: jeannie.vanderlinde@up.ac.za

Your participation would highly be appreciated. If you wish to participate in this study, please complete the informed consent from and return it to the researcher.

Many thanks,

Rouxjeanne Vermeulen
**Student**

Dr J. Van Der Linde
**Supervisor**

Miss. S. Abdoola
**Supervisor**

Dr J. Van Der Linde
**Head: Department of Speech-Language Pathology and Audiology**

**INFORMED CONSENT TO PARTICIPATE IN THIS STUDY**

I have read or had read to me the above information before signing this consent form. The content and meaning of this information have been explained to me. I have been given opportunity to ask questions and am satisfied that they have been answered satisfactorily. I understand that if I do not participate it will not alter my management in any way. I hereby volunteer to take part in this study.

I have received a signed copy of this informed consent agreement.

............................................... ........................

Participant name Date

............................................... ........................

Participant signature Date

......................................................... .........................

Investigator's name Date

......................................................... .........................

Investigator's signature Date

.............................................. ..........................

Witness name and signature Date

## Appendix C: Letter to Director of Student Affairs

January 2018

Dr M Madiba
Director: Student Affairs
University of Pretoria
Email: matete.madiba@up.ac.za

Dear Dr Madiba

**PARTICIPATION OF STUDENTS AT THE DEPARTMENT OF MUSIC AS PART OF A POSTGRADUATE RESEARCH PROJECT.**

**Study title:**
The effect of superficial hydration, with or without systemic hydration, on the voice quality of female professional singers

**Introduction:**
As a Speech-Language Pathology Master's degree student, I am conducting a research project in the field of Voice.

**The aim of the study:**
This study aims to contribute to the body of research in the field of Speech-Language Pathology and more specifically Voice in professional singers. Due to the voice being an occupational instrument, a singer's professional and vocational success relies heavily on optimal voice quality. Even though vocal hygiene education is an important aspect that forms part of singing students' training, the role of hydration and the different methods of keeping the vocal mechanism hydrated are overlooked at times.

Research will be conducted to evaluate the effect of superficial hydration and/or systemic hydration on singers' vocal quality.

**Participants:**
24 female under- or postgraduate vocal students between the ages of 18 and 32 will be invited to participate in the study. Participants must be enrolled in the BA Music program at the University of Pretoria with singing as first instrument, in any genre. Regrettably participants with a current diagnosis of a voice disorder by an Ear-Nose and Throat Specialist cannot participate as this will affect the data collected.

**Procedures:**
This study involves a voice assessment before and after a routine singing rehearsal, where participants will be subjected to different vocal fold hydration techniques. These techniques include the vocal mechanism being exposed to superficial hydration through the use of a nebulized treatment only, or hydration applied systemically through the use of a water intake schedule in combination with the aforementioned nebulized treatment or lastly, not being exposed to either form of hydration. Superficial hydration used in the study will be through the participants receiving 4mL of nebulized isotonic saline before, in a 5-minute break in the middle of, as well as after the 2-hour signing rehearsal. Concerning the water intake schedule, they will be required to refrain from carbonated and caffeinated drinks including coffee, tea, and energy drinks. They will however, be allowed to eat their regular breakfast, but not within 2 hours prior to singing. In the schedule, it will be stipulated that the participant is only allowed to drink water 30 minutes prior to singing and will be required to drink 750 mL of water during the 2-hour rehearsal, focusing on drinking approximately 250 mL every 30 minutes of singing. The researcher will test the quality of the participant's voice perceptually and acoustically before the 2-hour rehearsal of a singing piece of her own choice. Hereafter, their voices will be tested again with the same measures for the sake of comparison. The testing involves simple vocalizations, brief reading and singing. The participants will also be required to complete two questionnaires on their vocal health habits and any personal history that could possibly influence the study outcomes

**Ethical Approval:**
The research is subject to ethical clearance from the Research and Ethics Committee of the Faculty of Humanities, as well as the permission of the Director of Student Affairs at the University of Pretoria.

**Risks involved in participating in this study:**
Participation in this study will not involve any risk and is non-invasive.

**The participant's rights in this study:**
Participation would be on a voluntary basis and if at any time the participant wishes to withdraw, they may do so without any negative consequences. All of the data collected

will be kept confidential and only the researcher and supervisors of the study will have access to the information. Data in this study will be stored on the University of Pretoria's databases and in hardcopy format in the Department of Communication Pathology and Audiology for archiving and possible future research and teaching. Steps will be taken to protect participants' identity and personal information. Each participant will receive a participant number in order to maintain anonymity and no identifying information will be captured by the researcher. Results will be published or presented in a manner in which participants remain unidentifiable.

**Compensation:**
Participation is entirely voluntary and therefore participants will not be compensated. They may however, benefit from their participation in this research by learning how to optimally hydrate their own singing voice through hydration schedules and superficial hydration practices and therefore optimize their voice quality and vocal performance.

Questions about the study can be directed to my academic supervisor, Dr J. Van Der Linde, at the Department of Speech-Language Pathology and Audiology via email: jeannie.vanderlinde@up.ac.za

Yours Sincerely,

Rouxjeanne Vermeulen
**Student**

Dr J. Van Der Linde
**Supervisor**

Miss. S. Abdoola
**Supervisor**

Dr J. Van Der Linde
**Head: Department of Speech-Language Pathology and Audiology**

**PERMISSION BY DIRECTOR OF STUDENT AFFAIRS TO CONDUCT RESEARCH**

I ____________________________________, was informed about all the details pertaining to the study titled: *"The effect of superficial hydration, with or without systemic hydration, on the vocal quality in female professional singers"*, and give permission to conduct the research with students at the University of Pretoria

________________________ ________________________

Signature Date (dd/mm/yy)

## Appendix D: Letter to H.O.D. – Music Department

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

**Faculty of Humanities**
Department of Speech-Language Pathology and Audiology

January 2018

Prof A Johnson
Head: Music Department
University of Pretoria

Dear Professor Johnson

**PERMISSION TO INCLUDE FEMALE VOCAL STUDENTS AT THE DEPARTMENT OF MUSIC AS PART OF A POSTGRADUATE RESEARCH PROJECT.**

**Study title:**
The effect of superficial hydration, with or without systemic hydration, on the voice quality of female professional singers

**Introduction:**
As a Speech-Language Pathology Master's degree student, I am required to conduct a research project. My project is within the field of Voice. As part of the scope of practice of speech-language therapists, our role includes prevention, assessment and the treatment of voice disorders.

**The aim of the study:**
This study aims to contribute to the body of research in the field of Speech-Language Pathology and more specifically Voice in professional singers. Due to the voice being an occupational instrument, a singer's professional and vocational success relies

heavily on optimal voice quality. Even though vocal hygiene education is an important aspect that forms part of singing students' training, the role of hydration and the different methods of keeping the vocal mechanism hydrated are overlooked at times. Research will be conducted that evaluates the effect of superficial hydration and/or systemic hydration on singer's vocal quality.

**Participants:**
24 female under- or postgraduate vocal students between the ages of 18 and 32 will be selected to participate in the study. Participants must be enrolled in the BA Music program at the University of Pretoria with singing as first instrument, in any genre. Regrettably, participants with a current diagnosis of a voice disorder by an Ear-Nose and Throat Specialist cannot participate, as this will affect the data collected.

**Ethical Approval:**
The research is subject to ethical clearance from the Research and Ethics Committee of the Faculty of Humanities, as well as the permission of the Director of Student Affairs at the University of Pretoria.

**Risks involved in participating in this study:**
Participation in this study will not involve any risk and is non-invasive.

**Procedures:**
This study involves a voice assessment before and after a routine singing rehearsal, where participants will be subjected to different vocal fold hydration techniques. These techniques include the vocal mechanism being exposed to superficial hydration through the use of a nebulized treatment only, or hydration applied systemically through the use of a water intake schedule in combination with the aforementioned nebulized treatment or lastly, not being exposed to either form of hydration. Superficial hydration used in the study will be through the participants receiving 4mL of nebulized isotonic saline before, in a 5-minute break in the middle of, as well as after the 2-hour singing rehearsal. Concerning the water intake schedule, they will be required to refrain from carbonated and caffeinated drinks including coffee, tea, and energy drinks. They will however, be allowed to eat their regular breakfast, but not within 2 hours prior to singing. In the schedule, it will be stipulated that the participant is only allowed to drink water 30 minutes prior to singing and will be required to drink 750 mL of water during the 2-hour rehearsal, focusing on drinking approximately 250 mL every 30 minutes of singing.

The researcher will test the quality of the participant's voice perceptually and acoustically before the 2-hour rehearsal of a singing piece of their own choice. Hereafter, their voices will be tested again with the same measures for the sake of comparison. The testing involves simple vocalizations, brief reading and singing. The participants will also be required two complete questionnaires on their vocal health habits and any personal history that could possibly influence the study outcomes.

The tests will not interfere with class times and all participation will be voluntary. All of the data collected will be kept confidential and only the researcher and supervisors of the study will have access to the information. Data in this study will be stored on the University of Pretoria's databases and in hardcopy format in the Department of Speech-Language Pathology and Audiology for archiving and possible future research and teaching. Steps will be taken to protect the identity and personal information of the participants. I hope that my request for vocal students from the Department of Music, at the University of Pretoria to participate in this study, will meet your approval.

Yours Sincerely,

________________________

Rouxjeanne Vermeulen
**Student**

________________________

Dr J. Van Der Linde
**Supervisor**

________________________

Miss. S. Abdoola
**Supervisor**

________________________

Dr J. Van Der Linde
**Head: Department of Speech-Language Pathology and Audiology**

**PERMISSION BY HEAD OF DEPARTMENT OF MUSIC TO CONDUCT RESEARCH**

I ________________________________________, was informed about all the details pertaining to the study titled: *"The effect of superficial hydration, with or without systemic hydration, on the vocal quality in female professional singers"*, and give permission to conduct the research with students from the Department of Music, University of Pretoria.

___________________________ ___________________________

Signature Date (dd/mm/yy)

## Appendix E: Case History Questionnaire

# Case History Questionnaire

Dear Participant

I am a Speech Language Pathology Master's degree student in the Department of Speech-Language Pathology and Audiology at the University of Pretoria. You are invited to volunteer to participate in my research project on the effect of superficial hydration, with or without systemic hydration, on voice quality in professional female singers.

I would like you to complete a questionnaire. This may take about 5 minutes. I will collect the questionnaire from you before you leave the lecture hall. Please do not write your name on the questionnaire in order to ensure confidentiality. I will be available to help you with any questions or to fill it in on your behalf if you are physically unable to do so.

Please Note: The implication of completing the questionnaire is that informed consent has been obtained from you. Thus, any information derived from your form (which will be completely anonymous) may be used for e.g. publication, by the researcher. Please note that confidentiality is assured.

I sincerely appreciate your participation.

Regards
Rouxjeanne van Zyl

For administrative use only

**Age:** V1 ☐☐ V2 ☐☐

**Date of Birth:** V3

| d | d | m | m | y | y |
|---|---|---|---|---|---|
| | | | | | |

**Medical History:**

Please check the box applicable to you.

Do you suffer from any of the following?

1. Voice Disorder diagnosed by an Ear Nose and Throat Specialist? Yes ☐ No ☐ V4 ☐
2. If yes, have you received voice therapy? Yes ☐ No ☐ V5 ☐
3. Allergies? Yes ☐ No ☐ V6 ☐

4 If yes, please specify? ______________________________

5 Postnasal drip? Yes ☐ No ☐ V7 ☐

| | | | | |
|---|---|---|---|---|
| 6 | Sinusitis? | Yes ☐ No ☐ | V8 | ☐ |
| 7 | Ear problems? | Yes ☐ No ☐ | V9 | ☐ |
| 8 | If yes, please specify? ______________________ | | V10 | ☐ |
| 9 | Chronic colds? | Yes ☐ No ☐ | V11 | ☐ |
| 10 | Chronic cough? | Yes ☐ No ☐ | V12 | ☐ |
| 11 | Chronic laryngitis? | Yes ☐ No ☐ | V13 | ☐ |
| 12 | Esophageal reflux? | Yes ☐ No ☐ | V14 | ☐ |
| 13 | Endocrine illness/ hormonal treatment? | Yes ☐ No ☐ | V15 | ☐ |
| 14 | If yes, please specify? ______________________ | | | |
| 15 | Are you aware of any laryngeal injuries you have sustained? | Yes ☐ No ☐ | V16 | ☐ |
| 16 | If yes, please specify extent and when you sustained it? ____________ | | | |
| 17 | Any laryngeal procedures where anesthetics were needed? | Yes ☐ No ☐ | V17 | ☐ |
| 18 | If yes, please specify procedure and when you underwent it? ________ | | | |
| 19 | Have you ever been intubated? | Yes ☐ No ☐ | V18 | ☐ |
| 20 | Other related medical problems? | Yes ☐ No ☐ | V19 | ☐ |
| 21 | If yes, please specify? ______________________ | | | |
| 22 | Are you currently on any form of birth control? | Yes ☐ No ☐ | V20 | ☐ |

| | | | |
|---|---|---|---|
| 23 | Are you currently using ANY medication? (chronic-, acute-, self –medication Yes☐No☐ | V21 | ☐ |
| 24 | If yes, please specify? ______________________ | | |

**Dietary Information:**

Please check the box applicable to you. Do you ingest any of the following daily?

| | | | |
|---|---|---|---|
| 25 | Liquid caffeine (tea, coffee, energy drinks, soda etc.)? Yes☐No☐ | V22 | ☐ |
| 26 | If yes, how many cups a day? ______________________ | V23 | ☐ |
| 27 | Other forms of caffeine (chocolate, energy bars etc.)? Yes☐No☐ | V24 | ☐ |
| 28 | | | |
| 29 | If yes, how many servings a day? ______________________ | V25 | ☐ |
| 30 | Water? Yes☐No☐ | V26 | ☐ |
| 31 | If yes, how many glasses? ______________________ | V27 | ☐ |
| 32 | Alcoholic beverages? Yes☐ No☐ | V28 | ☐ |
| 33 | If yes, please indicate amount and how often? ______________________ | V29 | ☐ |
| 34 | Carbonated drinks? Yes☐No☐ | V30 | ☐ |
| 35 | If yes, how many servings a day? ______________________ | V31 | ☐ |
| 36 | Dairy products (milk, cheese, yoghurt, etc.)? Yes☐No☐ | V32 | ☐ |
| 37 | If yes, how much? ______________________ | V33 | ☐ |

**Vocal hygiene habits:**

Please check the box applicable to you.

38 Do you smoke? Yes ☐ No ☐ V34 ☐

39 If yes, how often? ______________________ V35 ☐

40 How often do you have singing rehearsals during a week?______________ V36 ☐

41 Please specify how many hours in total? (per week) ___________________ V37 ☐

42 What is the duration of an average practice per week? (hours)____________ V38 ☐

43 Do you ever feel a change in voice quality before or after rehearsals?
Yes ☐ No ☐ V39 ☐

44 If yes, please mark with an [ x ] next to the correct symptom:

- Breathiness V40 ☐
- Pain V41 ☐
- Hoarseness V42 ☐
- Roughness V43 ☐
- Loss of voice V44 ☐
- Generally softer voice V45 ☐
- Only softer on certain pitch V46 ☐

45 Does your voice feel tired after rehearsal the next day? Yes ☐ No ☐ V47 ☐

46 Have you attended an event/environment where you were exposed to loud noise in the last three days? Yes ☐ No ☐ V48 ☐

47 Have you attended an event/environment where you were expected to shout, scream or cheer loudly? Yes ☐ No ☐ V49 ☐

48 If yes, was this within the last three days? Yes ☐ No ☐ V50 ☐

## Appendix F: Vocal Fatigue Index

VOCAL FATIGUE INDEX (VFI)

Age: ______

Date of Birth: d/d/m/m/y/y

Date: _ _ / _ _ / _ _

These are some symptoms usually associated with voice problems. Circle the response that indicates how frequently you experience the same symptoms (0-never, 1- almost never, 2-sometimes, 3- almost always, 4- always).

1) I don't feel like talking after a period of voice use. 0 1 2 3 4

2) My voice feels tired when I talk more. 0 1 2 3 4

3) I experience increased sense of effort with talking. 0 1 2 3 4

4) My voice gets hoarse with voice use. 0 1 2 3 4

5) It feels like work to use my voice. 0 1 2 3 4

6) I tend to generally limit my talking after a period of voice use. 0 1 2 3 4

7) I avoid social situations when I know I have to talk more. 0 1 2 3 4

8) I feel I cannot talk to my family after a work day. 0 1 2 3 4

9) It is effortful to produce my voice after a period of voice use. 0 1 2 3 4

10) I find it difficult to project my voice with voice use. 0 1 2 3 4

11) My voice feels weak after a period of voice use. 0 1 2 3 4

12) I experience pain in the neck at the end of the day with voice use. 0 1 2 3 4

13) I experience throat pain at the end of the day with voice use. 0 1 2 3 4

14) My voice feels sore when I talk more. 0 1 2 3 4

15) My throat aches with voice use. 0 1 2 3 4

16) I experience discomfort in my neck with voice use. 0 1 2 3 4

17) My voice feels better after I have rested. 0 1 2 3 4

18) The effort to produce my voice decreases with rest. 0 1 2 3 4

19) The hoarseness of my voice gets better with rest. 0 1 2 3 4

## Appendix G: Rainbow Passage

The Rainbow Passage

When the sunlight strikes raindrops in the air, they act as a prism and form a rainbow. The rainbow is a division of white light into many beautiful colours. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow. Throughout the centuries, people have explained the rainbow in various ways. Some have accepted it as a miracle without physical explanation. To the Hebrews it was a token that there would be no more universal floods. The Greeks used to imagine that it was a sign from the gods to foretell war or heavy rain. The Norsemen considered the rainbow as a bridge over which the gods passed from earth to their home in the sky. Others have tried to explain the phenomenon physically. Aristotle thought that the rainbow was caused by reflection of the sun's rays by the rain. Since then physicists have found that it is not reflection, but refraction by the raindrops, which causes the rainbows. Many complicated ideas about the rainbow have been formed. The difference in the rainbow depends considerably upon the size of the drops, and the width of the coloured band increases as the size of the drops increases. The actual primary rainbow observed is said to be the effect of super-imposition of a number of bows. If the red of the second bow falls upon the green of the first, the result is to give a bow with an abnormally wide yellow band, since red and green light when mixed form yellow. This is a very common type of bow, one showing mainly red and yellow, with little or no green or blue.