

# Effects of Adventitious Acute Vocal Trauma: Relative Fundamental Frequency and Listener Perception

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**Summary: Objective.** High voice users (individuals who demonstrate excessive or loud vocal use) are at risk for developing voice disorders. The objective of this study was to examine, both acoustically and perceptually, vocal changes in healthy speakers after an acute period of high voice use.

**Methods.** Members of a university women's volleyball team ( $n = 12$ ) were recorded a week before (pre) and week after (post) the 10-week spring season;  $n = 6$  control speakers were recorded over the same time period for comparison. Speakers read four sentences, which were analyzed for relative fundamental frequency (RFF). Eight naïve listeners participated in an auditory-perceptual visual sort and rate (VSR) task, in which they rated each voice sample's overall severity and strain.

**Results.** No significant differences were found as a function of time point in the VSR ratings for the volleyball group. Onset cycle 1 RFF values were significantly lower ( $P = 0.04$ ) in the postrecordings of the volleyball participants compared with prerecordings, but there was no significant difference ( $P = 0.20$ ) in offset cycle 10 RFF values. Receiver operating characteristic analyses indicated moderate sensitivity and specificity of onset cycle 1 RFF for discrimination between the volleyball and control participants. Changes were not apparent in the control group as a function of time for either, onset cycle 1 RFF, offset cycle 10 RFF, or either vocal attribute.

**Conclusions.** Onset cycle 1 RFF may be an effective marker for detecting vocal changes over an acute high voice use period of time before perceptual changes are noted.

**Key Words:** High voice use–Relative fundamental frequency–Dysphonia–Acoustic analysis–Auditory-perceptual judgment–Strain.

## INTRODUCTION

Voice disorders, which are often caused or exacerbated by improper voice use, can have negative social and emotional consequences.<sup>1</sup> Many individuals who present at voice clinics because of vocal misuse are diagnosed with vocal hyperfunction.<sup>2</sup> Vocal hyperfunction is a “condition of abuse and/or misuse of the vocal mechanism due to excessive and/or imbalanced muscular forces.”<sup>3</sup>(p373) This presence of heightened muscle tension often causes the voice to be perceived as strained<sup>3</sup> and can be especially problematic for individuals who rely heavily on their voices throughout the day, such as teachers, singers, aerobics instructors, and lawyers.<sup>1,2,4–6</sup> In fact, approximately 30% of the working population in the United States has an occupation that requires a substantial amount of voice use, and approximately 3% of the population has an occupation in which adequate vocal abilities are important for public safety.<sup>7</sup> High voice users are at an increased risk for developing a voice disorder.<sup>1,2,4–6</sup> Much of the previous work has focused on identifying individuals who are at high risk for developing voice disorders, but less work has examined the vocal changes after acute periods of such high voice use (ie, excessive or loud vocal use over a period

of time). The goal of this study was to examine acoustic and perceptual changes in the vocal characteristics of members of a university women's volleyball team, who display a unique model of high voice use over a relatively short period of time.

Teaching is a high voice use profession that has received a large amount of attention with respect to the risk of developing voice disorders.<sup>1,2,4,5,8–12</sup> Specifically, teachers have been shown to have a higher risk for experiencing voice disorders than nonteachers,<sup>4</sup> and many teachers report that their profession has an adverse impact on their voices.<sup>12</sup> In addition to the high vocal load required for teaching, the suboptimal acoustics of the classroom can also have a detrimental impact on teachers' voices. An increase in environmental noise has been associated with an increase in vocal symptoms, as teachers are required to speak louder to be heard over the noise.<sup>8,10</sup> Not surprisingly, in comparison with classroom teachers, physical education teachers have a further increased probability of developing a voice disorder, even independent of gender, age, and daily number of teaching hours.<sup>12</sup> The indoor physical education settings have a substantial amount of environmental noise, over which physical education teachers are required to constantly project their voices to conduct their classes.<sup>13</sup> One study following physical education student teachers across a semester found that ratings of voice quality and vocal fatigue were both increased in the middle and the end of the semester compared with the beginning.<sup>14</sup> Like physical education teachers, aerobics instructors also conduct classes in loud environments and have reported experiencing both acute and chronic vocal difficulties.<sup>15,16</sup> A survey of aerobics and group fitness instructors revealed an association between duration of exercise instruction and vocal problems.<sup>17</sup> It is

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hypothesized that these instructors are at risk for developing voice disorders due to the necessity to raise their voices, potentially in an inefficient manner, while teaching their classes.<sup>18</sup>

The participants in sporting events are a group of high voice users who have received less attention in the literature. Like teachers and instructors, members of athletic teams must regularly communicate in high noise environments to coordinate game play. In addition, some sporting activities, such as a tennis serve or a golf drive, are often accompanied by repetitive yelling and/or grunting, and this forceful adduction of the vocal folds places a large demand on the vocal mechanism that occurs over an acute period of time in a repetitive fashion.<sup>1,19</sup> For example, club tennis players may have a higher concentration of voice use during their tennis seasons than they do during other parts of the year. Because of their risk for developing voice disorders, cheerleaders are one group of athletes who have received attention in the literature. Surveys of high-school cheerleaders noted that 32–86% reported difficulty with their voices, ranging from mild dysphonia to aphonia at the time of the cheerleading event.<sup>20</sup> Relative to their peers, cheerleaders are more likely to experience chronic vocal problems and to be diagnosed with voice disorders.<sup>21</sup>

The benefit of examining athletes' vocal changes rests in the acute nature of their vocal trauma. Athletes who use their voices during sporting events have temporary but consistent patterns of voicing. This provides an advantage over examining teachers, who may exhibit more chronic patterns of potential vocal misuse and/or abuse. The present study examined members of a university club sports team before and after an athletic season, allowing examination of potential changes in acoustic and perceptual measures over a short 10-week time period. Acoustic analysis focused on changes in relative fundamental frequency (RFF), which has been shown to correlate with subjective ratings of strain<sup>22,23</sup> and has been implicated in individuals with voice disorders to be associated with vocal hyperfunction.<sup>24</sup> RFF is measured from a vowel-voiceless consonant-vowel speech sample, focusing on the 10 cycles of the vowel waveform directly preceding the voiceless consonant (offset) and the 10 cycles of the vowel waveform directly following the voiceless consonant (onset). Previous research has indicated that the 10th offset cycle (offset cycle 10) and first onset cycle (onset cycle 1) RFF values in individuals with vocal hyperfunction are lower than healthy controls.<sup>23,24</sup> However, previous work has not examined the utilization of RFF to detect small changes in the voices of participants undergoing high voice use. Perceptual assessment will focus on whether listeners can detect changes in the overall severity and strain. Thus, this study will examine both RFF and subjective impressions of overall severity and strain in individuals before (pre) and after (post) a 10-week indoor volleyball season.

We hypothesized that, because of the high voice use that occurred during the volleyball season, (1) the offset cycle 10 and onset cycle 1 of players would have a lower RFF in the recordings taken after the season than in recordings taken before the season and (2) listeners would rate the vocal samples recorded from players after the season as having higher overall severity and strain than those recorded before the season.

## METHODS

### Participants

All participants completed written consent in compliance with the Boston University Institutional Review Board and were compensated for their participation.

**Speakers.** Participants were 18 young adults (15 women); all were native speakers of American English. Twelve participants (volleyball group) were members of the Boston University women's volleyball club team (mean [M], 20.0 years; standard deviation [SD], 1.5 years; 11 players and 1 coach). One speaker reported seeing a speech-language pathologist as a child because of difficulty saying the phoneme /t/. Another speaker reported that it was previously recommended that she receive an evaluation for a possible voice disorder, but as her voice did not bother her, she did not follow the recommendation. As neither of these participants had a diagnosed voice disorder, they were included in the analyses. No other participants reported any speech, language, or hearing disorders. All participants in the volleyball group were recorded the week before the beginning of the spring volleyball season (pre) and returned approximately 1 week after the completion of the 10-week season (post; M, 81.8 days; SD, 9.2 days). Although many speakers in the volleyball group reported experiencing episodes of acute phonotrauma (eg, severe hoarseness and/or aphonia) during the period between the prerecordings and postrecordings, no speakers were experiencing these symptoms at the time of either recording. For qualitative comparison, six additional individuals (three women; M, 20.8 years; SD, 1.5 years) who were not participants in club sports formed a control group and were also recorded over the same time period as the volleyball season. They returned for a postrecording an average of 85.0 days after the prerecording (SD, 17.4 days).

**Listeners.** Eight young adults (four women; M, 19.8 years; SD, 6.4 years) acted as listeners. The listeners were native speakers of American English and reported no prior history of speech, language, or hearing disorders. Clinical training for perceptual judgment of vocal qualities can result in listeners who have their own approaches to rating voices because of their own personal experiences, and training with previous research indicating that the perceptual judgments between naïve raters are more consistent as compared with raters who are experienced listeners.<sup>25</sup> Therefore, listeners who had no prior experience with or coursework in voice disorders, formal exposure to individuals with voice disorders, or experience using rating scales for judging dysphonia were recruited. All listeners passed a hearing screening at 25 dB for the frequencies 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz in both ears.

### Stimuli collection and preparation

The speakers were recorded reading four sentences at two time points (pre and post), for a total of 144 speech samples (18 speakers × 4 sentences × 2 time points = 144 speech samples). The speech samples were recorded in a sound-treated room using a headset microphone (Shure model WH20, Niles, IL) placed at 45° angle from the mouth, with one of two soundcards, a PreSonus Firepod FP10 (PreSonus Audio Electronics,

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