Research Article

Electromyographic study of normal and deviant swallowing

Charles P. Overstake

Suggested Citation

Overstake, C. P. (1975). Electromyographic study of normal and deviant swallowing. *International Journal of Oral Myology*, 1(1), 29-60.

DOI: <https://doi.org/10.52010/ijom.1975.1.1.3>

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](#).

The views expressed in this article are those of the authors and do not necessarily reflect the policies or positions of the International Association of Orofacial Myology (IAOM). Identification of specific products, programs, or equipment does not constitute or imply endorsement by the authors or the IAOM. The journal in which this article appears is hosted on [Digital Commons](#), an Elsevier platform.

Electromyographic Study of Normal and Deviant Swallowing

Charles P. Overstake, Ph.D.

Over an extended period of time, while working with children who had swallowing problems, this investigator often observed inconsistencies and variability in swallowing behavior, even within a given child. Because there was so much variability in swallowing behavior, it seemed to be difficult, if not impossible, to make a positive and reliable identification of the type of swallowing a child most frequently used relying on only the traditional three diagnostic criteria (extreme tension in the labial and facial muscles, absence of contraction in the masseter muscles and forward thrusting of the tongue), or by following the common practice of observing the child swallow only three times. For this investigator, at least, it seemed that determination of the type of swallow pattern a child had might be more accurately assessed if one considered the kinesiology of the muscles involved in swallowing. While studies on animal swallowing have been done by electromyography (Doty and Bosma, 1956), few have been done on human swallowing, none on children.

Generally speaking, it was the investigator's opinion that by palpating, feeling, and visually inspecting the muscle activity of the child during swallowing, other possible indications of deviant swallowing could be observed. By carefully examining the functions of (1) the muscles of mastication, (2) the suprahyoid and infrahyoid muscles, (3) the orbicularis oris muscle, (4) the tongue, and (5) noting the configurations of the teeth, it seemed possible to make better judgments as to what the child was actually doing, than by the three traditional criteria alone.

To be explicit, it was this investigator's impression that during the act of swallowing, most deviant swallows presented a kinesiological pattern that was disarranged, a pattern in which the "timing was off." Variations in the phase relationships of the suprahyoid and infrahyoid muscles seemed to indicate deviant swallowing. The muscle behavior observed appeared to be asynchronous and felt "choppy," in comparison to that of normal swallowing which felt synchronous, smooth, flexible and precise. The deviant swallower appeared to have a labored swallow.

It was also observed that variations in anterior temporalis muscle contraction, rather than the lack of masseter contraction which others reported, seemed to be another

possible sign of deviant swallowing. The temporalis contracts when the back teeth are brought together in a normal bite, while the masseter contracts during any and all dental approximations. The temporalis is not noted to contract during light approximations, when the mandible is extended and the front teeth are brought together, a pattern which is often found in tongue thrusters.

Another observation concerned the orbicularis oris muscle, the sphincter muscle around the mouth. While others state that deviant swallowers use considerable labial and facial activity as a means of keeping what is to be swallowed in the mouth, it seemed to this investigator that the degree of orbicularis oris contraction in lip pursing and related grimacing was in direct proportion to the amount of "suck-up" a child used to get what was to be swallowed either on or over the back of the tongue. In normal swallowing, the child sucks up just enough to get the liquids or food onto the concave surface, which develops on the medial aspect of the tongue, just prior to the initiation of the swallow. Deviant swallowers need excessive "suck-up" and apparently continuous orbicularis oris muscle activity throughout the swallow. This child sucks-up hard, hard enough to get the substance to be swallowed over the back of the posterior part of the tongue and into the oro-pharynx.

Although in deviant swallowing the major organ of concern is the tongue, observations of the tongue alone are not sufficient, for the tongue is not an independent organ. It has muscles contained completely within itself, intrinsic muscles, but also muscles which originate outside the tongue, extrinsic muscles. It appears that the extrinsic muscles and muscle groups function in direct relation to what the tongue is doing. It would seem reasonable to assume that if the behavior of the tongue was deviant, the extrinsic muscles and muscle groups and their related activities, as a consequence, would also be deviant. The suprahyoid muscles comprise the extrinsic muscles of the tongue. Although the infrahyoid muscles are not considered to be extrinsic muscles of the tongue, functions of the infrahyoid muscles are related, indirectly, to the normal or deviant action of the tongue. It would seem to follow that variations in the supra- and infrahyoid muscles might constitute another sign of tongue-thrust swallowing.

Procedures

This study was proposed to identify and evaluate possible reliable signs of normal and deviant swallowing. To obtain potential subjects, a public school population was surveyed and examined for either normal or deviant tongue-thrust swallowing, based on multiple diagnostic signs suggested by this investigator. Quantitative measurements of the muscle behavior exhibited by some of these children, to determine how they might be related to the type of swallowing found to occur most frequently in a given child, were then obtained by electromyography. Analyses of the electromyographic tracings were done to provide more objective information about muscle function during the act of swallowing. It was thought that such information would be beneficial in determining more definitive signs for normal and deviant swallowing.

The following questions were formulated to secure the necessary segments of information needed to answer the principal question.

Is there activity and are there variations in activity that can be related to anterior tongue-thrust swallowing in the following muscles:

1. The anterior temporalis?
2. The masseter?
3. The suprahyoid muscle group?
4. The infrahyoid muscle group?
5. The orbicularis oris?

By comparing actual electromyographic tracings and the measured integrated muscle energy expended for each of these muscles and muscle groups, with and without anterior protrusion of the tongue during the act of swallowing, this investigator sought to identify and quantify those muscles and muscle group actions that seemed to be related to normal and deviant swallowing.

Subjects were selected from the public school population that had been surveyed for children having normal and deviant swallowing. Such a determination was made for 327 children, ages seven through twelve years, from grades two through six. Eventually, four children were selected from each age group for further study in this investigation, two with normal swallowing and two with deviant swallowing, for a total of twenty-four children.

All children seen in the public school survey were examined by this investigator according to the following procedures. All children seen were examined for normal or deviant tongue-thrust swallowing:

- a) Water was injected with a syringe into the child's mouth and he was asked to swallow it.
- b) Occlusion of the teeth throughout the swallow was ascertained by palpating and visually observing the mandibular muscles. A perceived increase in the density of the temporalis and masseter muscles was interpreted to be associated with biting. In this manner, judgments were made as to whether or not the child kept his teeth occluded during swallowing.
- c) Movements of the hyoid bone and thyroid cartilage were palpated and noted. Movement of the hyoid bone and thyroid cartilage is dependent on the function of the suprahyoid and infrahyoid muscles. Asynchronous action or movements that appeared to be "choppy" were interpreted as being indicative of deviant swallowing.
- d) The position of the tip of the tongue, after the child had gotten into the automatic reflex stage of swallowing, was observed visually. Parting the lips to permit observation of the tongue was accomplished by the examiner by manually opening the lips. The presence or absence of protrusion of the tongue was noted.

The activity of those muscles and muscle groups, previously identified as being involved in swallowing, was measured by electromyography.

Two specific methods for observing the results of electromyographic measurements of voluntary muscle behavior are commonly used: (1) viewing the tracings or wave forms on an oscilloscope, and (2) recording the tracings or wave forms on an oscillograph. In this study, the electromyographic tracings were recorded on an ink-writing oscillograph which is an instrument for recording alternating electrical current wave forms. These tracings represent the observable measured activity or energy output of the muscles being tested. Thus, these tracings are observable indications of muscle contraction, usually voluntary, during some motor activity.

Tracings or wave forms are indications of the muscle energy being expended at any given moment in time. The total amount of energy used during muscle contraction for a certain activity is the sum of the amplitudes of the individual waves in the tracings. Electronic integrators were used to summate automatically the energy output, as indicated by the individual wave forms, which was expended during the total time of each individual swallow. Both the electromyographic tracings of wave forms, and the total voluntary muscle energy output data, summated by the integrators, were used. This permitted two comparisons to be made between muscle activities in normal and deviant swallowing: (1) the phase relationships of the muscles and muscle groups during a swallow, and (2) total muscle energy output for each episode of the swallowing.

Electromyographs were obtained using the Beckman Type S-II dynograph with a direct writing recorder. The dynograph was equipped with eight type 486 amplifiers, and eight 481B preamplifiers with signal couplers. It was also equipped with a type 386A power supply, type 524 chart drive, 5524A control panel, type 711 series timers, type 536 writer unit and a type 51AC series event marker.

Three resetting integrator couplers, type 9873B, were used. This kind of integrator supplies the time integral analog signals from other bio-medical couplers. It integrates the A.C. or D.C. output that measures neurophysiological functions, in this case, voluntary muscle activity. The totalized mode was used. The coupler continued to integrate the signal from the preamplifier of the primary channel until the integrator re-set button was pushed or until the re-set level, pre-set in the total mode window of the integrator, was reached. For this study, the re-set button was pushed and integrators re-set just prior to the initiation of each swallow. The event marker, manually controlled, was engaged just prior to each swallow and released when swallow activity had subsided for each swallow. Integrated muscle activity prior to and after the swallow was not computed as a part of the voluntary muscle activity for that event.

Beckman miniature skin electrodes were used. These electrodes measure ten millimeters in diameter, five millimeters in thickness and weigh twenty-four grams. Each electrode has a plastic housing with a two millimeter electrode exposure for skin contact. The electrodes were placed over the muscles and/or muscle groups of concern and held in place with Beckman adhesive collars. Burdick electrode paste was used in preparing the skin and facilitating electrode contact with the skin surface. Skin resistance was around 20,000 ohms for each child. This level of resistance was considered good in view of the fact that all children had had considerable wind and sun exposure.

To obtain the desired electromyographic tracings and voluntary muscle energy output surface electrodes were placed over:

1. The temporalis muscle to measure the voluntary action and energy output of this muscle as it may be related to maintaining dental occlusions throughout the swallow;
2. The masseter muscle to measure the voluntary action and energy output of this muscle as it may be related to dental occlusions during the swallow;
3. The suprahyoid muscles to measure their voluntary action and energy output in relation to hyoid bone movement during the process of swallowing;
4. The muscles between the hyoid bone and thyroid cartilage to measure the voluntary action and energy output of the infrahyoid muscles in relation to

thyroid cartilage movement during the process of swallowing; and

5. The mandibular portion of the orbicularis oris muscle to measure its voluntary action and energy output relative to pursing and protrusion of the lips as they may be involved in sucking action during swallowing.

An attempt was made to relate these objective measurements with tongue behavior and arrive at decisions relative to their significance as measures of normal and/or deviant swallowing.

Electromyographic tracings and integrated voluntary muscle energy output data were collected for each child, as he swallowed 18 different times. These measurements permitted an analysis to be made of the muscle functions of the group of deviant swallows and the group of normal swallows. Comparisons were made between the children comprising each group and between the two groups. The electromyographic tracings for each muscle and muscle group were compared for consistent signs of normal and deviant swallowing. Comparisons were also made between difference in the means of the voluntary muscle energy output of the muscles and muscle groups specified as they related to normal and deviant swallowing. It was intended that this information would provide definitive answers for the operational research questions outlined for this part of the study.

Findings

The findings relative to identifying the reliable signs that would indicate which occurred most frequently in a child, normal or deviant swallowing, will be presented as follows: (1) muscle energy output relative to the suggested signs for normal and deviant swallowing; and (2) suggested temporal signs of deviant and normal swallowing observed in the electromyographic tracings.

The following information is being included, in brief review, to serve as specific points of reference for the results of the investigation to be reported.

The signs of normal swallowing were suggested to be: (1) the mouth is closed and the teeth are occluded; (2) the tip of the tongue is placed against the rugae behind the central incisors; (3) food and liquid are forced over the back of the tongue; (4) the pharyngeal space is obliterated by raising the larynx and retracting the tongue; (5) the hyoid bone and larynx are raised with the hyoid bone being displaced in a series of movements upward and forward; (6) the hyoid bone and larynx descend; (7) the tongue is displaced down and forward; (8) the muscles of mastication relax and the teeth obtain their normal resting position. There was some question among investigators as to the amount of orbicularis oris contraction. The normal act of swallowing is said to be a very relaxed episode.

Certain variations in the act of swallowing have been considered to be indicative of abnormal or deviant swallowing. Traditionally, the most prevalent variations and thus signs of deviant swallowing have been suggested to be: (1) the muscles of mastication are not used to bring the jaws tightly together; hence, the teeth are not brought together; (2) there is strong lip activity in teeth-apart swallowing when the masseter is inactive thus there is extreme tension in the circumoral musculature; (3) the tip of the tongue is placed or pushed through or against the anterior teeth.

This investigator has suggested other variations in the act of swallowing which may also be signs of deviant swallowing, namely: (1) there is variable or a lack of anterior

temporalis muscle contraction; (2) there is asynchronous activity in the muscles and muscle groups involved, resulting in (3) an asynchronous, choppy or out-of-phase functioning of the suprahyoid and infrahyoid muscle groups.

With the above criteria in mind, this investigator proceeded to search for the possible reliable signs of normal and deviant swallowing.

The voluntary muscle energy expended by each child for each muscle was recorded electromyographically for each swallow. It was found that the level of muscle energy for each muscle varied from swallow set to swallow set, but the energy output per muscle within each set remained relatively constant. Table 1 presents the means and standard deviations of muscle energy expended by each child for all activities measured. Children are listed by age and group classification. Also given is the mean muscle energy output for each group of children for each group of children for each muscle. The number of swallows for each child is twelve for all muscles except the orbicularis oris, which is six. In the analysis of the muscle energy expended, to be presented, the group means for each swallow were used. Each muscle or muscle group tested will be presented independently.

Table 1. Electromyographic Data: Means and standard deviations, expressed in millivolts, of the voluntary muscle energy output expended by each subject for all muscles and muscle groups measured in this study.

Age	Class	Masseter		Temporalis		Suprahyoid		Infrahyoid		Orbic.oris	
		M.	S.D.	M.	S.D.	M.	S.D.	M.	S.D.	M.	S.D.
		N=12		N=12		N=12		N=12		N=12	
12	O	0.85	0.37	0.38	0.14	1.75	0.26	0.88	0.16	1.44	0.29
12	N	0.67	0.28	0.89	0.32	2.80	0.48	2.29	0.24	2.31	0.53
12	D	0.66	0.26	0.42	0.29	2.25	0.59	1.16	0.32	3.18	0.51
12	N	1.60	0.42	0.46	0.20	3.13	0.62	2.99	0.36	1.33	0.38
12	D	0.85	0.33	0.71	0.44	2.33	0.69	0.76	0.23	2.45	0.92
11	O	0.69	0.35	0.47	0.29	1.48	0.29	0.76	0.17	1.39	0.15
11	N	0.76	0.38	1.19	0.74	2.45	0.49	1.15	0.63	2.57	0.86
11	D	1.81	0.65	0.83	0.50	2.70	0.30	2.88	0.42	2.23	0.84
11	N	0.57	0.34	0.05	0.05	1.52	0.73	0.58	0.16	1.00	0.15
11	D	2.19	0.33	1.00	0.49	3.69	0.41	3.57	0.31	2.69	0.55
10	O	0.32	0.25	0.11	0.14	1.65	0.76	0.49	0.09	1.17	0.23
10	N	0.66	0.37	0.16	0.21	2.69	0.38	2.81	0.51	0.55	0.14
10	D	0.58	0.26	0.48	0.29	2.45	0.41	1.70	0.34	2.10	0.33
10	N	1.26	0.36	0.60	0.38	2.27	0.55	2.06	0.28	2.32	0.73
10	D	0.71	0.39	0.52	0.27	1.99	0.74	0.60	0.16	1.03	0.24
9	O	1.30	0.50	2.12	0.30	2.44	0.67	1.57	0.26	1.95	0.22
9	N	0.36	0.27	0.27	0.27	2.10	0.97	0.56	0.25	0.61	0.22
9	D	1.45	0.53	0.73	0.40	4.07	0.42	2.68	0.32	1.35	0.16
9	N	0.89	0.43	0.37	0.36	2.36	0.51	1.16	0.17	0.92	0.33
9	D	1.03	0.37	0.56	0.30	2.21	0.29	2.09	0.24	2.91	0.27
8	O	0.95	0.42	0.39	0.24	2.42	0.48	1.77	0.21	1.45	0.25
8	N	0.82	0.25	0.70	0.29	2.13	0.22	1.21	0.27	2.43	0.50
8	D	0.87	0.40	0.51	0.13	2.73	0.43	2.03	0.27	3.65	0.89
8	N	0.77	0.26	0.83	0.31	2.73	0.30	2.25	0.46	1.26	0.51
8	D	1.45	0.42	0.54	0.33	2.84	0.38	1.88	0.28	1.46	0.24
7	O	0.71	0.24	0.51	0.19	2.55	0.47	1.71	0.25	1.48	0.39
7	N	0.84	0.42	0.47	0.46	2.40	0.88	1.32	0.37	0.84	0.32
7	D	1.32	0.64	0.47	0.43	3.21	0.51	2.12	0.20	0.56	0.24
7	N	0.54	0.39	0.43	0.47	2.10	0.69	1.06	0.15	0.99	0.48
7	D	1.52	0.35	0.37	0.31	2.85	0.45	2.53	0.25	2.70	0.43
Mean of O		0.80		0.66		2.05		1.20		1.48	
Mean of N		0.81		0.54		2.39		1.62		1.43	
Mean of D		1.20		0.59		2.78		2.00		2.19	

^aO=Orthodontic; N=Normal; D=Deviant

The anterior temporalis contracts when the back teeth are approximated in a normal bite. This muscle does not contract when the mandible is protruded and only the anterior incisors are approximated. This muscle was tested for its possible contribution to keeping the teeth together during the act of swallowing.

Measurements of anterior temporalis muscle activity were obtained on twelve swallows in four sets of three swallows for each group of twelve children. Information concerning the integrated voluntary muscle energy output per group of children per swallow for the temporalis is presented in Table 2. The table identifies the groups of normal and deviant swallowers, and gives the group means and standard deviation for each swallow and the grand means and standard deviations for the twelve swallows per group.

The mean voluntary muscle energy output for the normal swallowers was 0.53 millivolts per millimeter with a standard deviation of 0.31. The mean output for the deviant swallowers was 0.59 millivolts with a standard deviation of 0.18. An F-ratio obtained by an analysis of variance indicated that the difference between these two means was not significant.

Although not significant, it must be noted that the deviant swallowers did exert somewhat more voluntary muscle activity with the temporalis muscle than did the normal swallowers for the twelve swallows (see Figure 1). Also of interest is the obvious variation in the mean muscle energy output from swallow to swallow which was observed in both groups. There is an increase in energy output for the last three swallows in both groups. There is the possibility that muscle energy output was due to the child becoming "full" of water resulting in more effort to swallow, thus recruiting more muscle motor units.

Table 2. Electromyographic data: Means and standard deviations, expressed in millivolts, of the voluntary muscle energy output of the Temporalis muscle expended by normal and deviant swallowers during each of twelve swallows.

No. of Swallow	Normal Swallowers N = 12		Deviant Swallowers N = 12	
	Mean	S.D.	Mean	S.D.
1	0.28	0.22	0.41	0.16
2	0.35	0.28	0.34	0.18
3	0.43	0.46	0.39	0.18
4	0.33	0.31	0.41	0.21
5	0.28	0.23	0.43	0.32
6	0.42	0.45	0.49	0.23
7	0.51	0.38	0.35	0.18
8	0.46	0.39	0.54	0.35
9	0.66	0.68	0.43	0.13
10	0.95	0.61	1.02	0.35
11	0.84	0.39	1.25	0.38
12	0.92	0.47	1.08	0.29
Grand Means and Stand. Dev.	0.54	0.31	0.59	0.18

F-ratio: 0.25; Not significant

Figure 1. Group means, expressed in millivolts, of the voluntary muscle energy output of the Temporalis muscle expended by groups of normal and deviant swallowers for each of twelve swallows.

The masseter, another muscle of mastication which contracts when the teeth are approximated, was tested. The amount of contraction is directly related to the intensity of the bite (Hamilton, Lockhart, and Fyfe, 1960, pp. 156-157). A sign of normal swallowing is said to be a contraction of the masseter muscle throughout the swallow, while in deviant swallowing the lack of same is said to occur.

Measurements of the masseter muscle energy output for twelve swallows in four sets of three swallows were obtained for each group. The means and standard deviations of the electromyographic integrated data for the masseter muscle per swallow for each group is presented in Table 3. The Table gives the numbers of the swallows for the total group, and the standard deviation of the group for that swallow. Also given is the grand mean and standard deviation for the entire group for the twelve swallows.

The mean voluntary muscle energy output for the normal group was 0.81 millivolts per millimeter with a standard deviation of 0.31 millivolts. The mean for the deviant group was 1.20 millivolts per millimeter with a standard deviation of 0.48 millivolts. The F-ratio for the significance of the difference between the means of the normal and deviant swallows was found to be 9.29 which is significant beyond the .01 level.

The preceding would appear to indicate that the deviant swallows use significantly more voluntary masseter muscle energy during swallowing than do the normal swallows. The Figure 2 indicates the differences found per swallow for each group. The graph clearly depicts the increased energy output by the deviant swallows. At no time did the amount of voluntary muscle energy output during swallowing approach that indicated during biting for both groups.

Table 3. Electromyographic data: means and standard deviations, expressed in millivolts, of the voluntary muscle energy output of the Masseter muscle expended by normal and deviant swallows during each of twelve swallows.

No. of Swallow	Normal Swallows N = 12		Deviant Swallows N = 12	
	Mean	S.D.	Mean	S.D.
1	1.05	0.27	1.46	0.52
2	1.05	0.31	1.49	0.60
3	1.15	0.32	1.48	0.62
4	1.12	0.32	1.51	1.44
5	1.09	1.31	1.53	0.52
6	1.09	1.45	1.54	0.51
7	0.54	0.39	0.66	0.29
8	0.47	0.32	0.79	0.52
9	0.54	0.39	0.83	0.46
10	0.58	0.46	1.03	0.75
11	0.56	0.52	1.08	0.69
12	0.52	0.45	1.03	0.64
Grand Means and Stand. Dev.	0.81	0.31	1.20	0.48
F-Ratio: 9.29; significant at the .01 level.

Figure 3. Group means, expressed in millivolts of the voluntary muscle energy output of the Masseter muscles expended by groups of normal and deviant swallowers for each of twelve swallows.

Of note is the sharp drop in muscle energy output between the sixth and seventh swallows. Notable is the finding that both groups dropped in muscle activity on the seventh swallows. No reasoned explanation for the drop can be found. There is the possibility that the drop was due to a fatigue factor or an adaptation effect. Another possibility is that there may have been a drop in the number of muscle motor units employed indicating less recruitment of motor units.

Suprahyoid muscle activity is said to be directly related movement of the hyoid bone. This muscle group contracts during the act of swallowing which causes the hyoid bone to move upward and anteriorly. After swallowing, the hyoid bone resumes its normal level. The activity of this muscle group as it might be related to deviant and normal swallowing has not been measured electromyographically prior to this study.

Suprahyoid muscle activity was measured during twelve swallows for each child. The means and standard deviations of the electromyographic integrated energy output per swallow for the two groups are presented in Table 4. Again the Table gives the number of swallows in sequence and the mean energy output and standard deviations for the total group for each swallow, and the grand means and standard deviations for the twelve swallows for the two groups.

Table 4. Electromyographic data: means and standard deviations, expressed in millivolts, of the voluntary muscle energy output of the Suprahyoid muscles expended by normal and deviant swallows during each of twelve swallows.

No. of Swallow	Normal Swallowers N = 12		Deviant Swallowers N = 12	
	Mean	S.D.	Mean	S.D.
1	1.62	0.92	2.08	0.79
2	1.89	0.90	2.30	1.14
3	1.72	0.95	2.45	1.10
4	2.41	0.39	2.80	0.61
5	2.55	0.39	2.95	0.65
6	2.48	0.47	3.01	0.55
7	2.68	0.45	2.84	0.51
8	2.69	0.35	3.01	0.55
9	2.85	0.84	2.93	0.56
10	2.78	0.41	2.79	0.46
11	2.55	0.25	2.86	0.40
12	2.49	0.28	2.87	0.58
Grand Means and Stand. Dev.	2.39	0.40	2.74	0.59
F-Ratio: 5.60; significant at the .05 level

Figure 3. Group means, expressed in millivolts, of the voluntary muscle energy output of the Suprahyoid muscles expended by groups of normal and deviant swallowers for each of twelve swallows.

Table 5. Electromyographic data: means and standard deviations expressed in millivolts, of the voluntary muscle energy output of the Infrahyoid muscles expended by normal and deviant swallows during each of twelve swallows.

No. of Swallow	Normal Swallowers N = 12		Deviant Swallowers N = 12	
	Mean	S.D.	Mean	S.D.
1	1.64	0.81	1.96	0.89
2	1.61	0.80	2.14	1.02
3	1.62	0.91	2.23	0.91
4	1.52	0.88	1.80	0.78
5	1.55	0.76	1.97	1.00
6	1.81	1.00	2.08	0.87
7	1.53	0.71	1.83	0.76
8	1.64	0.93	2.06	0.75
9	1.67	0.99	2.00	0.96
10	1.69	0.85	1.95	0.80
11	1.54	0.79	1.98	0.78
12	1.60	0.90	1.98	0.89
Grand Means and Stand. Dev.	1.62	0.79	2.00	0.84
F-ratio: 79.32 significant at the .005 level				

Table 6. Electromyographic data: means and standard deviations, expressed in millivolts, of the voluntary muscle energy output of the Orbicularis oris muscle expended by normal and deviant swallows during each of six swallows.

No. of Swallow	Normal Swallowers N = 12		Deviant Swallowers N = 12	
	Mean	S.D.	Mean	S.D.
1	1.46	0.72	2.26	1.13
2	1.28	0.75	2.34	1.02
3	1.37	0.68	2.31	1.12
4	1.71	1.09	1.95	0.82
5	1.60	1.14	2.12	1.01
6	1.14	0.56	2.18	1.05
Grand Means and Stand. Dev.	1.43	0.72	2.19	0.94
F-Ratio: 55.19; significant at the .005 level.

Figure 4. Group means, expressed in millivolts, of the voluntary muscle energy output of the Infrahyoid muscles expended by groups of normal and deviant swallowers for each of twelve swallows.

Figure 5. Group means, expressed in millivolts, of the voluntary muscle energy output of the Orbicularis oris muscle expended by groups of normal and deviant swallows for each of six swallows.

The F-ratio for the significance of the difference between the means of the normal and deviant swallowers was found to be 5.60, significant at the .05 level.

The preceding would appear to indicate that the deviant swallowers use significantly more suprahyoid muscle activity during swallowing than do normal swallowers. Figure 3 shows the differences found per swallow per group. Noticeable is the somewhat parallel energy output of the two groups.

To measure the activity of the thyro-hyoid musculature, which is responsible for the movement of the larynx, electrodes were placed just above the wings of the thyroid cartilage. It was not possible to specify exactly which muscle or muscle groups were measured by these electrodes. Whether or not electromyographic data was gathered from the thyro-hyoid ligament cannot be stated with certainty. The electrodes were deliberately not placed parallel to the muscle fibres of the superior belly of the omohyoid or over the thyro-hyoid muscle. In placing the electrodes, an attempt was made to assess, electromyographically, what one feels when a finger is placed just above the thyroid cartilage and its movement palpated. Variations in the activity of this muscle group may be another sign for deviant or normal swallowing which has not been measured electromyographically prior to this study.

Measurement of infrahyoid muscle activity during twelve swallows was obtained for each child. Information concerning the means and standard deviations of electromyographic tracings per swallow per group is presented in Table 5. The Table gives the number of the swallows in sequence, and the mean and standard deviation for the total group for each swallow.

The mean voluntary muscle energy output for the infrahyoid muscle group for the normal swallowers was found to be 1.62 millivolts per millimeter with a standard deviation of 0.79. The deviant swallowers had a mean voluntary muscle energy output of 2.00 millivolts per millimeter with a standard deviation of 0.84. An analysis of variance to test the significance the difference between the means revealed an F-ratio of 79.32 which is significant beyond the .005 level.

The preceding would appear to indicate that the deviant swallowers in this study used significantly more infrahyoid voluntary muscle activity during the act of swallowing than did the normal swallowers. Figure 4 shows the difference between the two groups. The graphs are parallel with somewhat the same contour from swallow to swallow.

The orbicularis oris muscle is a sphincter muscle around the mouth. Evidence of a contraction of this muscle is thought to be diagnostic of deviant swallowing. Normal swallowers are said to use no orbicularis oris contraction.

Measurement of orbicularis oris muscle activity for the swallows in two sets of three swallows was obtained for each child. The means and standard deviations of electromyographic data of the orbicularis oris muscle per swallow for each group is presented in Table 6.

The mean voluntary muscle energy output for the orbicularis oris muscle for the normal group was 1.43 millivolts per millimeter with a standard deviation of 0.72. The mean for the deviant swallowers was found to be 2.19 millivolts per millimeter with a standard deviation of 0.94. The F-ratio for the significance of the difference between the means of the normal and deviant swallowers was found to be 55.19 which is significant beyond the .005 level.

The preceding would appear to indicate that the deviant swallowers in this study

used significantly more orbicularis oris contraction than did the normal swallows. The Figure 5 displays the differences found for each swallow for the two groups. It is interesting to note that while the graphic representation of muscle energy output clearly indicates that the deviant group used much more orbicularis oris activity during the act of swallowing than did the normal group, the normal swallows also used some orbicularis oris contraction, contrary to what is reported in the literature.

Observation and analysis of the electromyographic tracings of the normal and deviant swallows in this study appeared to suggest certain characteristic patterns. All records were analyzed concerning phase relationships between muscles and muscle groups during swallowing. Representative electromyographs are presented in Figures 6 to 11.

Electromyographic tracings of normal swallows appeared to reveal that:

1. For all subjects suprahyoid and infrahyoid activity occurred simultaneously at the moment of peak activity in the swallowing set.
2. Temporalis and masseter contraction appeared to occur just prior to the swallow. The contraction was not always sufficient intensity to record. In all cases where there was contraction, it always occurred just before the peak activity of the supra- and infrahyoid muscle activity.
3. In none of the normal swallows were there indications of temporalis or masseter contraction following the peak activity which indicated that the swallow had occurred.
4. Activity of the orbicularis oris muscle occurred ahead of the peak activity of the supra- and infrahyoids and then dropped off.
5. Normal swallows had much cleaner or clear-cut tracings, indicating less build-up of muscle activity prior to the swallow. The tracings appeared to indicate a clean approach to swallow activity, a clear-cut swallow and less superfluous muscle activity after the swallow.

The electromyographic tracings of the *deviant swallows* appeared to reveal that:

1. In the majority of cases, (ten of twelve), suprahyoid and infrahyoid peak activity was not simultaneous. There appeared to be suprahyoid contraction prior to the swallow which then decreased and then peaked again during the swallow. There appeared to be considerable "getting-ready-to-swallow" activity in these muscle groups. Suprahyoid activity appeared to occur just prior to infrahyoid activity during the actual swallow.
2. The masseter muscle appeared to contract prior to suprahyoid and infrahyoid peak activity and then declined in activity. It also appeared that the temporalis and masseter tended to contract at or near the end of the swallow. At times it appeared that the temporalis contracted after the suprahyoids had been activated relative to the swallow.
3. Deviant swallows had electromyographs which were full of excessive activity. This activity appeared to occur both before and after the swallow. The patterns were not as clear-cut or decisive as those of normal swallows.

On the basis of the total electromyographic findings, there appear to be many more characteristics of normal and deviant swallowing which can be assessed for diagnostic purposes than have previously been reported. Of particular interest is the preceding

analysis of the electromyographic tracings which seems to indicate that the phase relationships of the various muscle groups involved, as they participate in the overall activity, may also be of diagnostic value.

Summary

The findings reported in this investigation appear to indicate that normal swallowing is a synchronous, precise behavior that utilizes some muscle energy output in all muscles of concern. Deviant swallowing is not only a habitual thrusting of the tongue anteriorly through or against a deviant dental configuration, but also appears to be a disarranged, asynchronous pattern utilizing more muscle energy output in all muscles of concern than in normal swallowing.

If the samples of subjects used in this study were representative of the populations from which they were selected, and if the research data obtained were also indicative of true characteristics of the problems of concern, then, based on the findings of this study, one may say that there are reliable diagnostic signs, other than the traditional three previously specified, that are indicative of deviant swallowing. An extensive examination of all the signs for normal and deviant swallowing presented in this study, as they appear in the swallow behavior of a given child, should result in a much more reliable decision as to whether the child is a normal or deviant swallower.

Fig. 16. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for a normal swallower, during a sequence of three swallows, reading right to left.

Fig. 17. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for a normal swallower, during a sequence of three swallows, reading right to left.

Fig. 18. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for a normal swallower, during a sequence of three swallows, reading from right to left.

Fig. 19. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for a deviant swallower, during a sequence of three swallows, reading right to left.

Fig. 20. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for a deviant swallower, during a sequence of three swallows, reading right to left.

Fig. 21. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for a deviant swallower, during a sequence of three swallows, reading right to left.

Fig. 22. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for an orthodontic swallower, during a sequence of three swallows, reading right to left.

Fig. 23. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for an orthodontic swallower, during a sequence of three swallows, reading right to left.

Fig. 24. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles involved in swallowing, for an orthodontic swallower, during a sequence of three swallows, reading right to left.

Fig. 25. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles, for a normal swallower, during a series of three bites and three tight lip approximations.

Fig. 26. Electromyographic tracings (A) and integrated muscle energy output (B) for selected muscles, for a deviant swallower, during a series of three bites and three tight lip approximations.

REFERENCES

- Andersen, Wynn S., The Relationship of the Tongue-thrusting Syndrome to Maturation and Other Factors. *Amer. J. Orthodontics*, 49, 264-275 (1963).
- Andrews, R. G., Tongue Thrusting. *J. So. Calif. State Den. Asso.*, 28, 47-53 (1960).
- Barclay, A. E., The Normal Mechanism of Swallowing. *British J. Radiology*, 3, 534-545 (1930).
- Barrett, R. H., One Approach to Deviant Swallowing. *Amer. J. Orthodontics*, 47, 726-736 (1961).
- Basmajian, J. V., *Muscles Alive*. Baltimore: Williams and Wilkins (1967).
- Bell, D. and Hale, A., Observations of Tongue-thrust Swallow in Pre-school Children. *J. Speech and Hearing Dis.*, 28 (2), 195-197 (1963).
- Crosby, E. C., Humphrey, T., and Lauer, E. W., *Correlative Anatomy of the Nervous System*. New York: Macmillan Co. (1962).
- Field, J., Magoun, H. W., and Hall, V. E., *Handbook of Neurophysiology, Vol. II*. Washington, D.C.: Amer. Physiological Soc. (1960).
- Fletcher, S. G., Casteel, R. L., and Bradley, D. P., Tongue-thrust Swallowing, Speech Articulation, and Age. *J. Speech and Hearing Dis.*, 26, 201-208 (1961).
- Gwynne-Evans, E., An Analysis of the Orofacial Structures with Special Reference to Muscle Behavior and Dental Alignment. *Speech*, 16:36, (1952), with deletions in *Amer. J. Orthodontics*, 40, 715-720 (1954).
- Hoffman, J. A. and Hoffman, R. L., Tongue-thrust and Deglutition: Some Anatomical, Physiological and Neurological Considerations. *J. Speech and Hearing Dis.*, 30, 105-120 (1965).
- Jann, G. R., Ward, M. M. and Jann, H. W., A Longitudinal Study of Articulation, Deglutition and Malocclusion. *J. Speech and Hearing Dis.*, 29, 424-435 (1964).
- Lay, T. N., Investigation of Atypical Swallowing Patterns Among Children in Kindergarten Through Eighth Grade. Northwestern Univ., *Unpub. dissertation* (1964).
- Lockhart, R. D., Hamilton, H. F. and Fyfe, F. W., *Anatomy of the Human Body*. Philadelphia: J. B. Lippincott Co. (1960).
- Macleod's *Physiology in Modern Medicine*. Bard, P., (Ed.) St. Louis: C. V. Mosby Co. (1941).
- Palmer, J. M., Tongue Thrusting: A Clinical Hypothesis. *J. Speech and Hearing Dis.*, 27, 323-333 (1962).
- Proffitt, W. R., Chastain, B. B. and Norton, L. A., Linguopalatal Pressure in Children. *Amer. J. Orthodontics*, 55, 154-166 (1969).
- Ray, H. G. and Santos, H. A., Consideration of Tongue Thrusting as a Factor in Periodontal Disease. *J. Periodontology*, 25, 250-256 (1954).
- Rix, R. E., Deglutition and the Teeth. *Dental Record*, 66, 103-108 (1946).
- Shelton, R. L., Displacement of the Pharyngeal Portion of the Tongue and of the Hyoid and Larynx in Deglutition, Phonation and Postural Change. Univ. of Utah, *Unpub. dissertation* (1959).
- Stepovich, M. L., A Cephalometric Positional Study of the Hyoid Bone. *Amer. J. Orthodontics*, 51, 882-899 (1965).
- Ward, M. M., Malone, H. D., Jann, G. R. and Jann, H. W., Articulation Variations Associated with Visceral Swallowing and Malocclusion. *J. Speech and Hearing Dis.*, 26, 334-341 (1961).
- Whillis, T. W., Movements of the Tongue in Deglutition. *Tr. Brit. Soc. Study Orthodontics*, 121 (1946).