Research Article

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Changes in Masticatory Muscle Activity Over Time by Facial Skin Temperature Area During Gum Chewing

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ABSTRACT

***Aim**: The purpose of this study was to quantify the change in facial skin temperature during mastication, and analyze the two aspects of habitual masticatory side and masticatory ability, and to clarify the change of masticatory muscle activity over time.*

***Method**: Subjects were 23 healthy women (21.3±0.4 years old). An infrared thermography camera was used to measure the left and right facial skin temperatures at rest and when chewing gum. The subjects were given dental xylitol gum and freely chewed it at a rate of once per second for 15 minutes. Skin temperature was measured 5, 10, and 15 minutes after the start of chewing. The facial reference area was measured between 30 to 36°C with a resolution of 1°C per pixel. The habitual masticatory side was determined by the stopping method, and from the 2 minute rest facial skin temperature area of the habitual non-masticatory side, and two groups were formed according to chewing strength.*

***Results**: There were 13 subjects in the weak chewing group and 10 in the strong group, with no significant difference in age, height, weight, BMI, and body fat percentage. The skin temperature increased with chewing, but the increase was less on the habitual non-masticatory side than on the masticatory side. Although there was no difference in muscle activity between the habitual masticatory side of the strong and weak chewing group, the muscle activity on the non-masticatory side was less than on the habitual masticatory side in the weak chewing group.*

***Conclusions**: The amount of masticatory muscle activity at rest was classed as either strong or weak chewing ability, and muscle activity was examined on both the habitual masticatory side and the habitual non-masticatory side. This significant difference suggests that using thermography was useful for determining masticatory ability on the chewing muscle activity at rest. Furthermore, being able to determine muscle activity by measuring changes in the skin temperature area by thermography, suggests that the method used in this study was viable.*

Keywords

Thermography, Gum chewing, Facial skin temperature area, Habitual masticatory side, Chewing ability.

Introduction

Mastication is carried out by the activity of the masticatory muscles, and is accompanied by changes in muscle potential and heat produced due to the contraction and relaxation of these muscles. Methods for evaluating the activity of the masticatory muscles are the electromyogram [1-4], deep body thermometer [5-7], and thermography [8-10]. Measurments using electromyograms or a deep body thermometer, involve attaching a sensor directly to the measurement site. Consequently, subtle differences in positioning of the sensors can cause the data to be

biased and discomfort caused by wearing the sensors can produce inacurate data.

Thermography does not involve sensors and measurements are made as if using a camera, so it is not invasive, causes no discomfort in the subject, and simple to use. However, although several previous studies used thermography, the methods and results are different. Berry et al. [8] reported that as a result of chewing gum on either the left or right side, there was no difference in skin temperature between the masticatory side and the non-masticatory side and that the skin temperature did not necessarily increase on the masticatory side. Hijiya et al. [9] reported that the temperature area determined for each individual expanded after chewing. Sadamitsu [10] examined the skin temperature for 5 parts of the masticatory muscle and facial area, and reported no difference between the habitual masticatory side and the habitual non-masticatory side. Previous studies have not fully clarified whether changes in facial skin temperature during chewing cause differences between masticatory sides.

The purpose of this study was to quantify and analyze the change in facial skin temperature during mastication from the aspects of habitual masticatory side and masticatory ability, and to clarify the change of masticatory muscle activity over time.

Method

Subjects

The subjects were 23 healthy female university students (21.3±0.4 years old: average value ± standard deviation) who understood the contents of this study and agreed to participate. In carrying out this research, we obtained the approval of the Ethics Committee of Nagoya University of Literature and Science (No. 44) based on the Declaration of Helsinki.

Measurement of facial skin temperature

We followed the method used by Takahashi et al. [11,12]. An infrared thermography camera, Thermo GEAR G100 (Avionics Japan), was used to measure the left and right facial skin temperature when at rest (0 minutes) and while chewing gum. The subject was given Dental xylitol gum (Lotte) to chew, and freely chewed the gum at a rate of once per second for 15 minutes. The left and right facial skin temperatures were measured at 5, 10, and 15 minutes after the start of chewing. Each image was analyzed using InfReC Analyzer NS9500 (Avionics Japan), and the facial reference area was determined by the number of pixels between 30 to 36°C where each pixel is 1°C. For each subject the corrected value of temperature was taken as the skin temperature area.

Determination of habitual masticatory side

The main occluding area was determined using stopping [13]. Test food used as stopping was placed on the subject's tongue and bitten at an arbitrary position. This was done 5 times to determine the main occluding area, and the habitual masticatory side and the habitual non-masticatory side. According to Tochikura et al. [14], there was a functional difference between mastication on the main masticatory side and the non-main masticatory side, and the main masticatory side chewing time was reported as having more efficient and had more stable movement with a stronger force than on the non-main masticatory side. From this, the habitual non-masticatory side was considered functionally inferior, and there was a big difference in chewing ability on the habitual non-masticatory side. Therefore this study analysed the habitual non-masticatory side.

Determination of masticatory ability

The strong masticatory ability group and weak masticatory ability group were formed from the 2 minute rest facial skin temperature area of the habitual non-masticatory side.

Statistical analysis

Using statistical analysis software SPSS (IBM), the physical status and skin temperature area of each subject were tested with a significance level of 5%. The skin temperature area of each masticatory side of the two groups were tested at 0, 5, 10, and 15 minutes using the Wilcoxon signed rank-sum test. To determine muscle activity, the skin temperature area was measured in the range 31 to 36°C.

Result

Subjects

Table 1 shows the physical status of the subjects. There were 13 people in the weak chewing group and 10 in the strong group. There was no significant difference between the groups in age, height, weight, BMI, or body fat percentage.

Comparison of muscle activity by masticatory side and ability of each group

1) Habitual masticatory side

Table 2 shows the results for the habitual masticatory side. The 32°C area at 5 to 10 minutes ($p= 0.011$), and 5 to 15 minutes ($p= 0.002$) significantly increased in both cases.

2) Habitual masticatory side of the strong chewing group

Table 3 shows the results for habitual masticatory side of the strong chewing group. The 32°C area significantly increased from 5 to 15 minutes ($p= 0.022$).

3) Habitual masticatory side of the weak chewing group

Table 4 shows the result for habitual masticatory side of the weak chewing group. The 32°C area significantly increased from 5 to 10 minutes ($p= 0.039$), and 5 to 15 minutes ($p= 0.028$). The 33°C area significantly increased from 10 to 15 minutes ($p= 0.023$).

4) Habitual non-masticatory side

Table 5 shows the results for the habitual non-masticatory side. The 35°C area increased significantly from 0 to 5 minutes ($p= 0.047$), and significantly decreased from 5 to 15 minutes ($p=0.020$). The 36°C area significantly decreased from 10 to 15 minutes ($p= 0.046$).

Table 1: Clinical characteristics of the 23 subjects.

Masticatory ability group	n	Age (year)	Body hight (cm)	Body weight (kg)	Body Mass Index (BMI) (kg/m^2)	Body fat (%)
Weak	13	21.2 ± 0.7	157.9 ± 3.7	53.7 ± 7.9	21.5 ± 3.1	30.8 ± 5.9
		n.s.	n.s.	n.s.	n.s.	n.s.
Strong	10	21.2 ± 0.4	155.8 ± 4.7	57.2 ± 10.5	23.6 ± 4.5	31.4 ± 8.6
Total	23	21.3 ± 0.4	157.0 ± 4.2	55.2 ± 9.1	22.4 ± 3.8	31.1 ± 7.0

The data are expressed as the mean ± standard deviation (SD). There were 13 people in the weak chewing group and 10 in the strong group. There was no significant difference between the groups.

Table 2: Comparison of muscle activity by habitual masticatory side (n=23).

Facial skin temperature	Facial skin temperature area			
	Rest (0 minutes)	After the start of chewing gum		
		5 minutes	10 minutes	15 minutes
36℃	0.107 ± 0.230	0.165 ± 0.427	0.094 ± 0.239	0.058 ± 0.188
35℃	3.153 ± 4.071	4.563 ± 6.364	4.141 ± 5.410	4.068 ± 8.080
34℃	16.563 ± 16.734	18.076 ± 16.681	18.111 ± 17.115	15.249 ± 15.564
33℃	27.898 ± 17.896	26.547 ± 16.771	24.902 ± 13.224	25.337 ± 13.324
32℃	21.214 ± 10.930	19.676 ± 11.400 ^{a*b**}	23.817 ± 14.331 ^{a*}	27.353 ± 15.031 ^{b**}
31℃	18.690 ± 16.490	18.974 ± 16.052	18.623 ± 16.863	20.458 ± 17.627
				*: $p < 0.05$, **: $p < 0.01$

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.
There were significant differences in 32 ℃ value (a: p=0.011, b: p=0.002).

Table 3: Comparison of muscle activity by habitual masticatory side of the strong chewing group (n=10).

Facial skin temperature	Facial skin temperature area			
	Rest (0 minutes)	After the start of chewing gum		
		5 minutes	10 minutes	15 minutes
36 ℃	0.138 ± 0.222	0.359 ± 0.607	0.198 ± 0.339	0.118 ± 0.277
35 ℃	6.035 ± 4.423	8.909 ± 7.330	8.298 ± 5.751	8.548 ± 10.868
34 ℃	31.865 ± 13.004	32.802 ± 13.738	32.433 ± 14.955	27.562 ± 15.304
33 ℃	43.010 ± 10.830	39.003 ± 11.248	34.108 ± 6.901	32.068 ± 11.599
32 ℃	14.426 ± 11.077	13.457 ± 9.118 ^{a*}	19.221 ± 16.665	23.688 ± 20.850 ^{a*}
31 ℃	3.880 ± 2.152	4.056 ± 2.340	3.977 ± 2.149	5.876 ± 4.534
				*: $p < 0.05$

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.
There was significant difference in 32 ℃ value (a: p=0.022).

Table 4: Comparison of muscle activity by habitual masticatory side of the weak chewing group (n=13).

Facial skin temperature	Facial skin temperature area			
	Rest (0 minutes)	After the start of chewing gum		
		5 minutes	10 minutes	15 minutes
36 ℃	0.084 ± 0.242	0.016 ± 0.057	0.014 ± 0.052	0.013 ± 0.045
35 ℃	0.936 ± 1.863	1.219 ± 2.467	0.943 ± 1.835	0.622 ± 1.238
34 ℃	4.791 ± 6.429	6.748 ± 6.989	7.095 ± 8.178	5.778 ± 6.701
33 ℃	16.274 ± 12.747	16.966 ± 13.858	17.821 ± 12.647 ^{c*}	20.159 ± 12.560 ^{c*}
32 ℃	26.435 ± 7.686	24.459 ± 10.903 ^{a*b*}	27.352 ± 11.710 ^{a*}	30.172 ± 8.268 ^{b*}
31 ℃	30.083 ± 13.101	30.450 ± 11.839	29.890 ± 14.198	31.675 ± 15.515
				*: $p < 0.05$

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.
There were significant differences in 32 ℃ value (a: p=0.039, b: p=0.028) and 33 ℃ value (c: p=0.023).

Table 5: Comparison of muscle activity by habitual non-masticatory side (n=23)

Facial skin temperature	Facial skin temperature area			
	Rest (0 minutes)	After the start of chewing gum		
		5 minutes	10 minutes	15 minutes
36 ℃	0.039 ± 0.139	0.084 ± 0.207	0.181 ± 0.509 [c*]	0.017 ± 0.038 [c*]
35 ℃	2.929 ± 3.991 [a*]	5.330 ± 7.783 [a*b*]	5.167 ± 9.010	3.371 ± 5.880 [b*]
34 ℃	17.020 ± 17.579	17.788 ± 18.220	16.039 ± 17.289	18.123 ± 19.290
33 ℃	27.904 ± 17.945	25.176 ± 15.859	24.755 ± 14.486	25.113 ± 15.428
32 ℃	21.200 ± 11.801	20.531 ± 11.747	23.828 ± 15.578	23.383 ± 15.296
31 ℃	19.430 ± 16.640	18.606 ± 15.411	19.524 ± 15.857	19.897 ± 16.311
				*: $p < 0.05$

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.
There were significant differences in 35 ℃ value (a: p=0.047, b: p=0.020) and 36 ℃ value (c: p=0.046).

Table 6: Comparison of muscle activity by habitual non-masticatory side of the strong chewing group (n=10).

Facial skin temperature	Facial skin temperature area			
	Rest (0 minutes)	After the start of chewing gum		
		5 minutes	10 minutes	15 minutes
36 ℃	0.024 ± 0.063	0.151 ± 0.282	0.188 ± 0.307	0.040 ± 0.051
35 ℃	5.395 ± 4.219	10.593 ± 9.051	10.039 ± 11.522	7.331 ± 7.298
34 ℃	32.985 ± 14.825	33.381 ± 16.256	30.699 ± 15.798	30.149 ± 17.384
33 ℃	43.603 ± 13.166	37.472 ± 12.224	34.018 ± 12.718	32.354 ± 9.003
32 ℃	13.919 ± 8.849	13.751 ± 9.830 [a*]	19.343 ± 19.178	22.515 ± 19.362 [a*]
31 ℃	3.401 ± 1.603	3.547 ± 1.444	4.172 ± 3.162	6.025 ± 5.392
				*: $p < 0.05$

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.
There was significant difference in 32 ℃ value (a: p=0.028).

Table 7: Comparison of muscle activity by habitual non-masticatory side of the weak chewing group (n=13).

Facial skin temperature	Facial skin temperature area			
	Rest (0 minutes)	After the start of chewing gum		
		5 minutes	10 minutes	15 minutes
36 ℃	0.050 ± 0.180	0.033 ± 0.110	0.176 ± 0.635	0
35 ℃	1.032 ± 2.623	1.282 ± 2.965	1.420 ± 3.777	0.324 ± 0.553
34 ℃	4.739 ± 5.093	5.793 ± 7.206	4.761 ± 6.628	8.873 ± 15.567
33 ℃	15.827 ± 9.848	15.718 ± 11.231 [a*]	17.630 ± 11.701 [a*]	19.543 ± 17.272
32 ℃	26.801 ± 10.883	25.746 ± 10.618	27.277 ± 11.806	24.051 ± 12.111
31 ℃	31.761 ± 11.263	30.190 ± 9.974	31.333 ± 10.294	30.567 ± 13.500
				*: $p < 0.05$

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.
There was significant difference in 33 ℃ value (a: p=0.022).

5) Habitual non-masticatory side of the strong chewing group
Table 6 shows the results for the habitual non-masticatory side of the strong group. The 32°C area significantly increased from 5 to 15 minutes (p=0.028).

6) Habitual non-masticatory side of the weak chewing group
Table 7 shows the results of the habitual non-masticatory side masticatory group. The area of 33°C area significantly increased from 5 to 10 minutes (p= 0.039).

Considerations

Determination of habitual masticatory side

In this study, the main occluding area was determined using stopping and was used to determin the habitual masticatory side. Christensen et al. [15] and Kazazoglu et al. [16] chewed gum and observed the chewing strokes to determine the habitual masticatory side. Pond et al. [17] and Delport et al. [18] used the side of the initial chewing movement and reported that side as the habitual masticatory side, and that initial movement correlated with wide on which chewing continued. In this study, the authors [19] determined the habitual masticatory side using the same method, and after 2 minutes of chewing, a relationship was found between chewing ability and exercise tolerance. From our previous study, the method of determining the habitual masticatory side from the main occluding area by stopping is considered appropriate for this study.

Determining masticatory ability by facial skin temperature using thermography

Chewing ability was evaluated from the facial skin temperature at 0 minutes on the habitual non-masticatory side, tested on the habitual

masticatory side and masticatory ability were obtained. The amount of masticatory muscle activity was significantly different. Methods for determining chewing ability, include chewing gum [20] color changing gum [21], gummies [22], peanuts [23], and raw rice [24]. However, these evaluation methods involve multiple factors such as bite, salivation volume, the ability to mix with saliva, and tongue movement. In this study, skin temperature due to masticatory muscle activity was measured by thermography, and the facial reference area was corrected. Therefore, masticatory muscle activity is measured quantitatively and comprehensively compared to previous research. In patients with craniomandibular disorder, masticatory muscle activity was significantly lower than in normal people, and treatment produced a significant increase in muscle activity [25,26]. Since there is a correlation between masticatory efficiency and craniomandibular disorder [27], masticatory efficiency and muscle activity are considered to be closely related. This study suggests that the masticatory muscle activity obtained from thermography was useful in determining masticatory ability.

Changes in muscle activity

Habitual masticatory side and habitual non-masticatory side

The 32°C area on the habitual masticatory side significantly increased from 5 to 10 minutes and from 5 to 15 minutes. After a significant increase in the 35°C area in the habitual non-masticatory side from 0 to 5 minutes, it decreased significantly from 5 to 15 minutes, and the 36°C area decreased significantly from 10 to 15 minutes. The skin temperature increased when chewing, which gave results similar to previous studies. However, the skin temperature increase was less on the habitual non-masticatory side compared to the habitual masticatory side. Nimura et al. [28] performed a study to clarify the difference in masticatory movement during chewing on the habitual masticatory side and non-masticatory side. They reported that the stability of both the motor pathway and the movement rhythm in the masticatory movement during chewing is greater on the habitual masticatory side than the other side. The smaller increase in skin temperature on the habitual non-masticatory side was considered to be due to reduced muscle activity on that side.

Strong chewing group and weak chewing group

The habitual masticatory side of the strong chewing group had a significant increase in the 32°C area from 5 to 15 minutes, and the 32°C area on habitual non-masticatory side also significantly increased from 5 to 15 minutes. The 32°C area of the habitual masticatory side for the weak chewing group significantly increased from 5 to 10 minutes, 5 to 15 minutes, and the 33°C area significantly increased from 10 to 15 minutes, and from 5 to 10 minutes on the habitual non-masticatory side. The muscle activity of the strong chewing group showed no difference between the sides, while the muscle activity on the habitual non-masticatory side was less than on the habitual masticatory side in the weak chewing group. The muscle activity on the habitual masticatory side is considered to be less involved in mastication due to the high load on the masticatory muscles in the strong chewing group due to the amount of chewing they do on a daily basis. Suzuki et al. [29] reported that for 5 types of chewing gum with different hardness, significantly increased the total carotid blood flow on the right hand side during chewing for 10 minutes, and that the blood flow is greater when chewing food of moderate hardness than soft or hard foods. The masticatory muscles on the habitual non-masticatory side of the weak chewing group are poorly developed. The gum used in this study is not considered to have increased blood flow any more than moderate hardness gum would have done for the weak chewing group. Yamamura [30] examined the effect of persistent mastication on masticatory movements only on the habitual non-masticatory side for 15 days. They reported that the stability and smoothness of the masticatory movement on the masticatory side increase daily. The effect of strengthening the habitual non-masticatory side for evaluating masticatory ability will be examined in the future.

Limitations of research

This study only examined the activity of masticatory muscles while chewing gum in young women, but different sex, age, and chewing samples may produce different results.

Conclusion

The facial skin temperature was measured by thermography, and the subjects were placed into either the strong or weak chewing group according to chewing muscle activity at rest, and the transition of muscle activity over time was examined on the habitual masticatory side and the habitual non-masticatory side. As a result, it was suggested that using thermography to measure the masticatory muscle activity at rest was useful for determining masticatory ability, due to a significant difference in muscle activity. Furthermore, since the muscle activity level could be determined from changes in the skin temperature area measured by thermography, the method used in this study is conisdered to be useful.

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Clinical Trial Registry or Grant Details

Since this study is not a clinical trial, no clinical study registration has been made, but the ethics committee was obtained.Ethical approval was obtained from the Research Ethics Committee of Nagoya Bunri University (No. 44). The authors have no conflicts of interest directly relevant to the content of this article.

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