

**THE EFFECT OF HYDRATION ON VOICE QUALITY IN ADULTS:  
A SYSTEMATIC REVIEW**

**by**

**Maxine Alves  
(13050232)**

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**FACULTY OF HUMANITIES**

**SUPERVISOR: Dr Jeannie Van Der Linde**

**CO-SUPERVISORS: Mrs Esedra Krüger and Mrs Bhavani Pillay**

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## **\*AUTHOR NAMES AND AFFILIATIONS:**

### **Miss Maxine Alves**

Department of Speech-Language Pathology and Audiology, University of Pretoria,  
South Africa.

Corner of Roper and Lynnwood Road, Pretoria, Gauteng, South Africa.

Maxine.alves1@gmail.com

### **Mrs Esedra Krüger**

Department of Speech-Language Pathology and Audiology, University of Pretoria,  
South Africa.

Corner of Roper and Lynnwood Road, Pretoria, Gauteng, South Africa.

Esedra.kruger@up.ac.za

### **Mrs Bhavani Pillay**

Department of Speech-Language Pathology and Audiology, University of Pretoria,  
South Africa.

Corner of Roper and Lynnwood Road, Pretoria, Gauteng, South Africa.

Bhavani.pillay@up.ac.za

### **Dr Jeannie van der Linde**

Department of Speech-Language Pathology and Audiology, University of Pretoria,  
South Africa.

Corner of Roper and Lynnwood Road, Pretoria, Gauteng, South Africa.

Jeannie.vanderlinde@up.ac.za

## **\*CORRESPONDING AUTHOR:**

Miss Maxine Alves

Maxine.alves1@gmail.com

Postal address: PO BOX 11663, Selcourt, Springs, Gauteng, 1567

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## **\*AUTHOR CONTRIBUTIONS**

- Miss Alves was responsible for the literature review, data collection, data analysis and synthesis, writing and editing of the article.
- Dr van der Linde generated the research topic, was responsible for providing consensus regarding inclusion of selected studies and presence of bias and was involved in editing and guidance throughout the generation of the article.
- Mrs Pillay was responsible for providing consensus regarding inclusion of selected studies and presence of bias and was involved in editing and guidance throughout the generation of the article.
- Mrs Kruger was responsible for editing and guidance throughout the generation of the article.

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RESEARCH PROPOSAL & ETHICS COMMITTEE

# DECLARATION

Full name: Maxine Alves

Student number: 13050232

Degree/qualification: MA Speech-Language Pathology

Title of dissertation: The effect of hydration on voice quality in adults: A systematic review

I declare that this dissertation is my own original work. Where secondary material is used, this has been carefully acknowledged and referenced in accordance with university requirements.

I understand what plagiarism is and am aware of university policy and implications in this regard.

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# TABLE OF CONTENTS

<b>FIGURES</b> .....	<b>viii</b>
<b>TABLES</b> .....	<b>viii</b>
<b>APPENDICES</b> .....	<b>viii</b>
<b>LIST OF ABBREVIATIONS</b> .....	<b>ix</b>
<b>FORMATTING</b> .....	<b>ix</b>
<b>ABSTRACT</b> .....	<b>x</b>
<b>CHAPTER 1: INTRODUCTION</b> .....	<b>1</b>
1.1 Background .....	1
1.1.1 Parameters of voice production .....	1
1.1.2 Body hydration .....	5
1.1.3 Hydration of the vocal folds .....	6
1.2. Rationale.....	9
1.3. Research question .....	12
<b>CHAPTER 2: METHOD</b> .....	<b>13</b>
2.1. Research aim.....	13
2.2. Research design.....	13
2.3. Data collection procedures .....	14
2.3.1. Search strategy.....	14
2.3.2. Data management.....	15
2.3.3. Inclusion criteria.....	15
2.3.4. Exclusion criteria .....	16
2.3.5. Ethical considerations.....	17
2.3.6. Publication bias.....	17
2.4. Reliability and validity of research .....	18
2.5. Data analysis.....	19
2.6. Hypothesis.....	21
<b>CHAPTER 3: THE EFFECT OF HYDRATION ON VOICE QUALITY: A SYSTEMATIC REVIEW</b> .....	<b>22</b>
<b>CHAPTER 4: DISCUSSION AND CONCLUSION</b> .....	<b>51</b>
4.1. The value of the systematic review.....	52
4.2. Clinical implications .....	53
4.3. Future research needs.....	55
4.4 Critical evaluation .....	56
4.5. Conclusion .....	56

<b>REFERENCES .....</b>	<b>57</b>
<b>APPENDICES.....</b>	<b>64</b>
Appendix A: Evidence of item checklists within the review adapted from the PRISMA-P checklist (Shamseer, et al., 2015) .....	65
Appendix A continued: Evidence of item checklists within the review adapted from the PRISMA-P checklist (Shamseer, et al., 2015) .....	66
Appendix B: Ethical clearance form.....	67
Appendix C: The Cochrane Collaboration’s Tool to Assess the Risk of Bias within studies.	68
Appendix C continued: The Cochrane Collaboration’s Tool to Assess the Risk of Bias within studies. ....	69

## **FIGURES**

- Figure 1: Types of voice disorders.
- Figure 2: Three-tiered approach to evidence based practice.
- Figure 3: Process of data collection.

## **TABLES**

- Table 1.1: Descriptions of measures of voice quality.
- Table 1.2: States of water balance within the body.
- Table 1.3: Levels of evidence.
- Table 1.4: Description of the quality indicators.
- Table 2.1: Characteristics of selected studies.
- Table 2.2: Risk of bias across selected studies.
- Table 2.3: Results for the vocal quality measures in systemic dehydration, hydration or rehydration interventions.
- Table 2.4: Results for measures in surface dehydration, hydration or rehydration interventions.

## **APPENDICES**

- Appendix A: Evidence of item checklists within the review adapted from the PRISMA-P checklist.
- Appendix B: Ethical clearance form.
- Appendix C: The Cochrane Collaboration's Tool to Assess the Risk of Bias within studies.



## **LIST OF ABBREVIATIONS**

ASHA: American Speech-language-Hearing Association

CAPE-V: Consensus Auditory-Perceptual Evaluation of Voice

CPP: Cepstral peak prominence

CSID: Cepstral spectral index of dysphonia

DSI: Dysphonic severity index

EBP: Evidence based practice

ENTs: Ear, nose and throat specialists

F<sub>0</sub>: Fundamental frequency

GNE: Glottal-to-noise excitation ratio

H/N: Harmonics-to-noise ratio

LHR: Low/high spectral ratio

NHR: Noise-to-harmonics ratio

MPT: Maximum phonation time

PPE: Perceived phonatory effort

PRISMA: Preferred reporting items for systematic reviews and meta-analyses

PTP: Phonation threshold pressure

PVU: Professional voice users

RCT: Randomized control trial

SLTs: Speech-language therapists

VHI: Voice Handicap Index

VTI: Voice turbulence index

## **FORMATTING**

The APA referencing style was used in this dissertation.

## ABSTRACT

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Objectives.	To critically appraise scientific, peer-reviewed articles, published in the past 10 years on the effects of different levels of hydration on voice quality in adults.
Study design.	Systematic review.
Method.	Five databases were searched using the key words “vocal fold hydration/dehydration”, “voice quality”, “and “hygienic voice therapy”. The PRISMA-P guidelines were followed. The included studies were scored based on ASHA’s levels of evidence and quality indicators, as well as, the Cochrane Collaboration’s risk of bias tool.
Results.	Systemic dehydration as a result of fasting and not ingesting fluids had a significant, negative effect on the parameters of NHR, shimmer, jitter, frequency and the s/z ratio. Water ingestion led to significant improvements in shimmer, jitter, frequency and MPT values. Caffeine does not appear to negatively affect voice production. Laryngeal desiccation challenges by oral breathing led to surface dehydration which negatively affected jitter, shimmer, NHR, PTP and PPE. Steam inhalation significantly improved NHR, shimmer and jitter. Only nebulization of sterile water, isotonic solution and saline solution improved PTP, throat and mouth dryness and fundamental frequency respectively. An indication of a potential positive effect of nebulization substances was observed. Treatments in high humidity environments prove to be effective and adaptations of low humidity environments should be encouraged.
Conclusion.	Recent literature regarding vocal hydration is high quality evidence. Systemic hydration is the easiest and most cost effective solution to improve voice quality. Surface hydration using steam inhalation and nebulization as well as environmental modification can be suggested for professional voice users. Recent evidence therefore supports the inclusion of hydration in a vocal hygiene program.
Key words.	Vocal hydration/dehydration/rehydration–Voice quality–Vocal hygiene–Systematic review–Superficial/surface hydration

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## CHAPTER 1: INTRODUCTION

*“Words mean more than what is set down on paper. It takes the human voice to infuse them with deeper meaning.” (Maya Angelou).*

### Chapter aim:

The aim of chapter one is to provide clarification on the physiological, acoustic and perceptual parameters of model voice. The proposed effect of hydration on overall body functioning, with particular emphasis on the vocal folds, is also discussed. The need for a systematic review of recent literature regarding the effectiveness of hydration on voice quality is highlighted towards the end of the chapter as findings regarding this matter are contradictory. The chapter concludes with the rationale and the research question for the current review.

## 1.1 Background

### 1.1.1 Parameters of voice production

Voice is a vital aspect of the physical, emotional, cultural and lifestyle status of an individual (Stemple, 2005) and the normality of the voice is dependent on these factors (Colton, Casper & Leonard, 2006). The voice conveys a wealth of information about a speaker (Franca & Simpson, 2009) and is altered during different emotional states, differing environments and reflects an overall state of health of the body and the mind (Colton, Casper & Leonard, 2006). Normal voice production, however, requires balance and synchronicity amongst three components, namely: respiration, phonation and resonance (Franca, Simpson & Schuette, 2013; Ferrand, 2011 & Schwartz, 2004). When these mutually dependent components work in perfect harmony, voice quality is optimized.

During the exhalation phase of respiration, the airflow provided from the lungs, ensures the necessary energy for voicing is generated (Schwartz, 2004). It is this airstream that forms the basis of all voice and subsequent speech production (Ferrand, 2012). Phonation or voicing, occurs at the level of the larynx. The larynx is a complex structure formed by interlinked cartilages, membranes, ligaments, muscles and soft tissues (Ferrand, 2012). The vocal mechanism, residing within the larynx, consists of the true and the false vocal folds (Ferrand, 2012). These folds adduct and abduct in a symmetrical fashion.

The vocal folds are composed of layers of ligaments, muscles and soft tissue (Miri, Barthelat & Mongeau, 2011) and within them is a highly hydrated interstitial tissue. Outwardly, they are covered by a thin layer of liquid (Ahmed, et al., 2012). As air is pushed through them, the resultant consequence is their vibration. This vibration is perceived as “voice” and the process of phonation occurs (Schwartz, 2004).

The third and final component needed for optimal voicing is resonance. Resonance refers to manipulation of the sound stream as it passes through the oral and nasal resonator cavities (Schwartz, 2004). All of these systems lead to the measurable aspect of voice quality. Although there are predetermined norm values for voice, it is important to remember that voices come in many varieties (Colton, Casper & Leonard, 2006). The norms of voice quality have thus been suggested to occur on a continuum of ranges as opposed to a set, singular norm (Colton, Casper & Leonard, 2006).

Voice quality refers to measures of an acoustic nature, perceptual nature and an aerodynamic nature (Boominathan, Samuel, Arunachalam, Nagarajan & Mahalingham, 2014). Acoustic analysis refers to the objective, quantifiable measures of voice quality using instruments such as the Visi-Pitch, Computerized Speech Lab (CSL) (Kay Elemetrics) and Dr. Speech (Tiger Electronics) (Schwartz, 2004). A description of acoustic and aerodynamic measures is provided in Table 1.1 below.

**Table 1.1: Descriptions of measures of voice quality.**

Term	Description
Fundamental frequency (Fo)	Amount of cycles produced by the vocal folds. Correlates perceptually to pitch (de Felipe, Grillo & Grecht, 2006).
Amplitude/ intensity	The energy of a sound with the perceptual correlate being loudness (Schwartz, 2004).
Jitter	Cycle to cycle frequency variations in vocal fold vibration (Ferrand, 2011). High levels of jitter are typically associated with pathologic voices (Santana, et al., 2016).
Shimmer	Cycle to cycle variation in vocal fold amplitude or intensity (Ferrand, 2012). High levels of shimmer are typically associated with vocal pathology (Santana, et al., 2016).
Harmonics-to-noise ratio (H/N)	A measure of the frequency structure of the voice signal to the noise within that signal (Schwartz, 2004).
Phonation threshold pressure (PTP)	Minimum amount of subglottal pressure needed to set the vocal folds into vibration (Ferrand, 2012).
Sound pressure level	A measure of the voice intensity (Franca, Simpson & Schuette, 2013).
Voice turbulence index (VTI)	Refers to the deviance from normal voice (Hamdan, et al., 2011).
Maximum phonation time (MPT)	The longest possible phonation of a selected sound after maximum inspiration (Van Wyk, et al., 2017).
s/z ratio	Measures respiratory and phonatory efficiency (Van Wyk, et al., 2017).
Dysphonic severity index (DSI)	A multiparametric instrument that is able to establish a quantitative, objective format of voice quality. It is calculated using the measures of lowest intensity, highest frequency, MPT and jitter (Van Wyk, et al., 2017).
Cepstral peak prominence (CPP)	A measure of the degree of harmony or regularity within a voice sample. The more periodic the voice signal, the more harmonious and the greater the CPP value (Herman-Ackah, et al., 2014).
Low/high spectral ratio (LHR)	The ratio of low versus high frequency spectral energy. Higher values indicated greater low frequency energy, commonly seen in normal voice (Watts, Awan & Lambert, 2010)
Cepstral spectral index of dysphonia (CSID)	A treatment outcomes measure of dysphonia severity (Peterson, et al., 2013).
Glottal-to-noise excitation ratio (GNE)	Used to calculate the noise in a series of pulses created by vocal fold oscillation (Santana, et al., 2016).
Noise	Corresponds to the aperiodic component of the signal (Santana, et al., 2016).
Irregularity	The fluctuation of voice over time (Santana, et al., 2016).

Perceptual analysis usually involves rating the quality of a voice using scales as the tool of measurement. Scales regarding the perception of voice can be completed by voice practitioners, as well as, the individual voice users themselves. The most common scales for assessments by voice practitioners include, amongst others, the *GRBASI 4-point Rating Scale* (Yamauchi, Imaizumi & Maruyama et al., 2010) and the *Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V; ASHA, 2003)*. The GRBASI Scale looks at the grade of hoarseness, roughness, breathiness, asthenia, strain and instability of the voice. The CAPE-V is an auditory-perceptual rating tool that has similar attributes to the GRBASI Scale. These attributes include the overall severity, roughness, breathiness, strain, pitch and loudness of the voice (ASHA, 2003).

The Voice Handicap Index (VHI) (Jacob, Johnson, Grywalski, Jacobson, Benninger & Newman, 1997) and the Voice-Related Quality of Life Measure (V-RQOL) (Hogikyan & Sethuraman, 1999) are self-rating scales which can be used by any individual to rate their perceptions of their own voice. They are four- and five-point scales respectively which describe how an individual's voice impacts their life (Verdolini, Rosen & Branski, 2006). The VHI consists of categories which assesses the functional, physical and emotional impact that their voice has on themselves and others (Jacob, et al., 1997). Rating scales should be interpreted carefully as there is controversy regarding the reliability of these scales due to their reliance on perceptual and subjective judgements (Schwartz, 2004; Webb, et al., 2003).

Another perceptual evaluation conducted in many studies included in the review, was the assessment of perceived phonatory effort (PPE). PPE was assessed similarly in all the studies using visual analogue scales. Participants were required to draw a line ranging from "no effort" to "maximal effort" using different stimuli upon which they rated their effort, for example singing "happy birthday" (Sundarrajan, Fujiki, Loerch, Venkatramen, & Sivasankar, 2017) or singing certain musical notes (Tanner, Roy, Merrill, Muntz, Houts, Sauder, Elstad, & Wright-Costa, 2010). The distance of this line was then measured to give the PPE value (Sandage, Conner & Pascoe, 2013; Sivasankar & Erickson-Levendoski, 2012; Sundarrajan, et al., 2017; Tanner, et al., 2010). In essence, PPE refers to a psychological, self-perceived measure of vocal effort (Franca, 2006).

Along with the perceptual, acoustic and aerodynamic measures of voice, a full voice assessment should include a visual analysis of the vocal mechanism's structure and physiology. Ear, nose and throat specialists (ENTs) work in conjunction with speech-language therapists (SLTs) to achieve optimal voice quality. An ENT makes a diagnosis based on a clinical and endoscopic visual examination (Boominathan, 2014). Visual assessment of the vocal folds includes an assessment of the parameters of glottal closure pattern, regularity, symmetry of the vibration, the mucosal wave and the amplitude of the vibration (Boominathan, 2014; Hirano & Bless, 1993).

When there is asynchronicity in any of the above parameters, a voice disorder can occur. A voice disorder refers to a disturbance in parameters of quality, pitch, loudness and flexibility of voice that differs from individuals of similar age, gender and cultural group (Boominathan, et al., 2014). Although not life threatening, the result is a significant impact on activities of daily living (Boominathan, et al., 2014).

The consequences of a voice disorder can impact on an individual's ability to perform certain tasks within their occupations (Roy, Merrill, Gray & Smith, 2005). It may also have social consequences such as individuals avoiding environments with vocally challenging tasks and thus having a negative effect on their social-emotional component of life (Pack, 2008). Voice disorders can be classified into three main categories that may overlap. These categories are discussed and examples provided in Figure 1 below. The most common voice disorders are functional in nature and may often lead to organic pathology of the vocal folds (Roth & Worthington, 2011).

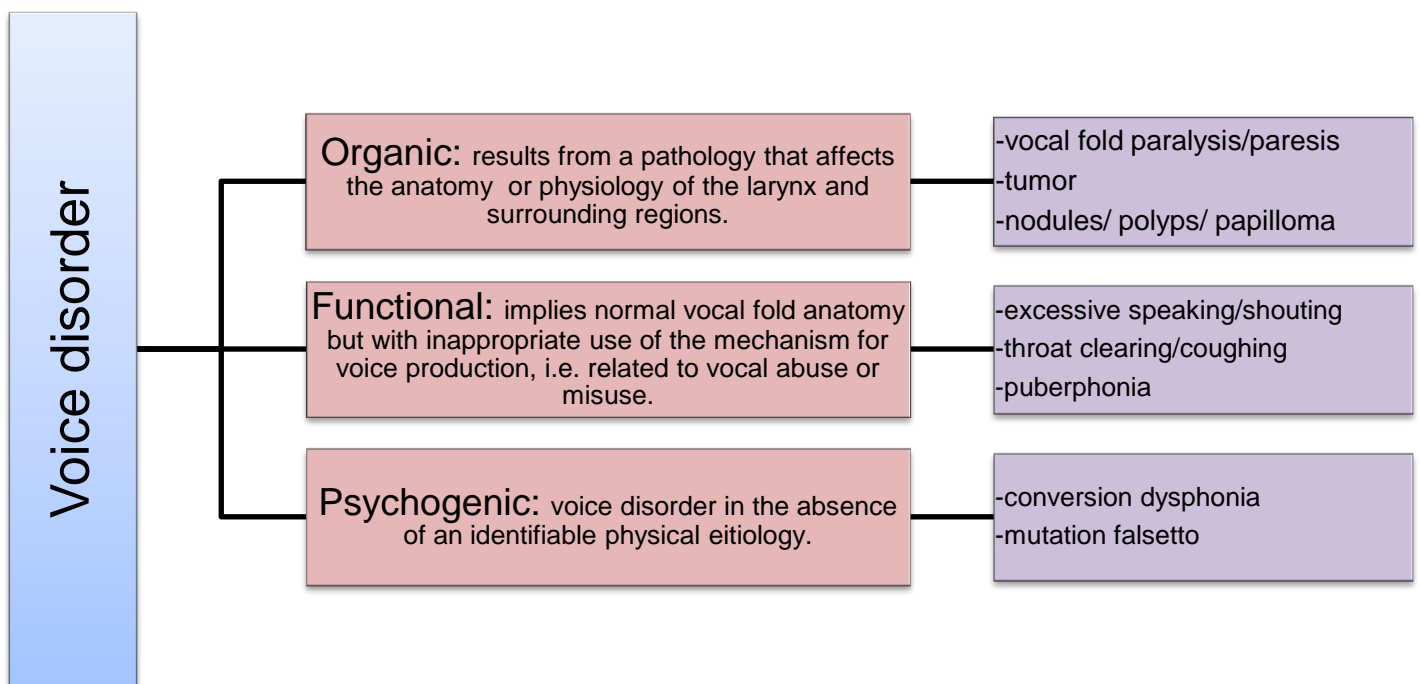


Figure 1: Types of voice disorders (Boone & McFarlane, 2010; Roth & Worthington, 2011; Schwartz, 2004).

### 1.1.2 Body hydration

Humans are reliant on water for overall health and wellbeing (Hartley & Thibeault, 2014) as water comprises 55% to 65% of body mass (Thomas, Cole, Lawnorne, Levenson, Rubinstein, Smith, Stefanacci, Tangolas & Morley, 2008). It plays a role in the physiological functioning of the various systems of the body, such as, the respiratory, digestive, circulatory and urinary systems (Hartley & Thibeault, 2014). Generally speaking; hydration can be described as an adequate level of water in the body and dehydration as a lack of water (Franca, 2006; Hartley & Thibeault, 2014). However, there are more refined definitions describing the aspects pertaining to the amount of water present in the body (Hartley & Thibeault, 2014). These definitions are discussed in Table 1.2.

**Table 1.2: States of water balance within the body according to Hartley and Thibeault (2014).**

<b>Hydration</b>	Refers to the current state of water balance in the body.
<b>Euhydration</b>	Refers to the normal state of hydration necessary to sustain normal physiological function of the body.
<b>Hypohydration</b>	A less amount of water present than euhydration.
<b>Hyperhydration</b>	An excess amount of water in the body.
<b>Dehydration</b>	Refers to the process of uncompensated water loss reducing the total body water to below the average value required.

Body fluid reduction can occur as vapour loss during respiration or water loss which occurs during perspiration, urination and stool excretion (Verdolini, Rosen & Branski, 2006). Ways of reducing the body to a hypohydrated state may include, consuming diuretics such as alcohol or caffeine or by minimizing the intake of fluids. Caffeine and alcohol are said to induce frequent urination which can ultimately cause body dehydration if these liquids are not replenished (Franca, Simpson & Schuette, 2013).

Some medications may also have an effect on the hydration status of an individual (Thomas, et al., 2008), as well as, abstinence from eating, drinking, taking medications and intravenous fluids, referred to as the process of fasting (Hamdan Ashkar, Sibai, Oubari, & Hussein, 2011). As a result of fasting, dehydration, electrolyte imbalance, malnutrition and general discomfort may occur (Hamdan, Sibai, & Rameh, 2007). Hydration, however, is not unidimensional. It occurs at different levels in the body and thus has differing effects on the vocal mechanism. Each level will be discussed with reference to the vocal mechanism.

### **1.1.3 Hydration of the vocal folds**

As previously mentioned, healthy vocal folds have a layer of mucous surrounding their surface (Behrman, 2007) which is continuous with the fluid that covers the distal and proximal airway (Sivasankar, Carroll, Kosinski & Rosen, 2013). This layer is formed by mucous, electrolytes and water (Sivasankar, et al., 2013) and is supplied from the vocalis muscle and the epithelium (Miri, Barthelat & Mongeau, 2011). One function of the surrounding liquid layer is to serve as a physical and biochemical barrier that protects the underlying tissue from damage (Leydon, Sivasankar, Falciglia, Atkins & Fisher, 2008). The cover also ensures that the vocal folds are moist and well lubricated; a necessity for optimal vocal fold vibration (Colton, Casper & Leonard, 2011).



Changes in the layer are observed after environmental and systemic alterations such as low humidity conditions, mouth breathing, pollution, inflamed tissue, hypersecretion of mucous and/or reflux of gastric contents (Sivasankar, et al., 2013). The vocal fold surface may become dry as a result of environmental and behavioural aspects (Leydon, et al., 2008). These non-optimal environments may lead to drying of the vocal folds, resulting in reduced pliability and increased stiffness and thus may lead to poorer vocal quality (Leydon, et al., 2008). Alternatively, such environments may result in thick secretions which increase the weight of the vocal folds and subsequently affect their vibratory pattern (Do Prado Franca, 2006). These conditions can also lead to phonotraumatic behaviours such as coughing or throat clearing, further exacerbating vocal fold irritation (Do Prado Franca, 2006).

During the collision of the folds during phonation, an interstitial transfer occurs that pushes fluid away from the area of vocal fold contact (Erath, Zañartu & Peterson, 2016). As a result, increased stress gradients are formed. These stress gradients are exacerbated in dehydrated tissue (Erath, Zañartu & Peterson, 2016). Frequent rehydration is thus not only required to maintain regular phonatory function (Miri, Barthelat & Mongeau, 2011), but also to prevent vocal fold lesions due to these stress gradients (Erath, Zañartu & Peterson, 2016).

Vocal fold lesions can develop as a result of acute trauma but also due to the vocal tissue being subjected to excessive, repetitive mechanical stresses during vocal collision (Erath, Zañartu & Peterson, 2016). Voicing requires high intensity muscle action. As a result, the vocal fold tissues endure frequent and prolonged vibration (Solomon & Dimattia, 2000), thereby, increasing the susceptibility of the larynx to injury and disease (Franca & Simpson, 2009). A compromised state of hydration, even as little as one or two percent (Hartley & Thibeault, 2014), is believed to limit physical performance of these sustained or intermittently repeated efforts (Horswil & Janas, 2011). These adverse alterations can result in greater contact time between the vocal folds and increased pulmonary effort for phonation (Sivasankar, et al., 2013). The delicate larynx, therefore requires proper care (Franca, Simpson & Schuette, 2013), considering these high intensity and long endurance muscle activities have been reported to be especially susceptible to dehydration (Hartley & Thibeault, 2014).

Voice care is comprised of maintaining two levels of hydration. The first level, systemic hydration, refers to general body hydration that keeps mucosal tissue healthy. This level of hydration is achieved by ingesting fluids, with the typical recommendation of eight glasses of water per day (Hartley & Thibeault, 2014).

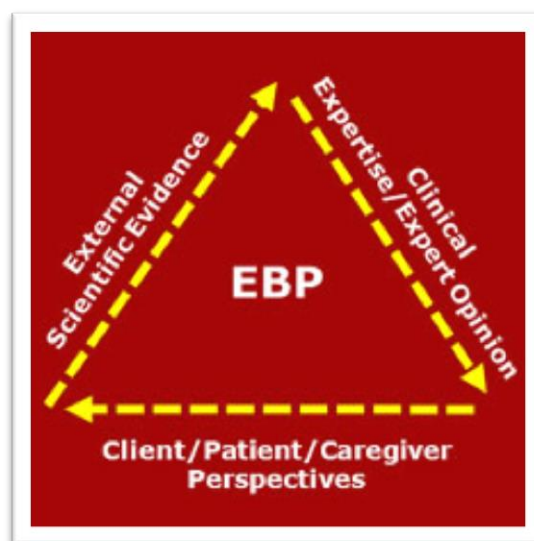
Systemic hydration is speculated to make secretions thinner resulting in easier production of voice (Franca & Simpson, 2009). Avoidance of dehydrating substances, such as caffeine and alcohol, is also suggested as an important aspect in maintaining systemic hydration (Rubin, Korovin & Epstein, 2003).

The second level, superficial or surface hydration, refers to the moisture level that keeps the epithelial surface of the vocal folds healthy and pliable (Franca, 2006). It is suggested that inhalation of steam or vapour from a humidifier is beneficial as it directly lubricates the vocal fold surface (Ferrand, 2012). Mucolytic medications can also be used to thin out bodily secretions and make them less viscous (Ferrand, 2011), resulting in easier phonation. Another method involves nebulization. Nebulization refers to the process of administering a medication or solution by a fine spray into the respiratory tract of the individual (Mosby, 2012). Lastly, in conjunction with the above, nasal breathing is emphasized as inspired air is humidified before it reaches the posterior pharynx. This process reduces evaporation of the fluid lining the larynx and trachea (Sivasankar, et al., 2008). Superficial hydration can thus be accomplished using the above measures in addition to avoidance of drying environments (Franca & Simpson, 2009; Hartley & Thibeault, 2014). These drying environments include smoke filled areas, dusty areas or places with air conditioning.

Literature has emphasised the maintenance of adequate ingestion of liquids, the use of steam or both in combination as an important component of voice care and voice intervention (Roy, Merrill, Thibeault, Gray, & Smith, 2004; Sivasankar & Fisher, 2003; Tanner, et al., 2015). However, the relationship between physiology, hydration and voicing is not yet fully understood. It is speculated that “dry” and “sticky” vocal folds do not oscillate as easily as “wet” and “loose” vocal folds (Solomon & Dimattia, 2000) and that an increased subglottal pressure is required for phonation, especially at higher pitch levels (Verdolini, Rosen & Branski, 2006). These dry or mucous filled conditions can lead to vocally abusive behaviours, such as chronic throat clearing or coughing (Franca, 2006) and subsequent symptoms such as hoarseness, poor pitch and loudness control, increased effort and breathiness (Higgins & Smith, 2012). Voice complaints also include thick secretions within the vocal tract (Verdolini, Rosen & Branski, 2006). These conditions are further exacerbated by reduced lubrication. These symptoms can affect the quality of an individual’s voice and may even lead to secondary organic pathologies, such as nodules, further impacting the use of voice. When optimal vibration is disturbed, deviant laryngeal quality can occur and result in increased dysphonia (Verdolini, Rosen & Branski, 2006). Overall, the optimality of the voice can be disrupted by unevenly weighted vocal folds, inadequate vocal fold closure or insufficient airflow (Ferrand, 2012).

## 1.2. Rationale

As emphasized by Schwartz (2004), it is of vital importance that SLTs, ENTs and other voice practitioners remain up to date with the current literature regarding methods of intervention, to ensure best practice for each client that they serve. Evidenced-based practice (EBP) refers to the “conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients... [by] integrating individual clinical expertise with the best available external clinical evidence from systematic research” (Sackett, Rosenberg, Gray, Haynes & Richardson, 1996, p. 71). It calls for a three-tiered approach that combines client preferences and values within the framework of evidence and expertise of clinicians, as evidenced in Figure 2 below (Ferrand, 2012).



**Figure 2: Three-tiered approach to evidence based practice (ASHA, 2004).**

It is thus vital to obtain accurate information and empirical data in order to provide clinical advice and develop preventative programs (Franca, Simpson & Schuette, 2013). This systematic review is necessary to ensure EBP is provided for the voice population to improve the quality of services provided to clients with voice disorders (ASHA, 2004), and for the prevention of these disorders.

Almost one third of the population of the United States of America will have some form of voice disorder across their life-span (Roy, et al., 2005). A more recent study showed the incidence rate of voice disorders in the American population to be 7.6%. A study conducted in South Africa found a slightly lower incidence rate of 5.2% (Fourie, Richardson, van der Linde, Abdoola & Mosca, 2017).

However, the prevalence rate is suggested to be higher as the majority of individuals experiencing a voice disorder do not always seek intervention, possibly due to the lack of knowledge that they have a voice problem (Fourie, et al., 2017). More specifically, professional voice users (PVUs) exhibit the highest prevalence of voice disorders due to excessive voice demands (Santana, Masson, & Araújo, 2016). A PVU is considered as an individual who depends on consistent and optimal voice quality for their employment (Hazlett, Duffy & Moorhead, 2011). PVUs such as teachers, singers, actors, SLTs and politicians, show an incidence of 40-50% in India (Boominathan, Rajendran, Nagarajan, Jayashree, & Muthukumaran, 2008). PVUs exert unusual and excessive demands on respiration, phonation and resonance (Boone & McFarlane, 2010). The heavy vocal demands experienced by these individuals can result in an occupational voice disorder (Hazlett, Duffy & Moorhead, 2011). These voice disorders are also hyperfunctional in nature, which can ultimately progress to an organic voice disorder. Judgements about PVUs are often linked to their vocal performance, which needs to be excellent (Franca & Simpson, 2009). Singers, one group of PVUs, often experience functional and/or organic problems of the voice (Boone & McFarlane, 2010). A voice disorder can have negative effects on an individual and may adversely impact their quality of life in terms of occupational change or loss, social isolation or withdrawal, depression and/or a difficulty being understood by others (Ferrand, 2011).

An eclectic approach to intervention for hyperfunctional voice disorders constitutes a variety of techniques to improve voice production and quality (Stemple, 2005). By following an eclectic approach to treatment, the individual is considered holistically. The approach includes an analysis of the individual's physical, nutritional, environmental, emotional, social and lifestyle values, which could all have an impact on the effectiveness of voice intervention (Stemple, 2005). An aspect included within an eclectic approach is hygienic voice therapy, a patient-centred or indirect behavioural treatment (Behlau & Oliveira, 2009). Vocal hygiene focuses on eliminating and/or modifying inappropriate phonotraumatic behaviours (Stemple, 2005).

Discouraged behaviours may include shouting, singing out of range, chronic throat clearing (Behlau & Oliveira, 2009; Stemple, 2005) and eliminating dehydrating agents, such as caffeine (Erikson-Levendoski & Sivansankar, 2011). Also included in a vocal hygiene program is education regarding the vocal mechanism and voice production, identification and reduction of vocal abuse and misuse behaviours, voice conservation and finally controlling reflux and allergies (Behlau & Oliveira, 2009).

Minimizing the effect of medications, environmental factors and lifestyle changes on voice are also discussed (Behlau & Oliveira, 2009). However, the most suggested method to improve vocal hygiene is to increase hydration levels (Erickson-Levendoski & Sivansankar, 2011; Franca & Simpson, 2012).

Although there are speculated benefits that, in theory, appear plausible, there have been few studies to support the beneficial effects of hydration (Franca & Simpson, 2009). In more recent years, however, vocal hydration has received renewed attention but many have reported contradictory findings (Erickson-Levendoski, et al., 2014; Franca & Simpson, 2013; 2012; Fujiki, et al., 2017; Mahalingham, et al., 2016; Patel, et al., 2015; Sandage, et al., 2013; Santana, et al., 2016; Sivasankar & Erickson-Levendoski, 2012; Sundarranjan, et al., 2017; Tanner, et al., 2010; 2015). The effects of dehydration can be seen on various aspects of voice acoustics; however, the effects of rehydration or dehydration often indicate non-significant changes (Franca & Simpson, 2009; 2013; Hamdan, et al., 2007; 2011; Tanner, et al., 2007; 2010; 2015 & Van Wyk, Cloete, Hattingh, van der Linde & Geertsema, 2017). Research by Roy, and colleagues focused on the mechanisms of water transport in the vocal folds and suggested that methods such as drinking water daily, using lubricants and steam inhalation may not be effective (Branski & Sivasankar, 2006; Roy, Blomgren, Fisher, Gray & Tanner, 2003).

Overall, the literature suggests that in order to improve voice quality, hydration should involve retaining enough fluids within the body in order for the larynx to function optimally and permit the healthy and unstrained vibration of the vocal mechanism (Franca, 2006). The quality of this literature should, however, be appraised to ensure methodologically sound results were obtained. Previous studies and reviews have generally focused on the impact of hydration on the effort of phonation or on the physiological aspects of voicing and not necessarily on voice quality and the acoustic parameters of the voice (Roy, Weinrich, Gray, Tanner, Toledo, Dove, Corbin-Lewis & Temple, 2002), hence the topic of the current review. It was of great importance, that the literature be critically appraised to identify if an increase in hydration is warranted as an effective approach to the prevention and intervention of voice disorders.

The conclusion of this review indicates the efficacy of suggesting vocal hydration as part of a vocal hygiene program and also presents the quality of evidence available regarding this matter. Shortfalls within the literature are also identified and reveal targets for further research within the field of vocology.

### **1.3. Research question**

Does hydration have an effect on voice quality in adults?

## **CHAPTER 2: METHOD**

### **Chapter aim:**

The aim of chapter two is to provide further insight into the aspects of the methodology that were not discussed in the method section of the journal article (Chapter 3). The method provides the aims of the research, the exact description of the search strategy employed and how the data is analysed. Overall it provides an indication of the validity of the study. It also allows for the study to be replicated in the future.

### **2.1. Research aim**

The aim of the study was to systematically review recent evidence, over the past 10 years (2007 – 2017), to determine the effect of hydration on voice quality in adults.

### **2.2. Research design**

The research design encompassed the completion of a systematic review to achieve the above aim. A systematic review provides statistical analysis of a large collection of results from individual studies. The aim is to integrate and collate evidence in a summarised, yet accurate manner (Berman & Parker, 2002). A systematic review uses methods that are explicit and systematic in nature to minimise bias in the identification, selection, compilation and summary of the selected studies (Shamseer, et al., 2015). A valid and reliable systematic review requires careful planning (Berman & Parker, 2002) to ensure that information is correctly reported. They are also useful in assisting clinicians with keeping up to date with the most recent, evidence-based methods of assessment and intervention.

Transparent and complete reporting of systematic reviews is ensured by following the guidelines set out by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) (Shamseer, et al., 2015). The PRISMA-P is intended to be used as a tool to guide the development of systematic reviews and meta-analyses by evaluating how effective they are within a therapeutic setting (Shamseer, et al., 2015). The PRISMA-P checklist consists of 17 items which should be described or mentioned in a systematic review to ensure a high level of integrity is achieved. These items are divided into three main categories of guidelines for the aspects of administration, introduction and methodology (Shamseer, et al., 2015). The statement was used as a guideline to provide structure to the systematic review.

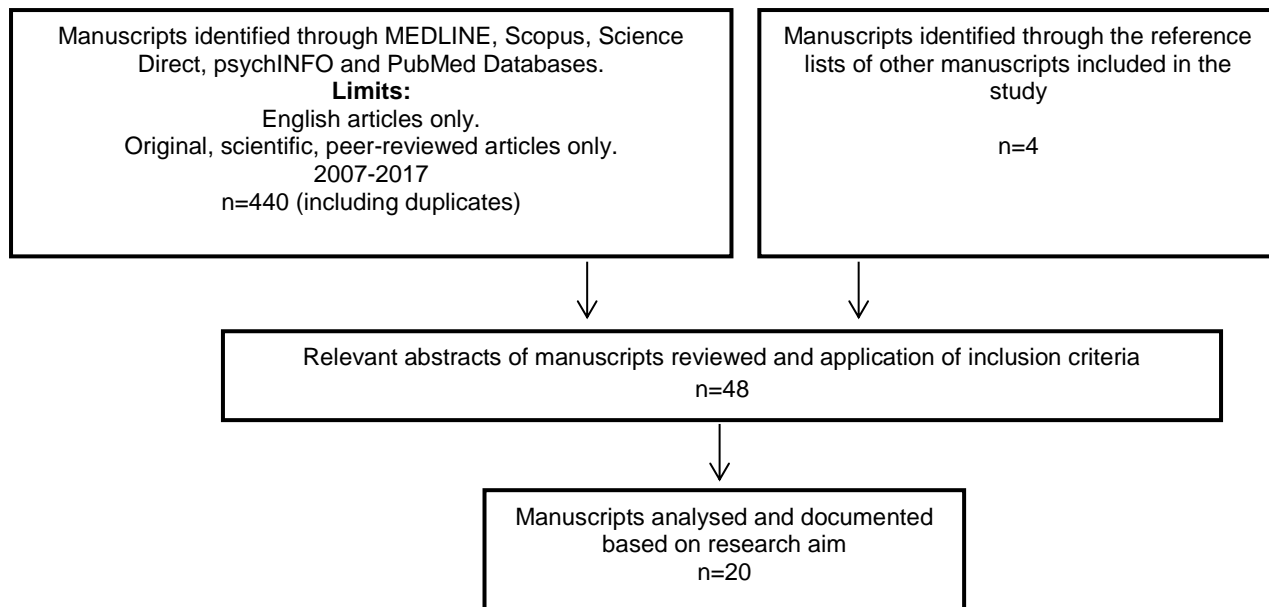
Approximately 170 health science journals endorse the PRISMA and PRISMA-P Statements for the reporting of systematic reviews, further motivating its use in the current study (Moher, Liberati, Tetzlaff, & Altman, 2009; Shamseer, et al., 2015). The current systematic review has included all relevant topics as suggested by the checklist (see Appendix A). From the review, the reader will be able to clearly assess the strengths and weaknesses of the review as well as determine the usefulness and clinical applicability of findings from the information provided from the review.

## **2.3. Data collection procedures**

### **2.3.1. Search strategy**

Five electronic data bases were searched in April 2017. The databases selected were identified based on their relevance to medical literature and included, MEDLINE, Scopus, Science Direct, psychINFO and PubMed. Multiple databases were selected because coverage provided by a single database is inadequate and varies according to the subject field, resulting in insufficiency (Moher, et al., 2009). The final search phrase used consistently across the databases included synonymous phrases and Boolean operators. The phrase was entered as follows: (vocal fold hydration OR vocal cord hydration) AND (voice OR vocal quality OR phonation) OR (vocal dehydration OR rehydration OR vocal lubrication) OR (hygienic voice therapy). The reference lists of the included articles were hand scanned to identify related articles and also served as a secondary literature search. After all duplicates and unrelated reports were excluded, the remaining reports were reviewed, in full, to determine if they met the inclusion criteria. Three independent raters were incorporated throughout the review. To avoid bias, consensus was reached between the raters regarding the final inclusion of the articles. Figure 3 below represents the process of data collection.





**Figure 3: Process of data collection, adapted from the PRISMA Statement (Moher, et al., 2009).**

### **2.3.2. Data management**

Screenshots of the results obtained from each database after the initial search of the databases were captured. Following this, all the titles were placed in an excel spreadsheet and duplicates and non-relevant studies removed. The selected articles were then reviewed and divided into surface and systemic hydration. A summary of each of these articles was conducted. All the acoustic, perceptual and aerodynamic measures were then included and the quantitative data from these results inserted into the spreadsheet. The data from the spreadsheet was then tabulated to present the overall results from the studies included in the review.

### **2.3.3. Inclusion criteria**

All studies selected were presented in English as original research data within the last 10 years (2007-2017). The studies identified from the database phrase searches also met the criteria discussed below.

#### Population

Articles which included adult voice users (above 18 years of age) were included in this systematic review. No limit was placed on gender or occupational group of the participants. Studies which focused on the effect of hydration on voice disorders were excluded and only participants with appropriate perceptual voice quality and respiratory function were included.

Factors that contributed to vocal dehydration, such as smoking or environmental pollutants, were mentioned, should articles have individuals exposed to these agents. The inclusion of a larger range of participants provided further insight into the effect of vocal fold hydration and enhanced the generalisation of results.

### Intervention

The selected studies compared the effects of various states of hydration, dehydration and rehydration on acoustic, perceptual and aerodynamic voice quality measures. Both systemic and superficial hydration, were included and described in the systematic review. No specifications were made in terms of dose, duration and type of intervention included. Combinations of qualitative and quantitative outcomes were analysed within the selected articles. For the purpose of this study, voice quality referred to aspects that measured using acoustic and perceptual analysis, as well as self-rating scales. Acoustic measures included aspects such as, frequency, intensity, noise-to-harmonics ratio (NHR) and perturbation measures. Acoustic measures are thus used as an objective indication of voice quality and will provide insight into vocal fold functioning (Franca, 2006). Non-instrumental or aerodynamic measures such as the s/z ratio, and maximum phonation time (MPT) were also included.

Perceptual measures included perceived phonatory effort (PPE) measures and the perceptual rating scales, the CAPE-V (ASHA, 2002) and the GRBASI (Yamauchi, Imaizumi, & Maruyama, 2010) scales. Self-reported participant measures such as vocal fatigue, vocal hoarseness, deepening, mouth or throat dryness and increased pitch are also reported on. Perceptual rating scales were included in the data analysis, to provide an overview of the effect of hydration on the perception of voice quality and overall voice use. These rating scales and self-reports were, however, interpreted with caution as there is controversy regarding the inter- and intra-rater reliability thereof due to reliance on perceptual and subjective judgements (Schwartz, 2004; Barsties & De Bodt, 2015).

#### **2.3.4. Exclusion criteria**

Reviews, editorial notes, letters and short surveys were not included in the analysis for the current review. Reviews were excluded based on the fact that they do not provide original information which could lead to reporting bias. Editorial notes, letters and short surveys were excluded as they are considered as the lowest level of evidence (ASHA, 2004). Studies conducted on children (under 18 years of age) or excised animal larynges were also not included.

Studies which focused on the effect of hydration in adults with voice disorders were also excluded from the current review owing to poor comparison of results due to differing acoustic and perceptual voice parameters.

### **2.3.5. Ethical considerations**

The research project obtained ethical clearance from the Research Committee of the Department of Speech-Language Pathology and Audiology, and the Research Ethics Committee of the Faculty of Humanities of the University of Pretoria (see Appendix B). As the study was a systematic review, no human participants were selected to participate in the study. The ethical principles regarding human research subjects were therefore not applicable to the current study. Academic integrity was, however, still achieved by ensuring that all sources, from which information was obtained, were correctly acknowledged within the text and in the reference list of the research project (Leedy & Ormrod, 2015). According to the Oxford Dictionary (2017), plagiarism refers to “the practice of taking someone else's work or ideas and passing them off as one's own”. Plagiarism of another author's work was avoided and full acknowledgement of material belonging to others was given where due (Leedy & Ormrod, 2015). The methods and results of the study were reported in a complete and honest fashion. The results were not misinterpreted to mislead others about the nature of the findings (Leedy & Ormrod, 2015). Biases and weaknesses of the study were explicitly identified and described as a final measure of ensuring academic integrity.

### **2.3.6. Publication bias**

The purpose of the systematic review was to include evidence from relevant studies. However, some studies presented with absent or ill-defined information which may have led to a publication bias. Bias refers to a systematic error, or a deviation from the truth in a studies' results (Higgins & Green, 2011) which ultimately poses a threat to the validity and reliability of the systematic review. Moher, et al. (2009) suggests that data may be incomplete due to some studies not being published or perhaps as a result of incomplete or inadequate reporting within a published article.

To reduce publication bias, multiple searches using primary and secondary phrases were conducted on various databases in order to access a large amount of evidence regarding the effect of hydration on voice quality. These sources were then analysed further to assess the risk of further biases within each selected study.

The Cochrane Collaboration's tool for assessing risk of bias (Higgins & Green, 2011) (see Appendix C) served as a guideline for assessing possible risk of bias in the selected articles. The tool is domain-based in which assessments are made separately for each domain (Higgins & Green, 2011). The tool consists of the following descriptions (Higgins & Green, 2011) for the domains of:

- **Selection bias:** refers to systematic differences in the baseline characteristics of the comparison groups. *Sequence generation*, specifying a rule for allocation of interventions, based on some random process, is one method of reducing selection bias. The second method, *allocation concealment*, prevents knowledge of the forthcoming allocations to interventions.
- **Reporting bias:** refers to differences between reported and unreported outcomes. Often studies fall subject to reporting bias because significant results are reported on more often than the non-significant results, leading to an inaccurate description of the effects of intervention.
- **Performance bias:** refers to differences in the groups in the care provided, or the exposure to a specific intervention. Blinding of study participants and personnel can reduce this risk of bias.
- **Detection bias:** refers to differences between comparison groups in how outcomes are determined. Blinding of outcome assessors may reduce the knowledge of the intervention received and is especially important for subjective outcome assessment.
- **Attrition bias:** refers to differences between the groups in the amount of withdrawals from the study which results in incomplete outcome data.

According to the tool, judgement involves assessing each domain as 'low risk', 'high risk, or as an 'unclear risk' (Higgins & Green, 2011). There was no explicit assessment of risk of bias discussed in any of the selected articles, other than limited statements pertaining to possible bias. Conditions were labelled as "unclear" when information was absent or ill-defined and could not be reliably reported on. The presence of bias was assessed by the primary research. Following this assessment, ten percent of the articles were rated on the presence of bias by two additional, qualified speech-language therapists as a measure of reliability of the findings.

#### **2.4. Reliability and validity of research**

According to Golafshani (2003), reliability refers to the "extent to which results are consistent over time" and validity "determines whether the research truly measures that which it was intended to".

The integrity of the evidence included in this systematic review was ensured by:

- Following the guidelines suggested by the PRISMA and the PRISMA-P Statement Checklist (Moher, et al., 2009; Shamseer et al., 2015).
- Performing a search of multiple databases using more than one primary and secondary search phrases.
- Critically appraising the evidence found for its ability to be included in this systematic review according to the stipulated inclusion criteria and based on consensus between the researcher and secondary raters.
- Raters independently assessed the risk of bias for 10% of the selected articles, followed by a discussion of the potential biases and an overall consensus between the researcher and raters was reached.
- Avoiding selection bias by ensuring that all data obtained was reported on and data was not selected in favour of a desired result (Shamseer, et al., 2015).

## 2.5. Data analysis

The articles were critically appraised according to the following guidelines suggested by the American Speech-language Hearing Association [ASHA] (2004) shown in table 1.3.

**Table 1.3: Levels of evidence (ASHA, 2004).**

Level	Description
Ia	Well-designed meta-analysis of >1 randomized controlled trial.
Ib	Well-designed randomized controlled study.
IIa	Well-designed controlled study without randomization. Selected when there was a control and experimental group but procedures were not randomized.
IIb	Well-designed quasi-experimental study. Was selected when within-participant control measures were discussed.
III	Well-designed non-experimental studies, i.e., correlational and case studies. Selected when within-participant design was not discussed.
IV	Expert committee report, consensus conference, clinical experience of respected authorities.

The articles were then described (see Table 2.1 and Table 2.2) in terms of the following which were adapted from the PRISMA checklist (Moher, et al., 2009):

- 1) Title, author and date and place of publication
- 2) Participant demographics
- 3) Research method or design
- 4) Level of evidence
- 5) Blinding of participants, personnel, or outcome assessors
- 6) Control groups
- 7) Inter-rater agreement
- 8) Vocal characteristics measured within the studies
- 9) Possible bias identification in the selected study
- 10) Quality indicator scores

The qualities of the articles were assessed according to the following indicators presented in Table 1.4 (Cherney, Patterson, Raymer, Frymark, & Schooling, 2008):

**Table 1.4: Description of the quality indicators according to Cherney et al. (2008).**

Quality indicator	1-point received for...
<b>1. Study design</b>	A controlled trial, retrospective case control or a single participant study.
<b>2. Blinding</b>	For blinding of assessors
<b>3. Group/participant comparability</b>	Comparable baseline characteristics or important factors (includes between- and within-subject designs which were adequately described).
<b>4. Sampling</b>	Adequate description of a random sample
<b>5. Outcomes</b>	At least one primary outcome measure that was valid and reliable.
<b>6. Significance</b>	Reporting or ability to calculate the p value.
<b>7. Precision</b>	A reported or calculable effect size and confidence interval.
<b>8. Intent-to-treat</b>	For participants being analysed according to the group to which they were initially assigned.

The indicator of treatment fidelity was excluded based on the fact that none of the selected articles included a treatment study. The maximum achievable score was therefore eight. A score of five or more indicated that the quality of the study was good and achieved a score for most of the indicators. A score of below five, however, indicated that the study was of a poorer quality (Cherney, et al., 2008). Along with the above data, data was also collected for each measure assessed within the articles. This was necessary to determine the effects that dehydration, hydration and rehydration had across multiple studies. The measures which were assessed in more than one research article were synthesized in Table 2.3 and Table 2.4 to provide a visual depiction of the effects of dehydration, hydration and rehydration in various studies. Measures which were only assessed in a single study are discussed at the beginning of systemic and surface hydration.

Once the data was collected and critically appraised, descriptive statistics were employed to discuss the results of the data and make a firm conclusion as to the effects of hydration on voice quality. Thematic and inferential analysis was then employed to analyse, organise and synthesize the information extracted from the appraised articles to explain the findings in a qualitative manner. The main themes were identified within the data and extrapolated. Descriptive statistics are used when a summary of the general nature of the data obtained is needed (Leedy & Ormrod, 2015). In this review, the average effect in different research studies of differing levels of hydration was described. Inferential statistics assist with making decisions regarding the research data (Leedy & Ormrod, 2015). By performing this systematic review, a decision regarding the quality of the research articles included was made and thus the effects of the differing levels of hydration were large enough. These statistics were employed to condense the large amount of information included within each original article (Leedy & Ormrod, 2015).

## **2.6. Hypothesis**

It was hypothesized that both systemic and superficial hydration will have a positive effect on voice quality in adults.

# CHAPTER 3: THE EFFECT OF HYDRATION ON VOICE QUALITY: A SYSTEMATIC REVIEW

Authors: Alves, M., Krüger, E., Pillay, B., van Lierde K., & van der Linde, J.

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Objectives.	To critically appraise scientific, peer-reviewed articles, published in the past 10 years on the effects of hydration on voice quality in adults.
Study design.	Systematic review.
Method.	Five databases were searched using the key words “vocal fold hydration”, “voice quality”, “vocal fold dehydration” and “hygienic voice therapy”. The PRISMA-P guidelines were followed. The included studies were scored based on ASHA’s levels of evidence and quality indicators, as well as, the Cochrane Collaboration’s risk of bias tool.
Results.	Systemic dehydration as a result of fasting and not ingesting fluids significantly negatively affected the parameters of NHR, shimmer, jitter, frequency and the s/z ratio. Water ingestion led to significant improvements in shimmer, jitter, frequency and MPT values. Caffeine intake does not appear to negatively affect voice production. Laryngeal desiccation challenges by oral breathing led to surface dehydration which negatively affected jitter, shimmer, NHR, PTP and PPE. Steam inhalation significantly improved NHR, shimmer and jitter. Only nebulization of isotonic solution decreased PTP and showed some indication of a potential positive effect of nebulization substances. Treatments in high humidity environments prove to be effective and adaptations of low humidity environments should be encouraged.
Conclusion.	Recent literature regarding vocal hydration is high quality evidence. Systemic hydration is the easiest and most cost effective solution to improve voice quality. Recent evidence therefore supports the inclusion of hydration in a vocal hygiene program.
Key words.	Vocal hydration/dehydration/rehydration–Voice quality–Vocal hygiene–Systematic review–Superficial/surface hydration.

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## 1. INTRODUCTION

Almost a third of the population of the United States of America will have some type of voice disorder across their life-span [1]. More specifically, professional voice users (PVUs) exhibit the highest prevalence of voice disorders due to excessive voice demands [2]. A voice disorder can have negative effects on an individual and may adversely impact their quality of life in terms of occupational change or loss, social isolation or withdrawal, depression and/or a difficulty being understood by others [3, 4]. A targeted or eclectic approach tailored to the specific needs of the client describes an approach to intervention for voice disorders, constitutes a diverse range of techniques which voice professionals implement to improve voice production and quality [5]. One aspect often included in an eclectic approach is hygienic voice therapy, which focuses on eliminating and/or modifying phonotrauma. The most suggested method, however, is to improve vocal hygiene by increasing hydration levels [6].

Hydration can be described as an adequate level of water in the body and dehydration as a lack of water [7, 8]. Hydration occurs at different levels in the body. The first, systemic hydration refers to general body hydration that keeps mucosal tissue healthy. This level of hydration is achieved by ingesting fluids, with the typical recommendation of eight glasses of water per day [8]. The second level, superficial or surface hydration, refers to the moisture level that keeps the epithelial surface of the vocal folds healthy and pliable [7]. Superficial hydration is accomplished by inhalation of humidified air, nebulization and/or avoidance of drying environments [8, 9]. The role water plays within the body is therefore not only anatomical by adding mass and form but also physiological by providing lubrication to adjoining tissues [10]. The relationship between hydration, vocal physiology and vocal quality is, however, not yet fully understood. It is, however, believed that during collision of the folds during phonation, an interstitial transfer occurs that pushes fluid away from the area of vocal fold contact [11]. As a result, increased stress gradients are formed. These stress gradients are exacerbated in dehydrated tissue [11]. Frequent rehydration is thus not only required to maintain regular phonatory function [12], but also to prevent vocal fold lesions due to these stress gradients [11].

Voicing, depending on the vocal demand, may be considered as a high intensity, long endurance muscle action. As a result, the vocal mechanism and subsequently the voice has been reported to be especially susceptible to dehydration [8]. A compromised state of hydration, even as little as one to two percent [8], is believed to limit physical performance of these sustained or intermittently repeated efforts [10]. These adverse alterations can result in greater contact time between the vocal folds and increased pulmonary effort for phonation [13].

Disturbances in the movement of the vocal folds and/or changes in glottal closure as a result of hydration changes may add to perturbations in the acoustic signal [14]. It is thus speculated that “dry” and “sticky” vocal folds do not oscillate as easily as wet and “loose” vocal folds [15].

These non-optimal conditions can also lead to phonotraumatic behaviours [7]. Subsequently symptoms such as hoarseness, poor pitch and loudness control, increased effort and breathiness [16] are exacerbated further by reduced lubrication. Symptoms such as these can affect the quality of an individual’s voice and may even lead to secondary organic pathologies, such as nodules, and subsequently impact the use of voice [17].

Although there are speculated benefits of hydration that, theoretically, appear plausible, in the past only a few studies reported on the beneficial effects of hydration on voice quality [9]. Recently, however, vocal hydration has received renewed attention. Many studies have been conducted to determine the effect of hydration on the vocal folds and their functioning [9, 18-22] however, contradictory findings have been reported. The effects of dehydration can be seen on various aspects of voice acoustics; but the effects of rehydration or dehydration are contradictory, often indicating non-significant changes [9, 19, 20, 22-26].

Previous studies have mostly focused on the impact of hydration on the effort of phonation and not necessarily on voice quality and the acoustic parameters of the voice [27]. As a result it is of great importance, that the literature be critically appraised to determine if an increase in hydration is warranted as an approach to prevention and intervention of voice disorders. In addition, the quality of the studies should be evaluated to determine the validity and reliability of the results obtained within these studies.

## **2. METHOD**

### **2.1. Study design**

A systematic review was completed by following the Preferred Reporting Items for Systematic Review and Meta-Analyses Protocols (PRISMA-P) [28].

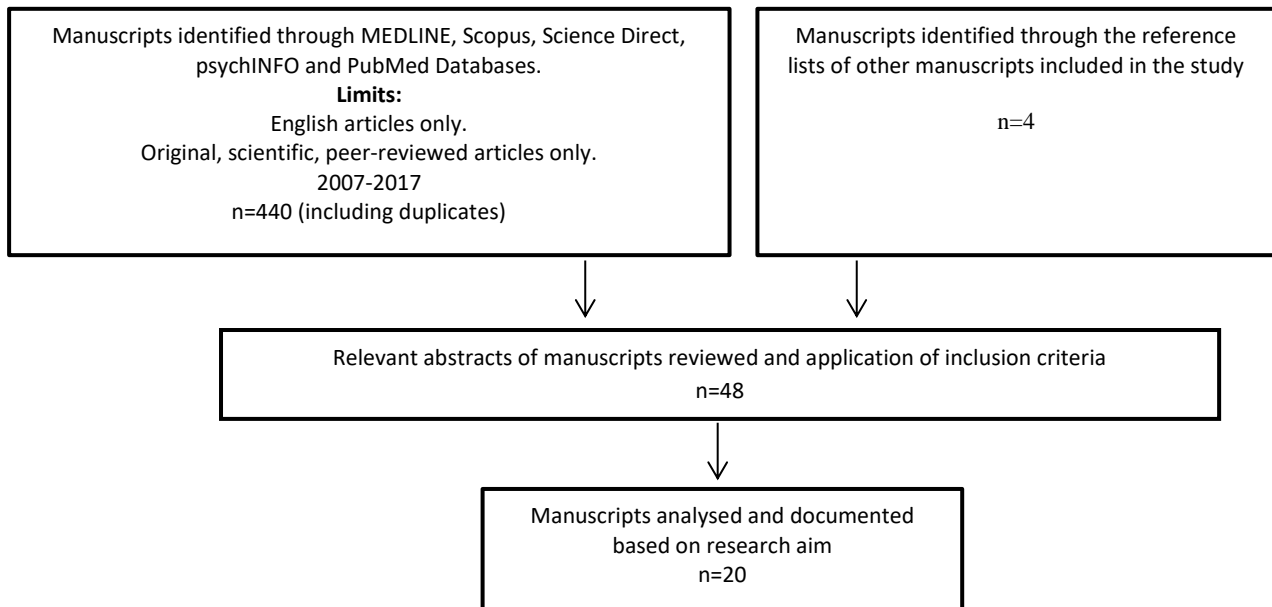
### **2.2. Study inclusion criteria**

The inclusion criteria comprised of descriptions of the effects of various hydration states on the vocal quality measures of adults only. All studies selected were presented in English, based on the authors' proficiency in English and presented original research data within the last 10 years (2007-2017). All studies were required to be scientific and peer reviewed to be included in the current review. Only human studies were included and no limit was placed on the occupational group or gender. All participants within the studies were required to have normal perceptual voice quality and respiratory function and overall general good health as self-reported on by the participants. Three (85%) studies mentioned the use of the CAPE-V to perceptually assess the voice quality. Across the studies participants denied the presence of an upper respiratory tract infection, allergies, nasal congestion, use of medication (except oral contraceptives), presence of laryngeal disease or a voice disorder, coronary disease, high blood pressure, recent microlaryngeal surgery, hearing impairment and/or reflux. Three (85%) studies visually ensured that the participant had a normal laryngeal appearance using videolaryngealstroboscopy and assessed nasal resistance and respiratory function using spirometry. Reviews were excluded based on the fact that they do not provide original information which could lead to reporting bias. Editorial notes, letters and short surveys were excluded as they are considered as the lowest level of evidence [29].

### **2.3. Search methods for identification of the studies**

Five online electronic databases were searched in April 2017. The databases selected were MEDLINE, Scopus, Science Direct, psychINFO and PubMed, based on their relevance to medical literature. The final search phrase used consistently across the databases was: "(vocal fold hydration OR vocal cord hydration) AND (voice OR vocal quality OR phonation) OR (vocal dehydration OR rehydration OR vocal lubrication) OR (hygienic voice therapy)" and received a total of 440 hits across the databases. Duplicates found during the search were removed and the abstracts of the articles screened by the primary researcher for applicability.

The reference lists of the included articles were hand scanned to identify related articles (n=4) and also served as a secondary literature search. After all duplicates and unrelated reports were excluded, the remaining reports (n=48) were reviewed, in full, to determine if they met the inclusion criteria. To avoid bias, consensus was reached between three authors regarding the final inclusion of the articles (n=20). Figure 3 below represents the process of manuscript identification.



**Figure 3: Process of data collection, adapted from the PRISMA Statement [27].**

#### 2.4. Data collection process and data items

Each article was analysed for the following data items: title, authors, year of publication, country in which the study was conducted, the number of participants, participant age range and gender, the methodology, level of evidence, level of hydration and acoustic, perceptual and self-rating measures. The American Speech-Language-Hearing Association’s (ASHA) level of evidence rating scale [29, adapted from 31, 32], and the quality indicators in the ASHA levels-of-evidence scheme [33] were used to rate and score the articles based on various measures. Consensus was achieved between the primary author and two additional authors for two of the twenty (10%) selected articles on the levels of evidence and quality indicator scores.

## **2.5. Risk of bias**

The Cochrane Collaboration's tool for assessing risk of bias [34] served as a guideline for assessing possible risk of bias in the selected article. The domains of selection bias, reporting bias, performance bias, detection bias attrition bias and the presence of any other biases were included. According to the tool, judgement involves assessing each domain as 'low risk', 'high risk', or as an 'unclear risk' [34]. There was no explicit assessment of risk of bias discussed in any of the selected articles, other than limited statements pertaining to possible bias. Conditions were labelled as "unclear" when information was absent or ill-defined and could not be reliably reported on. Decisions on the presence of bias were made by consensus between the authors.

## **2.6. Data analysis**

Descriptive statistics was used to describe features of the data obtained and to summarise findings of the research. Thematic and inferential analysis was employed to analyse, organise and synthesize the information extracted from the appraised articles to explain the findings in a qualitative manner. The main themes were identified within the data and extrapolated.

# **3. RESULTS AND DISCUSSION**

## **3.1. Study characteristics**

Studies that compared surface and systemic hydration, dehydration and rehydration effects on acoustic and perceptual voice quality measures were selected. Any dose, duration and type of intervention was included. A combination of qualitative and quantitative outcomes were analysed.

For the purpose of this study, voice quality referred to aspects measured using acoustic and perceptual analysis, as well as self-rating scales. Acoustic measures included aspects such as, frequency, intensity, noise-to-harmonics ratio (NHR) and perturbation measures. Non-instrumental measures such as the s/z ratio, and maximum phonation time (MPT) were also included. Perceptual measures included perceived-phonatory effort (PPE) measures and the perceptual rating scales, the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) [35] and the GRBASI scale [36]. Self-reported participant measures such as vocal fatigue, throat and mouth dryness were also reported on.

The characteristics of the twenty selected articles are presented in Table 2.1. Data were collected mostly (n=16; 80%) in the United States of America, a developed country. Four studies were conducted in the developing countries of South Africa (n=1; 5%), Lebanon (n=1; 5%), India (n=1; 5%), and Brazil (n=1; 5%) [34].

Participants' ages ranged from 18 – 78 years across the selected articles. The numbers of participants vary across the studies from the lowest of 10 to the highest of 63 participants. Seven studies (35%) looked at the effect of systemic hydration and 13 (65%) studies focused on the effect of surface hydration. Eight were prospective studies (40%), four randomized-control studies (20%). Half of the studies used pre-test, post-test measures (n=10; 50%) and nine had within-participant comparisons (45%).

In terms of the ASHA levels of evidence [29, adapted from 31, 32] four studies (20%) achieved a level Ib and thus made use of randomization. Three studies (15%) scored a level IIa and nine studies (45%), a level IIb. Although these studies did not use randomization, they did include a within-subject comparison which reduces error variance and increases sensitivity of the experiment as individual factors are kept constant [9]. Four (20%) of the studies achieved a lower level of evidence at a level III. Overall, the majority (n=16; 80%) of the studies achieved a level IIb and above and are thus considered as high level studies.

Seventeen (85%) articles received a score of five and higher for the ASHA quality indicator [30] section revealing they are of good quality. Three (15%) articles received a score of four, which is indicative of a poorer quality. All articles (n=20; 100%) received a score for an appropriate study design, intent-to-treat, at least one outcome measure that was valid and reliable and reported significance values within their article. Only nine studies (45%) reported blinding of the assessors.

### **3.2. Risk of bias**

The Cochrane Collaboration's Risk of bias tool was used to assess each study (see Table 6). Tanner et al. (2007) [22] was the only study to present with a score of "low risk" in all domains, and thus appeared to have limited bias within the study. All articles received a "low risk" judgement for reporting and attrition bias as all data was completed and reported on within all the articles.

Although most (n=14; 70%) articles achieved a “low risk” score for random sequence generation, only three articles (15%) adequately described how the allocations were concealed. Majority (n=17; 85%) of articles showed an “unclear” risk of bias due to inadequate description of allocations. Eleven (55%) of the articles achieved interrater reliability, showing a high consensus rate for the results achieved in the articles.

**Table 2.1: Characteristics of selected studies.**

Title	Study: Authors, year and country	Participant age range (M;SD) & gender	Nr of participants (incl controls)	Research method	Control groups	Level of evidence (ASHA, 2004)	Quality indicator score*	Vocal characteristics measured
Systemic hydration								
1. Effects of hydration on voice acoustics	Franca & Simpson, 2009, USA	18 – 35 years (NR) Females	19	Repeated measures design	within-subject	IIb	6	RAP, shimmer
2. Effects of systemic hydration on vocal acoustics of 18- to 35-year-old females	Franca & Simpson, 2012, USA	18 – 35 years (24; NR) Females	38	Randomized-controlled trial, pretest–posttest design	✓	Ib	6	Jitter, shimmer
3. Effects of caffeine on vocal acoustic and aerodynamic measures of adult females	Franca, et al., 2013, USA	18 – 35 years (NR) Females	58	Randomized-controlled trial	✓	Ib	6	RAP, shimmer, SPL, airflow
4. Effect of fasting on voice in women	Hamdan, et al., 2007, Lebanon	21 – 45 years (29.7; 7.7) Females	28	Prospective study, within-subject design	within-subject	IIb	5	Fo, RAP, shimmer, NHR VTI, MPT, habitual pitch, vocal fatigue, self-perceived phonatory effort
5. Effect of fasting on voice in males	Hamdan, et al., 2011, Lebanon	22 – 50 years (28; 5.46) Males	26	Prospective study, within-subject design	within-subject	IIb	6	Fo, RAP, shimmer, N/H ratio, VTI, MPT, habitual pitch, vocal fatigue, self-perceived phonatory effort
6. The effect of hydration on the voice quality of future professional vocal performers	Van Wyk, et al., 2017, South Africa	18 – 32 years (21.75; 4.18) Females	12	Within-subject, comparative, pretestposttest design	within-subject	Ila	7	GRBASI, MPT, s/z ratio, jitter, shimmer, highest frequency, lowest intensity, DSI
7. Investigating the effects of caffeine on phonation	Erickson-Levendoski & Sivasankar, 2011, USA	18 – 23 years (23; NR) Males and females	16 (8m/ 8f)	Prospective, double-blind, sham-controlled study	✓	Ila	6	PTP, PPE



Title	Study: Authors, year and country	Participant age range (M;SD) & gender	Nr of participants (incl controls)	Research method	Control groups	Level of evidence (ASHA, 2004)	Quality indicator score*	Vocal characteristics measured
Surface/ superficial hydration								
8. Vocal loading and environmental humidity effects in older adults	Sundarranjan, et al., 2017, USA	65 – 78 years (72; NR) Males and females	13 (5m/ 8f)	Within-participants, pretest- posttest design	×	III	6	PTP, PPE, perceived tiredness, CPP, LHR
9. The interaction of surface hydration and vocal loading on voice measures	Fujiki, et al., 2017, USA	18 – 28 years (22; NR) Males and females	16 (8m/ 8f)	Within-participants, pretest-posttest design	within-subject	IIb	5	CPP, RFF, PPE, perceived tiredness
10. Laryngeal desiccation challenge and nebulized isotonic saline in healthy male singers and non-singers: effects on acoustic, aerodynamic, and self-perceived effort and dryness measures	Tanner, et al., 2015, USA	18 -26 years (21.8; 2.4) Males	20	Prospective, double-blind, within-subjects experimental design	within-subject	IIb	6	Speaking vocal effort, mouth dryness, throat dryness, singing vocal effort, PTP, CSID
11. Voice function differences following resting breathing versus submaximal exercise	Sandage, et al., 2013, USA	20 – 24 years (21.72; 1.27) Males and females	18 (9m / 9f)	Within-participant repeated measures design	✓	IIb	4	PTP, PPE
12. Influence of obligatory mouth breathing, during realistic activities, on voice measures	Sivasankar & Erickson-Levendoski, 2012, USA	18 – 38 years (21; NR) Males and females	63 (32m/ 31f)	Prospective, between-group, repeated-measures design	within-subject	IIb	4	PTP, PPE
13. Nebulized isotonic saline versus water following a laryngeal desiccation challenge in classically trained sopranos	Tanner, et al., 2010, USA	18 – 56 years (30.2; 11.9) Females	34	Double-blind, within-subject crossover design	✓	IIb	7	PTP, PPE
14. The effects of three nebulized osmotic agents in the dry larynx	Tanner, et al., 2007, USA	18 – 50 years (28; 7.7) Females	60	Double-blind, randomized group design with a non-treatment control group, placebo controlled design	✓	Ib	8	PTP, PPE

Title	Study: Authors, year and country	Participant age range (M;SD) & gender	Nr of participants (incl controls)	Research method	Control groups	Level of evidence (ASHA, 2004)	Quality indicator score*	Vocal characteristics measured
15. Phonatory effects of airway dehydration: preliminary evidence for impaired compensation to oral breathing in individuals with a history of vocal fatigue	Sivasankar, et al., 2008, USA	19 – 26 years (23; NR) Females	16	Repeated- measures design	✓	Ila	5	PTP, PPE
16. Reducing the negative vocal effects of superficial laryngeal dehydration with humidification	Erickson-Levendoski, et al., 2014, USA	19 – 37 years (21 and 24) Males and females	40	Single experimental session	×	III	5	PTP
17. Effects of steam inhalation on voice quality-related acoustic measures	Mahalingham, et al., 2016, India	18 – 30 years (22.41; 8.91) Females	45	Prospective, single blinded experimental trial	within-subject	IIb	6	Jitter, shimmer, NHR
18. The effect of surface hydration on teachers' voice quality: an intervention study	Santana, et al., 2016, Brazil	NR (44.9; NR) Males and Females	27 (12m/15f)	Examiner-blinded, pretest and posttest intervention study with single group of subjects	within-subject	Ib	6	CAPE-V, Fo, intensity, jitter, shimmer, GNE, noise, irregularity
19. Spatiotemporal quantification of vocal fold vibration after exposure to superficial laryngeal dehydration: A preliminary study	Patel, et al., 2015, USA [44]	21 – 29 years (22.85; NR) Males and Females	10 (4m/6f)	Prospective study	×	III	6	VOT, PTP, jitter
20. Short-duration accelerated breathing challenges affect phonation	Sivasankar & Erickson, 2009, USA	18 – 36 years (23; NR) Females	24	Prospective study with between-subjects, repeated measures design	×	III	4	PTP

\*Highest achievable score is 8. ≥5 = Good quality. <5 = Poor quality. M= mean, SD= standard deviation, NR= not reported. m=male, f=female

(RAP: relative average perturbation, SPL: sound pressure level, Fo: fundamental frequency, VTI: voice turbulence index, NHR: noise-to-harmonic ratio, MPT: maximum phonation time, PTP: phonation threshold pressure, PPE: perceived phonatory effort, CPP: cepstral peak prominence, LHR: low/high ratio, RFF: relative fundamental frequency, CSID: cepstral spectral index of dysphonia, VOT: voice onset time, GNE: glottal-to-noise excitation ratio)

**Table 2.2: Risk of bias across selected studies.**

Study	Selection bias		Performance bias	Detection bias	Reporting bias	Attrition bias	Inter-rater agreement achieved	Possible bias or limitations identified
	Random sequence generation	Allocation concealment	Blinding of: (1) participants (2) personnel	Blinding of outcome assessment	Selective reporting	Incomplete outcome data		
1. Franca & Simpson, 2009	Low	Unclear	High	High	Low	low	×	Prohibits generalization to males, those out of age range, presence of voice disorder. Patient adherence to study pre-test protocol (e.g. fasting).
2. Franca & Simpson, 2012	Low	Unclear	High	High	Low	Low	×	Prohibits generalization to males, those out of age range, presence of voice disorder. Methodological concern in participant's self-reports and adherence to study protocol.
3. Franca, et al., 2013	Low	Unclear	(1) Low	High	Low	Low	×	Prohibits generalization to males, those out of age range, presence of voice disorder. Reliance on self-reports, adherence to pre-test protocol (e.g. fasting).
4. Hamdan, et al., 2007	Low	Unclear	High	High	Low	Low	×	Prohibits generalization to males, those out of age range, presence of voice disorder.
5. Hamdan, et al., 2011	Low	Unclear	Unclear	Low	Low	Low	×	Absence of scientific measures of hydration (e.g. weight loss). Presence of confounding factors, reliance on self-reports, adherence to protocol (e.g. fasting).
6. Van Wyk, et al., 2017	Low	Unclear	Unclear	Low	Low	Low	✓	Prohibits generalization to males, those out of age range, presence of voice disorder, and different occupational groups. Small sample size.
7. Erickson-Levendoski & Sivasankar, 2011	High	High	(1) (2) Low	Low	Low	low	✓	Reliance on self-reports, adherence to test protocol, no strict observation of adherence to protocol. Fluid loss post caffeine ingestion was not quantified.
8. Sundararajan, et al., 2017	High	High	High	Unclear	Low	Low	✓	Prohibits generalization to younger individuals and people with voice disorders. Small sample size. Reliance on self-reports. No within-subject design mentioned.

Study	Selection bias		Performance bias	Detection bias	Reporting bias	Attrition bias	Inter-rater agreement achieved	Possible bias or limitations identified
	Random sequence generation	Allocation concealment	Blinding of: (1) participants (2) personnel	Blinding of outcome assessment	Selective reporting	Incomplete outcome data		
9. Fujiki, et al., 2017	Low	Unclear	High	Low	Low	Low	×	Reliance on self-reports.
10. Tanner, et al., 2015	Low	Unclear	(1) (2) Low	Low	Low	Low	✓	Prohibits generalization to males, those out of age range, presence of voice disorder. Small study (n=20), small statistical significance.
11. Sandage, et al., 2013	Low	Unclear	High	High	Low	Low	×	Prohibits generalization to older generation, presence of voice disorder. Reliance on self-reports, adherence to pre-test protocol (e.g. fasting). Exclusion of acoustic measures.
12. Sivasankar & Erickson-Levendoski, 2012	High	High	High	High	Low	Low	✓	Duration of mouth breathing of a short-duration (3 minutes). PTP not obtained at pitch extremes.
13. Tanner, et al., 2010	Low	Unclear	(1) (2) Low	Unclear	Low	Low	✓	Type I error inflation due to multiple comparisons. Singers may be more sensitive to modest increases in vocal effort associated with surface hydration.
14. Tanner, et al., 2007	Low	Low	(1) (2) Low	Low	Low	Low	✓	Failed to document return of PTP to baseline. Cognitive reasoning/processing and anticipation shown to influence self-perceived ratings of effort. Only examined high-pitched PTP. Prohibits generalization to males, those out of age range, people with voice disorders and different race groups.

Study	Selection bias		Performance bias	Detection bias	Reporting bias	Attrition bias	Inter-rater agreement achieved	Possible bias or limitations identified
	Random sequence generation	Allocation concealment	Blinding of: (1) participants (2) personnel	Blinding of outcome assessment	Selective reporting	Incomplete outcome data		
15. Sivasankar, et al., 2008	Low	Unclear	High	High	Low	Low	✓	PTP and PPE not assessed at the same pitch. Task anticipation training, resource allocation and/or the scale used to measure PPE could be a cause of poor correlation. Prohibits generalization to males, those out of age range, people with voice disorders. Hormonal levels and patterns of voice usage may have varied across participants.
16. Erickson-Levendoski, et al., 2014	High	High	High	High	Low	Low	✓	Temperature of lab and total body mass not recorded. No within-subject comparison mentioned.
17. Mahalingham et al., 2016	Low	Low	(1) low	High	Low	Low	×	Changes in surface viscosity were inferred rather than directly measured.
18. Santana, et al., 2016	Low	Low	(2) Low	High	Low	Low	✓	Small sample size= non-significant result and may contribute to type-2 error. Problems using the analogue scale. Limited the generalization. Absence of a control group.
19. Patel, et al., 2015	High	High	High	High	Low	Low	×	Vocal instabilities and patient reports not subject to statistical analysis. Methodological variations in PTP data acquisition and instrumentation. Within-subject comparison not mentioned.
20. Sivasankar & Erickson, 2009	High	High	High	High	Low	Low	✓	Results may not be generalizable to those who do have a long history of smoking or have pulmonary problems. Between subjects design, groups not comparable.

### **3.3. Effect of systemic hydration on vocal characteristics**

As a result of all parameters not being measured in multiple studies, a discussion of these isolated parameters follows. A recent study revealed a statistically significant increase ( $p=0.041$ ) in the s/z ratio of a hypohydrated control group, indicating a possible decline in phonatory efficiency with inadequate hydration [26]. Scores for the GRBASI revealed a statistically significant increase ( $p=0.046$ ) for the grade of hoarseness measure in the hypohydrated group in comparison to the hydrated group. This indicates a negative effect of low hydration conditions and thus a decline in perceptual voice quality [26].

Voice turbulence index (VTI), defined as the overall degree of deviance of voice, decreased significantly ( $P=0.045$ ) during fasting [23]. The decrease in VTI, which essentially shows less deviance from normal voice, did not reveal significant negative results after a dehydrating condition as expected. Similarly, no significant results were found for the effects of hydration and hypohydration on the Dysphonia Severity Index (DSI) [26]. Also, no significant differences between the caffeine and sham condition were found leading to the conclusion that caffeine, did not worsen the effects of loading on phonation threshold pressure [39]. However, systemic dehydration as a result of fasting resulted in a significant increase in perceived phonatory effort (20-23). Table 2.3 below presents parameters which were reported on in more than one study.

**Table 2.3: Results for the vocal quality measures in systemic dehydration, hydration or rehydration interventions (n=7).**

Author	Vocal quality after dehydration	Vocal quality after hydration	Vocal quality after rehydration	Overall consensus
<b>Noise to Harmonics Ratio (NHR)</b>				
Hamdan, et al., 2007	Increase	N/A	N/A	Non-significant increase in NHR after dehydrating condition (fasting).
Hamdan, et al., 2011	Decrease* (P= 0.001)	N/A	N/A	Significant decrease in NHR after dehydrating condition (fasting).
<b>Shimmer</b>				
Van Wyk, et al., 2017	Decrease* (P=0.050)	Increase	N/A	Shimmer appeared to worsen in the hydration group that ingested water and improved significantly in the experimental dehydration group that did not ingest water.
Hamdan, et al., 2007; 2011	Decrease	N/A	N/A	No significant decrease if shimmer after dehydration (fasting).
Franca & Simpson, 2009	Increase	N/A	Decrease* (P=0.05)	Ingesting fluids after fasting significantly improved shimmer values.
Franca, et al., 2013	Increase	N/A	N/A	Non-significant increase in shimmer after ingesting caffeine.
<b>Jitter (RAP)</b>				
Van Wyk, et al., 2017	Increase* (P=0.041)	Decrease	N/A	No water ingestion revealed a significant increase in jitter. A non-significant decrease in jitter was found after water ingestion.
Hamdan, et al., 2007; 2011	Increase	N/A	N/A	Dehydration (fasting) non-significantly increased jitter.
Franca & Simpson, 2009	N/A	N/A	Decrease* (P=0.05)	Statistically significant improvement in jitter after rehydration via ingestion of fluids
Franca, et al., 2013	Decrease	N/A	N/A	Caffeine showed a non-significant decrease in jitter.
Franca & Simpson, 2012	N/A	Decrease	N/A	Non-significant decrease in jitter after hydration,
<b>Fundamental frequency (Fo)</b>				
Hamdan, et al., 2007	Increase	N/A	N/A	Statistically non-significant increase in fundamental frequency after fasting.
Hamdan, et al., 2011	Increase	N/A	N/A	
<b>Habitual pitch</b>				
Hamdan, et al., 2007	Decrease	N/A	N/A	Statistically non-significant decrease in habitual pitch after fasting.
Hamdan, et al., 2011	Decrease* (P=0.018)	N/A	N/A	Statistically significant decrease in habitual pitch after fasting.
<b>Maximum Phonation time (MPT)</b>				
Hamdan, et al., 2007	Decrease	N/A	N/A	Non-significant decrease in MPT.
Hamdan, et al., 2010	Increase	N/A	N/A	Non-significant increase in MPT.
Van Wyk, et al., 2017	Increase* (P=0.015)	Increase* (P=0.015)	N/A	Significantly increased MPT following hydration via ingestion of water.

\*Statistically significant  $\leq 0.05$

Hamdan and colleagues conducted studies on males and females during fasting [20,23]. Only the later study found a significant decrease ( $p=0.001$ ) in NHR, highlighting the negative effects of fasting on the NHR [20]. Van Wyk and colleagues (2017) [26] found that ingesting water had a significant positive effect on the maximum frequency ( $p=0.015$ ) singers could produce. This indicates that hydrated vocal folds are more pliable, allowing singers to reach higher notes than singers with dehydrated vocal folds, as dehydration affects the elastic and viscous properties of the vocal fold mechanism [26].

Four studies assessed the effects of hydration on shimmer. One study found a statistically significant decrease ( $p=0.050$ ) in shimmer in the hypohydrated condition, revealing an unexpected positive effect of a hypohydrated condition [26]. However, shimmer values are said to be more inaccurate in synthesized speech signals in comparison to jitter values and should thus be interpreted with caution [26]. Following the ingestion of fluids, a statistically significant ( $p=0.05$ ) decrease in shimmer results was reported [9]. The ingestion of caffeine, however, did not show significant effects on shimmer ( $p=0.35$ ) and jitter ( $p=0.88$ ). Higher doses of caffeine may have a more significant impact on vocal performance as a higher dose should theoretically have a larger dehydrating effect [19].

Jitter, the variation in frequency increased significantly in a hypohydrated condition ( $p=0.041$ ) in one of three studies [26]. This suggests that dehydration has a significant negative effect on jitter by increasing jitter values. Results revealed a statistically significant decrease ( $p=0.05$ ) in scores after a hydration schedule was implemented [9]. Although not always significant, the decrease in each comparison above for hydrating and rehydrating conditions points in a favourable direction for the inclusion of hydration regimes [9]. Fundamental frequency did not reveal significant changes, however, in one study of habitual pitch, a significant decrease was found after fasting [23]. Despite the decrease in habitual pitch, the values were still within normal limits.

Mixed, non-significant results for the effect of dehydration on MPT were found [20,23]. The decrease in MPT can be explained on the basis of a decrease in breath support and control, often evidenced in cases of vocal fatigue [2]. Short MPTs can also be indicative of vocal fold pathology [26]. However, one study found a statistically significant increase in MPT for sounds /a/ ( $p=0.012$ ) and /s/ ( $p=0.024$ ) after hydration [26]. Increased MPT may be as a result of pliable, light and thus easy to vibrate vocal folds which do not require a large subglottic pressure to vibrate for longer periods. Thus, the results found for the MPT further support the hypothesis of the benefits of systemic hydration [26].



### 3.4. Results as per surface hydration

Surface hydration appeared to have a positive effect on the noise-to-harmonic ratio (NHR) as a statistically significant increase ( $p < 0.05$ ) was found after steam inhalation thus ameliorating the negative effect of the desiccation challenge [43]. Fundamental frequency ( $F_0$ ), showed a statistically significant increase in frequency for the /a:/ vowel ( $p = 0.036$ ) but not for the /ɛ:/ ( $p = 0.093$ ) and /i:/ vowels ( $p = 0.068$ ). The increase was considered as a positive finding as the vocal folds may have become lighter and thus able to vibrate quicker when well lubricated [2]. No statistical difference was found for the effect of low and moderate humidity on relative fundamental frequency ( $p = 0.97$ ) or the cepstral peak prominence (CPP) ( $P > 0.05$ ) [44] or the low/high ratio (LHR) ( $p > 0.05$ ) [45]. Superficial hydration also did not have significant effects on noise, the aperiodic component of the signal ( $p = 0.668$ ), the irregularity of the voice over time ( $p = 0.795$ ), or the glottal-to-noise excitation ratio (GNE) ( $p = 0.616$ ). Perceptual characteristics in CAPE-V scores ( $p = 0.171$ ) also revealed non-significance [44].

Tanner et al (2010, 2015) looked at the effect of oral desiccation and subsequent rehydration using nebulization of an isotonic saline solution [25]. Cepstral spectral index of dysphonia on the rainbow passage demonstrated significant negative effects by increasing after laryngeal desiccation ( $p = 0.0047$ ) [25]. The same results were not observed for sustained vowels ( $p = 0.2399$ ) [25]. Statistical significance was also revealed for an increase in throat ( $P < 0.001$ ) and mouth ( $P < 0.0001$ ) dryness after a laryngeal desiccation challenge of oral breathing [25]. After nebulization, a significant decrease in throat ( $P < 0.0001$ ) and mouth ( $P = 0.0039$ ) dryness was measured. Overall, nebulization of an isotonic solution showed positive results for the measures of CSID and throat and mouth dryness [25]. Measures that have been reported on in more than one study are discussed in Table 2.4 for comparison between studies.

**Table 2.4: Results for measures in surface dehydration, hydration or rehydration interventions (n=13).**

Author	After dehydration	After hydration	After rehydration	Overall consensus
<b>Shimmer</b>				
Santana, et al., 2016	N/A	Decreased	N/A	Hydration revealed a non-significant decrease in shimmer.
Mahalingham, et al., 2016	Increase* (P<0.05)	N/A	Decrease* (P<0.05)	Dehydration after mouth breathing resulted in a statistically significant increase in shimmer. Rehydration via steam inhalation resulted in a statistically significant decrease in shimmer.
<b>Jitter</b>				
Santana, et al., 2016	N/A	Decreased	N/A	Hydration via nebulization of saline solution revealed a decrease in jitter.
Mahalingham, et al., 2016	Increase* (P<0.05)	N/A	Decrease* (P<0.05)	Dehydration after mouth breathing resulted in a statistically significant increase in jitter. Rehydration via steam inhalation revealed a significant decrease in jitter.
Patel, et al., 2015	Increase	N/A	N/A	Dehydration revealed a non-significant increase in jitter after a laryngeal desiccation challenge.
<b>Phonation threshold pressure (PTP)</b>				
Levendoski, et al., 2014	Increase*	N/A	Decrease	PTP increased significantly following mouth breathing in low humidity and showed non-significant decrease after rehydration.
Sandage, et al., 2013	Increase* (P=0.019)	N/A	N/A	PTP increased significantly after dehydration challenge induced by submaximal exercise.
Sivasankar & Erickson, 2009	Increase	N/A	N/A	Increase in PTP was not statistically significant following accelerated oral breathing.
Tanner, et al., 2015	Increase	N/A	Decrease	Effect of dehydrating and rehydrating conditions were non-significant on PTP.
Tanner, et al., 2010	Mixed results for different frequencies	N/A	Isotonic= decrease Sterile water= increase* (P=0.001)	Baselines in one group non-significantly increased post dehydration and the other group decreased. Significant results were found only for the sterile water condition for rehydration.
Tanner, et al., 2007	Increase* (P=0.0277)	N/A	Hypertonic= increase Isotonic= decrease Sterile water= increase	All groups showed a statistical increase in PTP post desiccation via oral breathing. Non-significant decrease in PTP following nebulization.
Sivasankar, et al., 2008	Oral breathing= increase* (P=0.038) Nasal breathing= decrease	N/A	N/A	Oral breathing resulted in a significant increase in PTP <sup>10</sup> . Nasal breathing decreased PTP, however, this result was non-significant.

Author	After dehydration	After hydration	After rehydration	Overall consensus
<b>Phonation threshold pressure (PTP) continued</b>				
Sivasankar & Erickson, 2009	Increase* (P=0.001)	N/A	N/A	Results revealed a significant increase in PTP <sub>20</sub> only and not PTP <sub>10</sub> or PTP <sub>80</sub> after an accelerated breathing challenge.
Sundarrajan, et al., 2017	N/A	Decrease	N/A	Decrease in PTP in moderate humidity compared to low humidity, but this decrease was non-significant.
Sivasankar & Erickson-Levendoski, 2012	Increase* (P<0.01)	N/A	N/A	Results revealed a significant increase in PTP during exercise and loud reading conditions.
<b>Perceived phonatory effort (PPE)</b>				
Sandage, et al., 2013	Increase* (P=0.001)	N/A	N/A	Statistically significant increase after dehydration challenge induced by submaximal exercise.
Tanner, et al., 2010	Increase* (P=0.001)	N/A	Control= increase* (P=0.006) Isotonic= decrease Sterile water= increase	A laryngeal desiccation challenge of oral breathing resulted in significant increases in PPE. Rehydration via nebulization did not have a significant effect on PPE following.
Tanner, et al., 2007	Decrease* (P=0.0181)	N/A	Hypertonic = increase Isotonic= increase Sterile water= decrease	Dehydration after oral breathing resulted in a significant decrease in PPE. Rehydration had no significant effect on PPE.
Erickson-Levendoski & Sivasankar, 2011	Decrease	N/A	N/A	Non-significant increase in PPE after dehydration.
Tanner, et al., 2015	Increase* (P<0.0001)	N/A	Decrease* (P=0.0009)	Significant increase in PPE after laryngeal desiccation challenge, Significant decrease in PPE after rehydration by nebulized isotonic saline solution.
Sivasankar & Erickson-Levendoski, 2012	Increase	N/A	N/A	Increase in PPE was non-significant during loud reading and exercise.

\*Statistically significant  $\leq 0.05$

One of three studies examining the effects of surface desiccation on jitter and shimmer revealed significant negative effects. Steam inhalation too showed significant positive effects on jitter and shimmer values [43]. Overall, results revealed a significant increase in jitter ( $p < 0.05$ ) and shimmer ( $p < 0.05$ ) values post dehydration and a significant decrease ( $p < 0.05$ ) in values after a hydrating agent was introduced. These results indicated the significant negative effect of surface dehydration on jitter and shimmer and emphasized the positive effects of hydration.

Phonation threshold pressure (PTP) was increased significantly ( $p < 0.05$ ) after obligatory oral breathing in six of the ten (60%) studies, confirming that vocal desiccation challenges are detrimental to phonation at low humidity [22,38,39]. PTP was also examined during resting breathing, during exercise and during reading aloud [21,37,38]. The results revealed PTP increased significantly during reading ( $p < 0.01$ ), exercise ( $p < 0.01$ ) [41] and submaximal exercise ( $p = 0.019$ ) [21]. This increase was likely as a result of increased vocal demand, oral breathing and mouth opening that resulted in increased surface dehydration. Only two (50%) of the four studies found a significant positive effect of higher humidity levels on PTP, as PTP was found to decrease in higher humidity conditions [38; 39]. However, it may be that moderate humidity is not sufficient enough to optimally hydrate the airway to attenuate the negative vocal effects of loading or it may be that the amount of change could not be detected in PTP [44,45]. A high humidity condition may thus be required to see greater change. The nasal route of breathing did not have significant effects on PTP [38].

Various pitch levels at the 10th, 20th and 80th pitch percentage of their maximum frequency range were used across the studies to represent pitch levels of a low, comfortable and high pitch respectively [41]. The study found that accelerated breathing only revealed a significant increase for  $PTP_{20}$  ( $p = 0.001$ ) but not for  $PTP_{10}$  ( $p = 0.06$ ) and  $PTP_{80}$  ( $p = 0.60$ ) [41]. Although the increase was of small magnitude, it was especially noteworthy considering the short duration of the accelerated breathing challenge at a comfortable frequency [41]. Accelerated breathing, likened to that during exercise, induces airway dehydration as a result of fluid evaporation [41].

Other studies, however, also found significant effects for the pitch extremes of  $PTP_{10}$  and  $PTP_{80}$  [37-39], indicating differing hydration levels have significant effects on PTP at all pitch levels, which is especially noteworthy for both normal and professional voice users. Sivasankar & Erickson (2009) [41] and Tanner, et al (2015) [25], found that mouth breathing did not significantly increase PTP. These results were contradictory to the majority (60%) of the studies which revealed a significant increase in PTP following laryngeal desiccation.

None of the nebulized treatments were sufficiently robust to reverse or enhance the reversal of the negative effects associated with laryngeal desiccation on PTP, hence a lack of significant findings [22].

Following rehydration with sterile water, PTP remained significantly increased ( $p=0.001$ ) from the baseline measures, indicating that rehydration using nebulization of sterile water did not ameliorate the negative effects of the dehydration challenge [25]. Overall, results reveal that nebulization has limited benefits for improving PTP after vocal fold dehydration.

The final measure discussed is perceived phonatory effort (PPE). Many studies ( $n= 4$  of 6) found that PPE increased significantly ( $p<0.05$ ) post dehydration thus confirming a negative effect of dehydration on PPE [21, 23-25]. Only one study showed contradictory results that PPE decreased significantly ( $p=0.0181$ ) following the dehydrating condition, thus signalling a positive effect of dehydration on PPE [22]. Results indicated that nebulizing various solutions had no significant effect on PPE and did not significantly ( $p>0.05$ ) combat the negative effects of dehydration [22,24]. Only nebulizing an isotonic solution after a laryngeal desiccation challenge of breathing dry air, resulted in a significant improvement ( $p=0.0009$ ) and thus decrease in PPE [25]. Only one study by Sundarrajan (2017) [45] reported a significant decrease ( $p=0.01$ ) in PPE when humidity was increased, however other studies found non-significant effects ( $p>0.05$ ) [37,38].

#### **4. CONCLUSION**

Systemic dehydration as a result of fasting and not ingesting fluids significantly affected the parameters of NHR, shimmer, jitter, maximum habitual pitch, the s/z ratio, VTI, phonatory effort and the grade of hoarseness [20,26]. Individuals who fast are thus encouraged to increase water intake prior to fasting and to decrease vocally demanding tasks that can predispose voice disorders [23]. A conservative dose of caffeine did not negatively affect voice production, which is of particular interest to individuals interested in maximizing vocal quality [19]. Systemic rehydration via ingestion of water was assumed to replenish the moisture level lost to dehydrating conditions by creating a more optimal condition for vocal fold movement [18]. Water ingestion thus had positive, significant effects on shimmer, jitter, maximum frequency and MPT. These results suggest that well lubricated vocal folds require less subglottic pressure to vibrate [9], optimizing the efficiency of vocal vibration and thus enhancing voice quality [8, 46].

Laryngeal desiccation challenges by oral breathing led to surface dehydration which had significant negative effects on several acoustic parameters such as, jitter, shimmer, NHR, PTP and PPE. With regards to surface hydration, steam inhalation had positive significant effects on NHR, shimmer and jitter. Limited significant effects were found for moderate humidity conditions, however, low humidity environments revealed more significant negative effects.

Avoidance or alterations of these low humidity environments should be encouraged. Humidifiers that do not increase environmental humidity to a high level may thus not be useful in decreasing the negative effects of loading [44] as detrimental phonatory effects only appear to be reversed at 100% humidity [41]. Nebulization of sterile water did not reduce PTP significantly and PTP remained significantly increased. Nebulization of isotonic saline solution, however, showed positive significant effects by reducing the cepstral spectral index of dysphonia (CSID) rainbow passage and reducing mouth and throat dryness, which are self-reported measures. Nebulization appears to be perceived as having positive effects, however, it should not be recommended solely as a supplement to increasing surface hydration with the aim of improving vocal quality as perceived measures are not objective.

Although not all results for the outcomes of hydration were significant, an overall positive finding for both systemic and surface hydration was found. The most negative, significant results were seen for dehydration conditions and thus lead to the recommendation of maintaining an adequate state of hydration.

The knowledge of substances that may affect voice production is essential to further improve vocal hygiene programs [19]. Most of the recent literature regarding hydration of the voice is of good quality evidence. The results above add to the knowledge of preventative and therapeutic procedures that are applicable for all voice users [9]. We can thus infer that systemic hydration, is the simplest and most cost effective way to improve voice quality as it has shown to have an effect on the acoustic and some perceptual parameters of voice. Surface hydration, via steam inhalation can also be suggested, however, this solution is not as practical and accessible as simple ingestion of water.

Future research should specifically focus on the effects of differing doses and durations of hydration schedules. Also, the combined effect of superficial and systemic hydration should be determined. By determining the most beneficial doses and durations, personalized hydration schedules can be designed and implemented for voice users. These studies should also ensure accurate data collection by including control of menstrual cycles, urine and blood analysis and weight collection in their methodological protocol. They should also include control for time, voice rest and vocal training. More studies can look at the effect of various dehydrating agents such as smoking, alcohol and caffeine and the detrimental doses and durations of these substances. Finally, further research can explore the effects of hydration schedules on various types of voice disorders.

In conclusion, maintenance of systemic hydration and increasing water intake should be encouraged in vocal hygiene programs. Avoidance or adaptation of surface dehydrating conditions and the addition of steam inhalation can be included in the program as an adjunct to systemic hydration. It is still, however, important that each individual's behaviours and environments be assessed in order to provide them with a unique and relevant program suited to their individualized needs.

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## CHAPTER 4: DISCUSSION AND CONCLUSION

### Chapter aim:

The aim of this chapter is to discuss and summarize the results of recent literature through a systematic review. The information obtained may describe how the use of a hydration protocol may aid in the selection of prevention and treatment protocol for individuals with and without voice disorders. These results are then discussed in terms of their clinical significance to the field of vocology. The value of the systematic review is highlighted and a critical evaluation provided. Future research needs are discussed and a conclusion on the overall effect of hydration on voice quality in adults is made.

A systematic review was conducted and a final number of 20 articles were selected and appraised. From the appraisal, the evidence was deemed to be of high quality as most articles (n=16; 80%) received a score of level IIb and above (ASHA, 2004). The quality indicators (Cherney, et al., 2008) also depicted a picture of high quality as seventeen (85%) of the articles appraised achieved a score of five and above. The risk of bias was variable amongst the selected articles. Seventy percent of the articles (n=14) achieved a low risk of bias score for random sequence generation and a hundred percent received a low risk of bias in both reporting and attrition bias indicating that all measures were reported on and there were no withdrawals from the studies. Seventeen of the articles (85%) received an unclear or high risk of bias for allocation concealment indicating that there was poor randomization in the knowledge of forthcoming events. This is problematic as selective enrolment of participants based on prognostic factors can occur, leading to results that aren't always accurate (Higgins & Green, 2011). Just over half (n=11; 55%) of the articles received a high risk for performance and fourteen (70%) of the articles received a high or unclear risk of detection bias indicating that measures of blinding were not always employed which may have led to improper results. These results indicate that there was not always adequate blinding of participants, personal or outcome measures in over half of the selected studies.

The results obtained from the qualitative analysis of the articles were mostly variable with many non-significant findings ( $p < 0.05$ ) for the effects of hydration or dehydration. In terms of a systemic hydration level, a hypohydrated state due to fasting resulted in a significant negative impact on the acoustic measures of jitter, noise-to-harmonic ratio (NHR) and the habitual pitch (Hamdan, et al., 2011; Van Wyk, et al., 2017). A negative effect of a dehydrated state was found in the aerodynamic measure of s/z ratio and in the perceptual measures of the grade of hoarseness in the GRBASI scale and phonatory effort (Hamdan, et al., 2007; 2011; Van Wyk, et al., 2017).

Hydration measures of consuming 250mls of water per 30 minutes of high vocal demand and consuming one litre of water in 20 minutes after fasting significantly improved shimmer, jitter, MPT and maximum frequency (Franca & Simpson, 2009; Van Wyk, et al., 2017). With regards to surface dehydration, laryngeal surface desiccation challenges, as a result of oral breathing from just ten minutes to two hours, resulted in negative impacts on PTP and PPE (Sandage, et al., 2013, Sivasankar, et al., 2008; Sivasankar & Erickson, 2009; Tanner, et al., 2007).

Eight minutes of submaximal exercise (Sandage, et al., 2013), three minutes of accelerated breathing and fifteen minutes of loud reading and exercise all resulted in a negative impact on PTP (Sivasankar & Erickson-Levendoski, 2012). Only low humidity conditions had the most significant ( $p < 0.05$ ) negative effects on measured variables. Ambient humidity had limited effects on improving variables after desiccation challenges but high humidity revealed more positive results (Erickson-Levendoski, et al., 2014; Sundarrajan, et al., 2017).

Steam inhalation as a hydration measure, for three minutes using a facial steamer, significantly improved NHR, jitter and shimmer scores (Mahalingham & Boominatham, 2016). Only nebulization of 5ml of saline solution for five minutes, 3ml of isotonic solution and 3ml of sterile water significantly improved fundamental frequency, throat and mouth dryness and phonation threshold pressure respectively (Tanner, et al., 2010). Other measures were not significantly affected by nebulization processes and the nebulization of hypertonic and isotonic solutions did not significantly affect other aspects of voice production (Tanner, et al., 2010; Tanner, et al., 2007).

#### **4.1. The value of the systematic review**

The systematic review described the most recent, evidence-based research regarding the impact of differing hydration levels on the acoustic parameters of voice (Table '2.1, 2.2, 2.3, 2.4). Adherence to the PRISMA-P checklist (Shamseer, et al., 2015) ensured greater accuracy and reliability in the reporting of the identified effects. The Cochrane Collaboration's risk of bias tool allowed for comparison of possible biases between the selected articles and ultimately indicated studies which showed a high potential for bias. The PRISMA (Moher, et al., 2009) and PRISMA-P (Shamseer, et al., 2015) were used as a guideline throughout the review. Appendix A is adapted from the checklist and presents each checklist item and where the information is presented within the current review.

In summary, the appraisal process depicted high quality evidence studies. Despite some aspects presenting with a possible bias, it is important to note that none of the articles explicitly mentioned a presence of bias. Inferences were therefore made using tools and systematic evaluation of the articles regarding bias and the articles are only said to be at risk of bias, not that a bias is actually present (ASHA, 2004; Higgins & Green, 2011; Moher, et al., 2009).

The review highlighted that most of the recent literature on hydration is based on high levels of evidence. A need to develop more objective measures for aspects of self-report such as PPE and throat and mouth dryness was emphasized. Thematic analysis allowed for identification of gaps and challenges more explicitly than in a general literature review. The greatest challenge in determining the effects of hydration on voice acoustics is that differing doses, types of hydration and durations are discussed within the literature, making it difficult to conduct meta-analyses on the results of the reviewed articles.

Finally, health care providers in voice therapy have limited time and/or resources to research and appraise all the literature regarding the effect of hydration on voice. The review ensured the most recent literature was systematically summarized and critically appraised so these practitioners can gain an objective view of the effect of hydration. The review adheres to the EBP guidelines (ASHA, 2004) by making use of external scientific evidence which was obtained from peer reviewed articles. It also encompassed client perspectives and clinical expertise of voice practitioners in terms of impact of hydration of voice. By including the most recent literature from the past ten years it ensures that practitioners are not relying on outdated research and subsequently outdated intervention methods.

#### **4.2. Clinical implications**

The voice generally needs rest and care to function optimally and to prevent vocal hyperfunction (Van Wyk, et al., 2017). The review further emphasizes the importance of voice care in terms of implementation of a hydration schedule. The encouragement of evidence in support of assessment and intervention decisions regarding voice care ensures the profession of vocology becomes more theoretically grounded in objective data (Ferrand, 2012). By conducting studies on the effects of hydration and dehydration a further understanding of the mechanism of voice production is added. The results found from this study ensure accurate recommendations for an aspect that has an essential focus in clinical voice science. These results also confirm that the role water plays within the body is not only anatomical by adding mass and form but also physiological by providing lubrication to adjoining tissues (Horswil & Janas, 2011).

The primary goal of voice therapy should be to identify and eliminate phonotraumatic behaviours or reduce them with acceptable patterns of voice production (Colton, Casper & Leonard, 2006). A hydration schedule should form part of a primary intervention approach to prevent a voice disorder from occurring. Secondary prevention to improve the effects of the voice disorder and tertiary prevention to reduce the negative effects on a chronic condition protocol should also be considered when designing hydration schedules, depending on the client's specific needs. The study highlights specific guidelines which should be considered when implementing a hydration schedule for a client.

The first guideline suggests that fasting not only causes body dehydration but also has an impact on the voice quality of an individual that is fasting. It is thus of vital importance that hydration is maintained when individuals break their fast. It is also recommended that in periods of fasting, refrainment from or reduction of vocally demanding behaviours occurs as the voice is especially susceptible during these periods of being in a hypohydrated state. After fasting, improvements were noted in vocal quality after ingesting one litre of water within 20 minutes after fasting (Franca & Simpson, 2009). Individuals who are fasting regularly should ensure consumption of at least one litre of water before the fasting commences and directly after the fasting period ceases for the day.

However, regardless of whether an individual is fasting or not, the aim should still be to obtain an adequate level of hydration as the benefits of systemic hydration have been emphasized. For example, when individuals are engaging in a vocally demanding task, they should aim to consume 250ml of water per 30 minutes (Van Wyk, et al., 2017). A second guideline is related to the creation of a hydration schedule. In this case, the client's specific environment should be considered. Laryngeal desiccation as a result of oral breathing during rest and during high vocal demand such as reading aloud, singing or exercising has shown to have the most significant negative effects on voice quality (Sandage, et al., 2013; Sivasankar & Erickson, 2009). It is thus important that these vocally abusive behaviours be identified and minimized to the maximum possible extent. In cases where these behaviours cannot be eliminated, certain interventions can ameliorate the negative effects of these behaviours.

Another guideline suggests that one way of ameliorating these negative effects is by ensuring the environment's humidity level is not at a low level as this has proven to result in further negative effects (Fujiki, Chapleau, Sundarajan, McKenna & Sivasankar, 2016; Sundarajan, et al., 2017).



Although moderate humidity has shown limited benefits, an environment with a high humidity has proven more beneficial in ameliorating the negative effects of laryngeal desiccation. Steam inhalation can be suggested as a form of increasing voice quality, especially for PVUs as it has shown that just three minutes of steam inhalation using a facial steamer, improved voice quality after a laryngeal desiccation challenge (Mahalingham & Boominatham, 2016). Nebulization of three or nine millimetres of sterile water or saline solution can also be used as a complimentary measure to obtain optimal voice quality if the goal is improvement of fundamental frequency, a decrease in throat and mouth dryness and a decrease in PTP. The above guidelines can be utilized by any individual voice user; however, it is imperative that professional voice users implement a vocal hygiene programme which includes a hydration schedule. This hydration schedule should be developed based on the client's unique needs and requirements.

In general, the results that were obtained in the review will guide clinicians in decision making in the intervention plans of their clients and add to preventative programs for voice disorders. They also add to the literature of the best practices for optimizing vocal quality. Finally, gaps in the literature were identified and provide a pathway for future research needs.

#### **4.3. Future research needs**

Gaps within the literature were noted across the studies in the reviewed articles. All studies used different stimuli such as singing or counting on which participants rated their effort. These stimuli are different and may thus result in variable results.

Consistent methods for collecting measures that are self-perceived should therefore be developed to further ensure accuracy and consistency across studies. Also, allowing participants to refer back to previous ratings may increase internal consistency of raters which can be implemented in future studies. With regard to hydration itself, many studies showed improvement in a positive direction after hydration, however, this improvement was not always significant. Further research should therefore focus specifically on the effects of differing doses and durations of a hydration schedule. By determining the most beneficial doses and durations, personalized hydration schedules can be designed and implemented for voice users. Further studies should ensure accurate data collection by including control of menstrual cycles, urine and blood analysis and weight collection in their methodological protocol. They should also include control for time, voice rest and vocal training.

It is recommended that more research be conducted in low-to-middle income countries as the effect of different environmental factors should also be considered. This differing environment may result in differences in voice characteristics and should thus be investigated further. More studies can look at the effect of various dehydrating agents such as smoking, alcohol and caffeine and the detrimental doses and durations of these substances. Further research can draw comparisons between jet and ultrasonic nebulizers to determine if the type of nebulizer shows differing results. The effects of hydration and dehydration on voice disordered populations should be determined so appropriate intervention techniques for the voice disordered population can be employed. Finally, it is recommended that more randomized-controlled trial (RCT) methodologies are conducted as only four (n=20%), RCTs were found to have been conducted in the current review. This type of methodology limits possible bias further and promotes the use of the highest level of evidence in prevention, assessment and intervention. These studies should also use larger samples and individuals with differing demographics to ensure a higher generalizability to a wider range of individuals is ensured.

#### **4.4 Critical evaluation**

A limitation in the systematic review may be the exclusion of the effect of hydration on individuals with established voice disorders. However, it was assumed that results for hydration or dehydrating conditions would be similar for individuals with and without voice disorders. For example, if hydration showed a positive significant effect on a normal voice, it may have benefits for a disordered voice. This, however, is speculation and should be investigated further in future research.

#### **4.5. Conclusion**

Hydration forms a crucial element of a vocal hygiene program which should be included in an eclectic approach to the assessment, prevention and intervention of voice disorders. This systematic review motivated the need for future studies to assess differing effects of dose, type and duration of hydrating and dehydrating conditions. The identified benefits of hydration and risks of dehydration provide a guideline for improved service delivery by speech-language therapists as well as otolaryngologists in the normal and voice disordered population.

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## APPENDICES

**Appendix A: Evidence of item checklists within the review adapted from the PRISMA-P checklist (Shamseer, et al., 2015)**

	Section and Topic	Checklist item	Evidence in article
<b>Administrative</b>	Title identification	Identify the report as a protocol of a systematic review	Title page [i]
	Title update	If the protocol is for an update of a previous systematic review, identify as such	N/A
	Registration	If registered, provide the name of the registry (such as PROSPERO) and registration number	N/A
	Authors contact details	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author	[ii]
	Author contributions	Describe contributions of protocol authors and identify the guarantor of the review	[iii]
	Amendments	Amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	N/A
	Support sources	Indicate sources of financial or other support for the review	[ii]
	Sponsor	Provide name for the review funder and/or sponsor	[ii]
	Role of sponsor or funder	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	N/A
<b>Intro-duction</b>	Rationale	Describe the rationale for the review in the context of what is already known	Rationale [1.2]
	Objectives	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	Research question [1.3]
<b>Methods</b>	Eligibility criteria	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review	Inclusion criteria [2.3.3]
	Information sources	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other grey literature sources) with planned dates of coverage	Search strategy [2.3.1] Figure 2
	Search strategy	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	Search strategy [2.3.1] Figure 2
	Data management	Describe the mechanism(s) that will be used to manage records and data throughout the review	Data management [2.3.2]
	Selection process	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)	Search strategy [2.3.1] Publication bias [2.3.6]
	Data collection process	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	Data collection procedures [2.3]
	Data items	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications	Inclusion criteria [2.3.3], Exclusion criteria [2.3.4], data analysis [2.5]

**Appendix A continued: Evidence of item checklists within the review adapted from the PRISMA-P checklist (Shamseer, et al., 2015)**

	<b>Section and Topic</b>	<b>Checklist item</b>	<b>Evidence in article</b>
<b>Methods continued</b>	Outcomes and prioritization	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	Data analysis [2.5]
	Risk of bias in individual studies	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	Publication bias [2.3.6]
	Data synthesis	Describe criteria under which study data will be quantitatively synthesised	Data analysis [2.5]
		If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency	N/A
		Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)	Data analysis [2.5]
		If quantitative synthesis is not appropriate, describe the type of summary planned	Data analysis [2.5]
	Meta bias(es)	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)	Publication bias [2.3.6]
Confidence in cumulative evidence	Describe how the strength of the body of evidence will be assessed (such as GRADE)	Data analysis [2.5]	

## Appendix B: Ethical clearance form



UNIVERSITEIT VAN PRETORIA  
UNIVERSITY OF PRETORIA  
YUNIBESITHI YA PRETORIA

Faculty of Humanities  
Research Ethics Committee

26 May 2017

Dear Ms Alves

**Project:** The effect of hydration on voice quality in adults: A systematic review  
**Researcher:** M Alves  
**Supervisor:** Dr van der Linde  
**Department:** Speech-Language Pathology and Audiology  
**Reference number:** 13050232 (GW20170510HS)

Thank you for the application that was submitted for ethical consideration.

I am pleased to inform you that the above application was **approved** by the **Research Ethics Committee** at a meeting held on 25 May 2017. 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

A handwritten signature in black ink, appearing to read 'Maxi Schoeman'.

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

CC: Prof B Vinck (HoD)  
Dr J van der Linde (Supervisor)

Research Ethics Committee Members: Prof NWE Schoeman (Deputy Dean); Prof HJ Harris; Dr L Blokland; Ms A dos Santos; Dr R Fassell; Ms KT Govindar; Dr E Johnson; Dr C Panethiano; Dr C Puttgill; Dr D Reyburn; Dr M Teub; Prof GM Spiess; Prof E Taljard; Ms B Tsebe; Dr E van der Kleinhorst; Dr G Wolmarans; Ms D Mokolape

## Appendix C: The Cochrane Collaboration’s Tool to Assess the Risk of Bias within studies.

Use the modified Cochrane Collaboration tool to assess risk of bias for randomized controlled trials. Bias is assessed as a judgment (high, low, or unclear) for individual elements from five domains (selection, performance, attrition, reporting, and other).

### AUB KQ1 Risk of Bias Assessment (Reference ID # )

Domain	Description	High Risk of Bias	Low Risk of Bias	Unclear Risk of Bias	Reviewer Assessment	Reviewer Comments
<i>Selection bias Random sequence generation</i>	Described the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups	Selection bias (biased allocation to interventions) due to inadequate generation of a randomized sequence	Random sequence generation method should produce comparable groups	Not described in sufficient detail	High Low Unclear	
<i>Selection bias Allocation concealment</i>	Described the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen before or during enrollment	Selection bias (biased allocation to interventions) due to inadequate concealment of allocations prior to assignment	Intervention allocations likely could not have been foreseen in before or during enrollment	Not described in sufficient detail	High Low Unclear	
<i>Reporting bias Selective reporting</i>	Stated how the possibility of selective outcome reporting was examined by the authors and what was found	Reporting bias due to selective outcome reporting	Selective outcome reporting bias not detected	Insufficient information to permit judgment †	High Low Unclear	
<i>Other bias Other sources of bias</i>	Any important concerns about bias not addressed above*	Bias due to problems not covered elsewhere in the table	No other bias detected	There may be a risk of bias, but there is either insufficient information to assess whether an important risk of bias exists or insufficient rationale or evidence that an identified problem will introduce bias	High Low Unclear	

\* If particular questions/entries were pre-specified in the study's protocol, responses should be provided for each question/entry.

† It is likely that the majority of studies will fall into this category.

Assess each main or class of outcomes for each of the following. Indicate the specific outcome.

**Appendix C continued: The Cochrane Collaboration’s Tool to Assess the Risk of Bias within studies.**

<b>AUB KQ1 Risk of Bias Assessment (Reference ID # )</b>						
Outcome:						
<b>Domain</b>	<b>Description</b>	<b>High Risk of Bias</b>	<b>Low Risk of Bias</b>	<b>Unclear Risk of Bias</b>	<b>Reviewer Assessment</b>	<b>Reviewer Comments</b>
<i>Performance bias Blinding (participants and personnel)</i>	Described all measures used, if any, to blind study participants and personnel from knowledge of which intervention a participant received. Provided any information relating to whether the intended blinding was effective.	Performance bias due to knowledge of the allocated interventions by participants and personnel during the study.	Blinding was likely effective.	Not described in sufficient detail	High Low Unclear	
<i>Detection bias Blinding (outcome assessment)</i>	Described all measures used, if any, to blind outcome assessors from knowledge of which intervention a participant received. Provided any information relating to whether the intended blinding was effective.	Detection bias due to knowledge of the allocated interventions by outcome assessors.	Blinding was likely effective.	Not described in sufficient detail	High Low Unclear	
<i>Attrition bias Incomplete outcome data</i>	Described the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. Stated whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomized participants), reasons for attrition/exclusions where reported.	Attrition bias due to amount, nature or handling of incomplete outcome data.	Handling of incomplete outcome data was complete and unlikely to have produced bias	Insufficient reporting of attrition/exclusions to permit judgment (e.g., number randomized not stated, no reasons for missing data provided)	High Low Unclear	