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An Electromyographic Study to Evaluate the Effect of Age and Gender on Masseter Muscle Activities During Chewing of Different Textured Foods

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ABSTRACT

EMG is being used now days for describing various mechanical attributes of food for their texture analysis, During EMG the generated bioelectrical activity of the muscles are used for providing the real time information for the complete process of chewing. The objective of this study was to investigate the effect of gender and age on the bioelectrical activities of masseter muscles obtained during mastication of five different textured foods namely *jelly, cake, dhokla, rasgulla* and *paneer*. The electromyographic study was conducted on twelve healthy human subjects [4 females aged between 28 to 30 years (Group 1), 4 females aged between 18-20 years (Group 2), and 4 males aged between 18-20 years]. Eighteen electromyographic variables were obtained from each experimental session. The values of various masticatory parameters of Group 1 and Group 2 subjects were not significantly ($p \leq 0.05$) different. Also comparison of male with female electromyographic data, obtained during mastication, showed no significant ($p \leq 0.05$) difference except for inter burst duration per chew and early burst duration. The study indicated that the group for electromyographic data acquisition can be formulated from the subjects of both genders with age varying from 18 to 30 years.

KEY WORDS: ELECTROMYOGRAPHY, MASTICATION, TEXTURE, GENDER, AGE.

INTRODUCTION

Food texture and mouthfeel are the two important characteristics for consumers' food preference and acceptance (Guinard and Mazzucchelli, 1996). Texture depends on mechanical, geometrical and surface characteristics of foods which are perceived through various sense organs. It is an important factor which affects food eating behaviour (Chen, 2009). Social, cultural, physiological and psychological factors mainly govern the attributes of texture (Szczesniak and Khan, 1971; Kohyama, 2015). Gummy or slimy food with hard particles or lumps is generally considered as unacceptable. Learning about texture of food is a continuous process (Szczesniak, 2002). Texture assessment of food is based on various physical and sensory parameters and governed by surface response of food inside the mouth, by masseter muscles activities and by auditory means. Electromyography is a non-invasive and upcoming technique being used to investigate the textural perceptions of foods as accessed by masseter muscle activities of human subjects during chewing. The electromyography studies have been conducted on some regionally prevalent foods like *japonica* rice, kelpsnack,

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buckwheat noodles (Kohyama et al., 2000; Kohyama et al., 2010; Kohyama et al., 2016; Kohyama et al., 2018; Rustagi, 2020).

Also, various mastication parameters have been analyzed during chewing, by electromyography, for some continental foods like processed cheese, gummy candy, marshmallow, dried prunes, rice crackers, sponge cake, carrot and chewing gums, apples, meat, beef, idli and cookies (Duizer et al., 1996; Karkazis and Kossioni, 1997; Mioche and Martin, 1998; Karkazis and Kossioni, 1998; Mathoniere et al., 2000; Kohyama et al., 2005; Ioannides et al., 2009; Miyaoka et al., 2013; Dhillon et al., 2020a; Dhillon et al., 2020b). Gender and age are the two attributes which govern the development of suitable foods on the basis of physiological and psychological characteristics. Electromyography studies have been conducted to access the chewing behaviour of elderly and young subjects also by considering their dental status (Kohyama et al., 2002). Various studies have been conducted to find the relationship between oral physiologies like effect of salivary production rate (Affoo et al., 2015). During ageing body composition changes in terms of cell mass, cell fat etc. (Steen, 1988) and human subjects adapt to these changes during mastication process (Peyron et al., 2004). The chewing pattern of different textured foods varies from person to person (Wilkinson et al., 2000; Kohyama et al., 2003; Kohyama et al., 2005).

In old age weak muscle action, swallowing problem (dysphasia), difficulty in chewing, poor dentition and incomplete bolus formation occurs (Kohyama et al., 2015). Age and gender effects were studied on the basis of different anatomical characteristics of human body like height, weight, size of face and also on the basis of orofacial strength (Zhuang et al., 2010; Clark and Solomon, 2012). During chewing male and female differences were studied on the basis of mean bite force, salivary rate and mandibular movement (Braun et al., 1996; Nagasawa et al., 1997; Inoue et al., 2006). Significant differences in the chewing patterns were observed, as analyzed through electromyography, between two wider age groups having a mean age difference of about 38 years (Kohyama et al., 2002). However, to the best of our knowledge no study has been conducted on the narrower age groups. Thus, the aim of this study was to find the effect of gender and age (a smaller age gap of maximum up to 12 years for relatively younger age groups) on the masseter muscle activities during chewing, through electromyography, of five different textured foods (Kohyama et al., 2015).

MATERIAL AND METHODS

For the subjects, the experimental setup of this experiment was approved by Ethical Committee of Guru Nanak Dev University, Amritsar, Punjab, India. Twelve volunteers, eight females divided in to two groups: Group I (aged between 18 to 20 years) and Group II (aged between 28-30 years) and four males aged between 18-20 years, free from any mastication problems were selected as subjects for this study (Kohyama et al., 2003). All subjects gave their written consent to participate in the study. For the electromyography (EMG), bioelectrical activities of both left and right masseter muscles were recorded, simultaneously, using EMG setup (MP-150 System, Biopac Systems Inc., Goleta, CA, USA). Five different textured foods namely jelly, cake, dhokla, rasgulla and paneer were selected for the study. Cake, dhokla and paneer were cut into pieces weighing 5 grams each while jelly and rasgulla (approx. 5 grams) were given in their original shape to the human subjects.

Bipolar surface electrodes (EL 503) were used to acquire EMG signals of masseter muscles from both sides of face which were then filtered (10-500Hz) with removal of noise at 50 Hz caused by the power supply and amplified (×1000) with EMG 100C amplifiers (Biopac Systems Inc.) and stored on PC at 1000 Hz frequency using MP-150 system (Biopac Systems Inc.) (Kohyama et al., 2014). EMG signals were acquired and analyzed using AcqKnowledge Software (ver. 4.4, Biopac Systems Inc.). The detailed procedure for setting up of electrodes on human subject, data acquisition and analysis were performed as discussed earlier (Rustagi et al., 2018a; Rustagi et al., 2018b). For the statistical analysis, the masseter muscle activities acquired using surface EMG were subjected to analysis of variance (ANOVA) test using Minitab Statistical Software (Minitab Inc., USA).

RESULT AND DISCUSSION

The acquired EMG data for both male and female subjects were analyzed from electromyogram to obtain eighteen EMG variables divided in to entire mastication period, per chew mastication and different stages of mastication viz. early, middle and late (Pratiksha et al., 2018; Sodhi et al., 2019). The mean values of duplicate EMG variables for both male and female subjects, while masticating five different textured foods, were subjected to analysis of variance. For the effect of age, the analysis of EMG variables obtained for Group I of female subjects (Table 1) revealed that EMG variables except muscle activity per chew, cycle time per chew, burst duration per chew and burst durations at different stages of mastication can differentiate ($p < 0.05$) these different textured foods. The cycle time per chew can also be used to distinguish these foods by lowering the level of confidence ($p < 0.10$).

So, it may be summed up here that out of eighteen EMG variables acquired to examine the bioelectrical activity of masseter muscles of female subjects, thirteen variables are effective ($p < 0.10$) in representing the textural differences of these five different textured foods investigated in the present study. The analysis of EMG variables obtained for Group II of female subjects (Table 2) revealed that EMG variables except muscle activity per chew and muscle activity at different stages of mastication can differentiate ($p < 0.05$) these different textured foods. A statistical analysis for comparison of EMG variables obtained from masseter muscles' activities by different aged subjects (Group I and Group II), while masticating five different textured foods, is presented

in Table 3. It was observed that during chewing there is no significant difference ($p < 0.05$) in the acquired EMG variables. This reveals that the chewing pattern of both age groups is similar. The significantly different values of masticatory parameters for young (mean age of 29.4 years) and elderly (mean age of 67.7 years) subjects were earlier reported (Kohyama et al., 2002; Matsuo et al., 2020).

Table 1. Electromyographic variables acquired from female subjects (Group I) during mastication of different textured foods.

EMG variables	Jelly	Cake	Dhokla	Rasgulla	Paneer	p-value
Chews	15.38	24.38	16.13	21.25	26.38	0.00
Mastication time (s)	13.34	19.96	13.00	16.49	20.17	0.02
Total burst duration (s)	4.67	7.73	5.06	6.64	8.12	0.00
Total muscle activity (mV·s)	0.26	0.54	0.33	0.69	0.54	0.01
Burst duration per chew (s)	0.30	0.31	0.31	0.31	0.31	0.97
Interburst duration per chew (s)	0.59	0.53	0.52	0.47	0.47	0.02
Cycle time per chew(s)	0.89	0.84	0.83	0.79	0.78	0.07
Muscle activity per chew(mV·s)	0.06	0.24	0.22	0.13	0.21	0.51
Amplitude per chew(mV)	0.91	1.00	0.84	1.21	0.89	0.01
Early burst duration (s)	0.21	0.16	0.10	0.15	0.09	0.23
Middle burst duration (s)	0.23	0.14	0.13	0.13	0.10	0.16
Late Burst duration (s)	0.19	0.15	0.10	0.14	0.12	0.51
Early muscle Activity (mV·s)	0.02	0.03	0.02	0.04	0.02	0.00
Middle muscle Activity (mV·s)	0.02	0.02	0.02	0.03	0.02	0.00
Late muscle Activity (mV·s)	0.02	0.02	0.02	0.03	0.02	0.00
Early amplitude (mV)	0.91	1.06	0.73	1.25	0.86	0.01
Middle amplitude (mV)	0.95	1.01	0.81	1.29	0.83	0.00
Late amplitude (mV)	0.90	0.97	0.94	1.21	0.88	0.01

Table 2. Electromyographic variables acquired from female subjects (Group II) during mastication of different textured foods.

EMG variables	Jelly	Cake	Dhokla	Rasgulla	Paneer	p-value
Chews	18.25	22.00	22.13	20.50	34.13	0.00
Mastication time (s)	14.74	19.32	17.58	17.25	25.44	0.00
Total burst duration (s)	4.76	5.79	5.47	5.97	8.50	0.00
Total muscle activity (mV·s)	0.45	0.58	0.52	0.71	0.82	0.00
Burst duration per chew (s)	0.28	0.28	0.26	0.29	0.26	0.00
Interburst duration per chew (s)	0.59	0.64	0.58	0.57	0.53	0.00
Cycle time per chew(s)	0.86	0.92	0.84	0.86	0.78	0.00
Muscle activity per chew(mV·s)	0.41	0.13	0.13	0.47	0.12	0.14
Amplitude per chew(mV)	1.15	1.23	1.12	1.37	1.15	0.00
Early burst duration (s)	0.23	0.22	0.18	0.17	0.20	0.00
Middle burst duration (s)	0.17	0.10	0.18	0.19	0.19	0.00
Late Burst duration (s)	0.20	0.10	0.16	0.14	0.14	0.00
Early muscle Activity (mV·s)	0.02	0.03	0.02	0.27	0.02	0.34
Middle muscle Activity (mV·s)	0.02	0.02	0.03	0.42	0.03	0.32
Late muscle Activity (mV·s)	0.03	0.03	0.02	0.27	0.02	0.34
Early amplitude (mV)	1.04	1.23	1.11	1.30	1.25	0.00
Middle amplitude (mV)	1.08	1.29	1.19	1.42	1.21	0.00
Late amplitude (mV)	1.26	1.17	1.07	1.37	1.04	0.00

Table 3. Comparison of Group I and Group II female subjects' electromyographic variables acquired during mastication of different textured foods.

EMG variables	p-values				
	Jelly	Cake	Dhokla	Rasgulla	Paneer
Chews	0.09	0.14	0.26	0.86	0.39
Mastication time	0.09	0.22	0.45	0.91	0.53
Total burst duration	0.22	0.32	0.58	0.88	0.5
Total muscle activity	0.76	0.85	0.8	0.84	0.8
Burst duration per chew	0.87	0.8	0.78	0.85	0.93
Interburst duration per chew	0.48	0.07	0.13	0.68	0.29
Cycle time per chew	0.5	0.14	0.1	0.61	0.21
Muscle activity per chew	0.34	0.79	0.81	0.17	0.82
Amplitude per chew	0.78	0.76	0.77	0.7	0.8
Early burst duration	0.32	0.51	0.73	0.25	0.71
Middle burst duration	0.69	0.29	0.58	0.52	0.78
Late Burst duration	0.64	0.11	0.71	0.37	0.66
Early muscle Activity	0.79	0.66	0.77	0.52	0.67
Middle muscle Activity	0.81	0.8	0.74	0.5	0.71
Late muscle Activity	0.68	0.71	0.79	0.51	0.77
Early amplitude	0.83	0.72	0.73	0.8	0.68
Middle amplitude	0.8	0.76	0.8	0.77	0.69
Late amplitude	0.71	0.73	0.8	0.65	0.82

Variations in preferences to different textures for younger (mean age of 32-33 years) and elderly (mean age of 75-76 years) subjects were also reported (Roininen et al., 2003). A study on subjects varying in age from 20 to 90 years and observed lesser amplitude for elderly subjects as with ageing there is change in the density and area of masseter muscles as well as decrease in number of teeth (Newton et al., 2003). A conclusion from the above discussion can be made that the chewing pattern is relatively similar for subjects having narrow age difference, among younger group of subjects aged between 18-30 years, as it was a maximum of 12 years in our study. This could be attributed to the fact that masseter muscle activities are more dependent on dental status, weakness of masticatory muscles with age, chewing and swallowing. There is also increase in mastication load which thus increases the muscle activity in elder subjects' disorders (Kohyama et al., 2003; Peyron et al., 2004; Kohyama et al., 2015).

It is highly unlikely that any such problem onsets in the relatively young age groups selected in this study irrespective of the age differences for both the groups (Matsuo et al., 2020). To study the effect of gender, significant differences ($p < 0.05$) were observed for the most of the EMG variables obtained for male subjects except mastication time, interburst duration per chew, cycle time per chew and burst durations at different stages of mastication for these five different textured foods (Table 4). However, out of these parameters mastication time can also be used to differentiate these foods at the reduced level of confidence ($p < 0.10$). So it may be concluded from this discussion that thirteen EMG variables obtained from the analysis of bioelectrical activities of masseter muscles of male subjects can effectively ($p < 0.10$) distinguish these five different textured foods investigated in the present study (Matsuo et al., 2020).

A statistical analysis to compare EMG variables obtained for masseter muscles' activities of male and Group 1 female subjects while masticating five different textured foods, is presented in Table 5. It was observed that there is no significant difference ($p < 0.05$) in the acquired EMG variables except for inter burst durations in case of jelly, cake and dhokla while early burst durations for cake, dhokla and rasgulla for male and female subjects. The inter burst durations were significantly ($p \leq 0.05$) higher for female subjects for jelly, cake and dhokla. These results may be attributed to the reason that female subjects require a greater number of chews and mastication time as they chew food slowly with low value of mastication force and exhibits longer bursts of muscle activity and total duration of cycle (Nagasawa et al., 1997; Youssef et al., 1997; Matsuo et al., 2020).

However, the early burst durations were higher in male subjects for cake, dhokla and rasgulla. These differences may be due to the reason that the frequency of mastication for both hard and soft foods is greater in male subjects (Khamnei et al., 2016). The differences in basal metabolic rate for male and female subjects may also be a contributory factor for these variations. According to differences in age and gender, oral

processing behaviour of consumers shows variations in their bolus properties however there is small differences observed during dynamic texture perception. The present study revealed that masseter muscle activities during mastication process of these five different textured foods, as a whole, are not affected by gender variations (Henry et al., 2018; Monica et al., 2020).

Table 4. Electromyographic variables acquired from male subjects during mastication of different textured foods.

EMG variables	Jelly	Cake	Dhokla	Rasgulla	Paneer	p-value
Chews	21.63	23.75	20.38	20.25	25.25	0.03
Mastication time (s)	15.78	18.82	14.81	16.06	18.41	0.08
Total burst duration (s)	5.85	7.34	5.79	6.52	7.27	0.05
Total muscle activity (mV·s)	0.35	0.47	0.37	0.46	0.38	0.04
Burst duration per chew (s)	0.27	0.31	0.28	0.32	0.28	0.00
Interburst duration per chew (s)	0.46	0.48	0.43	0.46	0.44	0.60
Cycle time per chew(s)	0.73	0.79	0.71	0.78	0.72	0.76
Muscle activity per chew(mV·s)	0.02	0.02	0.02	0.02	0.01	0.00
Amplitude per chew(mV)	0.77	0.81	0.79	0.88	0.62	0.01
Early burst duration (s)	0.33	0.36	0.34	0.42	0.36	0.37
Middle burst duration (s)	0.28	0.31	0.29	0.31	0.29	0.40
Late Burst duration (s)	0.26	0.27	0.26	0.28	0.23	0.41
Early muscle Activity (mV-s)	0.02	0.02	0.02	0.03	0.02	0.02
Middle muscle Activity (mV-s)	0.02	0.02	0.02	0.02	0.01	0.00
Late muscle Activity (mV-s)	0.02	0.02	0.02	0.02	0.01	0.02
Early amplitude (mV)	0.74	0.86	0.84	0.87	0.55	0.02
Middle amplitude (mV)	0.83	0.85	0.82	0.90	0.61	0.00
Late amplitude (mV)	0.80	0.85	0.80	0.90	0.55	0.03

Table 5. Comparison of male and female (Group I) subjects' electromyographic variables acquired during mastication of different textured foods.

EMG variables	p-values				
	Jelly	Cake	Dhokla	Rasgulla	Paneer
Chews	0.27	0.93	0.54	0.85	0.87
Mastication time	0.45	0.82	0.76	0.92	0.70
Total burst duration	0.44	0.87	0.78	0.95	0.76
Total muscle activity	0.64	0.80	0.88	0.55	0.61
Burst duration per chew	0.42	0.66	0.54	0.74	0.45
Interburst duration per chew	0.02	0.03	0.05	0.12	0.08
Cycle time per chew	0.24	0.52	0.39	0.94	0.54
Muscle activity per chew	0.31	0.22	0.22	0.34	0.19
Amplitude per chew	0.80	0.69	0.91	0.51	0.55
Early burst duration	0.20	0.05	0.02	0.03	0.07
Middle burst duration	0.63	0.14	0.10	0.11	0.07
Late Burst duration	0.49	0.17	0.16	0.19	0.36
Early muscle Activity	0.99	0.55	0.91	0.59	0.61
Middle muscle Activity	0.89	0.71	0.88	0.58	0.60
Late muscle Activity	0.71	0.57	0.65	0.32	0.33
Early amplitude	0.79	0.66	0.78	0.46	0.44
Middle amplitude	0.84	0.76	0.97	0.47	0.61
Late amplitude	**0.86**	**0.82**	**0.78**	**0.46**	**0.46**

CONCLUSION

The present study was conducted to acquire the masseter muscle activities of human subjects by electromyography during chewing of five different textured foods namely jelly, cake, dhokla, rasgulla and paneer. The study was undertaken to evaluate the effect of age difference and gender on the masseter muscle activities. No significant differences were found in various masticatory parameters as observed by electromyographic analysis for the selected age groups viz. 18-20 years and 28-30 years indicating that this narrow difference in age does not influence the chewing patterns. The analysis of acquired EMG variables also revealed that both male and female subjects can effectively ($p<0.10$) distinguished these different textured foods. Further on comparison of these EMG variables for male and female subjects, it was found that their mastication process is also similar. So it may be concluded that for EMG sessions mixed group of young male and female subjects having narrower age differences can be selected for design and development of different textured foods.

Conflict of Interests: There was no conflict of interest among the authors.

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