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An Electromyographic Study of the Effect of Negative Intraoral Air Pressure on the Perioral Musculature

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AN ELECTROMYOGRAPHIC STUDY OF THE EFFECT OF

NEGATIVE INTRAORAL AIR PRESSURE ON

THE PERIORAL MUSCULATURE

by

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LIFE

David Leonard Edgar was born in Detroit, Michigan, April 12, 1931. He graduated from Central High School, Detroit, January 1949. In February 1949, he entered the University of Michigan where he received the degree Doctor of Dental Surgery in June 1955.

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CHAPTER I

INTRODUCTION

A. Introductory Remarks and Statement of the Problem

A negative intraoral air pressure is formed during many activities of the stomatognathic system. Sucking, sipping fluids, and drinking are made possible by a reduction of air pressure within the oral cavity. In addition to these normal functions numerous perverse habits such as thumb sucking, lip sucking, and tongue sucking are attended by a negative intraoral pressure.

Although the formation of negative intraoral air pressure is an important part of the activity of the masticating mechanism, little research has been done on negative air pressure originating in the oral cavity. The purpose of this investigation is to study the behavior of the perioral musculature when a negative intraoral air pressure is present in the mouth.

B. Review of Literature

The first significant work on negative intraoral pressure was reported by a Dutch physician, Donders (1875). He believed that in normal tongue position a "vacuum space" (Donders' vacuum space) was formed by a slight separation of the posterior part of the dorsum of the tongue from the soft palate while the anterior part of the tongue remained in contact with the hard palate. He inserted a manometer tube into this "space" and claimed

that he found a negative pressure of 2 to 4 mm. Hg.

Although many of his ideas about tongue function and the existence of a "vacuum space" were refuted long ago, his work is significant because for many years it had a great influence on scientific thought concerning the oral mechanism. This influence is reflected in much of the early literature on such diverse topics as facial development, mandibular posture, and respiration.

For many years it was believed that the rest position of the mandible was maintained by the negative intraoral air pressure found in "Donders' vacuum space". An anatomist, Cryer (1916), studied the tongue position on cross - sectioned cadavers which had been frozen shortly after death. He supported Donders' views on tongue position and the presence of a space between the soft palate and the tongue. Referring to Donders' observations, Cryer states:

> "Owing to the weight of the jaw, there is a negative pressure in this space of 2 to 4 mm. Hg. The jaw is maintained in position not by muscular effort but by the pressure of the air; so that, if a tube from a manometer is placed in that area it shows a slight negative pressure corresponding to the weight of the jaw."

Dewey (1921) also believed that "Donders' vacuum space" was responsible for maintaining the postural position of the mandible. He offers "proof" of the validity of this theory with the erroneous deduction from his observation that it is difficult to maintain the jaw in a fixed position when it is opened beyond the distance in which the lips can close to seal the oral

cavity.

Herbst (1935) reiterated this notion about mandibular posture. He states:

> "The normal atmospheric pressure is effective only with one who really breathes through the nose. In this case the mandible is held firmly to the maxilla like a set of teeth to the suction disk. The weight of the mandible forms at the highest point of the palate the so-called Donders' suction space, in the same way as the suction chambers in the suction plate."

The growth of the palate in a downward direction was also believed to be influenced by negative intraoral pressure. Howard (1915) made a clinical study of respiration. Discussing normal breathing, he states:

> "The tongue, which lies equally between the upper and lower arches, stimulates the lateral development of the teeth; while the vacuum created between the dorsal surface of the tongue and the roof of the arch contributes to the development of the vault of the mouth in a downward direction."

Dewey (1925) also suggested that there was a strong relation between negative intraoral pressure and the downward growth of the palate. He observed that after a person stops speaking he unconsciously swallows. Dewey believed that a vacuum created during swallowing was the force that "pulled" the palate downward.

James and Hastings (1931) repeated Donders' experiment using a water manometer, and reported finding a negative intraoral pressure of 10 cm. H_2O. Some of the subjects tested failed to demonstrate a negative pressure. The authors believed that this was due to: ".....failure of either the anterior

or posterior oral seal or both." They also state: "The negative pressure produced in this manner constitutes, in our opinion, the most important feature for the development of the normal growing mouth and for prevention of local disease."

With the deeper understanding of the facial growth process and the roll of the masticating muscles in maintaining mandibular posture, most of the early theories concerning negative intraoral pressure have been discarded. Although the statements made by most of the forementioned authors would not receive much serious consideration today, it should be remembered that many of the research techniques used today such as electromyography and radiography were not generally available when these men made their observations.

Thompson (1938) doubted many of the early views on the existence of "Donders' vacuum space." He studied the movements of the tongue radiographically; four lateral head plates were taken during a 2 minute interval following swallowing. The results of his study did not agree with the current views concerning tongue position. He found that in most instances the tongue at rest was not placed against the palate as was previously believed. In those few cases in which the tongue rested against the hard palate he could find no evidence of a space. He takes particular issue with Cryer's belief in the existence of a "vacuum space". Thompson maintains

that the tongue position observed on frozen cadaver specimens was not its true position. He points out that other features shown in Cryer's diagrams of sagittal sections of the head do not agree with the roentgenograms of living subjects.

Concerning mandibular posture, Thompson states: "The results of this investigation suggest that a vacuum or negative pressure within the mouth is not so important a factor in the maintenance of the mandible in its rest position as has been assumed." He mentions that muscle tonus might be the primary factor in maintaining the rest position of the mandible. However, he did not elaborate on this idea.

The importance of muscular activity in maintaining the rest position of the mandible has been well established. Sicher (1949) states:

> "The rest position is constant in each individual due to the individually fixed and only slightly variable tonus of the masticatory muscles, which in their relaxation, allow the mandible to drop slightly. The rest position is therefore not dependent on the presence of the teeth or on their shape or position but on the musculature and on muscular balance alone."

Several investigators such as MacDougall and Andrews (1953), Jarabak (1957), and Latif (1957), have used the electromyograph to study muscular activity during mandibular movement and at rest.

Sucking is the most pronounced activity of the oral mechanism in which a negative pressure is created within the mouth. Auerbach (1888) was one of the first to describe the mechanism of the creation of negative intraoral pressure during sucking. He observed that the essential element in this

activity was the enlargement of the oral cavity after the mouth was first sealed from the atmospheric air pressure at both its anterior and posterior boundries; anteriorly air can enter the mouth when the lips are parted; posteriorly the mouth is exposed to the air passing through the nasal pharynx and oropharynx. Auerbach explained that before a negative pressure could be created, the mouth was first sealed by pursing the lips together and placing the posterior part of the tongue against the soft palate to seal off the oropharynx from the oral cavity.

According to Auerbach, the increase in volume of the oral cavity and, therefore, the drop in air pressure was accomplished by two activities; (1) depression of the anterior part of the tongue away from the hard palate, and (2) depression of the mandible. Discussing the activity of the tongue and mandible during sucking, he states:

> "We have, therefore, to consider, that with the mouth closed, the dorsum of the tongue is nearly applied to the hard and soft palate so that only a minimum air-containing space is present near the tip. With the mouth closed the simplest way to enlarge the oral cavity is by lowering the jaw."

Auerbach does not ascribe to the cheeks any active part in the sucking process other than that they serve as firm walls to the enlarged oral cavity. He also observed the "sucking groove" or "trough" formed by the tongue during sucking.

Strang (1933) has also described the sucking act. Discussing the primary function of the muscular activity involved in sucking, he states:

"The muscles that are active in the sucking function have, for one objective, the production of a vacuum within the oral cavity whereby fluids or air may be drawn into the mouth." The principle activities which take place in the sucking act, as observed by Strang, are summarized as follows:

1. The muscles of the lips contract to prevent air from rushing into the mouth and destroying the vacuum created by the downward movement. of the mandible.
2. The tongue is withdrawn from contact with the lingual surface of the incisor, canine and premolar teeth and also from the mucous membrane of the hard palate. Simultaneously the central part of the tongue is depressed and the sides are rolled upward to form the "sucking trough". (Also observed by Auerbach).
3. The muscles of the soft palate (tensor veli palatini and levator veli palatini) are relaxed so that it comes down to meet the raised root of the tongue. This closes off the pharynx from the oral cavity and prevents air from entering the oral cavity posteriorly.
4. The mandible is depressed in order to enlarge the space within the oral cavity and thereby make possible a negative pressure.
5. The central fibers of the buccinator muscles and the tissues of the cheeks are drawn between the occlusal surfaces of the molars, premolars and canines by the intraoral vacuum.

Strang emphasized that sucking is confined entirely to the oral cavity.

He points out that sucking and normal breathing may take place simultaneously.

Much of our present knowledge of the oral activities associated with negative intraoral pressure has been contributed by four Englishmen; Gwynne-Evans, Rix, Tully, and Ballard.

Gwynne-Evans (1948, 1951, 1954) has done extensive work on the development and maturation of oro-facial muscular patterns. Using movies and lateral soft tissue radiographs of the head, he studied many of the oral activities of infants and children. His findings regarding suckling, sipping fluids, sucking, and spoon feeding are pertinent to this research.

He considers suckling as the first instinctive reflex activity in the development of a mature feeding mechanism. His studies of infant suckling revealed that the perioral musculature plays only a minor roll during this act. Slow motion movies showed that during suckling the upper lip protruded over the lower lip and enveloped the teat while the lower lip supported the teat and formed the anterior wall of the oral cavity. Although the lips were lightly sealed around the teat, they seemed to take no active part in conveying the milk to the infant.

Gwynne-Evans contends that the milk is brought into the oral cavity almost entirely by the activity of the tongue. Studies of infants with bilateral hair lip revealed the importance of tongue activity during suckling. The cleft in the lip permitted viewing tongue activity posteriorly to the soft palate.

Gwynne-Evans describes three stages in the suckling cycle. During the first stage, the mandible is depressed and the dorsal surface of the tongue is grooved or furrowed as it is applied to the nipple. Following the expression of the milk into the infant's mouth the infant elevates the jaw and compresses the teat against the upper gum pad with his tongue. In the final stage of suckling the space between the tongue and hard palate is obliterated from before backwards by a peristaltic contraction of the transverse fibers of the tongue. The soft palate is depressed and tensed so that the compression of the tongue against it "squirts" the milk into the pharynx.

Gwynne-Evans also observed that nasal respiration always accompanied suckling in the infants that he studied. He attributes this phenomenon to their small tidal air space and the fact that infants can exert little conscious control over their respiratory rate. He theorizes that continued nasal respiration is made possible by the close approximation of the epiglottis to the soft palate.

The need for continued respiration during suckling was shown in his studies of an infant who was born with bilateral atresia of the posterior nares. His initial instinctive efforts at nasal breathing resulted in the collapse of the soft tissues of the oropharynx and submandibular triangles. This respiratory distress was relieved when the infant learned to take a few breaths through the mouth while bottle feeding.

Although Gwynne-Evans concurs with Auerbach's observation on the grooving of the tongue during suckling, he differs from Auerbach in explaining this phenomenon. Auerbach states that the grooving is a result of a negative pressure. Gwynne-Evans believes that it is the cause of the negative pressure.

The development of the sucking pattern and the contrast between this act and suckling has received considerable attention from Gwynne-Evans (1951). His observations reveal that the sipping of fluids is accomplished by a series of sucking movements. He found that during sucking the lips were firmly sealed around the edges of the cup or spoon. The mandible was lowered and the anterior half of the tongue depressed away from the hard palate while the posterior half of the tongue remained in firm contact with the tensed soft palate.

Comparing his findings on suckling and sucking, Gwynne-Evans summarizes the physiology of the two activities:

> "Suckling therefore, is an inborn function of the oro-facial muscles initiated by the contact of the nipple or teat with the lips. It is a reflex process involving a rythmical pumping and squirting action of the soft palate, tongue and jaw muscles.
>
> Sucking is an acquired function of the oro-facial muscles. It involves the creation of an intraoral negative pressure and is not a continuous process like suckling. When sufficient fluid has accumulated in the mouth the act of sucking is interrupted by a swallowing movement to dispose of the oral contents and at the same time nasal breathing is interrupted by the closure of nasopharyngeal and laryngeal sphincters. Suckling and sucking therefore are not synonymous terms."

Gwynne-Evans work also includes studies of the development of adult facial expression (1954). He contrasts the expressive face of the adult with the vacant passive appearance of the infant's face and explains that well differentiated activity of the facial musculature must be learned by a child just as he must learn to walk. He states that two conditions must be active for normal development of perioral muscular function:

1. Sufficient maturation of the central nervous system to provide the necessary neuromuscular control.
2. Adequate learning stimulus.

He points out that many of the infantile facial patterns that persist have no organic basis but are due to the failure of the child to learn more mature control of the perioral muscles. Thus in discussing the often observed "open mouth habit", he says:

> "It is not that the child cannot keep his mouth and lips closed at will, but that there are times when he does not choose to use the oro-facial muscles as he should. At any rate, through the slow and steady progress of maturation and with training, most children can be taught to keep the lips closed at rest as a habitual pattern of behavior unless there is some structural defect such as a short upper lip or an overjet of the upper teeth or jaw which would make lip closure difficult to achieve without constant effort."

In 1948 Gwynne-Evans suggested the use of the Andresen appliance in modified form to provide a stimulus for the development of mature facial behavior patterns. The modifications are not described but he states that no tooth movement is involved. In subsequent writing the use of this

appliance is not mentioned.

Paralleling the work of Gwynne-Evans, Rix (1946, 1953) has done extensive research on the activity of the perioral musculature during swallowing. His method of study, movie records and soft tissue radiography, was similar.

He traces the development of the swallowing reflex from infancy to the adult form and notes that the perioral musculature takes a very active part in infancy but when the adult swallowing pattern is developed pronounced activity of the facial muscles is no longer necessary. He demonstrates that in the infant swallow the tongue is thrust foreward and upward against the hard palate and that the lips must be tightly sealed to meet the foreward thrust of the tongue. Rix shows that as the deciduous dentition develops the teeth and alvealor process replace the cheeks and lips as walls to contain the activity of the tongue, and therefore, the activity of the facial muscles decreases. Rix also observed that in the normal adult swallow the teeth are in contact and thus the dental arch forms a barrier against which the tongue can act.

The persistence of the infantile swallowing pattern has been thoroughly reported by Rix. He notes that older children often swallow with the jaws apart and the tongue thrust between the teeth against tensed lips and cheeks. He found that these "atypical" swallowers showed very firm contraction of the mentalis and zygomatic group of muscles.

He has also called attention to the effects of lip activity on the arrangement of the teeth. He states that excessive lip pressure is responsible for the crowded maxillary incisors in Class II, Division II malocclusion. Rix also found a very high correlation between the degree of intermaxillary opening during "atypical" swallowing and the amount of overbite. Deepest overbites were found where the widest separation of the teeth existed.

Rix disagrees with Gwynne-Evans' contention that closure of the lips at rest is an acquired pattern of behavior. This conclusion is based on his observation that most new born infants have their lips closed.

Ballard (1951) has done extensive work on lip posture and the influence of adverse oro-facial muscular behavior in producing malocclusion.

In presenting his work on lip posture, he introduced the term "competent" to describe lips which have normal length, form, and tonus. His studies indicate that the habitual "lips apart" postural attitude is caused by two separate conditions:

1. In some individuals it is caused by a dropping of the mandible. Although the lips are "competent", they are separated. Ballard found that mouth breathing was the cause of this type of lip posture. All the individuals in this group had some type of nasal obstruction and were forced to keep the lips apart to breathe. When the nasal obstruction was removed (excision of the pharyngeal

tonsil), the children reverted to nasal respiration and normal lip posture in a very short time.

2. In the second group the lips were too "incompetent" to permit them to be in contact with the mandible at rest. Ballard observed that this defect was very common among English children and suggested that genetic factors were the principal cause of "incompetent" lips. He firmly emphasized that this defect was not due to mouth breathing. His radiographic and clinical findings showed that many of these children breathed through the nose and had a normal freeway space. The radiographs also demonstrated a normal posterior oral seal with the tongue resting against the soft palate.

He also refutes the theory that chronic nasal obstruction produces maxillary mal-development. He says: "It would appear that as long as the lips are competent and the swallowing normal, chronic mouth breathing will not produce a dental irregularity."

Ballard also found that in children with oral "incompetence" a considerable effort is required of the orbicularis oris and mentalis muscle to keep the lips in contact. He also observed that Class II, Division I malocclusion is closely associated with "incompetent" lips. Referring to this malocclusion, he states that the overjet is produced and maintained by such acts as swallowing in which the lips are closed by the contraction of the mentalis muscle which places the lower lip lingual to the upper incisors.

These latter findings are essentially the same as those reported by Rix.

Ballard's observations on abnormal sucking and swallowing behavior are summarized in the following statement:

> "In discussing abnormal muscle behavior during swallowing, it must be said that clinically they appear to have some association with the sucking behavior patterns. I would even go so far as to suggest that they may all be related. In my experience, most children who have had a sucking "habit" have an abnormal swallow and dento-alveolar irregularity. Although the majority with abnormal swallows do <u>not</u> give a history of sucking habits, rarely do I see a child who has produced an irregularity by a sucking habit who has not an abnormal swallow."

Although Ballard agrees with Rix and Gwynne-Evans on the close association between perverse oral muscular patterns and dental irregularity, he disagrees with them on the basic philosophy of treatment to correct these anomalies. Rix and Gwynne-Evans feel that many of these abnormal behavior patterns can be corrected by training the child to consciously alter the habit. Ballard believes that the cause of many of the habits lies in genetic factors. He reasons that the influence of genetic forces is too strong to be permanently altered by the treatment suggested by Rix and Gwynne-Evans.

Tully (1953, 1956) used the electromyograph to study the perioral muscles. For many years previous to these investigations, he had been closely associated with Rix and Gwynne-Evans and was a co-worker in many of their studies. However, he felt that the electromyograph would provide a more accurate means for study than the clinical and radiographic methods

used by these two men. Discussing the value of the electromyograph as an aid to clinical study of the facial musculature, Tully states (1953):

> "There is no difficulty in observing clinically the more extreme activities of lips and tongue which are seen in some children but assessment in other cases has been difficult. If a scientific evaluation could be made of these patterns by producing tracings of the general activity in a way comparable to that used for other muscles, further investigations could be made. After several trials with a small sample of patients, a method has evolved using the electromyograph."

The primary purpose of his initial studies was to obtain electromyographic records of abnormal perioral muscle activity. He also wished to determine whether the atypical behavior seen in children was present in the adult as well and whether it was related to a particular malocclusion. His initial studies (1953) were done on forty pre-clinical dental students. Electrodes were placed on the lips and masseter muscle. Records were taken during such activities as sucking fruit, swallowing, and sipping from a cup. He found that fifteen subjects exhibited normal behavior, ten pronounced atypical behavior, and fifteen demonstrated activity which was mainly normal but with occasional relapses to abnormal behavior. He reported that the latter group did not occlude the teeth with the same "vigor" as the normal group and that the activity of the lips and masseter were about the same for this group. Although he states that no attempt was made to analyze the occlusion of these subjects, he says that a marked degree of malocclusion was present in those subjects showing the most atypical forms of behavior.

Three studies also confirmed Rix's clinical observations on normal and abnormal swallowing patterns. The electromyographic records showed that during the typical swallow, the contraction of the masseter is intense and the circumoral activity is minimal. In the atypical swallow the reverse is true; masseter contraction is slight compared to the circumoral activity.

The placement of the lip electrodes in these studies was done in such a way as to produce only a partial picture of the muscular activity of the perioral region. These electrodes were placed just medial to the corner of the mouth. Commenting on this electrode position Tully states: "Admittedly in this position the full contraction of the mentalis muscle is not recorded but a fair picture of the circumoral activity is obtained."

Tully divides abnormal muscular behavior patterns into two groups according to his beliefs on their etiology:

1. True "habits" which are acquired and which can be modified and corrected.
2. "Innate" muscular behavior which is genetic in origin and cannot be altered.

He strongly urges the use of the term "habit" only for conditions which are acquired. Thus, although Tully agrees with Rix's observations on "atypical" swallowing he states: "It should not be called a "habit" as swallowing is a basic vegetative function below the conscious level of the mind." He demonstrates that certain types of abnormal perioral muscular

behavior which are generally considered to be "habits" are of genetic origin. To illustrate this point he presents photographs showing a father and two sons with similar lip morphology and lip tension resembling that which is found in a typical "mentalis habit".

Tully feels that growth, both physically and emotionally, is an important factor in eliminating abnormal perioral muscular behavior. His ideas on the prognosis in correcting various perverse habits is presented in the following statement by Tully:

> "Ballard has presented a rather pessemistic picture of the immutability of some types of behavior; I agree with him up to a point but we all see remarkable changes taking place in the face of our child patients as they grow older. We also notice remarkable changes in children when we do no more than observe them. This is true of the child with lack of lip seal where there is no interference of the incisors between the lips. The answer to many of these changes lies in the fulfillment of the growth potential not only of the skeleton, but of the soft tissues also, and in the maturation of the facial musculature which takes on the adult "mask". With the increasing worries of raising a family and of income tax we do not expect to see the same lax lip positions of childhood."

This statement of Tully's reflects the present controversy among orthodontists concerning treatment of perioral muscular problems. Some authors believe that very little can or should be done to treat these problems. Others, such as Rogers (1950) have emphasized the importance of myofunctional exercises and appliances in the correction of perverse habits. Jarabak (1959) has discussed the various views concerning the treatment of oral habits, and has described various appliances which have been used.

successfully to stop such habits as thumb sucking, lip sucking, and tongue thrusting.

A brief study of sucking and suckling was made by Eschler (1954) using the electromyograph. The infants who served as subject material were divided into three groups according to the early methods of feeding. The first group was fed only by breast from the first day of life; the second group received bottle feeding exclusively; the last group had been fed by breast and bottle.

Comparing the activity of the breast fed and bottle fed child, he found greater activity of the masseter in the breast fed child. He also shows that when a bottle fed child was given suck for several weeks this nursing had a favorable influence on the masseter during this period. The formerly nursed child evoked greater activity of the masseter.

He also demonstrated when the breast fed child began to drink from a bottle the muscular activity of the masseter is at first similar to the activity when sucking. This activity, however, passes very quickly to the more even tonus seen in sucking. Eschler concludes: "It is apparent that breast feeding requires stronger muscular forces which the child makes use of at first when sucking the bottle too. But very soon it feels that these muscular forces are not necessary." This finding seems to support Gwynne-Evans idea that sucking is an acquired activity.

Eschlers' records were made by means of movies of the masseter activity shown on a cathode ray oscillograph. He used specially designed bipolar

electrodes and affixed them with "sticking plaster". No description was given of the electrodes or the material used to attach them to the skin.

Cook (1958) studied the forces exerted by the thumb during thumb sucking. Twenty-fve thumb sucking children ranging in age from five years and six months to thirteen years and four months served as subjects. A rubber cot or stall was placed over the thumb to record the forces exerted during the sucking activity. On the basis of his findings, Cook was able to divide the subjects into three groups:

1. "Alpha group", those who produce a positive pressure only against the lingual surface of the anterior teeth and/or the palate,
2. "Beta group", those who produce negative pressures only in the oral cavity by a vigorous sucking action,
3. "Gamma group", those who produce both positive and negative pressures by alternately pressing with the digit and then sucking.

Cook also found that marked labial displacement of the maxillary anterior teeth was associated with the "Alpha group", and posterior cross-bites were found mostly in the "Beta group".

Baril (1959) conducted an electromyographic study of the muscular activity of thumb and finger sucking subjects. His subjects were the same group of children used by Cook. Monopolar disk electrodes were used to investigate the activity of the temporalis, mentalis, buccinator, and orbicularis oris muscles. Recordings were made during the following

exercises: biting, sucking, taping, and swallowing. An analysis of the subjects' malocclusion was also done.

Baril found that the mentalis, orbicularis oris, and buccinator muscles showed the greatest activity during sucking, while the temporalis remained relatively inactive during this act. Contraction of the buccinator was also demonstrated during the swallowing exercise, but not during taping or biting. He was surprised to find that the buccinator muscle exhibited low activity and stated: "The persistent strength of the mentalis muscles presented a surprising contrast to the weakness of the buccal wall."

In sixteen of the twenty-four subjects studied, the mentalis muscle was the most active muscle during sucking; five subjects showed predominent orbicularis contraction; and three had similar activity for the mentalis and orbicularis oris.

Although his findings regarding swallowing agree with Tully's investigations, Baril disagrees with the observations of Rix, Ballard, and Gwynne-Evans. Commenting on this conflict, Baril states: "The muscular behavior was found not to be altered in the short period following sucking but rather the abnormal patterns appeared to be firmly established and persist."

Only three electromyographic studies of the perioral musculature have been reported in the literature. The work of Tully and Baril have already been discussed. The third investigation was carried out by Schlossberg (1954). He studied the activity of the lips and mentalis muscle of subjects

with normal occlusion and Class II malocclusion. Electromyographic recordings were taken while the subjects sucked water through a straw, when swallowing, and in forced sucking without taking in water. Schlossberg found that the malocclusion subjects showed a higher degree of activity than the subjects with normal occlusion. He also stated:

> "A constant rest positon or condition of minimal recordable activity for the muscles that were investigated could be obtained on all subjects, both of normal and abnormal dental occlusion. This condition of minimal activity was reproducible to a high degree."

Winders (1955) and Abrams (1958) used strain gauges to study perioral muscle forces during sucking. The method was similar to Schlossberg's; the subjects were asked to suck water through a straw during which time the force of muscle contraction was recorded. These studies were mainly concerned with developing a method of measuring perioral muscle force. The data pertaining to sucking was not presented.

CHAPTER II

METHOD AND MATERIALS

A. Subjects

Ten white male adults having normal perioral musculature were used in this study. The following requisites were employed to select these subjects:

1. Normal postural position of the lips.

In this condition the lips have adequate length and tonus. The upper and lower lip meet continuously along their respective free borders without strain when the mandible is at rest. Ballard (1951) describes individuals whose lips are habitually held in this position as having "competent" lips.

The subjects were tested for this criterion in the following manner: Each individual was asked to swallow and allow the mandible to assume its resting postural position. A visual examination was then made to determine whether the lips were in contact. Further examination was carried out by gently separating the lips with the forefinger. The purpose of this digital examination was to find out whether excessive muscular contraction (above tonus activity) was necessary to hold the lips together.

2. The absence of tension or strain in the facial musculature.

This was determined by palpation and visual examination of the soft tissue surrounding the oral cavity.

3. Symmetry of facial form.

One of the experimental variables tested in this study was the comparison of muscular activity on the right and left sides of the face. Since anatomic differences in form and size on either side could be expected to influence muscular function, an attempt was made to control this factor by examining for facial disharmonies. It is realized, however, that a very detailed study of the face would reveal a lack of true symmetry. Although embryologic development is largely a bilateral process, small variations occur in all "normal" individuals.

B. Selection of Electrodes

The purpose of the electrode is to receive or "pick up" the electrical activity which muscles yield when they contract. Two general types of electrodes are used in electromyographic studies; needle electrodes and surface electrodes. Needle electrodes are inserted directly into a muscle and are used to study a small specific part of a muscle. The highly selective nature of surface electrodes permits the study of individual motor units and is particularly useful for basic research in muscle physiology. They are also

used to study muscles that are not readily accessible with surface electrodes.

Surface electrodes are less selective than needle electrodes. They are well adapted to the assessment of muscle activity from a general area of muscle tissue such as the lip, which is composed of fibers from several anatomically distinct facial muscles. These electrodes receive the electrical impulses from the muscle tissue subjacent to the area of electrode placement. Surface electrodes were selected for this investigation because the experiment was designed to study representative areas of the perioral muscles. These electrodes can receive the activity of these muscles as functioning units.

C. Electrode Placement (Fig. 1)

Eight 8 mm. silver disk electrodes manufactured by the Grass Instrument Company were used in this study. The insulated leads from these electrodes were of different colors so that they could more easily be traced from the subject to their proper position on the terminal board. Electrodes were placed in the following positions about the mouth:

1. Upper Lip

The position of the two electrodes for the upper lip was established by bisecting the horizontal distance from the philtrum to the corner of the mouth and also bisecting the vertical distance from the vermillion border to the base of the nose. An electrode was placed on each side of the philtrum at the intersection of the

the lines formed by the above method of measurement.

2. Lower Lip

The two electrodes for the lower lip were placed directly below the upper lip electrodes. The distance between the vermillion border and supramentale (Down's point B) was bisected to determine the vertical position of these electrodes.

3. Buccinator

Right and left buccinator electrodes were placed midway between the corner of the mouth and the anterior border of the masseter muscle along a line corresponding to the occlusal plane. The subjects were asked to bite forcefully and the anterior border of the masseter was palpated.

4. Mentalis

Right and left electrodes were placed over the belly of the mentalis muscle. The area of the chin corresponding to the muscle belly was found by palpation while the subject pressed his lips together.

A clip reference electrode was attached to the left ear lobe. The subject was grounded with a plate electrode placed upon the ventral surface of the left forearm. Various views of the electrodes are shown in Figures, 1, 5 and 6.

D. Apparatus

1. Electromyograph (Figs. 2 and 4)

An electromyograph is an instrument designed to greatly amplify and record the electrical activity produced during muscular contraction. An Offner six channel electromyograph was employed in this study. Auxillary equipment included a four channel integrator, a crystograph capable of recording the output of the six channels, and a time-base marker which gave ten pips each second.

The integrator is a very useful aid for quantitating electromyographic activity because it measures the total signal in terms of known units of electircal energy. These units are recorded by the crystograph as pips which can be counted. In contrast to integrated channels, the output of non-integrated channels is recorded as a graph of voltage against time. Quantification requires the linear measurement of the amplitude. The non-integrated electromyograph is preferred for qualitative study because it gives a visual analysis of muscle activity.

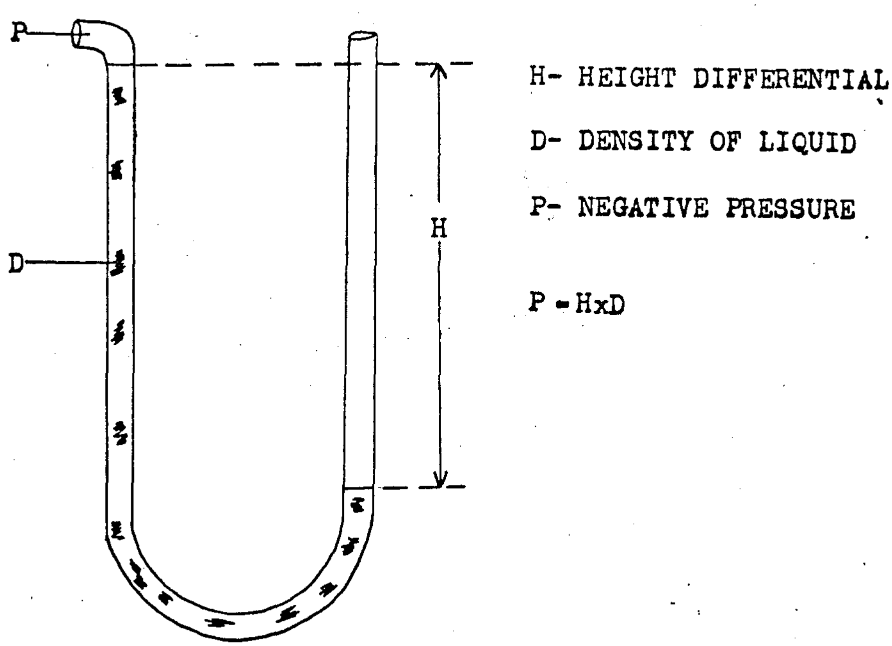
The theory underlying the mechanics of the integrator is as follows: Within each integrator circuit there is a capacitor which is charged by the signal received from the initial stages of amplification of the electromyograph. After a given quantity of electrical energy is received, the capacitor fires a gas discharge tube. This closes a relay contact which in turn discharges the capacitor. This discharge activates the crystograph and

a pip is recorded on the trace paper by the pen writer. Fig. 3 shows a schematic diagram of an integrator circuit.

Paper speed for all recording was 2.5 centimeters per second.

D. Manometer (Figs. 8 and 9)

A modified, open tube water manometer was constructed to regulate and measure the negative intraoral pressure developed by the subjects during sucking. The following diagram of a simple open U-tube liquid manometer illustrates the physical principles upon which this instrument is based:



Thus, pressure is a function of two factors:

1. The vertical differences in height between the liquid levels in the two arms of the U-tube (height differential).
2. The density of the liquid.

The shape or diameter of the tube has no effect upon the operation of this type of manometer.

The manometer used in this study was designed to allow the pressure readings to be made at eye level when the subject was sitting. This was done by providing a fixed upper index in one arm of the U-tube and a variable level in the contralateral arm of the U-tube. For descriptive purposes the two arms of the manometer will be designated arms A and B (Fig. 8).

1. Arm A (variable).

   Arm A consists of a 1000 ml. Erlenmeyer flask attached to a rigid vertical steel rod by a flask clamp. This clamp can slide along the steel rod and be locked at any height by a set screw; thus the water level in arm A can be varied. A meter stick placed parallel to the rod is used to measure the height of the water surface. A pointer mounted on the flask clamp increased the accuracy of this measurement.

   The mouth of the flask is closed by a two-hole rubber stopper. One hole contains an open glass tube. This increases the effective depth of the flask and prevents overflow when the flask is placed at

a low level. The other hole contains another section of glass tubing. A thick-walled piece of rubber tubing passes from the glass tube to the lower end of arm B. The thick walls of the rubber tubing prevent kinking when flask height is changed.

2. Arm B (fixed).

The lower end of arm B is formed by the rubber tubing which passes from the Erlenmeyer flask. The upper end of arm B is a forty cm. length of glass tubing bent in the center to form an offset directed ten degrees above horizontal. The glass tube is securely attached to a plywood back in a vertical position parallel to the steel rod. The purpose of the ten degree incline in the offset portion of arm B is to permit the subject to position the water level more precisely as the reference point is approached.

A long piece of light weight rubber tubing was connected to the open end of arm B. A specially constructed mouthpiece was inserted in the opposite end of this rubber tubing. The mouthpiece was made by fusing a small tube to a short section of larger tubing. The mouthpiece had a bore of 3 mm. and an outside diameter of 5 mm. A narrow tube was used to minimize perioral muscle contraction necessary to grasp the mouth piece with the lips.

The three legs supporting the base of the apparatus were adjustable. Leveling the manometer was accomplished by screwing

the legs to raise or lower the base until the plumb line and steel rod were in a parallel relation.

A water manometer was used instead of a mercury manometer for several reasons:

1. The water density (1 gm. per cc.) permits calibration of the units of pressure as a simple function of height (P = H x 1).
2. The height of the U-tube can be made longer than would be possible in a mercury manometer. Hence, greater precision in calibration and reading the liquid level can be expected.
3. Distilled water is readily available and inexpensive.

E. Operation of the Manometer

Before each use of the manometer, the water was boiled for ten minutes to drive off any dissolved gases which would decrease the water density. After cooling, the water was siphoned into the system to minimize absorbtion of atmospheric gases. A few drops of red dye were added to the system to increase the visibility of the water.

The Erlenmeyer flask was placed at the desired height. When the water level in arm B was raised to the reference mark by the sucking activity of subject, the negative intraoral pressure within the oral cavity corresponded to the pressure represented by the height differential between the reference level and the water level in the flask.

The perioral muscle activity was studied at four levels of negative pressure; -20 gm./cm.^{2}, -40 gm./cm.^{2}, -60 gm./cm.^{2} and -80 gm./cm.^{2}. Preliminary pilot studies indicated that the maximum negative intraoral pressure developed by most subjects was between -75 gm./cm.^{2} and -90 gm./cm.^{2}

F. Procedure

After washing the perioral skin area with soap and water, the skin was rubbed with acetone until an erethema was produced. The electrodes were then affixed to the skin with flexible collodion. Offner electrode jelly, placed in a blunt end needle hypodermic syringe, was introduced under the electrode through a small hole in the disk. The ground and reference electrodes were also placed at this time. Skin resistance was checked with an ohmmeter to insure that all skin resistances were below 3000 ohms (Figs. 5, 6 and 7).

The subject was seated in a Faraday cage to minimize extraneous electrical "noises" and the electrodes were connected to the terminal board. The subject was instructed to place the mouthpiece between his lips and to hold it with his hand in a horizontal position without allowing the teeth or tongue to come in contact with the glass (Fig. 10).

Flask height was adjusted and then the subject was asked to suck until the water rose to the reference point. The subject maintained this pressure while breathing through his nose. This was done to insure that the negative pressure developed was a pure intraoral pressure and not a combination of

intraoral and intrapulmonary pressure. When the water level reached the reference point and the subject felt he could maintain this level, he signalled with a buzzer to notify the experimenter. Electromyograph recordings were then started. Since the manometer was placed outside of the Faraday cage, the precision with which the exercise was performed could be checked visually by the experimenter. Five duplicate recordings were made at each of the four pressure levels. Rest was recorded during the interval between duplicate exercises. The mouth piece remained in the mouth during rest recordings. Fig. 11 shows a record of the same subject at the low and high limits of negative pressure (-20 gm./cm.^{2}, and -80 gm./cm.^{2}).

Since only four of the channels were integrated, two runs were made in order to obtain integrated records of the eight muscle areas studied. The two remaining non-integrated channels were used as monitors. "Before and after" calibrations were made for each subject. Calibration recordings were made at the following peak microvoltages; 10, 20, 40, 60, 80, 100, 125, 150, 200, and 250. The "before" calibration was used in analyzing the first run; the "after" calibration was used for the second run.

As a matter of technical interest to those planning similar studies it should be mentioned that only very light pressure should be used in placing the electrodes. The lips and cheeks are relatively flacid when at rest. They are easily "dimpled" if too much force is used to position the electrode. The dried collodion will maintain this distortion after the pressure is released.

G. Statistical Method

This experiment was designed as a quantitative study of muscle activity. Fisher's Analysis of Variance was employed to evaluate the data. This analysis is particularly useful in experiments that have several dependent variables. The main experimental elements in this study can be categorized as follows:

1. Sources of variation
   a. Negative intraoral pressure
   b. Subjects
   c. Muscles
      1. Groups
      2. Sides
   d. Duplicates

2. Medium

   Male adults having normal perioral musculature.

3. Quantity to measure

   The electrical activity of certain perioral muscles as recorded by an electromyograph.

4. Null hypothesis

   None of the sources of variation has an effect on the activity of the perioral musculature.

Ten subjects performed the sucking exercises five times at each of four negative pressure levels (-20 gm./cm.^{2}, -40 gm./cm.^{2}, -60 gm./cm.^{2} and -80 gm./cm.^{2}). Two of the five duplicate tracings were selected at random for statistical analysis. The number of pips/sec. was determined by counting the

pips in a four second period and dividing by four. The energy equivalent of pips/sec., expressed as microvolt seconds, was determined from calibration curves constructed from "before" and "after" calibration records.

The analysis of variance was designed to be applied to normally distributed data. Histograms of the raw data revealed that these data did not come from a normally distributed population. It was necessary, therefore, to transform the original data by means of the logarithmic transformation.

H. Randomizing Technique

Whenever possible the treatments in this study were randomized. Randomization helps to decrease the effect of unknown or uncontrollable variables. The following experimental procedures were randomized:

1. Assigning electrodes to the six channels.
2. Assigning the eight muscles to the first or second run for each subject.
3. The order in which the four negative pressures were applied.
4. The selection of duplicate readings for statistical analysis from the five recordings at each negative pressure level.

FIGURE 1

ELECTRODE PLACEMENT

FIGURE 1

FIGURE 2

ELECTROMYOGRAPHIC EQUIPMENT

This illustration shows (left to right); power supply, cathode ray oscilloscope, amplifiers, integrators, oscilloscope camera, crystograph. Part of the Faraday cage is seen at the far left.

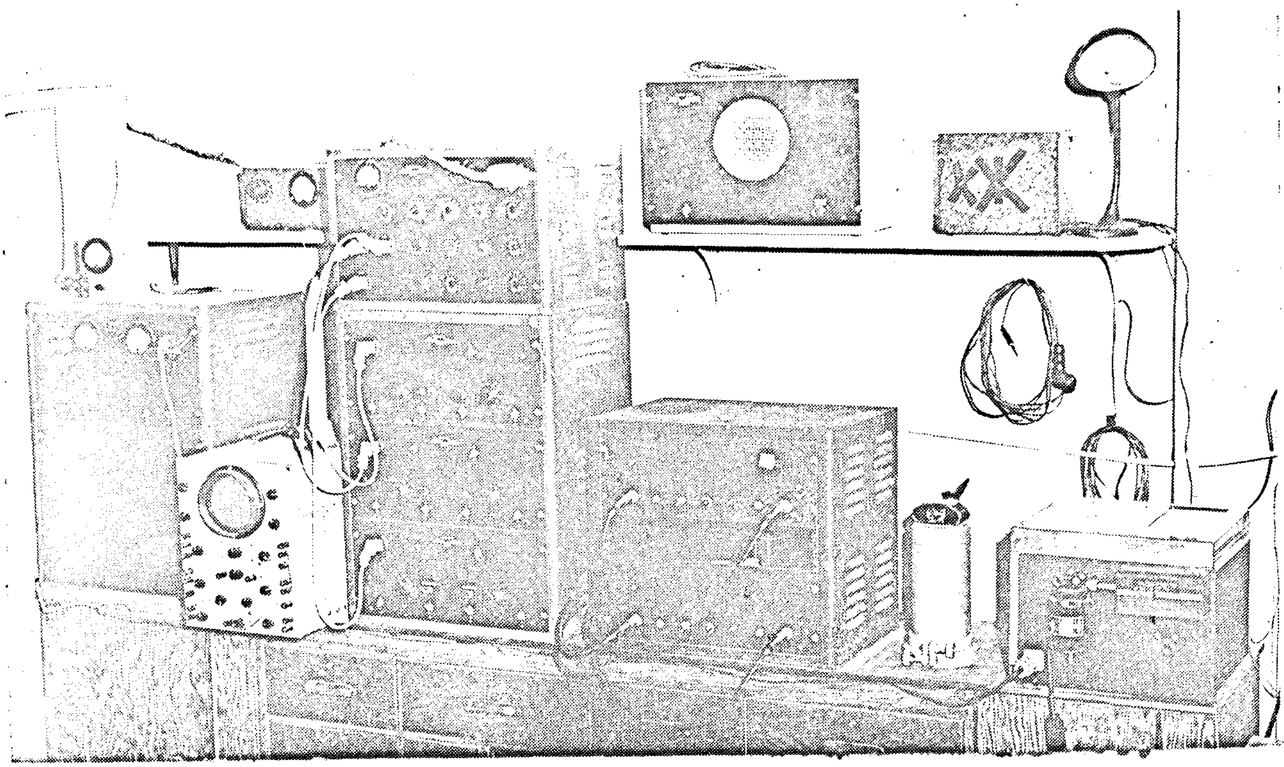


FIGURE 2

FIGURE 3

INTEGRATOR CIRCUIT

BLOCK DIAGRAM OF ONE CHANNEL WITH SCHEMATIC OF INTEGRATOR

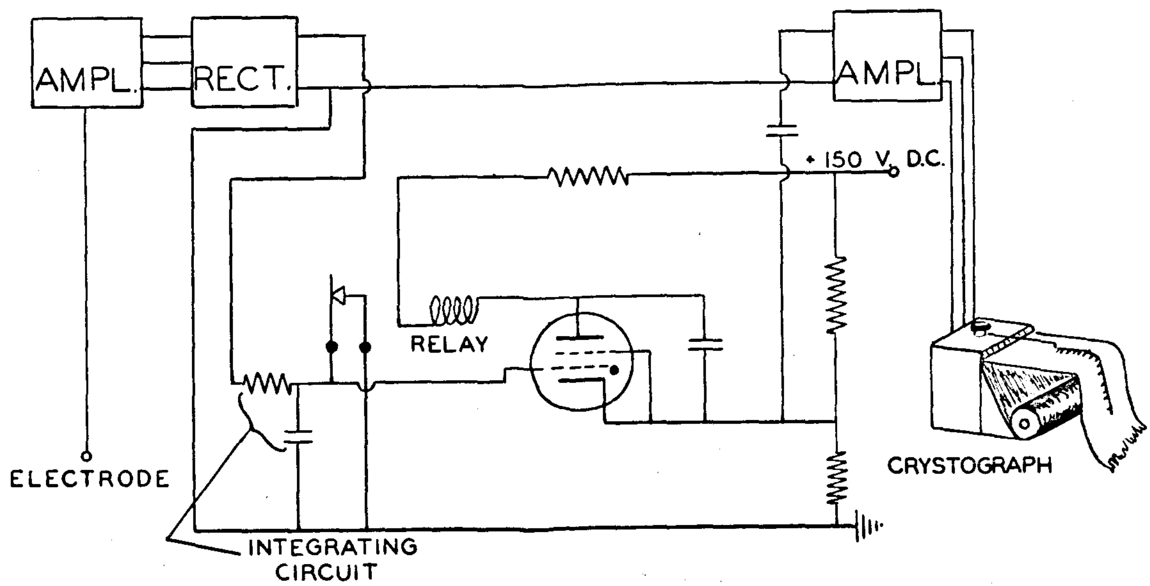


FIGURE 3

FIGURE 4

SIX CHANNEL VARIABLE SPEED CRYSTOGRAPH

The right stylus is the time base marker.

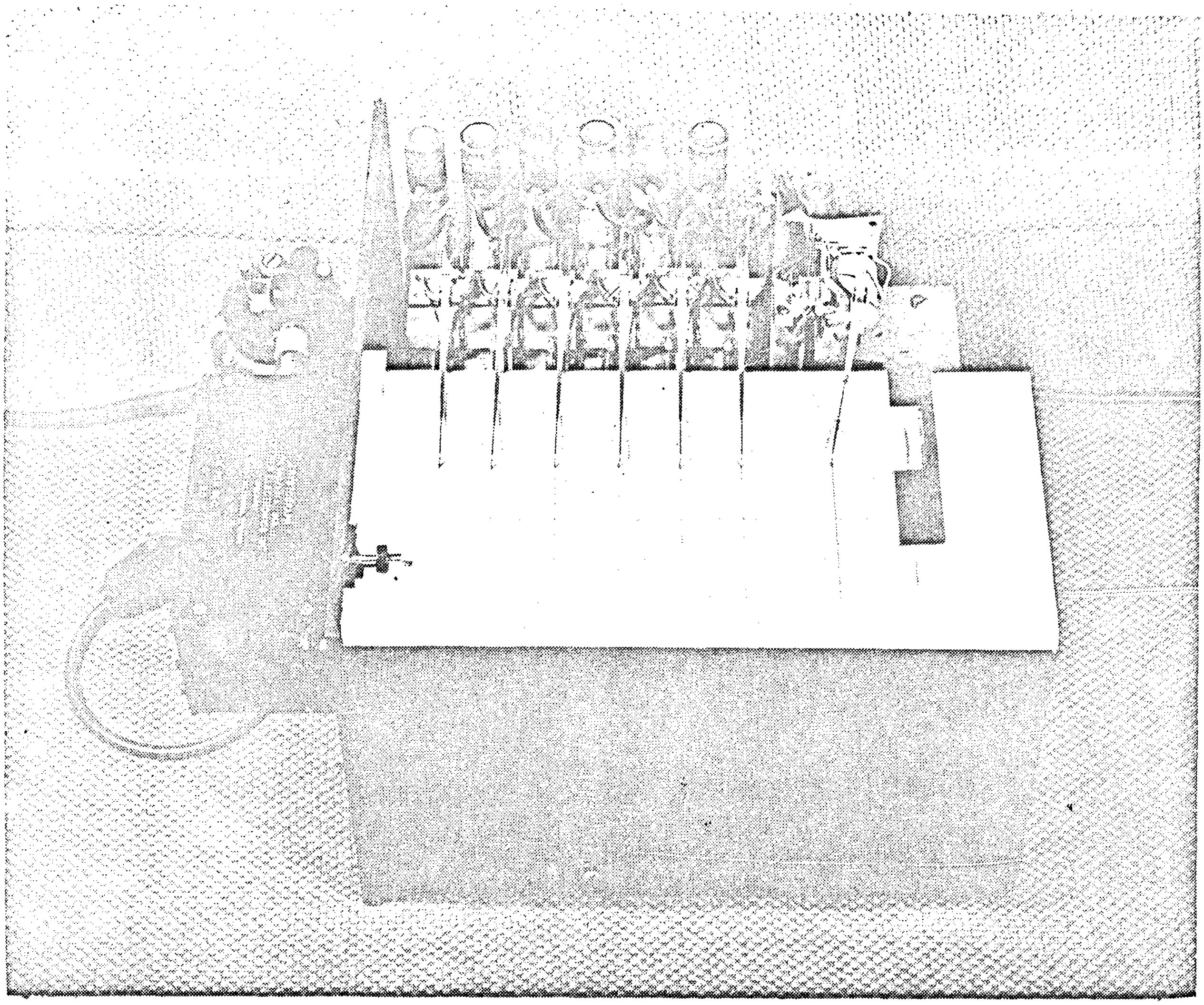


FIGURE 4

FIGURE 5

MATERIALS FOR AFFIXING ELECTRODES TO THE SKIN

The three types of electrodes used in this study:

1. Surface electrode.
2. Clip reference electrode.
3. Plate ground electrode.

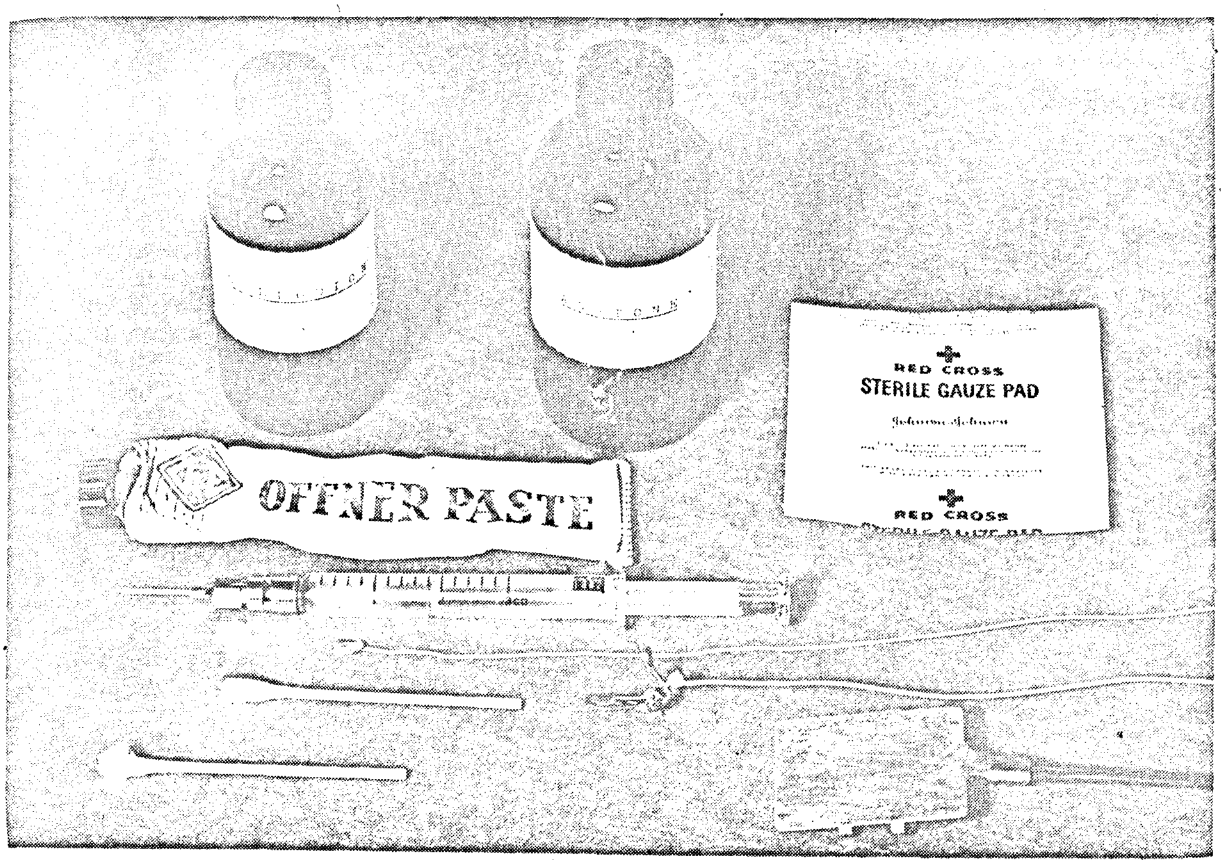


FIGURE 5

FIGURE 6

METHOD OF INTRODUCING ELECTRODE JELLY UNDER THE SURFACE ELECTRODES

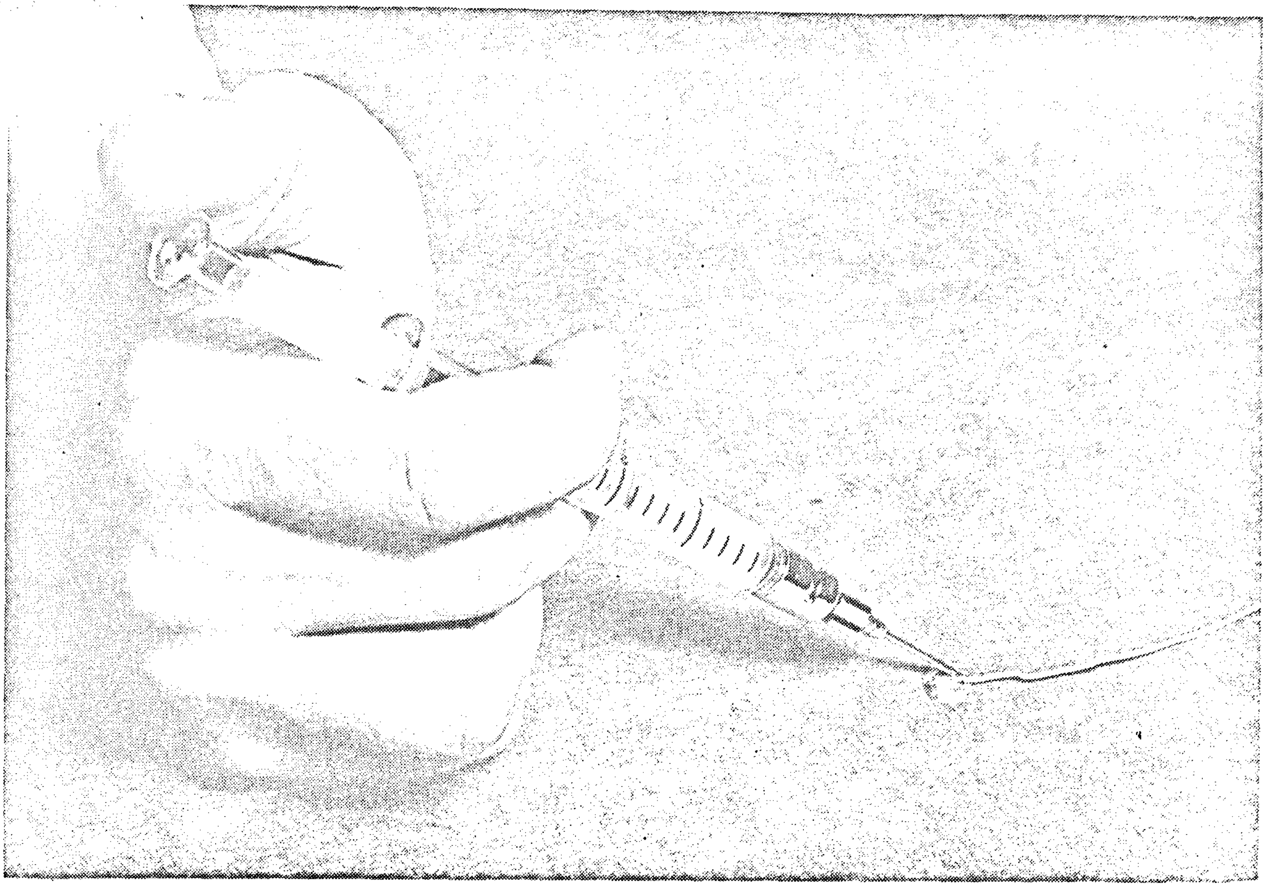


FIGURE 6

FIGURE 7

OHMMETER

This instrument was used to measure skin resistance.

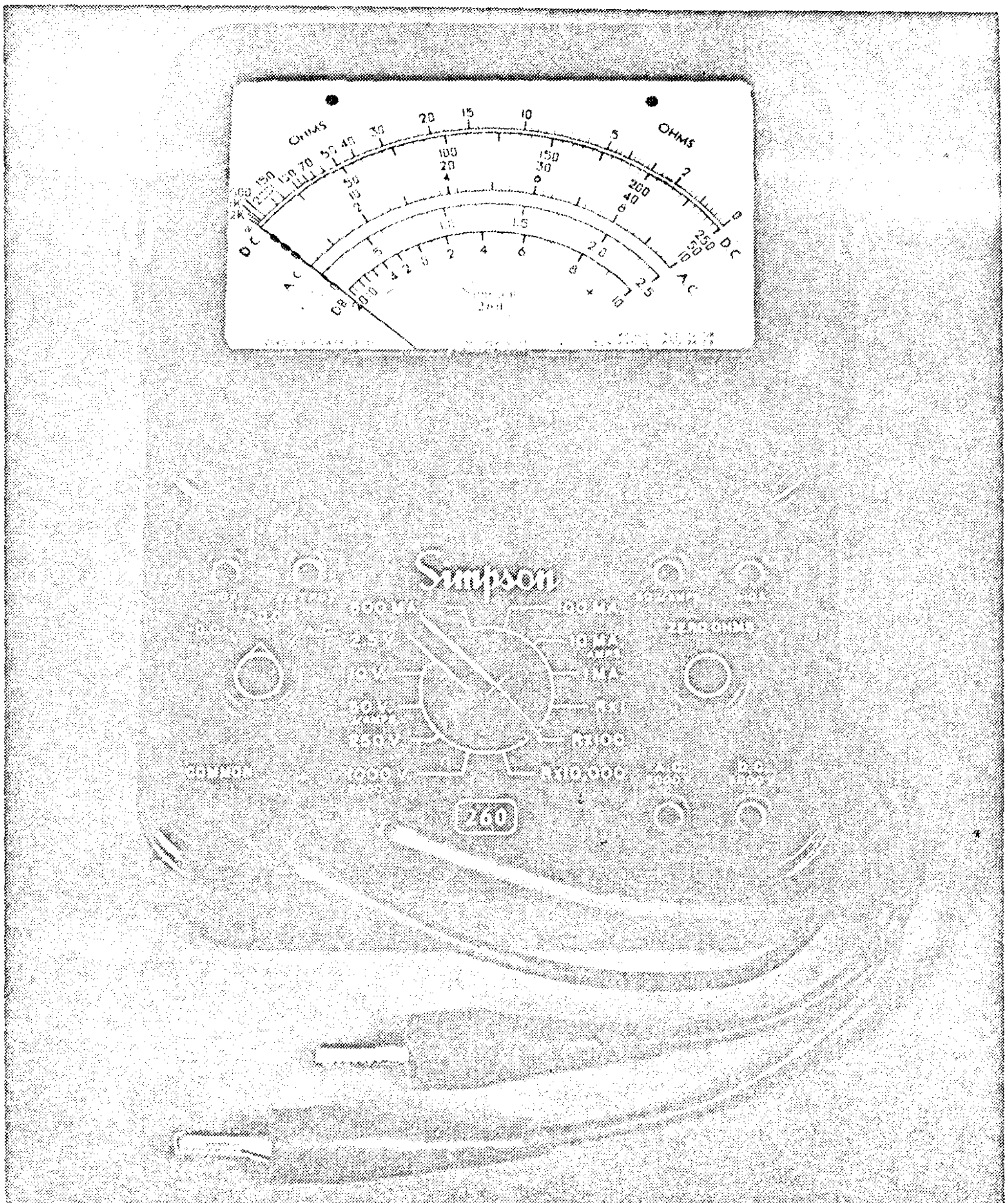

OHMS
OHMS
D C
A C
D C
A C
Simpson
100 MA.
ZERO OHMS
10 V
250 V
1 MA
RX100
RX10,000
COMMON
260

FIGURE 7

FIGURE 8

MODIFIED OPEN TUBE WATER MANOMETER

The Erlenmeyer flask has been raised to its maximum height. In this position the water levels in arm A (variable) and arm B (fixed) are both at the zero pressure reference level. The buzzer is shown at the base of the apparatus.

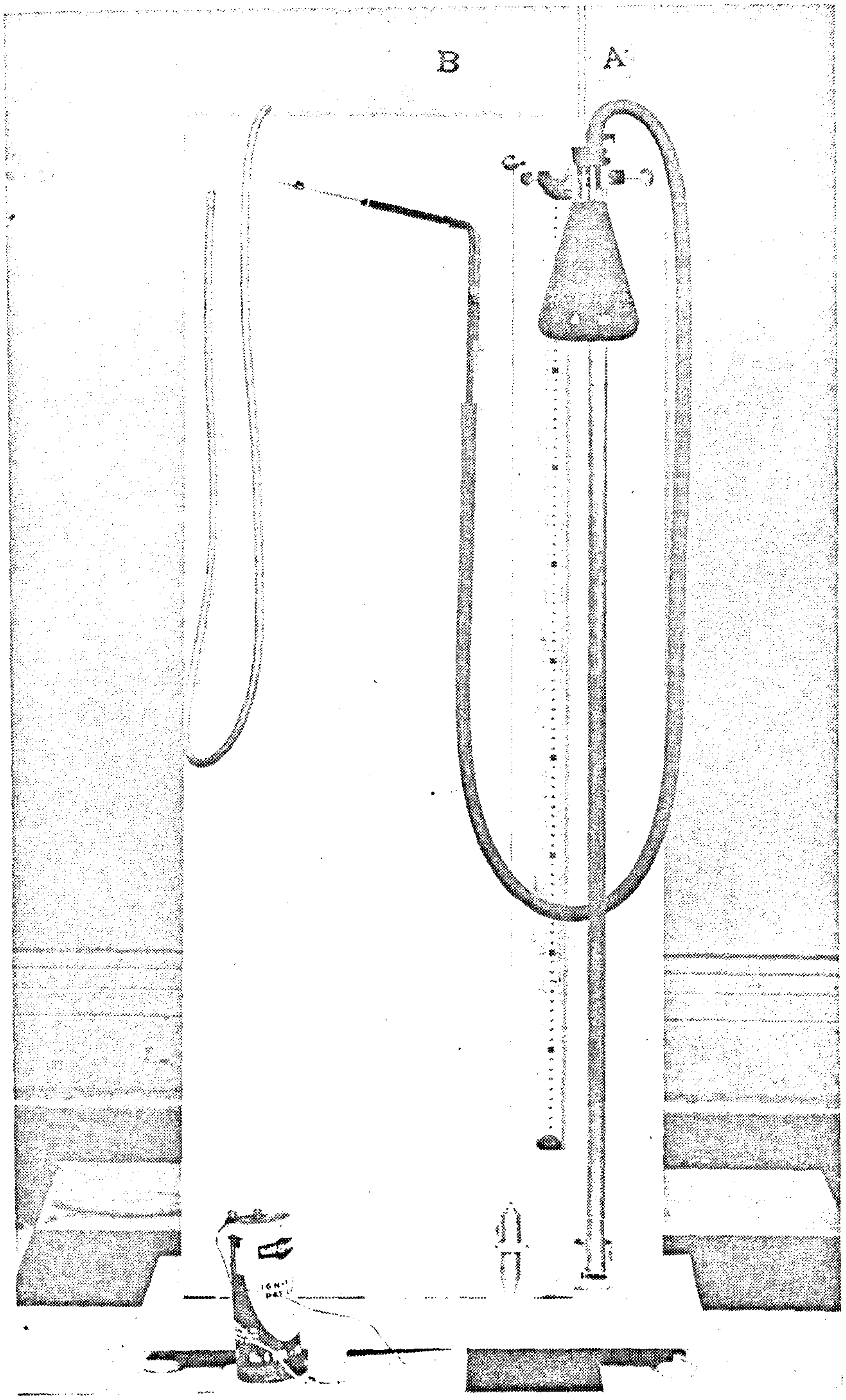


FIGURE 8

FIGURE 9

DETAILS OF THE MANOMETER

The mouthpiece is shown at the left.

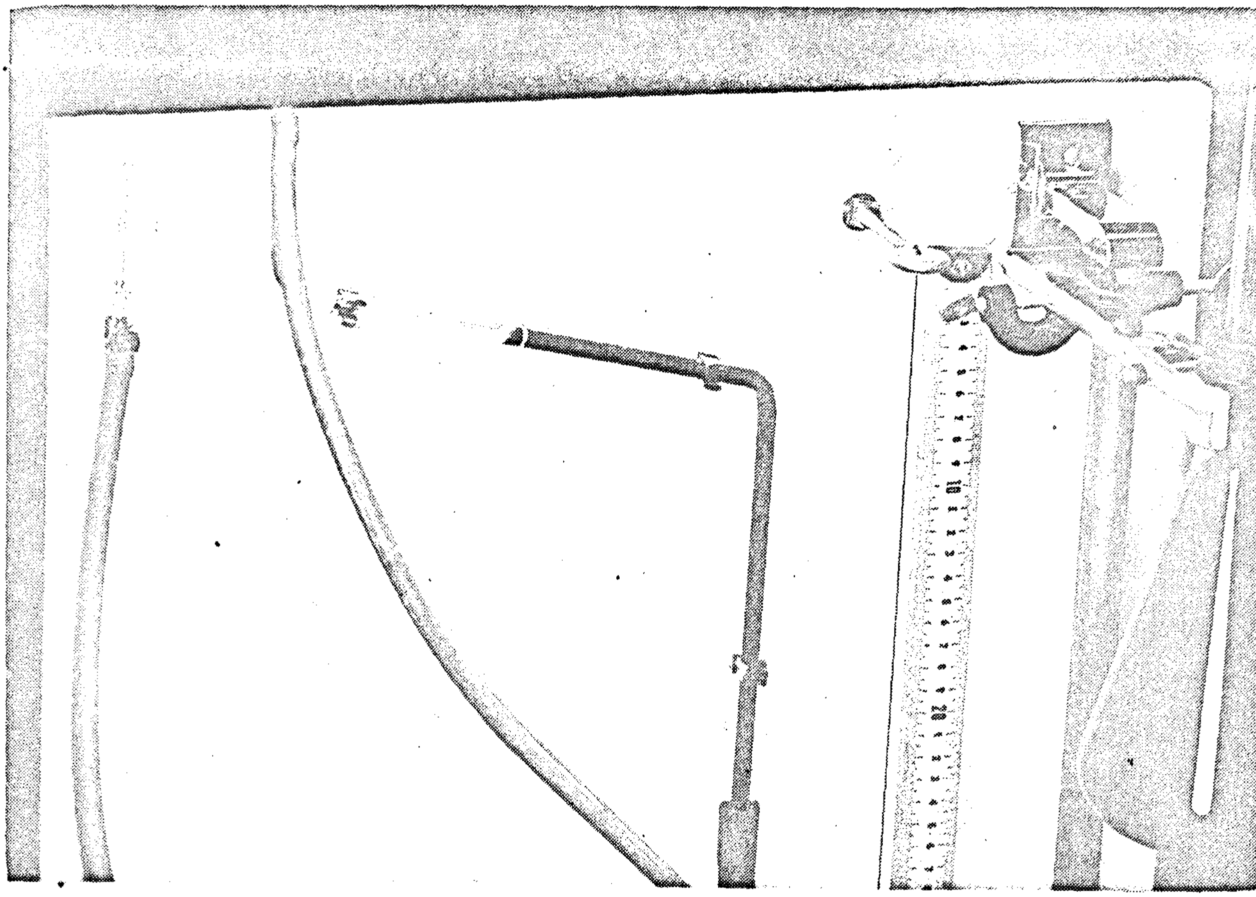


FIGURE 9

FIGURE 10

SUBJECT PERFORMING EXPERIMENTAL EXERCISE

The flask has been lowered to the -40gm./cm.^{2} level. The manometer was placed at an angle to permit the experimenter to view the zero reference mark while recordings were made. The door to the Faraday cage has been opened for photographic purposes.

FIGURE 10

FIGURE 11

ELECTROMYOGRAPH RECORDINGS OF THE SAME SUBJECT AT THE HIGH AND LOW NEGATIVE PRESSURE LEVELS. CHANNELS A, B, D, F, ARE INTEGRATOR CHANNELS. CHANNELS C AND E ARE NOT INTEGRATED AND WERE USED AS MONITORS OF MUSCLE ACTIVITY RECORDED ON CHANNELS D AND F.

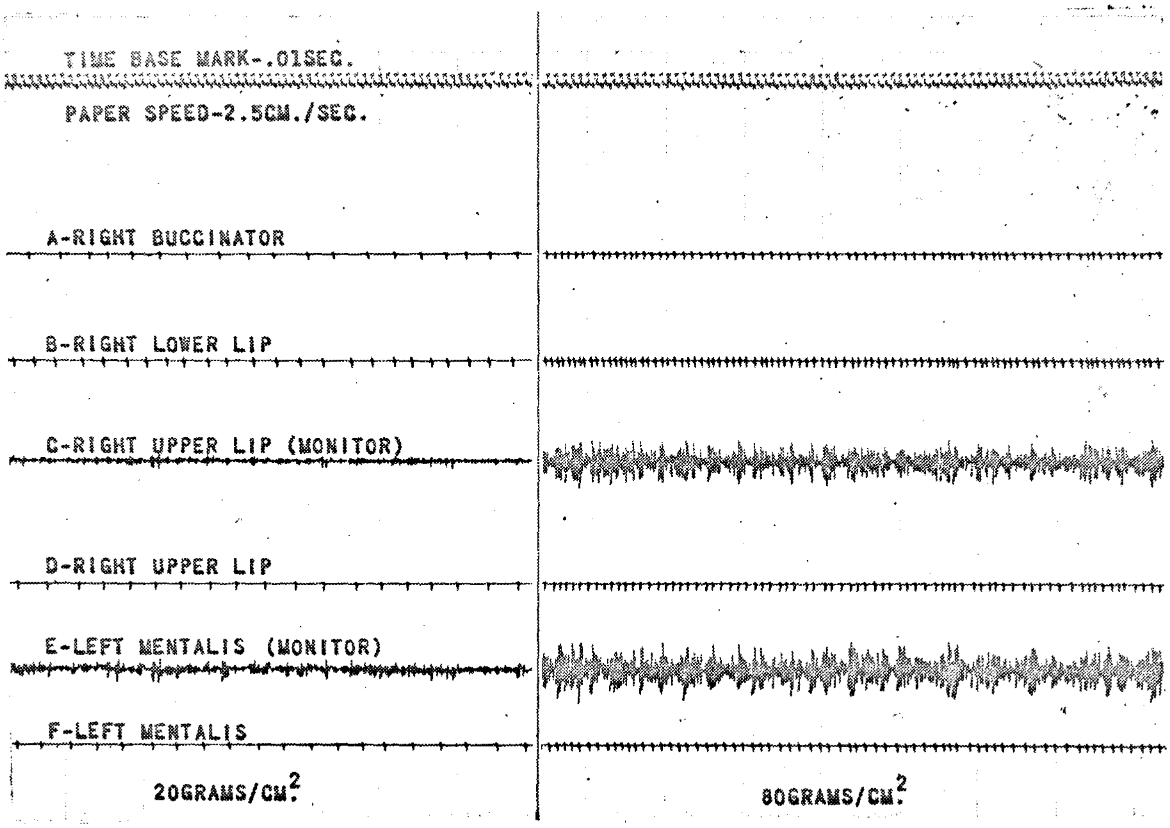

TIME BASE MARK-.01SEC.
PAPER SPEED-2.5CM./SEC.
A-RIGHT BUCCINATOR
B-RIGHT LOWER LIP
C-RIGHT UPPER LIP (MONITOR)
D-RIGHT UPPER LIP
E-LEFT MENTALIS (MONITOR)
F-LEFT MENTALIS
20GRAMS/CM.²
80GRAMS/CM.²

FIGURE 11

CHAPTER III

RESULTS

This experiment was designed to permit a quantitative evaluation of the electromyograph records by Fisher's analysis of variance.

The logarithm of the microvolt second data was used for all calculations because this transformation satisfied the assumptions underlying the analysis of variance more closely than the microvolt second data. The particular denominator used to set up the F or variance ratios for the principal sources of variation was obtained by consulting a "Components of Variance" table. Groups and sides were tested against the residue mean square. Subjects was tested against the groups x subject interaction mean square. Pressure was tested against the groups x pressure interaction mean square.

The variance ratios, shown in the analysis of variance table (Fig. 12), give the following results on the muscle activity when a negative air pressure is present in the oral cavity:

A. Muscles

1. Groups

   There is a significant difference in energy output of the muscles under investigation.

2. Sides

   There is no significant difference in energy output of the muscles on the right and left sides of the face.

B. Pressures

The energy output of the muscles varies significantly with different degrees of negative intraoral pressures.

C. Subject

The level of energy output of the muscles varies significantly from subject to subject.

The low figure for duplicate mean square indicates that each subject was able to repeat his activity at any given pressure with a high degree of precision. The low value for residue mean square indicates that the experimental routine was performed uniformly throughout the study. In this sense "routine" means preparing the subject, calibrating the equipment, and reducing the records to numerical data.

Interactions are secondary effects which could influence or confound the results for the principal sources of variation. The analysis of variance revealed no significant interactions.

The energy output of the muscles for the principal sources of variation have been tabulated (Fig. 13). These values, expressed as mean microvolt seconds, were determined by calculating the mean of the appropriate transformed data and then taking the antilog of this figure. The numerical data from each subject was pooled in the calculations, so that the mean microvolt second values are averages of all experimental observations for each source of variation.

The mean microvolt second values for the principal sources of variation are also presented graphically (Figs. 14, 15 and 16). Fig. 14 is a bar graph showing the energy output of the muscles for groups and sides. Fig. 15 is a linear graph showing the effect of increasing negative intraoral pressure on the energy output of the muscles. Fig. 16 shows the energy output of each of the subjects.

FIGURE 12

ANALYSIS OF VARIANCE

This table shows the analysis of transformed data. The logarithm of the raw data was used for the transformation. *** represents a confidence level of .01%.

ANALYSIS OF VARIANCE

SOURCES OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	VARIANCE RATIO (F)
I. PRINCIPAL SOURCES				
A. MUSCLES				
1. GROUPS	3	5.5497	1.8499	62.6112***
2. SIDES	1	.0101	.0101	.3423
B. PRESSURE	3	35.8307	11.9436	17.4366***
C. SUBJECTS	9	18.3850	2.0428	23.1353***
D. DUPLICATES	320	3.2346	.0101	
II. INTERACTIONS				
PRES. X SUBJ.	27	2.5675	.0951	
GROUP X SUBJ.	27	2.3840	.0883	
SIDES X SUBJ.	9	.4448	.0494	
PRES. X GROUP	9	.6165	.0685	
RESIDUE	231	6.8251	.0295	
TOTAL	639	75.8480		

FIGURE 12

FIGURE 13

MEAN MICROVOLT SECOND VALUES FOR PRINCIPAL SOURCES OF VARIATIONS

These values were used to make the graphs in figs. 14, 15 and 16.

GROUPS

UPPER LIP	BUCCINATOR	LOWER LIP	MENTALIS
28.97	18.65	31.17	31.28

SIDES

RIGHT	LEFT
26.69	27.19

SUBJECTS

A	B	C	D	E	F	G	H	I	J
25.24	19.32	30.18	23.32	17.92	58.79	14.56	26.39	37.16	39.05

PRESSURE

	-20gm./cm.^{2}	-40gm./cm.^{2}	-60gm./cm.^{2}	-80gm./cm.^{2}
UPPER LIP	14.78	25.25	41.63	53.02
BUCCINATOR	7.02	16.26	28.03	37.94
LOWER LIP	14.41	25.16	42.70	60.96
MENTALIS	14.19	27.28	43.07	57.38

FIGURE 13

FIGURE 14

Bar graphs representing "GROUPS" and "SIDES" sources of variation.

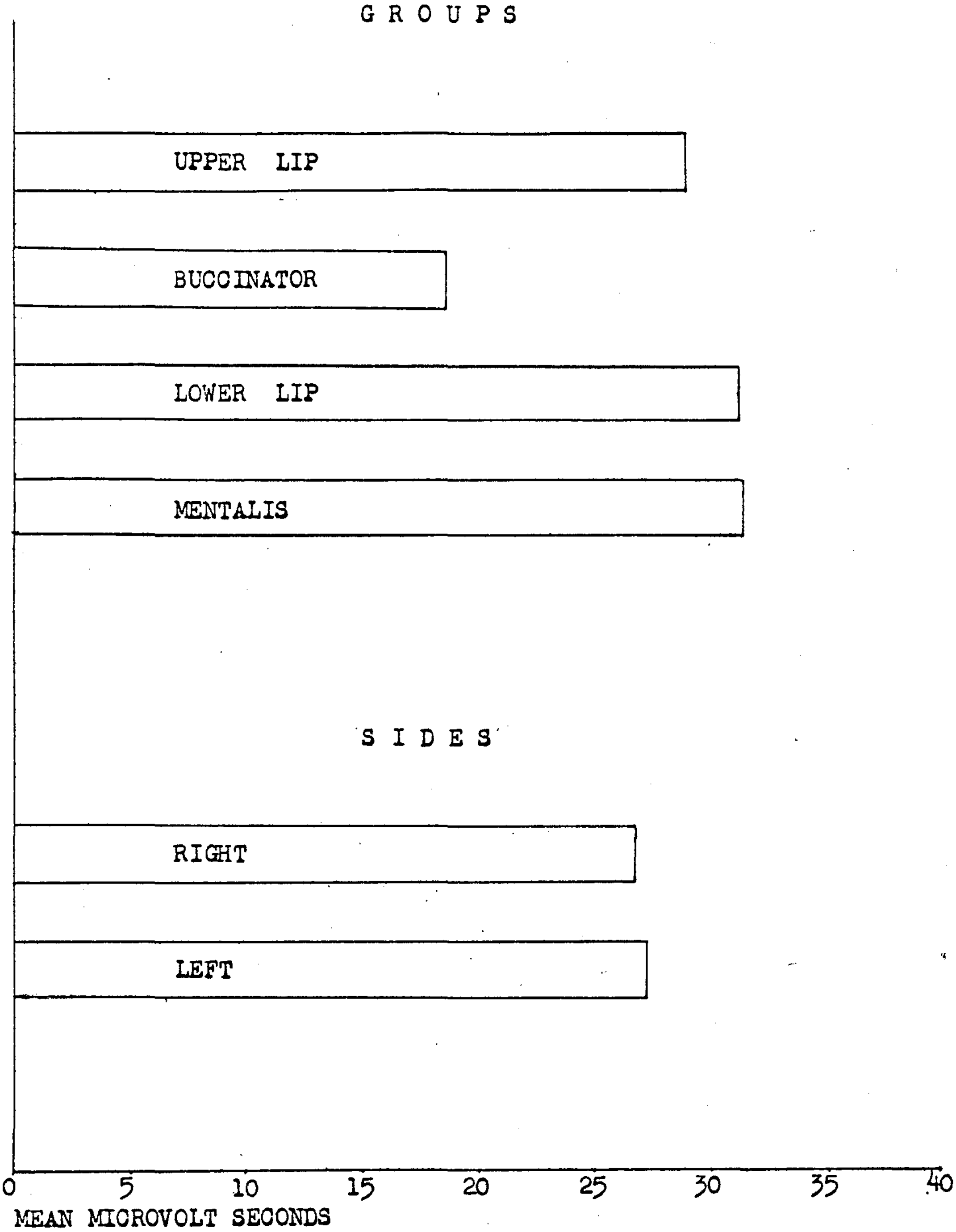

GROUPS
UPPER LIP
BUCCINATOR
LOWER LIP
MENTALIS
SIDES
RIGHT
LEFT
0
5
10
15
20
25
30
35
40
MEAN MICROVOLT SECONDS

FIGURE 14

FIGURE 15

Graphical representation of "PRESSURE" source of variation.

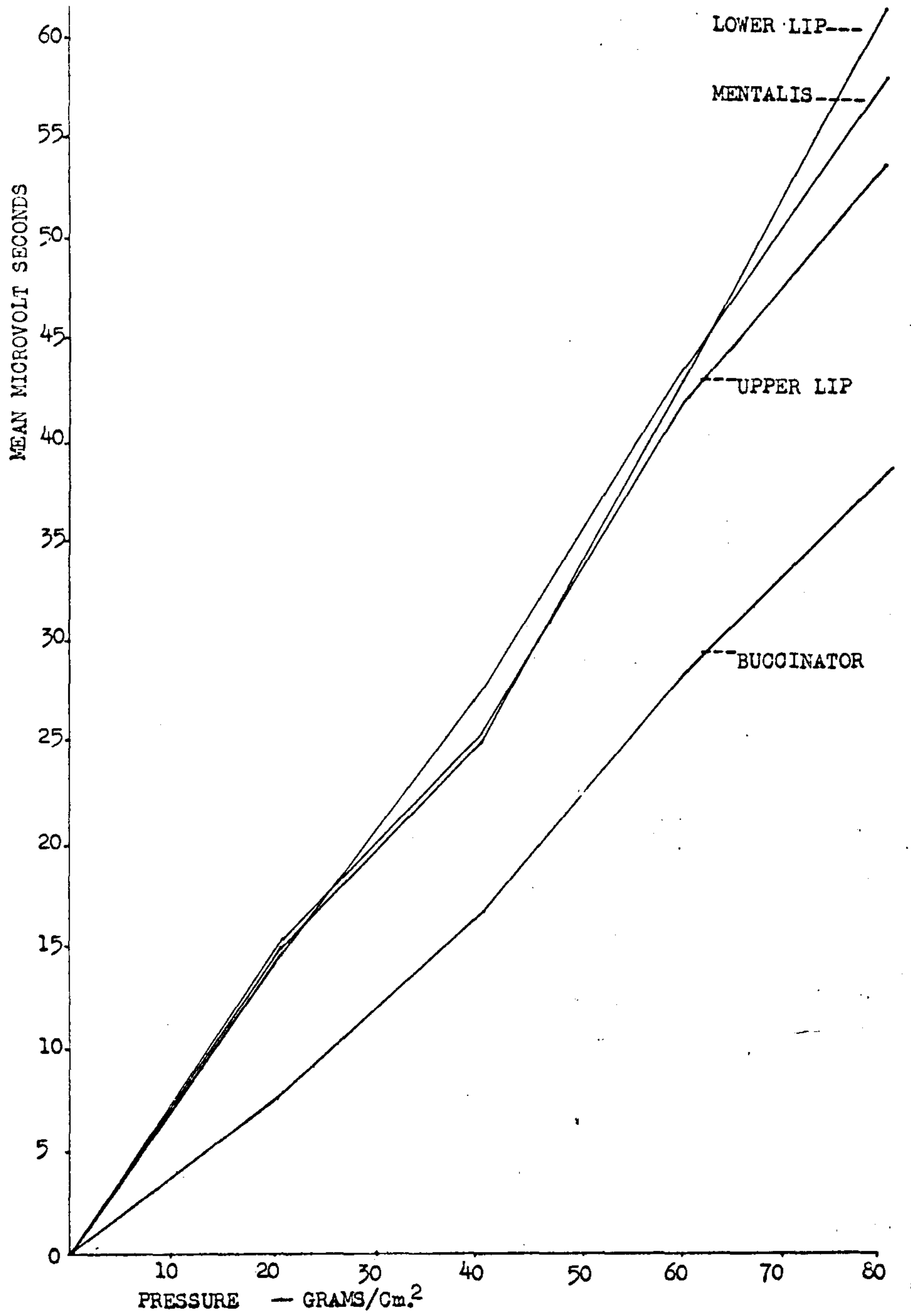

LOWER LIP
MENTALIS
UPPER LIP
BUCCINATOR
MEAN MICROVOLT SECONDS
0
5
10
15
20
25
30
35
40
45
50
55
60
10
20
30
40
50
60
70
80
PRESSURE — GRAMS/Cm.^{2}

FIGURE 15

FIGURE 16

Graph representing "SUBJECT" source of variation.

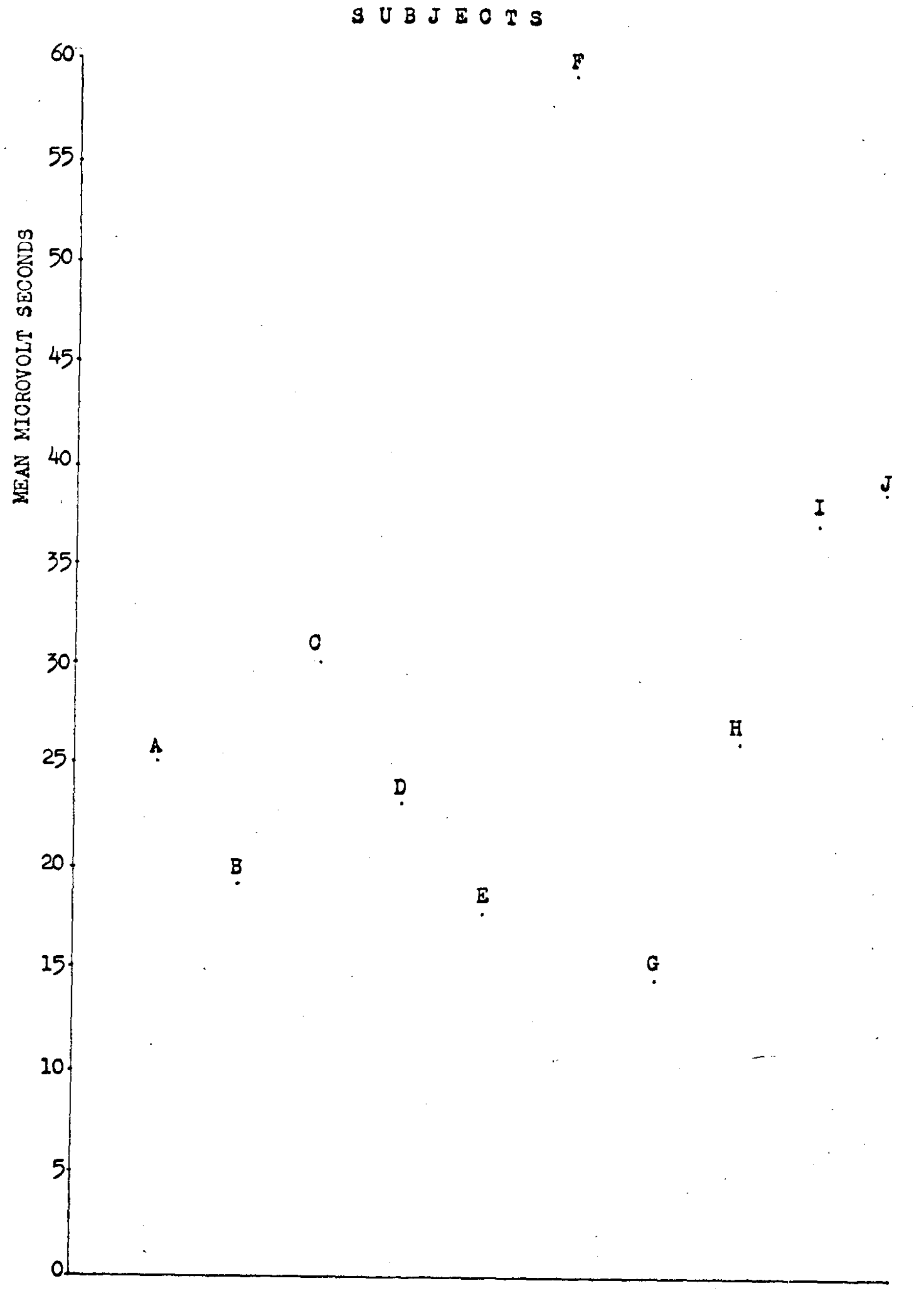
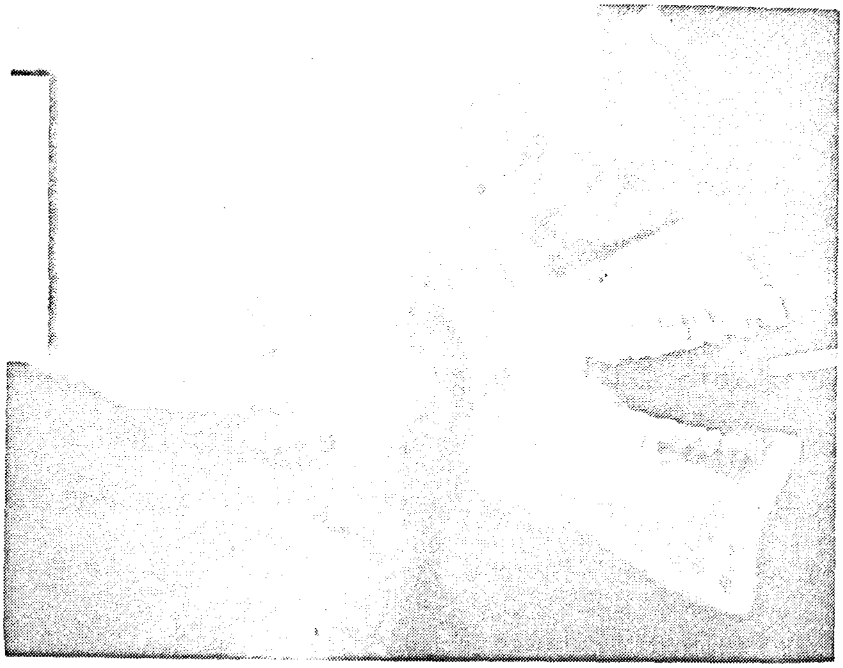

SUBJECTS
MEAN MICROVOLT SECONDS
60
55
50
45
40
35
30
25
20
15
10
5
0
A
B
C
D
E
F
G
H
I
J

FIGURE 16

FIGURE 17

Lateral head radiograph of subject at -80gm./cm.^{2} and tracings of the same subject at -20gm./cm.^{2}, -40gm./cm.^{2}, -60gm./cm.^{2}, and -80gm./cm.^{2} The F.M.A. has been used to show the mandibular depression that occurs as negative intraoral pressure increases.



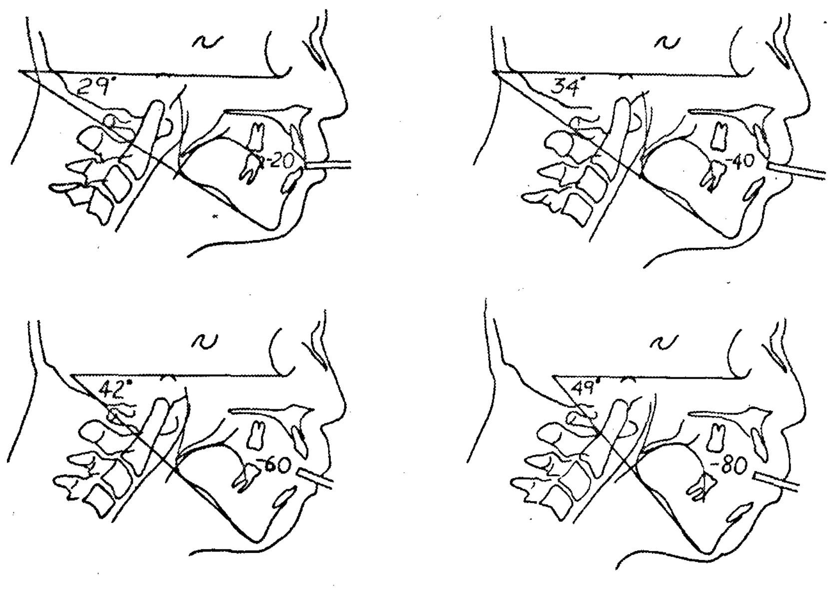


FIGURE 17

CHAPTER IV

DISCUSSION

A. General Considerations

The purpose of this investigation was to study, electromyographically, the behavior of certain perioral muscles under the influence of specific amounts of negative intraoral air pressure. The stimulus for undertaking this study was derived from the observation that many normal oral activities, such as sucking, sipping liquids, and drinking, are made possible by a reduction of the air pressure within the oral cavity. In addition to these normal functions, a negative intraoral pressure accompanies such perverse oral habits as thumb and finger sucking and lip sucking. These activities are of particular interest to the orthodontist because it is believed that they are a partial cause of certain malocclusions.

There have been very few previous electromyographic studies from which information could be drawn in planning this experiment. Only three electromyographic investigations of the perioral muscles have been reported in the literature; Tully (1953), Schlossberg (1954), and Baril (1959). One of the activities studied by Tully was "sucking fruit". However, the data pertaining to this activity was not presented. Schlossberg studied the activity of the lips and mentalis muscle of subjects with normal occlusion and Class II malocclusion. "Sucking water through a straw" and "forced sucking without taking

in water" were among the activities studied by Schlossberg. He found that the malocclusion subjects showed a higher degree of activity than the subjects with normal occlusion. The specific data pertaining to the above activities were not reported. Baril's work proved to be more informative. He studied the perioral muscular activity of thumb and finger sucking subjects. Electromyographic records were taken during the following activities; biting, sucking, taping, and swallowing. Compared to the other three exercises, sucking evoked the most activity of the mentalis, orbicularis oris, and buccinator muscles.

In reviewing the work of these three men it seemed that the method used to study such activities as "sucking", "sipping water through a straw", and "forced sucking" did not provide for a consideration of the intensity of these activities. Sucking is under voluntary neuromuscular control. It is not an involuntary reflex action such as swallowing. (Gwynne-Evans has pointed out that sucking is an acquired oral function which is learned.) The magnitude of the negative intraoral pressure does vary during many oral activities. For example, when we are thirsty we drink faster than when our thirst is quenched. We also recognize that more effort is required to sip a soft drink through one straw than through two straws. Because of this variability in negative intraoral pressure, it was desirable to have some method of controlling this pressure. The purpose of the manometer was to standardize the magnitude of negative intraoral pressure of each subject and to study the effect of known variations in this pressure.

The most important phenomenon observed during the creation of a negative intraoral pressure is the enlargement of the oral cavity after it has first been sealed from the influence of atmospheric air pressure. The mouth is isolated from the surrounding air by two activities:

1. Closure of the lip
2. Placing the posterior part of the dorsum of the tongue against the soft palate.

The volume of the oral cavity is then increased by lowering the anterior part of the tongue and depressing the mandible.

The need for increasing the volume of the oral cavity is directly related to Boyle's law, which is one of the fundamental laws of physics governing the behavior of gases. This law, discovered by Robert Boyle nearly 300 years ago, states that the pressure exerted by a confined mass of gas is inversely proportional to the volume occupied by the gas. If the volume of the gas is increased, its pressure is decreased. Conversely, if the volume decreases, the pressure will rise. Boyle's law, as applied to negative intraoral pressure, is illustrated in Fig. 17. It shows how oral volume is increased as the intraoral pressure decreases. The four tracings are of the same subject at each of the experimental negative pressures. This illustration is presented to give a visual description of the formation of a negative intraoral pressure since, to the authors' knowledge, none are available in the literature. Although the degree of mandibular depression is shown for each negative

pressure, these figures are not intended to imply any quantitative correlation between mandibular depression and negative intraoral pressure. The figures have been included just to show that the mouth opened more as negative intraoral pressure increased.

The accepted methods of measuring pressure do not record absolute pressures; they only record a pressure gradient relative to atmospheric air pressure. For example, a negative intraoral pressure of 20gm./cm.^{2} really means that the air pressure outside the mouth is 20gm./cm.^{2} higher than the pressure within the mouth. This pressure gradient (vacuum) has no inherent "sucking force" in itself. However, it allows atmospheric pressure to become an effective force. A soft drink is not "sucked up" through a straw but is really "pushed" through the straw by the force of atmospheric air pressure acting upon the surface of the liquid. This physical principle was operating in this experiment when the subjects produced a negative intraoral pressure to raise the water level in the manometer.

The foregoing discussion of certain physical principles of gases has been presented because these principles help to explain many phenomena observed in this experiment. The following is a discussion of the principal sources of variation:

B. Muscles (Groups and Sides)

The principal function of the lips and mentalis muscle during the

formation of a negative intraoral pressure is to seal the oral cavity. This prevents air from rushing into the oral cavity and destroying the vacuum. The results of this experiment show that the activity of the lips and mentalis muscle is much higher than the activity of the buccinator (Figs. 13 and 14). The energy output of the lower lip and mentalis were particularly close, indicating an intimate synergistic relation between their functions. Rix and Ballard both reported similar findings in their studies of abnormal swallowing. In a sense, muscular function during the creation of a negative intraoral pressure can be compared to the muscular behavior during atypical swallowing because in both activities the lips function to seal the oral cavity while the teeth are apart. The relatively low activity of the buccinator muscle during sucking was also reported by Baril.

The buccinator is a thin flat muscle. In normal function the contraction of this muscle flattens the cheek to protect it from injury when the teeth occlude. According to Sicher the buccinator relaxes when the jaws are apart and contracts as the mouth closes. The buccinator does not seem to take an active roll in the formation of a negative intraoral pressure. The "contraction" of this muscle, as seen in the electromyographic records, can be attributed to stretching of the cheek; when the intraoral pressure is reduced the atmospheric air exerts a force against the cheek and pushes it between the teeth. The buccinator attempts to resist this deformation. As the intraoral pressure drops, the effect of atmospheric pressure becomes very noticeable;

the form of the cheek is distinctly concave. The buccinator is also stretched by the contraction of the orbicularis oris. Some of the fibers of the buccinator insert into the skin of the lips near the corner of the mouth. Thus, when the orbicularis oris contracts it pulls these fibers foreward and medially.

The same pressure that acts on the cheek also acts against the lips. However, the lips are more capable of resisting this force. One of the problems anticipated in designing this experiment was the possibility that the subjects would vary in the manner in which they grasped the mouthpiece with their lips. Observation of individuals sipping a drink through a straw revealed that, while most of these individuals protruded their lips, some did so with the lips involuted. However, all of the experimental subjects grasped the mouthpiece with the lips protruded. This method seems to be more efficient because a larger surface area of the lip is in contact with the mouthpiece. The force necessary to grasp the mouthpiece is distributed over a larger area. Protrusion of the lips also enlarges the oral cavity slightly and thereby aids in producing the negative intraoral pressure. Another possible explanation for the manner in which the subjects grasped the mouthpiece might be found by examining the lip function in other animals. Many animals, particularly herbivorous ones, use the lips in a prehensile manner to gather food. They grasp the food by protruding the lips and then pass it back into their mouths for mastication. Although man uses his hands to place food into his mouth, it

is quite possible that evolution has not completely eliminated the prehensile function of the lips.

C. Sides

A comparison of the activity of the muscles on each side of the face showed that there was no significant difference in activity. This result was expected because the muscles of the face are arranged in a bilaterally symetrical manner. However, the degree of similarity between the two sides was surprising. The calculated averages of total energy output for all subjects at all experimental negative pressures showed less than one microvolt second difference between the right and left side of the face (Fig. 13 and 14). This finding may be due to the fact that the pressure of a gas on a surface is exerted uniformly on all areas of the surface with the same magnitude. At each of the negative intraoral pressures the atmospheric air pressure exerted the same force on the right and left side of the face. Since the muscleson both sides are under the same load it seems logical that they would have to contract in a similar manner to resist the load.

Baril found that the activity of the orbicularis oris differed on the right and left side. It is difficult to understand how he came to this conclusion since his findings were based on a unilateral analysis of the activity of this muscle. Furthermore, he did not place any electrode on the lower lip. Since the fibers of the orbicularis are continuous within the

lower lip, a better picture of the activity of this muscle would have been obtained if an electrode had also been used on the lower lip. In the discussion of his findings Baril seems to question his method of appraising the activity of the orbicularis oris. He states:

> "It was also found that the orbicularis oris muscle can and does behave as two separate muscles, right and left. A unilateral analysis can be accepted for a study such as this, but a precise analysis of the function of this muscle would call for a bilateral analysis."

D. Pressure

Increasing the negative intraoral pressure caused an increase in muscle activity (Figs. 13 and 15). All muscles showed a definite increase in energy output. The manner in which this increase occured for the lips and mentalis was surprising. The rate of increase in activity for these muscle portions was almost identical. This phenomenon is most evident at $-20 gm./cm.^2$, $-40 gm./cm.^2$, and $-60 gm./cm.^2$ At $-80 gm./cm.^2$ there is a divergence in activity; the upper lip does not increase at as a high a rate as the lower lip and mentalis. The uniformity of activity shown by the lips and mentalis muscle may be a reflection of their common function in sealing the oral cavity during the creation of a negative intraoral pressure. Although the buccinator muscle also showed a pronounced increase in activity, the rate of increase was not as great as that shown for the lips and mentalis.

Two factors are probably responsible for the increase in energy output

when negative intraoral pressure is reduced:

1. Atmospheric air pressure increases in proportion to the decrease in air pressure within the oral cavity. This places a greater load on the muscles and elicits a greater response from these muscles in order to resist the pressure.
2. As negative intraoral pressure increases the mandible is depressed more in order to enlarge the oral volume. It is more difficult for the lips to maintain a seal with the lips apart; they must be extended more to remain in contact.

E. Subjects

Comparing the activity of the ten subjects showed that there was a wide variation in energy output between the subjects (Fig. 16). It is possible that this subject variability could be related to the anatomical form of the oral cavity. When two individuals reduce the intraoral air pressure to any given level they must both increase the oral volume by the same proportional amount (Boyle's law). A subject with a narrow oral cavity would require a greater degree of mandibular depression to effect the same volume change than one who had a wide oral cavity. Therefore, greater muscular activity could be expected from the former individual.

This hypothesis is not based on any evidence derived from the experiment, but merely represents a possible deduction from Boyle's law.

F. Duplicates

Although there was a wide variability between subjects, each subject was able to repeat his pattern of activity with a high degree of precision. This finding was particularly gratifying because it suggests that the method used in this investigation might be employed to aid in the study of oral habits such as thumb sucking. One of the difficulties that confronted Baril in his study of thumb suckers was the lack of some standard by which he could judge their behavior. In discussing his work, he states:

> "No electromyographic study was done on a control group. Many actions other than sucking have been studied electromyographically by different workers. These studies will serve as partial controls for the present work. In regards to sucking, three non-sucking subjects (without sucking habits) have tried unsuccessfully to register a consistent sucking pattern. .....One feels obliged to accept this limitation and recognize it when drawing conclusions."

Since the present study indicates that the magnitude of negative intraoral pressure has a measurable effect on normal sucking behavior, it would seem that this factor should also be considered in the appraisal of perverse sucking behavior. Knowledge of the abnormal requires previous knowledge of what is normal.

It is hoped that this study will aid in understanding the part that negative intraoral pressure plays in the function of the masticating mechanism.

CHAPTER V

SUMMARY AND CONCLUSIONS

A. Summary

The effect of negative intraoral air pressure on the perioral musculature was investigated electromyographically.

Ten male adults having a normal perioral musculature served as subjects. Surface electrodes were placed bilaterally on the face over the following areas of the skin: upper lip, lower lip, buccinator, and mentalis. A specially designed manometer was used to regulate the negative intraoral pressure developed by the subjects. Recordings were taken while the subjects maintained the following negative intraoral pressures: $-20 gm./cm.^2$, $-40 gm./cm.^2$, $-60 gm./cm.^2$, and $-80 gm./cm.^2$

A four channel integrator was connected to the crystograph circuit to simplify the quantitative analysis of the data. Fisher's Analysis of Variance was employed in the statistical evaluation of the data.

B. Conclusions

The following conclusions may be drawn from the results of this experiment:

1. A decrease in intraoral pressure (increased negative intraoral pressure) causes an increase in the energy output of the perioral

musculature. There appears to be a linear relation between the pressure gradient, as measured by the manometer, and the energy output of each of the muscle groups studied.

2. The energy output of the buccinator at any given negative intraoral pressure is considerably lower than the energy output of the other muscle groups.

3. At a given negative intraoral pressure, the energy output of the perioral musculature on both sides of the face is similar.

4. There is a wide variation in energy output among different individuals at a given negative intraoral pressure.

5. In spite of this variation, this experiment demonstrated that a given negative pressure will evoke similar muscular response (energy output) in duplicate trials on the same individual.

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APPROVAL SHEET

The thesis submitted by Dr. David Leonard Edgar has been read and approved by four members of the Departments of Anatomy and Oral Anatomy.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

Date

Signature of Adviser