Perceptual-auditory and Acoustic Analysis of Air Traffic Controllers' Voices Pre- and Postshift

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Summary: Objective. To characterize the vocal quality and acoustic parameters of voices of air traffic controllers (ATCs) without any vocal complaints before and after a shift.

Method. The voices of a group of 45 ATCs were recorded before and after a 2-hour shift, regardless of their operational position or number of previously worked shifts; both genders were included, participants had a mean age of 25 years, and they had a mean length of occupational experience of 4 years and 2 months. Each of these professionals was recorded phonating a sustained /a/ vowel and counting from 1 to 20, and the recordings were acoustically analyzed using the *Praat* software. A perceptual-auditory analysis of the recordings was then performed by three speech therapists specializing in voice, who evaluated the characteristics of each emission using a visual analog scale (VAS). The acoustic analysis was performed on the sustained /a/ vowel. The measures of intensity; frequency; maximum phonation time (MPT); and the first, second, third, and fourth formants were considered in this analysis.

Results. There were no significant differences between the random pre- and postshift samples, either in the acoustic or in the perceptual-auditory analysis. The perceptual-auditory analysis revealed that 44% (n = 20) of ATCs showed alterations in vocal quality during the sustained /a/ vowel emission, and this dysphonia was also observed in connected speech in 25% (n = 5) of this group.

Conclusion. Perceptual-auditory analysis of the /a/ vowel revealed that a high percentage of ATCs had vocal alterations (44%), even among a group of subjects without vocal complaints.

Key Words: Voice–Voice disorders–Dysphonia–Acoustic–Perceptual-auditory.

INTRODUCTION

An air traffic controller (ATC) is a professional who performs air traffic control functions in air traffic control units under the Brazilian Aeronautics Command. These professionals are responsible for controlling one of the various stages of a flight.[1] The aircraft normally passes through three levels of traffic control between takeoff and landing. The tower is responsible for the aircraft until it loses visual contact with the aircraft; approach control, or APP, and the area control center, or ACC, are both responsible for the direction of the plane in the air. These professionals must have good vocal quality, moderate-to-high voice loudness (to facilitate intelligibility), vocal resistance, and emphasis on key words, as well as good articulation and intonation when issuing instructions to convey safety to the pilots of the aircraft they control.

The function of APP controllers is to ensure a minimum distance between planes near the airports under their command and to indicate by radio the coordinates (headings), speeds, and altitudes that the pilot must adopt to fly with maximum safety and avoid collisions.[2] This is a very dynamic task that requires the special attention of these controllers because in addition to providing the final sequence for landing, they must separate the aircraft that are landing from those that are taking off. The voice is therefore of utmost importance, as it is the main tool used by these workers in the exercise of their function,[3] and any vocal alterations that influence the transmission of their voice to pilots, even if temporary, may put hundreds of lives at risk. Voice disorders and poor communication patterns, as well as phonemic deviation, may interfere with this function. Nevertheless, few studies regarding communicative competence in this group have been published.

São Paulo Approach Control (APP-SP) is responsible for an area of approximately 260 km in diameter, which is above the Viracopos/Campinas International, Guarulhos International, Congonhas/São Paulo, Campo de Marte/São Paulo, Jundiaí, and São José dos Campos airports, as well as other smaller airfields such as Sorocaba, Bragança Paulista, and Taubaté. The airports of Congonhas/São Paulo, Campo de Marte/São Paulo, and São José dos Campos were collectively responsible for the movement of 337,325 aircrafts in 2014, which represents 17% of the annual aircraft movement of the airports administered by the Brazilian Company of Airport Infrastructure (Empresa Brasileira de Infraestrutura Aeroportuária—INFRAERO).[4] The ATCs of this control area therefore tend to be at a higher risk of dysphonia because in addition to the natural stress of their work, they are subject to greater demands, being placed on their voices, in comparison with the ATCs of other operating bodies.

The aim of this study was to characterize the vocal quality and acoustic parameters of APP-SP ATCs before and after their shifts, as well as to assess their voice quality before and after 2 hours of work, including one working period at peak time (6 PM), when the levels of traffic control are higher due to the increased number of takeoffs and landings.

METHODS

This was an observational and prospective study. It was approved by the Research Ethics Committee of the Federal University of Sao Paulo (Brazil).

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The sample consisted of 45 ATCs belonging to the APP-SP, without vocal complaints, of whom 25 were men and 20 were women. The ages of the ATCs were between 20 and 35 years (mean age of 25 years), and they had a mean of 4 years and 2 months of professional experience (from an intern with 9 months of experience to a coordinator/instructor with more than 13 years of service). This group is quite typical as it reflects the mean age of ATCs in many Brazilian air traffic control organizations.

The ATCs of APP-SP work for periods of eight consecutive hours followed by a period of rest between 8 and 48 hours, according to their previous schedule. These periods may include morning (6 AM to 2 PM), afternoon (2 PM to 10 PM), or night/dawn (10 PM to 6 AM). The 8-hour work periods are further divided into four intervals of 2 hours, of which at least three intervals are worked with a period of 2 hours of rest. During these three shifts, the ATC can occupy different operational positions, such as control (the position that controls the aircraft), assistant (assisting the controller), or coordinator (a more experienced professional who coordinates the activities of the different sectors of the control body). The voices of these professionals were recorded before and after a 2-hour work shift, regardless of their operating position (control, assistant, or coordinator) or whether they had worked in previous shifts.

Those ATCs performing another form of work in which they overuse their voice, such as working as a teacher, those complaining of upper respiratory tract infection, and those with a current dysphonia complaint, were excluded from the sample.

The sustained /a/ vowel emissions and number counting (1–20) were performed by each volunteer ATC in a quiet room at their workplace. The vowel /a/ was used because it is part of the protocol, and the acoustic program used in this study recommends its use. Numbers were included because they reproduce a speech pattern that is similar to the task performed by the ATCs. These recordings were made at varying times to measure the varied vocal demands of this group caused by their operational schedule. The recording samples were collected using a microphone (Sansom CO3) that was attached directly to an HP 210-1062BR Mini Notebook PC, and recorded in sound wave format. This was accomplished using the speech analysis program *Praat*[5] version 5.3.16 (Institute of Phonetic Sciences, University of Amsterdam). The microphone was placed at a 45° angle from the speaker's mouth at a distance of approximately 10 cm to best capture the emissions. The program was also used to edit the samples and perform an acoustic analysis of the recordings of sustained /a/ vowel emissions.

When editing the voice samples, the first and last 2 seconds of the recording were extracted. A file was then created for each sample type (/a/ vowel and numbers) with all recordings, plus 20% of random repetition for inter and intra-rater reliability analysis. The researcher gave each of the evaluators a file of 108 samples on which to perform the perceptual-auditory analysis.

This perceptual-auditory analysis was performed by three speech therapists specializing in voice, with at least 5 years of clinical training. For each analysis (vowels or numbers), the evaluators were given three sheets with 108 numbered lines 100 mm in length with which to mark the general grade for each sample, with 0 representing the best voice quality and 100 representing the worst voice quality. These pre- or postshift recordings were presented randomly. After analysis, the researcher measured each line with a ruler and assigned values for each vocal sample. Each millimeter was considered to be one point. The values obtained were entered into a table for sample comparison and analysis. The three professionals analyzed the recordings and rated the characteristics of each emission using a visual analog scale (VAS).[6]

The Kappa concordance index was used to assess inter- and intra-rater reliability, although it was noted that this measure was not precise enough because it uses the vocal subclassifications scale as a parameter. The concordance rate of each evaluator was thus adopted as a reliability parameter, as it is more accurate for this purpose. The evaluation of the same sample at two different times was considered reliable if there was a variation of up to 10 mm in either direction for each value considered. The perceptual-auditory analysis performed by the evaluator with the highest concordance rate (77%) was selected for comparing the pre- and postshift samples.

To determine the similarity between the samples evaluated in the pre- and postshift periods, a descriptive analysis of the data was first performed using the following statistical tools: a scatter plot of the pre- and postshift samples, a scatter plot of the difference between the pre- and postshift evaluations for each sample, and the Pearson linear correlation coefficient. The scatter plot of the pre- and postshift samples indicates smaller differences between the pre- and postshift evaluations when the points are closer to the line. The scatter plot of the difference between the pre- and postshift evaluations for each sample indicates smaller differences as the points approach zero. Finally, Pearson linear correlation coefficient ranges from −1 to 1, and the values closer to 0 indicate greater differences between the pre- and postshift evaluations. These tools are very useful, as they allow greater understanding of the study results through visual analysis of data variability and a comparison of the pre- and postshift evaluations of each sample.

After descriptive analysis of these data, the paired Student t test and Wilcoxon test were applied; the results of these tests were interpreted by means of their respective P values (≤0.05).

To ascertain whether the peak time, when there is an increase of the level of traffic control, affects the ATCs' vocal quality, this parameter was compared before and after 2 hours of work, in which the pre- or postshift periods included the peak time, which is considered to be 6 PM. The samples recorded in the second and third afternoon shifts (4–6 PM and 6–8 PM, respectively) were analyzed using the 6 PM sample as the reference to establish whether increased vocal demand occurred during the peak hours, when the level of traffic control was increased. Adding together the two periods, a total of 15 samples were analyzed; 10 belonged to the first period, and 5 belonged to the second period.

For variables with a normal distribution in both periods (pre- and postshift), the paired Student t test was used with the acoustic analysis. The paired nonparametric Wilcoxon test was used for variables with nonnormal distributions in both periods (pre- and postshift). A value of 5% was used as the significance level (P value ≤ 0.05). Measures of intensity (dB); fundamental