The Effect of Hydration on Voice Quality in Adults: A Systematic Review

*,†Maxine Alves, *,†Esedra Krüger, *,†Bhavani Pillay, *,†Kristiane van Lierde, and *,†Jeannie van der Linde, *Pretoria, South Africa, and †Ghent, Belgium

Summary:
Objectives. We aimed 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. This is a systematic review.
Methods. Five databases were searched using the key words "vocal fold hydration", "voice quality", "vocal fold dehydration", and "hygienic voice therapy". The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines were followed. The included studies were scored based on American Speech-Language-Hearing Association'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 noise-to-harmonics ratio (NHR), shimmer, jitter, frequency, and the s/z ratio. Water ingestion led to significant improvements in shimmer, jitter, frequency, and maximum phonation time 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, phonation threshold pressure, and perceived phonatory effort. Steam inhalation significantly improved NHR, shimmer, and jitter. Only nebulization of isotonic solution decreased phonation threshold pressure 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.
Conclusions. 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.

INTRODUCTION

Almost a third of the population of the United States will have some type of voice disorder across their life span.[1] More specifically, professional voice users 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 and 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 required not only 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 have been reported to be especially susceptible to dehydration.[8] A compromised state of hydration, even as little as 1%–2%,[8] is believed to limit

From the *Department of Speech-Language Pathology and Audiology, University of Pretoria, Pretoria, South Africa; and the †Department of Speech, Language and Hearing Sciences, University Ghent, Ghent, Belgium.

Address correspondence and reprint requests to Maxine Alves, Department of Speech-Language Pathology and Audiology, University of Pretoria, PO BOX 11663, Selcourt, Springs, Gauteng 1567, South Africa. E-mail: Maxine.alves1@gmail.com

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 nonoptimal conditions can also lead to phonotraumatic behaviors.[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 nonsignificant 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.

METHODS

Study design

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

Study inclusion criteria

The inclusion criteria comprised 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 Consensus Auditory-Perceptual Evaluation of Voice (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]

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 were 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 1 represents the process of manuscript identification.

Data collection process and data items

Each article was analyzed 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 References 28 and 29) 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.

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, judgment 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

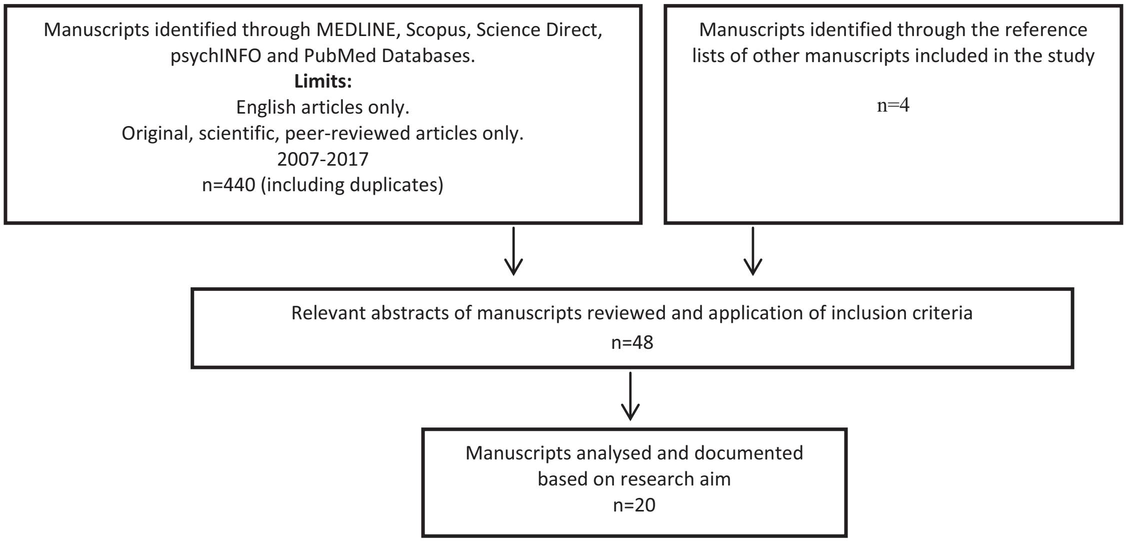

FIGURE 1. Process of data collection, adapted from the PRISMA statement.[30]

than limited statements pertaining to possible bias. Conditions were labeled 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.

Data analysis

Descriptive statistics was used to describe features of the data obtained and to summarize findings of the research.

Thematic and inferential analysis was employed to analyze, organize, 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.

RESULTS AND DISCUSSION

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. Combinations of qualitative and quantitative outcomes were analyzed.

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. Noninstrumental 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[35] and the GRBASI scale.[36] Self-reported participant measures such as vocal fatigue and throat and mouth dryness were also reported on.

The characteristics of the 20 selected articles are presented in Table 1. Data were collected mostly (n = 16; 80%) in the United States, 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%).[42]

Participants' ages ranged from 18 to 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%) and four were randomized-control studies (20%). Half of the studies used pretest, posttest measures (n = 10; 50%) and nine had within-participant comparisons (45%).

In terms of the ASHA levels of evidence[29] (adapted from References 28 and 29), 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[33] 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.

Risk of bias

The Cochrane Collaboration's risk of bias tool was used to assess each study (Table 2). 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" judgment for reporting and attrition bias as all data were completed and reported on within all the articles. Although most (n = 14; 70%) articles achieved a "low-risk" score

TABLE 1.
Characteristics of the Selected Studies

Title	Study: Authors, Year, and Country	Participant Age Range (M;SD) and Gender	No. of Participants (Including 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 and Simpson, 2009, USA[9]	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 and Simpson, 2012, USA[18]	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[19]	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[20]	21–45 years (29.7; 7.7) Females	28	Prospective study, within-subject design	Within-subject	IIb	5	f_0, 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[23]	22–50 years (28; 5.46) Males	26	Prospective study, within-subject design	Within-subject	IIb	6	f_0, 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[26]	18–32 years (21.75; 4.18) Females	12	Within-subject, comparative, pretest posttest design	Within-subject	IIa	7	GRBASI, MPT, s/z ratio, jitter, shimmer, highest frequency, lowest intensity, DSI
7. Investigating the effects of caffeine on phonation	Erickson-Levendoski and Sivasankar, 2011, USA[6]	18–23 years (23; NR) Males and females	16 (8 m/8 f)	Prospective, double-blind, sham-controlled study	✓	IIa	6	PTP, PPE

(*Continued*)

TABLE 1.
(*Continued*)

Title	Study: Authors, Year, and Country	Participant Age Range (M;SD) and Gender	No. of Participants (Including 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 (5 m/8 f)	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 (8 m/8 f)	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 nonsingers: effects on acoustic, aerodynamic, and self-perceived effort and dryness measures	Tanner et al, 2015, USA[25]	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[21]	20–24 years (21.72; 1.27) Males and females	18 (9 m/9 f)	Within-participant repeated measures design	✓	IIb	4	PTP, PPE
12. Influence of obligatory mouth breathing, during realistic activities, on voice measures	Sivasankar and Erickson-Levendoski, 2012, USA[37]	18–38 years (21; NR) Males and females	63 (32 m/31 f)	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[24]	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[22]	18–50 years (28; 7.7) Females	60	Double-blind, randomized group design with a nontreatment control group, placebo controlled design	✓	Ib	8	PTP, PPE

(*Continued*)

TABLE 1.
(*Continued*)

Title	Study: Authors, Year, and Country	Participant Age Range (M;SD) and Gender	No. of Participants (Including 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[38]	19–26 years (23; NR) Females	16	Repeated-measures design	✓	IIa	5	PTP, PPE
16. Reducing the negative vocal effects of superficial laryngeal dehydration with humidification	Erickson-Levendoski et al, 2014, USA[39]	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[2]	NR (44.9; NR) Males and females	27 (12 m/15 f)	Examiner-blinded, pretest and posttest intervention study with single group of subjects	Within-subject	Ib	6	CAPE-V, f_0, 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[40]	21–29 years (22.85; NR) Males and females	10 (4 m/6 f)	Prospective study	×	III	6	VOT, PTP, jitter
20. Short-duration accelerated breathing challenges affect phonation	Sivasankar and Erickson, 2009, USA[41]	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.

Abbreviations: CPP, cepstral peak prominence; CSID, cepstral spectral index of dysphonia; f, female; f_0, fundamental frequency; GNE, glottal-to-noise excitation ratio; LHR, low/high ratio; m, male; M, mean; MPT, maximum phonation time; NHR, noise-to-harmonics ratio; NR, not reported; PPE, perceived phonatory effort; PTP, phonation threshold pressure; RFF, relative fundamental frequency; SD, standard deviation; RAP, relative average perturbation; SPL, sound pressure level; VOT, voice onset time; VTI, Voice Turbulence Index.

TABLE 2.
The Risk of Bias Across the Selected Studies

Study	Selection Bias: Random Sequence Generation	Selection Bias: Allocation Concealment	Performance Bias: Blinding of: (1) Participants (2) Personnel	Detection Bias: Blinding of Outcome Assessment	Reporting Bias: Selective Reporting	Attrition Bias: Incomplete Outcome Data	Inter-Rater Agreement Achieved	Possible Bias or Limitations Identified
1. Franca and Simpson, 2009[9]	Low	Unclear	High	High	Low	Low	×	Prohibits generalization to males, those out of age range, presence of voice disorder. Patient adherence to study pretest protocol (eg, fasting).
2. Franca and Simpson, 2012[18]	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[19]	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 pretest protocol (eg, fasting).
4. Hamdan et al, 2007[20]	Low	Unclear	High	High	Low	Low	×	Prohibits generalization to males, those out of age range, presence of voice disorder.
5. Hamdan et al, 2011[23]	Low	Unclear	Unclear	Low	Low	Low	×	Absence of scientific measures of hydration (eg, weight loss). Presence of confounding factors, reliance on self-reports, adherence to protocol (eg, fasting).
6. Van Wyk et al, 2017[26]	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.

(*Continued*)

TABLE 2.
(*Continued*)

	Selection Bias		Performance Bias	Detection Bias	Reporting Bias	Attrition Bias		
Study	Random Sequence Generation	Allocation Concealment	Blinding of: (1) Participants (2) Personnel	Blinding of Outcome Assessment	Selective Reporting	Incomplete Outcome Data	Inter-Rater Agreement Achieved	Possible Bias or Limitations Identified
7. Erickson-Levendoski and Sivasankar, 2011[6]	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.
9. Fujiki et al, 2017	Low	Unclear	High	Low	Low	Low	×	Reliance on self-reports.
10. Tanner et al, 2015[25]	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[21]	Low	Unclear	High	High	Low	Low	×	Prohibits generalization to older generation, presence of voice disorder. Reliance on self-reports, adherence to pretest protocol (eg, fasting). Exclusion of acoustic measures.
12. Sivasankar and Erickson-Levendoski, 2012[37]	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[24]	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.

(*Continued*)

TABLE 2.
(*Continued*)

Study	Selection Bias: Random Sequence Generation	Selection Bias: Allocation Concealment	Performance Bias: Blinding of: (1) Participants (2) Personnel	Detection Bias: Blinding of Outcome Assessment	Reporting Bias: Selective Reporting	Attrition Bias: Incomplete Outcome Data	Inter-Rater Agreement Achieved	Possible Bias or Limitations Identified
14. Tanner et al, 2007[22]	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.
15. Sivasankar et al, 2008[38]	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[39]	High	High	High	High	Low	Low	✓	Temperature of laboratory and total body mass not recorded. No within-subject comparison mentioned.

(*Continued*)

TABLE 2.
(*Continued*)

Study	Selection Bias: Random Sequence Generation	Selection Bias: Allocation Concealment	Performance Bias: Blinding of: (1) Participants (2) Personnel	Detection Bias: Blinding of Outcome Assessment	Reporting Bias: Selective Reporting	Attrition Bias: Incomplete Outcome Data	Inter-Rater Agreement Achieved	Possible Bias or Limitations Identified
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[2]	Low	Low	(2) Low	High	Low	Low	✓	Small sample size = nonsignificant 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[40]	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 and Erickson, 2009[41]	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.

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 inter-rater reliability, showing a high consensus rate for the results achieved in the articles.

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.[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 (PTP).[39] However, systemic dehydration as a result of fasting resulted in a significant increase in PPE.[20,23] Table 3 presents the parameters that were reported on in more than one study.

Hamdan and colleagues conducted studies on males and females during fasting.[20,23] Only the latter study found a significant decrease ($P = 0.001$) in NHR, highlighting the negative effects of fasting on the NHR.[23] 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]

For 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 favorable direction for the inclusion of hydration regimes.[9] Fundamental frequency (or f_0) 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, nonsignificant 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.[20] 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 a result of pliable, light, and thus easy to vibrate vocal folds that 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]

Results as per surface hydration

Surface hydration appeared to have a positive effect on the NHR as a statistically significant increase ($P < 0.05$) was found after steam inhalation, thus ameliorating the negative effect of the desiccation challenge.[43] 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 ($P > 0.05$)[44] or the low/high ratio ($P > 0.05$).[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 ($P = 0.616$). Perceptual characteristics in CAPE-V scores ($P = 0.171$) also revealed nonsignificance.[44]

Tanner et al looked at the effect of oral desiccation and subsequent rehydration using nebulization of an isotonic saline solution.[25] Cepstral spectral index of dysphonia (CSID) 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 4 for comparison between studies.

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

TABLE 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
Noise-to-harmonics ratio (NHR)				
Hamdan et al, 2007[20]	Increase	N/A	N/A	Nonsignificant increase in NHR after dehydrating condition (fasting).
Hamdan et al, 2011[23]	Decrease* ($P = 0.001$)	N/A	N/A	Significant decrease in NHR after dehydrating condition (fasting).
Shimmer				
Van Wyk et al, 2017[26]	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[20,23]	Decrease	N/A	N/A	No significant decrease in shimmer after dehydration (fasting).
Franca and Simpson, 2009[9]	Increase	N/A	Decrease* ($P = 0.05$)	Ingesting fluids after fasting significantly improved shimmer values.
Franca et al, 2013[19]	Increase	N/A	N/A	Nonsignificant increase in shimmer after ingesting caffeine.
Jitter (RAP)				
Van Wyk et al, 2017[26]	Increase* ($P = 0.041$)	Decrease	N/A	No water ingestion revealed a significant increase in jitter. A nonsignificant decrease in jitter was found after water ingestion.
Hamdan et al, 2007; 2011[20]	Increase	N/A	N/A	Dehydration (fasting) nonsignificantly increased jitter.
Franca and Simpson, 2009[9]	N/A	N/A	Decrease* ($P = 0.05$)	Statistically significant improvement in jitter after rehydration via ingestion of fluids.
Franca et al, 2013[19]	Decrease	N/A	N/A	Caffeine showed a nonsignificant decrease in jitter.
Franca and Simpson, 2012[18]	N/A	Decrease	N/A	Nonsignificant decrease in jitter after hydration.
Patel et al, 2017	Increase	N/A	N/A	Nonsignificant increase in jitter after a dehydrating condition.
Fundamental frequency (f_0)				
Hamdan et al, 2007[20]	Increase	N/A	N/A	Statistically nonsignificant increase in fundamental frequency after fasting.
Hamdan et al, 2011[23]	Increase	N/A	N/A	
Habitual pitch				
Hamdan et al, 2007[20]	Decrease	N/A	N/A	Statistically nonsignificant decrease in habitual pitch after fasting.
Hamdan et al, 2011[23]	Decrease* ($P = 0.018$)	N/A	N/A	Statistically significant decrease in habitual pitch after fasting.
Maximum phonation time (MPT)				
Hamdan et al, 2007[20]	Decrease	N/A	N/A	Nonsignificant decrease in MPT.
Hamdan et al, 2010	Increase	N/A	N/A	Nonsignificant increase in MPT.
Van Wyk et al, 2017[26]	Increase* ($P = 0.015$)	Increase* ($P = 0.015$)	N/A	Significantly increased MPT following hydration via ingestion of water.

* Statistically significant ≤0.05. N/A, Not applicable.

TABLE 4.
Results for Measures in Surface Dehydration, Hydration, or Rehydration Interventions (n = 13)

Author	After Dehydration	After Hydration	After Rehydration	Overall Consensus
Shimmer				
Santana et al, 2016[2]	N/A	Decreased	N/A	Hydration revealed a nonsignificant 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.
Jitter				
Santana et al, 2016[2]	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[40]	Increase	N/A	N/A	Dehydration revealed a nonsignificant increase in jitter after a laryngeal desiccation challenge.
Phonation threshold pressure (PTP)				
Levendoski et al, 2014	Increase*	N/A	Decrease	PTP increased significantly following mouth breathing in low humidity and showed nonsignificant decrease after rehydration.
Sandage et al, 2013[21]	Increase* ($P = 0.019$)	N/A	N/A	PTP increased significantly after dehydration challenge induced by submaximal exercise.
Sivasankar and Erickson, 2009[41]	Increase	N/A	N/A	Increase in PTP was not statistically significant following accelerated oral breathing.
Tanner et al, 2015[25]	Increase	N/A	Decrease	Effect of dehydrating and rehydrating conditions were nonsignificant on PTP.
Tanner et al, 2010[24]	Mixed results for different frequencies	N/A	Isotonic = decrease Sterile water = increase* ($P = 0.001$)	Baselines in one group nonsignificantly increased post dehydration and the other group decreased. Significant results were found only for the sterile water condition for rehydration.
Tanner et al, 2007[22]	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. Nonsignificant decrease in PTP following nebulization.
Sivasankar et al, 2008[38]	Oral breathing = increase* ($P = 0.038$) Nasal breathing = decrease	N/A	N/A	Oral breathing resulted in a significant increase in PTP_{10}. Nasal breathing decreased PTP; however, this result was nonsignificant.
Sivasankar and Erickson, 2009[41]	Increase* ($P = 0.001$)	N/A	N/A	Results revealed a significant increase in PTP_{20} only and not PTP_{10} or PTP_{80} after an accelerated breathing challenge.
Sundarrajan et al, 2017[45]	N/A	Decrease	N/A	Decrease in PTP in moderate humidity compared to low humidity, but this decrease was nonsignificant.

(*Continued*)

TABLE 4.
(*Continued*)

Author	After Dehydration	After Hydration	After Rehydration	Overall Consensus
Patel et al, 2017	Decrease	N/A	N/A	Nonsignificant decrease in PTP_{10} and PTP_{80}.
Sivasankar and Erickson-Levendoski, 2012[37]	Increase* ($P < 0.01$)	N/A	N/A	Results revealed a significant increase in PTP during exercise and loud reading conditions.
Perceived phonatory effort (PPE)				
Sandage et al, 2013[21]	Increase* ($P = 0.001$)	N/A	N/A	Statistically significant increase after dehydration challenge induced by submaximal exercise.
Tanner et al, 2010[24]	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[22]	Decrease* (I = 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 and Sivasankar, 2011[6]	Decrease	N/A	N/A	Nonsignificant increase in PPE after dehydration.
Tanner et al, 2015[25]	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 and Erickson-Levendoski, 2012[37]	Increase	N/A	N/A	Increase in PPE was nonsignificant during loud reading and exercise.

* Statistically significant ≤0.05. N/A, Not applicable.

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.

PTP was increased significantly ($P < 0.05$) after obligatory oral breathing in 6 of the 10 (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 and 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 that 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 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 signaling 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 a 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 nonsignificant effects ($P > 0.05$).[37,38]

CONCLUSIONS

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 before 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 regard 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 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 led 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 been 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 behaviors and environments be assessed to provide them with a unique and relevant program suited to their individualized needs.

REFERENCES

1. Roy N, Merill RM, Gray SD, et al. Voice disorders in the general population: prevalence, risk factors, and occupational impact. *Laryngoscope*. 2005;115:1988–1995. doi:10.1097/01.mlg.0000179174.32345.41.

2. Santana ER, Masson MLV, Araújo TM. The effect of surface hydration on teachers' voice quality: an intervention study. *J Voice*. 2016;doi:10.1016/j.jvoice.2016.08.019. Article in press.
3. Ferrand C. *Voice Disorders: Scope of Theory and Practice*. Pearson Education; Indiana, USA, 2012.
4. Roy N, Merrill RM, Thibeault S, et al. Prevalence of voice disorders in teachers and the general population. *J Speech Lang Hear Res*. 2004;47:281–293. doi:10.1044/1092-4388(2004/023).
5. Stemple L. A holistic approach to voice therapy. *Semin Speech Lang*. 2005;26:131–137.
6. Erickson-Levendoski E, Sivasankar M. Investigating the effects of caffeine on phonation. *J Voice*. 2011;25:e215–e219. doi:10.1016/j.jvoice.2011.02.009.
7. Franca MC. Effects of hydration on voice performance. ProQuest; 2006.
8. Hartley NA, Thibeault SL. Systemic hydration: relating science to clinical practice in vocal health. *J Voice*. 2014;28:652.e1–652.e20. doi.org/10.1016/j.jvoice.2014.01.007.
9. Franca MC, Simpson KO. Effects of hydration on voice acoustics. *Contemp Issues Commun Sci Disord*. 2009;36:142–148. doi:1092-5171/09/3602-0142.
10. Horswill CA, Janas LM. Hydration and health. *Am J Lifestyle Med*. 2011;5:304–315. doi:10.1177/1559827610392707.
11. Erath BD, Zañartu M, Peterson SD. Modelling viscous dissipation during vocal fold contact: the influence of tissue viscosity and thickness with implications for hydration. *Biomech Model Mechanobiol*. 2016; doi:10.1007/s10237-016-0863-5.
12. Miri AK, Barthelat F, Mongeau L. Effects of dehydration on the viscoelastic propertiesof vocal folds in large deformations. *J Voice*. 2011;26:688–697. doi:10.1016/j.jvoice.2011.09.003.
13. Sivasankar MP, Carroll TL, Kosinski AM, et al. Quantifying the effects of altering ambient humidity on ionic composition of vocal fold surface fluid. *Laryngoscope*. 2013;123:1725–1728. doi:10.1002/lary.23924.
14. Goy H, Fernandes DN, Pichora-Fuller MK, et al. Normative voice data for younger and older adults. *J Voice*. 2013;27:545–555. doi.org/10.1016/j.jvoice.2013.03.002.
15. Solomon NP, DiMattia MS. Effects of a vocally fatiguing task and systemic hydration on phonation threshold pressure. *J Voice*. 2000;14:341–362. doi:10.1016/S0892-1997(00)80080-6.
16. Higgins KP, Smith AB. Prevalence and characteristics of voice disorders in a sample of university teaching faculty. *Contemp Issues Commun Sci Disord*. 2012;39:69–75. doi:1092-5171/12/3902-0069.
17. Schwartz SK. The source for voice disorders. Adolescent and adult. Illinois, USA: LinguiSystems Inc; 2004.
18. Franca MC, Simpson KO. Effects of systemic hydration on vocal acoustics of 18- to 35-year-old. *Commun Disord Q*. 2012;34:29–37. doi:10.1177/1525740111408886.
19. Franca MC, Simpson KO, Schuette A. Effects of caffeine on vocal acoustic and aerodynamic measures of adult females. *CoDas*. 2013;25:250–255. PubMed PMID: 24408336.
20. Hamdan A, Sibai A, Rameh C. Effect of fasting on voice in women. *J Voice*. 2007;21:495–501. doi:10.1016/j.jvoice.2006.01.009.
21. Sandage M, Connor NP, Pascoe DD. Voice function differences following resting breathing versus submaximal exercise. *J Voice*. 2013;27:572–578. doi:10.1016/j.jvoice.2013.04.001.
22. Tanner K, Roy N, Merrill RM, et al. The effects of three nebulized osmotic agents in the dry larynx. *J Speech Lang Hear Res*. 2007;50:635–646. doi:10.1044/1092-4388(2007/045).
23. Hamdan A, Ashkar J, Sibai A, et al. Effect of fasting on voice in males. *Am J Otolaryngol*. 2011;32:124–129. doi:10.1016/j.amjoto.2009.12.001.
24. Tanner K, Roy N, Merril RM, et al. Nebulized isotonic saline versus water following a laryngeal desiccation challenge in classically trained sopranos. *J Speech Lang Hear Res*. 2010;53:1555–1566. doi:10.1044/1092-4388(2010/09-0249).
25. Tanner K, Fujiki RB, Dromey C, et al. 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. *J Voice*. 2015;30:670–676. doi:10.1016/j.jvoice.2015.08.016.
26. Van Wyk L, Cloete M, Hattingh D, et al. The effect of hydration on the voice quality of future professional vocal performers. *J Voice*. 2017;31:111.e29–111.e36. http://dx.doi.org/10.1016/j.jvoice.2016.01.002.
27. Roy N, Weinrich B, Gray SD, et al. Voice amplification versus vocal hygiene instruction for teachers with voice disorders: a treatment outcomes study. *J Speech Lang Hear Res*. 2002;45:645–714. doi:10.1044/1092-4388(2002/050).
28. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols: elaboration and explanation. *BMJ*. 2015;1–25. https://doi.org/10.1136/bmj.g7647.
29. American Speech-Language Hearing Association. Evidenced-based practice in communication disorders: an introduction. Rockville: ASHA; 2004. Accessed 8 May 2017. Available at: http://www.asha.org/policy/TR2004-00001/.
30. Moher D, Liberati A, Tetzlaff J, et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. *Ann Intern Med*. 2009;151:264–269. https://doi.org/10.1371/journal.pmed.1000097.
31. Scottish Intercollegiate Guidelines Network. Glossary of key terms; 2002. Available at: http://www.sign.ac.uk. Accessed 8 May 2017.
32. Mullen R. The state of the evidence: ASHA develops levels of evidence for communication sciences and disorders. *ASHA Leader*. 2007;12:8–25. doi:10.1044/leader.FTR4.12032007.8.
33. Cherney LR, Patterson JP, Raymer A, et al. Evidence-based systematic review: effects of intensity of treatment and constraint-induced language therapy for individuals with stroke-induced aphasia. *J Speech Lang Hear Res*. 2008;51:1282–1299. doi:10.1044/1092-4388(2008/07-0206).
34. Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]. The Cochrane Collaboration; 2011. Available at: http://handbook.cochrane.org. Accessed 2 June 2017.
35. Consensus ASHA. Auditory-Perceptual Evaluation of Voice (CAPE-V). Special Interest Division 3. Voice and Voice Disorders. 1–3; 2002.
36. Yamauchi EJ, Imaizumi S, Maruyama H, et al. Perceptual evaluation of pathological voice quality: a comparative analysis between the RASATI and GRBASI scales. *Logoped Phoniatr Vocol*. 2010;35:121–128. doi: 10.3109/14015430903334269.
37. Sivasankar M, Erickson-Levendoski E. Influence of obligatory mouth breathing, during realistic activities, on voice measures. *J Voice*. 2012;26:813.e9–813.e13. doi:10.1016/j.jvoice.2012.03.007.
38. Sivasankar M, Erickson E, Schneider S, et al. Phonatory effects of airway dehydration: preliminary evidence for impaired compensation to oral breathing in individuals with a history of vocal fatigue. *J Speech Lang Hear Res*. 2008;51:1494–1506. doi:10.1044/1092-4388(2008/07-0181).
39. Erickson-Levendoski E, Sundarrajan A, Sivasankar P. Reducing the negative vocal effects of superficial laryngeal dehydration with humidification. *Ann Otol Rhinol Laryngol*. 2014;123:47–481. doi:10.1177/0003489414527230.
40. Patel RR, Walker R, Sivasankar PM. Spatiotemporal quantification of vocal fold vibration after exposure to superficial laryngeal dehydration: a preliminary study. *J Voice*. 2015;30:427–433. doi:10.1016/j.jvoice.2015.07.009.
41. Sivasankar M, Erickson E. Short-duration accelerated breathing challenges affect phonation. *Laryngoscope*. 2009;119:1658–1663. doi:10.1002/lary.20530.
42. International Monetary Fund. World Economic and Financial Surveys World Economic Outlook Database—WEO Groups and Aggregates Information; 2015.
43. Mahalingham S, Boominathan P. Effects of steam inhalation on voice-quality related acoustic measures. *Laryngoscope*. 2016;126:2305–2309. doi:10.1002/lary.25933.
44. Fujiki RB, Chapleau A, Sundarajjan A, et al. The interaction of surface hydration and vocal loading on voice measures. *J Voice*. 2016;31:211–217. doi:10.1016/j.jvoice.2016.07.005.
45. Sundarrajan A, Fujiki RB, Loerch SE, et al. Vocal loading and environmental humidity effects in older adults. *J Voice*. 2017;doi:10.1016/j.jvoice.2017 .02.002. Article in press.
46. Leydon C, Wroblewski M, Eichorn N, et al. A meta-analysis of outcomes of hydration intervention on phonation threshold pressure. *J Voice*. 2010;24:637–643. doi:10.1016/j.jvoice.2009.06.001.