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# Effects of Hydration on Voice Acoustics

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One of the most important aspects of communication is the human voice, which can express more than words alone. The voice speaks for itself, providing infinite nuances for communication. The voice conveys a wealth of information about a speaker, and it is as unique as an individual's face (Greene, 1991). The power of human voice is demonstrated every day in telephone conversations, radio communications, public address systems, professional exchanges, and chats among friends (Kent, 1997). However, the human voice relies on a biological structure, the larynx, which is susceptible to injury and disease and needs to be treated carefully.

ABSTRACT: **Purpose:** Caring for the professional voice involves an understanding of the aspects of vocal function and the aspects affecting vocal function. The significance of the voice is especially obvious for individuals whose careers rely on speech. Clinical advice and support programs to improve voice conditions for professional voice users should be based on a foundation of empirical research. The purpose of this study was to increase scientific knowledge in determining the effects of hydration on vocal performance.
**Method:** A sample of students ranging between 18 and 35 years of age and not presenting a history of voice disorder was used in this study. Two repeated measures designs were applied to the data analysis, allowing investigation of the effects of hydration on the voice of participants using two parameters of perturbation, jitter and shimmer, in vocal fold vibration as dependent variables across the two levels of the intervention. Jitter and shimmer are objective indicators of variability in vocal fold vibration.
**Result:** Statistically significant reduction of jitter and shimmer on systemic hydration supports the claim that hydration has a positive impact on voice.

KEY WORDS: jitter, shimmer, professional voice, systemic hydration, variability in vocal fold vibration

The significance of the voice is especially clear for people whose careers rely on speech. Judgments about their work may be linked to their vocal performance, which often needs to be excellent (Kaufman & Blalock, 1988). With the advent of the information age, voice has assumed an increasingly important role in job functioning (Verdolini & Ramig, 2001). It has been estimated that 5%–10% of the workforce in the United States are heavy occupational voice users (Titze, Lemke, & Montequin, 1997). The term *occupational voice* is becoming increasingly important as more people rely on their voices for work (Williams, 2003). Individuals who use the spoken voice as an occupational instrument are susceptible to voice problems because their vocal use occurs frequently, and at times may be exhausting (Kaufman & Blalock, 1988).

A general consensus is that systemic hydration is important for the prevention and treatment of voice disorders. Clinical advice to improve hydration status is widely given and should have empirical substance. However, few studies have been conducted to investigate the effects of hydration status on acoustic voice parameters. The objective of this study was to enrich the scientific literature by investigating and quantifying acoustic changes in the voice related to two different conditions: hydration and dehydration. Jitter and shimmer, which are measures of perturbation that reflect the quality of voice production, were applied. Jitter and shimmer are objective indicators of rate variation of vocal fold vibration that correlate with perceptual indications of voice quality (Martens, Versnel, & Dejonckere, 2007; Ng, Wong, Wei, Wong, & Lam, 2008; Yiu, Murdoc, Hird, & Lau, 2002).


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Investigations involving a variety of professions that use voice as an occupational instrument, such as teachers and singers, have demonstrated that there are occupational issues that interfere with routine vocal function and can ultimately affect career development (Milbrath & Solomon, 2003; Roy et al., 2002; Roy et al., 2004; Rubin, Korovin, & Epstein, 2003; Smith, Gray, Dove, Kirchner, & Heras, 1997; Titze et al., 1997; Williams, 2003; Yiu & Chan, 2003). Appropriate hydration has been identified as a therapeutic and preventive approach to minimize voice problems (Titze & Verdolini, in press). According to Roy et al. (2002), the focus of most prior studies has been the impact of hydration on vocal function as measured by phonation effort.

## Systemic/Surface Dehydration Related to Voice Performance

Systemic and surface body dehydration are thought to be reflected in the vocal fold mucosa, increasing its viscosity and reducing mucosa mobility (Verdolini-Marston, Sandage, & Titze, 1994; Verdolini-Marston, Titze, & Druker, 1990). Excessively dry vocal folds are irritated by repeated impact more easily than are folds with normal lubrication. Thick and sticky secretions may increase the weight of a fold, impeding smooth vibratory patterns and predisposing the speaker to habituate coughing and throat clearing, which may exacerbate irritation (Andrews, 1999). The process of systemic hydration occurs when fluids that are ingested are transported throughout the body by the vascular system after being absorbed by intestinal cells and transferred to the capillary network. Homeostasis, a natural mechanism that regulates fluids in the body, is achieved on average across a 24-hr period; therefore, identical hydration levels do not occur in all body tissues at the same time. In addition, temporary and long-term shifts in hydration can occur in the vocal folds (Titze & Verdolini, in press). Several investigations have examined the effects of systemic hydration on voice. Relevant studies associated with the relationship between hydration and voice production will be described throughout the subsequent sections.

In order to determine the relationship between hydration levels and vocal effort, Verdolini-Marston et al. (1994) investigated a combination of systemic and surface hydration/dehydration using a hydration treatment, a dehydration treatment, and a control treatment. The results indicated an inverse relation for phonatory effort and hydration level; that is, positive effects were primarily verified in high-pitched phonation tasks. These findings indicate a possible role of vocal fold tissue viscosity for hydration and dehydration effects. In a study that found similar results, Verdolini-Marston et al. (1990) investigated the biological mechanisms underlying voice changes due to dehydration, specifically, the mechanisms by which dehydration produces changes in the subglottic pressure required for vocal fold oscillation. In this study, 3 groups of untrained healthy adults used either a diuretic, an oral antihistamine, or a placebo (control group). The results supported the hypothesis that systemic dehydration from diuretics increases vocal fold tissue viscosity, thereby increasing the phonation threshold pressure (PTP). It appears, therefore, that dehydration leads to greater phonation effort. Comparisons of systemic hydration and dehydration effects on voice were conducted by Solomon and DiMatia (2000) using PTP as the measure. In their investigation, 3 of the 4 participants demonstrated a greater or an earlier increase in PTP with prolonged loud talking when they were underhydrated. According to the investigators, these results imply that laryngeal tissue viscosity may decrease by drinking water, which supports the hypothesis that systemic hydration decreases PTP.

The effect of dehydration on voice quality was investigated by Selby and Wilson (n.d.) with participants who avoided food and fluid ingestion for 18 hr before simultaneous speech and electrolaryngograph (EGG) recordings. Tasks included the production of sustained vowels at a comfortable fundamental frequency, a reading passage, and informal conversation. After a pretest, each participant drank 2 L of an electrolytic drink and waited 1 hr for full rehydration before the posttest. The investigators concluded that an increase of fundamental frequency in conversation was associated with elevated levels of hydration.

Verdolini-Marston et al. (1994) investigated 6 adult females with laryngeal nodules or polyps using systemic hydration to examine the effects of hydration in persons with voice disorders. In this investigation, each participant received 5 consecutive days of systemic hydration treatment and 5 consecutive days of placebo treatment. The results demonstrated the greatest improvements in voice following the hydration treatment.

Moist vocal fold mucosa should require less subglottic air pressure to oscillate than dry mucosa (Titze, 1988). The effect of relative humidity on voice was investigated by Hemler, Wieneke, and Dejonckere (1997) in dry, humidified, and standard humidity environments using measures that concluded that human voice is very sensitive to decreases in the humidity of inhaled air.

## Hydration Intervention

Hydration interventions such as water ingestion and steam inhalation are often advised for professional voice users and are claimed to benefit voice production by making phonation less effortful (Sataloff, 1991; Verdolini et al., 1994). Systemic hydration is thought to thin secretions, which makes it easier for the voice to perform (Andrews, 1999; Verdolini-Marston et al., 1990; Verdolini-Marston et al., 1994). Systemic and surface hydrating agents such as saline sprays may limit the symptoms of uncomplicated upper respiratory infection, helping to increase the production of a thin and nonviscous layer of mucus, especially during the phase of infection involving reduced secretions of the mucus layer (Harris & Rubin, 2003). Hydration and humidification are usually indicated as complementary treatment for several inflammatory processes that involve the larynx, including common viral laryngitis, acute laryngotracheitis, bacterial laryngitis, allergic laryngitis, traumatic laryngitis, and also radiation laryngitis, which may occur as a consequence of radiation therapy for laryngeal malignancies (Postma & Kaufman, 1993).

Although hydration has traditionally been recommended as a therapeutic and preventive approach to minimize voice problems, its application has also been questioned (Titze & Verdolini, in press). For example, Valtin (2002) claimed that there is a lack of controlled scientific studies to support the common recommendation of eight daily glasses of fluid intake. In order to develop a scientific basis for hydration intervention in the prevention of voice disorders, it is necessary to further investigate the effects of fluid intake and the consequences of its use. Therefore, we designed this study to answer (a) whether a hydration condition would improve jitter, and (b) whether a hydration condition would improve shimmer.

## METHOD

The participants in this investigation were 19 university students ranging in age from 18 to 35 years, all of whom were native English speakers who self-reported normal voice. Participants reported on general and vocal health, indicating, for example, the presence of voice problems; normal usage of voice; and typical use of substances that may affect the normal vocal function or the larynx mucosa such as tobacco, caffeine, alcohol, and medications. The study began with a large sample of students, which was narrowed by eliminating participants with current voice disorders and those who were taking medications that are associated with laryngeal drying issues. To avoid a confound from variation in fundamental frequency across males and females, which could introduce unwanted variability in the data, we included only female participants in the study.

### Experimental Design

A repeated measures design was used in this investigation. Acoustic measurements were obtained from all participants, once before and once after receiving hydration. In this within-participants design, each participant served as her own control, keeping individual differences constant throughout the experiment (Weinfurt, 1995). This procedure substantially reduces error variance, increasing the sensitivity of the experiment and making it a powerful technique (Christensen, 2004; Huck, 2004; Stevens, 1994).

The types of utterances chosen for voice analysis in this investigation were sustained vowels because they elicit a stationary process in vocal fold vibration (Titze, 1994) and reflect the sound power that is produced by the vocal folds, thereby enhancing the chances of controlling intensity for research purposes (Colton & Woo, 2003). In order to obtain a representative selection of vowel sounds, two front vowels, two back vowels, and one central vowel were elected for this investigation: the high-front vowel [i], the low-front vowel [æ], the low-back vowel [a], the high-back vowel [æu], and finally, the central vowel [ʌ]. One investigator modeled the five vowels for participants, along with word examples using each vowel.

In an effort to minimize learning effects that could occur from the dehydration condition to the rehydration condition, the participants were instructed to practice the vocal task before the experimental day by following specific written instructions. Participants were instructed, for example, to refrain from food and liquids for 14 hr before testing. On the day of the experiment, vocal quality was assessed over a period of approximately 2 hr. Each of the two separate tests measured jitter, which was measured as relative average perturbation (RAP), and shimmer on sustained vowels. In order to obtain reliable perturbation measures, multiple tokens of sustained vowels were recorded (Scherer, Vail, & Guo, 1995). The assessment of each condition required three sustained productions of each of the five vowels. Each participant produced three averaged repetitions of five sustained vowels for each condition, yielding a total of 95 data points that were analyzed in both the dehydration and the rehydration condition. During the next 20-min period, each participant ingested 1 L of water. Scientific controlled studies concerning the ideal amount of water intake and time needed for voice benefits have not been conducted (Titze & Verdolini, in press). Therefore, the amount of water and time needed for this experimental procedure was selected based on a pilot project that was conducted before the study, indicating changes in the desired direction. Each participant was required to remain in a quiet environment and avoid talking while waiting for the posttest, which occurred 90 min after beginning water ingestion.

### Variables

The independent variable for the two research questions in this investigation was hydration. There were two levels of the independent variable: a dehydration condition and a rehydration condition. The dependent variable for the first research question was jitter. Jitter is defined as variation of the frequency (number of cycles or events per unit) of successive cycles (Titze, 1994). Jitter was demonstrated by the RAP parameter, which provides an evaluation of the variability of the pitch period within the analyzed voice sample at smoothing factor 3 periods (Gonzales & Carpi, 2004). Shimmer is defined as short-term (cycle-to-cycle) variability in vocal fold vibration amplitude (Titze, 1994). The dehydration condition was defined as fasting for 14 hr, or not ingesting foods or liquids for this period of time. The rehydration condition was defined as ingesting 1 L of water in a period of 20 min.

### Data Collection

Each vowel production was captured three times using the Multi-Dimension Voice Program (MDVP) module of Visi-Pitch IV Model 3950 of Kay Elemetrics, which is equipped with analog input/output channels with a frequency response of 5 Hz–22 Hz (Kay Elemetrics, 2004). The computer software was installed on a 500 MHz Pentium III PC with 64 MB RAM and a Windows XP operating system. The Visi-Pitch generates a square wave that matches the periods of the analog signal stored in the program-read-only-memory and is retrieved by the computer (Karnel et al., 1991). The MDVP is a multiparameter acoustic analysis tool (Gonzales & Carpi, 2004). The MDVP module acquires, analyzes, and displays voice parameters from vocalizations, such as RAP and shimmer.

Participants were instructed to stand and maintain a 10-cm mouth-to-microphone distance, as suggested by Titze (1994), and to maintain constant pitch and loudness throughout the recording, as suggested by Karnell, Scherer, and Fischer (1991). In order to obtain stability in the fundamental frequency of utterances, the habitual pitch was estimated for each participant using an electronic keyboard (Yamaha F.150). Each individual produced a comfortable pitch, which was identified in the keyboard and was recorded for future reference. Additionally, participants were required to produce voice with a comfortable intensity multiple times before data collection (Titze, 1994). Loudness trials were analyzed using the real-time mode of the Visi-Pitch. All trials tokens were kept within the normal conversational range of 50 dB–70 dB (Andrews, 1999).

Next, a professional cardioid microphone (Shure Dynamic Model BG with a frequency response of 85 Hz–14,000 Hz) was placed on a stand for stability, and a straw measuring 10 cm was strategically positioned to maintain the necessary mouth-to-microphone distance. Recommendations for optimal acquisition of acoustic voice signals using off-axis positioning of 45º to 90º from the mouth axis were observed in order to reduce any aerodynamic noise from the mouth in speech. Additionally, the ambient noise in the room was kept under 50 dB (Titze, 1994). A token corresponding to 0.5 s was selected from the second half of the second second of each vowel sound produced by each participant. The statistical profile of RAP (jitter) and shimmer were extracted for each token.

## Data Analysis

A statistical comparison of the dehydration condition and rehydration condition values was calculated using SPSS software version 12.0. Demographic information for this population included age, typical use of voice, and past incidence of voice disorder (Table 1). In addition, the participants' profile contained questions concerning the amount of their tobacco, alcohol, and caffeine use. This qualitative data was collected with the purpose of conducting post-hoc analyses associating extreme results to specific aspects, such as lifestyle characteristics. Frequency distributions were applied to examine demographic information in relation to the results.

## Measurement Reliability

In order to assess reliability across vocalizations, 10% of the data were further examined. Randomly selected portions corresponding to 10% of the jitter and shimmer values associated to the measurements of each condition were analyzed. Pearson's product–moment correlation coefficients of .44 to .89 were found in association to jitter during the dehydration condition, and of .78 to .96 in association to jitter during the rehydration condition. Regarding shimmer, correlation coefficients of .56 to .91 were established during the dehydration condition, and .83 to .97 for the posttest. These results indicate suitability and reliability during the rehydration condition.

# RESULTS

## Data Analysis

The hydration condition data were analyzed using two one-way repeated measures analyses of variance (ANOVAs). Because a change in the level of significance will affect the risk for both Type I and Type II error, the traditional alpha level of .05 was selected for the current study (Huck, 2004). The one-way repeated measures ANOVA was applied because each participant was tested before the hydration intervention (i.e., the dehydration condition) and after the hydration intervention (i.e., the rehydration condition).

Results related to the impact of the hydration condition on voice performance as measured by RAP were found to have statistical significance. The significant results led to the conclusion that the hydration condition had a positive impact on voice performance ($M$ = .74; $SD$ = .47) when compared to the dehydration condition ($M$ = .88; $SD$ = .47). RAP statistics related to the rehydration condition

**Table 1.** Summary of study participants' voice usage.

| *Component* | *Description* |
|---|---|
| Gender | Female |
| Age range | 18–35 |
| Typical environment of voice usage | Home and school (1 participant indicated singing at church, another participant described reading books on tape) |
| Hours per day speaking | 5–13 |
| Smoking | 3 participants |
| Alcohol | 10 participants reported having an average of 4–7 drinks on weekends |
| Caffeine | 3 coffee consumers, 3 soda consumers, 7 coffee & soda consumers |
| Health self-rating (on general health as well as specific digestive, respiratory, and hearing disorders) | 1 report of asthma, 1 report of asthma and allergies, 3 reports of mild allergies |

were within the range of normative threshold, which, according to Kay Elemetrics (2004), is .68, as opposed to the average RAP level of .88 during the dehydration condition. Practical significance of the results was demonstrated by eta-squared, the strength-of-association index, of .107. Cohen (1988) characterizes $\chi^2 = .01$ as a small effect size, $\chi^2 = .06$ as a medium effect size, and $\chi^2 = .14$ as a large effect size. Thus, the effect size of .08 may be classified as a medium effect size. Additionally, the calculated power for the RAP test was .807. According to Huck (2004), a power of approximately .80 indicates a relatively comfortable situation where Type I and Type II errors are avoided most of the time. In other words, within reasonable power parameters, it is less expected to reject true null hypotheses or fail to reject false hypotheses.

Results related to the impact of the hydration condition on voice performance as measured by shimmer were also found to have statistical significance. The significant results led to the conclusion that the hydration condition had a positive impact on shimmer ($M$ = 3.97; $SD$ = 1.88) when compared to the dehydration condition ($M$ = 4.42; $SD$ = 1.68). Shimmer statistics related to the rehydration condition were within the range of normative threshold, which, according to Kay Elemetrics (2004), is 3.81, as opposed to the average shimmer level of 4.5 during the dehydration condition. The effect size of .107 may be classified as a medium effect size. The calculated power for the shimmer test was .914.

## DISCUSSION

Although the data supported both research questions, the method did not create the expected results in every participant. Although it was not the focus of this study to analyze every possibility, it is interesting to observe that not every outcome was consistent with the majority of data. For example, the person who demonstrated the largest decrease in jitter and shimmer after rehydration was Participant 2, whose average RAP decreased by .64 and whose shimmer decreased by 2.8. Participant 11, however, increased RAP after rehydration by an average of .17 and increased shimmer by an average of 1.5. The increase in jitter and shimmer may be explained in part by the fact that Participant 11 reported having allergies.

Because significance was found when using the data from all of the vowels, a post-hoc analysis was conducted on the five distinct vowels. Analysis of each vowel separately by grouping the results of all participants revealed a decrease related to every vowel comparison for both jitter and shimmer after the rehydration condition. However, not all comparisons demonstrated statistically significant results. Applying repeated measures ANOVAs to each vowel comparison using voice productions of all 19 participants, the decrease in jitter for vowels [i] and [æ] was statistically significant at the .05 alpha level, whereas the decrease in jitter for vowels [ʌ], [u], and [a] was not statistically significant at the .05 alpha level. When applying repeated measures ANOVAs to each vowel comparison using the voice productions of all 19 participants, the decrease in shimmer for vowels [æ] and [ʌ] was statistically significant at the .05 alpha level, whereas the decrease in shimmer for vowels [i], [u], and [a] was not statistically significant at the .05 alpha level. In a broad sense, the decrease in every single comparison reveals that the effects of the hydration condition on the vocal acoustics as measured by jitter and shimmer point in a positive direction, even though statistical significance was not verified at all levels.

The lack of statistically significant decreases for some of the utterances when individual vowels were inspected may be explained by the point of vowel production. Vowel production is commonly described according to certain parameters, such as vocal tract shape, the part of the tongue that is raised, and the extent to which the tongue is raised in the direction of the palate (Kent, 1998; Story, 2002). The vowel quadrilateral of General American English describes vowels according to the horizontal and vertical dimensions (Shriberg & Kent, 1995). Divisions along a horizontal plane are related to the section of the tongue that is elevated, generating a classification of front, central, and back vowels. Points along a vertical plane give high, mid, and low vowels relating to the extent to which the tongue is raised (Bauman-Waengler, 2004).

Jitter values decreased significantly after the rehydration condition for the [i] and [æ] utterances, both of which are considered front vowels. Shimmer values decreased significantly for [æ], a front vowel, and [ʌ], a central vowel. Thus, most of the statistically significant results involved front vowels.

### Limitations

The participants in this investigation were female college students who ranged between 19 and 35 years of age and reported no voice disorders. Thus, results need to be interpreted with caution because the results were derived from a limited sample. In addition, although the investigator stressed to all participants the importance of avoiding ingesting liquids and food during the stipulated time before the pretest, it was not possible to ensure that all participants strictly followed the instructions. It would be helpful to increase nourishment control during the required time. One possible way is to assign family members, roommates, or partners to join the experiment by monitoring the participant's behavior during the 14 hr before testing. This procedure would add to self-reporting records, strengthening the reliability of the research.

The present study used participants who belong to one gender and a limited range of years of age, patterns of vocal use or misuse, and with no voice disorders. The reason for following these guidelines was to obtain experimental control by avoiding confound caused by extraneous variables.

### Conclusion

This study provided evidence that was consistent with previous investigations concerning the impact of hydration on voice. Results from this study have a variety of implications and uses. Determining preventive and therapeutic procedures that are applicable and manageable has important implications for people who use their voice as a work instrument.

Further studies should be conducted using participants who belong to other groups. One potential replication of this investigation could be developed using young males with no voice disorders. This course of action would establish an attempt to measure the impact of body hydration in the voice performance of males as determined by jitter and shimmer scores. Moreover, having equivalent conditions in two distinct investigations would create an opportunity to compare the effect of systemic hydration conditions on the voice performance of males and females. Other supplementary studies would use participants from other age ranges and levels of vocal use, as well as individuals with a variety of voice disorders.

Finally, extended research concerning the effect of hydration on the voice might be achieved by employing a variety of dependent variables. Past studies have been conducted on measures of PTP using specific populations. A replication of the procedures performed in the investigation using PTP as an assessment could contribute to scientific knowledge of voice hydration relationships.

Results from this study may be applied in prevention planning for voice disorders as well as voice counseling and treatment. Therefore, these findings may be useful for professionals who provide services in the voice field, such as speech-language pathologists and voice coaches. In addition, employers of individuals for whom voice performance is a work requirement may benefit from the application of the results of this research. Finally, this study could inspire future research on the relationship of systemic hydration and voice performance.

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