A Study on the Recovery of EMG Power Spectrum and Pressure Pain Threshold of Masticatory Muscles after Sustained Isometric Contraction

Byoung-Cheol Lee, D.D.S., **Eun-Suk Kim**, D.D.S., M.S.D., Ph.D.,
Young-Ku Kim, D.D.S., M.S.D., Ph.D.

Department of Oral Medicine and Oral Diagnosis, College of Dentistry, Seoul National University

- CONTENTS -

Ⅰ. INTRODUCTION

The increased prevalence of chronic pain has caused serious social problems. Chronic pain including headache occurs mostly in head and neck area and especially, craniomandibular disorders (CMD) are the majority of the cases. Though CMD could be classified into tempomandibular joint disorders and muscular pain dysfunction, these joint disorders and muscular pain dysfunction occur together in most cases. Chronic muscle pain is characterized by dull aching pain in the involved muscles, elevated tenderness to palpation, reduced endurance, prolonged recovery and limited or guarded movement when the pain is severe[1].

Parafunction, postural activity and hyperactivity of the masticatory muscles and the consequent muscular fatigue are major causes for pain in the masticatory muscles in myogenous craniomandibular disorders[2,3]. This suggests that habitual clenching of the teeth induce regional pain in the involved jaw muscles. This suggestion are supported by previous studies which reported that experimentally induced muscle contraction of sufficient strength and duration does lead to pain [4,5].

Muscular fatigue has been defined as reduction or vanishment of force generating and sustaining capacity of muscles at the required level in spite of intentional effort[6]. There is another more reasonable opinion that muscle fatigue should be regarded as not one static condition but dynamic course from the onset of activity to the time when force can not be maintained[7]. Recovery from muscle fatigue is a phenomenon that necessarily occurs after fatigue, therefore recovery is considered as a natural counterpart to fatigue[8].

Several studies reported on the characteristics of myoelectric signals in jaw elevator muscles and in other muscles to investigate the mechanism of

*This paper was supported by a grant no. 02-97-237 from the Seoul National University Hospital Research Fund.

muscle fatigue and recovery[8-10,24,31,42]. The electromyography(EMG) is an electronic technique by which the action potentials of contracting muscle fibers and motor units are recorded and displayed, and extensive researches on the characteristics of myoelectric signals have been performed in the field of dentistry for the diagnosis and treatment assessment of myogenous CMD. By evaluating the EMG signals in masticatory muscles, Palla and Ash[11], Sims and Rugh[12], Van Boxtel and Goudwaard[13] and Kim and Lee[14] proved that EMG power spectrum of myoelectric signals is compressed to lower frequency range as muscle contraction is sustained. Van Boxtel et al.[15] and Palla and Ash[16] reported the differences in the power spectrum according to age, gender and the kind of muscles i.e., temporalis and masseter muscles.

Pressure pain threshold(PPT) of muscles and/or subjective pain estimation have been used mainly in measuring pain level or its change in masticatory muscles. Tenderness is one of the most commonly reported signs of myofascial pain and musculoskeletal dysfunction, but the mechanism responsible for tenderness is unknown: it is suspected that type Ⅲ or Ⅳ muscle nociceptors are in some way sensitized to pressure stimuli[17]. Although muscle palpation is the most common method of determining the degree of tenderness, interpretation of results may be difficult due to subjectivity and examiner's bias. For this reason, it is supposed that the measurement of PPT, which means minimum pressure value from which a subject feels pain, is more reliable and accurate method. To determine PPT, many kinds of algometers have been used in the clinical situation. Reeves et al.[18] and Schiffman et al.[19] demonstrated excellent reliability and validity of electronic algometry in evaluating myofacial trigger points. Chung et al.[20,21] studied the intra-examiner and inter-examiner reliability of PPT measurements on normal capsules and muscles of the head and neck region. They also reported validity in evaluating capsulitis.

Several studies have been reported on the recovery of EMG power spectrum in jaw elevating muscles. However, the study which investigated the recovery of EMG power spectrum and PPT simultaneously has not been reported. The author performed the present study to investigate the characteristics of recovery pattern of EMG power spectrum and PPT after sustained isometric contraction in masticatory muscles by use of surface EMG system and electronic algometer.

Ⅱ. MATERIALS AND METHODS

Subjects

Twenty-six subjects, 14 males(24.3±0.8 years) and 12 females(23.4±0.7 years), without past history or present symptoms of pain and discomfort in TMJ and masticatory muscles, fully dentate with normal occlusion and in good health were included in this study. All of the subjects were students at the College of Dentistry, Seoul National University, Seoul, Korea.

Recording apparatus

The EMG system, "SCU-1" developed by Department of Electrical Engineering, Seoul City University, Seoul, Korea was used for recording myoelectric signals. This system could calculate the median frequency(MF) through the power spectrum analysis from recorded myoelectric signals.

A pressure pain threshold meter (strain-gauge type, Electronic Algometer Type Ⅰ, Somedic, Stockholm, Sweden) was applied to the subjects. The instrument consists of a gun-shaped application handle with round rubber tip(diameter

=11mm) and a main body which has a digital display panel, calibration knob, control knob of application rate slope and the patient-operated switch. As the subject press the push button on the patient-operated switch, the digital display stops immediately and then remains for about five seconds with the red light on so the operator can record the value easily.

Recording Procedure

Myoelectric signals were recorded in the left anterior temporal and masseter muscles, and PPT values were measured in the right anterior temporal and masseter muscles of subjects. The subjects were seated in a dental chair with headrest so that Frankfort planes were parallel to the floor. Two channels of EMG activity were recorded simultaneously from the anterior temporal and masseter muscles in left side using bipolar Ag-AgCl surface EMG electrodes placed according to the position described by Jankelson and Pully[22]. In order to estimate the maximum voluntary contraction level(MVC), the subjects were asked to clench three times for 3 s with maximum forces in maximal intercuspal position and the highest value among the three values was defined as the maximum voluntary contraction level in this study. After 5 min rest, the subjects performed a sustained clenching as long as possible at 70% MVC with visual feedback. They exerted brief(3s) contraction at 70% MVC at 20s, 40s, 60s, 120s, 180s, 240s after sustained contraction. During all of the above efforts, surface EMGs from the left anterior temporal and masseter muscles were recorded onto FM tape for later analysis, and were transferred from tape to computer. Data were filtered with a high pass frequency of 5Hz and a low pass frequency of 512Hz and then fed to the computer. The analogue tape signals of all task were digitized at a sampling rate of 1024Hz.

To measure the pressure pain threshod, the examiner applied the tip of the algometer perpendicularly to the right anterior temporal and masseter muscles and increased pressure gradually while maintaining an application rate of 40kPa/sec according to the method described by Chung et al.[21] The subjects were instructed to push the button on the patient-operated switch at the first point of experiencing pain. The displayed digital reading was recorded at this point. Measurements were performed once each time before, immediately after, 10 min, 20 min, 30 min, 40 min, 50 min after the sustained isometric contraction.

Statistics

All the statistical analyses were performed by SPSS/PC^{+} program. Paired t-test was performed to evaluate the difference between anterior temporal and masseter muscles and the difference of median frequency and PPT with time. Group t-test was performed to examine the gender difference.

III. RESULTS

The mean of median frequencys(MMFs) showed no significant difference between male and female groups but MMFs were significantly higher in anterior temporal muscles than those in masseter muscles at the beginning of sustained isometric contraction ($p<0.05$). The amount of changes in MMFs during sustained contraction showed no significant difference between male and female groups/between anterior temporal and masseter muscles (Table 1).

Before sustained isometric contraction, PPTs in anterior temporal muscles were significantly higher than those in masseter muscles in both

Table 1. Means and standard deviations of MF value during sustained isometric contraction.

		MF-start	MF-end	⊿MF
Male	1) A.T.	162±22	125±24	37±22
	2) M.	153±24	118±21	35±23
Female	3) A.T.	174±17	147±17	27±18
	4) M.	165±19	139±22	26±20
p	1-2)	*		n.s.
	3-4)	*		n.s.
	1-3)	n.s.		n.s.
	2-4)	n.s.		n.s.

*: $p<0.05$, n.s.: not significant
MF-start : median frequency at the beginning of sustained isometric contraction
MF-end : median frequency at the end of sustained isometric contraction
⊿MF : the difference between MF-start and MF-end
A.T. : anterior temporal muscle
M. : masseter muscle

Table 2. Means and standard deviations of PPT value before and after sustained isometric contraction.

		PPT-before	PPT-after	⊿PPT
Male	1) A.T.	157±18	110±16	47±18
	2) M.	133±25	86±17	47±23
Female	3) A.T.	141±19	101±22	40±20
	4) M.	109±21	67±25	42±23
p	1-2)	***		n.s.
	3-4)	***		n.s.
	1-3)	*		n.s.
	2-4)	*		n.s.

*: $p<0.05$, ***: $p<0.001$, n.s.: not significant
PPT : pressure pain threshold(kPa)
PPT-before: PPT value before sustained isometric contraction
PPT-after : PPT value immediately after sustained isometric contraction
⊿PPT : the difference between PPT-before and PPT-after
A.T. : anterior temporal muscle
M. : masseter muscleTable

male and female groups($p<0.001$) and higher in anterior temporal and masseter muscles of male group than in those muscles of female group ($p<0.05$).

The amount of changes between PPTs before and after sustained isometric contraction showed

Table 3. Means and standard deviations of MF value during and after sustained isometric contraction.

		MF-start	MF-end	20s	40s	60s	120s	180s	240s
Male	A.T.	162±22	125±24***	149±22***	153±23***	158±24**	161±22	161±22	163±24
	M.	153±24	118±21***	132±27***	140±26***	148±26**	151±24	152±23	151±23
Female	A.T.	174±17	147±17***	157±19***	164±17***	168±19***	173±18	174±18	174±18
	M.	165±19	139±22***	152±18***	156±20***	161±18**	164±19	165±17	165±17
Total	A.T.	168±26	135±23***	154±21***	158±21***	163±23***	167±21	167±20	168±22
	M.	159±22	128±24***	141±23***	147±23***	154±23***	157±22	158±21	158±21

**: $p<0.01$, ***: $p<0.001$

(Significances denote the difference between the values of MF-start and each one)

MF-start : median frequency at the beginning of sustained isometric contraction

MF-end : median frequency at the end of sustained isometric contraction

20s, 40s, 60s, 120s, 180, 240s : 20, 40, 60, 120, 180, 240 seconds after sustained isometric contraction

A.T. : anterior temporal muscle

M. : masseter muscle

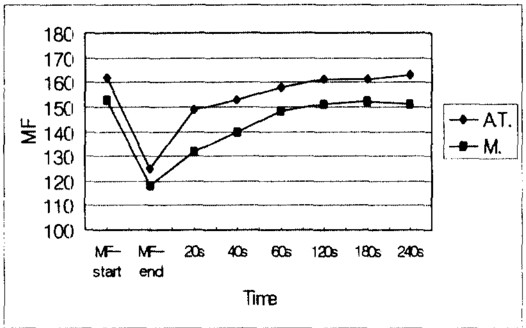

Fig. 1. MF of male group during and after sustained isometric contraction

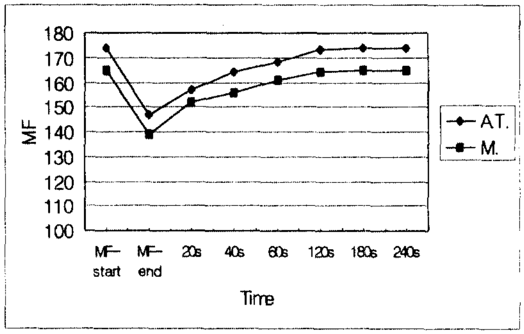

Fig. 2. MF of female group during and after sustained isometric contraction

no significant difference between male and female groups/between anterior temporal and masseter muscles (Table 2).

Table 3 and Figure 1,2 show the MMF shift pattern of the anterior temporal and masseter muscles during and after sustained isometric contraction. MMFs were found to be compressed significantly to lower frequency range as muscle contraction was sustained($p<0.001$) and MMFs were recovered to the same level of the beginning of contraction between 60 and 120 s after sustained isometric contraction in all muscles.

Table 4 and Figure 3, 4, 5, 6 show the change pattern of PPT over the experimental period. PPTs right after sustained isometric contraction were significantly lower than those before sustained isometric contraction($p<0.001$) and PPTs were recovered to the precontraction level

Table 4. Means and standard deviations of PPT value before and after sustained isometric contraction.

		before	after	10min	20min	30min	40min	50min
Male	A.T.	157±18	110±16***	120±17***	127±15***	139±14***	144±16**	156±14
	M.	133±25	86±17***	92±20***	112±26***	118±22***	124±25*	131±20
Female	A.T.	141±19	101±22***	107±22***	118±22**	136±23	142±19	139±17
	M.	109±21	67±25***	80±22***	92±21**	104±21	103±16	107±20
Total	A.T.	150±19	106±19***	115±21***	123±19***	138±18***	143±17**	148±16
	M.	122±26	77±21***	87±21***	103±25***	112±23***	114±23**	120±23

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$

(Significances denote the difference between the value of before and each one)

PPT : pressure pain threshold(kPa)

before: PPT value before sustained isometric contraction

after : PPT value immediately after sustained isometric contraction

10min, 20min, 30min, 40min, 50min : 10, 20, 30, 40, 50 minutes after sustained isometric contraction

A.T. : anterior temporal muscle

M. : masseter muscle

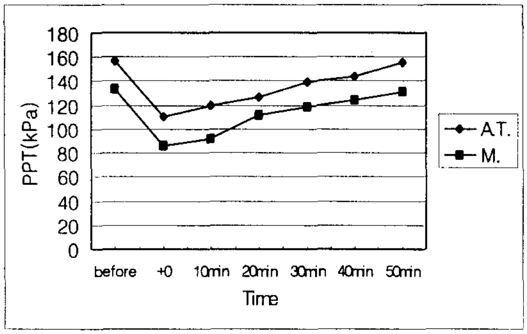

Fig. 3. PPT of male group before and after sustained isometric contraction

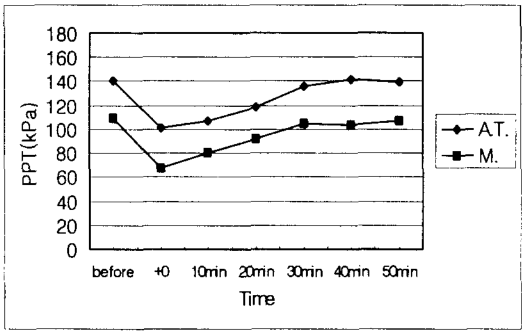

Fig. 4. PPT of female group before and after sustained isometric contraction

at 30 min in anterior temporal and masseter muscles of female group, at 50 min in anterior temporal and masseter muscles of male group after sustained isometric contraction.

Subjective feeling of pain disappeared at 28 min in anterior temporal and at 42 min in masseter muscles in female group , at 30 min in anterior temporal and at 40 min in masseter muscles in male group after sustained isometric contraction

Ⅳ. DISCUSSION

We investigated recovery pattern of EMG power spectrum and PPT after sustained

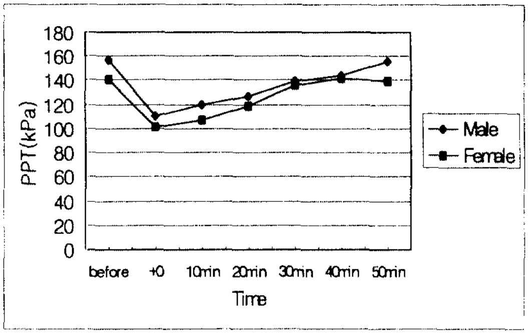

Fig. 5. PPT of anterior temporal muscle before and after sustained isometric contraction

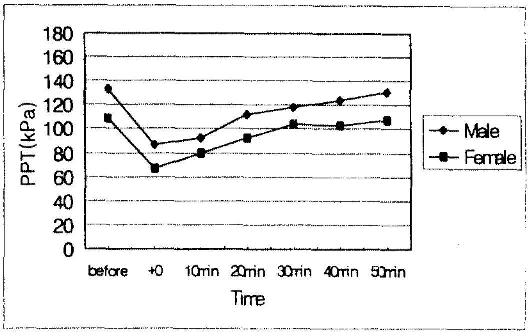

Fig. 6. PPT of masseter muscle before and after sustained isometric contraction

left anterior temporal and masseter muscles and PPTs were measured in right anterior temporal and masseter muscles. It has been isometric contraction in masticatory muscles by use of surface EMG system and electronic algometer. Myoelectric signals were recorded in reported in previous studies that no significant differences were found between right and leftsides of masticatory muscles in median frequency and PPT in normal subjects[20,21,23]. The same results were found in pilot study for this investigation.

The author induced experimentally sustained isometric muscle contraction to study muscle fatigue and pain. The reason is that isometric contraction results in rather rapid onset of muscle fatigue and pain. In addition, consistent power spectrum is difficult to obtain during non-isometric contraction because the number of firing motor units alters variously [24].

Commonly used frequency parameters in EMG power spectrum are mean frequency and median frequency, but it was reported that the median frequency was less sensitive to noise[25] and more sensitive to the change of power spectrum in the lower frequency range[26] than the mean frequency. Therefore median frequency was used as frequency parameter in this study.

At the beginning of sustained isometric contraction, MMFs showed no significant difference between male and female groups but MMFs in anterior temporal muscles were significantly higher than those in masseter muscles ($p<0.05$). Lund and Widmer[27] suggested that the difference of the proximity of the muscle fibers to the skin surface was an affecting influence on the power spectrum, because connective tissue and fat act as low-pass filter. Therefore, the fact that it is nearer to the surface may be reason why MMFs are relatively higher in the anterior temporal muscles than in masseter muscles.

Before sustained isometric contraction, PPTs in anterior temporal muscles were significantly higher than those in masseter muscles in both male and female groups($p<0.001$). It is presently unclear why PPTs in temporalis muscles are higher. however, it is possible that there may be fewer cutaneous and muscle receptors in the temporal region. Another function might be the difference in the density of connective tissue tendon in the anterior temporalis compared with the masseter muscles[28]. PPTs are higher in anterior temporal and masseter muscles of male group than in those muscles of female group and this is similar to the result of Lee et al. [29] This result might be closely related to the fact that CMD patients in the orofacial pain clinics appeared to be prominently females aged 20-40 years.

In this study, recovery pattern of MMFs followed a logarithmic course with fast recovery of early phase and slow recovery of late phase. This result could be explained by theory of Juel[30] that the recovery should be two-phased, having a fast potassium dependent phase and a slow pH-dependent phase. MMF were recovered to the same level of the beginning of sustained contraction between 60 and 120 s in all muscles. This is similar to the study of Kuolinka[31] who reported that restitution of the spectra followed a logarithmic course, and the original level of the mean frequency was reached mostly during 1 to 3 min of recovery in the upper limb muscles.

Chritensen [32] studied the the pain of masticatory muscles under a variety of muscle contraction conditions. He reported that severe jaw pain occurred after one minute of maximum sustained clenching, but the pain decreased significantly two to five seconds after the clenching was stopped. Scott and Lunden[33] reported that pain following hyperactivation of the lateral pterygoid muscles by vigorous forward thrusting of mandible for 5 min continued for a long time and suggested that future studies should follow up the subjects for at least 24 hours after the experiment to evaluate this post-exercise pain phenomenon. Christensen et al.[34] reported that isometric muscle pain was elicited immediately through maximum voluntary contraction when subjects experienced jaw muscle fatigue after 10 min of right-sided gum chewing. Continuous and low level tooth clenching appears to be associated with extended periods of ensuing muscle pain. By contrast, intermittent and high level tooth clenching does not appear to be associated with persistent muscle pain[35,36]. This suggests that the level of isometric force as well as its duration determine when isometric pain appears, and how long it can be ensured.

In this study, severe jaw pain occurred during sustained isometric contraction and the pain did not last for extended periods but ceased whithin an hour. This is supposedly because high level and comparative short duration of tooth clenching was sustained. However, In case of excentric contractions such as the masseteric contractions of teeth grinding or biting on a unilateral occlusal interference, the external work would result in delayed(hours, days) onset of excentric muscle pains because of traumatic muscle injury[34].

The cause or mechanism of skeletal muscle pain is still unclear, but lately there is evidence that muscle pain may be produced by some sensitization of muscle nociceptors due to one or more endogenous chemical substances. Mense[37] suggested that a muscle that is forced to perform physical work of unaccustomed intensity or duration is likely to be physically damaged. Potassium leaks into the interstitial fluid from the muscle fibers and depolarizes nerve endings and fibers. Extravasation of blood leads to liberation of 5-hydroxytryptamine from platelets and of bradykinin from plasma proteins. Bradykinin in turn releases prostaglandines from various tissue cells. Moreover the activation of muscle nociceptors is associated with a release of neuropeptides such as calcitonin gene-related peptide(CGRP) and substance P from the nerve endings. This in turn triggers the liberation of further substances such as histamine from tissue mast cells. All these substances sensitize muscle receptors and even though muscle contraction is stopped, activity of these substances maintains and muscle pain continues.

Sustained isometric contraction leads to muscle acidosis. Accumulation of acidic metabolites including lactic acid and potassium ions have been proposed as causal factors for ischemic pain by Moore et al.[38] On the other hand, through a non-invasive procedure, Lam and Hannam[39] showed that intermittent isometric contraction for 4 min caused pH decrease by only 2% in all masseteric regions, from about pH 7.14 to pH 7.01 and assited that the accumulation of lactic acid is not the cause of isometric pain. Another proposed mechanism for muscle pain is reduced blood flow in the painful muscle. During 90s of 40% MVC level tooth clenching, Möller[40] found that blood flow in masseter muscle was decreased by about 20%, and the flow was increased by about 900% after 120s of rest. Accordingly, he persisted that ischemia or reactive hyperemia have not been shown to be associated with pain. Lewis et al.[41] found that interuption of the blood supply for prolonged periods of 20 min is not painful, but pain develops in about 1 min if the muscle is forced to contract under ischemic conditions. They suggested that ischemia itself is not the causal factor for muscular pain but may contribute to ischemic pain indirectly by inducing increase in metabolite concentration. In this study, the pain did not ceased immediately after the clenching was stopped but lasted for about 40 min. It is supposedly because that overload by sustained isometric contraction induce change of physiologic environment in muscle fiber and some sensitization of muscle nociceptors.

Miller et al.[42] suggested that there were three phases of recovery : an early phase of recovery attributed to the normalization of electrical responce takes 6 min ; an intermediate phase of recovery, with a time course that is similar to the generation of maximum force, takes 20 min and in which levels of high energy phosphates and pH are completely restored ; and in prolonged phase, the recovery of neuromuscular efficiency(NME= force/rectified integrated EMG) takes more than 60 min and this is probably related to altered excitation-contraction coupling. In experiment of isometric handgrip contraction, Funderburgh et al.[43] found that despite that the capacity of the muscle to exert MVC was recovered completely in about 10 min, the endurance capacity was still only 85-90% of the duration of the first contraction even after 40 min. The results in this study that recovery time of PPT is about 50 min and subjective feeling of pain ceased in 40 min or so are similar to prior studies. This suggests that the mechanical and physiological recovery of muscle from a fatiguing exercise seems to take longer than recovery of the EMG spectrum. Furthermore the recovery time from muscle fatigue obviously depends on the nature and duration of the exercise, and especially on what criteria we are looking for.

Further researches are necessary on the level and change of muscle fatigue and pain under various conditions, and difference of these parameters between normal and patient groups. This information can bring further clues on the mechanism of muscle fatigue and pain.

V. CONCLUSIONS

The purpose of this study was to investigate the changes of EMG power spectrum and pressure pain threshold of anterior temporal and masseter muscles after sustained isometric contraction in normal subjects.

Twenty-six healthy volunteers(14 males and 12 females), without past history or present symptoms of craniomandibular disorders (CMD) and fully dentate with normal occlusion, were included in this study.

The author came to the following conclusions after having examined the results of this experiment.

1. MMFs showed no significant difference between male and female groups but MMFs in

anterior temporal muscles were significantly higher than those in masseter muscles at the beginning of sustained isometric conraction ($p<0.05$).

2. PPTs in anterior temporal muscle were significantly higher than those in masseter muscles in both male and female groups ($p<0.001$) and higher in anterior temporal and masseter muscles of male group than in those muscles of female group before sustained isometric contraction ($p<0.05$).
3. The amount of changes in PPTs and MMFs during sustained contraction showed no significant difference between male and female groups/between anterior temporal and masseter muscles.
4. MMFs were found to be compressed significantly to lower frequency range as muscle contraction is sustained($p<0.001$) and MMFs were recovered to the level at the beginning of contraction between 60 and 120 s after sustained isometric contraction in all muscles.
5. PPTs right after sustained isometric contraction were significantly lower than those before sustained isometric contraction($p<0.001$) and PPTs were recovered to the pre-contraction level at 30 min in anterior temporal and masseter muscles of female group, at 50 min in anterior temporal and masseter muscles of male group after sustained isometric contraction.
6. Subjective feeling of pain disappeared at 28 min in anterior temporal and at 42 min in masseter muscles in female group, at 30 min in anterior temporal and at 40 min in masseter muscles in male group after sustained isometric contraction.

REFERENCES

1. Clark, G.T., Koyano, K., and Browne, P.A. : Oral motor disorders in humans. Can. Dent. Assoc. J., 21:19-30, 1993.
2. Laskin, D.M. : Etiology of the pain-dysfunction syndrome. J. Am. Dent. Ass., 79:147-153, 1969.
3. Gay, T., Maton, B., Rendell, J., and Majourau, A. : Characteristics of muscle fatigue in patients with myofascial pain-dysfunction syndrom. Arch. Oral Biol., 39:847-852, 1994.
4. Christensen, L.V. : Some subjective experimental parameters in experimental tooth clenching in man. J. Oral Rehabil., 6:119-136, 1979.
5. Clark, G.T. and Carter, M.C. : Electromyographic study of human jaw-closing muscle endurance, fatigue and recovery at various isometric force levels. Arch. Oral Biol., 30:563-569, 1985.
6. DeLuca, C.J. : Myoelectric manifestations of localized muscular fatigue in humans. Crit. Rev. Biom. Eng., 11:251-279, 1984.
7. Marton, B. : Muscular Fatigue : Biochemical and Physiological Aspects., Paris, 1991, Eds Masson, pp. 207-221.
8. Hori, H., Kobayashi, H., Hayash, T., and Kohno S. : Mean power frequency shift during fatigue and recovery in patients with craniomandibular disorders. J. Oral Rehabil., 22:159-165, 1995.
9. Kroon, G.W. and Naeije, M. : Electromyographic evidence of local muscle fatigue in a subgroup of patients with myogenous craniomandibular disorders. Arch. Oral Biol., 37:215-218, 1992.
10. Koyano, K., Kim, Y.J., and Clack, G.T. : Electromyographic signal changes during exercise in human chronic jaw muscle pain. Arch. Oral Biol., 40:221-227, 1995.
11. Palla, S. and Ash, M.M. : Power spectral analysis of the surface electromyogram of human jaw muscles during fatigue. Arch. Oral Biol., 26:547-553, 1981.
12. Sims, D.B. and Rugh, J.D. : Myoelectric power spectral analysis using surface electrodes. J. Dent. Res., 61:257-262, 1982.
13. Van Boxtel, A. and Gouwaard, P. : Changes in EMG power spectra during fatigue in muscle contraction and migrane headache patients. Headache, 23:223-228, 1983.
14. Lee, H.S. and Kim, Y.K. : A study on the analysis of myoelectric signals of anterior temporal and masseter muscles at voluntary isometric contraction levels and during chewing. J. Dent. Coll.

SNU, 17(1):237-259, 1993.
15. Van Boxtel, A., Gouwaard, P., Molen, G.M., and Bosch, W.E.J. : Changes in EMG power spectra of facial and jaw elevator muscles during fatigue. J. Appl. Physiol., 54:51-57, 1983.
16. Palla, S. and Ash, M.M. : Effect of bite force on the power spectrum of the surface electromyogram of human jaw muscles. Arch. Oral Biol.,26:287-295, 1981.
17. Langemark, M., Jensen, K., Jensen, T.S., and Olesen, J. : Pressure pain threshold and thermal nociceptive in chronic tention-type headache. Pain,, 38:203-210, 1989.
18. Reeves, J.L., Jaeger, B., and Graff-Radford, S.B. : Reliability of the pressure algometer as a measure of myofascial trigger point sensitivity. Pain, 24:313-321, 1986.
19. Schiffman, E., Fricton, J., Haly, D., and Tylka, D. : A pressure algometer for myofascial pain syndrom. : Proceedings of the 5th world congress on pain, Amsterdam, 1988, Elsevier Science publishers BV, pp.407-413.
20. Chung, S.C., Kim, J.H., and Kim, H.S. : Evaluation of pressure pain threshold in head and neck muscles by electronic algometer: intrarater and interater reliability. J. Craniomandib. Prac., 10:28-34, 1992.
21. Chung, S.C., Kim, J.H., and Kim, H.S. : Reliability and validity of the pressure pain thresholds (PPT) in the TMJ capsules by electronic algometer. J. Craniomandib. Prac., 11:171-176, 1993.
22. Jankelson, R. and Pully, M.L. : EMG in clinical dentistry. Seattle & Washinton, 1984, Myotronic Reasearch Inc., pp. 1-14.
23. Kim, Y.J. and Lee, S.W. : A study on electromyographic power spectral analysis of masticatory muscles. J. Dent. Coll. SNU, 14(1):185-201, 1990.
24. Petrofsky, J.S., Glaser, R.M., and Phillips, A. : Evaluation of the amplitude and frequency components of the surface EMG as an index of muscle fatigue. Ergonomics, 25:213-223, 1982.
25. Stuln, F.B. and DeLuca, D.J. : Frequency parameter of the myoelectric signal as a measure of muscle conduction velocity. IEEE Trans. Biomed. Eng. BME., 28:515-523, 1981.
26. Broman, H., Bilotto, C.J., and DeLuca, C.J. : Myoelectric signal conduction velocity and spectral parameters: influence of force and time. J. Appl. Physiol., 58:1428-1437, 1985.
27. Lund, J.P. and Widmer, C.G. : An evaluation of the use of surface electromyography in the diagnosis, documentation and treatment of dental patients. J. Craniomandib. Disord., 3:125-137, 1989.
28. Mcmillan, A.S. : Effect of tooth clenching and jaw opening on pain-pressure thresholds in the human jaw muscles. J. Orofac. Pain, 8:250-257, 1994.
29. Lee, K.H., Lee, M.H., Kim, H.S., Kim, J.H., and Chung, S.C. : Pressure pain threshold of head and neck muscles in a normal population. J. Musculoskel. Pain, 2:67-81, 1994.
30. Juel, C. : Muscle action potential propagation velocity changes during activity. Muscle Nerve, 11:714-719, 1988.
31. Kuolinka, I. : Restitution of EMG spectrum after muscular fatigue. Eur. J. Appl. Physiol. Occup. Physiol., 57:311-315, 1988.
32. Christensen, L.V. : Jaw muscle fatigue and pains induced by expemental tooth clenching. J. Oral Rehabil., 8:27-36, 1981.
33. Scott, D.S. and Lunden, T.F. : Myofascial pain involving the masticatory muscles:An experimental model. Pain, 8:207-215, 1980.
34. Christensen, L.V., Tran, K.T., and Mohamed, S.E. : Gum chewing and jaw muscle fatigue and pain. J. Oral Rehabil., 23:424-437, 1996.
35. Jow, R.W. and Clark, G.T. : Endurance and recovery from a sustained isometric contraction in human jaw-elevating muscles. Arch. Oral Biol., 34:857- 862, 1989.
36. Mills, K.R., Newham, D.J., and Edwards, R.H.T. : Textbook of pain, Edinburgh, 1989, Churchill Livingstone, pp.420-432.
37. Mense, S. : Nociception from skeletal muscle in relation to clinical muscle pain. Pain, 54:241, 1993.
38. Moore, R.M., Moore, R.E., and Singleton, A.O. : Experiments on the chemical stimulation of pain-endings associated with small blood vessels. Am. J. Physiol., 107:594-602, 1934.
39. Lam, E.W.N. and Hannam, A.G. : Regional ^{31}P magnetic resonance spectroscopy of exercising human masseter muscle. Arch. Oral Biol., 37-49, 1992.

40. Møller, E. : Kiefergelenke und Okklusion, Berlin, 1980, Quintessenz, pp36-65,.
41. Lewis, T., Pickering, G.W., and Rothschild, P. : Observations upon muscular pain in intermittent claudication. Heart, 15:359-383, 1931.
42. Miller, R.G., Giannini, D., Milner-Brown, H.S., Layzer, R.B., Koretsky, A.P., Hooper, D., and Weiner M.W. : Effects of fatiguing exercise on high-energy phosphates, force and EMG: evidence for three phases of recovery. Muscle Nerve, 10: 810-821, 1987.
43. Funderburgh, C. F., Hipskind, S.G., Welton, R.C., and Lind, A.R. : Development of and recovery from fatigue induced by static effort at various tensions. J. Appl. Physiol., 37:392-396, 1974.

국문초록

저작근의 지속적인 등척성 수축후 근전도 power spectrum과 압력통각 역치의 회복에 관한 연구

서울대학교 치과대학 구강내과 · 진단학 교실

이 병 철 · 김 은 숙 · 김 영 구

본 연구는 정상인의 저작근에서 지속적인 등척성 수축후 근전도 power spectrum과 압력통각 역치의 회복 특성을 규명하기위해 시행되었다. 악안면 영역의 동통과 기능장애의 병력 및 현증이 없고 정상적인 교합관계를 가진 26명의 정상인(남자 14명, 여자 12명)을 대상으로 최대근활성도의 70% 수준에서 인내가능 할 때까지의 등척성 수축과 수축후 회복기 동안의 근전도 power spectrum과 압력통각 역치를 컴퓨터를 이용한 근전도 시스템과 전자식 압력통각계를 사용하여 분석한 결과 다음과 같은 결론을 얻었다.

1. 지속적인 등척성 수축 시작 시점의 중간주파수에서 남녀간에는 통계적으로 유의한 차이가 관찰되지 않았지만, 근육간 비교에서는 전측두근에서 교근보다 유의하게 높게 나타났다($p<0.05$).
2. 지속적인 등척성 수축전 압력통각 역치는 전측두근에서 교근보다 유의하게 높았고($p<0.001$), 남성에서 여성보다 유의하게 높게 나타났다($p<0.05$).
3. 지속적인 등척성 수축시 중간주파수와 압력통각 역치의 변화량은 성별간, 근육간에 유의한 차이가 관찰되지 않았다.
4. 지속적인 등척성 수축말기 중간주파수는 수축초기에 비하여 유의하게 감소하였으며($p<0.001$), 이의 회복은 모든 근육에서 60초와 120초 사이에서 이루어졌다.
5. 지속적인 등척성 수축후 압력통각역치는 수축전에 비해 유의하게 감소하였으며($p<0.001$), 수축전 수준으로의 회복은 여자군의 전측두근과 교근에서는 30분후에 남자군의 전측두근과 교근 에서는 50 분후에 이루어졌다.
6. 지속적인 등척성 수축후 주관적인 동통이 소실된 시각은 여자군의 전측두근에서는 28분, 교근에서는 42분으로 남자군의 전측두근에서는 30분, 교근에서는 40분으로 나타났다.

Key words : EMG power spectrum, PPT, masticatory muscle, isometric contraction, median frequency, recovery time