Normative Standards For The Measurement Of Oro Facial Muscle Strength

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ABSTRACT

This study attempts to establish normative standards for the measurement of oro facial muscle strength of an adult population.

Two examiners used two different instruments, the EMG and myoscanner, to measure the strength of the orbicularis oris and masseter muscles. Four different measures of muscle strength were examined on two different days for the twenty-four subjects used.

Mean and standard deviation scores and percentile ranks were established for the measures of facial muscle strength.

Chapter 1

INTRODUCTION

One of the newer roles of the speech pathologist is that of the myofunctional therapist or clinician, a specialist in oro facial(muscles of and relating to the mouth and face) muscle functions. The myofunctional therapist or clinician works to correct abnormal or imbalanced muscle functions that may affect speech production, physical health or cosmetic appearance(Garliner, 1974).

A myofunctional therapist or clinician must have a basic understanding of the function and importance of the oro facial muscles and their relation to speech production. The entire oral structure must be considered in the treatment of oro facial muscle imbalance. Therefore the myofunctional therapist or clinician has to be aware of the functions and the strengths or weaknesses of the lips, cheeks, and tongue, as well as their anatomy(Garliner, 1974).

The dental profession has recognized the position of the myofunctional therapist or clinician and realizes that their experience with and knowledge of the oral musculature can be a valuable asset in the elimination of dental problems related to muscle imbalance and dental occlusion. Incidence studies report that 25 to 40 percent of children with the myofunctional disorder of "tongue thrust" also have speech problems and the myofunctional therapist can provide a more

complete habilitative program for the patient with this or a related disorder with a regime of therapeutic exercises and techniques(Barrett, et al., 1978).

Graber(1972) points out the apparent relationship between the occlusion of the teeth and the function of the oro facial muscles when he states that:

> . . . function must always be considered, even though it is not 'diagrammed.' Form and function must mean more than semantic euphony or associated verbiage like 'ham and eggs.' Form and function are the very backbone of modern orthodontics.

It is necessary that the form and structure of the oral mechanism be in harmony with the functions of the mechanism. Otherwise, they may work against each other and possibly cause further oral problems.

Garliner(1974) stated that "The function of the oro facial muscles and the structure of the oral orifice will have a significant influence on the eventual speech patterns of the patient." Thus, speech implications in myofunctional therapy are evident: speech production can be influenced by the oro facial muscles and imbalance or dysfunction of these muscles may lead to or contribute to a specific speech defect. It appears that a person with imbalanced oro facial muscles is more likely to have speech problems than one who has normal oro facial muscle functions.

One of the major facial muscles that the myofunctional therapist works with is the orbicularis oris, or lip muscle. This muscle encompasses the peripheral area of the mouth and

when contracted, puckers or purses the lips(Palmer, 1972). A normally functioning orbicularis oris muscle will have firm muscle tonus, as opposed to being weak and flaccid or too strong and tense.

Another muscle that the myofunctional therapist may need to retrain is the masseter muscle. The masseters originate on the zygomatic arch and insert upon the angle of the mandible on both sides of the face. This muscle is responsible for protruding or retracting and elevating the mandible(Kaplan, 1960), and is most active upon forceful occlysion of the teeth(Basmajian, 1967). The masseters should be firm upon palpitation; a weak masseter muscle may be soft and spongy, and one that is too strong may feel rigid when the teeth are occluded.

The orbicularis oris and masseter muscles are only two of the many muscles used for speech, but these particular muscles have the most apparent and direct implications for therapeutic retraining when there is a problem with poor oral functions or habits.

The myofunctional therapist's decision of whether or not these muscles are abnormally balanced and need retraining is based upon his prior diagnostic work with the patient. His decision can be made more readily and reliably if he has normative information on muscle function and strength with which to compare his own information and base his opinion.

STATEMENT OF THE PROBLEM

To be able to determine whether a patient's oro facial muscles are in proper balance, and if the patient does indeed, require myofunctional therapy, the therapist needs normative standards upon which to base his decisions. Currently there is insufficient normative information available on oro facial muscle strength and functions.

Purpose of the Study

The purpose of this study is to establish normative standards for the measurement of oro facial muscle strength. The right and left masseters, and the orbicularis oris muscles will be examined as these muscles are most readily investigated on the instruments available for this study.

Instrumentation

The instruments to be used for measurement of the right and left masseters and the orbicularis oris muscles are the electromyograph(EMG J33, Cyborg Corporation), Figure 1; an instrument that measures muscle neuron activity in terms of microvolts(number of motor unit firings in a muscle), and the myoscanner(Neilco Corporation), Figure 2; an instrument that uses a probe to measure exerted muscle force in terms of pounds, and provides an index of muscle strength.

Figure 1

Electromyograph

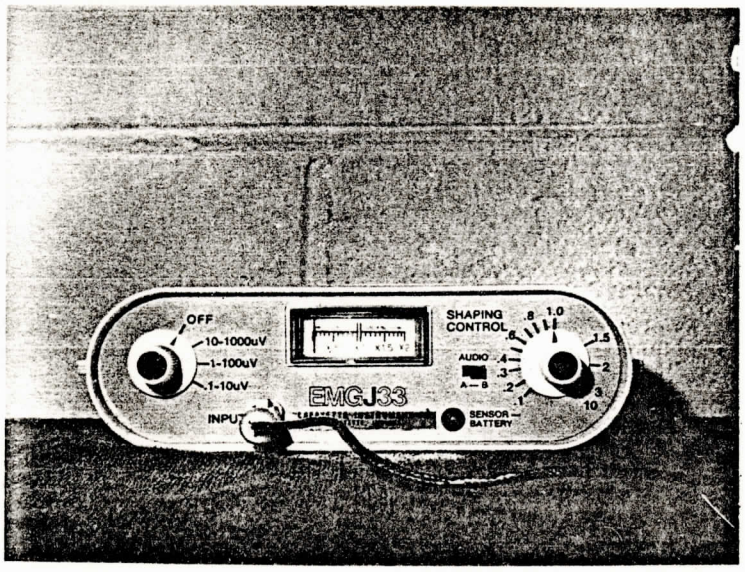
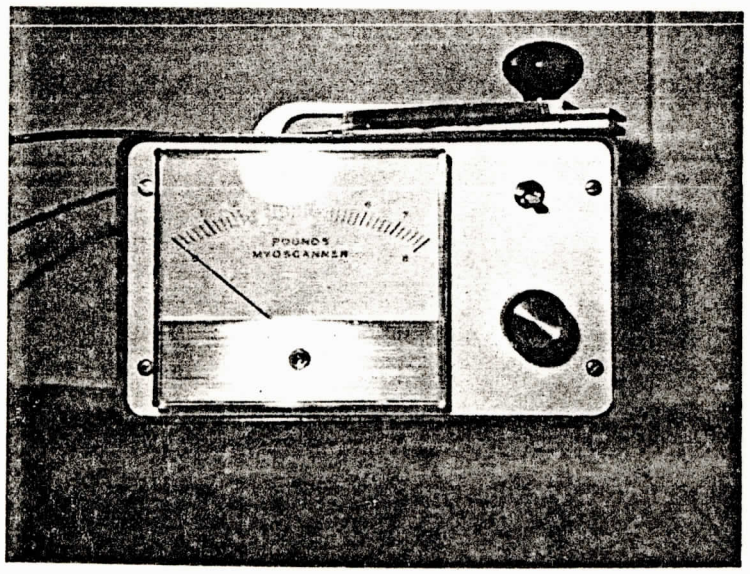


Figure 2

Myoscanner



Major Hypothesis

The collected normative data on the specific measured muscles should be representative of normal or average adult facial muscle strength.

Null Hypothesis

Measurement reliability between the instruments should not exceed the .05 level of significance for the measurement of strength of the orbicularis oris and masseter muscles.

REVIEW OF RESEARCH AND LITERATURE

The literature concerning normative studies of the oro facial muscles is scarce and limited in it's scope (e.g., the modification or re-education of specific muscles). However, there are some technically acceptable studies where electromyography has been used to examine the facial muscles and their functions and also studies that emphasize placement of the muscle sensor devices and techniques to be incorporated when using electromyography. These are reviewed in this section.

Isley and Basmajian(1973) employed multichannel electromyography with intramuscular electrodes to investigate the facial muscles during facial expression and during musical performance(trumpet and trombone playing). They found that there was considerable intersubject variation, although there apparently was a pattern for most of the tasks.

A study to examine EMG activity and make comparisons

between the jaw-closing muscles during speech was done in 1978(Folkins, et al.). In this study it was found that the activity of the masseter muscle increased dramatically as jaw-closing velocity increased.

Netsell and Cleeland(1973) attempted to reduce the postural hypertonicity of the orbicularis oris muscle in a Parkinsonian patient by using EMG feedback. After five half-hour sessions there was considerable progress towards removing the lip retraction and improved facial appearance.

In 1973(Sussman, et al.) electromyography was used to obtain recordings of upper lip, lower lip, and jaw movements during the production of bilabial consonants. This study considered the different aspects of speech production dynamics during lip and jaw movements.

Budyanski and Stoyva(1973) developed a system for reducing muscle tension in the masseter muscle with electromyographic feedback. In this study surface electrodes were placed over the belly of the masseter muscle with a ground electrode on the mastoid bone.

Matson(1975) used electromyography to examine the masseter muscle during dental occlusion. His technique with electrodes involved securing them with Scotch tape 10mm below the zygomatic apophysis and 10mm apart.

Wolf(1978) suggested that surface electrodes be mounted close together and overlying the muscle to be examined or trained. He also observed that since the motor end-plates are in the region of the muscle belly in most human muscles,

placing the electrodes over the belly of the muscle is usually a sound decision.

A study to investigate the electromyographic silent period of the jaw muscles was done in 1977(McNamara, et al.) and advocated abrading the area of electrode placement and then using conductive cream between the electrodes and the skin to reduce contact impedance.

This review indicates that research of the oro facial muscles has been done and much of it is by speech pathologists. The need for further research is seen by the lack of normative information available.

The implications and techniques used in the former studies were considered as guidelines or suggestions for this study.

Chapter II

METHOD AND PROCEDURE

SUBJECTS

The subjects involved in this study were male and female students attending Appalachian State University who were approximately twenty-one years of age. It was established from a questionaire administered to each subject prior to the testing that they had never had myofunctionally oriented speech therapy, no known neurological problems and no significant or interferring oral or facial surgery.

To establish reliability, each of the twenty-four subjects was tested twice, on two consecutive days. The first time he was tested with instrument A, then with instrument B; the second day he tested with instrument B first, and then with instrument A. See Table 1 for study design.

There were two examiners testing muscle strength and the testing schedule was divided into four randomly assigned, groups of six subjects each. The testing and retesting by the different examiners and the order of instrument use for each session was alternated to insure that the variable of order had no effect on the test results. For example: the first group of six subjects were tested by examiner one the first session; first with the EMG and second with the myoscanner. The second day the first examiner retested the six subjects;

Table 1

Study Design

SESSION ONE		SESSION TWO	
Examiner 1	A EMG B MYOSCANNER	Examiner 1	B EMG A MYOSCANNER
Examiner 1	A EMG B MYOSCANNER	Examiner 2	B EMG A MYOSCANNER
Examiner 2	A EMG B MYOSCANNER	Examiner 1	B EMG A MYOSCANNER
Examiner 2	A EMG B MYOSCANNER	Examiner 2	B EMG A MYOSCANNER

A-instrument used first

B-instrument used second

first with the myoscanner, and second with the EMG.

The examiners followed a standardized procedure for placement of the muscle sensor which allowed for reproducible testing and placement for each subject.

The measurements taken were those of (1) lip retention(LR), the resistive strength of the orbicularis oris with external pulling force; (2) lip compression(LC), vertical pressure of the lips pressing together against an object; and (3) and(4), right and left masseter strength, contraction of the masseter when the teeth are occluded for the right(RM) and left(LM) masseter muscles. These measurements were derived from specific muscle training exercises suggested by Garliner(1974). Each measure was taken three times.

The probe unit of the myoscanner was used with orbicularis oris testing for both instruments for measurement consistency.

For the electromyographic testing silver/silver chloride surface electrodes were used. The skin where each electrode was placed was first abraded with electrocardiography conduction paste and then the electrode was filled level with the paste. Cloth tape was used to anchor the electrode securely to the skin. A ground electrode was placed on the coronoid process for each electromyographic measure(Figure 3).

For all electromyographic testing, the dials of the EMG were initially set at a range of 10-1000 microvolts and a threshold of 1.0(see Figure 1). If a subject either exceeded or didn't reach this 100 microvolts setting, the dials were

Figure 3

Electrode Placement on Coronoid Process

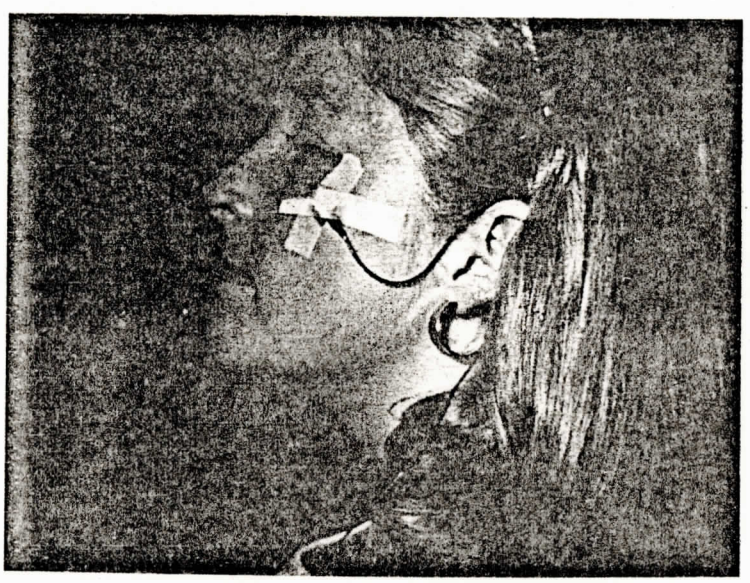
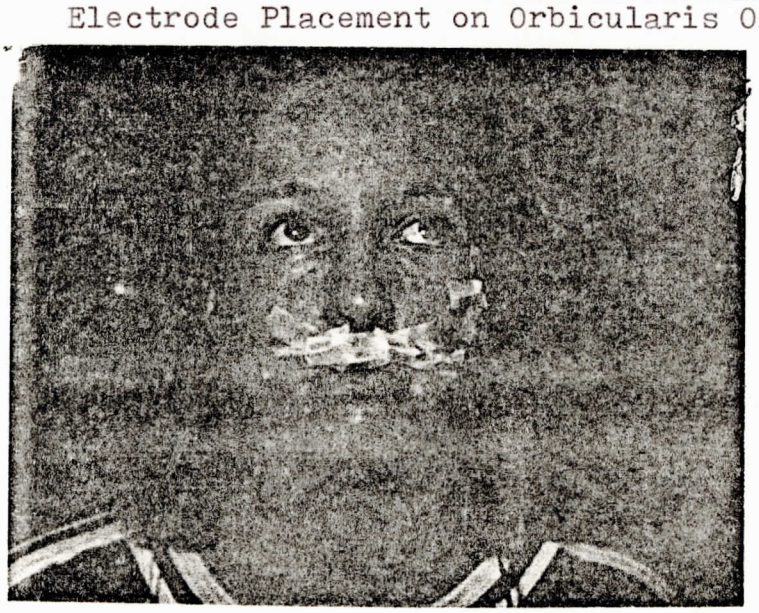


Figure 4

Electrode Placement on Orbicularis Oris



adjusted and later converted into corresponding measures. The highest unit of microvolts reached on each of three trials was recorded.

The sensor battery light on the EMG was monitored and timed after electrode placement for each measure to check for good electrode contact with the skin. If the amount of time it took the sensor light to turn off exceeded three seconds, then it was assumed that the contact was not good, and the electrodes were either adjusted or replaced.

For the testing of the orbicularis oris muscle, electrodes were placed right above the vermillion border of the lip, directly in line with the nares. This placement was replicated for each subject via facial landmarks(Figure 4).

For the measurement of LC, the examiner held the probe up to the subject's lips and instructed him to "press as hard as you can when I say go, for a count of three, then relax." The subject was also instructed not to use his gums or teeth to help him press(Figure 5).

The measure of LR required the subject to place a button, the size of a quarter, in a vertical plane, in front of his teeth, and behind his lips. A string approximately nine inches long was strung through the button and anchored around the probe. The examiner instructed the subject to keep the button inside his lips while the examiner pulled away as hard as he could for three seconds without pulling out the button (Figure 6).

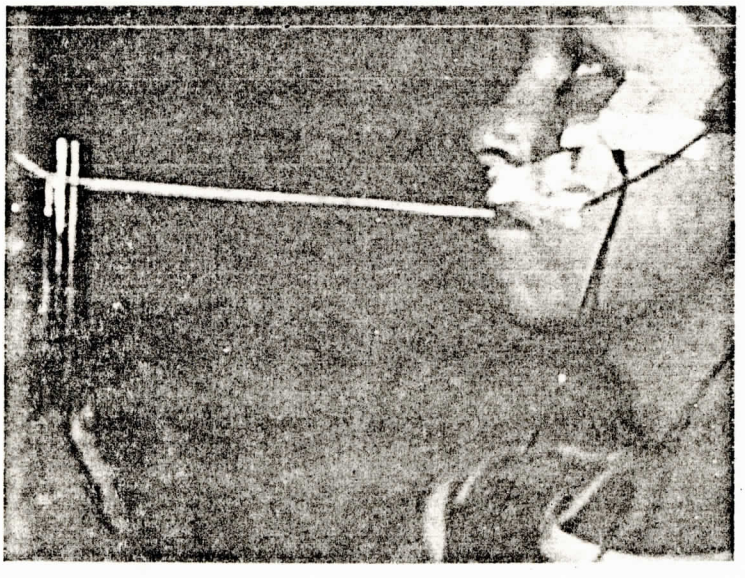
For the measure of right and left masseter strength,

Figure 5

Lip Compression

Figure 6

Lip Retention



electrodes were placed approximately 1mm apart, directly over the belly of the masseter muscle. The subjects were instructed to "bite down as hard as you can for a count of three, then relax(Figure 7)."

The measures for the myoscanner used the same exercises and directions as that for the EMG, but without the electrodes. The highest unit of pounds reached on the myoscanner for each measure was recorded for each of three trials.

LC measures used the myoscanner probe to press on and the measure was recorded from the myoscanner dial.

LR measures used the myoscanner probe to pull the button away from the subject's lips, without causing the subject to release the button.

The measures of masseter strength used an attachment that connected to the probe unit and the probe was placed against the subject's face and pressed down for one pound of pressure for continuity of dial readings. The subject was then asked to occlude for three seconds. The reading was recorded, less the one pound of pressure(Figure 8).

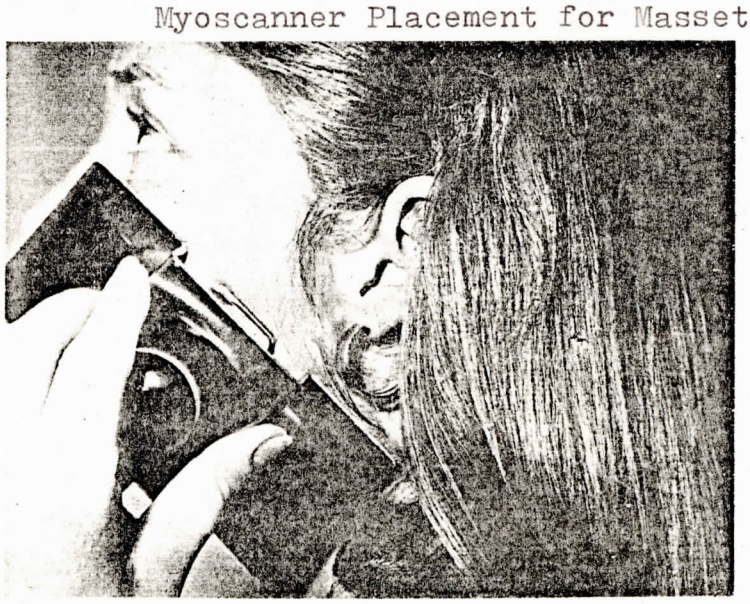
The entire procedure took approximately twenty-five minutes for each subject for each testing session.

Figure 7

Electrode Placement for Masseter

Figure 8

Myoscanner Placement for Masseter



Chapter III

RESULTS AND DATA ANALYSIS

The three trials taken for each measure of muscle strength on the myoscanner and EMG were averaged and recorded for each of the two test sessions. These results appear in Tables 2 and 3.

The mean scores, standard deviations(SD) and ranges of scores for each of the four measures taken for each instrument appear as Table 4. These scores were derived from the average of both test sessions of the twenty-four subjects.

Mean scores for the separate four groups of six subjects were also computed for each of muscle strength and are listed in Table 5.

Percentile ranks for both instruments for the four measures are listed in Table 6. These were computed from the average of both test sessions for all twenty-four subjects.

Test/retest reliability of the measures were computed between the scores of the same measures taken on the two different days. Myoscanner test/retest reliability of the four measures were: LC= .52; LR= .66; RM= .77; and LM= .91. All four measures exceed the .01 level of significance.

EMG test/retest reliability of the measures were: LC= ,78; LR= .80; RM= .11; and LM= .43. The measures of LC and LR exceeded the .01 level of significance: the measures of RM and LM did not reach the .01 level of significance.

Table 2

Three Trial Mean Score on Myoscanner

Subjects	LC		LR		RM		LM	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
1	1.3	1.0	2.1	1.8	1.6	1.2	1.9	1.7
2	1.0	1.0	1.2	2.1	1.0	.7	.9	1.0
3	1.0	1.2	1.0	2.9	1.1	1.3	1.7	1.7
4	.9	.4	1.5	1.3	.5	.4	.8	.6
5	.8	1.3	2.5	2.3	.7	1.1	1.0	1.1
6	.7	.7	1.8	1.3	1.0	.7	1.2	1.4
7	.9	.9	2.6	2.6	.7	.7	1.0	1.1
8	1.1	1.1	1.5	1.5	.7	.7	1.0	1.1
9	1.1	1.2	2.3	2.2	1.3	1.2	1.7	1.6
10	.7	.7	1.1	1.2	.7	.7	1.0	1.1
11	.9	.9	1.7	1.6	.8	.9	1.2	1.3
12	.8	.9	2.3	2.3	.7	.6	.8	.7
13	2.0	.6	1.2	1.6	.9	.6	.7	.7
14	1.1	.9	1.2	1.5	.9	.9	.9	1.0
15	1.1	.9	1.1	1.6	.7	.8	1.1	1.0
16	2.0	1.8	1.9	1.7	1.7	1.1	1.3	1.1
17	.9	.8	1.1	2.4	1.3	1.0	1.3	1.1
18	1,2	1.4	1.4	2.0	1.3	1.3	1.5	1.5
19	1.3	1.3	1.4	1.5	1.4	1.3	1.1	1.1
20	1.5	1.4	1.5	1.4	1.3	1.3	1.1	1.2
21	1.7	1.8	1.9	2.0	.9	.8	1.1	1.0
22	1.2	1.3	1.0	1.1	.8	.8	.8	.9
23	1,1	1,3	,9	1.5	1.1	1.1	1.2	1.2
24	1.3	1.3	1.7	1.6	1.3	1.3	1.1	1.1

Table 3

Three Trial Mean Score on EMG

Subjects	LC		LR		RM		LM	
	Day 1	/Day 2	Day 1	/Day 2	Day 1	/Day 2	Day 1	/Day 2
1	140	137	163	133	255	1.7	230	16
2	123	140	127	103	13	1.8	14	1.7
3	97	113	97	113	12	15	11	16
4	87	120	127	130	180	31	2.6	165
5	143	140	153	140	26	97	7	3.5
6	87	117	100	97	18	8	10	12
7	170	177	147	147	1.1	9.7	9	7.7
8	127	127	147	150	11.5	120	25	23
9	100	117	137	143	9.7	10	140	153
10	90	97	103	117	11	18	27	28
11	137	137	123	120	10	93	7	83
12	77	100	127	130	12	11	6	5.7
13	167	147	127	145	90	7.3	73	14
14	100	107	140	113	93	87	73	107
15	127	153	117	120	90	63	1.1	15
16	160	230	180	153	153	31	130	313
17	127	127	113	107	153	50	150	77
18	117	147	100	110	15	173	10	25.5
19	150	153	140	137	133	137	97	97
20	157	163	143	150	130	127	127	120
21	133	133	153	147	83	77	67	73
22	113	127	117	117	73	93	80	77
23	163	150	153	130	160	153	130	107
24	130	130	177	167	130	130	107	117

Table 4

Mean and Standard Deviation Scores and Score Ranges For Measures Taken on EMG and Myoscanner

		LC	LR	RM	LM
EMG (microvolts)	Mean	131.5	131.9	71.0	62.3
	S.D.	28.0	20.7	62.4	63.1
	Range	87.0-230.0	97.0-180.0	1.7-255.0	1.1-313.0
MYOSCANNER (pounds)	Mean	1.1	1.7	.95	1.1
	S.D.	.35	.45	.30	.30
	Range	.4-2.0	.9-2.6	.4-1.7	.6-1.9

Table 5

Mean Scores For Measures of Individual Groups

	EMG				MYOSCANNER			
	LC	LR	RM	LM	LC	LR	RM	LM
Group 1	120	124	179	41	1.0	1.9	.9	1.3
2	121	158	26	50	.9	1.7	.8	1.1
3	143	127	84	82	2.2	1.6	1.4	1.1
4	142	140	119	100	1.4	1.5	1.1	1.1

Table 6

Percentile Ranks for Myoscanner and EMG

MYOSCANNER
Percentiles

	10	20	30	40	50	60	70	80	90
LC	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.6
LR	1.1	1.3	1.5	1.5	1.7	1.8	2.0	2.1	2.3
RM	.6	.7	.8	.9	.95	1.0	1.1	1.2	1.4
LM	.8	.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5

EMG

LC	96.4	108.2	116.8	124.5	131.5	138.4	146.1	154.8	166.9
LR	105.4	114.5	120.9	126.7	131.9	137.1	142.9	151.2	158.5
RM	-8.9	18.7	33.2	55.7	71.0	87.1	104.7	124.1	151.7
LM	-20.5	9.5	30.5	49.5	62.3	83.4	102.5	123.5	153.4

Examiner reliability was computed for groups one and four(six subjects each) to determine the magnitude of the correlation between the measure scores when the same examiner retested the subjects.

Examiner reliability for the measures for group one (examiner one) on the myoscanner are as follows: LC= .15; LR= .95; RM= .65; and LM= .92. LC did not reach the .01 level of significance; LR, RM, and LM exceeded the .01 level of significance.

Group one examiner reliability for the measures on the EMG are as follows: LC= .90; LR= .78; RM= -.21; and LM=-.19. LC and LR measures exceeded the .01 level of significance; RM and LM measures did not reach a level of significance.

Examiner reliability measures for group four(examiner two) on the myoscanner are as follows: LC= .88; LR= .76; RM= .99; and LM= .91. All four measures exceed the .01 level of significance.

EMG examiner reliability for the measures for group four are as follows: LC= .89; LR= .86; RM= .96; and LM= .89. All four measures exceed the .01 level of significance.

In groups two and three the subjects were tested by one examiner and retested by the other. Examiner test/retest reliability was computed for these two groups to see if there was a correlation between the measures taken on different days, by different examiners.

Myoscanner examiner reliability for groups two and three was as follows: LC= .43; LR= .63; RM= .81; LM= .91. The

measures of LR, RM and LM exceeded the .01 level of significance. The measure of LC did not reach a level of significance.

EMG examiner reliability for the measures in groups two and three was as follows: LC= .80; LR= .77; RM= -.15; and LM= .69. LC, LR, and LM measures exceeded the .01 level of significance. RM did not reach a level of significance.

The measures of LC and LR were more consistent for the EMG and the measures of RM and LM were more consistent on the myoscanner.

Examiner reliability for group four(examiner two) was greater than for group one(examiner one).

Chapter IV

DISCUSSION

The purpose of this study was to establish normative standards for the measurement of oro facial muscle strength. The results of testing the orbicularis oris and masseter muscles with the EMG and myoscanner yielded mean and standard deviation scores for four different measures of muscle strength. Percentile ranks and test/retest and examiner reliability measures were also computed for the measures of muscle strength.

Test/retest reliability of the measures reveals that the myoscanner yielded significantly consistent results, with the measures of the masseter muscles having the highest correlation.

EMG test/retest reliability reveals that only the orbicularis oris measures were at the .01 level of significance.

Examiner reliability(same examiner retests) for groups one and four showed that scores for group four(examiner two) were much more consistent from day to day than those for group one(examiner one).

Examiner reliability for groups two and three(different examiner retests) was significant for all measures on the myoscanner, and for the LC, LR, and LM measures on the EMG.

Implications and Conclusions

Test/retest reliability indicates that the highest reliability for measures of LC and LR can be reached on the EMG, and the highest reliability for measures of RM and LM can be reached on the myoscanner.

Examiner reliability was much higher for one group of subjects which indicates that there may have been discrepancy in the techniques used for measurement of muscle strength between the two examiners. This would indicate the need for a more reliable technique or procedure to be incorporated when using different instruments to measure strength of the oro facial muscles.

Limitations of the Study

This study attempted to establish normative standards for a specific population. The norms established are indicative of adult facial muscle strength and should not be implied for other populations.

There were only twenty-four subjects used in this study and this may have reduced the validity or reliability of the study.

The orbicularis oris and masseter muscles were the only facial muscles investigated, and therefore the norms are indicative only of these specific muscles.

The EMG and myoscanner were the instruments used and the normative information gained from this study is applicable only to these two instruments.

Suggestions for Further Research

Further research in this area should include:

1. A standard protocal, and more reliable procedures and techniques for the measurement of the oro facial muscles should be investigated and incorporated in future studies.

2. Other facial muscles should be examined and normative standards set for their strength and functions.

3. Different types of instruments should be investigated and compared for measurement of the facial muscles.

4. Normative standards for other populations for measurement of oro facial muscle strength.

BIBLIOGRAPHY

Barrett, Richard H, and Hanson, Marvin L. Oral Myofunctional Disorders. St. Louis: The C.V. Mosby Co., 1978.

Basmajian, J.V. Muscles Alive: Their Functions Revealed by Electromyography. Baltimore: The Williams and Wilkins Company, 1967.

Budyanski, Thomas, and Stoyva, Johann. "An Electromyographic Feedback Technique for Teaching Voluntary Relaxation of the Masseter Muscle." Journal of Dental Research, 52(1): 116-119, January-February, 1973.

Folkins, John W., Zimmerman, Gerald N., and Cooper, Donald S. "Activity in Jaw-closing Muscles during Speech." A Paper presented to the American Speech and Hearing Association, November, 1978.

Garliner, Daniel. Myofunctional Therapy in Dental Practice. Second Edition. New York: Bartel Dental Book Company, Inc., 1974.

Graber, T.M. Orthodontics: Principles and Practice. Philadelphia: W.B. Saunders Company, 1972.

Isley, Jr., Charles L., and Basmajian, John V. "Electromyography of the Human Cheeks and Lips." Anatomical Records, 176, 143-148, 1973.

Kaplan, Harold M. Anatomy and Physiology of Speech. New York: McGraw-Hill Book Company, 1960.

Matson, E. "The Masseter Muscle. Electromyographic Study During Dental Occlysion." Rev Fac Odontol Sao Paulo, 14(1): 29-34, 1976.

McNamara, David C., Crane, Patrick F., McCall, Jr., Williard D., and Ash, Jr., Major M. "Duration of the Electromyographic Silent Period Following the Jaw-Jerk Reflex in Human Subjects." Journal of Dental Research, 56(6): 660-664, June, 1977.

Netsell, Ronald, and Cleeland, Charles S. "Modification of Lip Hypertonia in Dysarthria Using EMG Feedback." Journal of Speech and Hearing Disorders, 38(1), 131-140, 1973.

Palmer, John M. Anatomy for Speech and Hearing. New York: Harper and Row, 1972.

Silverman, Franklin H. Research Design in Speech Pathology and Audiology. New Jersey: Prentice-Hall, Inc., 1977.

Sussman, Harvey M., MacNeilage, Peter F. and Hanson, Robert J. "Labial and Mandibular Dynamics During the Production of Bilabial Consonants: Preliminary Observations." Journal of Speech and Hearing Research, 16: 397-420, 1973.

Wolf, S.L. "Essential Considerations in the Use of EMG Biofeedback." Physical Therapy, 58(1): 25-31, January, 1978.