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TRUMPET PERFORMERS

APPROVED BY

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ELECTROPHYSIOLOGICAL EXAMINATION OF
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CHAPTER I

INTRODUCTION

Writing on the subject of organisms adapting to a given situation, Prosser states that "organisms respond to environmental change in different ways according to the time during which the environmental change persists and according to the magnitude of the stress."[1] Coping with various stresses imposed upon the lips by the forces of the mouthpiece is regarded as a major problem associated with effective trumpet performance. Understandably, the problem is more prevalent among non-professional players; however, professional players are reputed to have experienced less chronic periods of ineffectiveness from this type of an environment. In fact, so paramount is the problem that it is inconceivable that there is any student of the trumpet

[1] C. Ladd Prosser, Adaptation to the Environment (Baltimore, Maryland: Waverly Press, Inc., 1964), p. 1.

who has not had some difficulty in developing a resistance to the effects of mouthpiece stress.

Physiologically, the trumpet performer must alter patterns of body function when striving to become more proficient. When the mouthpiece is placed against the lips normal hemodynamics are interrupted. As the player produces a pitch the lip-reed mechanism necessitates a continuous flow of air from the lungs, and thus inhibits normal ventilatory function. No doubt, both ischemia and hypoxia are responsible for the fatigue effects which occur in the vibratory portion of the labial structure during trumpet performance; thus, the purpose of this examination is to explore adaptation of the structure in question to such an environment.

Basic Anatomy and Physiology of Regional Skeletal Muscle

When the mouthpiece is positioned against the lips the muscles of mastication must execute rather complex motor functions. Logically, both the *superioris* and the *inferioris* muscle groups respond rather covertly and in a very unique manner. While most of the facial muscles (in that there is a linkage system) are utilized, only the orbicularis oris will be examined in the present inquiry.

The orbicularis oris is one of a class of muscles within the human body known as regional skeletal muscle.

Karpovich,[1] describes rather straightforwardly the properties of skeletal muscle tissue. A muscle is constituted by many thousands of muscle fibers, each being wrapped in a sheath of elastic membrane known as sarcolemma. The main content of the fiber is a large number of myofibrils (several thousand) which then contain several thousand filaments. When neural activation occurs there is then a polarity interaction between myosin and actin in the filament which is highly suspect as to the responsibility for contraction.

When a muscle is effectively stimulated a number of almost instantaneous transformations take place. The muscle shortens or attempts to shorten, and simultaneously, or nearly simultaneously, electrical, structural, chemical, and thermal changes occur.[2] This stimulation is commonly referred to as contraction, of which several types exist. Fulton,[3] suggests that when a muscle shortens and its function is on the order of acceleration, that contraction is isotonic. If there is a fixation of function and the length remains constant, the contraction is isometric.

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[1]Peter V. Karpovich, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1965), pp. 3-24.

[2]John F. Fulton, A Textbook of Physiology (Philadelphia and London: W. B. Saunders Company, 1955), p. 124.

[3]*Ibid.*, p. 126.

Active muscles cause changes in the metabolic rate. As the muscle continues to work various chemical concentrations become greater and the anaerobic state of the muscle causes the work to become more laborious. Aerobic capacity is, in part, a function of hemoglobin supply. Each muscle receives blood through one or more arteries. An artery branches freely to supply a profuse network of capillaries in the connective tissue supporting the individual muscle fiber. The blood is separated from the muscle substances by only the sarcolemma, therefore, allowing comparative freedom of exchange between hemoglobin and muscle fiber.[1] Capillary beds, noted by Karpovich,[2] are abundant in muscle, consisting of as many as four-thousand per square millimeter.

Brief Anatomy and Physiology of Ventilation and Hemodynamics

Musicians in general do not recognize that development of larger inspiratory capacities serve to reduce oxyhemoglobin debt as well as assisting with "breath support." It is therefore difficult to dichotomize respiratory and circulatory functions as applied to the trumpet performer.

On the way to the depths of the lungs inspired air is warmed, moistened, and cleansed in the nose and pharynx,

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[1] Karpovich, op. cit., p. 8.

[2] Ibid., p. 8.

and is conducted through the trachea and bronchi with little change in composition. As the air reaches the lungs, alveoli situated on the lung walls allow gas exchanges of O_2 and CO_2 with the blood by process of diffusion.

Vital capacities in the average adult male include some six liters. The volume in athletes, particularly those engaged in sports which demand maximum muscular effort over a period of time, may greatly exceed this figure.[1]

When oxygen reaches the blood stream the cardiovascular system must then be responsible for distribution throughout the body. This complex cycle involves flow through arteries, veins, and capillaries which ultimately anastomose, and cause the process to be duplicated many times during a life time. As the blood reaches the tissues there is a similar exchange of gases which assists in keeping the body's basal metabolism rate. Obviously, the flow rate is considerably lower as blood circulates in the smaller arteries and arterioles. Acknowledging capillary flow rate, coupled with ischemia, and the decreased oxygen tension brought about by altered ventilation, the writer finds it rather remarkable that some performers condition a resistance in the lip to such adversities, while understandably other performers become victims of the condition.

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[1]Fulton, <u>op. cit.</u>, p. 815.

Review of Physiological Wind Instrument Studies

In the past few years several physiologists in various countries of the world have focused some attention on the physical aspects of brass wind instrument performance. One such examination was undertaken at the Institut fur Leistungsmedizin of Berlin by Mellerowicz, as reported by Faulkner.[1] A special X-ray device was used to photograph the heart during trumpet performance on a mouthpiece. Before blowing, the heart volume in the adult male subject measured 781 cubic centimeters; but during performance the volume decreased to 731 cubic centimeters. It was concluded that the decrease in heart size during the processes of performing on the mouthpiece was normal for work of similar activities found in athletes. Whether this decrease is normal for such musical function may only be established after measuring larger numbers of players.

Mellerowicz[2] investigating other cardiac functions attached a six lead electrocardiogram system to several trumpet performers and recorded rate changes. During the first six seconds the rate rose eighteen strokes per minute in some subjects, while in others the rate fell. There was the suggestion that patterns of blowing correlate with

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[1]Maurice Faulkner, "Measurement of Heart Volume and the Results of an Electrocardiogram During Blowing of a Trumpet Mouthpiece," The Brass World, Vol. III, 1966, p. 245.

[2]*Ibid*., p. 252.

heart rate changes. Noted also, was the fact that the amplitude of the R-wave changed during the examination, which no doubt warrants additional study.

That playing long loud high notes on the trumpet caused circulatory effects similar to the effects of Valsalva manoeuvre was demonstrated by Faulkner.[1] In this study intrathoracic pressures were measured along with arterial pressures. In the non-professional the arterial pressures were considerably greater than in the professional. Intrathoracic pressures were much less in the non-professional than in the professional player. Pressure readings in the professional were recorded at 160 mm. Hg, well below that tolerated during a cough or a sneeze which has been recorded at 450 mm. Hg. Less experienced players registered near 60 mm. Hg. Suggested in the study was that similar pressures might be recorded during training in order to demonstrate errors in technique.

In that the cardiovascular cycle appears to undergo changes during trumpet playing, one might necessarily inquire as to what local changes in circulation result. One such attempt was made recently by Weast and Hake.[2] Their conclusions were that "the turgid lip condition is due to

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[1] Maurice Faulkner, "Circulatory Effects of Trumpet Playing," <u>The Brass World</u>, Vol. I, 1965, pp. 3-4.

[2] Robert Weast and Ardell Hake, "A Definitive Analysis of Mouthpiece Pressure," <u>The Brass World</u>, Vol. I, 1965, pp. 38-43.

the accumulation of tissue fluid. Mouthpiece pressure is the main precipitator, increased capillary pressure is a second cause and the vibrating lip activity itself is a probable third cause."[1] It was observed that players can, at will, vary the amount of mouthpiece pressure on any note. In some instances such force could be varied by as much as 18 pounds for a given pitch. One professional player utilized 41 pounds of external mouthpiece pressure while performing. It was suggested that there was not a maximum or minimum pressure level for each note in a given continuum. Finally, three rather salient observations were made in that: (1) inexperienced players or out-of shape players use more pressure than do well developed players; (2) as fatigue sets in, pressure increased somewhat proportionately; and (3) nervousness causes the player to utilize more pressure.

Several studies have recently been performed to investigate effects of respiration change during wind instrument performance. During the Summer of 1966, Dr. Maurice Faulkner conducted an experiment at the University of Munich in Germany.[2] His findings revealed that when sustaining a loud long phrase the trumpeter's oxygen and carbon dioxide levels within the blood fell. Acid-alkali balance in the blood chemistry also underwent alterations. Faulkner

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[1] Ibid., p. 40.

[2] Maurice Faulkner, "The Function of the Lungs in Playing a Brass Instrument: Blood Gas Measurement," The Brass World, Vol. III, 1967, p. 205.

suggests that "the performer should organize his musical phrases, which require such physical exertions, into shorter periods of time so that oxygen recovery can be obtained at more frequent intervals."[1]

Writing on the subject of lung volumes and breathing patterns of wind instrument players, Bouhuys'[2] research finds that professional wind players, especially brass instrumentalists, have a vital capacity which is larger than normal. He also finds that their breathing patterns vary according to the demands of the performance. Trumpet players tended to over-inhale when they were asked to perform in the upper register with high amplitudes.

Physiological Studies Concerning Muscular Activity

Although little quantitative evidence is available at this time linking trumpet performance with physical conditioning, the writer nevertheless suspects that there might be a rather remarkable relationship. Not uncommon are trumpet players who appear to be totally "out-of-shape." In fact, if examined, a great number of performers would no doubt qualify as physically "unfit."

The human body, when conditioned through exercise, is quite capable of adapting to physical stress. In

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[1] Ibid., p. 205.

[2] Arend Bouhuys, "Lung Volumes and Breathing Patterns in Wind-Instrument Players," Journal of Applied Physiology, Vol. XIX, 1964, pp. 967-975.

microbiology it has been observed that the longevity of the single cell protozoa has been increased from three to four times upon subjection to exercise induced by oscillation in water. No longer are cardiovascular patients inactive for indefinite periods of time. Restoration to an active life can be prompted through carefully administered physical fitness programs. Biomedical investigations in astounding quantities present evidence which demonstrates that respiration, vascularity and muscle tonus function with greater effectiveness when subjected to exercise. Logically, it is assumed that if greater human effectiveness can be attained through physical fitness, knowing something about the nature of such improvement could reveal new techniques and knowledge for more consistent trumpet performance.

Much research has been done recently on the importance of "balanced states" within the multi-complexity of human physiology, and many studies of these balanced states--homeostasis--are looking deeply into the means by which the body maintains them.[1] Investigating the changes which occur in man during work, Bock, Vancaulaert and associates[2] indicate that training enables the organism to

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[1]M. H. Applezweig, "Neuroendocrine Aspects of Stress," Psychophysiological Aspects of Space Flight (New York: Columbia University Press, 1961), p. 142.

[2]A. V. Bock and C. Vancaulaert and Associates, "Dynamical Changes Occurring in Man at Work," Journal of Physiology, Vol. LXVI, 1928, p. 160.

maintain an internal environment approaching that of the normal resting state even during severe work. They conclude that changes in the oxidative mechanism speed up the rate of effective oxidation.

The ancient discipline of Yoga has long been practiced through various physical exercises to condition the mind. In 1959, Anand Chhina and Singh[1] conducted an experiment on Shri Ramanand to determine what dynamic changes took place when he was sealed in a metallic-cum-glass box for a ten hour period. Oxygen consumption of Ramanand under basal conditions, as determined by B.M.R. apparatus, was calculated to be 19.5 liters per hour; however, during confinement the average rate of oxygen was 13.3 liters per hour. Another very striking observation was that the heart rate during the experiment stayed between 60 and 72 beats per minute, considerably lower than his normal 85 beats per minute. It was not until the last two hours of confinement that Ramanand's respiration rate rose significantly, from 20 to 26 per minute. Most dramatic was the fact that when oxygen decreased and carbon dioxide increased, the subject did not show any hyperpnea or tachycardia. Although only results of one Yogi were reported in this experiment, these are of great significance, as he could voluntarily decrease

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[1]B. K. Anand, G. S. Chhina and B. Singh, "Studies on Shri Ramanand Yogi During His Stay in an Air-Tight Box," Indian Journal of Medical Research, Vol. XLIX, 1961, pp. 82-89.

his oxygen intake and carbon dioxide output much lower than his basal requirements, an excellent demonstration of oxygen conservation.

Investigating the phenomenon of sudden death in man, Wolf[1] attempts to find relationships between the oxygen-conserve function of man and animal. Not fully understood is the variation among human beings to overcome oxygen deprivation. On many occasions following drownings, autopsies fail to disclose any presence of water in the lung cavities. Richter showed several years ago that bradycardia with ultimate cardiac arrest, rather than drowning, provided the mechanism of death.[2] Experimenting on ducks with the tracheas being tied-off, Richter immersed one group in water while the other group was left on land. The result was that the ducks immersed in water lived three times as long as the ducks which remained on land, certainly a convincing demonstration of the "dive reflex."[3] Exploring the dive reflex in man at the University of Oklahoma Department of Medicine, Wolf[4] observed marked bradycardia in 30 healthy

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[1]Stewart Wolf, "Sudden Death and the Oxygen-conserving Reflex," American Heart Journal, Vol. LXXI, 1966, p. 840.

[2]C. P. Richter, "On the Phenomenon of Sudden Death in Animals and Man," Psychosomatic Medicine, Vol. XIX, 1957, p. 191.

[3]Wolf, op. cit., p. 840.

[4]Stewart Wolf, "The Turned-off Heart," Medical Times, Vol. LXLVI, 1968, p. 137.

males when the face was immersed in water; on the basis of this and other experiments, he concluded that oxygen conservation can be induced by various stimuli including breath-holding and a variety of threatening emotional states.

Karpovich[1] reveals the findings of Petren and his co-workers, in that oxyhemoglobin transport was significantly improved by increased capillary beds, and that this condition improved muscle tonus. They showed that, in guinea pigs, repeated exercise may increase the number of capillaries in muscles 40 to 50 per cent. Their conclusions were that in endurance training, the bulk of muscle increases because of proliferation of capillaries.

Experimenting on human muscle working with and without blood supply, Maison and Broeker[2] find some interesting results. In the study, the right arm was worked without normal blood supply by attaching a sphymomanometer cuff, the left with normal blood supply. Training patterns without blood supply showed very small and slow gains in the work done amounting to an increase of about 30 per cent in 16 months. It was finally concluded that nervous direction and vascular supply were largely responsible for improved muscle tonus.

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[1]Karpovich, op. cit., p. 8.

[2]G. L. Maison and A. G. Broeker, "Training in Human Muscles Working with and Without Blood Supply," American Journal of Physiology, Vol. CXXXII, 1941, p. 404.

Since trumpet playing may produce the same condition, passive hyperemia was examined in the skin by DiPalma and associates[1] in 1942. A ring was placed under the armpit and pressure in varying degrees was applied. On the area where the ring came in contact, a blanching occurred, and in the center portion erythema was observed. He then concluded that the pressure induced capillary and arteriole injury and even rupture; thus, the condition has been called the DiPalma effect.[2]

Even though muscle training has been practiced for hundreds of years, and with obvious success, one may be surprised to discover that present research indicates that there is no complete agreement as to the "best method" for muscle training. Karpovich[3] states that regular and heavy muscular work tends to thicken and toughen the sarcolemma of the muscle fiber; therefore, accounting for the increase in size when conditioned.

Older methods of muscle training support the premise that the strength of a muscle can be developed by exercising it against gradual increase of resistance. Springs, weights or the weight of the body itself are commonly employed for

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[1]J. R. DiPalma, S.R.M. Reynolds and F. S. Foster, "Quantitative Measurement of Reaction of Hyperemia in Human Skin," American Heart Journal, Vol. XXIII, 1942, p. 377.

[2]Ibid., p. 377.

[3]Karpovich, op. cit., p. 25.

this purpose. Even though the identical method of training is used, the rapidity and the ultimate degree of development in different persons will be different. This variation to some extent may be explained and even predicted through examination of the anatomical characteristics of individuals. Usually, a person with small bones, or a tall, skinny individual, will reach the limit of development before a stocky man with large bones attains the limit.[1]

Reports coming from the Max-Planck Institute in Dortsmund, Germany, recently have indicated that dynamic exertion for extended periods is not necessary in the development of muscle strength.[2] These reports indicate that a single daily isometric contraction continued for six seconds and utilizing only two-thirds of maximum strength will give best results in gaining muscular strength. Special investigations on the effects of Vitamins C and D along with ultraviolet radiation are now in progress. Adaptation of isometric and isotonic contractions are being used in patients who have casts over broken bones, to reduce atrophy. Enthusiastically, many of the athletes of the world await the results of such experimentation, in hope of finding methods for improving performance.

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[1]Karpovich, op. cit., p. 25.

[2]Theodore Hettinger, Physiology of Strength (Springfield, Illinois: Charles C. Thomas, Publisher, 1961), p. 25.

Psychophysical Measurement of Strength

During trumpet performance the player must alter the labial tension in order to change pitch. Upper register playing involves greater tension than that employed in the middle and lower registers. Since alteration of tension is so vital, it would seem logical that there would be a conditioned ability on the part of the player to estimate strength with some degree of accuracy.

The psychophysical measurement of sensory function has been given considerable attention in the past few years by Stevens.[1] He suggests that one must forego arguments concerning the mind and inquire intelligently about the input-output regulations of sensory transducers as the relations are disclosed in the behavior of experimental organisms, both man and animal.

Like any other sensation, the subjective impression of muscular tension can be measured on scales of psychological magnitude. Stevens and Mack[2] have designed scales of apparent magnitude, constructed on several different principles. One such method of magnitude estimation involves the estimating of apparent strengths or intensities, based on subjective impressions relative to a standard, set

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[1] S. S. Stevens, "The Psychophysics of Sensory Function," <u>American Scientist</u>, Vol. XLVIII, 1960, pp. 226-253.

[2] J. C. Stevens and J. D. Mack, "Scales of Apparent Force," Journal of <u>Experimental Psychology</u>, Vol. LVIII, 1959, pp. 405-413.

either by himself or by the experimenter. In this investigation a subject, using several handgrip dynamometers and employing various scaling methods, was asked to judge relative magnitude. The results were not conclusive, as only the action of one man's sensory transducer was examined; however, Stevens suggests that the subjective scaling of forces of muscular activity is gaining interest and that replication is necessary.

Statement of Purpose

The purpose of this study is three-fold: (1) to reveal physiological phenomena generally unknown to students of the trumpet, (2) to examine strength and oxyhemoglobin function in the labial structure and (3) to suggest future inquiry which might be of significance to the development of trumpet performance.

Statement of Problem and Hypotheses

Improved homeostasis in the human organism while encountering various stresses is an important purpose for conditioning. There is considerable variation in ability to maintain "balanced states" during stress on an individual basis. Many scientific examinations have been performed in order to determine the reasons for such variation in human beings subjected to stress. The stress syndrome during trumpet performance assumes characteristics similar to those observed in other physical stress environments. Therefore, the writer, to project the nature of the problem poses the following questions: (1) On the basis of past scientific investigation, what changes in the labial function have been observed as a result of trumpet playing? (2) Acknowledging these changes, what response might be expected considering the characteristics of the structure and the nature of the function? (3) What conditioning might be employed to increase the capacity of the lip function to more favorably adjust to the specific stresses?

Relative to the duration of performance, deformation occurs in the lip vibratory area during and after the playing of the trumpet. This deformation is primarily due to edema. Blanching and erythema can be observed in the epithelial tissue. Ischemia imposed by mouthpiece pressure causes passive hyperemia, resulting from the DiPalma effect along with hypoxia. As the player continues to perform, attempting to execute the demands of the composition (for this inquiry only range and endurance are of interest), fatigue becomes the prime factor in the breakdown of resistance offered by the lips to the forces of the mouthpiece.

If there is any connection between homeostasis of physiological function during stress and labial conditioning of trumpet performers, then the following hypotheses could be valid:

1. Lip structures of trumpet players are significantly stronger than lip structures of those who do not engage in trumpet performance.
2. Psychophysical judgments are significantly more consistent in trumpet players than in those who do not play the instrument.
3. Oxyhemoglobin tension in the labial structure of trumpet players is significantly lower in players who have stronger lips.
4. Oxyhemoglobin tension in the labial structure of trumpet players is significantly invariant during aerobic conditions in players who have stronger lips.

CHAPTER II

THE METHOD

The general purposes of this study are: (1) to reveal physiological phenomena generally unknown to students of the trumpet and (2) to suggest future inquiry which might be of significance to the development of trumpet performance.

The specific purpose is to examine strength and oxyhemoglobin function in the labial structure of college-age trumpet performers. The following independent variables are involved in the experimental design:

1. Measurement of forces exerted by the upper lip.
2. Psychophysical estimation of forces by the upper lip.
3. Oxyhemoglobin tension in the ear under various stress situations.
4. Oxyhemoglobin tension in the upper lip before and after trumpet performance.

Subjects

There were two groups of male subjects: (1) nine non-trumpet performers and (2) nine trumpet performers. All students used in the investigation were actively fulfilling degree requirements in the undergraduate curriculum at the University of Oklahoma.

Non-trumpet performers were randomly selected, with the only qualifications being that they had not previously, or were not at present, engaged in any type of special activity involving the labial structure.

The trumpet performers were selected on the basis of enrollment in private study in the School of Music. Careful attention was placed on obtaining a cross-section of various strata which were: (1) players who excelled in performance, (2) players who were of average ability and (3) players who appeared to have difficulty with performance.

Mean age, weight and height were calculated for both groups. The mean age for the non-performers was 20 years, while in the performers the mean age was 19.5 years. The mean weight in the non-performers was 167 pounds as compared to the mean of 164 pounds in the performers. Mean height of the non-performers was five-foot ten inches, while the mean height in the performers was five-foot nine inches. Statistically, there would appear to be no significant difference between the two groups.

A physiological data sheet (Appendix A) was completed by each subject in the performance group. All of the subjects indicated that there was no heart trouble, high blood pressure, low blood pressure or kidney disorders in their medical histories. The median number of hours of sleep per day was seven. At the time of the examination, none of the subjects was using any sedatives. Only one performer was a smoker.

Instrumentation

Since the main purpose of the study was to examine strength and oxyhemoglobin, two types of apparatus were necessary.

Prior to the experiment, the writer was unable to learn of any existing device which could be used to measure the forces of the human lip. Upon the recommendations of several dentists and orthodontists, various mouthguards, used by athletes, and various other substances utilized therein, were investigated for construction of such a device. As the implanting of electrical circuitry and the bonding of such materials proved unsatisfactory in these substances, other possibilities were explored.

A labial force transducer (Fig. 1) was finally devised on the simple principle that when forces are exerted across the exposed ends of two parallel beams bonded together as a single unit, a resultant strain occurs. Two very brittle hack-saw blades were broken at a length of six and one-half inches. The teeth were filed off and a very fine sanding paper was used to remove the original coating of paint. One inch from the rounded tips, a piece of steel one and three-fourths inches in length, one-eighth of an

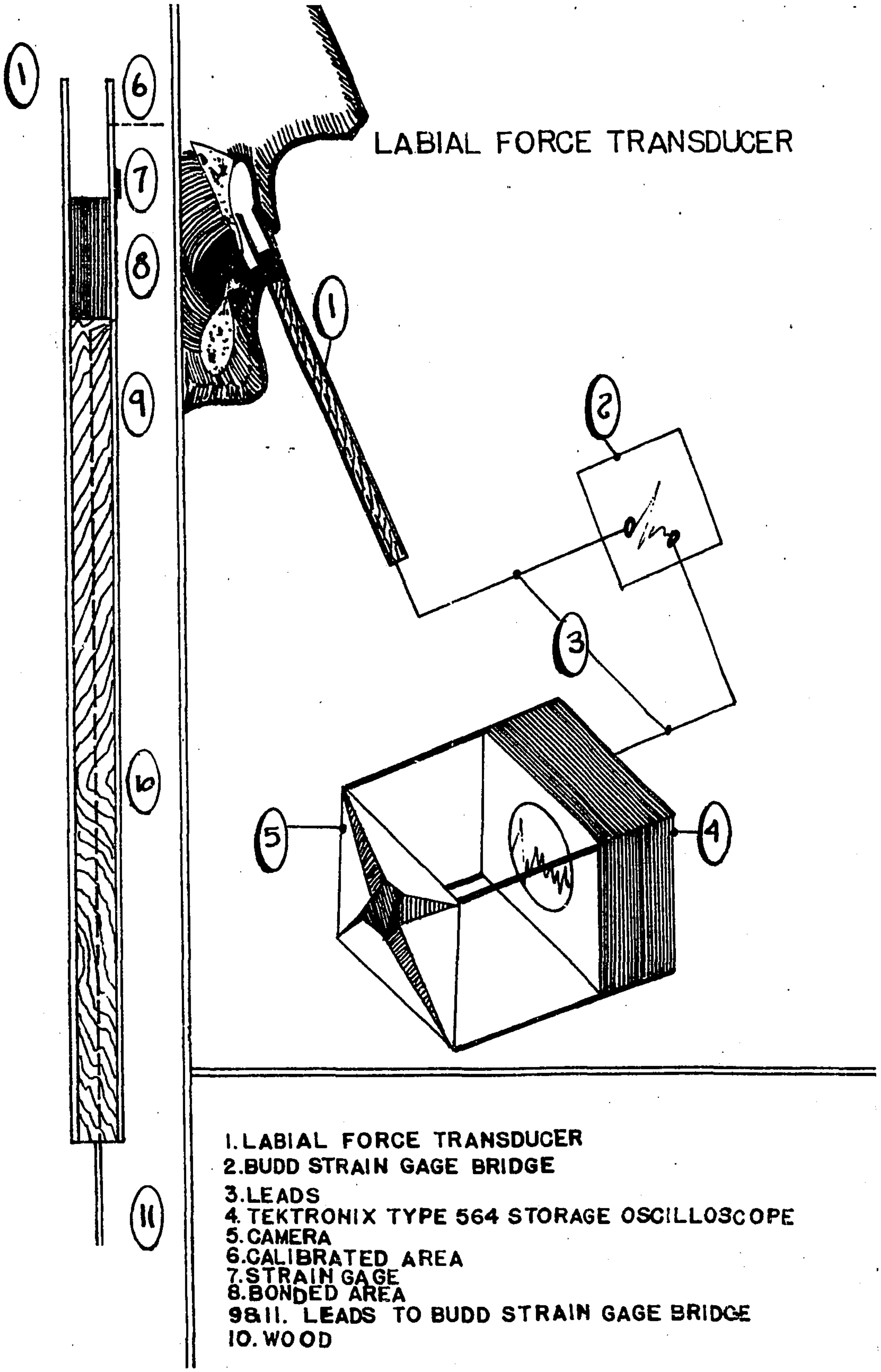


Fig. 1.--Labial force transducer

inch thick and one-half inch in width was placed between the two blades and bonded together with an acetylene torch. Between the remaining area of the two bonded blades, a wooden strip was prepared with a carved canal for the electrical leads. On the outer surface of one of the blades a strain gage (Type EA-06-125AD-120-LT) was attached with contact cement, so that the wiring within the gage for recording impedance changes was directly above the steel bonding area. A hole had been drilled three inches from the rounded tip, through which the gage leads were pulled, and the wires were then placed in the carved wooden strip and secured by epoxy. A rubber balloon was then used to cover the device as it was immersed in a cold sterile solution (Sparkl Instrument Cleaner Disinfectant) before being placed in the mouth. The device was then fed into a Budd Strain Gage Bridge, which in turn was fed into a Tektronix Type 564 Storage Oscilloscope. Weights were then placed on the transducer for the purpose of calibration. Trace deflection on the oscilloscope screen (slowest sweep available, three seconds per centimeter) was calibrated at approximately one pound per centimeter. Two assumptions were then necessary relative to the placement of the force transducer in the mouth: (1) that the lip force was exerted at the same place of calibration and (2) that the hand did not produce any force.

Oxyhemoglobin was measured with a Waters Corporation X-90A Oximeter Recording System (Fig. 2). Photo-electric devices of this type have been developed to monitor continuous oxygen saturation of hemoglobin as well as monitoring various dye-solutions injected into the blood stream, without necessitating punctures. The photo-electric cell within the earpiece (Type XE-60A) involves the principle that light absorption varies in hemoglobin with corresponding variations of oxygen tension. The earpiece is attached to the oximeter by electrical leads. Transduction takes place within the oximeter unit and the attached pen-recorder yields the results on a calibrated paper.

Procedure

To obtain strength measurements the subject was first told by the experimenter to place the tip of the index finger of the right hand against the maxillary incisors, with the finger parallel to the body. The subject was then instructed to bring the upper lip down over the finger tip and execute contraction against the finger. The experimenter pointed out to the subject that the orbicularis oris muscle could then easily be felt. Once the subject grasped the concept he was then given the force transducer which he positioned in the identical manner. As the labial structure differs from individual to individual, relative to size, shape and tissue composition, the next step was to match the orbicularis oris region with the calibrated area on the

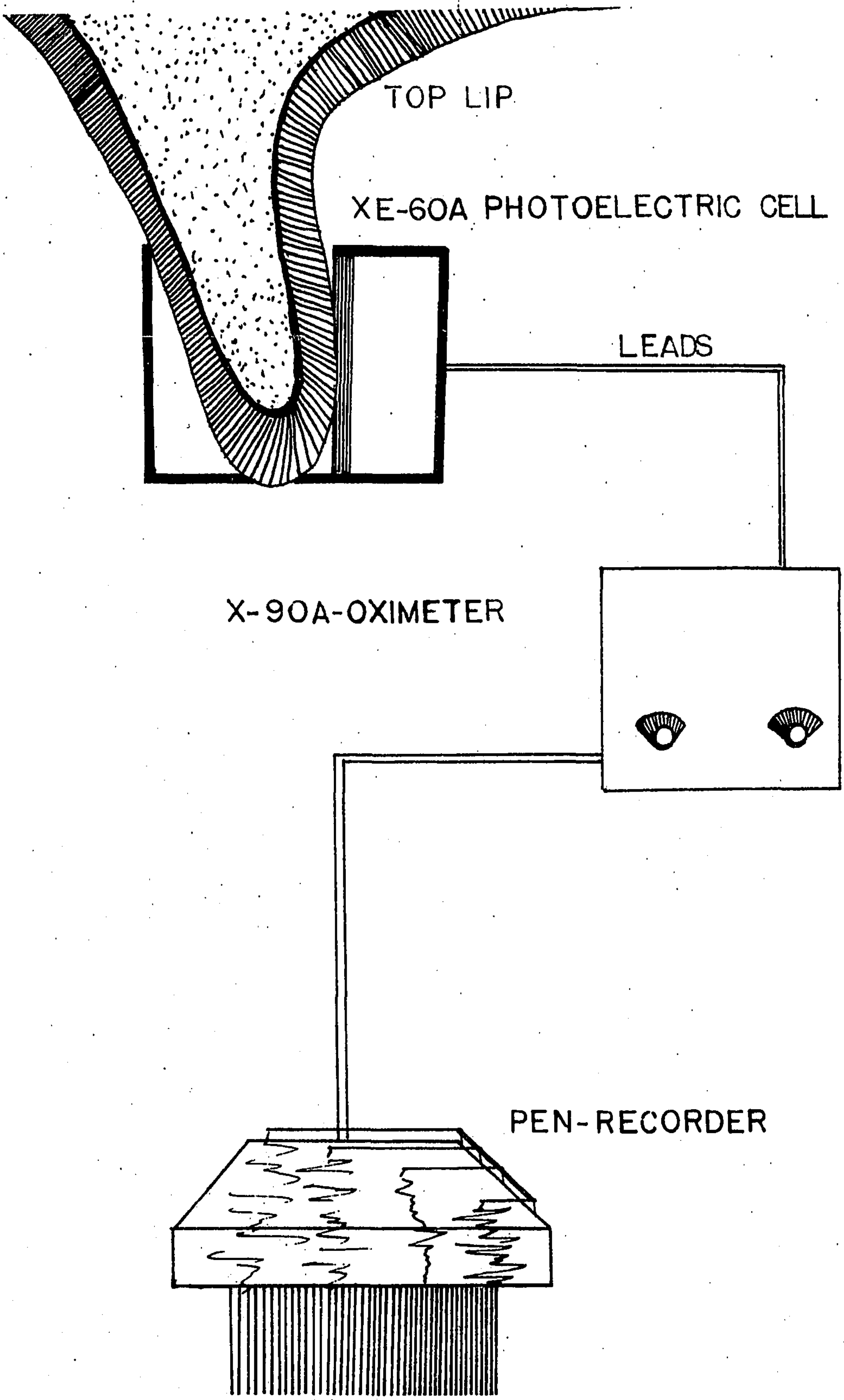


Fig. 2.--Oximeter recording system

transducer. This was done by having the subject exert light forces while looking at the oscilloscope screen. Observing these light forces, the experimenter could discern from the trace deflection and from the rate of trace deflection whether or not the orbicularis oris region of the upper lip was on the calibrated region of the transducer. Once the subject achieved the desired position, he was then allowed to contract the muscle and become acclimated to the device and the manipulation. Careful attention was given to the fact that fatigue would onset quite rapidly, therefore only a few contractions were allowed. The subject was then asked to step from view of the oscilloscope screen and the experimenter explained in several brief statements the experimental procedure. First, an explanation of the two types of muscle contractions was presented: (1) sustained or fixation (Isometric) and (2) accelerated or "jerk" (Isotonic). The experimenter, by using a chart (Fig. 3), explained the psychophysical measurement test. The subject was told that the first sustained contraction would be of maximum force and that the second sustained contraction would be of minimum force. Minimum force was that of experiencing the smallest exertion with legitimate movement by the lip. It was then pointed out that the subject would have established a maximum-minimum value scale, and thus, three other points one-half, one-fourth and three-fourths were next to be estimated, respectively. Upon completion

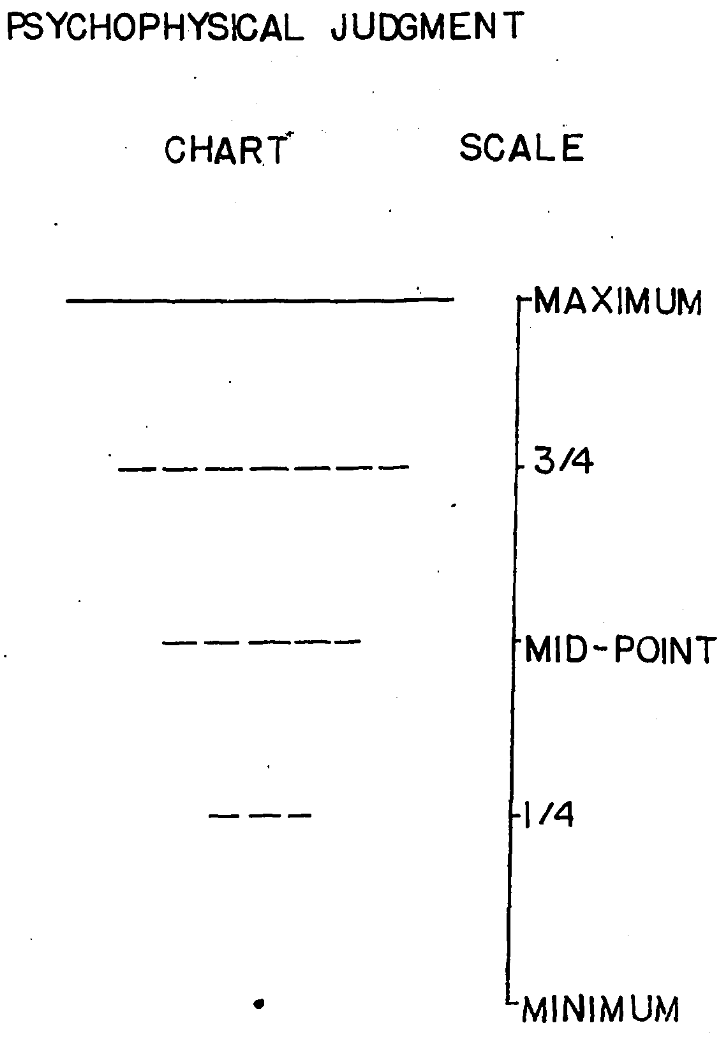


Fig. 3.--Psychophysical judgment chart

of the psychophysical judgments the subject was then told that he would execute five maximum isotonic contractions to complete the test. Once the test got underway the experimenter used a metronome (60 pulsations per minute) in order to assure uniformity. Isometric contractions were sustained for a period of seven seconds. During these sustained contractions the experimenter counted in the tone of voice which was suggestive of the magnitude of force. This assured a lack of confusion as to inception, duration and termination of contraction. Isotonic contractions were only of maximum nature. Throughout the testing period the experimenter reminded the subject of the financial remuneration which would be given to the participant who could exert the strongest force.

The non-performers were involved in the test only once; however, the performers took the test before playing on the trumpet and again after playing on the instrument.

The playing test (Fig. 4) was devised on a physiological basis. The test could be performed at sight and involved no specific musicianship, only the playing of tones which were designed to induce stress symptoms. On the day of the experiment the subjects were instructed not to perform prior to the testing. Each subject was allowed to play two short duration tones before beginning the test, for purposes of adjusting to the acoustical nature of the experimental laboratory. During performance a metronome

Fig. 4.--Musical stress test

(60 pulsations per minute) was employed along with the experimenter's vocal execution of the pulse. Upon completion of the playing test, the strength test was again administered.

Oxyhemoglobin saturation was measured in only the performers by an oximeter in the phono-cardiac module at the University of Oklahoma School of Medicine. The photo-electric cell earpiece was first placed on the left pinna of the subject by a special technician who assisted the experimenter throughout the examination. Upon stabilization of the saturation level as determined by the pen-recording, the subject was asked to expire and hold for as long a period as possible. The next step was to inspire and maintain the breath hold. The photo-electric cell earpiece was then placed on the maxillary lip portion of the embouchure region. Expiratory and inspiratory recordings were made in precisely the same manner as they were for the ear. When this examination was terminated, the playing test (Fig. 4) was given again, as administered during the strength analysis. Immediately upon completion of performance the earpiece was again attached to the lip and only the oxyhemoglobin saturation percentage was recorded in a normal environment.

CHAPTER III

RESULTS

In order to test the hypotheses, two groups of nine each were examined--(1) a control group of non-trumpet performers and (2) an experimental group of trumpet performers. The control group was examined only once. On two separate days the trumpet performers were examined and data were obtained from the labial force transducer and the oximeter, respectively. During those occasions, the trumpet performers were asked to perform a musical stress test (Fig. 4). In each situation, prior to the musical test, data were obtained from each player. Upon termination of the musical test, data were again collected for each trumpet performer. Data were recorded from the following tests: (1) maximum force in the control group, (2) maximum force in the experimentals, both before and after the musical test, (3) psychophysical force judgments in the control group, (4) psychophysical force judgments in the experimentals, both before and after the musical test, (5) oxyhemoglobin levels in the ear and lip of the experimentals before the musical test and (6) oxyhemoglobin saturation changes in the lip only, of the experimentals after the musical stress test.

The Maximum Force Data

Maximum force values were obtained by measuring the highest trace deflection of a series of isotonic contractions (Fig. 5).[1] The highest single individual value, and the group mean are presented in Table 1.

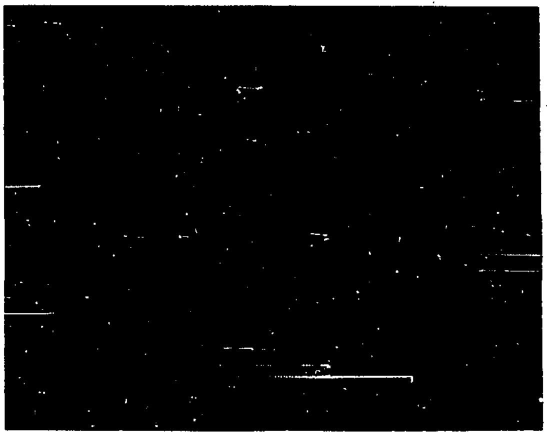
TABLE 1

HIGHEST INDIVIDUAL FORCE VALUE AND GROUP MEAN
(Ounces)

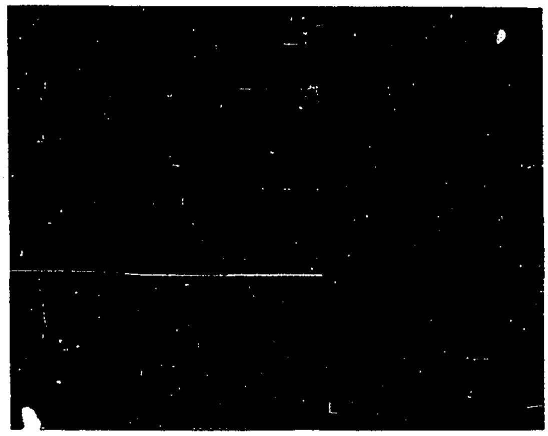
Subject	1	2	3	4	5	6	7	8	9	Mean
(C)	38	34	33	31	30	26	24	23	18	29
(E Pretest)	44	39	31	30	27	26	24	20	12	28
(E Posttest)	38	39	30	22	24	22	22	23	12	26

It was predicted (Hypothesis I) that the lip structures of trumpet players are significantly stronger than those of persons who do not play the instrument. For each pair of samples (1) controls versus experimentals pretest, (2) controls versus experimentals posttest and (3) experimentals pretest versus experimentals posttest, a hypothesis

[1]Reading from left to right, and beginning with the bottom trace sweep, deflection amplitude indicates maximum, minimum, one-half, one-fourth and three-fourths isometric psychophysical judgments. The isotonic contractions (one per second) are recorded by the hightest trace sweep (upper right).

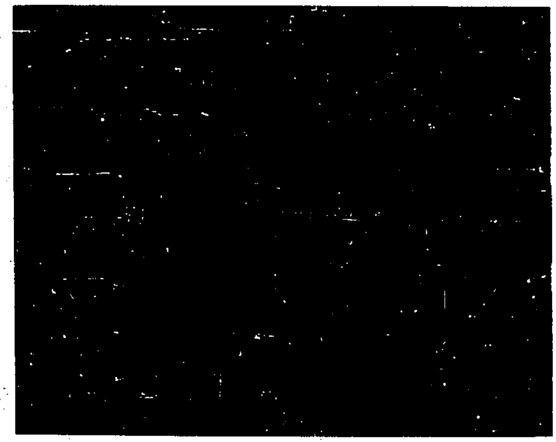


Experimental No. 1 Pretest



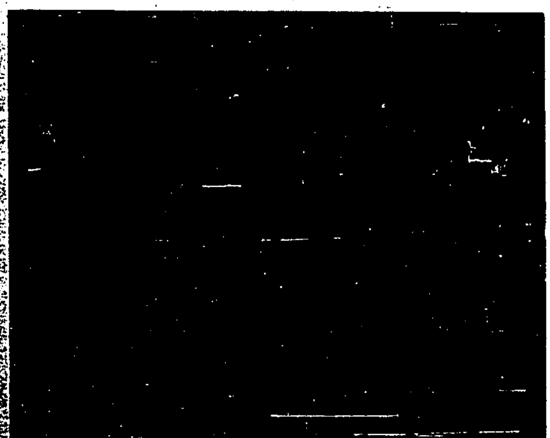
Experimental No. 1 Posttest

Experimental No. 2 Pretest



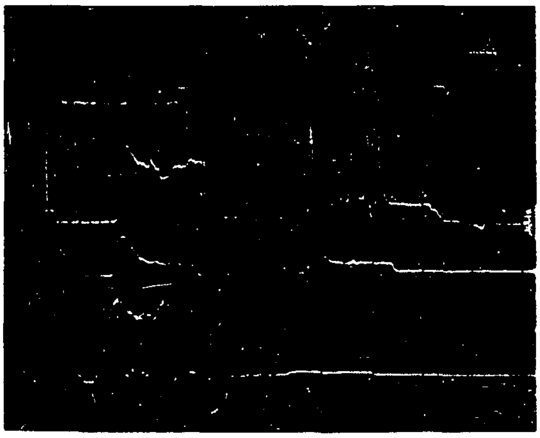
Experimental No. 2 Posttest

Experimental No. 3 Pretest

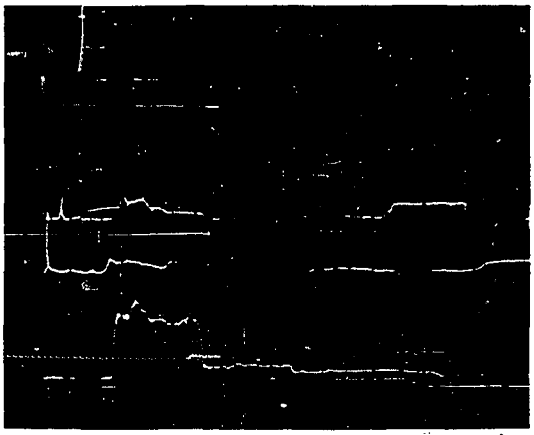


Experimental No. 3 Posttest

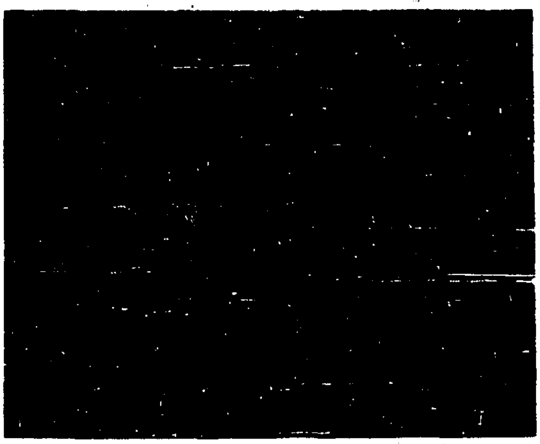
Fig. 5.--Force transducer results



Experimental No. 4 Pretest

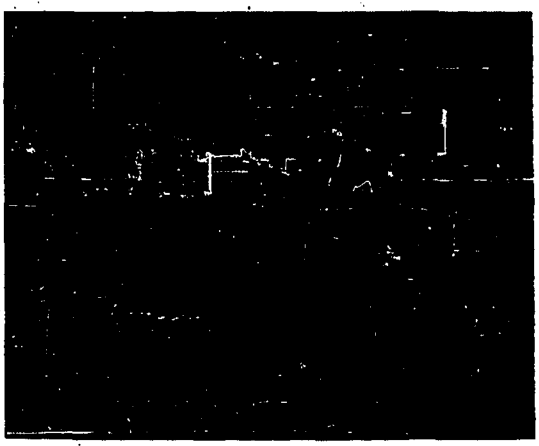


Experimental No. 4 Posttest

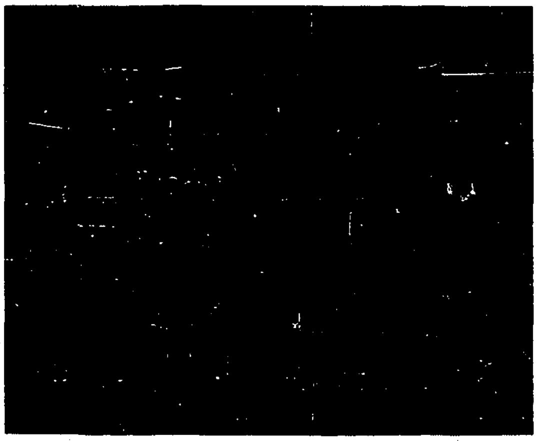


Experimental No. 5 Pretest

Experimental No. 5 Posttest



Experimental No. 6 Pretest

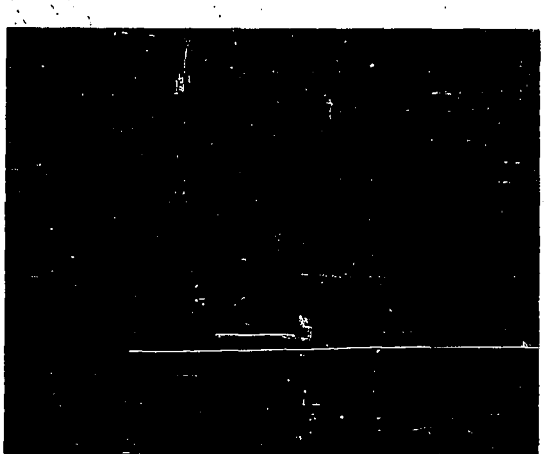


Experimental No. 6 Posttest

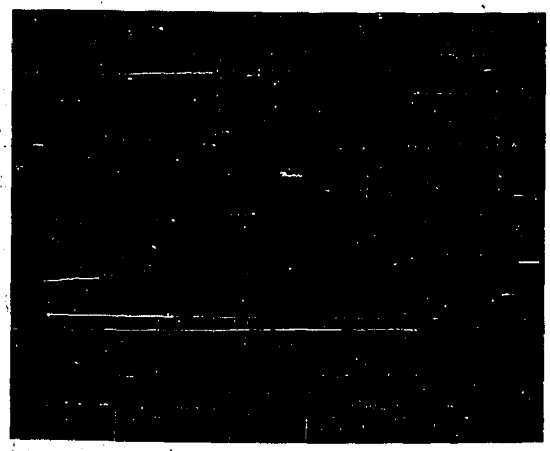
Fig. 5.--Continued

Experimental No. 7 Pretest

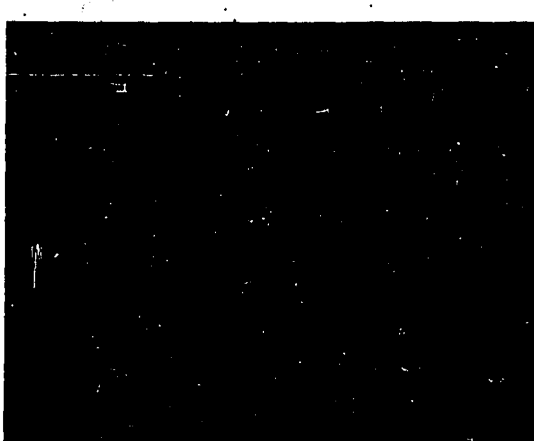
Experimental No. 7 Posttest



Experimental No. 8 Pretest



Experimental No. 8 Posttest



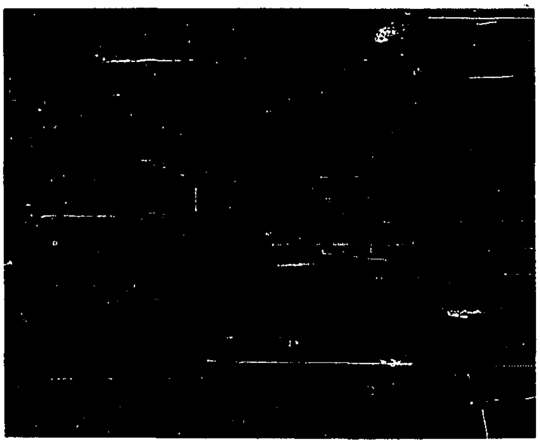
Experimental No. 9 Pretest

Experimental No. 9 Posttest

Fig. 5.--Continued

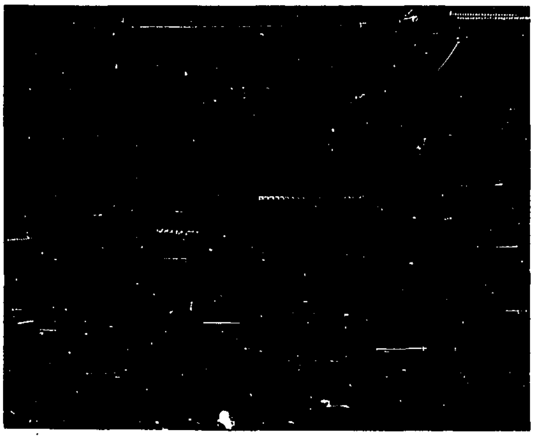
Control No. 1

Control No. 2

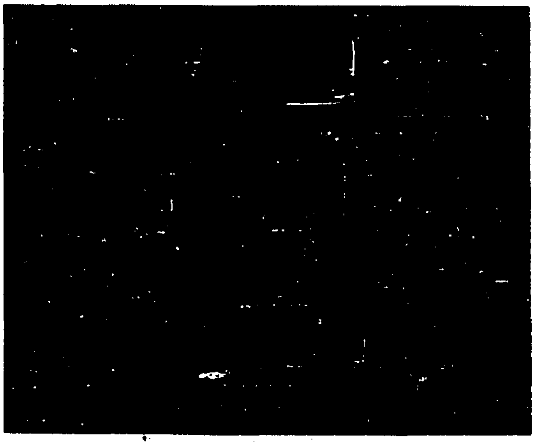


Control No. 3

Fig. 5.--Continued



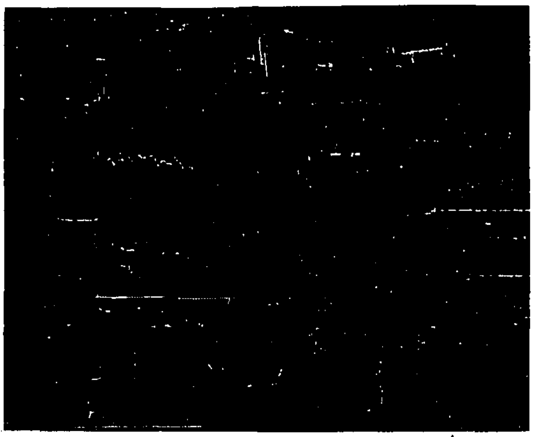
Control No. 4



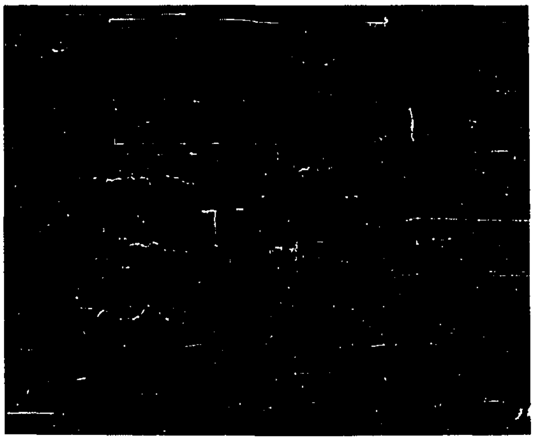
Control No. 5

Control No. 6

Fig. 5.--Continued



Control No. 7



Control No. 8

Control No. 9

Fig. 5.--Continued

test was made. In cases where one sample was non-trumpet performers the test was a one-tailed, with the null hypothesis being that there was no significant difference in lip strength and the alternative that the lip structures of the trumpet performers were stronger. In the test between the trumpet players involving pretest and posttest conditions a two-tailed test was made with the null hypothesis being that there is no significant difference in strength and the alternative that there is a significant difference in strength. There were no reasons to suspect that the samples were not representative, and a t-test was calculated in all three cases. The t values computed in the test of the difference between two means are: (1) controls versus experimentals pretest $t = .267$, (2) controls versus experimentals posttest $t = .683$ and (3) experimentals pretest versus experimentals posttest $t = .474$. At a 10% level of significance the null hypothesis was not rejected in any case. The critical value of t in the first two cases was 1.337. In the third case the critical value of t was $\pm$ 1.746. Therefore, the null hypothesis was not rejected in any case. The maximum strength data in this examination thus failed to support Hypothesis I.

The Psychophysical Judgment Data

Since trumpet performance involves alteration of labial tension, Hypothesis II suggests that psychophysical estimation of strength magnitudes would be significantly more consistent in the trumpet performer than in the non-trumpet performer.

On a five point scale (Fig. 3), measurements were obtained from a sustained isometric contraction for a period of seven seconds. These data were recorded for the control group, and for the experimental pretest and posttest group (Fig. 5).[1] An average for each judgment was calculated after measuring the trace deflection at the beginning of the contraction, at the four-second point, and at the point of termination of the contraction. Tables 2, 3 and 4 present the results of the calculations of the psychophysical force judgments produced in the three cases.

TABLE 2

PSYCHOPHYSICAL FORCE JUDGMENTS PRODUCED BY THE CONTROL GROUP*
(Ounces)

Subjects	Maximum	3/4	1/2	1/4	Minimum
1	31	25	13	8	5
2	15	12	4	3	0
3	24	21	21	7	1
4	26	16	9	4	4
5	29	15	16	6	3
6	30	16	11	11	6
7	23	19	10	5	2
8	23	14	10	5	3
9	22	18	7	3	2

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

[1] *Supra*, p. 33.

TABLE 3

PSYCHOPHYSICAL FORCE JUDGMENTS PRODUCED BY THE EXPERIMENTAL PRETEST GROUP*
(Ounces)

Subjects	Maximum	3/4	1/2	1/4	Minimum
1	34	21	9	5	3
2	28	16	8	6	1
3	25	12	6	3	0
4	23	19	9	5	1
5	24	8	5	2	1
6	24	15	18	11	1
7	19	14	13	7	2
8	16	8	7	5	4
9	16	9	3	1	2

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

TABLE 4

PSYCHOPHYSICAL FORCE JUDGMENTS PRODUCED BY THE EXPERIMENTAL POSTTEST GROUP*
(Ounces)

Subjects	Maximum	3/4	1/2	1/4	Minimum
1	32	19	14	6	3
2	31	21	18	10	1
3	23	6	6	2	0
4	20	6	4	1	1
5	24	6	4	2	0
6	21	15	12	9	2
7	20	16	12	3	1
8	16	8	7	4	3
9	10	5	3	0	1

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

Degree of error of the psychophysical force judgments was calculated as the amount by which the force produced deviated from the force which was demanded. Both the maximum and minimum values on the produced scale were considered the parameters, for which the three-fourth, one-half and the one-fourth judgments were then relative. Exact values of individual mean error deviations and group error deviations for the judgments in question were obtained by subtracting the minimum value from the maximum value and dividing by the number of attempts (Fig. 6). The results are presented in Table 5.

TABLE 5

INDIVIDUAL MEAN ERROR DEVIATIONS OF PSYCHOPHYSICAL JUDGMENTS*
(Ounces)

Subjects	Controls	E Pretest	E Posttest
1	- 4	-20	-13
2	- 6	-14	+ 1
3	+11	-16	-20
4	-16	- 3	-21
5	-10	-23	-24
6	-16	+ 6	+ 1
7	- 3	+ 6	- 1
8	-10	-10	- 9
9	- 8	-13	-10

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

Mean group error deviations were calculated for the controls, and the experimentals pretest and posttest (Fig. 6). Of some interest is the fact that the judgments of non-trumpet performers were more accurate than those of the trumpet performers.

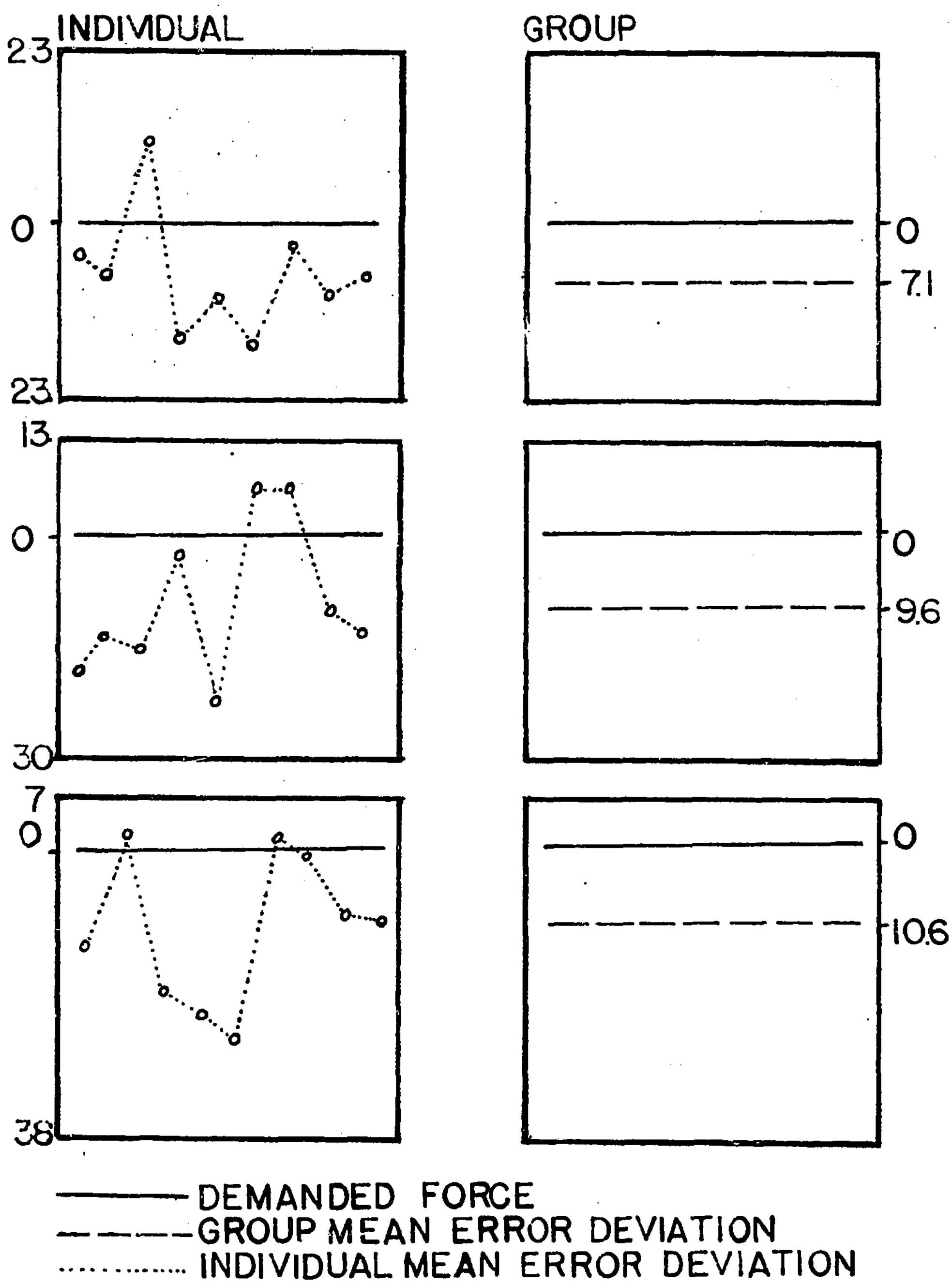


Fig. 6.--Individual and group mean error deviations of psychophysical judgments.

A pairing of the three cases was performed and a hypothesis test was made for each pair of samples. In the cases where one sample was non-trumpet performers the test was one-tailed, with the null hypothesis being that there is no significant difference in the judgment ability and the alternative that trumpet players have greater judgment ability. In the comparison of the pretest trumpet performers with the posttest trumpet performers, a two-tailed test was made, with the null hypothesis being that there is no significant difference in the judgment ability, and the alternative that there is a significant difference in the judgment ability. The samples were not assumed to be representative, and the Central Limit Theorem was invoked to permit use of a t-test. The t values computed in the test of the difference between two means are: (1) controls versus experimentals, pretest $t = -.81$, (2) controls versus experimentals, posttest $t = -.92$, (3) experimentals pretest versus experimentals, posttest $t = .15$. The critical value of t in the first two cases is 1.30, in the third case it is $\pm$ 1.67, which provides no basis for rejecting the null hypothesis in any case. The null hypothesis was accepted at a 10% level of significance, and failed to support Hypothesis II.

Oxyhemoglobin Data

Oxyhemoglobin saturation recordings were obtained from only the trumpet performers. Prior to the musical stress test (Fig. 4), oxygen saturation levels were measured in the ear (the level in the ear being indicative of arterial oxygen tension) and in the vibratory portion of the maxillary labial area, both at rest and while voluntarily imposing stress through sustained expiratory and inspiratory breath holding. Tables 6 and 7 present the electrophotometric results, in the ear and in the lip, before the playing test.

Upon obtaining these measurements the players were ask to perform the musical stress test. Having completed the test, the photo-electric cell earpiece was attached only to the lip, and the subject was requested to sit quietly until the oxyhemoglobin saturation stabilized. Due to the nature of the earpiece and the zeroing process, it was impossible to couple the device to the subject's lip immediately after the musical stress test. On two of the subjects it took as long as thirty-five seconds to complete the connection; therefore, oxyhemoglobin tension was calculated from the pen-recording for all players at that point. Table 8 reveals the percentage of saturation thirty-five seconds after the playing test.

On the day of the strength evaluation a reading of the sound energy out-put for the final note performed on the musical stress test was recorded, and a ranking of range and endurance was obtained. The energy out-put (using decibel values) was assigned a percentage with the greatest

TABLE 6

OXYHEMOGLOBIN SATURATION IN THE EAR*

Subjects	Basal O_2	Desaturation Rate (Expiratory)	Desaturation Rate (Inspiratory)	Breath Hold Sec. (Expiratory)	Breath Hold Sec. (Inspiratory)
1	89%	.140	.085	50	129
2	88%	.409	.097	22	63
3	81%	.250	.097	36	82
4	91%	.096	.074	31	94
5	85%	.051	.037	39	54
6	83%	.139	.097	43	123
7	90%	.233	.138	30	144
8	92%	.090	.107	22	28
9	88%	.235	.047	34	84

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

TABLE 7

OXYHEMOGLOBIN SATURATION IN THE LIP*

Subjects	Basal O_2	Desaturation Rate (Expiratory)	Desaturation Rate (Inspiratory)	Breath Hold Sec. (Expiratory)	Breath Hold Sec. (Inspiratory)
1	78%	.017	.000	57	94
2	84%	.000	.000	28	78
3	67%	.000	.000	45	90
4	82%	.000	.047	32	63
5	82%	.000	.000	34	46
6	69%	.000	.000	27	98
7	86%	.027	.089	48	134
8	77%	.000	.057	23	35
9	73%	.023	.041	33	75

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

TABLE 8

OXYHEMOGLOBIN SATURATION IN THE LIP THIRTY-FIVE SECONDS AFTER THE PLAYING TEST*

Subject:	1	2	3	4	5	6	7	8	9
	86%	84%	76%	70%	67%	69%	88%	73%	66%

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

out-put being that of 100%. The results are shown in Table 9.

TABLE 9

RANGE AND ENDURANCE RANKING OF TRUMPET PLAYERS*

Subject:	1	2	3	4	5	6	7	8	9
	86%	78%	99%	80%	84%	100%	92%	49%	48%

*Subjects are in rank order from strongest to weakest as determined by the maximum strength test using isotonic contraction.

Statistical Treatment of Oximeter Data

To find if the data supported Hypotheses III and IV, correlation coefficients were computed between range and endurance, maximum strength values, and various oxyhemoglobin levels in the trumpet performers. The coefficients were computed by an IBM Computer System 1130, using the IBM Statistical Software Design (number 1130-CA-06X). The correlations in this test, deemed significant, are those where $r > .6$ or $r < -.6$. Using these coefficients, and considering that a zero correlation might exist, there would then be less than a 10% possibility that the relationship in question would be due to chance alone. On the basis of a t-test at a level of 10% significance the null hypothesis is rejected in these cases, so that these correlation coefficients may be considered significant (Appendix B). Table 10 shows the correlation coefficients germane to Hypotheses III and IV.

TABLE 10

CORRELATION COEFFICIENTS OF VARIABLES GERMANE TO HYPOTHESES III AND IV

	O_2 Basal (Ear)	O_2 Basal (Lip)	O_2 Saturation 35 seconds after Performance
Maximum Strength Before Performance	-.08	.21	.60
Maximum Strength After Performance	-.09	.18	.67
O_2 Basal (Lip)	---	---	.43

Hypothesis III suggests that oxyhemoglobin tension is lower in trumpet players who have a stronger labial structure. A .21 correlation was found between the maximum strength value before performance and the oxyhemoglobin tension in the lip in that same environment; however, when the maximum strength value prior to playing the trumpet was correlated with oxyhemoglobin saturation after trumpet performance, a significant .60 relationship was obtained. An even larger coefficient, .67 was found between maximum strength after performing on the trumpet and the oxygen saturation in the blood of the lip after performance. Upon examination of the raw data (Appendix C), the relationship was inverse to the prediction. Of interest is the inverse relationship (-.60) found between performer range and endurance, and the arterial oxygen percentage prior to the playing of the instrument. The indication is that several players who were less than strongest (Appendix C), but stronger than those who were the weakest, had significant lower oxygen percentage saturation. On the basis of the data, Hypothesis III is not supported.

The prediction that oxyhemoglobin tension is somewhat invariant in trumpet players who have stronger lips was the basis of Hypothesis IV. In this case a correlation was made between the lip oxygen saturation before performance and the blood oxygen percentage in the lip thirty-five seconds after the musical stress test was performed. While r is only .43, a close examination of the raw data, Tables 6 and 7, tends to yield several rather significant trends. The three strongest players either maintained the same saturation level or the level showed an elevation. The two weakest players experienced marked declines in oxyhemoglobin. On the basis of the statistical analysis however, no support is found for Hypothesis IV.

Additional Relationships Observed in the Data

Several relationships were found other than those directly associated with the Hypotheses. Table 11 shows those which would appear to be of some significance.

Trumpet performance involves considerable alteration of normal ventilatory function. At all times during tone production the player is utilizing an expiratory flow for sustaining vibration. In order to observe any variations which might occur in the oxyhemoglobin percentage under similar stresses, the subjects were asked to impose stress voluntarily by expiratory and inspiratory breath holding. The rates of desaturation (the normal limits being .090 through .150) in the arterial blood (Table 6) of four of the subjects, during expiration, were considerably above that of the normal. Two others were observed in the upper normal range. The duration of the breath holding (expiratory) was from 22 to 57 seconds. Desaturation rates during inspiratory breath holding were, as expected, significantly decreased. Truly remarkable are the findings that when the desaturation rates in the labial structure were observed, under identically imposed stress situations, no oxygen deprivation was recorded. Even more amazing is the fact that desaturation rates were observable to a degree of regularity in the last three subjects, who were the weakest as

TABLE 11

OTHER SIGNIFICANT CORRELATION COEFFICIENTS

	Basal O_2 (Ear)	Desaturation Rate (Lip) (Expiratory)	Sec. of Breath Hold (Lip) (Expiratory)	Sec. of Breath Hold (Lip) (Inspiratory)	O_2 Saturation 35 Sec. After Performance	Range and Endurance	Maximum Strength Prior to Performance
Sec. of Breath Hold (Ear) (Inspiratory)				.88		.60	
Basal O_2 (Lip)	.66						
Desaturation Rate (Lip) (Inspiratory)		.71					
Sec. of Breath Hold (Lip) (Inspiratory)			.61		.61	.60	
O_2 Saturation 35 Sec. After Performance			.60				
Range and Endurance	-.60						.60
Maximum Strength Prior to Performance					.60		
Maximum Strength After Performance					.67		

determined by the maximum strength test (Table 7). It would be logical to assume that the .017 desaturation rate in the first performer might well be due to the 57-second expiratory breath hold, which greatly exceeded that of any other subject.

Brief Review of the Results

Tests of significance were made between both controls and experimentals for maximum strength values and psychophysical force judgments of the labial structures. The t-tests computed failed to support Hypotheses I and II. Oxyhemoglobin saturation levels were obtained from only the trumpet performers. Hypotheses III and IV were not supported; however, Hypothesis III was confirmed inversely to the prediction. Due to the size of the samples and the absence of replication in administration of the tests, statistical significance may well be unimportant; however, the trends in the raw data might lead to some future plausible inquiry.

CHAPTER IV

DISCUSSION AND INTERPRETATION

The hypotheses advanced in this examination led to the predictions that (a) labial structures of trumpet players are stronger than of those who do not perform on the instrument, (b) labial force judgments of trumpet players are better than of those who do not engage in the playing of the trumpet, (c) oxygen tension is lower in trumpet players who have stronger lips, and (d) oxygen tension is more stable during stresses, prior to fatigue, in trumpet players who have stronger lips. None of the Hypotheses was confirmed statistically. Hypothesis III was confirmed inversely, in one environment. In view of the small sampling (primarily contingent upon the number of college-age performers available who were actively enrolled in private study), statistical results would appear to be of little value; however, the various trends within the raw data suggest rather salient support of several phenomena.

The Maximum Strength Test

Tests of significance failed to reveal any difference between the controls, the experimentals pretest and the experimentals posttest. In the controls versus the experimentals pretest, only slight marginal values are demonstrated when pairing subjects one, two and nine. When comparing the experimentals pretest versus the experimentals posttest, a small decrease in strength is noted in five of the performers. The remaining four subjects either maintained the pretest value or showed an increase in strength. The trumpet performer showing the smallest force value is largely responsible for those variations which did occur between the mean values of the three cases. This performer who produced the minimum force values had experienced a severed lip in an accident several years ago, and is at present attempting again to adapt to the instrument.

As evidenced by the strength apparatus utilized in this examination, the importance of the logarithmic function becomes more significant during the second pound of exerted force. All subjects, with the exception of the weakest trumpet player, easily produced a force of one pound. During trial attempts, prior to the investigation, a number of persons who did not perform in the experiment were asked to produce maximum forces. Among those were several youngsters in the 9 through 10 age group. No difficulty was observed until the forces produced were greater than one pound.

In that there is a logical explanation for the force values of the subject who had been involved in an accident, a marked consistency was found between the controls and the experimentals. In the control group were two outstanding members of the University of Oklahoma football team. Employing traditional somatotyping, both subjects would doubtless be classified as mesomorphs. Neither demonstrated ability to exert significantly greater forces than the other subjects in the control group.

In support of the hypothesis, the two strongest trumpet performers exerted forces that were somewhat above those who ranked one and two in the control group. After the musical stress test was performed, the strength reading for the strongest performer was the same as that of the strongest control subject. The second performer, after the playing test, exerted a force four ounces greater than that of the second control subject.

The mean strength values of the three cases were much closer than what might have been expected. One ounce was observed between the controls and the experimentals pretest. Only a two ounce difference in the mean values was obtained in the pretest-posttest experimentals.

It seems logical that there can not be a total rejection of the possibility that trumpet performer labial function might be similar to other organismic responses during the conditioning process. Athletes as well as trumpet players speak of "warming-up." The truly remarkable human biological clock (circadian rhythm) accounts, in part, for the preparation which usually preceeds physical activity.

Fulton (1955) suggests when skeletal muscle is inactive, especially after arising from sleep, that many of the arterioles assume a state of collapse. Upon stimulation, the blood flow increases and the muscle is better prepared to engage in work. If the findings of Petren (1936) apply to human skeletal muscle, and there is an increase in blood flow as a result of stimulation (in this case warming-up), then the forces exerted by the trumpet players in this examination are indicative of muscle which had not been stimulated, for the performers were instructed not to play the instrument prior to the tests. It might be assumed that had the muscle been subjected to stimulation before the testing (warming-up), significantly greater strength values would thus have been produced. The problem, however, is in defining on the U-Curve of physical performance an ideal point for terminating the preparatory stimulation period. It was the design of this study to avoid that ambiguity.

The Psychophysical Force Judgments

Significance of difference tests failed to yield any relationships between the three cases. The controls were generally more consistent than were the experimentals. In the first two subjects, who were the strongest of the control group, only a mean error of minus four and minus six ounces was recorded, respectively. An over-estimation of eleven ounces was observed for the third subject in the control group. The last three subjects did not under-estimate to any large extent. Discounting the first two, the last three subjects were more accurate than the remaining four. No particular trend can be observed in the experimentals pretest. The three strongest players had rather high individual mean error deviations. Weaker players were somewhat more accurate. With the exception of subjects three, four and five in the experimentals posttest, all of the performers were more consistent after the musical stress test.

The group mean error deviations, which for the controls would be indicative of performance, were nevertheless non-representative for the experimentals. The fourth subject in the performer group was considerably less accurate after the playing test, thereby accounting for the group mean error of a one ounce difference between the experimentals pretest versus posttest.

Of major interest is the fact that upon completion of the playing test, three of the performers recorded only a ± one ounce individual mean error deviation. One of the subjects was the second strongest, while the other two ranked one and three respectively, on the range and endurance scale.

In obtaining such judgments, special care was given to the fact that isometric contractions of this nature might produce a severe state of fatigue in the trumpeter's lip muscles. It should be noted that in attempting to learn the capabilities of the force transducer during a period of only fifteen minutes, the experimenter, being a trumpet player, fatigued the lip to the extent that performance could not be undertaken for one week. It was therefore mandatory that very short sustained contractions be required of the subjects during the tests.

The results of the psychophysical force judgments would perhaps be influenced to some degree by muscle stimulation prior to the testing. By a comparative analysis between the pretest and posttest experimentals, six of the players were more accurate after performing on the instrument. The performance test might have provided the muscle stimulation necessary for more accurate feedbacks; therefore, yielding less inconsistent judgments in the post-performance situation. Whether or not the musical stress test provided such a stimulation is not known; however, all but one of the trumpet players indicated that the performance test induced stresses at a much faster rate than their usual warm-up routines.

Psychophysical scaling in this examination was employed under the assumption that when players have stronger lips, a greater utilization of muscle as a resistance factor to mouthpiece pressure is exhibited. It thus follows that should such an assumption be valid, those performers would likely have greater sensory awareness of the muscles of mastication.

Subjective impressions of labial muscle tension were measured on a scale as suggested by Stevens (1959). A maximum and minimum value was first produced. Three other judgments were then made through bisectioning. Generally, the judgments were under-estimated; while in the study by Stevens (1959) using magnitude estimations and employing the movable handle dynamometer, mean values proved to be somewhat above those which were demanded. More judgments are needed before any conclusions might be reached as to the significance of force estimation and such relationships to trumpet performance.

<u>The Oxyhemoglobin Test</u>

Correlation coefficients were obtained by pairing the variables in question (Appendix C). The following are those which were examined in this study:

A. Basal O_2 saturation in the ear

B. O_2 expiratory rate of desaturation in the ear

C. O_2 inspiratory rate of desaturation in the ear

D. Number of seconds breath was held during expiration

E. Number of seconds breath was held during inspiration

F. Basal O_2 saturation in the lip

G. O_2 expiratory rate of desaturation in the lip

H. O_2 inspiratory rate of desaturation in the lip

I. Number of seconds breath was held during expiration

J. Number of seconds breath was held during inspiration

K. O_2 saturation 35 seconds after the musical stress test

L. Range and endurance ranking (using decibel values)

M. Maximum strength prior to the musical stress test

N. Maximum strength after the musical stress test

Hypothesis III predicted that players with stronger lips would have lower oxyhemoglobin levels, based on the assumption that the principle of homeostasis is a significant factor in the conditioning of human skeletal muscle. The prediction was not supported, although, an inverse relationship was found. Basal saturation percentages prior to the performance test proved to be unrelated to either maximum strength values. However, when oxyhemoglobin levels in the lip (posttest) were correlated with maximum strength values both before and after performance, $r = .60$ and $r = .67$ were obtained.

In the basal readings prior to performance six of the nine players had normal arterial oxygen saturation. Players three, five and six (in rank as determined by the maximum strength test) showed below normal oxygen levels. All performers recorded lower levels in the lip, which would be representative of what might be expected in the capillary network of inactive skeletal muscle. The only explanation that might be offered for the lack of support of the Hypothesis, is that, with high arterial oxygen saturation and inactive regional muscle, any levels recorded will reveal their own natural relationship, dependent on the state of the organism.

While it was not predicted, it was not surprising to find a positive direction of confirmation of Hypothesis III. It might be assumed that the musical stress test acted as a stimulation to the muscle in question. As a result, vasodilation occurred and an increase in blood flow was recorded. Since trumpet playing causes passive hyperemia, precipitated in part by the DePalma effect (1942), an increase in blood volume no doubt on-sets. Such an increase in hemoglobin was probably the reason for the elevation in oxyhemoglobin after the musical stress test.

The electrophotometric device used in this study was not designed to measure a single vessel, but a network of capillaries and arterioles. Attachment of the photoelectric cell was made twice. Every effort was made to position the instrument in the same place on the second recording. There is the possibility, however, that some variability did occur, and should this have happened the second examination would have been made of a different vascular bed.

A .43 relationship was found in support of Hypothesis IV. The term invariant as used in this study refers to the stability of the lip oxyhemoglobin percentage when the basal saturation is compared to the percentage of saturation after the musical stress test. To the knowledge of the writer, no data exists at this time which would serve as a scale for comparing an observed frequency and an expected frequency. Therefore, any variation that is negative might be considered as variant, as a thirty-five second period of time elapsed prior to the attachment of the photo-electric cell. The assumption for the positive values is that during the elapsed time period, total oxygen recovery took place, and any elevation which occurred was in part due to passive hyperemia.

If these assumptions are valid then the results may provide very plausable foundations for future inquiry. In the first three trumpet performers who had the maximum strength values, no oxygen deprivation was found when comparing the basal saturation with the saturation after performing on the trumpet. Subject number six who, subjectively is one of the finest trumpet performers at the University of Oklahoma and who obtained the highest ranking on the range and endurance scale, recorded no variation in oxygen saturation after the playing test. The weakest two performers, who in general remained on the bottom of most of the rankings, recorded oxyhemoglobin declines.

The nature of the oximeter made it impossible to compute a recovery quotient. Of special interest is the rate of oxyhemoglobin recovery after subjection to performance stress, and the findings in this study amplify that interest.

Additional Significant Correlations

When the basal oxyhemoglobin saturations of the ear and lip were correlated, a coefficient of .66 was obtained. All percentages in the lip were below those recorded in the ear. Generally, the weaker players showed a greater deficit between the two recordings. There is the possibility that in weaker players, proliferation of vascular collateral circulation is not as predominant. Performer number six, one of the better musicians, had a fourteen percentage point difference. The writer is rather certain that this subject did not demonstrate his maximum force on the strength test. He informed the experimenter at the time of the test that the lip was very tired, due to a very rigorous performance schedule. In the preliminary trial attempts this subject was ranked second in the maximum strength category.

One of the highest coefficients was obtained when the oxyhemoglobin desaturation rates were compared during the holding of the breath. A .71 relationship was found between the oxygen desaturation rate in the lip for an expiratory breath hold and the oxygen desaturation rate in the lip for an inspiratory breath hold. Table 7 reveals the cluster of rates which appear in the weakest three players. Marked elevations in rates of decline were observed during inspiratory breath holding. This is due in part no doubt to the lack of oxygen consumption during longer periods of ventilatory cessation. Player number seven who was in the best general physical condition, as determined by the physiological data sheet, had the highest desaturation rate, however, the breath holding well exceeded that of two minutes. Inspiratory breath holding yielded a .88 correlation. Obviously, players able to hold the breath for specific durations could replicate the process. A similar correlation of .61 was found between observed expiratory breath holding in the lip and observed inspiratory breath holding in the lip. If in either environment one was high, a corresponding high value occurred in the alternate environment.

The oxyhemoglobin saturation in the lip after the musical stress test correlated with several of the other variables investigated in this study. The duration of expiratory breath holding in the lip was found to correlate at a .60 level with oxyhemoglobin tension after the playing of the trumpet. The relationship seemed to imply that with longer expiratory breath holding the higher the oxygen tension in the lip after performance stresses. Since trumpet playing involves expiratory flow, it would appear significant that with normal oxygen saturation a conditioning to longer periods of expiration tolerance might decrease oxygen deprivation in the lip. A .61 coefficient was found for the same variables for the inspiratory function.

Range and endurance was found to be influenced by several factors. Correlation coefficients of .60 were obtained when range and endurance was paired with observed breath holding during expiratory and inspiratory cessation. Both ear and lip values suggest that in players who could hold the breath for longer periods of time, range and endurance proficiency was increased. In the correlation of strength prior to the musical stress test (.60), the two weakest performers ranked at the bottom of the range and endurance scale. Players one and three as determined by the maximum strength values were at the top of the range and endurance continuum.

The most striking relationship of the study was found to be the -.60 coefficient obtained between the arterial oxyhemoglobin saturation and the performer range and endurance scaling. Basal arterial saturation levels as recorded by the Waters Oximeter System were normal for six of the trumpet performers. Of the remaining three players, who subjectively would no doubt rank as the three outstanding in the undergraduate program at the University of Oklahoma, basal arterial saturation levels of oxyhemoglobin were below normal. These performers ranked three, five and six on the strength test and one, two and four on the range and endurance scale. A natural query here is to whether or not these three players have a below normal oxyhemoglobin level, for only one recording was made in this study. Still another query might be that of whether or not the principle of oxygen-conserve (Wolf 1966) might be operating.

General Findings and Implications

Tests of significance failed to support the predications that the labial structures of trumpet performers are stronger than those of non-trumpet performers and that psychophysical force judgments are more accurate in trumpet players than in non-trumpet players. Possibly due in part to a lack of muscle stimulation (warming-up) prior to the force tests, trumpet players were weaker and were less accurate in estimating forces than the non-trumpet players.

Correlation coefficients were computed for the pairs of variables which were obtained by a Waters Oximeter System. Twelve significant relationships were found (Table 11). The results to some extent should be considered inconclusive, due to the size of the sample and the number of replications of the test; however, several striking trends in the raw data offer some support to the reasoning of this study.

The ranking on the range and endurance scale was considerably better when the arterial oxyhemoglobin saturation level was below that of normal. Better range and endurance performers were able to hold the expiratory and inspiratory breath for longer periods of time. The two players with the highest range and endurance ranking had the lowest arterial and lip oxygen saturation levels.

Some interesting trends were observed in the rates of desaturation for the performers examined in this study. Generally, expiratory rates were somewhat higher, but when the expiratory breath holds were longer the desaturation rates were lower. Desaturation rates in the labial structure were most prominent in the weaker players. When the percentages of saturation were closely related in both the arterial blood and in the labial blood, the desaturation rates were higher.

After the completion of the musical stress test it is noted that rather wide variability existed between the arterial and labial oxyhemoglobin percentages of the weaker players. The lip oxygen tension was either the same or higher in the three strongest performers after the induced stress. The top four performers on the range and endurance scale had either the same or higher oxygen percentages upon the termination of the musical stress test.

Measurements of maximum strengths and psychophysical judgments of relative strengths were obtained from a force transducer constructed especially for this experiment. Several physicians showed interest in the apparatus, as there might be direct application for such a device to various disciplines. At one point the experimenter had nearly completed the testing, only to find that the data looked suspect and the labial force transducer was finally bonded together with steel. It is not known whether or not the device was comfortable for all of the subjects, although none of the subjects in the two samples indicated that this was the case. Extreme care was exercised in having the subject place the upper lip as near or on the calibrated area of the transducer as possible. Some variations in the positioning no doubt resulted between the experimentals (pretest and posttest). However, examination of the relative values would indicate that variations were only slight. A similar device in the future might be constructed with a larger rounded surface area, so as to fit the individual contour of the teeth and either lip. It was found that the more "bulky" the instrument the less flexibility there would be in various testing situations.

Adapting the photo-electric cell of the Waters Corporation Oximeter System to the lip received varying responses from physicians qualified to offer analysis. The general conclusion was that relative readings in the lip would be more valid than those of actual percentages. Variations in the thickness of the individual lip structure and the re-positioning of the cell for the posttest examination were the two major factors of concern. Future investigations might utilize two such systems in order to obtain arterial and lip recordings at the same time. In this study there is little reason to suspect that relative readings would be non-representative; however, actual values for the labial saturation might be questioned.

Only aerobic work capacities were the object of examination in the design of this experiment. There is the implication that the lip structures of trumpet performers might be stronger, acknowledging the U-Curve of physical performance for conditioned organisms. As might be expected, upon the termination of the musical stress test, psychophysical judgments were less accurate, possibly due to a loss of sensitivity in the lip. The less stronger players were more accurate, probably based on the decreased total force range. Studies in the future might prove valuable in investigating later stages of aerobic work and even anaerobic work. Examining maximum force, psychophysical judgments of force and mouthpiece pressures (Weast and Hake 1965) would no doubt prove meaningful to the trumpet teacher and performer.

The one enigma which is unique among trumpet performers is that of the varying abilities to cope with labial deformation, brought about by stresses during performance. Degree of metabolic changes during the playing of the instrument initiate such responses. In this study oxyhemoglobin tension was examined and it was found that two distinct groups were present. In the one group oxygen tension in the blood was found to be normal, while in the other group a below normal oxygen level was found. The three performers who had below normal oxygen readings were the finest trumpet players at the University of Oklahoma. Objectively, they also ranked at the top of the range and endurance scale in this study.

The implication is that players with normal arterial oxyhemoglobin tension face the problems of desaturation during the playing of the trumpet, which may provide greater "unbalanced states" than in those players who have a below normal oxyhemoglobin tension. Whether or not this is an inherited characteristic or whether it is conditioned by accident through trumpet playing is not known. Only more examinations using control and experimental subjects from many disciplines of life might reveal salient answers.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Modern trumpet players are confronted daily with stresses imposed by performance. However, little research has been devoted to the studying of methods which might assist the performer in learning to resist the effects of those stresses. Coping with the problem of mouthpiece pressures seems to be one of the most prevalent among all players from the novice to the professional. The design of the present study, which investigated only the labial function of the upper lip of trumpet performers, was of a threefold nature: (1) to define the physiological functional behavior of the lip involvement during performance, (2) to examine muscle strength and oxyhemoglobin variations both before and after a musical stress test and (3) to suggest direction for future research design of trumpet performance.

The procedure involved obtaining data from maximum force efforts, psychophysical force judgments and oxyhemoglobin saturation levels. Tests of significance and tests of correlation were then made to determine if relationships existed between any of the cases.

The subjects were nine non-trumpet players and nine trumpet players selected randomly from the student body at the University of Oklahoma. The trumpet performers were all enrolled in private study in the School of Music.

In the case where experimental data were required, the Hypotheses formulated resulted in the following predictions: (1) trumpet players are able to exert greater forces with the labial structure than non-trumpet players, (2) trumpet players are able to estimate labial forces with greater degrees of accuracy than non-trumpet players, (3) trumpet players with stronger labial structures have lower oxyhemoglobin saturation levels than those with weaker structures and (4) during aerobic work, trumpet players with stronger lips have significantly invariant oxyhemoglobin saturation levels than those with less stronger lips.

In order to collect the data a labial force transducer was constructed for measuring maximum strengths and for measuring psychophysical estimation of force judgments. For these cases, the group of nine non-trumpet performers were compared with those subjects who performed on the instrument. One case involved only the performers, for which values were obtained prior to the musical stress test and again upon the termination of the test. A comparative analysis between the pretest-posttest values of the trumpet players would not project any specific reasons for suspecting that the labial force transducer might be inconsistent. The oxyhemoglobin data were obtained through the use of a Waters Corporation Oximeter System. The system was operated by a special technician, along with the experimenter. Since the device had not previously been used in measuring oxyhemoglobin in the lip, actual values to some extent may be in question; however, relative values would appear valid.

Conclusions

This study has undertaken a search for a better understanding of the problem involving labial stresses during trumpet performance. Physiologically, when the mouthpiece is placed against the lips and a hermetic seal is formed, pressure from the rim causes ischemia, with resultant passive hyperemia due in part to the DiPalma effect. Initial blowing of the instrument appears to induce vasodilation which accounts for the passive hyperemia, and as blowing continues hypoxia causes various metabolic changes that result in labial deformation and a loss of sensitivity.

To determine if Hypothesis I was valid, all of the subjects were asked to produce a maximum force on the labial force transducer. A test of significance was made of the resulting values and it was found that no support of the Hypothesis could be given. Quite remarkable was the fact that the mean values of the three cases were nearly identical.

Hypothesis II suggested that estimation of force judgments would be more consistent in the trumpet performers. A test of significance was again made and no support for the Hypothesis could be found. Similarity among the mean values was, as with Hypothesis I, rather evident.

While Hypothesis III was not found to be valid, an inverse relationship was yielded. Passive hyperemia may be, in part, responsible for such a result. The correlation coefficient computed for Hypothesis IV did not support the prediction.

The following trends found within the data would seem to be of interest:

(1) Expiratory desaturation rates were higher than the inspiratory rates.

(2) Longer breath holds during expiration yielded lower desaturation rates.

(3) Players who could hold the breath longer were more proficient with range and endurance.

(4) Differences in arterial oxyhemoglobin prior to the musical stress test and oxyhemoglobin after the musical stress test were wider in the weaker performers.

(5) Oxyhemoglobin saturation after the musical stress test was the same as or higher than the recorded basal for the three strongest players.

(6) Oxyhemoglobin saturation after the musical stress test was the same as or higher in the four top range and endurance performers.

Finally, and perhaps the most interesting finding in the present investigation was that of the apparent divisions within the trumpet performer group. Three of the nine subjects recorded an arterial oxyhemoglobin saturation level of below normal. No doubt these players rate as the finest trumpet performers in the undergraduate music program at the University of Oklahoma. Objectively, on the range and endurance scale in this study, these players ranked at the top.

As evidenced by this study, with only a small sample, strength may not be a prime asset for offering a resistance to the external forces of the mouthpiece. It is entirely possible that some metabolic factor may be of greater significance than ever before conceived.

Recommendations

As a result of the findings in this study the following recommendations are offered:

(1) A study of this type with a much larger sample and more replication of the tests would seem in order.

(2) Studies using plethsymographic, radiometric and ultrasonic sound techniques might yield valuable information about labial deformation.

(3) Adaptation of techniques used at the Max Planck Institute for muscle training might assist the trumpet player in coping with such stresses.

(4) Studying players from the novice to the professional with varying oxyhemoglobin saturation levels might be of significance.

(5) Investigate the logic of physical fitness to trumpet performance.

(6) Biopsies might assist in determining the nature of the changes within the tissue as a result of trumpet performance.

(7) Due to the nature of the problem, long range studies over a period of years would be of great significance.

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APPENDICES

APPENDIX A

PHYSIOLOGICAL DATA SHEET

Name: ______________________ Date of Birth: ___________

Height: ____________________ Weight: ________________

1. Number of times hospitalized? ___ General nature of illness(es) ______________________________________

2. Have you ever been told you had:

   Heart trouble? ______________ High blood pressure? ___

   Low blood pressure? _________ Kidney trouble? _______

3. Asthma? ___________

4. At present are you aware of any chronic infection? _____

   What? ____

5. Hours of sleep you usually get? __________.

6. What time do you go to bed? ______________.

7. Fall asleep easily? _____________________.

8. Did you sleep well last night? ___________ Hours? ____

9. Do you smoke? _______ Number per day? ________________

10. Physical exercise regularly? ___ Kind? ___ Amount? _____

11. Currently using any sedatives? ___________ Kind? _______

12. Do you suffer muscle pain frequently? ________________

13. General physical condition at present? _______________

14. Frequent dizziness? __________________.

15. Frequent swelling of lip during__and after__performance?

16. Difficulty with range? _______________.

17. Difficulty with endurance? ___________.

18. Connection time? ______________________________.

19. Performance? ______________________________.

20. Warm-up time gradient? ________ Faster? ________

Same? ______________________________ Slower? ________

KEY TO APPENDIX B

A = Basal O_2 saturation in the ear

B = O_2 expiratory rate of desaturation in the ear

C = O_2 inspiratory rate of desaturation in the ear

D = Number of seconds breath was held during expiration (ear)

E = Number of seconds breath was held during inspiration (ear)

F = Basal O_2 saturation in the lip

G = O_2 expiratory rate of desaturation in the lip

H = O_2 inspiratory rate of desaturation in the lip

I = Number of seconds breath was held during expiration (lip)

J = Number of seconds breath was held during inspiration (lip)

K = O_2 saturation 35 seconds after the musical stress test

L = Range and endurance ranking (using decibel values)

M = Maximum strength prior to the musical stress test

N = Maximum strength after the musical stress test

APPENDIX B

MATRIX OF CORRELATION COEFFICIENTS

VARIABLE*	A	B	C	D	E	F	G	H	I	J	K	L	M	N
ROWA	1.0	-.13	.17	-.44	-.00	.66	.27	.58	-.00	-.19	.25	-.60	-.00	-.00
ROWB	-.13	1.0	.17	-.38	-.00	-.00	.17	-.00	-.00	.43	.49	-.00	.20	.37
ROWC	.17	.17	1.0	-.21	.41	.00	.52	.48	.23	.58	.53	.32	.00	.15
ROWD	-.44	-.38	-.21	1.0	.56	-.37	-.12	-.48	.50	.29	-.00	.46	.30	-.00
ROWE	-.00	.08	.41	.56	1.0	.00	.57	.14	.54	.88	.43	.60	.22	.00
ROWF	.66	.00	.00	-.37	.00	.00	.45	.41	.00	.00	.43	.00	.21	.18
ROWG	.27	.17	.52	-.12	.57	.45	1.0	.71	.42	.50	.55	.19	-.17	-.18
ROWH	.58	-.00	.48	-.48	.14	.41	.71	1.0	-.00	.17	.14	-.36	-.54	-.53
ROWI	-.00	.00	.23	.50	.54	.00	.42	-.00	1.0	.61	.60	.43	.45	.35
ROWJ	-.19	.43	.58	.29	.88	.00	.50	.17	.61	1.0	.61	.60	.18	.11
ROWK	.25	.49	.53	-.00	.43	.43	.55	.14	.60	.61	1.0	.33	.60	.67
ROWL	-.60	.00	.32	.46	.60	-.00	.19	-.36	.43	.60	.33	1.0	.60	.41
ROWM	-.00	.20	.00	.30	.22	.21	-.17	-.54	.45	.18	.60	.60	1.0	.53
ROWN	-.00	.37	.15	.00	.00	.18	-.18	-.53	.35	.11	.67	.41	.53	1.0

*Key appears on facing page.

Note: Underlined coefficients are deemed significant.

KEY TO APPENDIX C

A = Basal O_2 saturation in the ear

B = O_2 expiratory rate of desaturation in the ear

C = O_2 inspiratory rate of desaturation in the ear

D = Number of seconds breath was held during expiration (ear)

E = Number of seconds breath was held during inspiration (ear)

F = Basal O_2 saturation in the lip

G = O_2 expiratory rate of desaturation in the lip

H = O_2 inspiratory rate of desaturation in the lip

I = Number of seconds breath was held during expiration (lip)

J = Number of seconds breath was held during inspiration (lip)

K = O_2 saturation 35 seconds after the musical stress test

L = Range and endurance ranking (using decibel values)

M = Maximum strength prior to the musical stress test

N = Maximum strength after the musical stress test

APPENDIX C

RAW DATA USED IN CORRELATIONS

SUBJECT	Variable*													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
01	.89	.140	.085	50	129	.78	.017	.00	57	94	.86	.86	44	38
02	.88	.409	.079	22	63	.84	.00	.00	28	78	.84	.78	39	39
03	.81	.250	.097	36	82	.67	.00	.00	45	90	.76	.99	31	30
04	.91	.096	.074	31	94	.82	.00	.047	32	63	.70	.80	30	22
05	.85	.051	.037	39	54	.82	.00	.00	34	46	.67	.84	27	24
06	.83	.139	.097	43	123	.69	.00	.00	27	98	.69	100.	26	22
07	.90	.233	.138	30	144	.86	.27	.089	48	134	.88	.92	24	22
08	.92	.090	.107	22	28	.77	.00	.057	23	35	.73	.49	20	23
09	.88	.235	.047	34	84	.73	.023	.041	33	75	.66	.48	12	12

*Key appears on facing page.