Journal of Medical Sciences

ISSN 1682-4474

Research Paper

JMS (ISSN 1682-4474) is an International, peer-reviewed scientific journal that publishes original article in experimental & clinical medicine and related disciplines such as molecular biology, biochemistry, genetics, biophysics, bio-and medical technology. JMS is issued six times per year on paper and in electronic format.

For further information about this article or if you need reprints, please contact:

B. Hatef
Sports Medicine Research Center,
AleAhmed Highway, Tehran,
Islamic Republic of Iran

Tel: 98(21) 88630227-8
Fax: 98(21) 88003539

J. Med. Sci., 7 (3): 339-346
1st April, 2007

Effect of Tempromandibular Joint Sounds on Timing of the Masseter Muscle Activity in the Open-close-clench Cycle

B. Hatef, S. Talebain, G.R. Oliyae and H. Bagheri

The aim of the present study was to investigate the effect of tempromandibular joint (TMJ) sounds and distribution of malocclusion on the timing pattern of the masseter muscle in the open-close-clench (OCC) cycle. A total of 39 adult women were participated in two part of study. They completed OCC cycles in the functional condition, with 80 cycles in a minute. Two separated recording for 15 sec with an interval 2-3 min from each side were done. The results of comparing the synchronized signals of motion in sagittal plan and electromyography in first part demonstrated the earlier onset of masseter activity in two side and longer duration of right masseter in group with TMJ sounds (21 subjects) compare to controled group (18 subjects). In second part ten subjects were selected which they had only one joint with sound, the ipsilateral masseter (side with TMJ sound) contracted sooner and for a longer duration in comparison with contralateral side. Also in the first part that distribution of occlusion was significantly different between two groups, the two-way ANOVA showed that it had an interaction effect on the increase of the duration of masseter activity. In conclusion, TMJ sounds in accompany with malocclusion without obvious symptoms such as pain and limitation can change timing pattern of masseter activity in the functions same a mastication. This abnormal pattern may affect TMJ and other structures to produce vicious cycle and other problems.

Key words: TMJ sounds, EMG, masseter, timing pattern, motor control

ANSInet
Asian Network for Scientific Information

Department of Physical Therapy, Faculty of Rehabilitation,
Tehran University of Medical Sciences and Health Services, Tehran, Iran

INTRODUCTION

It is well known that peripheral input of muscles, joints and other tissues around them can influence the controlling action of Central Nervous System (CNS) that design and product functional pattern of muscular activity (Kandel *et al*., 2000).

Electromyography studies in some painful disorders such as Tempromandibular Disorder (TMD), headache and other craniomandibular muscle pain, has often demonstrated an increase in the resting amplitude and a decrease in maximal contraction of involved muscles such as masseter muscle (Jensen *et al*., 1994; Bodere *et al*., 2005; Liu *et al*., 1999; Nielsen *et al*., 1990; Piho *et al*., 2000 and Yamaguchi *et al*., 2002). However a little is known about pattern of muscle activation in TMD (Chong-Shan and Heri-Yun, 1989; Murno *et al*., 1975; Vogt *et al*., 2003 and Graven-Nielsen *et al*., 1995). It is argued that Pattern of muscle activation can better identify involvement of muscles in disorders rather than amplitude (Lahman, 2002).

There are few evidences showing change of amplitude and pattern of masticatory muscles activity in pain free subjects with biomechanical dysfunction such as malocclusion and TMJ sounds (Murno *et al*., 1975; Yoshida, 1995; Riise, 1984). It means that several factors effect motor activity.

Electromyography of masseter muscle activity is an appropriate choice to study the effect of internal sensory feedback on motor control, because 1) Tempromandibular Joint (TMJ) continually experience cyclic loading in mastication or speech, 2) brain stem and cortical centers control these functions (McDevitt, 1989), 3) masseter muscle is a jaw closer and a surface muscle with many muscle spindles and it has an out standing dynamic role in mastication (Scutter and Turker, 2001).

The purpose of this study was to investigate effect of the TMJ sounds and distribution of the malocclusion on the timing pattern of masseter muscle in OCC cycle in subjects with no pain in cephalic and cervical regions and no limitation in Mandibular Range of Motion (ROM). We recorded masseter EMG activity simultaneously with OCC cycles of mandibular in sagittal plane. This investigation consisted two part. In first part, subjects with TMJ sounds versus subjects without TMJ sounds. In second part, ipsilateral comparison in same subject (those subjects were chosen who had only one TMJ sound). The aim of second part was to understand direct and indirect effect of TMJ sounds on the pattern of masseter activation, it means that if only one joint had sound, changes in masseter of both sides will be equal. We hypothesize that few dysfunctions in TMJ regularity such as malocclusion and abnormal tracking of mandibular motion that cause sound, would elicit a disturbance sensory signal to CNS and may be effect neuromuscular controlling of craniomandibular region specially in the same side.

MATERIALS AND METHODS

Subjects and examination: The present study was a case-control study, which was carried out of 2003 at Tehran University of Medical Science and Health Services on 39 healthy adult female, aged between 19-32. All subjects were consisted students and employees of rehabilitation department. They were fully informed of the nature of the study. All subjects satisfied the following criteria: 1) no history of any pain, limitation and locking in TMJ and surgery or trauma in the craniomandibular region, 2) no history of orthodontic treatment, 3) no frequent taking of drugs that may effect on neuromuscular system, 4) no missing tooth except for the third and/or second molar. In first part were considered twenty-one subjects had single or both joints with sound (Group 1) and eighteen subjects had joint without sound (Group 2). In second part ten subjects were selected who had only one joint with sound. Thus in this part ipsilateral masseter (a side with TMJ sound) was compared with contralateral masseter (a side without TMJ sound).

To detect type of occlusion, relationship of upper and lower first molar and upper and lower canine had been considered (Jaggr *et al*., 1994). For examination of TMJ sounds, bilateral posterior palpation of TMJ through the external auditory meatus was performed by fingertips and the participant was requested to open and close her jaw rhythmically in functional range (2-3 cm) while teeth did not contact. Those joints, which had repeatable sound or abnormal grinding, were recognized as TMJ sound. For confirming, this test was done several times even in lateral deviation and history of hearing sounds by subjects was also noticed (Jaggr *et al*., 1994; Boyling *et al*., 1997; Hertling and Kessler, 1996).

Electromyography recording: The skin was cleaned by alcohol and bipolar surface electrodes (Ag/Ag-Cl), with 20 mm inter-electrode distance, were filled with specific gel and were placed on a line parallel to the masseter muscle fibers (bulk of masseter muscle was prominence by strong clench) (Burnett *et al*., 2000; Pancherz *et al*., 1986). Then electrodes were fixed by adhesive tapes until impedance of skin did not become more than 5 kÙ (Burdette and Gale, 1990). Ground electrode was attached around the wrist. The electromyography signal of masseter muscle was recorded using a 4-channel Amplified differentially electromyograph (Medelec, Premiere model) with CMRR>100 db. The parameters of record were: Gain: 500 μv/Div., Sweep: 1sec/Div., Bandpass filter:10-500 Hz.

Motion recording: Mandibular motion cycles in sagittal plane were recorded with mandibular recorder switch which is a simple electrical circuit with output voltage of 3 V. The switch of this circuit had two parts, first part was fixed (by adhesive tape) on mandible and the second part was placed on the opposite side of the first part. The unit was set in a way which jaw could be opened and closed for only 2 cm (Fig. 1). When the participant moved her jaw, the first part alternately contacted and separated from upper and lower plate of the second part. Thus, the switch turned on and off following the change in voltage of output signal. In fact, the unit detected the starting point and duration of the closing and opening of jaw motion in any cycles (Fig. 2a).

Exercise protocol

Reliability of EMG recording: Electromyography of the right and left masseter muscles of seven women (20-27 years), without any painful problem in the mandibulocraniocervical region and orthodontic therapy were taken under the condition of this study for two times with one week interval. Intraclass correlation coefficient of the timing factors (duration and onset latency) of masseter EMG between two sessions was significant and had well to excellent correlation (Table 1).

Accuracy of mandibular recorder switch: To study the accuracy of the unit we used digital camera (Mercury, CyberPix, E-560 M) and Ulead video studio software (version 7). This test was done on 5 women (20-27 years) who had no pain in the mandibulocraniocervical region and orthodontic therapy. Interval time between start of jaw closing and turn on of upper plate of switch detected by video was compared with recorded signal of same cycle. This method was also used from the beginning of jaw opening to switch closing of the lower plate. Maximum delay time of switch (measurement error) for detection of start jaw closing was 49±12 m sec and maximum delay time of switch (measurement error) to detect beginning of jaw opening was 32±18 m sec in study's condition (80 cycles of OCC in minute). Although jaw motion was limited by apparatus for 2 cm and mandibular part was sticked perfectly on the subject's mandible, these delays was due to 1) adhesive attachment of mandibular part on the skin and 2) subjects usually opened their mouths more than 2 cm, but this delay was technical error and did not differ in Groups. For minimizing this error we analyzed cycles with similar pattern in each subject.

Table 1: Intraclass correlation coefficient between two sessions

Parameters	Onset latency (m sec)	Duration (m sec)
Right masseter	ICC = 0.89	ICC = 0.77
	Sigf = 0.007	Sigf = 0.04
Left masseter	ICC = 0.87	ICC = 0.91
	Sigf = 0.01	Sigf = 0.003

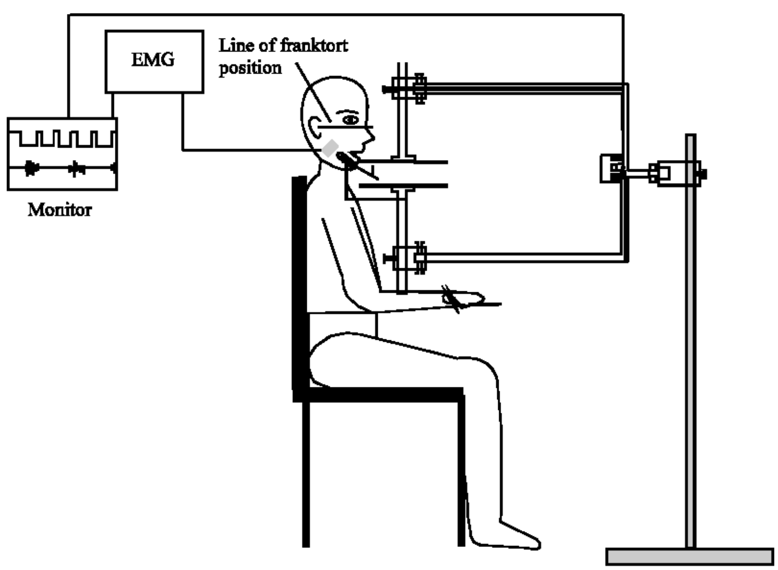

Fig. 1: The set up for synchronizing electromyography and mandibular recorder switch records

Testing procedures: Subjects were asked to sit on a chair with arm rest and without head rest. They were instructed to maintain their head in Frankfort to horizontal position (the line parallel horizontal from anterior cartilage of ear to inferior prominence of orbit) and did not change this position during the recording (Fig. 1). After placing the instruments, they were requested to do cycles of OCC same as in chewing gum until near to its functional movement. Speed of motion was standardized with metronome (80 cycles/minute). We tried to create peer conditions for all subjects, because the position of head, speed and power of motion influence on onset of masseter activity (Uchida *et al.*, 1999; Winnberg *et al.*, 1988; Ahlgren, 1967). Masseter is a phasic muscle and fast fatigable (almost 5000 m sec mastication) (Buzinella and Berzin, 2001), so we recorded EMG before reaching this fatigue point. Total duration of each session was around 45 min.

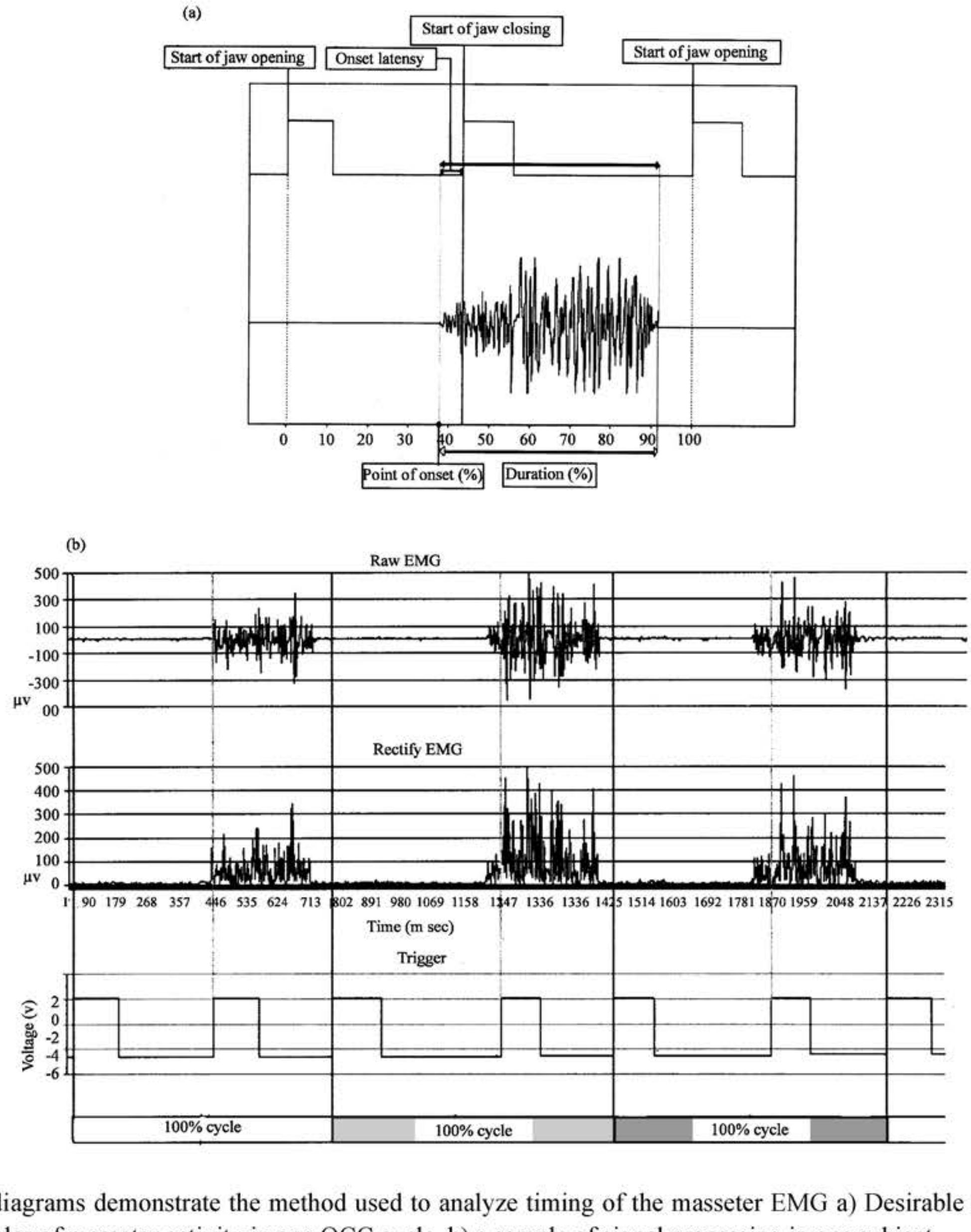

Fig. 2: The diagrams demonstrate the method used to analyze timing of the masseter EMG a) Desirable investigatory variables of masseter activity in one OCC cycle. b) a sample of signal processing in one subject

Analyzing processing: These two signals (EMG and mandibular motion) were transferred synchronously to computer by 12-bite A/D board with 1000 Hz sampling rate. There were two-separated recording from each side, for 15 sec with interval of 2-3 min. The mean of 10 cycles was analyzed by Excel software.

To detect onset of the activity, before starting the test, participant opened her mouth 1 cm in order to relaxed and minimized her masseter activity (Manns *et al*., 1981). to determine baseline of activity on-set and off-set of activity was a point where its intensity was equal to the average of 200 m sec of baseline plus two standard deviation.

By comparing the synchronized signal of motion and rectified EMG, the investigable variables were; 1) onset latency: start of masseter activity until beginning of the jaw closing. So, the muscle activity that preceded jaw closing was indicated as plus and delayed activity was indicated as minus. 2) Duration of masseter activity in OCC cycle. 3) Percentage of duration of masseter activity in OCC cycle 4) Percentage of onset of masseter activity in OCC cycle (Fig. 2). Last two variables were measured to normalize with regard to the OCC cycle (one cycle corresponds to 100%).

Statistical analysis: Statistical analysis was done with SPSS software (version 11.5). Chi-square was used for comparing distribution of occlusion, which was a qualitative variable and analyses of EMG variables were performed with student t-test, because they were normally distributed (using the Kolmogorovb Smirnov test). Factors analysis (two-way ANOVA) was used to study interaction of distribution of occlusion and TMJ sounds. We considered differences significant at $p<0.05$.

RESULTS

First part of study: In the first part, the onset of both masseter activities in OCC cycle in Group 1 was significantly earlier than the subjects in Group 2 (Table 2). The duration and duration percent of right masseter activity in OCC cycle in Group 1 was significantly more than Group 2 ($p<0.001$). Onset percent of right masseter activity in OCC cycle in Group 1 was significantly earlier than Group 2 ($p<0.001$) (Table 2).

Distribution of occlusion in left side was approximately similar in two Groups, but in right side, distribution differenced and type I of occlusion in Group 2 was significantly more than Group 1 ($p<0.05$). Type II of occlusion in Group 1 was more than Group 2, but this difference was not significant (Fig. 3).

Table 2: Duration, onset latency, duration %onest of right and left masseter activity in open-close-clench cycle in Group 1 (with sound) and Group 2 (without sound)

	Left		Right	
Parameters	Non-sound	Sound	Non-sound	Sound
Duration (m sec)†	340.3±53.8	376.2±51.3	334.7±55.1	401.3±39.2**
Onset latency (m sc)†	-4.8±32.4	19.9±26.1*	-13.2±37.1	25.2±17.6**
Duration percent (%)†	46.0±7.3	50.5±6.3	44.6±8.5	53.4±4.6**
Onset percent (%)†	41.9±7.7	36.9±7.7	43.7±8.8	34.2±4.6**

†Data are mean±SD, *$p<0.05$, **$p<0.001$

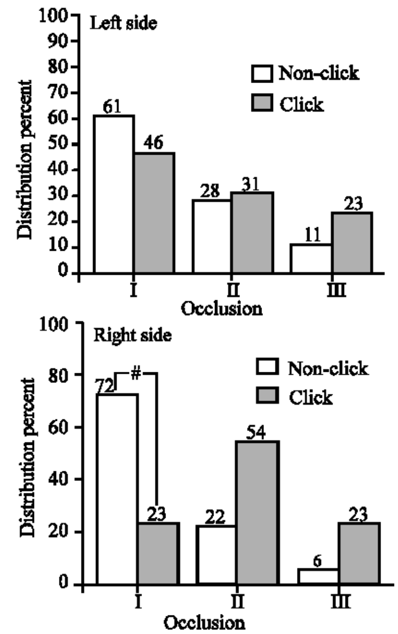

Fig. 3: Distribution of the types of occlusion in two Groups and two side (*p≤0.05)

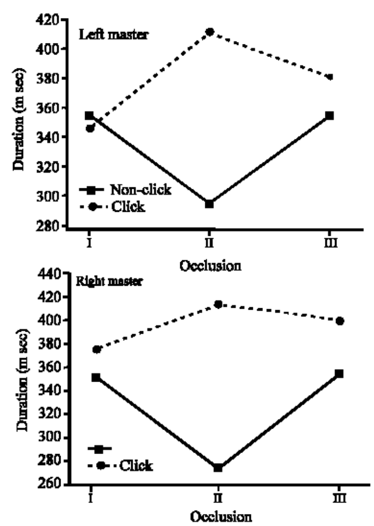

Fig. 4: Interaction effect of occlusion on duration of masseter in two Group with and without sound. two-away ANOVA was significant ($p<0.05$) in both side

Table 3: Duration, Onset latency, % duration and %onset of the masseter activity in OCC cycle in Ipsilat. Contralat masseter (N = 10)

Parameters	Duration (m sec)†	Onset latency (m sec)†	Duration (%)†	Onset (%)†
Contralat-Masseter (Non-sound)	356.58±37.0	-23.58±44.2	47.94±4.7	37.65±4.5
Ipsilat-Masseter (Sound)	395.68±44.7*	16.36±36.6*	53.24±5.3*	35.11±4.6

†Data are mean±SD, *p<0.05

In factors analysis, type of occlusion had significant interaction effect with the TMJ sounds on the duration (Left masseter: $F(2, 25) = 4.74$; $p<0.05$, Right masseter: $F(2, 25) = 4.62$; $p<0.05$) (Fig. 4) and on the duration percentage (Left masseter: $F(2,25) = 6.54$; $p<0.005$, Right masseter: $F(2, 25) = 3.5$; $p<0.05$). This interaction did not significant for onset latency and onset percentage.

Second part of study: In second part, result of student t-test demonstrated sooner and longer muscular activity in ipsilateral as compare to contralateral masseter. The onset percentage was not sensitive same as other factors (Table 3). Distribution of occlusion between two side had no significant difference.

DISCUSSION

The main finding of the first part, which we compared timing factor of masseter activity in the subjects with TMJ sounds versus subjects without TMJ sounds, was the early onset of masseter in the both side, Increase of duration and its percentage and earlier onset percentage of the right masseter in the subjects with sound as compare to the subjects without sound. The second part, which ipsilateral comparison was done, showed the early onset and increase of duration and duration percent in the ipsilateral masseter (a side with TMJ sound) as compare to contralateral masseter in the subjects with only one TMJ sound. The interest finding base on factors analysis was demonstrated that distribution of occlusion had interaction effect on increasing the duration and duration percentage of right masseter activity in the first part. This finding show, that malocclusion may had more effect on the duration of masseter activity rather than onset latency.

Biomechanical dysfunction in TMJ is mostly due to disk displacement (Elfving *et al*., 2002) which is a result of insufficiency of involved muscles such as lateral Pterygoid and digastrics muscles in disk sliding in normal motion of mandible (Liu *et al*., 1989) or is a result of structural variations such as abnormal functional occlusion (Liu *et al*., 1999). Riise and Sheikholeslam, (1984) demonstrated that small occlusal interference (about 0.5 mm) in the intercuspal position in eleven normal males could reduce the intensity and prolong duration of masseter activity during natural mastication (Riise and Sheikholeslam, 1984). Accordingly, we found in first part morphological variation can affect on the duration of masseter activity. Increase in duration of masseter activity may increase the time of cyclic loading on the TMJ, so when these abnormally is stabilize and don't adjust, this can sensitize trigeminal system and can be source of other problem sec in craniomandibulocervical region. But there is not evidence whether malocclusion is cause of long activity of masseter or these two matters exist parallel.

Without exact paraclinical studies such as CTS, MRI and arthroscopy, we cannot recognize which TMJ really has pathology. On the other hand clinical palpation for examination of click is not an accurate method because some sounds being under audibility threshold (Tallent *et al*., 1993) and some joints with sound are not really pathologic (Tallent *el al*., 1993; Gay *et al*., 1987). We modified the palpation method to acquire the best result from this test to differentiate normal and abnormal joints. In this study, when the subjects opened and closed or laterotruded, first, we noticed any sounds and palpable abnormal joint motion under our fingers and asked subjects about history of hearing the click in the past. Secondly, subjects were ordered to open their mouth in sub maximal range (2-3 cm) to decrease the appearance of click in the end of mouth opening which it has high probability in normal joint, also based on other studies we can say prevalence of dysfunction in TMJ with click were higher than joints without click, even the pain and limitation in mandibular range of motion did not exist, or never appear (Gay and Bertolami, 1988; Motoyoshi *et al*., 1994).

Our results support previous finding of Munro (1975) who had demonstrated significant increase in the duration of masseter and anterior tempolaris activity from start of activity until teeth contact in subjects with TMD (They had painful and limited TMJ) and potential of TMD (they had click or criptus with or without centric slide in TMJ) in compare to controled subjects (Murno, 1975). Yoshida (1995) also showed various changes in EMG patterns, recorded during open-close movement from the superior and inferior heads of the lateral pterygoid muscle, the anterior belly of the digastrics muscle and the temporal muscle in painless TMJ sound with click (Yoshida, 1995).

In conclusion, slight abnormality in biomechanical regulation such as sound in joint could often promote muscular activity such as masseter specific in the side with TMJ sound in second part we observed that TMJ sound had more effective directly on the ipsilateral masseter than indirectly on the contralateral masseter. Thus in the order to TMJ is a complex joint and two sides act together, but structural and functional dysfunction in one side more effect on masseter activity of same side. On the other hand structural variations such as malocclusion could often increase duration of muscles activity.

These alternations of masseter activity had similar pattern to painful disorders such as TMD (Murno, 1975) and low back pain (Vogt *et al*., 2003). It was suggested that in painful disorder if we just notice to remove pain, other silence mechanical dysfunctions that do not have trouble signs, create constant changes in neuromuscular regularity. Thus in any successful treatment process we should consider these elements and find appropriate way to resolve them.

Further studies to investigate different muscles, in different function and disorder in the craniomandibulocervical region can be useful to know: what is the cause of altered timing pattern of muscular activity in dysfunctions, painful or not painful elements or both? Do the pattern of muscular activity alter equal in any change of sensory inputs? How much a muscle contributes to the altered pattern of function, For example masseter muscle may alter a lot in one disorder and do not change in the other one?.

ACKNOWLEDGMENTS

The authors would like to thank Hosein Asheri MD for statistical assistance and Fahime Hashemirad M.Sc. PT for her help in preparing this manuscript.

Grants Supporter: Physical Therapy Department, Rehabilitation Faculty, Tehran University of Medical Science and Health Services

REFERENCES

Ahlgren, J., 1967. Kinesiology of the mandible: An EMG study. Acta Odontologica Scandinavica, 25: 593.

Bodere, C., S.H. Tea, M.A. Giroux-Metges and A. Woda, 2005. Activity of masticatory muscles in subjects with different orofacial pain conditions. Pain, 116: 33-41.

Boyling, J.D., N. Palastanga and P.G. Grieve, 1997. Grieve's Modern Manual Therapy. Hardcover, 3E., pp: 523-529.

Burdette, B.H. and E.N. Gale, 1990. Reliability of surface electromyography of the masseteric and anterior temporal areas. Archs Oral. Biol., 35: 747-751.

Burnett, C.A., L. Fartash, B. Murray and P.J. Lamey, 2000. Masseter and temporalis muscle EMG levels and bite force in migraineurs. Headache, 40: 813-817.

Buzinella, R.V. and F. Berzin, 2001. Electromyographic analysis of fatigue in temporalis and masseter muscles during continuous chewing. J. Oral. Reh., 28: 1-165.

Chong-Shan, S. and W. Hui-Yun, 1989. Value of EMG analysis of mandibular elevators in OCC cycle to diagnosing TMJ disturbance syndrome. J. Oral. Reh., 16: 101-107.

Elfving L., M. Helkimo and T. Magnusson, 2002. Prevalence of different temporomandibular joint sounds, with emphasis on disc-displacement, in patients with temporomandibular disorders and controls. Swed. Dent J., 26: 9-19.

Gay, T., C.N. Bertolami, B. Donoff, D.A. Keith and J.P. Kelly, 1987. The acoustical characteristics of the normal and abnormal temporomandibular joint. J. Oral. Maxiillofac. Surg., 45: 397-407.

Gay, T. and C.N. Bertolami, 1988. The acoustical characteristics of the normal temporomandibular joint. J. Dent Res., 67: 56-60.

Graven-Nielsen, R., P. Svensson, L. Arendt-Nielsen and H. Svarrer, 1995. The influence of low back pain on muscle activity and coordination during gait: A clinical and experimental study. Pain, 64: 231-240.

Hertling, D. and R. Kessler, 1996. Management of Commen Musculoskeletal Disorders. Physical Therapy Principles and Methods. 3rd Edn., lippincott, Chapter 15.

Jaggr, R.G., J.F. Bates and S. Kopp, 1994. Trempromandibular Joint Dysfunction, the Essentials 1st Edn., Wright, Chapters: 1, 4.

Jensen, R., A. Fuglsang-Frederiksen and J. Olesen, 1994. Quantative surface EMG of pericranial muscles in headache. A population study. Electro. Encephaogr. Clin. Neurophysiol., 93: 335-344.

Kandel, E.R., J.H. Schwartz and T.M. Jesseu, 2000. Principles of Neural Science 4th Edn., MC Grow-Hill.

Lahman, G.J., 2002. Clinical considerations in the use of surface electromyography: Three experimental studies. J. Manipulative Physiol. Ther., 25: 293-299.

Liu, Z.J., H.Y. Wang and W.Y. Pu, 1989. A comparative electromyographic study of the lateral pterygoid muscle and arthrography in patients with temporomandibular joint disturbance syndrome sounds. J. Prosthet. Dent, 62: 229-33.

Liu, Z.J., K. Yamagata, Y. Kasahara and G. Ito, 1999. Electromyographic examination of jaw muscles in relation to symptoms and occlusion of patients with trempromandibular joint disorders. J. Oral. Reh., 26: 33-47.

Manns, A., R. Miralles and F. Guerrero, 1981. The changes in electrical activity of the postural muscles of the mandible upen varing the vertical dimension. J. Prosth. Dentis., 45: 438-445.

McDevitt, W.E., 1989. Functional Anatomy of the Masticatory System, Softcover 1st Edn., Chapter 6.

Motoyoshi, M., M. Ohya, M. Hasegawa and S. Namura, 1994. A study of temporomandibular joint sounds; Part 1. Relationship with articular disc displacements. J. Nihon. Univ. Sch. Dent., 36: 48-51.

Murno, R.R., 1975. Electromyography of the masseter and anterior temporalis muscles in the OCC cycle in tempromandibular joint dysfunction. Monogr. Oral. Sci., 4: 117-125.

Nielsen, I.L., C. Mcneill, W. Danzig S. Goldman, J. Levy and A.J. Miller, 1990. Adaptation of craniofacial muscles in subjects with craniomandibular disorders. Am. J. Orthod. Dentofac., 97: 20-34.

Pancherz, H., A. Winnberg and P.L. Westesson, 1986. Masticatory muscle activity and hyoid bone behavior during cyclic jaw movemens in man (a synchronized electromyographic and videofluorographic study). Am. J. Orthod., 89: 122-131.

Piho, J.C., F.M. Caldas, M.J. Mora and U. Santana-Penln, 2000. Electromyographic activity in patients with temporomandibular disorders. J. Oral. Reh., 27: 985.

Riise, C. and A. Sheikholeslam, 1984. Influence of experimental interfering occlusal contacts on the activity of the anterior temporal and masseter muscles during mastication. J. Oral. Reh., 11: 325-333.

Scutter, S.D. and K.S. Turker, 2001. The role of muscle spindles in human masseter. Human Movement Sci., 20: 489-497.

Tallent, R.H., M. Hatala, R.W. Katzberg and L.Westesson, 1993. Tempromandibular joint sounds in asymptomatic volunteers. J. Prosthet Dent., 69: 298-304.

Uchida, S., H. Inoue and T. Maeda, 1999. Electromyographic study of the activity of jaw depressor muscles before initiation of opening movement. J. Oral. Reh., 26: 503-510.

Vogt, L., K. Pfeifer and W. Banzer, 2003. Neuromuscular control of walking with chronic low-back pain. Manual Therapy, 8: 21-28.

Winnberg, A., H. Pancherz and P.L. Westesson, 1988. Head posture and hyo-mandibular function in man (a synchronized electromyographic and videofluorographic study of the OCC cycle. Am. J. Orthop., 94: 393-404.

Yamaguchi, T., K. Satoh, K. Komatsu and N. Inoue, 2002. Electromyographic activity of the jaw-closing muscles during jaw opening-comparison of cases of masseter muscle contracture and TMJ closed lock. J. Oral. Reh., 29: 1063-1068.

Yoshida, K., 1995. The electromyographic activity of the masticatory musces during temporomandibuar joint cicking. Schweiz Monatsschr Zahmmed, 105: 24-29.