ABSTRACT • Objective: The purpose of the study is to examine vocal fold closure in fasting subjects using frame by frame analysis. Subjects and Methods: Twenty-two male subjects were recruited for this study. All subjects were evaluated while fasting and non fasting. Frame by frame analysis of at least three glottic cycles was performed and reported as a mean closed quotient. The degree of phonatory effort and vocal fatigue was also reported. Results: The mean closed quotient for all subjects while non fasting was 0.427 ± 0.098 and while fasting 0.441 ± 0.073, with no significant difference between the two ( \( p \) value 0.417). There was a significant increase in the phonatory effort while fasting (0.23 non fasting vs. 0.77 fasting, \( p \) value 0.036). Conclusion: There is no change in the mean closed quotient in male subjects while fasting. However, most subjects exhibit a significant increase in phonatory effort.

Keywords: fasting; glottis; larynx; voice

INTRODUCTION

Fasting is defined as abstinence from water and food intake from sunrise to sunset. It is commonly practiced by Moslems in the month of Ramadan as one of the rituals of Islam. The intermittent intake of water and food has several effects on the body and the vocal apparatus [1-3]. Previous studies have clearly illustrated that there are metabolic changes more often than not accompanied by sleep deprivation and circadian rhythm alterations [4-5]. The metabolic changes have been described as hypoglycemia, hyperlipidemia, increase in uric acid and disturbances in electrolytes. The fluctuation in the lipid profile and many of the blood parameters has been attributed to the alteration in the lifestyle often experienced by the fasting subjects [6,7]. Most Muslims in order to compensate for the water and food deprivation that occurs during the day increase their alimentary intake during the night between sunset and sunrise.

As a result, this behavioral change, metabolic alterations do occur with weight loss and dehydration being the most common. The weight loss has been reported to vary between 0.1-1.4 kg and signs of dehydration are invariably encountered. As a result, cardiovascular, respiratory, urinary, ocular and, last but not least, phonatory health problems may occur [2-3,8-9].

The authors of this manuscript have previously reported on the effect of fasting on voice in both females and males using a questionnaire, acoustic analysis and laryngeal video-endoscopic examination [2,3]. In a prospective study on 28 female subjects, vocal fatigue was reported in almost 53% of the cases and phonatory effort had increased in 23 out of the 28 cases. These symptoms were coupled by a significant decrease in the maximum phonation time and no changes in the remaining acoustic parameters. Likewise, in the male group, the incidence of vocal fatigue was higher while fasting compared to non fasting and 50% of the 26 subjects had an increase in their phonatory effort. In both studies, the laryngeal video-endoscopic findings were clinically irrelevant. Hence, the explanation for the increased phonatory effort and fatigue was based hypothetically on the systemic effects of fasting namely dehydration, neuromuscular fatigability and metabolic changes.

The purpose of this study is to examine further the vocal mechanism while fasting. Is the increase in phonatory effort and or vocal fatigue experienced by fasting subjects accompanied by changes in the glottic closure time, namely in the ratio of the closing and opening phase? Previous reports have indicated the presence of vocal fold edema, anterior glottal gap, and spindle shaped opening or incomplete glottic closure with vocal fatigue following specific phonatory tasks [10-14]. However, no previous studies have examined glottic closure in fasting subjects using frame by frame analysis.
Absence of changes in the closed glottic quotient while fasting should allude to other causes for the increase in phonatory effort and fatigue such as respiratory muscle fatigue or increased vocal fold viscosity.

MATERIALS AND METHODS

A total of twenty-two male subjects have been recruited for this study. All participants have signed the informed consent that was approved by the Institution Review Board and the work was performed in accordance with the principles of the 1983 Declaration of Helsinki. Subjects with vocal fold pathologies, recent history of upper respiratory tract infection or laryngeal manipulation were excluded from the study. Demographic data included age, weight, and history of smoking.

All subjects were evaluated while fasting and non fasting. The authors have made sure that the number of fasting hours exceeded 12 hours in all subjects. The evaluation consisted of self-reporting degree of phonatory effort and vocal fatigue in addition to frame by frame analysis of at least three glottic cycles using laryngeal video-endostroboscopic recording.

The degree of phonatory effort and vocal fatigue was graded from 0 to 3 where 0 indicates absence, 1 mild, 2 moderate, and 3 severe.

The subjects underwent laryngeal video-endostroscopy using the 70-degree rigid telescope coupled to the Digital Rhino-Laryngeal-Strobe model 9100S. Frame by Frame Analysis (FBFA) technique was used to evaluate at least three glottic cycles per subject. Count of the open frames was defined as the number of frames starting with the first evidence of mid-membranous vocal fold opening and ending with the frame before the first evidence of mid-membranous vocal fold closure. The count of closed phase was considered as the number of frames starting with the first evidence of mid-membranous vocal fold closure and ending with the frame before the first evidence of mid-membranous vocal fold opening. See Figure 1.

The percentage of closure duration was measured by computing the ratio of closed frames over the total number of frames, i.e. open plus closed.

Frequencies and means (± SD) were used to describe the sample, for categorical and continuous variables respectively. For each subject, the parameters were collected before and after fasting, and the appropriate statistical analysis for small-size samples (Wilcoxon non-parametric paired test) was conducted. The analysis took into consideration the design (before and after) and modality of data collection (paired data).

Differences were considered significant for $p < 0.05$. All analysis was conducted using SPSS software.

Figure 1. Frame by frame analysis of a glottic cycle. Note the mid membranous vocal fold opening on the third frame and beginning of mid membranous vocal fold closure on frame number eight, indicating a closed quotient of 0.5.
RESULTS

Demographic data
Twenty-two healthy male subjects were recruited for this study. Age ranged between 20 to 48 years with a mean of 30.23 ± 8.38 years. Forty-five percent of the subjects were smokers. While non fasting, the mean weight was 78.65 kg ± 13.40 kg. While fasting, the mean weight was 77.46 kg ± 13.29 kg. It is worth noting that the decrease in weight while fasting ranged between 0.5-3.30 kg and close to 81% of the subjects had a decrease in weight. See Table I.

Phonatory effort and vocal fatigue
There was a significant increase in the phonatory effort while fasting compared to non fasting (0.23 non fasting vs. 0.77 fasting, p value 0.036). Forty percent of the subjects had an increase in the phonatory effort while fasting and in 22.7% the increase was by two points. As for the vocal fatigue, there was an increase while fasting in the overall mean by 0.32; however the increase was not statistically significant (p value 0.07). This was accompanied by a significant decrease in weight (p value 0.00). See Table II.

Frame by frame analysis
For the frame by frame analysis, the mean closed quotient for all subjects while non fasting was 0.427 ± 0.098 and while fasting 0.441 ± 0.0734, with no significant difference between the two (p value 0.417). It is worth noting that 13 subjects out of the 22 had no change in the closed quotient while fasting and non fasting. In the nine remaining subjects 5 had an increase and 4 had a decrease in the closed quotient while fasting. See Table III.

DISCUSSION

Several measures have been used to assess glottic closure during phonation. These include subjective measures like perceptual evaluation using the GRBAS (grade, roughness, breathiness, asthenia, strain) classification and the Voice Handicap Index, and objective ones such as spectroacoustic analysis, airflow measurements and laryngeal video-stroboscopy [15-17]. The latter has also been used to assess the extent of mucosal waves which is a reflection of vocal fold contact and malleability [18]. Other parameters reported in stroboscopy are closure pattern, symmetry and periodicity of closure. Despite the fact that stroboscopy is an illusionary representation of the glottic behavior, various phases of a glottic cycle is often described. These are the opening phase, open phase, closing phase and then closed phase.

Frame by frame analysis is a technique used to evaluate the glottic cycle recorded by laryngeal stroboscopy. The percentage of closure duration is usually measured by computing the ratio of closed frames over the total number of frames, i.e. open plus closed. Subjects with normal vocal folds phonating at a modal register will have 50% of their glottal cycle in an open phase [19]. This finding has been substantiated by many authors further documenting that the ratio of closed frames to rest of cycle is one to two [20].

A decrease in the glottic closure is a sign of glottic insufficiency whereas an increase is probably indicative of hyperfunctional behavior or excessive closure as in patients with hyperadduction of the vocal folds. Glottic insufficiency is defined as unintentional escape of air from the glottis during phonation. It is primarily due to paresis or paralysis of the vocal fold. Carroll et al. have shown that patients with atrophy or paresis of the vocal folds experience a reduction in the average closure duration to 32-38% compared to 50% in normal subjects [21]. Other causes of glottic insufficiency include hypoadduction as in patients with Parkinson’s disease, bowing of the vocal folds secondary to aging, scarring following phonosurgery and others. The clinical presentation of glottic insufficiency is a constellation of symptoms like breathiness, loss of range, loss of power, and aspiration. Among these symptoms is vocal fatigue and increase in vocal effort.

The authors of this manuscript have hypothesized that vocal fatigue and increase in phonatory effort could be associated with a change in the ratio of open to closed frames within a glottic cycle, either a decrease suggestive of glottic insufficiency or an increase suggestive of hyperfunction. A decrease in closed quotient could be hypothetically secondary to thinning of the vocal folds with the weight loss while fasting or secondary to bowing of the vocal folds with the adductor muscle fatigue. On the other hand, an increase in the closed quotient could be due to a hyperfunctional glottic

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### Table I

<table>
<thead>
<tr>
<th>Age</th>
<th>30.23 ± 8.38</th>
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<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
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<tr>
<td>Smoking</td>
<td>45.50%</td>
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<tr>
<td>Mean weight</td>
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<tr>
<td>While fasting</td>
<td>77.46 kg ± 13.29 kg</td>
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<tr>
<td>While non fasting</td>
<td>78.65 kg ± 13.40 kg</td>
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### Table II

<table>
<thead>
<tr>
<th>Mean Closed Quotient</th>
<th>Non-fasting</th>
<th>Fasting</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonatory effort</td>
<td>0.23</td>
<td>0.77</td>
<td>0.036</td>
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<tr>
<td>Vocal fatigue</td>
<td>0.36</td>
<td>0.68</td>
<td>0.071</td>
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### Table III

<table>
<thead>
<tr>
<th>Mean Closed Quotient ± SD</th>
<th>Non-fasting</th>
<th>Fasting</th>
<th>p value</th>
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<tr>
<td>0.441 ± 0.0734</td>
<td>0.427 ± 0.0985</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.3 - 0.6</td>
<td>0.3 - 0.6</td>
<td>0.417</td>
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behavior as a manifestation of the increase in phonatory effort and fatigability. The results of our study show that the increase in vocal fatigue and phonatory effort while fasting did not affect the mean closed quotient indicating that the closure pattern was not affected by either glottic insufficiency or hyperfunction. In our study the mean closed quotient was close to 50% (0.42 while non fasting and 0.44 while fasting) indicating that there was no glottic insufficiency in our subjects. More so there was no significant change in the mean closed quotient of the overall group in fasting compared to non fasting. As a matter of fact, 60% of the subjects had the same closed quotient while fasting and non fasting.

That being stated, possible explanations for the increase in phonatory effort and fatigue are many. The underlying mechanisms include neuromuscular fatigue, increased vocal fold viscosity, reduced blood circulation, neuromuscular tissue strain and respiratory muscle fatigue [22]. Among these are dehydration and or alterations in respiratory function. Fasting subjects are estimated to lose weight between 0.1 kg to 1.4 kg, most of which is water. In our study, 81 had a decrease in weight that varied between 0.5 kg to 3.3 kg with a mean of 1.29 kg. The decrease in weight while fasting is mostly water as evidenced by an increase in serum electrolytes and proteins [4]. Dehydration whether systemic or local can affect the vibratory behavior of the vocal folds by inducing rheologic changes that in turn can affect the viscoelastic properties of the vocal fold [23,24]. Adults subjected to systemic dehydration experience an increase in the phonatory effort that is reversed with hydration [17]. Similarly, Solomon et al. have demonstrated that the increase in phonatory threshold pressure witnessed after vocal loading can be attenuated by drinking water in three out of four female subjects [13]. Hence dehydration during fasting can explain the increase in phonatory effort and vocal fatigue.

A second possible explanation for the phonatory symptoms in fasting subjects is the alterations in respiratory function in fasting subjects. In a study by Duncan et al. there was a reduction in pulmonary expiratory flow and the ratio of dead space to tidal volume [25]. In a similar study Subhan et al. have reported an increase in the expiratory flow rates post Ramadan relative to Ramadan [26]. The differences in body mass and forced expiratory flow (FEF 75) in Ramadan and post Ramadan showed a significant correlation [26]. As breathing is a major component for voice production, the aforementioned changes in respiratory function can affect phonation.

A third important confounding factor that might have had an impact on the higher prevalence of vocal fatigue and increased phonatory effort while fasting is laryngopharyngeal reflux disease. The changes in the eating habits and behavior during the month of Ramadan submit the fasting subject to chronological and physiological changes [27-30]. There have been conflicting reports in the literature on the incidence of ulcer disease and gastro-intestinal bleeding in fasting subjects compared to non-fasting with no clear consensus [31,32]. Both acid and pepsin levels have been reported to increase during Ramadan, secondary to the aforementioned behavioral changes in relation to food intake [33,34].

The impact of the alteration in gastric secretions on the laryngopharyngeal complex is hard to measure in this study due to the lack of pH monitoring and or impedance measurements. Nevertheless, reflux remains hypothetically a possible coexisting confounding factor.

Last but not least is the possible correlation between religiosity and vocal symptoms. There are numerous reports in the literature suggesting that religion plays an important determining factor in mental health, cancer, cardiac disease, depression, psychopathology, oral health and health outcomes in general [35-40]. A comprehensive literature search on the impact of religious intervention on health outcomes revealed that acts such as prayer may decrease hospital stay, duration of disease, adverse outcomes of cardiac diseases and many other medical conditions. As such, and because religiosity emphasizes the supreme value of life and is regarded by many as an example of psychosocial health determinant, fasting subjects may either exaggerate or suppress the voicing of their phonatory complaints in view of their religious beliefs. This fact needs to be taken into consideration in the interpretation of our findings. A future study on the correlation between religiosity and vocal health may shed information on this topic.

Our study has three limitations. One is the lack of respiratory function tests as outcome measurement tools for better understanding of the phonatory symptoms. Second is the small sample size. Last but not least is the lack of a control group given the known variations in phonatory effort in relation to vocal loading, sleeping pattern and dietary factors. To that end, fasting by itself may not be the sole culprit for the increased phonatory effort and vocal fatigue, as the change in lifestyle often witnessed in non-fasting subjects with dual jobs and altered sleep patterns may also be responsible for these phonatory symptoms. This has been reiterated upon in the explanation of phonatory effort and vocal fatigue in the context of neuromuscular and respiratory fatigue. Unfortunately, a control group is missing in this study in view of the extreme hardship in recruiting subjects that match the fasting group in terms of the aforementioned factors. Fasting by itself may not be the sole culprit for the increased phonatory effort and vocal fatigue, as the change in lifestyle often witnessed in non-fasting subjects with dual jobs and altered sleep patterns may also be responsible for these phonatory symptoms. Nevertheless, this study casts more light on the interplay between phonatory effort, vocal fatigue and fasting. Looking at the phonatory threshold pressure should be the subject of a future investigation.

CONCLUSION

Fasting subjects have increased vocal effort and fatigue. These phonatory symptoms are accompanied by weight loss and dehydration in the majority of the cases. Frame by frame analysis failed to reveal any changes in the closing phase of the glottic cycle to indicate glottic insufficiency or hyperkinetic behavior. Future studies on vocal fold viscosity and respiration are needed to unveil the cause of increased effort and fatigability while fasting.
REFERENCES