Assessments of Voice Use and Voice Quality Among College/University Singing Students Ages 18–24 Through Ambulatory Monitoring With a Full Accelerometer Signal

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Summary: The multiple social and performance demands placed on college/university singers could put their still-developing voices at risk. Previous ambulatory monitoring studies have analyzed the duration, intensity, and frequency (in Hertz) of voice use among such students. Nevertheless, no studies to date have incorporated the simultaneous acoustic voice quality measures into the acquisition of these measures to allow for direct comparison during the same voicing period. Such data could provide greater insight into how young singers use their voices, as well as identify potential correlations between vocal dose and acoustic changes in voice quality.

The purpose of this study was to assess the voice use and the estimated voice quality of college/university singing students (18–24 years old, N = 19). Ambulatory monitoring was conducted over three full, consecutive weekdays measuring voice from an unprocessed accelerometer signal measured at the neck. From this signal, traditional vocal dose metrics such as phonation percentage, dose time, cycle dose, and distance dose were analyzed. Additional acoustic measures included perceived pitch, pitch strength, long-term average spectrum slope, alpha ratio, dB sound pressure level 1–3 kHz, and harmonic-to-noise ratio. Major findings from more than 800 hours of recording indicated that among these students (a) higher vocal doses correlated significantly with greater voice intensity, more vocal clarity and less perturbation; and (b) there were significant differences in some acoustic voice quality metrics between nonsinging, solo singing, and choral singing.

Key Words: Voice use–Vocal dose–Ambulatory voice monitoring–Vocal pedagogy–Voice quality.

Few previous studies provide empirical data regarding the typical vocal dose acquired by college/university students who participate in multiple singing activities. These students frequently experience heavy vocal demands: voice lessons, choral and theatre activities, student-organized music groups, church activities, busy social lives, sports, and sometimes jobs that involve heavy vocal demands (eg, waiting tables or phone centers).[1] They may develop less-than-desirable sleep and vocal hygiene habits.[2] Further, these students may be unaware of the negative, cumulative effects of heavy vocal loads on their voices, lacking or ignoring training in vocal hygiene.[3]

Both teachers and students would benefit from published, scientific standards of voice use for young singers with developing and stabilizing vocal instruments, but formulation of such standards remains an elusive task. To date, despite a considerable body of literature reporting on the vibratory, acoustic, and perceived effects of vocal loading among various populations, there remains a paucity of data pinpointing when particular vocal inefficiencies may first develop.[4–7] One potential explanation for this gap may be a lack of studies that simultaneously analyze vocal dose and voice quality in a real-time field setting.

Numerous studies, nearly all of them in controlled laboratory situations, have been completed analyzing the effect of vocal load through measurements of acoustic quality and sound pressure level (SPL). A majority of these studies show a positive correlation between potentially related factors (eg, increasing vocal doses, later hours of the day, reports of vocal fatigue, and/or the Lombard effect[8]) and changes in acoustic properties such as increases in fundamental frequency (F_0);[4] loudness (dB SPL),[9,10] harmonic-to-noise ratio (HNR),[11] and spectral energy as measured by long-term average spectrum (LTAS),[9,12] as well as decreases in voice perturbation (shimmer and jitter).[13,14]

It is possible that these acoustic characteristics might relate to vocal fatigue. For example, increases in F_0 and upper frequency LTAS energy have been linked to increases in dB SPL,[15,16] and the above changes to F_0, dB SPL, HNR, shimmer, jitter, and LTAS have been connected to increased muscular activity and tension that occurred following a fatiguing loading activity.[14] Nevertheless, Boucher and Ayad[5] found that individual variations in F_0 did not consistently reflect measured muscular fatigue in laryngeal structures. Further, there have been studies that either showed no change[6,17] or increases in shimmer and jitter following vocal-loading tasks.[18] Acoustic perturbation measures have not yet received attention in ambulatory field studies of voice use, where they could be measured at the vocal source by an accelerometer transducer.

A growing body of studies has also analyzed vocal load in the field, without acoustic voice quality analysis. Voice dosimeters, first developed in the early 2000s, were created to measure vocal dose, defined as vocal fold tissue exposure to vibration over time.[19,20] Rather than relying on acoustic audio-recording methods, these devices used an accelerometer transducer to record skin vibrations in the neck. In this way, phonation activities could be tracked in isolation from ambient sounds. Various methods for accelerometer-based voice dosimetry have been examined in the literature, and techniques for analyzing and calibrating accelerometer signals from

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voice have been discussed.[19,21–23] Švec et al found that mean SPL from voiced speech could be predicted by a skin accelerometer with an accuracy of better than ±2.8 dB.[21] Specifically, Mehta et al[24] showed that although an average F_0 error and estimated average SPL error dropped to 1% after 12 hours and 20 hours of monitoring, respectively, dose calculations past tense needed at least 26 hours of monitoring for average errors to drop below 10%. The study recommended that future voice dosimetry should involve the recording of raw, rather than sampled, accelerometer signals.

Several published studies began to quantify a typical vocal dose among different populations, including teachers,[25–29] children,[30,31] and various populations of singers (eg, high school students,[32] graduate student vocalists,[33,34] and undergraduate student vocalists[1]). Although these studies provided data that addressed questions about the typical vocal doses among different populations, voice data collected included only processed information about the duration, frequency, and amplitude of vibrations with no insight of the efficiency with which those vibrations were produced. Further, these studies did not examine voice quality alongside vocal dose because the dosimeters used in these studies did not allow for simultaneous real-time analysis of spectral and voice perturbation data.

To date, no ambulatory field study of healthy singers has simultaneously acquired a combination of the participants' vocal dose with additional measures obtained from postprocessing of a full recording signal to examine how the quality of vocal production might relate to the vocal dose and the vocal efficiency of each individual. Such measurements in the study of young singers could be important in understanding why some young singers demonstrate declines in vocal efficiency more quickly than others. Anecdotal experience suggests that some young singers may cultivate strong, efficient singing techniques through voice lessons or choral experience, yet develop vocal problems due to poor vocal hygiene, unhealthy quality of speech, and heavy speech doses.[35] The opposite could also be true if young vocalists with efficient speech habits develop inefficient singing habits.

The purpose of this study was to assess the voice use, voice quality, and perceived singing voice function of college/university singing students to answer the following research question: Are there statistically significant relationships between students' vocal dose measures and common metrics related to voice quality as calculated from a raw accelerometer signal?

METHODS

Participants

A convenience sample of 25 traditional-age college/university singing students (18–24 years old), enrolled in both voice lessons and choir, was recruited. The study was approved by the Human Subjects Committee at the primary author's university. None of these students reported a history of any vocal pathology. The students represented four different institutions of higher education (a private 2-year college, a private 4-year college, and two state universities) and five different private voice teachers. Although a balance of men and women was sought in the sample, voice type differences were not considered due to the large number of variables already being considered.

All participants completed a short demographic questionnaire during their first meeting. In addition to confirming their current participation in a college choir and in voice lessons, the questionnaire asked the students to provide details about number of semesters enrolled, estimated hours of singing per week during the current semester, years of voice lesson experience, years of choral experience, and details about any previous vocal limitation/injury that may have required a health-care professional. Because the effect of musical style was not a focus of this study, the participants were not asked to distinguish between their use of classical and contemporary commercial singing styles in solo singing.

Equipment

Recordings were conducted using a Roland R-05 digital audio recorder (Roland Corporation U.S., Los Angeles, CA) with storage to a 16 GB SD card and the collar of VoxLog portable voice analyzer collar (Sonovox AB) (Figure 1), adjusted to comfortably fit the circumference of the participant's neck (Figure 2). Within each collar were two transducers: (1) a Panasonic WM-61A omnidirectional microphone (Panasonic Corporation of North America, Secaucus, NJ) to sample the airborne acoustics, and (2) a Knowles BU-1771 Model accelerometer (Knowles Acoustics, Itasca, IL).

FIGURE 1. VoxLog collar.

FIGURE 2. VoxLog collar worn around the neck and attached to a Roland R-05 Digital Recorder.