A STUDY ON THE BILATERAL SYMMETRY OF MYOELECTRIC SIGNALS OF ANTERIOR TEMPORAL AND MASSETER MUSCLES DURING CHEWING

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I. INTRODUCTION

Mastication-the most important physiological movement of functional mandibular movements-is a periodic, autonomic and reflex-like activity produced by the cooperation of stomatognathic structural elements and central nervous system[1].

The mechanical digestion of food is the principal function of mastication and this activity helps the normal development of facial skeleton,[2] the relaxation of maxillofacial musculature and mental appeasement[3].

The alternate contractions of the elevators and the depressors produce mastication. The successive elevation of mandible during closure is the integral part of masticatory activity and a typical mandibular movement generated by the synergistically coordinated movements[1]. The masseter operates as a principal masticatory muscle and the temporal muscle operates as a powerful mandibular elevator in cooperation with masseter and internal pterygoid muscles, also the fibers of each parts stabilize mandible horizontally by contracting simultaneously.

The form of occlusion has the greatest influence on the pattern of mastication and several masticatory centers of central nervous system programmed by occlusal factors control masticatory movement through the neuromuscular mechanism[4-11].

Electromyography(EMG) is the most widespread method of researching the masticatory muscles activity. EMG-wave record of electronically induced and amplified myoelectric signals produced during muscle contraction-is extensively used to diagnose and treat the muscle disease, to evaluate the treatment outcome and to study neurophysiology.

Myoelectric signal is an intricate signal system that is affected by neuroanatomical characteristics of muscles, reflex of peripheral nervous system and the form and usage of recording apparatus.

In the fields of clinical dentistry analyzing the

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characteristics of myoelectric signals is used to diagnose and treat the muscle disease of maxillofacial region including TMD and to judge the improvement of muscle function after the treatment.

Clinically integration analysis method and frequency analysis method are used for quantitative analyses of myoelectric signals. Integration analysis method is used for measuring the degree of muscle activity and frequency analysis method is for measuring the amount of muscle fatigue.

Integration analysis method is an analysis of integrating and quantifying mathematically as well as electronically through induction, amplification and recording of myoelectric signals which are produced during muscle contraction. This method has been used for finding the interrelation between muscle contration and muscle activity. Jankelson,[12] Haraldson et al.[13] studied maticatory muscle activity during voluntary isometric contraction. In addition, Hannam et al.,[14] Moss et al.,[8] Tawa[15] and Mushimoto et al[16]. studied masticatory muscles activity during mastication.

Frequency analysis is the method of displaying probability density function with each size of frequency after dissolving wave form and signals into each frequency components and of finding characteristics of wave form and signal by finding the their regular periodicity. This method has been widely used to research the degree of muscular fatigue. Among frequency analysis methods, the power spectrum analysis method has been most frequently used and by using this many researchers have proved the fact that the power spectrum of myoelectric signals is compressed from a high frequency range to a low frequency range accompanied by a sustained muscle contraction.[17]

In the power spectrum analysis, mean frequency and median frequency are used for parameters. There is a report that mean frequency is affected by random wave more than median frequency[18]. Slope of median frequency calculated by linear regression analysis is used for parameter that shows the shift into low frequency range of the power spectrum. Palla and Ash,[19] Naeije[20] and Van Boxtel et al.[17] have reported that the power spectrum moves into low frequency range when the muscle is fatigued.

Though muscle activity and muscle fatigue have been studied chiefly during clenching, the judgement of masticatory muscle activity during dynamic functions is also very important to evaluate the health of stomatognathic system.

EMG recorded during masticatory movement reflects the isotonic and isometric contraction of several masticatory muscles under variable conditions. As mastication is a very complex physiological movement and stomatognathic system contains plasticity, many studies about the quantitative analysis of masticatory muscles activity show various results. But the integrated EMG value during mastication may be used for parameter of muscle activity if the research uses subjects who have normal occlusion, maintains constant chewing velocity within the normal range that does not make sudden change in muscle fiber length and if standardizes other experimental methods[9] [15]. Ahlgren[21] reported the interrelation between activities of masseter and anterior temporal muscles and masticatory movement in the study of homogeneous gum chewing.

Just as there are general preferred sidenesses in human body activities, there is also a preferred chewing sideness caused by various reasons in masticatory movement. Pond[22] reported that there existed chewing side preference in 78 % of the subjects. This fact may affect developments, balances and functional activities of right and left masticatory muscles, so it must be seriously considered when muscle function is diagnosed.

This research intended to study the bilateral symmetry of masticatory muscles that varies with chewing form and to inspect the reliability of experiment by measuring and analyzing myoelectric signals which are produced at principal masticatory muscles—anterior temporal and masseter muscles—during various chewing methods by using EMG.

II. MATERIALS AND METHODS

Subjects

Twenty seven students at the dental college of Seoul National University who did not have any history or symptoms of craniomandibular disorders(CMD) and had normal occlusion have participated in the present study. They were 14 male students and 13 female students aged from 22 to 29(24.4±1.3).

Recording apparatus

EMG system that was used to record and analyze the myoelectric signals is "SCU−1" which is composed of EMG computer, EMG scope, and EMG monitor. This system has abilities to calculate the integrated EMG, the median frequency, and slope of median frequency(SMF).

Recording procedure

Subjects were seated upright on the dental chair with head rest adjusted to parallel the FH plane to the floor. After placing bipolar Ag−AgCl surface EMG electrodes on the position of anterior temporal and masseter muscles according to method of Jankelson and Pully,[12] myoelectric signals were recorded.

In the present study, chewing gum was used as experimental medium. To obtain the inherent physical characteristics of gum subjects were made to chew a piece of gum for five minutes with least chewing force. In between each experimental session subjects had rests for 5 minutes.

At habitual chewing method, subjects were made to chew a piece of gum for 1 minute as their natural chewing habits, and myoelectric signals were recorded during the last 30 seconds.

At metronme-paced bilateral chewing method, 2 pieces of gums of same amount were placed on the right and left molar areas, subjects were made to chew 2 piece of gums for 1 minute with rhythm of metronome set at 60/min., and myoelectric signals were recorded during the last 30 seconds.

At metonome-paced right side chewing method a piece of gum was placed on the right molar area, subjects were made to chew a piece of gum for 1minute with the rhythm of metronome set at 60/min, and myoelectric signals were recorded during the last 30 seconds. At metronome-paced left side chewing, the methods are same as metronome-paced right side chewing with the single exception of sideness.

To confirm the reliability of this experiment and EMG system same experiment was done with the 19 subjects selected randomly 6 months later first experiment.

Statistical analysis

All statistical analyses were performed by SPSS/PC+ (Microsoft Co.) in IBM PC., The mean values and standard deviations(S.D.) of the integrated EMG, and the slopes of median frequency were attained. Student T−test and paired T−test were performed to examine the difference between right and left sides, and to examine the difference between first and second experimental results. The regression analysis was performed to evaluate the slopes of median frequency.

III. RESULTS

1. Reliability

At each chewing methods, results of first experiment showed no statistically significant difference with the results of second experiment in all values of parameters of anterior temporal and masseter muscles, which shows high reliability of this experiment.

Table 1. Results for the reliability of studies, comparing two results of lst and 2nd EMG examination at various chewing.

	Integrated EMG					Slope of median frequency				
	First		Second		Sig.	First		Second		Sig.
	Mean	S. D.	Mean	S. D.		Mean	S. D.	Mean	S. D.	
Habitual chewing										
Lt. Temp.	93.7	24.2	102.1	19.2	N. S.	.15	.45	.20	.51	N. S.
Lt. Mass.	97.9	31.7	99.8	18.3	N. S.	.14	.87	−.20	1.25	N. S.
Rt. Temp.	103.0	28.5	106.0	21.7	N. S.	.05	.58	.16	.51	N. S.
Rt. Mass.	116.6	45.0	111.5	23.2	N. S.	−.04	.86	.12	1.02	N. S.
Metronome−paced chewing with both side										
Lt. Temp.	104.5	31.2	109.7	31.5	N. S.	.03	.23	−.11	.59	N. S.
Lt. Mass.	110.8	31.7	109.3	20.2	N. S.	.00	.33	.03	.38	N. S.
Rt. Temp.	105.4	25.5	109.9	27.4	N. S.	.09	.26	−.10	.41	N. S.
Rt. Mass.	118.4	40.7	114.6	27.1	N. S.	−.02	.35	.22	.60	N. S.
Metronome−paced chewing with rigth side										
Lt. Temp.	92.4	21.8	99.0	15.5	N. S.	−.04	.34	−.15	.80	N. S.
Lt. Mass.	90.4	43.3	93.2	14.6	N. S.	−.15	67	−.51	1.14	N. S.
Rt. Temp.	110.7	38.9	111.2	20.6	N. S.	−.06	.28	−.35	.84	N. S.
Rt. Mass.	125.8	34.5	118.1	18.2	N. S.	−.00	.34	−.08	.73	N. S.
Metronome−paced chewing with left side										
Lt. Temp.	105.4	35.2	108.1	27.9	N. S.	−.02	.26	.12	.69	N. S.
Lt. Mass.	121.8	36.8	115.8	23.4	N. S.	.05	.25	.23	.51	N. S.
Rt. Temp.	96.2	19.8	103.2	20.6	N. S.	−.14	.19	.19	.67	N. S.
Rt. Mass.	96.6	25.4	93.3	18.1	N. S.	−.09	.45	.16	.79	N. S.

N.S. : not significant

2. Bilateral symmetry of Integrated EMG at each chewing methods

At habitual chewing method, right anterior temporal and masseter muscles all showed higher integrated EMG value than those of left side(table 2).

At metronome-paced bilateral chewing method, right masseter muscle showed higher integrated EMG value than that of left side but anterior temporal muscle did not show statistically significant bilateral difference(table 3).

At metronome-paced right side chewing method, the integrated EMG values of right anterior temporal and masseter muscles were significantly higher than those of left side(table 4).

At metronome-paced left side chewing method, the integrated EMG value of left masseter muscle was significantly higher than that of right side, but anterior temporal muscle did not show any statistically significant bilateral difference(table 5).

At all chewing methods, the slopes of median frequency did not show any significant bilateral difference.

Table 2. The integrated EMGs and the slpoe of median frequencies in comparison with right side to left side at habitual chewing.

		Left		Right		Sig.
		Mean	S. D.	Mean	S. D.	
IEMG	Ant. Temp.	84.0	15.8	90.5	14.1	*
	Masseter	101.5	30.7	116.4	44.6	*
SMF	Ant. Temp.	.10	.43	.01	.54	N. S.
	Masseter	.13	.88	−.13	.77	N. S.

IEMG : Integrated EMG
SMF : Slope of median frequency

N. S. : not significant
* : $p<0.05$

Table 3. The integrated EMGs and the slpoe of median frequencies in comparison with right side to left side at metronome-paced both side chewing.

		Left		Right		Sig.
		Mean	S. D.	Mean	S. D.	
IEMG	Ant. Temp.	90.3	17.6	92.9	14.3	N. S.
	Masseter	108.8	30.0	119.5	39.1	*
SMF	Ant. Temp.	−.02	.29	.03	.29	N. S.
	Masseter	−.00	.44	−.07	.47	N. S.

IEMG : Integrated EMG
SMF : Slope of median frequency

N. S. : not significant
* : $p<0.05$

Table 4. The integrated EMGs and the slpoe of median frequencies in comparison with right side to left side at metronome-paced right side chewing.

		Left		Right		Sig.
		Mean	S. D.	Mean	S. D.	
IEMG	Ant. Temp.	84.0	14.1	93.4	10.3	*
	Masseter	92.2	38.8	128.9	37.9	*
SMF	Ant. Temp.	−.09	.38	−.04	.31	N. S.
	Masseter	−.14	.62	−.00	.36	N. S.

IEMG : Integrated EMG
SMF : Slope of median frequency

N. S. : not significant
* : $p<0.05$

Table 5. The integrated EMGs and the slpoe of median frequencies in comparison with right side to left side at metronome—paced left side chewing.

		Left		Right		Sig.
		Mean	S. D.	Mean	S. D.	
IEMG	Ant. Temp.	91.0	14.6	85.9	9.8	N. S.
	Masseter	119.7	33.4	99.1	27.9	*
SMF	Ant. Temp.	−.02	.30	−.13	.25	N. S.
	Masseter	.03	.27	−.07	.45	N. S.

IEMG : Integrated EMG
SMF : Slope of median frequency

N. S. : not significant
* : $p<0.05$

3. Slopes of median frequency at each chewing method

At all chewing methods, the slopes of median frequency of anterior temporal and masseter muscles did not show any significant bilateral differnce.

Table 2,3,4,5 show the mean values and standard deviations of slopes of median frequency of right and left anterior temporal and masseter muscles as to the chewing methods.

Ⅵ. DISCUSSIONS

In the field of clinical dentistry, myoelectric signals from contracting muscles are measured and analyzed to diagnose objectively the maxillofacial muscles and head & neck muscles.

Integration analysis method and frequency analysis method are used for the quantitative analyses of myoelectric signals. Integration analysis method is used to evaluate the interrelation between muscle contraction and the degree of muscle activity, while frequency analysis method is used to evaluate the degree of muscular fatigue.

In the present study, the myoelectric signals of right and left anterior temporal and masseter muscles during habitual chewing, metronome—paced bilateral chewing and metronome—paced left and right sides chewing were measured and analyzed to calculate the intergrated EMG value and the value of slope of median frequency.

In the presecnt study, the activities of masseter muscles were significantly higher than those of anterior temporal muscles at all the four chewing methods. This fact corresponds to the research of Wood[7] and Vitti[23] who reported the fact that the masseter is the principal masticatory muscle and works chiefly during chewing hard foods and maximum clenching.

In the present study during habitual chewing, integrated EMG values of both right masseter and right anterior temporal muscles were significantly higher than those of left side. During bilateral chewing with the rhythm of the metronome, integrated EMG value of the right masseter muscle was noticeably higher than that of the left side, while there was no significant difference in anterior temporal muscles. This fact is similar to the research of Lee[24] and Chung[25] who reported that the muscle which most frequently caused pain in the subjects was right masseter muscle and the degree of muscular fatigue of the right masseter muscle was the highest.

Though there is little theoretical ground for explaining this result, the functional and morphological asymmetry is a common phenomenon which can be found in animal kingdom. Keller[26] affirmed that the side prefernce is a prehuman characteristic, that right or left side preference is existed in all animal kingdom and that the right side preference is superior to the left in primates. He also affirmed that the functional asymmetry in all creatures is a part of morphological asymmetry. There are various opinions about the time when the preference occurred. Gesell[27] claimed that at about 18 months, approximately the same time when language function begins in humans, manual dominance begins to become differentiated.

In Subirana's[28] left and right hand preference research, 271 random subjects were measured. Of those subjects 24.4% were purely righthanded;16.6% were weakly right hand predominant;10.3% were weakly left hand predominant;9.9% were strongly left hand predominant;and there were no purely lefthanded subjects. Bryden[29] and Roberts[30] claimed that righthanded preferance is superior because of cross regulation produced by decussation of pyramid and the general dominance of left cerebral hemisphere.

Barcia[31] have found the morphological difference in right and left temporal lobes, but Von Bonin[32] drew a conclusion that the morphological difference in right and left cerebral hemispheres is insufficient in explaining the functional differnce. Bodian[33] conducted a cellular organization analysis of cerebral cortex by using an electronic microscope, and Subirana[28] suggested the difference of motor integration that can not be found in histological research.

Recently, electroencephalographic reseacrch has become quite popular for the purpose of examining the difference in right and left cerebral hemispheres. Cornil[34] confirmed that the alpha wave amplitude of the right cerebral hemisphere was wider than that of the left cerebral hemisphere in his examination of 120 righthanders. Subirana[28] found that the alpha waves of righthanders were more organized than those of lefthanders, and claimed that there is a difference in cerebral maturation.

Many scholars have found that most lefthanders were found in abnormal groups. Gordon[35] distinguished natural lefthanders from pathological lefthanders. He found that the pathological lefthanders had many mental disabilities and hypothesized that this resulted from the lesion of the left cerebral hemisphere.

These kinds of body side preference can be observed by analyzing other parts of the body as well as the hand. Oller[36] reported that equal interrelation between handedness and footedness is found in right—handed people. Bryden[29] reported that there is a significant interrelation between right—left visual difference and preferred handedness.

Chewing movement is also under the opposite control of cerebral hemisphere by decussation of pyramid. Also chewing center which is in cerebral hemisphere controls very elaborate mastication movement, and chewing centers which are in limbic system etc. participate in the unconscious chewing movement.

In the present study 13 out of the 27 subjects showed the preference of right side chewing habits;4 showed the preference of left side chewing habits;and the other 10 did not show any noticeable preferred side of chewing.

The reasons for the habit of chewing side preference may be theorized as follows:1. occlusal discrepancies such as premature contacts,[37], lateral interferances,[4] the difference of right and left occlusal vertical dimensions 2. dental caries 3. periodontal diseases etc.

Though there are not so many reports about the definite interrelation between preferred chewing side and occlusion, Beyron[38] claimed that the preferred side of chewing is where the teeth contact more frequently during lateral excursion than the other side, that is where there are more frequent working side contacts than the other side. Pond[22] reported that 78% of his subjects had preferred chewing side, but did not find out the significant interrelation with any occlusal interferences.

The decisive elements of chewing patterns form are efferent signals from occlusal form, masticatory muscles and the TMJ[39].

Steiner[1] reported that chewing pattern of particular subject would always reflex the individual's attempt to achieve the maximum effect with minimum effort. And Wood[6] reported that the beginning time of chewing cycle, amplitude and frequency relate to the form of occusion, and occlusal morphology has close relationship with mandibular movement during the last few millimeters of the closing cycle. Moller[4] affirmed that the pattern of elevater relates to the stability of occlusion, and that the typical unilateral pattern of masseter muscle implies the occlusal contacts on the balancing side. Alsto Ahlgren[40] demonstrated that the person who had centric prematurity of balancing cuspal interferance showed chopping masticatory stroke, and that the muscle activities in normal groups were higher than those of abnormal groups. Moss[8] reported that the normal occlusion and the abnormal occlusion could be differentially diagnosed by EMG. Koibuchi[37] reported that premature contact which made experimentally reduced the degree of the contralateral muscle activity during maximum clenching, ant that it induced large muscle activity of ipsilateral elevator during unilateral chewing. Baba[41] reported that when the occlusal interference on the balancing side existed the temporal muscle activity of working side during chewing increased, and that when sugject was chewing gum on the working side the occlusal phase extended and the degree of muscle activity increased. And Nishigawa[42] reported that the change of occlusal contact points induces the change of mandibular border movemen as well as masticatory movement, and that the interference of balancing side weakens the degree of elevator muscle activity of non-chewing side.

In the present study, the muscle which had the most predominant integrated EMG value during metronome-paced unilateral chewing was the chewing side masseter muscle, and the masseter muscle of non-chewing side followed it, This fact is similar to the result of the research of Mushimoto et al.[16], according to them the masserer muscle activity of chewing side during unilateral chewing came to strengthen, and the degree of the opposite masseter muscle activity came to weaken. But the individual difference could be clearly observed when right and left temporal muscles were compared.

As powerful mandibular elevators, temporal muscles, synergy with masseter muscles and medial pterygoid muscles, and the fibers of each parts stabilize the horizontal position of mandible by contracting simultaneously. Masticatory movement results from the synergistical coordination of several jaw muscles. Kawabata[43] suggested that the mode of masticatory movement could be classified from the viewpoint of EMG coordination patterns.

These results are opposed to the result of researches of Kydd[4] and Choy[45] who reported that the degree of the contralateral masseter muscle activity was higher than that of ipsilateral masseter muscle of activity during isometric unilateral clenching. Masticatory movement is a compound of isometric contraction, isotonic contraction and relaxation of elevators, while clenching is a result of only isometric contraction movement. During unilateral chewing, chewing side comes to be working side, third-order lever where TMJ of same side operates as fulcrum comes to be formed, so the degree of masticatory muscles activity of chewing side becomes high, and EMG activity of working side masseter muscle is sustained longer as well as is less changeable than that of balancing side[46].

When there is a occulusal interference on the balancing side, second-order lever where working side TMJ operates as fulcrum is formed in masticatory system, so the degree of muscle activity of balancing side comes to be high. During unilateral clenching, since the experimental medium operates as balancing interference and this develope first-order lever where monworking interference operates as fulcrum and the degree of the contralateral masticatory muscles activity comes to be higher than that of ipsilatarat side[47].

The power spectrum analysis among frequency analysis methods is used to research the muscle fatigue. During mascle fatigue from sustained contraction, median fatigue. During mascle fatigue from sustained contraction, median frequency decreases. According to Palla and Ash[48] and Van Boxtel,[17] as temporal muscle contains a lot of type I fibers which are slow twitch oxidative and fatigue resistant, while masseter muscle contains a lot of type II fibers which are fast twitch glycolytic, poorly oxidative and easily fatigured fiber, and temporal is closer to skin than masster, anterior temporal muscle has more high frequency components on power spectrum than masseter muscle has. When the muscle is fatigued, the power spectrum of EMG moves into lower frequency range. This phenomenon can be explained by the decrease of action potential conduction velocity, the synchronization and the recruitment of movement unit. Mortimer[49] reported that the accumulations of lactate and pyruvate which are the metabolic intermediates of anaerobic glycolysis induce the decrease of conduction velocity. Also Jenkins[50] and Rasmussen et al[51]. reported that blood flow obstruction during muscle contraction induces the decrease of conduction velocity. Petrofsky[52] suggested that during the repetitive activation of muscle fiber, the accumulation of extracellular K^+ and the exhaution of Na^+ decreased the conduction velocity by lowering the excitability of membrane of muscle fiber.

The interrelationship of motor unit activity was frequently expressed as motor unit synchronization, and it was suggested that power spectrum moves into low frequency range because the syncronization between motor unit during muscula fatigue increases the duration of action potential of motor unit. Palla and Ash[48] suggested the recruitment theory that the small motor unit is replaced by the large one with sustained contraction. The large motor unit has action potential of high amplitude and longer duration, and then the recruitment by large motor unit leads the power spectrum to shift into low frequency range.

In this research, at the analysis of power spectrum of myoelectric signals of anterior temporal and masseter muscles during various chewing, the slope of median frequeny of anterior temporal and masseter muscles did not show any statistically significant difference between right and left muscles.

This fact means that their is no conspicuously induced muscle fatigue at anterior temporal or masseter muscles during short duration of chewing and slow chewing velocity as such as the the methods of this research. So the power spectrum analysis of myoelectric signals of masticatory muscles during chewing may require enough time of chewing and physiological chewing velocity.

By the way, this research proved the reliability of experiment by the fact that standardizations of the EMG system and methods which were used in this experiment recorded the least interrater discrepancy among researchers, after 19 out of 27 subjects were experimented again 6 months later than first experiment.

In the future study, the functional evaluation of masticatory muscles should consider the judgement of preferred chewing side, the timing of chewing and the chewing velocity of subjects.

V. CONCLUSION

To study the bilateral symmetry of masticatory muscles according to various chewing methods, the author analyzed the myoelectic signals from both anterior temporal and masseter muscles during habitual chewing, metronome-paced bilateral chewing, metronome-paced right and left chewing in twenty-seven normal subjects by using computerzed EMG system.

The author came to the following conclusinos :

1. At habitual chewing, the muscle activities of right anterior temporal and masseter muscles showed significantly higher value than those of left($P<0.05$).
2. At metronome—paced bilateral chewing, the muscular activity of right masseter muscle showed significantly higher value than that of left($P<0.05$), but the muscular activity of anterior temporal muscles showed no significant difference.
3. At metronome-paced right chewing, the muscular activities of right anterior temporal and masseter muscles showed significantly higher value than those of left($P<0.05$).
4. At metronome—paced left chewing, the muscular activity of left masseter muscle showed significantly higher value than that of right ($P<0.05$), but the muscular activities of anterior temporal muscles showed no significant difference.
5. At all chewing methods, the slpe of median frequency of right and left anterior temporal and masseter muscles showed no significant differences.

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저작시 전측두근 및 교근 근전기신호의 좌우균형성에 관한 연구

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<국문초록>

저자는 다양한 저작방법에 따른 전측두근과 교근의 좌우균형성을 규명하기 위하여 정상 성인 27명을 대상으로 습관성 저작시, 양측 규칙 저작시, 우측 규칙 저작시 및 좌측 규칙 저작시에 근활성도와 근전도 power spectrum을 컴퓨터를 이용한 근전도 시스템을 이용하여 분석한 결과 다음과 같은 결론을 얻었다.

1. 습관성 저작시 우측 전측두근 및 교근 모두 좌측에 비하여 높은 근활성도를 보였다($p<0.05$).
2. 양측 규칙 저작시 우측 교근은 좌측에 비하여 높은 근활성도를 보였으나($p<0.05$), 전측두근에서는 좌우측 근활성도의 유의한 차이가 없었다.
3. 우측 규칙 저작시 우측 전측두근 및 교근 모두 좌측에 비하여 높은 근활성도를 보였다. ($p<0.05$)
4. 좌측 규칙 저작시 좌측 교근은 우측에 비하여 높은 근활성도를 보였으나($p<0.05$), 전측두근에서는 좌우측 근활성도의 유의한 차이가 없었다.
5. 저작시 전측두근과 교근의 중간주파수 경사도는 좌우측에서 유의한 차이가 없었다.

주요어 : 근전기신호, 근활성도, 중간주파수 경사도, 좌우균형성