AN EXPLORATORY STUDY OF LARYNGEAL MOVEMENTS
DURING PERFORMANCE ON ALTO SAXOPHONE

THESIS

Presented to the Graduate Council of the
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Fulfillment of the Requirements

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MASTER OF MUSIC

by

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The purpose of this study was to investigate laryngeal movements in selected performance situations on alto saxophone. The specific research problems were to describe glottal activity in three selected musicians as they performed musical tasks with (1) various pitch ranges and registers, (2) fortissimo and pianissimo dynamic levels, (3) crescendo and decrescendo, (4) long tones with vibrato, and (5) legato and staccato styles of articulation.

A fiberoptic laryngoscope was employed to gather the visual images, which were recorded on a sound synchronized video tape. A rating system was devised to provide graphic representation of the data.

Results of the data indicated that the glottis was used as an airflow constrictor in certain performance situations, especially in pianissimo performance. Other conclusions were drawn, and suggestions for further research were discussed.
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CHAPTER I

PURPOSE OF THE STUDY

Introduction

Medical research studies have shown that one of the primary functions of the larynx is as a respiratory airflow constrictor. In inspiration the glottal opening widens, and it narrows to help control expiratory airflow.

Negus (4, 5) first proposed the theory that with the vocal fold adduction, the subsequent increase in subglottal air pressure increased the pulmonary gas exchange efficiency in the lungs. For many years this was thought to be the primary reason for vocal fold adduction and abduction during normal respiration. In 1959, O'Neil (6) concluded from the observation of people afflicted with laryngeal paralysis, or with missing vocal folds, that subglottal pressure did not measurably increase the pulmonary gas exchange efficiency in humans. O'Neil also investigated several other commonly held theories concerning glottal adduction during expiration, and found that the primary reason for the glottal constriction was to help control the duration of expiration.

It seems logical that the glottis might be used in this same manner in wind instrument performance since performing on a wind instrument demands control over airflow. Although
there is a fair amount of pedagogical literature written about airflow in wind instrument performance, none could be found which mention the glottis as a part of the airflow mechanism.

Leeson (3) wrote a pedagogical treatise in which he discussed the breathing mechanism. He described several different types of breathing, which he called "costal" breathing, "clavicular" breathing, and "diaphragmatic or abdominal" breathing, all as opposed to "natural physiological" breathing. The names themselves were derived from the section of the anatomy which is supposed to fill out the most in the first part of the inspiratory cycle. For all of these types of breathing, the primary attention was given to the inspiratory phase of the breathing cycle. When the expiratory phase of the breathing cycle was mentioned, the technique of chest or lower rib cage elevation was also mentioned as helpful in controlling expiratory airflow.

Leeson took these breath control concepts from vocal pedagogy and tried to apply them to saxophone performance. Although these concepts may work well to produce a more efficient use of air during singing, there is no evidence to show that these types of muscular effort are necessary or employed during wind instrument performance.

Teal (7), in his widely accepted treatise The Art of Saxophone Playing, devoted several pages to a detailed discussion of the breathing apparatus. The role of the
diaphragm, abdominal muscles, and intercostals were discussed in detail, but the larynx was only mentioned as a part of the anatomy.

O’Neil (6) and Green and Neil (2) have shown in medical research studies that the glottis is used to control expiratory airflow in normal respiration. At present, pedagogical theory does not appear to consider the glottis as a constrictor of airflow in saxophone performance.

The purpose of the present study was to investigate glottal changes in selected performance situations on alto saxophone.

Statement of Research Problems

The specific research problems of the study were to describe the activity of the glottis in selected musicians as they performed on the alto saxophone musical tasks with

1) various pitch ranges and registers,
2) fortissimo and pianissimo dynamic levels,
3) crescendo and decrescendo,
4) long tones with vibrato, and
5) legato and staccato styles of articulation.
Review of Laryngeal Anatomy

Some of the terminology to be used in this study may require some clarification or review, depending upon the reader's background and knowledge of laryngeal anatomy. Because of the nature of the study, muscles, cartilages, folds, and other parts of the anatomy will be referred to using the medical names as found in Fink and Demarest's *Laryngeal Biomechanics* (1). This source provided a much more in-depth description of the physiology of the larynx. The review provided herein will describe only the function of the laryngeal anatomy that is relevant to this study.

The framework of the larynx is made up mostly of hyaline cartilage, a light, elastic but strong material which can stand a substantial amount of wear. Figure 1 [(1), p. 9] shows a lateral view of the cartilages and hyoid bone of the larynx, assembled and disassembled. The hyoid bone is the only bone in the larynx, and its function is primarily to help suspend the larynx vertically.

The cartilages that are important to this investigation are the thyroid, the cricoid, the arytenoid, and the cuneiform cartilages. The cuneiform cartilage is not shown in Figure 1 because it, like the epiglottic and corniculate cartilages, is made of elastic fibrocartilage, which is slightly more springy than the hyaline.

The arytenoid cartilages are anchored on top of the posterior side of the cricoid cartilage. They are designed
Figure 1--Cartilages of the larynx
to move laterally, and their position is a primary determinant of the size of the glottal opening. Figures 2A and B [(1), p. 30] show the way the arytenoids are attached to the cricoid, and two muscles involved in stabilizing the position of the arytenoids.

Figure 2--Articulation of cricoarytenoid joint

Figure 3 shows a view of the vocal folds as can be seen through a fiberscope. Anteriorly, the vocal folds are connected to the thyroid cartilage, and posteriorly, they are connected to the arytenoid cartilages. The laryngeal sinus runs parallel to the vocal folds, and separates them from the vestibular folds.

Figure 3 and all of the figures in Chapter III are drawings made of still photographs taken from the data from the present study.
The vestibular folds (sometimes called the false vocal cords) are functional during swallowing and during effort closure. Figure 4 [(1), p.51] depicts the glottis during an effort closure. Note the position of the cuneiform cartilages, as they pinch closed the anterior section of the
folds. One of the subjects in the present study held his glottis in a position very similar to this effort closure position.

The muscles of the larynx are usually divided into two groups, the intrinsic muscles, which connect the different parts of the larynx with one another, and the extrinsic, which connect the larynx to other outside structures. The glottis is by definition the region of laryngeal cavity at the level of the vocal folds, and almost all of the intrinsic muscles of the larynx are somehow involved in the process of varying the size or shape of the glottal opening.

In Figure 2 the lateral and posterior cricoarytenoid muscles are shown. These two muscles work in an agonist-antagonist relationship to stabilize the posture of the arytenoids. Another important intrinsic muscle, which works as a tensor on the vocal folds is the cricothyroid. Figures 5A and B [(1), p. 81] show the cricothyroid and its effect.

Figure 5--Cricothyroid effect on tension on vocal folds
on the tension of the vocal folds with increased tension on the muscle. In Figure 5B the cricothyroid is tensed; the vocal folds are more stretched and elongated than in Figure 5A. The cricothyroid is a muscle which vocal researchers have investigated extensively because it is directly involved in pitch regulation in normal chest register singing.

The epiglottis is a leaf-shaped membrane, located at the very top of the larynx. It is connected to the epiglottic cartilage, near the base of the tongue, and the hyoid bone. The main function of the epiglottis is to move over the larynx to help cover it during swallowing.

Definition of Terms

The term glottis, as strictly defined, is the region of laryngeal cavity at the level of the vocal folds. The term laryngeal movements will be used in two different contexts. First, and more correctly, it will refer to all observable movements of both the intrinsic and extrinsic muscles, meaning both lateral movements in the glottis and the vertical movements of the whole larynx. The other manner in which this term will be used is a more restricted definition, referring only to the vertical movements of the entire larynx, and not to the lateral glottal movements. This meaning of the term will only be used when there must be a distinction made between the lateral and vertical movements observed, and the meaning will be made clear from its context.
All pitches referred to in this study will be written pitches for the saxophone. As performed by Eb alto saxophones, the pitches will sound a major sixth below where they are written. The written range begins at the Bb below middle C on the treble staff. The pitches in the first octave will be referred to as Bb1, C1, D1, etc., through the pitch A1. The next pitch is Bb2, and the rest of the pitches in the second octave will be called C2, D2, and so on through the tones in the third and fourth octaves.

The term pitch range will be used to refer to all of the notes within a particular pitch register. The term pitch register will for the purposes of this study, refer to four ranges, called low, medium, high, and altissimo. The low register will encompass all pitches below written C#2 (329.63 cps). The medium register will cover from D2 to C3 (349.23-622.25 cps), and the high register will include the pitches from C#3 to F3 (659.26-783.99 cps), or F#3 (880 cps) for instruments with a high F# key. The altissimo register covers F#3 (880 cps) or G3 (932.33 cps), and all pitches above. There is a marked distinction between the high and altissimo registers, in that the high register uses the continued shortening of the tube length to raise the pitch. The tones in the altissimo register, however, are harmonics of lower tones, aided by special fingerings.
The terms **fortissimo** and **pianissimo** are Italian musical terms meaning very loud and very soft, respectively. For the purposes of this study, fortissimo was more strictly defined as playing as loudly as possible with good tone control throughout the range of the musical task. Pianissimo was also more strictly defined as playing as softly as possible with a steady, audible sound throughout the range of the musical task.
CHAPTER BIBLIOGRAPHY


CHAPTER II

RELATED RESEARCH

One of the earliest successful attempts to look at the inside of the larynx in living human subjects was done in 1854 by Manuel Garcia, a singing teacher residing in London (11). Garcia described his laryngeal mirror as a series of mirrors designed to reflect sunlight onto the glottis, and reflect the image back to the eye of the observer. His accounts of vocal fold movements were based solely on his observations of one subject, himself.

Garcia's instrument was in turn developed for clinical use by Ludwig Türck, and its design was later improved by a Polish professor of physiology, Johann Czermak (19). The most important improvement made by Czermak was the introduction of an artificial light source. This improvement meant that the physician was no longer a captive of the weather conditions because of the need of sunlight to illuminate the glottis. The invention of these instruments became a major step in diagnosing disorders of the throat.

Some of the earliest objective examinations of airflow in wind instrumentalists were started around 1874, when Stone (23) attempted to measure wind pressure in human lungs during performance. Stone reported maximum and minimum air pressures as recorded by a water manometer, which was held
in the mouth using the side teeth during performance. The instruments used in this investigation were oboe, clarinet, bassoon, horn, cornet, trumpet, euphonium, and bombardon. His results showed that, except for the clarinet, less pressure was measured when the performance was in the lower register than in the higher in all instruments. This difference was much greater in the brass instruments, with the euphonium reading 3 inches in the low register and 40 inches in the highest. The average difference for the brass instruments was that the high register measured about seven times greater pressure than the low register. In the woodwind instruments, the average difference between the high and low registers was less than two times, with the clarinet registering slightly less than two times greater pressure in the low register than the high. This was opposite from all of the other instruments, as they all measured greater pressure in the higher registers.

Another similar investigation was done around the turn of the century by Barton and Laws (3). Their investigation involved only tenor trombone, trumpet, and cornet, again using the water manometer. Their findings showed that pressures increased with louder tones and higher pitches and were conclusive with Stone's findings. Some inconsistencies were found at softer volume levels, which were attributed to the size of the aperture opening. The findings of both of these studies supported common sense
reasoning, and they were successful attempts to objectively measure the air pressures used by wind instrumentalists.

By the mid 1950's, the technique of electromyography was used to study some of the intrinsic laryngeal muscles. Electromyography is a technique of determining muscle activity by measuring the amount of electrical activity within a particular muscle. Most of the earlier studies done with electromyography were done with animals because of the difficulty of attaching the electrodes to humans.

Studies done by Green and Neil (12) and Nakamura, Uyeda, and Sonoda (17) were designed to examine the respiratory function of the laryngeal muscles. The findings of both of these studies indicated that the abductor muscles, or muscles which pull away from the median axis of the body to widen the glottis, were active during inspiration. The adductor muscles, or muscles which pull toward the median axis of the body to close the glottis, were active during expiration. These studies, again done with animals, provided some much-needed information about the role of the glottis in respiration, and they also established that electromyography was a valid, though indirect, means of observing laryngeal activity.

One of the earliest studies using electromyography on human subjects was done by Floyd and Silver (10) in 1950. This study investigated the role of some of the anterior abdominal wall muscles during selected activities. The
muscles investigated were the rectus abdominis, the external oblique, and the internal oblique. Among other things, they examined the subjects while singing at soft, medium loud, and as loud as possible dynamic levels. Of the muscles examined during this activity, the internal obliques showed the most amount of activity, measuring as much as 550 μV. The largest activity of the external obliques was about 350 μV, and the recti showed only a trace of activity throughout the act of singing.

Faaborg-Anderson and Sonninen (8) examined the role of the extrinsic laryngeal muscles in determining pitch. This study, done with human subjects, used a combination of x-ray and electromyographic techniques. The muscles investigated were the sternothyroid, the thyrohyoid, and the mylohyoid. Three pitch areas were tested, the low (175 cps), medium high (490 and 517 cps), and very high (715 cps). Singing in the low register was associated with pronounced activity in the sternothyroid. Singing in the higher registers was associated with greater activity in the thyrohyoid and mylohyoid, and decreased activity in the sternothyroid. X-ray revealed the larynx in a more caudal position in the lowest and highest registers. It also showed the larynx in a more cranial position in the medium high register than in the low register or in resting position.

In 1963 Basmajian (4) published an article describing a new type of electrode, which eventually opened the way for
extensive research of the intrinsic laryngeal muscles with human subjects. Until this time, the concentric needle type electrode, first proposed by Adrian and Bronk (1) was used. This involved the use of a hypodermic needle with a copper wire inserted into it. The copper wire carried the signal to an amplifier, and the needle acted as a ground, so it had to remain in the muscle. The bi-polar electrode, as described by Basmajian, used two small gauge copper wires with hooks in the ends. These wires were inserted with a hypodermic needle, but once the wires were in place, the needle could be removed because the hooks in the wires would hold them in place.

Hirano and Ohala (14) described at length how the hooked-wire electrode could be used for investigation of the intrinsic laryngeal muscles. They reported that with this new type of electrode, virtually all of the intrinsic muscles could be reached through the neck, whereas before many of the muscles could only be reached through the floor of the mouth. Displacement of the hooked-wire electrodes happened much less frequently, even with the relatively large movements in swallowing, and the entire procedure was much less painful for the subjects.

These new advances prompted much more research into laryngeal activity by vocal and speech researchers. Vennard, Hirano, and Ohala (24) did a series of studies investigating the intrinsic muscles of the larynx, trying to determine
their role in the regulation of pitch, intensity, and register of voice.

Electromyography was at one time considered for the investigative technique in the present study, but it was dismissed in favor of the more direct laryngoscopic technique. In recent years, technical advances have made laryngoscopy a much more usable investigative tool. One such advance occurred in 1940, when Farnsworth (9) took high-speed motion pictures of the vocal folds through a laryngeal mirror. These were some of the first recorded observations of this part of the anatomy.

During the late 1960's a new investigative technique was being developed by Sawashima and Hirose (22), which allowed direct observation of the inside of the larynx with access being gained through the nasal passage instead of the mouth. The fiberoptic laryngoscope was a new instrument which could observe the glottis under near normal speaking or singing conditions. The fiberscope consisted of two sets of fiberglass strands, one designed to carry light from a light source to illuminate the glottis, and another to carry the image back to the eye of the observer. The fiberglass strands were housed in a cable, which was small enough that it could be inserted through the nasal passage and down into the pharynx.

One of the earlier fiberoptic investigations was done by Sawashima et al. (21), observing laryngeal adjustment
during running speech. One of the problems noted by these researchers in 1970 was that exact measurements of the glottal opening could not be made with fiberoptics. The reason for this was that placement of the fiberscope could not be held precisely, and vertical laryngeal movement tended to distort measurements of the glottal aperture. Nevertheless, the fiberscope provided an excellent view of the glottis, while causing no restrictions on normal oral or laryngeal sound production, as earlier laryngoscopic techniques did.

Hirose et al. (15) used fiberoptics along with electromyography to investigate the vocal technique of French stop production, demonstrating the feasibility of using fiberoptics to investigate vocal techniques. The technique of fiberoptics has also been used in combination with the stroboscope. Saito et al. (20) described this technique, which allowed the observers to examine the vocal folds during the singing of a note and view the glottis as if it were still. In this way the observers could more closely examine how the vocal folds vibrated and could study their role in the adjustment of pitch and register as well as other vocal practices.

Studies examining the vocal folds or larynx in wind instrumentalists are few, so this survey will discuss selected studies examining the oral cavities and breathing patterns of wind instrumentalists.
Anfinson (2) examined supralaryngeal adjustments in clarinet players, utilizing fluoroscopic x-ray techniques. In order for the tongue and other parts of the oral cavity to show up in x-ray, the areas to be x-rayed must be coated with an opaque fluid. He primarily looked at techniques of tonguing, such as staccato vs. legato tonguing, staccato tonguing at various speeds, and tonguing and slurring across registers. The data was analyzed by measuring the antero-posterior position of the high point of the tongue. Also measured was the amount of tongue touching the reed while tonguing, and the size of the "throat opening." Haynie (13) did a similar study of the physiological phenomena influencing trumpet performance. Both of these studies were important steps toward an objective analysis of oral cavity movements in wind instrument players.

Bouhuys (7) examined lung volumes and breathing patterns of wind instrument players. Forty-two subjects were given tests of pulmonary function, vital capacity, breathing rate patterns, and other lung function tests. These results were compared with a control group, and although it was not stated, it was implied that the control group consisted of non-wind instrument players. Bouhuys found that the wind instrument players generally did better on the respiratory function tests, and the lung vital capacity was generally larger than control group norms.
In 1965, Berger (5) reported a study very similar to the previously mentioned Barton and Laws study. Berger measured intraoral air pressure, rapidity of articulation, and quantity of air used in trumpet performance. For the measurement of intraoral air pressure he used a custom-made mercury manometer, similar to the one used by Barton and Laws, and his results supported their findings.

Berger and Hoshiko (6) reported a study in which they examined some of the respiratory muscles of trumpet players. This electromyographic study looked at the internal intercostal, the external abdominal oblique, the rectus abdominis, the external intercostals, and diaphragm muscles. It was found during the study that the diaphragm could not be measured using surface electrodes. From the two subjects examined, several tentative conclusions were reached. They found that at any frequency, the muscle action became greater as the air supply was deleted. They also found that higher frequencies showed progressively greater and earlier muscle activity than did the lower frequencies. One other observation made was that sustained tones of any frequency showed little activity from the external intercostals and rectus abdominis until after several seconds into the tone.

Several studies were done in the early 1970's investigating the role of certain facial muscles in wind instrument embouchure. Using the Basmajian techniques previously mentioned, Isley (16) developed a theory of brasswind embouchure.
Part of his investigation involved the use of electromyography in some of the facial muscles, in an attempt to objectively define which are important for the production of good brasswind tone.

A similar study was done by Newton (18), in which he investigated certain facial muscles during clarinet performance. Twelve subjects were used, with various performance capabilities; some of the subjects were saxophone players. The muscles investigated were the upper and lower orbicularis oris (sometimes called the oral sphincter, but generally known as the lip muscles) and the upper and lower buccinator, which stretches upward and back obliquely from the corners of the mouth.

Newton found that the upper and lower lips were used consistently in the formation and maintenance of the clarinet embouchure. The upper buccinator was used randomly and sporadically in forming and maintaining the embouchure, and the lower buccinator was used more consistently than the upper but less consistently than the upper or lower lips. There appeared to be very little adjustment in any of the muscles investigated to performance requirements. It was observed, however, that subjects who were judged to have better clarinet sound seemed to use the lower buccinator more regularly.

Only one study could be found in which the glottis had been viewed during performance on a wind instrument.
as a part of the study. Weait and Shea (25) attempted to determine the physiological factors involved in vibrato production on bassoon. They used a fluorographic x-ray technique to view from the level of the eyes to the pelvis in both anteroposterior and lateral directions. With regards to vibrato, no rhythmic oscillations could be seen in any part of the anatomy viewed, with the exception of the vocal folds. The vocal folds showed a marked lateral movement in synchronization with the vibrato pulsations.

Another observation made by Weait was that when relaxed during inspiration, the vocal folds were withdrawn laterally; then immediately before the tone began, they moved to a central position standing over the air passageway. During tones both with and without vibrato, the glottal opening was roughly one-third to one-fourth the size it was in relaxed position. Although this is only one study and with only one subject, a professional bassoonist, it does suggest that the glottis is involved in constriction of airflow during performance on a wind instrument.

When fiberoptics was first being considered as the investigative tool for the present study, it was looked upon with some concern that the presence of the fiberscope in the pharynx would make it difficult or impossible for a person to play the saxophone. The main concern was that, since the fiberscope had to be inserted into the nasal
cavity, air might leak from the oral into the nasal cavity. For this reason, a preliminary investigation was conducted with the aid of Dr. Philip Montalbo on November 2, 1983. Dr. Montalbo is an otolaryngologist from Westgate Medical Center in Denton, experienced in the use of the fiberscope.

This writer was the only subject used in the preliminary investigation. No recordings were made in this session, as its purpose was only to find out if the saxophone could be played with the fiberscope in a glottal-viewing position. During this preliminary investigation the fiberscope used had a cable diameter of 4.6 mm. For the rest of the research it was decided to use another fiberscope with a cable diameter of 3.3 mm. because it was thought this would be more comfortable for the subjects.

The fiberscope was inserted through the nasal passage and into the pharynx. The first placement was to check out the equipment and to allow the subject to get used to the fiberscope being in place. It also allowed the subject to see on the television monitor the types of images which would be produced. The fiberscope was then removed and reinserted when the subject was ready to play his saxophone. Although there was a small amount of discomfort with the fiberscope in place, it in no way appeared to inhibit normal sound production on the instrument, and the subject did not notice any air leakage into the nasal cavity. It was concluded from this investigation that it was possible to perform on an
alto saxophone with a fiberscope in glottal-viewing position, with only the minor discomfort of knowing that it was there.
CHAPTER BIBLIOGRAPHY


13. Haynie, J., "Videofluorographic Presentation of the Physiological Phenomena Influencing Trumpet Performance," Unpublished Pamphlet, School of Music, North Texas State University, Denton, Texas.


CHAPTER III

DESIGN OF THE STUDY

Subject Population

This study was designed to make observations of the glottis during performance on an alto saxophone. The first research problem was to describe glottal activity in selected musicians as they performed a musical task covering various pitch registers. There were three subjects used in this study; all were graduate students at least 18 years of age. All of the subjects were either at the time of the research, or had been previously teaching assistants at North Texas State University, majoring either in applied saxophone, woodwinds, or music education with saxophone as the principal instrument.

The researcher served as one of the subjects, and the other two subjects were volunteers who were interested in the research topic. Permission was obtained from North Texas State University to use human subjects for this research, and the subjects signed the appropriate release forms. The subject population was all male, although the study was not intentionally limited in this respect. Each subject filled out a questionnaire designed to gather some
information about performance history, what kind of instrument, reed, mouthpiece, and ligature each plays, and to record the fingerings used in the altissimo register. The responses to these questionnaires are compiled in Appendix A.

The study was limited to using alto saxophone only, because it is the most commonly used saxophone for concert performance. The subjects were asked to play on their own saxophones, with a reed and mouthpiece that they felt comfortable playing on. No controls were instituted on the specifications of this equipment, except that the subjects were required to play on the same mouthpiece, ligature, and instrument for at least a month prior to the testing. This was required so that the subject would be as secure as possible when he performed. Identical equipment was not required because it was the intention of this study only to observe what saxophone players do when they perform. The effect of specific reeds, mouthpieces, etc. was not a consideration of this study.

All sessions took place at the office of Dr. Philip Montalbo, Otolaryngologist practicing at Westgate Medical Center in Denton, Texas. He was the attending physician, and was present at all of the sessions, each of which lasted approximately forty-five minutes. For the convenience of the subjects and the attending physician, sessions were held 7:45-8:30 a.m. on separate mornings for Subjects One and Two, and 1:45-2:30 p.m. for Subject Three.
Investigative Equipment

The main investigative instrument used in the study was an Olympus E N F-P Rhinolaryngofiberscope. The light source was an Olympus C L K-3 halogen lamp. For recording the video, the fiberscope was attached to a Synavision color video camera, manufactured by Medical Dynamics, Inc. This was connected to an RCA Selectavision \( \frac{1}{2} \) inch VHS video cassette recorder. The camera was also connected to a 13 inch television monitor so that the attending physician, who held the fiberscope at the tip of the nose, could make adjustments in the positioning of the fiberscope during the session. The fiberscope needed to be held to help prevent vertical movement of the lense during the performance.

The sound produced by the saxophonists was recorded with a Realistic condenser microphone, through a small preamplifier that sent the sound signal into the video cassette recorder. This provided sound-synchronized recordings with the video image recordings.

Procedure

For each subject, the attending physician anesthetized the nasal passage with a 4% solution of cocaine, applied with a cotton pledget. In addition, the pharynx was anesthetized with an aerosol spray solution of benzocaine. This was done primarily for the "comfort" of the subject, but was especially necessary for Subject One, who gagged occasionally when the epiglottis touched the tip of the fiberscope. The
slight numbing of the epiglottis done with the benzocaine made it much easier and more comfortable for Subject One to perform.

It took about ten minutes for the nasal passage to be anesthetized, and during this time the subject could assemble and warm up his instrument. The subjects remained seated during the session, to help minimize movement of the fiberscope during performance.

The attending physician then inserted the fiberscope through the nasal passage and nasal pharynx, and into the pharynx to about the level of the hypopharynx. With the fiberscope in a glottal-viewing position, the subjects were then asked to play for a few moments to get used to the fiberscope in the pharynx. None of the subjects experienced any difficulty playing their saxophones with the fiberscope in place. At this point, the performance of the musical tasks could begin.

For the investigation of the first research problem, the following three octave C major scale was performed:

```
Figure 6--Musical task no. 1
```
The scale of three octaves was chosen to cover register changes and to show possible gradual changes in glottal movement.

Method of Analyzing Data

Since this type of fiberoptic investigation had never been done before, there had been no precedent set as to how the data should be analyzed. During the performance of the first musical task, several things were going on that could be observed with the fiberscope. These movements were first classified into various observation categories; then within each category, the movements were given an observation rating. A thorough explanation of this observation rating system is given below. The observations for this research problem were made in the middle of each tone of the musical task.

The rating system was not an attempt to give a quantified measurement of the data, but is instead designed merely to represent graphically the relative movement of the musculature of the larynx, as could be observed through the fiberscope. Direct off-screen measurements of the data were not made because there was presently no known quantitative analysis technique which would justify the variables which distort the data. These variables include precise positioning of the fiberscope and relative laryngeal elevation. The human observation technique used was done on three separate occasions, with virtually identical results each time.
Since precise representation of the data cannot be given, an edited copy of the video tape containing the rough data was submitted as a supplement to this thesis. An outline of the videotape, as well as some approximate digital counter numbers, is provided in Appendix B.

The first observation category was the relative lateral position of the arytenoid cartilages. The distance between the arytenoids was rated on a 10 point scale, with 10 being the widest apart, and 1 being the closest. The 4-7 section of the rating scale will require closer examination. A rating of 5 meant that the arytenoids were just barely touching, with no apparent tension. Figure 7 shows ratings of 4, 5, and 7 as demonstrated by Subject One. A rating of 6 indicated very slight separation of the arytenoids, with the interarytenoid fold just barely visible. The ratings of 7-10 indicate increasing length of the interarytenoid fold. A 4 rating meant that the arytenoids were touching, with some apparent inward lateral tension, and a rating of 3 meant

Figure 7--Subject One - Arytenoid lateral position ratings
increased tension. Ratings of 2 and 1 were not given, but the scale was kept a 10 point scale so that both categories observing lateral glottal movement (second category is discussed in the next paragraph) would be on a similar scale.

The lateral movement of the vocal folds was the second observation category, which was also rated on a 10 point scale. Although it might seem like this rating should be the same as the arytenoids, there is a certain amount of independence because of the way the folds are articulated. The vocal fold rating scale used the entire scale, with 1 indicating virtually adducted folds, and 10 indicating the very widest apart that the folds were observed during the session.

Figure 8 shows the unique quality of each subject's vocal folds. Subject Three was the most difficult to rate because of the "wine glass" shape of the glottis, caused by the anterior pinching of the vocal folds. The
ratings given were a 5 for Subjects One and Three, and 10 for Subject Two.

It was found necessary to include one more observation category for all three subjects, this being the relative elevation of the larynx. This was related on a 5 point scale, with 3 indicating what was perceived to be normal resting position. A rating of 5 indicated the highest elevation observed during the session, and 1 indicated the lowest.

Subjects Two and Three had some other laryngeal movements which needed to be categorized. With these two subjects, there was some anteroposterior movement of the glottis, which was rated on a 5 point scale. The primary determinant of this movement was the relative position of the arytenoid cartilages. A rating of 2 indicated the normal position, 5 was the most posterior position, and 1 indicated the most anterior. Figure 9 shows Subject Two with anteroposterior ratings of 2 and 5, respectively. In Figure 9A one can see

![Figure 9--Subject Two - Showing two anteroposterior positions](image)
the shape of the posterior side of the cricoid ring, but in Figure 9B this cannot be seen because of the posterior position of the arytenoid cartilages.

One final observation category, which was only necessary for Subject Three was what will be called a glottal pull to the side. This pull to the side was apparently the result of slightly stronger musculature on one side of the larynx for Subject Three. The rating scale was originally designed to go from 1 to 3, with 3 being the farthest pull to the side. It was later decided that 0 should indicate a centered position, so the scale was adjusted to go from -3 to +3. In the case of Subject Three, the pull was only to the subject's left side, so only positive numbers were used. A rating of 3 required that the glottis be pulled so far over to the side that the left side of the glottis could no longer be seen.

These observation categories were designed to cover all of the observable movements which occurred with some degree of regularity. Other movements observed will be mentioned in the presentation of the results, but did not occur with enough regularity to warrant an observation category.

The second research problem was to observe glottal activity in performance of fortissimo and pianissimo music. The same three subjects were used for the investigation of this problem, and the equipment and procedures were the same
as those described in the first research problem. The only difference was that for this problem, the subjects played the following musical task:

Each subject was asked to perform the example two times. The first time the subjects were asked to play with good tone control as loudly as they could. The second time they were asked to play as softly as possible with a steady audible sound.

The scale was chosen to cover the low, middle, high, and altissimo registers, and so that within these ranges, comparisons could be made with the first musical task. Differences in glottal movements between the two dynamic levels were also made in all registers.

The data were gathered using the same observation categories as described in the first research problem. The observations were again observed and reported in the middle of each pitch performed. As with all of the research problems, observation categories were only reported for each subject when there was some kind of movement observed.
The third research problem was to describe the glottal activity while playing musical tasks requiring a crescendo and decrescendo. Again, the same subjects, equipment, and procedures were used, but for this problem the following musical task was performed:

![Figure 11--Musical task no. 3](image)

The three written E's used in this example represent the middle, low, and high registers. The data were again gathered using observation categories as described earlier, but for this problem, the observations were timed and reported at two second intervals. In this way the gradual movements of the glottis could be represented graphically during the crescendo and decrescendo.

The fourth research problem was to describe glottal changes in tones with vibrato. Again, the same subjects equipment, and procedures were used, but for this problem, the following musical task was performed:

![Figure 12--Musical task no. 4](image)
The three E's were again used in this musical task, representing the low, middle, and high registers. For this problem a visual analysis was done of the data, looking for any type of observable movements which coincided with the audio vibrato pulsations. This same type of visual analysis was done comparing these results with the results of the previous problem, to see if the presence of vibrato in the tone brought about any other observable laryngeal movement, as compared with tones without vibrato.

The final research problem was to describe glottal activity in legato and staccato styles of articulation. For this problem, again the same subjects, equipment, and procedures were used, but for this problem, the following musical task was performed:

\[\text{Figure 13--Musical task no. 5}\]

For this research problem, the data for each section were analyzed visually for any activity which was unusual for the particular range being performed in. Especially looked
for was any movement which was coincidental with the articulation of each note. Then the data for each section were compared.
CHAPTER IV

RESULTS

The first research problem was to describe the glottal activity of selected saxophone players as they performed in various pitch ranges and registers. The results of the data for this first research problem, using the arbitrary rating scale described earlier, are compiled in Table I. The "+" or "lunge" indication in the Elevation of Larynx category indicates a short, temporary movement upward, or "lunge" during the change from the note before. The glottal attacks, indicated by an asterisk in the Vocal Fold category, indicate an apparent adduction of the vocal folds at the beginning of the note. The underlined numbers indicate the start of a new breath on that note.

The glottal opening of Subject One remained fairly constant during the performance of the first performance task. The most notable change was in the arytenoid cartilages over the register change from C2 to D2. In this case, the arytenoids jumped apart for the tone D2, and gradually moved back to their normal position during the following two pitches. The vocal folds also remained relatively constant throughout the range of this performance task, with the exception of the small but noticeable widening on the pitch D2. The elevation of the larynx also remained very constant,
### TABLE I

**RESULTS FOR FIRST RESEARCH PROBLEM**

| S# | Observation                  | Scale | C1 | D1 | E1 | F1 | G1 | A1 | B2 | C2 | D2 | E2 | F2 | G2 | A2 | B3 | C3 | D3 | E3 | F3 | G3 | A3 | B4 | C4 |
|----|------------------------------|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | Arytenoid Cartilages         | 1-10  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 6  | 6  | 5  | 5  | 5  | 5  | 5  | 5  | 5  |
|    | Vocal Folds                 | 1-10  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  |
|    | Elevation of Larynx         | 1-5   | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
| 2  | Arytenoid Cartilages         | 1-10  | 10 | 10 | 10 | 9  | 8  | 7  | 7  | 6  | 10 | 9  | 8  | 8  | 7  | 7  | 6  | 5  | 4  | 4  | 3  | 3  | 3  | 3  | 3  |
|    | Vocal Folds                 | 1-10  | 10 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 8  | 7  | 6  | 5  | 4  | 4  | 3  | 2  | 2  | 1  | 1  | 1  | 1  | 2  | 3  |
|    | Elevation of Larynx         | 1-5   | 5  | 5  | 5  | 5  | 5  | 4  | 4  | 4  | 5  | 5  | 4  | 3  | 3  | 3  | 2  | 2  | 2  | 1  | 1  | 1  | 2  | 3  | 4  |
|    | Anteroposterior Movement    | 1-5   | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 3  | 3  | 3  | 3  | 4  | 4  | 5  |
| 3  | Arytenoid Cartilages         | 1-10  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  |
|    | Vocal Folds                 | 1-10  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5* | 5* | 5* | 5* |
|    | Elevation of Larynx         | 1-5   | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3+ | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |
|    | Anteroposterior Movement    | 1-5   | 1  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 1  | 1  | 1  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 3  | 3  | 3  |
|    | Glottal Pull to Side        | -3 to 3 | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 3  | 3  | 3  |

*Indicates glottal attack  
†Indicates vertical lunge of larynx  
Underlining indicates first note after new breath
with the exception of the last three notes, during which there was a small gradual rise in elevation. This rise also coincided with the glottal attacks on the last three notes of the performance task.

Subject Two showed a great deal of glottal and laryngeal activity. As can be seen in Table I, this movement for the most part coincided with the pitch range within each register.

In the range from C1 to C2, there was a gradual lateral movement inward of the vocal folds and the arytenoids. The elevation of the larynx in this subject also showed a slight movement downward in this pitch range. In the crossover from C2 to D2, the laryngeal elevation came back up, the vocal folds widened, and the arytenoids moved back out to the 10 position. During the performance of the D2 to C3 range, the same gradual inward movement of the vocal folds and the arytenoids occurred to an even greater extent, and the laryngeal elevation dropped to near its lowest point. Beginning on the pitch D3, the vocal folds and arytenoids moved even closer toward adduction, and the glottis began to show some posterior movement. From D3 to G3 increasing tension on the musculature around the arytenoids could be observed, the vocal folds moved even closer toward adduction, and the laryngeal elevation dropped even more. During the last three pitches, however, the elevation of the larynx raised considerably for each note, the glottal opening widened somewhat for each note, and the posterior movement of the arytenoids increased.
Compared with Subject Two, Subject Three showed very little movement in the glottis during the performance of this task. The arytenoids and vocal folds for Subject Three remained virtually unchanged throughout the performance task, as their only observable movement was in the glottal attacks on the last four pitches. The elevation of the larynx remained somewhat constant, with the exception of the very noticeable lunge over the break between the pitches C2 and D2. Anteroposterior movement in Subject Three was rather difficult to define, because the fiberscope seems to have been moved during the performance of the musical task. If the fiberscope did move, it occurred during the first octave of the scale and not after. It is worth noting that this was a gradual posterior movement of the glottis from the pitch E2 all the way to C4.

The glottal pull to the side, which was unique to this subject, seems to have occurred most noticeably in two areas. The first was in the middle register pitches of D2 and E2, and the other area was on the last three pitches of the altissimo register. It should be noted that Subject Three played this performance task roughly twice as fast as the other two subjects.

A comparison of the findings among these three subjects showed a great many inconsistencies. There are, however, specific areas of performance in which all three subjects showed some kind of glottal or laryngeal movements. The
movement from C2 to D2 brought about some kind of movement in all three subjects. Subject One showed a marked lateral movement outward, Subject Two showed a widening of the glottis, along with a raising of the laryngeal elevation, and Subject Three showed the lunge during the register change.

This was the only register change to bring about any observable sudden change in the glottis or larynx for any of the subjects. The only other area in which all three subjects showed consistency of movement was in the altissimo register. The laryngeal elevation of all three subjects raised to at least some degree during the performance of the last three tones.

The second research problem was to describe and compare glottal activity in pianissimo and fortissimo performance. The data were analyzed using the same rating scale as was used in the results of the first research problem, and again the observations were made in the middle of each note of the scale. The observation categories were included as needed; those not included for a particular subject were left out because there was no observable movement during the performance. Table II presents a compilation of the results of the data for this research problem. Only the ascending form of the scale is presented because there were no observable differences between the ascending and descending forms of the scale as performed by these subjects.
## TABLE II

RESULTS FOR SECOND RESEARCH PROBLEM

| S# | V  | Observation         | Scale | C1 | D1 | E1 | F1 | G1 | A1 | B2 | C2 | D2 | E2 | F2 | G2 | A2 | B3 | C3 | D3 | E3 | F3 | G3 |
|----|----|---------------------|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | ff | Arytenoids          | 1-10  | 5  | 5  | 5  | 5  | 5  | 5  | 6  | 6  | 6  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  |
|    |    | Vocal Folds         | 1-10  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  | 5  |
|    | pp | Arytenoids          | 1-10  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  | 4  |
|    |    | Vocal Folds         | 1-10  | 5  | 5  | 5  | 5  | 5  | 5  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 6  | 5  | 5  | 5  | 5  | 5  | 5  | 5  |
| 2  | ff | Arytenoids          | 1-10  | 9  | 9  | 8  | 8  | 7  | 6  | 6  | 6  | 5  | 6  | 6  | 6  | 5  | 5  | 4  | 4  | 3  | 3  | 3  | 3  | 3  |
|    |    | Vocal Folds         | 1-10  | 9  | 9  | 8  | 8  | 7  | 6  | 5  | 5  | 6  | 5  | 5  | 5  | 5  | 5  | 4  | 4  | 3  | 2  | 2  | 2  | 2  |
|    |    | L. Elevation        | 1-5   | 4  | 4  | 4  | 4  | 3  | 3  | 3  | 3  | 4  | 3  | 3  | 3  | 3  | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  |
|    | pp | Arytenoids          | 1-10  | 6  | 5  | 5  | 4  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 2  | 2  | 2  | 2  | 1  | 1  |
|    |    | Vocal Folds         | 1-10  | 6  | 5  | 5  | 4  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
|    |    | L. Elevation        | 1-5   | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
| 3  | ff | Anteroposterior     | 1-5   | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
|    |    | Glottal Pull        | -3+3  | 2  | 2  | 2  | 2  | 2  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 2  | 2  | 2  | 2  | 2  | 2  |
|    |    | L. Elevation        | 1-5   | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
|    | pp | Anteroposterior     | 1-5   | 2  | 2  | 2  | 2  | 2  | -  | -  | -  | -  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
|    |    | Glottal Pull        | -3+3  | 2  | 2  | 2  | 2  | 2  | -  | -  | -  | -  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  | 3  |
|    |    | L. Elevation        | 1-5   | 3  | 3  | 3  | 3  | 3  | -  | -  | -  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  | 2  |

*Indicates glottal attack
†Indicates vertical lunge of larynx
-Indicates observation is blocked
Subject One showed nearly the same arytenoid and vocal fold movement for the fortissimo performance as he did for the same part of the scale in the first research problem. The only difference was a slightly less apparent response to the C2 to D2 register change in this performance. The pianissimo performance of this scale showed some noticeably greater inward tension on the arytenoids, which was consistent throughout the scale. The vocal folds appeared to be in the same position as for the fortissimo scale, but after the pitch F1 they were blocked from view by the epiglottis. During the performance of the pianissimo scale, the epiglottis moved posteriorly to a position which blocked the fiberoptic view of most of the vocal folds but allowed for viewing of the arytenoids.

A comparison of the fortissimo and pianissimo performances of this subject showed that there was some glottal and some apparent epiglottal constriction throughout the pianissimo scale, as compared with the fortissimo scale.

The fortissimo performance of Subject Two showed similar tendencies in response to pitch range and register as were found in the performance of the first task. One noticeable difference in this performance was the addition of the laryngeal lunge over the break from C2 to D2. This was not present during the performance of the first task because the subject breathed at that point during that performance. During the pianissimo performance, Subject Two
did not show as much glottal or laryngeal response to pitch range or register. The arytenoids, vocal folds, and laryngeal elevation remained constant over the C2 to D2 register change, except for the elevation lunge, which again occurred at this point. During the entire pianissimo performance, however, the vocal folds and arytenoids were noticeably more constricted than in the same tones of the fortissimo performance. The laryngeal elevation during the fortissimo performance was slightly higher during the first octave than the pianissimo performance, but for the remainder of the scale they were roughly the same.

For Subject Three, again the findings of the fortissimo performance were remarkably similar to the first musical task. There was one point at which the vocal folds could no longer be seen well enough to judge (indicated by the dashes) because the glottis was pulled too far to the side. The glottis during the pianissimo performance showed similar activity to the fortissimo, except that there appeared to be generally more tension on the laryngeal musculature. This was indicated most clearly by the glottal pull to the side in the second half of the scale. During the pianissimo performance, the glottal pull to the side remained constant throughout the upper half of the scale, whereas this movement relaxed somewhat in the higher register of the fortissimo performance. All of the observations were blocked off on the pitches A1, B2, and C2 of the pianissimo performance by a temporary posterior movement of the epiglottis.
All three subjects showed similar activity in comparing the loud and soft performances. Although Subject Two was the only subject to show consistent glottal constriction in the pianissimo performance, the other two subjects showed increased muscular effort, i.e., tension on the arytenoids of Subject One and the glottal pull to the side for Subject Three. One other movement which these two subjects had in common was the posterior epiglottal movement, which occurred for both subjects around the pitch G₁ or A₁ in the pianissimo performance.

The third research problem was to describe glottal activity during performance of music with a crescendo and decrescendo. The same observation rating scales were again used, and again the categories were used only as needed. The observations for this research problem were made at two second intervals, which seemed adequate for showing graphically the glottal activity during each tone. Because the length of the tones was not always the same, the observation tables were lined up so that the loudest point of each tone appeared in the same column.

Table III shows the results of this research problem for Subject One. For the pitch E₁, there was a definite widening of the glottis during the crescendo. The decrescendo shows a minor narrowing of the glottis, but it never equalled the starting point of the tone. For the pitch E₂, the epiglottis got in the way during some of the observation
### Table III

**Results of Subject One for Third Research Problem**

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<th>Pitch Observation</th>
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<th>7</th>
<th>9</th>
<th>11</th>
<th>13</th>
<th>Timing</th>
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<td>5</td>
<td>7</td>
<td>8@</td>
<td>7</td>
<td>7*</td>
<td>6*</td>
<td></td>
</tr>
<tr>
<td><strong>Vocal Folds</strong></td>
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<td>4</td>
<td>6</td>
<td>8@</td>
<td>7</td>
<td>7*</td>
<td>7*</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>7</td>
<td>7@</td>
<td>6</td>
<td>6</td>
<td>5*</td>
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<tr>
<td><strong>Cartilages</strong></td>
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<td>-</td>
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<td>5</td>
<td>5</td>
<td>6@</td>
<td>6</td>
<td>5*</td>
<td>5*</td>
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</tr>
<tr>
<td><strong>Cartilages</strong></td>
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<tr>
<td><strong>Vocal Folds</strong></td>
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</tr>
</tbody>
</table>

*Indicates erratic lateral movements; number is an average.
-Indicates epiglottis blocked the view.
@Indicates loudest point of tone.
time. Despite this, the widening and narrowing of the glottis can be seen clearly (indicated primarily by the arytenoids), this time to an equal extent. During the performance of the pitch E3, the epiglottis blocked the view of the vocal folds the entire time. Here there was only a slight widening and narrowing of the glottis, again indicated by the arytenoids.

The reason for the erratic lateral movements of the vocal folds is unclear. It is apparently not because the subject is running out of breath because for the pitches E2 and E3 the movement stopped before the end of the note. One other time was observed when the subject actually did run out of breath, causing erratic movements, but the movements were a good deal quicker in that instance. These movements were probably influenced by some other unobservable factor, but it should be noted that they always initially occurred at a comparable point in the decrescendo.

For all three of the pitches tested, this subject showed the crescendo accompanied by a widening of the glottis and the decrescendo by a narrowing of the glottis. This movement was more pronounced in the lower register than in the higher, but in the lower register the crescendo brought more movement than the decrescendo.

The results for Subject Two in this research problem are found in Table IV. During the crescendo on the pitch E1, the vocal folds of this subject started in a position which was
TABLE IV

RESULTS OF SUBJECT TWO
FOR THIRD RESEARCH PROBLEM

<table>
<thead>
<tr>
<th>Pitch Observation</th>
<th>1</th>
<th>3</th>
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<th>9</th>
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<td>8</td>
<td>8</td>
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<tr>
<td>Vocal Folds</td>
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<td>1</td>
<td>1</td>
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<td>3</td>
<td>2</td>
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</table>

@Indicates loudest point of tone.
quite wide open for this pitch range and dynamic level, then became slightly narrower during the crescendo. The folds continued to get narrower during the decrescendo, as did the arytenoids. The performance of the pitch E2 brought about very little movement in the vocal folds and arytenoids. The vocal folds remained unchanged until one-fourth of the way into the decrescendo, and the arytenoids remained unchanged until the last quarter of the decrescendo. It is interesting to note here that on this pitch only the laryngeal elevation dropped notably with the crescendo, then showed a slight return with the decrescendo.

During the pitch E3 this subject demonstrated a widening of the glottis during the crescendo, and a narrowing of the glottal opening back to the original size during the decrescendo.

A comparison of the three pitches tested for this subject showed that the only common movement of all three pitches was the marked narrowing of the glottis during the decrescendo. The glottal opening for the pitch E3 was generally smaller, which was probably in response to pitch range, but it was slightly wider for E2 than it was for E1. This was contrary to Subject Two's response to pitch range in the first two performance tasks.

The results of the third research problem for Subject Three are found in Table V. For this subject, the arytenoids were not included as an observation category because either
TABLE V

RESULTS OF SUBJECT THREE
FOR THIRD RESEARCH PROBLEM

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<thead>
<tr>
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<th>Observation</th>
<th>Timing (in seconds)</th>
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<tr>
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<td>Glottal Pull</td>
<td>1 1 1@ 2 2 2</td>
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<tr>
<td></td>
<td>Elevation of Larynx</td>
<td>4 4 3@ 2 3 5</td>
</tr>
<tr>
<td>E2</td>
<td>Vocal Folds</td>
<td>5 - - - - -</td>
</tr>
<tr>
<td></td>
<td>Glottal Pull</td>
<td>1 3 3@ 3 3 3</td>
</tr>
<tr>
<td>E3</td>
<td>Vocal Folds</td>
<td>3 3 3@ 3 3 3</td>
</tr>
<tr>
<td></td>
<td>Glottal Pull</td>
<td>3 3 3@ 2 2 2</td>
</tr>
<tr>
<td></td>
<td>Elevation of Larynx</td>
<td>4 4 3@ 3 3 3</td>
</tr>
</tbody>
</table>

-Indicates epiglottis blocked the view.
@Indicates loudest point of tone.
the glottis was pulled too far to the side to see them, or they remained constant. In his performance of the pitch E1, the vocal folds also remained constant, and the glottal pull to the side increased during the decrescendo. The laryngeal elevation dropped during the crescendo and raised during the decrescendo.

For the pitch E2, the vocal folds began in their normal position, but soon after the crescendo started, the glottis pulled so far off to the side that the vocal folds could no longer be seen. It remained in this position to the end of the tone. For this pitch, the laryngeal elevation also appeared to remain constant. For the pitch E3, even though the vocal fold opening remained constant, it did so with a smaller opening size than for any of the other pitches. The pull to the side was greater during the crescendo and tapered off during the decrescendo. The laryngeal elevation dropped slightly during the crescendo, and this time remained constant for the rest of the tone.

Comparisons between the registers for this subject show nothing conclusive. In the low register the glottal pull was stronger during the decrescendo, and in the high register it was stronger during the crescendo. In the middle register it seemed to be consistently strong. It should be noted that the performance of the pitch E3 showed the first real constrictive glottal movement for this subject.
In this research problem all three subjects agreed on only one thing, and that is that there is some kind of movement, glottal and/or laryngeal, during the performance of a crescendo-decrescendo. Even though Subjects One and Two demonstrated widening and narrowing of the glottis, their movements were at times inconsistent. Subjects Two and Three appeared to agree on the dropping and raising of the larynx during the crescendo and decrescendo, but their movements were also somewhat inconsistent.

The fourth research problem was to describe glottal activity in the performance of long tones with vibrato. Being observed were rhythmic pulses or oscillations occurring in time with the audio vibrato pulsation. For the first time, all three subjects were consistent in that there was no observable glottal movement in rhythm with the audio vibrato pulsation on the three pitches tested. The data for this research problem were also compared with the data from the previous research problem because there were some apparent differences in what was observed with the fiberscope.

For Subject One, the epiglottis was present in the picture for all three tones tested, but for the tone E2, it completely blocked the view of the glottis. For E1 it was present in the picture, and for E3 it blocked about two-thirds of the vocal folds, still allowing the arytenoids to be seen. In comparing these results with the results of the previous research problem, the only apparent difference
was that the epiglottis seemed to be in a more posterior position throughout in the tones with vibrato.

Although the epiglottis of Subject Two was never fully seen throughout the entire session, the E2 pitch played with vibrato allowed viewing of roughly half of the posterior side of the epiglottis. During the E1 pitch performance the epiglottis could not be seen at all, and for E3, it was just barely visible at the bottom of the picture.

For Subject Three, the epiglottis was again visible on all three pitches tested. During the performance of both E1 and E2, the epiglottis moved posteriorly shortly before the initiation of the tone. The extent to which it moved was difficult to determine because the fiberscope was slightly repositioned during the tone so that the glottis could be viewed. In the performance of E3, during approximately the middle one-third of the tone, the epiglottis moved posteriorly to block the view of all of the vocal folds.

In tones performed with vibrato, all three subjects demonstrated a more posterior positioning of the epiglottis, especially toward the middle of the tone. One other observation that must be made in relation to this is that, although it was not asked for, each of the subjects performed at least a small crescendo-decrescendo in these tones with vibrato. This may be at least partially explained by the fact that this musical task was performed after (but not directly after) the crescendo-decrescendo performance task.
The fifth and final research problem was to describe the glottal activity in legato and staccato performance. Because the results of the data for each subject were fairly consistent throughout the performance task, it was not considered to be essential to present complete tables of the results.

For the first subject the glottal opening during the legato performance was virtually the same as this same pitch range in the first performance task. The only difference was that the epiglottis could be seen moving in conjunction with the tonguing of each tone.

For the staccato performance, Subject One showed a good deal of laryngeal movement on each tone of the scale. On the pitches G1-C2, these movements were primarily short vertical lunges of the larynx, which occurred just after the beginning of each tone. The C2 and D2 pitches were transitional in that they showed a combination of the vertical lunge and a lateral widening and narrowing of the vocal folds and arytenoids occurring during each tone. The pitches above D2 showed only the lateral widening and narrowing. It was noted that this change occurred over the register change and that the movements are similar in both the ascending and descending forms of the scale. It should also be noted that the epiglottis moved in conjunction with the articulation in both the legato and staccato performances.
The legato performance of Subject Two showed no glottal movements in conjunction with the articulation, but it was learned after the session that he interpreted legato articulation as not being tongued, unless the note was repeated. For the staccato performance his glottis showed a marked vertical upward lunge, close to the beginning of each tone of the scale.

For Subject Three there was again no apparent glottal activity in conjunction with the articulation in the legato performance. For the staccato performance this subject also showed the vertical lunges for each tone, but the shape and size of the glottal opening for this performance should be brought to attention. The vocal folds are pinched closed from the anterior to a point approximately three-fourths of the way to the arytenoids. The arytenoids maintained their normal medium-open position, creating a very small, almost triangular shaped opening, resembling effort closure as described in Chapter I. This shape did not vary throughout the scale. Subject Three's normal glottal pull to the side is not evident here, although several of the lunges moved slightly to the side as well as vertically.

In comparing the three subjects on this research problem, there was agreement in the legato performance in that there was no glottal response to the articulation. The staccato performance also showed agreement in the vertical lunge toward the beginning of each note. The only variation came
from Subject One on the middle register tones of D2-G2.
Possible reasons for this difference will be discussed in
the following chapter. The epiglottal movements of Subject
One were probably related to the tongue movements. The
reason it could be seen so well in Subject One is that his
epiglottis was seemingly more posteriorly based and could
be seen more prominently throughout the study.
CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of the present study was to investigate glottal changes in selected musicians as they performed five musical tasks on the alto saxophone. The specific research problems of the study were to observe and describe glottal and/or laryngeal movements as the subjects performed musical tasks with (1) various pitch ranges and registers, (2) fortissimo and pianissimo dynamic levels, (3) crescendo and decrescendo, (4) long tones with vibrato, and (5) legato and staccato styles of articulation.

A fiberoptic laryngoscope was employed to make observations of the glottis during the performance, and the data were recorded on a sound synchronized video tape. The subject population included three performers, judged to be approximately equal in performance ability. This sample was deemed sufficiently large enough for an exploratory investigation.

The data were gathered by identifying and categorizing any observable movements of the laryngeal musculature. These movements included lateral movements of the arytenoid cartilages and vocal folds, vertical movements of the larynx, anteroposterior movement of the glottis (indicated primarily
by the arytenoids), and the glottal pull to the side, which was demonstrated by only one subject. Other movements were observed and reported but did not occur with enough regularity to warrant an observation category. Within each category, an observation rating scale was designed on a 3, 5, or 10 point scale. Observations were made at regular intervals, either in the middle of each tone of the musical task or at two second intervals.

The results of the observations of the three subjects seldom showed agreement in the types of laryngeal movements observed, but there were specific areas where they all showed some similar sorts of laryngeal movement. The results of the first research problem, which was to describe laryngeal movements in various pitch ranges and registers, indicated the laryngeal elevation rising through the pitches A₃, B₄, and C₄ for all three subjects. For the C₂ to D₂ register change, the subjects showed agreement only in that there was some sort of laryngeal movement during the register change. Subjects Two and Three showed the vertical laryngeal lunge during this register change, while Subject One demonstrated a lateral widening of the glottis.

In comparing the fortissimo and pianissimo performances in the second research problem, the subjects again agreed, but only in that there was an apparent increase in laryngeal muscular effort during the pianissimo performance. Subject Two showed very noticeable glottal constriction throughout
the pianissimo performance, while Subject One showed slight glottal constriction (indicated by the position of the arytenoids), and Subject Three showed increased glottal pull to the side, as compared with the fortissimo performance.

Subjects One and Three demonstrated a more posterior epiglottal position during the pianissimo performance. For Subject One, it was fairly consistent posterior positioning, while for Subject Three the epiglottis appeared to move back and forth sporadically.

For the crescendo-decrescendo task of the third research problem, the subjects again displayed agreement only in that there was some kind of laryngeal movement which was coincidental with the crescendo-decrescendo. Subject One showed regularly the widening and narrowing of the glottis, Subject Two showed primarily the dropping and raising of the laryngeal elevation, and Subject Three showed the glottal pull to the side, as well as some dropping and raising of laryngeal elevation.

The results of the fourth research problem indicated that no glottal or laryngeal movements were present in any of the subjects in synchronization with the vibrato pulsations. It should also be noted that all three subjects demonstrated a more posterior epiglottal position during performance of tones with vibrato.

The final research problem produced agreement among the subjects in that there was no apparent glottal or laryngeal
reaction to the legato style of articulation, with the exception of the epiglottal movements of Subject One. The staccato performance brought unanimous agreement in that glottal movements which resembled a pumping action were present on every note. All subjects showed the laryngeal lunge on each note of the scale, with the exception of the G1 to C2 range of Subject One's performance, in which he demonstrated the lateral widening and narrowing of the glottis on each tone.

The following conclusions were drawn from the results of the present study.

1) The results of the first research problem indicated that in the C2 to D2 register change some movement of the larynx could be observed. This movement was either a vertical laryngeal lunge or a lateral widening of the glottis. This was the only register change to bring about any observable movement in the larynx. Teal (3), in his discussion of the altissimo register mentions the importance of embouchure pressure, air support, throat position, and greater velocity of air required to play in the altissimo register. While the present study does not support the idea that something different is happening in the altissimo register, it cannot entirely refute the idea because the sample group was small.
2) The only pitch range within a register to produce consistent observable movement was during the pitches A3, B4, and C4 in the altissimo register, in which all three subjects evidenced a slight rise in laryngeal elevation.

3) The results of the second research problem suggested that the pianissimo performance appeared to require greater muscular effort than the same pitches at a fortissimo dynamic level. The increased muscular effort seemed to be consistent throughout all of the pitch ranges and registers tested.

4) The results of the third research problem suggested that the crescendo-decrescendo brought about two types of movements which coincided with the crescendo-decrescendo; (A) a dropping and raising of laryngeal elevation, and (B) a lateral widening and narrowing of the vocal folds. The subjects were not consistent with each other in these movements, nor were they consistent with themselves in what they did on the three pitches tested. At least one of the above movements, however, was apparent in almost all of the pitches tested in all of the subjects.

The increased laryngeal muscular effort during pianissimo performance does support common sense reasoning, since a relatively constant velocity of airflow must be maintained to assure uniformity of tone color. The increased muscular effort could be an attempt to reduce the volume of air leaving the lungs, without allowing the velocity to
diminish. Since all three subjects were not consistent in the type of muscular effort exerted during the pianissimo performance, there are probably other unobservable factors which may influence the velocity of airflow.

5) The results of the fourth research problem indicated there was no apparent glottal reaction to, or influence on the production of vibrato on alto saxophone. Weait (4) showed that the glottis was apparently used to produce vibrato on bassoon. The present study shows that this is probably not the case with regard to the alto saxophone.

6) The results of the fifth research problem indicated there was no glottal activity observed in music performed with legato articulation. With staccato articulation, however, there was a marked pumping action of the glottis. This took the form of either the vertical lunge, rising on each note, and falling back between the notes, or in the case of one subject on the pitches G1-C2, a lateral widening of the glottis during the note, and narrowing between the notes.

7) Laryngeal movements appeared to be most prevalent and consistent in two performance situations: (1) when variations in dynamic level were required, especially in pianissimo performance, and (2) in situations where the resistance of the instrument changed quickly, i.e., the stopping and starting of the tone in staccato performance and the C2-D2 register change.
8) The glottis does appear to be used as an expiratory airflow constrictor during performance on alto saxophone, especially during pianissimo performance, and to some extent, on higher register tones. Subject Two demonstrated the greatest variety of glottal movement, which may be explained by the fact that he used a slightly softer reed than the other two subjects, and his instrument had a slightly larger bore design than those of the other two subjects. These two factors can produce relatively less resistance in the instrument than in the instruments of the other two subjects, which may have required Subject Two to use more laryngeal control over airflow, since his instrument did not provide as much resistance.

Saxophone pedagogists such as Teal (3) and Leeson (2) have not considered the glottis as a part of the airflow or breath support system. Although the results of the present study cannot at this point be directly applied to pedagogical situations, they do indicate that present pedagogical thought about airflow in saxophonists may require re-examination.

It was observed that there may have been a relationship between the types of laryngeal movements observed and the vocal training of the subjects. There were several instances in which Subject One, who had had moderate vocal training and sang regularly with church and civic choirs, showed different types of laryngeal movement from the other two
subjects, who had had no vocal training and did not sing regularly. Subject One's performance differed mainly in that he showed very little vertical laryngeal movement. He, like the other subjects, showed a slight rise in elevation on the altissimo register pitches of A3-C4, and he also showed a small laryngeal lunge in the staccato performance of the pitches D2-G2. The other two subjects showed the lunge on all of the notes of the staccato scale, as well as over the C2-D2 register change. There was also vertical laryngeal motion in these two subjects during the crescendo-decrescendo, and to some extent, in the performance of various pitch ranges (especially for Subject Two, see Table I, p. 43). The possible influence of vocal training on the types of laryngeal movements should be examined in further research.

Another observation made, which was mentioned previously, was the fact that Subject Two, who used a slightly softer reed and different model of saxophone from the other two subjects, showed the greatest amount of laryngeal, and especially glottal activity during performance. No conclusions can be drawn concerning this relationship in the present study, but it does indicate that the brand of reed, mouthpiece, or instrument used may have some effect on laryngeal movement observed in the performer.

One final area in which movements were observed which should be mentioned is in the epiglottis. The epiglottis
assumed a more posterior position in all subjects in tones with vibrato, and in two of the subjects in pianissimo tones. Manuel Garcia (1), teacher of singing and inventor of the laryngoscope, noted the epiglottal influence on the quality of voice. He observed that when the epiglottis was in a more posterior position, nearly covering the orifice of the larynx, the voice is very brilliant, but when it is drawn back anteriorly, the voice becomes veiled.

This epiglottal effect on voice quality may not relate directly to the movements observed in the present study, but it does show that the epiglottis is functional in situations other than swallowing. Its role in saxophone performance may be revealed in further research.

The technique of fiberoptics was used as the investigative tool in the present study, and worked well as a tool to observe glottal movements in alto saxophone players. There seems to be no reason why this technique would not work with other wind instruments. It is hoped that future research will show more studies of laryngeal movements during performance on other wind instruments.
CHAPTER BIBLIOGRAPHY


APPENDIX A

SUBJECT NUMBER ONE

Age .................................. 25
Number of years played saxophone. . . . 16

Mouthpiece type .................. Selmer C* S-80, slightly modified.
Reed brand ......................... Vandoren
Reed strength ...................... 3
Ligature type (brand) ............. Rovner (light)
Saxophone type (model) ............ Selmer Mark VI

Vocal training? ................. some
Do you sing regularly? ............ yes, every Sunday in a choir.

Fingerings used in the altissimo register:
SUBJECT NUMBER TWO

Age ................. 29
Number of years played saxophone. ... 17

Mouthpiece type .......... Selmer C* S-80 (stock)
Reed brand. ................. Selmer Omega
Reed strength ............... 2½
Ligature type (brand) ........ Winslow
Saxophone type (model) .......... Selmer Mark VII

Vocal training? .......... none
Do you sing regularly? .......... no

Fingerings used in the altissimo register:

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<th>A3</th>
<th>B4</th>
<th>C4</th>
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<td>o</td>
<td>D</td>
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<tr>
<td>Bb</td>
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</tbody>
</table>
SUBJECT NUMBER THREE

Age ........................................... 25
Number of years played saxophone.......... 15

Mouthpiece type ................................ Selmer C* S-80 (stock)
Reed brand....................................... Vandoren
Reed strength................................... 3
Ligature type (brand)........................... Rovner (light)
Saxophone type (model)......................... Selmer Mark VI

Vocal training?................................ none
Do you sing regularly? ....................... no

Fingerings used in the altissimo register:

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<th>B4</th>
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## APPENDIX B

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<td>4</td>
<td>S1</td>
<td>M.T. 5</td>
</tr>
<tr>
<td>5</td>
<td>S2</td>
<td>M.T. 6</td>
</tr>
<tr>
<td>6</td>
<td>S3</td>
<td>Entire Session</td>
</tr>
<tr>
<td>7</td>
<td>End of Tape</td>
<td></td>
</tr>
</tbody>
</table>

Subject One, Subject Two, Subject Three, SI, S2, S3.
BIBLIOGRAPHY

Books


Articles


Farnsworth, D.W., "High Speed Motion Pictures of the Human Vocal Cords," *Bell Laboratories Record*, 18 (March, 1940), 203-208.


Unpublished Materials


Haynie, J., "Videofluorographic Presentation of the Physiological Phenomena Influencing Trumpet Performance," unpublished pamphlet, School of Music, North Texas State University, Denton, Texas.
