An Essay on the Evidence Base of Vocal Hygiene

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INTRODUCTION

The voice is nothing but beaten air —
Seneca (Lucius Annaeus Seneca),
Naturalinum Quoestionum (bk. II)

Despite the fundamental simplicity of the vocal mechanism, it holds extraordinary power. While an expressive, confident, engaging voice is extremely useful in most areas of life, a tired, lackadaisical voice can have equally damaging impact on a person's social interactions and self-esteem.[1] Voice function also can have a sizeable social and economic impact; in November 2004, the TUC, Britain's congress of trades union, stated the UK economy was losing an estimated £200m a year because of voice problems among workers.[2] The prevention of voice problems has a psychological, medical, social, and economic rationale.

But what is the nature of these problems? The most commonly reported voice problem is vocal fatigue, typified by effortful phonation and a self-perceived tired, weak voice.[3] It tends to be related to specific vocal behaviors, including misuse and overuse of the voice. Recently, a number of authors have assessed the impact of vocal fatigue within different occupational environments.[4]

How can voice problems be prevented? We all have intuitive ideas about what types of behavior are "good for the voice." Singing websites advocate a range of "vocal hygiene" (VH) measures that do not appear to be based on any empirical findings. However, evidence does exist that the speech and language therapist has an important role in supplying vocal hygiene advice to a range of groups susceptible to voice problems, including professional actors, singers, and teachers.[5]

In clinic, a range of measures often is recommended to those complaining of vocal problems, including various voice supporting measures such as direct steam inhalation, ambient humidification, and ingestion of mucolytics (drugs that thin the mucus lining of the laryngeal mucosa). Conversely, it is advised that certain behaviors are avoided that will tend to "dry out" the voice, including, smoking, drinking alcohol and caffeine, and spending time in smoky or dusty environments. While a number of pharmacological agents have detrimental effects on voice production, avoidance of these agents is not part of the standard vocal hygiene regimen, except in the case of caffeine. Avoidance of caffeine is a feature of the advice given out not only by speech and language therapists, but also by teachers of singing and other voice "experts." Despite the prevalence of this advice, it seems only a limited amount of scientific work has been done to link caffeine ingestion with changes in voice quality.[6]

Why does VH advice take the form it does? While empirical data may have played a significant role in originating VH advice, it seems likely that historical and anecdotal factors account for some aspects of vocal hygiene behavior. For example, there is a popularly held belief that milk intake is detrimental to voice quality because of effects on mucus production;[7] however, a Medline search produced no clinical data that assessed the impact of milk on voice production. A complex meshwork of historical factors and anecdotal evidence appears to have originated much of today's frequently used VH advice. This is especially the case among singers, where the practice of a vocal warm-up is usual before a performance. Despite the undoubted popularity of vocal warm-ups, there is as yet only a limited understanding of what is going in the larynx physiologically as the voice "warms up." All in all, behaviors invoked as being "good for the voice" by the scientific community and others do not seem to carry a large body of scientific data. This does not represent an ideal situation; a rigorously tested program of "evidence-based" vocal hygiene advice would be preferable to a situation where some advice appears to lack a significant basis in experimental fact. Thorough programs of research in this area have been hampered by the confounding effect of different levels of training among study participants; voice function varies considerably with the amount of vocal experience a person has.[8]

This study will attempt to analyze clinical and biomedical evidence for four aspects of VH: the promotion of adequate hydration, the avoidance of caffeine intake, the avoidance of milk products, and advocacy of a warm-up before extended periods of voice use. The impact of these findings on models of voice function also will be considered.

BACKGROUND

To analyze the effectiveness of these various VH measures, an index of vocal function is required. It seems reasonable to select the voice problem most frequently reported in the general population, that of vocal fatigue (VF). For the purpose of this study, VF will be defined as a clinical syndrome that arises as a result of overuse, or misuse, of the vocal apparatus.[9] However, as Welham notes, considerable debate continues regarding the exact definition of the VF phenomenon.[10] In general, most authors agree that the VF process involves a decrease in the efficiency of voice production.[11] Symptoms of vocal fatigue are legion, and sometimes vary among individuals (Table 1).[12] Apart from the sheer variety of ways in which someone with VF may present, the concept also raises problems for the clinical scientist. How is the severity of VF to be quantified? If we are to compare the effects of various voice treatments on VF, then we must have a way of measuring VF.

One approach to the problem of finding a physiological correlate of VF symptoms has been to reduce the clinical phenomenon to a biochemical and biomechanical process. However, even this method has floundered. A number of hypotheses exist as to what is going on microscopically during VF. Posited mechanisms of VF include neuromuscular fatigue,[13] increased vocal fold viscosity,[14] reduced perfusion of vocal apparatus, leading to an accumulation of lactic acid in the voice box,[15] fatigue of the respiratory apparatus, and deformation of the nonmuscular vocal tissue.[16] It appears that the issue of the cellular mechanism of VF has not been resolved.[17]

TABLE 1. Symptoms of vocal fatigue.

Hoarse/husky vocal quality	Running out of breath while talking
Breathy vocal quality	Unsteady voice
Loss of voice	Tension in neck/shoulders
Pitch breaks	Throat/neck pain
Inability to maintain typical pitch	Throat fatigue
Reduced pitch range	Throat tightness/constriction
Lack of vocal carrying power	Pain on swallowing
Reduced loudness range	Increased need to cough/throat clear
Need to use greater vocal effort	Discomfort in chest, ears, or back of neck

Another way of in some way quantifying VF has been to use clinically measurable parameters that appear to correlate with VF symptoms.

1. Phonatory threshold pressure (PTP)

Defined as the minimum subglottal pressure required to initiate phonation, PTP has been related to changes in voice function, principally by the theoretical work of Titze, who rationalized PTP in terms of several biophysical variables.[18] In the formula,

$$PTP = (2k/T)(Bc)(w/2),$$

Titze indicates that where k is a transglottal pressure coefficient (around 1.1), T stands for vocal fold thickness, B is a damping coefficient proportional to viscosity, c represents velocity of mucosal wave, $w/2$ is prephonatory glottal half-width, and viscosity is proportional to PTP.

As an index of the aerodynamic efficiency of phonation, this formula highlights the importance of tissue viscosity in allowing good voice production. Indeed, the work of Finkelhor, et al. has corroborated the idea of tissue viscosity being related to PTP: bathing excised canine larynges in fluid of different viscosities produced increased PTP when the tissue viscosity was increased.[19] However, as well as the problem of extrapolating from canines to humans, the inability to accurately measure vocal fold viscosity *in vivo* sheds some doubt on the effectiveness of PTP as a measure of VF on its own. Furthermore, one would expect a clinical-pathological correlation to exist between PTP and self-perceived phonatory effort. While a recent paper found a moderately significant association between the two,[20] previous results have been equivocal; for example, Verdolini-Marston, et al. stated that self-perceived phonatory effort may represent a more sensitive indicator of vocal fatigue than an estimated PTP, although PTP and effort were not measured at the same time.[21] They also found a high degree of inter-subject variability in PTP in their cohort, all of whom possessed vocal fold pathologies. The consistency of the PTP variable also can be questioned on the basis of its methodology; it may be possible for a person to "fake" a PTP reading, and Sivasankar and Fisher state the possibility of PTP being lowered by "motor learning."[22] Nevertheless, PTP remains the most popular available guide to voice efficiency.

2. Self-perceived changes in voice

Reports of fatigue symptoms by the subjects are another way of monitoring changes in vocal function. Unfortunately, many different ways of assessing phonatory effort exist, from simple ranking systems of vocal discomfort to a checklist method of recording particular VF symptoms, making it difficult at times to compare findings from different studies directly.[23] Furthermore, it seems likely that there is a considerable degree of variability in the "threshold of vocal discomfort" from subject to subject; the psychological factors involved in the symptoms of vocal fatigue are not well characterized.[24]

3. Laryngeal imaging

Expert rating of laryngoscopic appearance is used to assess directly changes occurring in the vocal folds during vocal loading tasks.[25] However, these approaches have depended upon the objectivity of human laryngological experts, although most studies have found expert rating of laryngeal appearance to be consistent across judges.[26] There are also methodological differences between different studies that have used laryngeal imaging; in Verdolini-Marston, a 1–5 rating of laryngeal appearance was used,[26] while in Solomon, et. al., experts were asked to record the presence of specific features such as oedema, anterior or posterior glottal chink, and "spindle-shaped glottis."[27] This variability in methods raises difficulties in making direct comparisons between different findings.

4. Acoustic measurements: jitter and shimmer

"Jitter" refers to the average cycle to cycle deviation on the period of the phonatory waveform, while "shimmer" is used to define the average cycle to cycle deviation in amplitude. These two variables have been suggested as being as good correlates of the changes in voice quality that occur in VF.[28] One report, however, suggests that these measurements are not sufficiently sensitive or reliable indicators of vocal function to assess the effective of voice treatments.[29] Still, the authors concede that that these measures have a role as part of an "integrated clinical evaluation"; acoustic measures such as jitter, shimmer, and noise to harmonic ratio need to be combined with a range of other indicators of voice function—including perceptual ones.

I have outlined some of the main methods available to quantify voice function. As well as the above, there are other, less commonly used variables, such as irregular-

TABLE 2. A summary of studies investigating the effects of altering hydration on voice.

Name of Study	Intervention	Vocal Load	Voice Changes Associated with the Intervention
Hemler, et al.[a]	Reduced humidity of inspired air	Normal everyday voice use	Increased jitter and shimmer
Solomon[b]	Increased systemic hydration	2 hrs. of loud reading	Increased PTP in 2 subjects, decreased PTP in other 2 subjects
Yiu and Chan[c]	Increased systemic hydration	Karaoke singing for as long as possible	Decreased effort, decreased average jitter, increased duration of singing before tiredness
Verdolini[d]	Decreased systemic hydration using diuretic	Normal everyday voice use	Increased PTP
Sivasankar and Fisher[e]	Increased oral breathing (decreased humidity of air passing across vocal folds)	Singing "Happy Birthday"	Increased PTP, increased self-perceived phonatory effort
Solomon[f]	Increased systemic hydration	2 hrs. of loud reading	Increased PTP, increased self-perceived phonatory effort
Verdolini, et al.[g]	Increased systemic hydration, ambient humidification of inspired air, ingestion of a mucolytic	Normal everyday voice use	Decreased PTP, decreased effort, decreased PTP, better laryngographic expert rating, better auditory expert rating, decreased shimmer, decreased jitter, and decreased signal to noise ratio

[a] I. L. Hemler, G. Wieneke, and P. H. Dejonckere, "The Effect of Relative Humidity of Inhaled Air on Acoustic Parameters of Voice in Normal Subjects," *Journal of Voice* 11, no. 2 (June 1997): 295–300.

[b] N. P. Solomon, L. E. Glaze, R. R. Arnold, and M. van Mersbergen, "Effects of a Vocally Fatiguing Task and Systemic Hydration on Men's Voices," *Journal of Voice* 17, no. 1 (March 2003): 31–46.

[c] E. M. Yiu and R. M. Chan, "Effect of Hydration and Vocal Rest on the Vocal Fatigue in Amateur Karaoke Singers," *Journal of Voice* 17, no. 2 (June 2003): 216–227.

[d] K. Verdolini, Y. Min, I. R. Titze, J. Lemke, K. Brown, M. van Mersbergen, J. Jiang, and K. Fisher, "Biological Mechanisms Underlying Voice Changes Due to Dehydration," *Journal of Speech, Language, and Hearing Research* 45, no. 2 (April 2002): 268–281.

[e] M. Sivasankar and K. V. Fisher, "Oral Breathing Increases Pth and Vocal Effort by Superficial Drying of Vocal Fold Mucosa," *Journal of Voice* 16, no. 2 (June 2002): 172–181.

[f] Solomon, Glaze, Arnold, and van Mersbergen.

[g] K. Verdolini, I. R. Titze, and A. Fennell, "Dependence of Phonatory Effort on Hydration Level," *Journal of Speech and Hearing Research* 37, no. 5 (October 1994): 1001–1007.

ities in fundamental frequency, amplitude, and pitch range. No single method gives a whole picture of VF, and as such the most appropriate approach seems to be to use a variety of different criteria to assess whether a treatment is good or bad for the voice.

DISCUSSION

The Hydration effect—an historical artifact?

As every singer knows, a dry throat is fatal to good tone work.
Irving Voorhees, 1923

A retrospective look at voice pedagogy books offers up a single, overarching model of vocal hygiene: wet is good, dry is bad. According to a massively popular work by Greene, not only is an arid atmosphere "responsible for vocal strain," a dry throat is more susceptible to attack from irritants; "these provoke coughing, which aggravates the damage already in existence."[30] For another writer on the voice, railway trains are damaging for similar reasons; "air laden with black soot, cinders and dust is a poor preparation for a stage performance."[31] Vices such as alcohol and tobacco are advised against because

TABLE 3. Average duration of singing before feeling fatigue.

Groups	Gender	Mean (minute)	Standard Deviation	Minimum	Maximum
HVR	Male	101.74	3.81	96.47	105.47
	Female	102.12	3.50	97.02	105.43
NonHVR	Male	86.15	3.79	82.53	91.60
	Female	84.80	5.45	78.02	92.40

HVR group—with Hydration (100 ml water) and Vocal Rest (one-minute) given between every song; NonHVR group—non-Hydration and non-Vocal Rest group.

of their effects on the wetness of the vocal folds; "as regards the local injury that may be sustained from tobacco, it consists of dryness and congestion of the mucous membranes of the mouth and pharynx."[32] Even apparently less insidious behavior is damaging for the hydration, and therefore performance, of the vocal folds; "sitting late in hot stuffy rooms . . . is especially pernicious, as the heat and irritation combined make the throat doubly sensitive."[33]

These extracts, while eloquently advocating the avoidance of dehydrating conditions, originate in an age before the advent of evidence-based medicine; no empirical evidence is quoted for the effects that are described. In recent years, however, the experimental evidence base for a "hydration effect" on voice function has grown. A number of carefully conducted studies have found that changes in body fluid volume, humidity of inspired air, and other alterations have the potential profoundly to affect voice. As discussed in the previous section, a number of vocal measures have been used. In general, each study employed an intervention (such as systemic hydration or oral breathing), and combined it with some form of vocal load (for example, a period of loud reading) designed to induce vocal fatigue processes. Then, one or more vocal parameters were used to assess whether the intervention had had an effect (Table 2).

With the exception of Solomon, whose results were equivocal with respect to the effects of hydration on PTP, all of the above studies appear to support the advocacy of "hydration treatments" as a VH tool. However, some evidence suggests the hydration effect may not be as strong as has been perceived historically. In the study by Verdolini, et al. a wide range of vocal function measures was used to assess the effectiveness of a hydration "combination treatment" in six female patients with vocal pathologies. While the hydrated group of subjects did have better vocal function compared to their counterparts, who were given a placebo, both the placebo and the hydration treatments were found to improve voice. Furthermore, hydration effect was not found to differ significantly from placebo effect in terms of any of voice measures used. Nevertheless, despite the use of a specific group of subjects outside the normal population, this study does suggest that advocating fluid intake and other hydration behaviors is better for voice than not doing so. Also, the relatively small difference between placebo and hydration could be a manifestation of homeostatic responses to the hydration treatment.

In contrast to Verdolini, other groups have sought to analyze more real-life situations. For example, the karaoke study of Yiu and Chan focused on hydration during an extremely popular vocal behavior. Here, hydration in a normal context, that is, taking on water between songs, did have a significant effect on singing duration (Table 3).[34] It remains to be seen whether similar results will be obtained in professional singers and other groups at high risk of vocal fatigue.

Thus, it is possible to relate a positive hydration effect to a series of vocal behaviors (Figure 1).

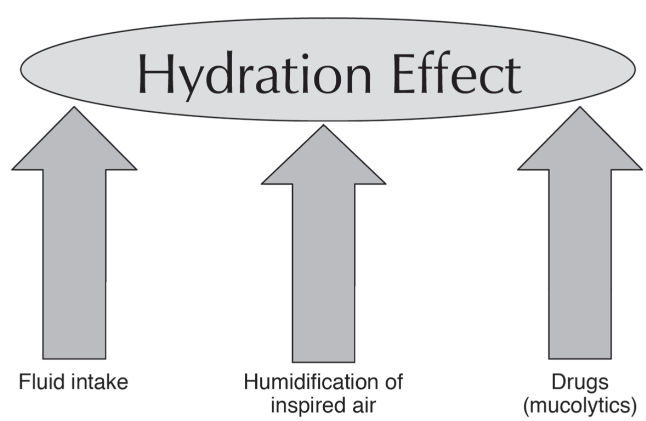

Figure 1. Behaviors and the hydration effect.

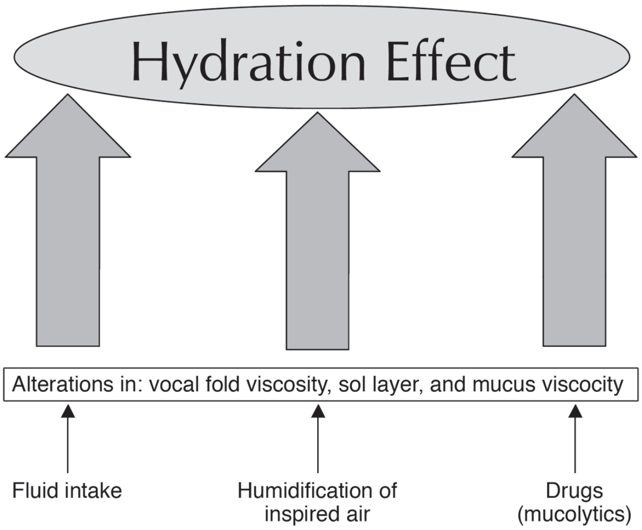

Figure 2. The relationship between VH behavior, the vocal mechanism, and the hydration effect.

The mechanism of the hydration effect

While Figure 1 links a series of VH behaviors to a hydration effect that improves the voice and alleviates vocal fatigue, it also raises some important questions. Having characterized the behaviors that are responsible for the hydration effect, the mechanism of the effect remains to be considered. Many studies, such as the two Verdolini papers, have used a combination of VH interventions.[35] This has made it difficult to assign the hydration effect specifically to one behavior or the other. Knowledge of the mechanism of the hydration effect could be crucial in determining the optimal behavior for maximizing vocal health benefit, and even lead to completely new therapies for vocal fatigue.[36] Three broad mechanisms have been postulated for the effect of hydration on voice: viscosity of the vocal fold mucosa, alterations in the sol layer (a film of surface water covering the vocal folds), and change in the viscosity in the mucus secretions overlying the sol layer (Figure 2). We will consider each in turn.

Viscosity of the vocal fold mucosa. The dominant hypothesis for the mechanism of the hydration effect has been modification of vocal fold viscosity. The viscosity of pure water is 0.01 Poise (*P*), while that of normal body tissues is 100*P*. The vocal folds, structures adapted for high levels of vibration and shear stress, have a viscosity intermediate between these two, between 1 and 10*P*. Titze proposed that an increase in water content of the vocal fold could cause a reduction in its viscosity and a concomitant reduction in PTP and perceived phonatory effort.[37] While the link between hydration and viscosity has been corroborated in other areas, for example, in mucus and tracheal secretions,[38] an inability to measure *in vivo* vocal fold viscosity directly has rendered *in vivo* proof impossible. Nevertheless, a number of findings indicate strongly that a link between hydration and vocal fold viscosity indeed does exist. In the Finkelhor study, osmotically induced alterations in the hydration status of four excised canine larynges were found to correlate with PTP, supporting a model linking increased hydration, decreased vocal fold viscosity and decreased PTP.[39] In a slightly more invasive protocol, submucosal fat grafts into injured canine vocal fold tissue decreased phonation threshold, linking decreased viscosity with a fall in PTP. Chan suggests that the Hyaluronic Acid (HA) content of the vocal folds is a key factor in regulating the water content and, hence, viscosity of the vocal folds; men have a higher HA content than women, and have lowered PTP values.[40]

However, a number of observations suggest that other factors, in addition to vocal fold viscosity, could have a role in the hydration effect. Some studies have found that PTP does not always correlate with whole body hydration status.[41] Another strand of exploration of the hydration effect has considered the effects of surface hydration at two histological sites, first at the sol layer, and also at the mucus layer of the vocal fold.

The sol layer and the viscosity of mucus secretions. The sol layer is a 10µm layer of surface water that lines the vocal fold. It is sometimes referred to as the "sol phase" of the overlying mucus layer. As well as providing mechanical support for the vocal folds against shear stresses and contact damage, it also has an important role in the lubrication of the vocal mechanism.[42] The sol layer also reduces the contact adhesiveness of the vocal folds as they come together during phonation, thereby reducing collision and shear stresses. An increase in adhesive forces, or stickiness, is associated with increased frequency perturbation and an impairment of acoustic voice parameters such as jitter and shimmer. Because the sol layer is in relatively close apposition with the inspired air, it could be hypothesized that alterations in the water content of inspired air have an impact on the thickness of the sol layer, and, hence

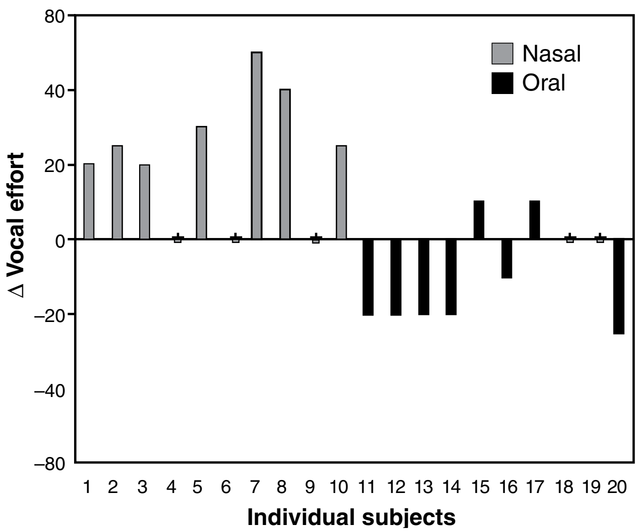

Figure 3. Mean effort ratings (pretreatment–posttreatment) for individual subjects. Nasal breathers and oral breathers are represented by stippled and filled bars, respectively. Filled stars represent subjects who showed no change in their vocal effort.

the ease and efficiency of phonation. Subjects who undertook fifteen minutes of oral breathing (where air would be expected to circumvent the warming and humidification effects of the nasal passages) were found to have increased PTP and phonatory effort compared to another group which undertook fifteen minutes of nasal breathing (Figure 3).[43]

Nasal breathing was advocated by the vocal physiologist Holmes: "the inside of the throat may suffer from its drying influence as it rushes in a large body over the mucous membrane."[44] The long standing anecdotal evidence for the benefits of nasal breathing in singers appears to have been backed up empirically by the findings of Sivasankar and Fisher.[45]

Other than nasal breathing, how else could the sol layer be regulated? In another study by the Fisher group, Western blotting, immunocytochemistry, and pharmacological techniques were used to characterize a vocal fold Na^+/K^+ ATPase α-subunit.[46] Addition of acetylstrophanthidin, a potent inhibitor of the human Na^+/K^+ ATPases, produced a rundown of the lumen-negative potential difference in the larynx and a decrease in water flux from the lumen in to the basal mucosal layer. This finding specifically raises the possibility of improving VH methods through the administration of specific topical agents. If the vocal Na^+/K^+ ATPase is subject to pharmacological regulation as this study suggests, then the pharmacological modulation of the vocal Na^+/K^+ ATPase could be a method of improving vocal function in clinic.

This possibility was more directly explored by Roy, et al., who found that the administration of nebulized mannitol, a hyperosmolar agent, produced a short-lasting reduction in PTP.[47] Mannitol was hypothesized to draw water from the vocal fold mucosa into the mucus lining of the vocal fold, leading to a decrease in the viscosity of the mucus blanket of the vocal folds, thereby decreasing PTP (Figure 4).

While the effects of mannitol were extremely fleeting, only a small amount was used, and, overall, the findings of this study do raise the possibly of designing topical agents that could improve vocal fold hydration by augmenting both the sol layer and the mucus lining the vocal folds.

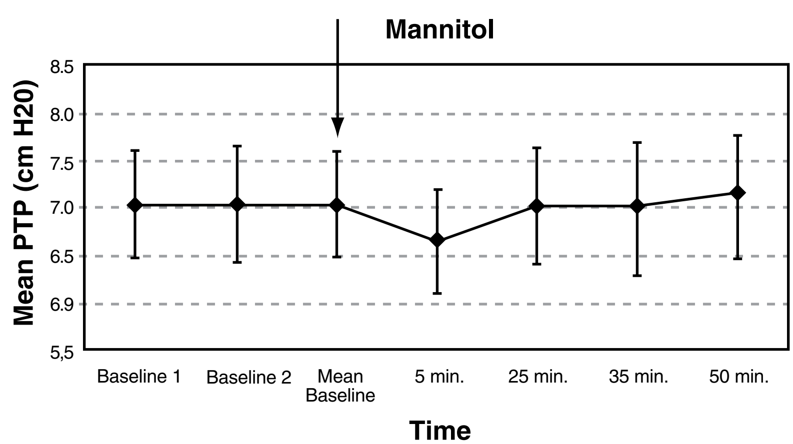

Figure 4. The effects of nebulized 2*mls* mannitol on PTP.

On the other hand, the avoidance of ingestible agents that have the opposite effect to mannitol, and increase the viscosity of mucus secretions, could be another VH recommendation. Milk is one of the agents that has been invoked anecdotally as increasing the thickness of mucus and therefore impairing voice. The website of the Greater Baltimore Medical Center suggests that milk ingestion increases the production of mucus. Similarly, the Head and Neck Surgery Department at a Virginia hospital advocates the avoidance of milk as it "thickens the mucus," as does the University of California—Davis School of Medicine. The vocal health writer Robert T. Sataloff states that "the casein in milk increases and thickens mucus secretions." A number of musical websites such as those of Judy Rodman, Anne Peckham, Denise Leigh, VocalUniverse, and WomanRock similarly advocate the avoidance of milk and dairy products because they adversely affect voice.

Unfortunately, a careful literature search of Medline produced no studies linking milk ingestion to adverse effects on voice, except in the case of children with milk allergy. Pinnock established that the belief that milk produces mucus was prevalent in the Australian population, and correlated with a 33 percent reduction in the ingestion of milk.[48] Among holders of the so-called "milk-mucus" belief, drinking milk caused a perceived difficulty in swallowing and an increased thickness of mucus, among other "congestive" symptoms. No association between milk intake and congestive symptoms was found. Interestingly, a 1993 study by Pinnock concluded that whether you held the milk-mucus belief or not was a significant indicator of whether or not you would report symptoms with milk intake.[49] So, it appears that while the milk-mucus belief is prominent among the general population, at no point has it been correlated with objective scientific findings relating to either mucus production or voice function. A retrospective consideration shows that, historically, milk ingestion even has been recommended by vocal theorists. Mandl suggests that the famous opera star Troy took milk before a performance.[50] Greene advocates dairy products as being protective against infection: "a balanced diet containing sufficient proteins—milk, eggs, fish, meat . . . provides the best immunity to colds." [51] Overall, this evidence suggests that milk avoidance is not appropriate VH strategy in light of the lack of any clinical evidence suggesting a direct effect of dairy products on vocal function.

The caffeine problem

The prevalence of the milk-mucus belief among singers and their teachers renders it an important issue for analysis. Caffeine is another agent that has putative negative effects on vocal function. Holmes describes caffeine as a "dietetic substance [that] should be taken in moderation."[52] Mackenzie suggests that "tea and coffee should be taken rather tepid than hot."[53] Today, the Center for Voice at Northwestern University and the University of Pittsburgh Voice Center both advocate the avoidance of caffeine on the basis of its diuretic properties. The National Center for Voice and Speech, an organization headed by distinguished phonation scientist Ingo Titze, advocates the limitation of caffeine for similar reasons. Although an Internet search yielded no advice that went contrary to these sources, a few historical sources did appear to advocate caffeine as a vocal enhancer. The *Pall Mall Gazette*, in a list of distinguished opera singers and their performance habits, said tenor Walter took cold black coffee before a performance, while Mlle. Brown-Biri drank a small cup of milky coffee after Act IV![54] Greene suggests that "a thermos of coffee can be brought from home and consumed in the office." [55]

Both sympathomimetic and diuretic actions of caffeine lead to a putative dehydrating action, based on the distribution of methylxanthine into all body fluid compartments.[56] Despite caffeine's reputation as a potent diuretic, however, evidence is lacking for a significant effect of caffeine on body fluid balance. A study performed by Grandjean, et al. found that the intake of caffeinated drinks had no significant effects on hydration status (measured by body weight loss and urinary output).[57] While this finding does not rule out a local dehydrating action of caffeine on the vocal fold mucosa, caffeine's diuretic effects are not significant enough to be implicated in the alterations in vocal fold hydration. On the same point, a study by Fiala, et al. found that rehydration with caffeinated drinks during exercise did not hinder hydration status.[58]

Could caffeine's reputation as a detrimental voice agent be related to more direct, local effects on the vocal mucosa? A small 1997 study considered the effects of caffeine ingestion on voice function.[59] Specifically, recordings of fundamental frequency were taken before and after ingestion of a single 200mg Proplus tablet of caffeine. Within the postingestion recordings, three different vocal activities were analyzed: free, conversational speech; reading a passage of prose; and singing the happy birthday tune.

Statistical analysis of all three sets of data was inconclusive, with caffeine found to have an insignificant effect on the results. However, in all three sets of data, at least six of the eight subjects demonstrated some increase in fundamental frequency irregularity (taken to be a measure of disordered voice production) after the vocal loading tasks. Despite this overall pattern, large standard deviation values indicated a great deal of variability between individuals.

Overall this study does not support the use of caffeine avoidance advice as VH strategy. Not only was the measured variable (fundamental frequency irregularity) just one of several voice parameters that correlate with impairment of voice, there also was considerable variation among individuals that use of another parameter, such as self-perceived effort, may have prevented. Indeed, the authors commented on the limitations of the study—the subjects were not matched for age or sex.

So, while this study produced some interesting relationships, none of the results stand up as significant evidence for a detrimental effect of caffeine on voice. While it was found that irregularity of fundamental frequency increased by around eight percent for free speech, the increases were around two percent for other tasks, suggesting that increased breath support (that subjects may have employed for the singing and passage reading) reduces the effect of caffeine on voice. Furthermore, it could be argued that statistical significance is the only barrier to interpreting these results as support for caffeine avoidance. In average terms, all three sets of tasks had increased fundamental frequency irregularity upon caffeine ingestion, although noncaffeine ingestion controls were not undertaken.

Finally, could another mechanism be the key to the belief in caffeine's damaging properties? Caffeine could affect voice via biochemical interactions between caffeine molecules and the fold mucosa, or a change brought about by the CNS stimulatory effects of caffeine, namely alterations in breathing patterns and relaxation of the bronchial smooth muscle. As yet, there has been no detailed analysis of caffeine's relationship with vocal fold function. In terms of VH advice, therefore, sufficient empirical evidence does not exist to recommend caffeine avoidance as a strategy to prevent vocal fatigue.

Vocal warm-up

In other forms of exertion, such as physical exercise, caffeine actually has a positive effect, producing bronchodilatation and increasing cardiac output.[60] The practice of a warm-up (usually a short-term, submaximal activity) before physical exercise has been found to improve physical performance.[61] In singing too, warm-up before performance is a widespread behavior; it is perceived to slow vocal fatigue processes and improve the ease of phonation, and is usually a prerequisite for optimal performance.[62]

If warm-up does have a physiological basis in singers, could warm-up be introduced as part of VH strategies for the general population? Singers appear to be more resistant to vocal fatigue than the general population.[63] Indeed, the application of a long term, systematized vocal warm-up strategy in nonsingers with vocal pathology was found to improve self-perceived and expert rated voice quality.[64] In this study, the subjects received specific warm-up directions. Warm-up exercises were conducted everyday for fifteen minutes. Measurements of voice quality were taken over the course of five measurement sessions; sessions were three weeks apart. While voice apparently improved in all subjects over time, no evidence suggests such an effect persists after exercises are discontinued. Furthermore, it is possible to assign the improvement in voice to factors other than the exercise of the vocal folds. For example, it is stated in the paper that all subjects were given advice on correct posture and breath support.

Aerodynamic changes during warm-up appear to run counter to predictions. Singers report a decreased phonatory effort following a warm-up, which ought to correlate with an decreased PTP. However, a study undertaken by Motel and Fisher contradicts this pattern.[65] In six out of nine subjects, PTH was increased for warm-up at 80 percent of pitch range, while a decrease was reported in phonatory effort. Similar results were not reported for low and comfortable pitches. Motel suggests that the increased ease of phonation at high pitches is brought about by a "stabilizing effect" due to increased viscosity of the vocal folds. Of course, repetition of the study is required before firm conclusions can be drawn; however, it does appear that the effects of warm-up on voice are complex.

A variety of mechanisms for the beneficial effects of vocal warm-up have been proposed. They include direct effects on the vocal fold mucosa or on the underlying vocalis muscle, motor learning, increased attention, and psychological changes associated with preparation for performance.[66] In skeletal muscle, physical warm-up induces a redistribution of ions and water within the muscle tissue.[67] The accumulation of osmotically active waste products in muscle results in the movement of water into exercising tissues, down an osmotic gradient. This results in an decrease in muscle viscosity over the course of physical exercise.[68] Clearly, the observations on vocal warm-up, where PTP is increased at high pitches, which should correspond to an increase in vocal fold viscosity,[69] need to be reconciled with the opposite behavior in skeletal muscle. Motel suggests that an increase in viscosity on vocal warm-up might result from a decrease in water transport into the vocal fold, brought about by temporary capillary collapse during phonation.[70] Overall, while the question of a mechanism for warm-up remains largely open, evidence does exist for the benefits of daily vocal exercise in those with chronic vocal fatigue.

Conclusions

This study analyzed four different vocal hygiene behaviors as treatment for vocal fatigue. A consideration of historical, scientific, and layperson sources produced mixed findings for the different strategies. While strong evidence was found for fluid intake and other hydrating behaviors, evidence for the other three behaviors was less solid. However, the use of a number of different acoustic, aerodynamic, and perceptual measures has made it difficult to directly compare the efficacy of different vocal treatments. Furthermore, small numbers of study participants and different levels of training have hindered drawing firm conclusions from the data.

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