Research Article

ISSN 2639-9490

Oral Health & Dental Science

Mastication and Bone Density of Young Women and the Relationship with Tolerance to Exercise -Analysis with thermography and a Bicycle Ergometer-

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Received: 17 January 2020; **Accepted:** 05 February 2020

Citation: Hidetaka Nakamura, Kazuyoshi Hashimoto, Kei Takahashi, et al. Mastication and Bone Density of Young Women and the Relationship with Tolerance to Exercise -Analysis with thermography and a Bicycle Ergometer-. Oral Health Dental Sci. 2020; 4(1); 1-8.

ABSTRACT

Introduction: *Chewing well is linked to preventing obesity and lowering the risk of type-2 diabetes and the importance of mastication is recognized. In the field of dentistry, there have been numerous reports on the relationship between bite and tolerance to exercise. However due to the lack of reports relating to mastication and tolerance to exercise we aim to clarify the relationship between mastication and tolerance to exercise and bone density.*

Method: *23 healthy young females (21.3 ± 0.4 years old) without a history of exercise had their habitual non-masticatory side determined by finding the main occluding area using stopping. The facial skin temperature at rest on the habitual non-masticatory side was measured using thermography and the area was multiplied by that temperature for each 1℃ and totaled. Each participant was placed in either the high or low chewing efficiency group depending on the average of that value. Tolerance to exercise was determined by a bicycle ergometer and exhaled gas analysis while ultrasound was used to determine bone density, and the 2 groups were compared.*

Results: *The bone density, peak oxygen consumption per 1kg of body weight and minute volume of ventilation from 5 minutes before the end of exercising to end of exercising were each considerably small in the low chewing efficiency group compared to the high chewing efficiency group.*

Conclusion: *The facial skin temperature was measured using thermography to give masticatory muscle activity when at rest as chewing efficiency and was confirmed to have a relationship with exercise tolerance. Chewing efficiency can be determined using thermography. Also, a relationship was confirmed between chewing efficiency and bone density, and since there is a relationship between bone density and heart pump functionality through mastication in eating habits and exercise habits, we reconfirmed the importance of mastication.*

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. The authors have no conflicts of interest directly relevant to the content of this article.

Keywords

Bone Density, Ergometer, Mastication, Thermography, Young women.

Introduction

In recent years in Japan, there is a concern that chewing is insufficient due to skipping breakfast or consuming soft foods due to the westernization of the diet. Mastication has a wide range of uses such as promoting growth of facial bones, promoting digestion or appetite regulation through endocrine exacerbation, regulating health by promoting the excretion of saliva, and brain activity [1]. Further, in cohort studies the stronger chewing group have a reduced risk of developing type 2 diabetes compared to the weaker chewing group [2], and chewing well is linked to preventing obesity [3,4], so the importance of mastication is verified.

The Cardiopulmonary Exercise Test (CPX) that uses exhaled gas analysis is one method of determining athletic ability. Combining knowledge gained form CPX, highly repeatable and objective information on the overall health of an individual can be obtained [5,6]. Previous studies on the use of CPX in medicine include standards for determining heart transplants for heart failure [7], determining severity [8], relation with prognosis on the life of a healthy person [9], relation with prognosis on the life of patients with heart disease [10]. Similar studies in sports science are on training using the anaerobic threshold (AT) [11], and in studies in dentistry on the relation between the state of occlusion and athletic ability [12,13]. In each field, there are many reports of the main test subjects in studies using CPX being junior or senior high school students and they report on the relationship between occlusion and athletic ability. However, studies on the relationship between mastication and athletic ability are few in number. Also, since there is a prevalence of osteoporosis in females, compared to males [14,15], this study targets young females and examines gradual load on CPX using a bicycle ergometer and measures bone density in addition to chewing efficiency obtained from thermography of masticatory muscle activity. The aim is to clarify the relationship between chewing efficiency and tolerance to exercise and bone density in young females.

Methods

Participants

Twenty-three healthy female university students with no history of exercise (age: 21.3 ± 0.4: average ± standard deviation) were enrolled in the study with informed consent. This study received authorization, based on the Helsinki Declaration, from the Nagoya Bunri University Ethics Council (No. 44).

Facial skin temperature measurement method

The method was used according to Takahashi et al. [16,17]. Namely, facial skin temperature measurements were taken on the left and right side of the face when at rest using the infrared thermography camera, Thermo GEAR G100 (Nippon Avionics Co., Ltd.). Using the analysis software, InfReC Analyzer NS9500 (Nippon Avionics Co., Ltd.), the number of pixels (area) in each image that corresponded to a change in 1oc between 30-36oc were counted for each temperature and corrected for a standard facial surface area. Each temperature was multiplied by this correction value and then summed to obtain the normal skin temperature for each participant.

Determining the habitual masticatory side

Stopping was used in accordance with the method to determine the main occluding area [18]. According to Tochikura et al. [19], there is a difference in functionality between the main masticatory side and the non-main masticatory side when biting, and they reported that the strength, stability of motion and chewing efficiency were higher in the main masticatory side than the non-masticatory side. From this we consider that the habitual non-masticatory side has weaker functionality and that there is a large difference in chewing efficiency for that side, therefore this study analyzed the habitual non-masticatory side.

Exercise load

The Bicycle ergometer 75 XLII (Combi Corporation) was used. The linear incremental load exercise used here is an exercise load method proposed by Whipp et al. [20], wherein the exercise difficulty is linearly increased. It is safe and the necessary data can be obtained in a short time and is widely used in the field of respiratory physiology. Previous studies used loads of 12.5 W every 30 s [21], 10 W or 20 W every 1 min. [22,23], 25 W every 2 min [24], and 25W every 3 min [25]. Since the subjects in this study have no experience with exercise, we began at 70 pedal revolutions per minute at 20 W and increased in 10 W increments every 3 min, and continued until either 30 min had elapsed or the rate of 70 pedal revolutions per minute could not be maintained. During the exercise, the exhaled breath was collected and analyzed using the breath-by-breath method with the exhaled gas analyzer VO2000 (S&ME Inc.). Furthermore, the heartbeat was continuously measured during the exercise using the simple cardiometer A360 (Polar Japan).

Bone density measurements

Quantitative ultrasound (QUS) was used. QUS is used to diagnose osteoporosis, as there is a correlation with the bone density measured via dual-energy X-ray absorptiometry (DXA) [26,27]. The speed of sound (SOS) (m/s) and transmission index (TI) through the calcaneus were measured using the ultrasonic bone density evaluation equipment AOS-100 (Hitachi Aroka Medical Inc.) and the bone density was obtained as the osteosonic index (OSI) from the following equation [28,29].

$OSI = TI \times SOS^2$

Statistical processing

The participants were placed in the low group (L-group) or high group (H-group) based on the average normal skin temperature on their habitual non-masticatory side, and the Mann-Whitney U test, with the statistical significance set to 5%, was run on SPSS statistical processing software (IBM).

Results

Participants

Table 1 shows the physical condition of the participants. Thirteen were in the L-group and 10 in the H-group. There was no significant difference in any of the age, height, weight, BMI or body mass percentage between the groups.

Masticatory group	n	Age (year)	Body hight (cm)	Body weight (kg)	Body Mass Index (BMI) (kg/m²)	Body fat (%)
Low (L)	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.
High (H)	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

Table 1: Clinical characteristics of the 23 subjects.
The data are expressed as the mean ± standard deviation (SD).

There were no significant differences in clinical characteristics.

Bone density

Table 2 shows the measured results for bone density. They were 2.568 ± 0.262 (×10^6) for the L-group and 2.776 ± 0.251(×10^6) for the H-group, with the L-group being significantly lower (p=0.036).

Masticatory group	n	Bone density (×10^6)
Low (L)	13	2.568 ± 0.262
		*
High (H)	10	2.776 ± 0.251
Total	23	2.659 ± 0.273

Table 2: Bone density value of the 23 subjects.
The data are expressed as the mean ± standard deviation (SD). *: $p < 0.05$.
There were significant difference in Bone density (p=0.036).

Peak oxygen consumption per 1kg of body mass

Table 3 shows the results for peak oxygen consumption per 1kg of body mass (peak VO^2/kg). They were 28.79 ± 8.10mL/kg/min for the L-group and 35.41 ± 6.20mL/kg/min for the H-group, with the L-group being significantly lower (p=0.036).

Masticatory group	n	Peak oxygen consumption per 1kg of body weight (mL/kg/min)
Low (L)	13	28.79 ± 8.10
		*
High (H)	10	35.41 ± 6.20
Total	23	31.67 ± 7.92

Table 3: Peak oxygen consumption per 1kg of body weight value of the 23 subjects.
The data are expressed as the mean ± standard deviation (SD). *: $p < 0.05$
There were significant difference in Peak oxygen consumption per 1kg of body weight (p=0.036).

Minute ventilation

Table 4 shows the results for minute ventilation (VE). At 5 min before the end of the exercise, the L-group was 32.98 ± 13.20L/min and the H-group was 53.55 ± 15.98L/min (p=0.002), at 4 min before, the L-group was 37.80 ± 10.06L/min and the H-group was 52.52 ± 15.23L/min (p=0.030), at 3 min before, the L-group was 34.82 ± 10.98L/min and the H-group was 52.71 ± 18.68L/min (p=0.010), at 2 min before, the L-group was 32.75 ± 16.02L/min and the H-group was 56.65 ± 16.49L/min (p=0.003), at 1 min before, the L-group was 38.79 ± 14.27L/min and the H-group was 58.69 ± 18.23L/min (p=0.008), and at the end of the exercise, the L-group was 32.35 ± 10.91L/min and the H-group was 57.33 ± 19.06L/min (p=0.001), and in all cases the L-group was significantly lower.

Discussion

Measurement of facial skin temperature using thermography and chewing efficiency

This study evaluated chewing efficiency from facial skin temperature using thermography. General methods for evaluating chewing efficiency include having the participant chew on chewing gum [30], colour changing gum [31], gummi drops [32], peanuts [33], or raw rice [34]. However, these methods involve numerous factors such as occlusion, masticatory muscles, salivary output, and mixing ability with saliva (tongue movement). Electromyography [35] can also be used, however small variations in the positioning of the sensor can lead to differences in results. A previous study be Berry et al. [36], thermography was used to measure the facial skin temperature distribution during mastication, and the facial surface temperature was shown to vary with chewing.

Tsuchiya et al. [37] measured the facial temperature distribution when the participant was chewing gum and compared the spread of high temperature regions from before and after chewing. The sum of the corrected surface area multiplied by the respective temperature used in this study is considered a more comprehensive and finer evaluation of facial skin temperature due to masticatory muscle movement than in previous studies.

Determining the habitual masticatory side

This study used to stop to determine the main occluding area and hence determine the habitual masticatory side. Christensen et al. [38] and Kazazoglu et al. [39] had participants chew gum and observed the chewing stroke to determine the habitual masticatory side. Also, Pond et al. [40] and Delport et al. [41] set the habitual masticatory side to be that on which the first stroke of the masticatory movement and reported that there was a correlation between the first stroke of the masticatory movement and the side used in continual chewing. Therefore, the current study considered it reasonable to use stopping to determine the main occluding area and hence determine the habitual masticatory side.

Masticatory group	n	Before the end of exercising					End of exercising
		5 minutes	4 minutes	3 minutes	2 minutes	1 minute	
Low (L)	13	32.98 ± 13.20	37.80 ± 10.06	34.82 ± 10.98	32.75 ± 16.02	38.79 ± 14.27	32.35 ± 10.91
		**	*	*	**	**	**
High (H)	10	53.55 ± 15.98	52.52 ± 15.23	52.71 ± 18.68	56.65 ± 16.49	58.69 ± 18.23	57.33 ± 19.06
Total	23	41.92 ± 17.55	44.20 ± 14.34	42.60 ± 17.05	43.14 ± 19.95	47.44 ± 18.68	43.21 ± 19.34

Table 4: Minute volume of ventilation value (L/min) of the 23 subjects.
The data are expressed as the mean ± standard deviation (SD). *: $p < 0.05$, **: $p < 0.01$
There were significant differences in 5 minutes before the end of exercising (p=0.002), 4 minutes before the end of exercising (p=0.030), 3 minutes before the end of exercising (p=0.010), 2 minutes before the end of exercising (p=0.003), 1 minute before the end of exercising (p=0.008) and end of exercising (p=0.001).

Mastication and bone density

The results of this study determined that the bone density was considerably lower in the group with lower chewing efficiency than in the other group. In previous studies, Teraoka et al. [42] examined bone density and chewing efficiency in elder people and confirmed a relation between bone densities and chewing efficiency in elder males yet found no significant difference with the elderly females and reported a strong influence due to aging. Iwasaki et al. [43] investigated the occlusal force and physical strength along with bone density of the calcaneus of female junior college students and stated that it is possible to increase bone density through using exercises to strengthen occlusal force. Mitsuki et al. [44] analyzed the relevance of calcaneus bone density and occlusal support, and confirmed a relationship between a decrease in the calcaneus bone density and loss of occlusal support. Occlusal force is one factor in setting chewing efficiency [45] and mastication is suggested as an influence on bone density.

Mastication and athletic ability

This study confirmed a relationship between mastication and athletic ability. In a previous study, Iwasaki et al. [46] investigated the relationship between occlusal force and physical strength in sportsmen, and reported a significant positive correlation between occlusal force and grip strength and back strength. Ishiyama [47] investigated the relationship between occlusal force and the physical fitness test of the Japanese Ministry of Education and Science of healthy young females, and reported that for participants with occlusal force greater than 45kgf had stronger grip strength, could stand on one leg with their eyes closed for longer and better full body endurance that those with a grip force up to 45kgf. From these reports, we can infer that there is a close relationship between occlusal force, upper and lower limb strength, and full body endurance.

There are also reports similar to this study that investigate the relationship between mastication and athletic ability. Ono et al. [48] investigated the relationship between masticatory force and physical test results of elementary school students, and reported that compared to the low masticatory force group, the high masticatory force group has significantly better scores for grip strength, seated toe touching stretch, 20m shuttle run and 50m dash. Iwasaki et al. [49] investigated the relationship between chewing ability and length of time standing on one leg in elderly participants, and reported a significant relationship between poor chewing ability and not being able to stand on one leg for more than 30s. Johnson et al. [50] reported on confirming a significant positive correlation between occlusal force, grip strength and back strength due to the direct proportionality of masticatory and limb muscle growth. From the above, occlusion and chewing ability can be inferred to have a close correlation with athletic ability, and suggests that mastication influences tolerance to exercise. This study confirmed a correlation between mastication and grip strength, as mentioned in previous studies. Grip strength reflects full body strength around the lower limb strength [51] and as the period of inactivity increases, amyotrophy progresses and muscle strength decreases [52]. The participants in this study had no history of exercise, and showed a decreasing trend in full body strength including grip strength. Since the strength of the masticatory muscles decreased slightly from chewing motions, we could not confirm a relation with grip strength, and this required further study.

Research limitations

The participants in this study were young females with no history of exercise and different results can be expected for different genders, ages, and exercise history.

Conclusion

Facial skin temperature was measured with thermography, and a relationship was confirmed between tolerance to exercise and chewing efficiency from masticatory muscle activity at rest. Therefore, thermography can be used to determine chewing efficiency. Furthermore, a correlation was confirmed between chewing efficiency and bone density and the importance of mastication was reconfirmed from the correlation of bone density and heart pumping ability with mastication through eating and exercise habits. Here the masticatory muscle activity on the habitual non-masticatory side was used, yet further study is required to investigate the relationship between tolerance to exercise and chewing efficiency from masticatory muscle activity on the habitual masticatory side.

Acknowledgments

Funding for this investigation was provided in part by Nagoya Bunri University. The authors have no conflicts of interest directly relevant to the content of this article. We would like to thank Konan Translation Service (www.konan-tr-s.com) for English language editing.

References

1. Kobayashi Y. A Long Life Built by Mastication and Occlusion. Ann Jpn Prosthodont Soc. 2011; 3: 189-219.
2. Yamazaki T, Yamori M, Asai K, et al. Mastication and Risk for Diabetes in a Japanese Population: A Cross-Sectional Study. PLOS ONE. 2013; 8: 64113.
3. Matsuda H. The Relation with Masticatory Power to Obesity in Female Students. The Japanese Journal of Nutrition and Dietetics. 1996; 54: 79-85.
4. Nakamura T, Hosoya N. Study on Eating Behavior and Physical Activities in Overweight Subjects. The Japanese Journal of Nutrition and Dietetics. 1986; 44: 69-78.
5. Keteyian SJ, Brawner CA, Ehrnan JK, et al. Abraham WT. Reproducibility of peak oxygen uptake and other cardiopulmonary exercise parameters. CHEST. 2010; 138: 950-955.
6. Weber KT, Kinasewitz GT, Jenicki JS, et al. Oxygen utilization and ventilation during exercise in patients with chronic cardiac failure. Circulation. 1982; 65: 1213-1223.
7. Manchi DM, Eisen H, Kussmaul W, et al. Value of peak exercise oxygen consumption for optimal timing of cardiac transplantation in ambulatory patients with heart failure. Circulation. 1991; 83: 778-786.
8. Weber KT, Jenicki JS. Cardiopulmonary exercise testing for

evaluation of chronic cardiac failure. Am J Cargdiol. 1995; 55: 22A-31A.
9. Myers J, Prakash M, Froelicher V, et al. Exercise capacity and mortality among men referred for exercise testing. N Engl J Med. 2002; 346: 793-801.
10. Arena R, Myers J, Abella J, et al. Development of a ventilatory classification system in patients with heart failure. Circulation. 2007; 115: 2410-2417.
11. Hanada S, Sekine M, Tamura T, et al. Estimation of Protocol in Interval Training under an Anaerobic Threshold. Transactions of the Japanese Society for Medical and Biological Engineering. 2011; 49: 48-53.
12. Kikkawa K, Munetaka H, Yamaguchi T. Effects of Malocclusion on Physical Growth and Development. Japan Journal of Human Growth and Development Research. 1998; 26: 86-90.
13. Ishiyama I. The Relationship between Occlusal Force and Physical Fitness in Healthy Young Women. Journal of Japanese Society for Masticatory Science and Health Promotion. 2008; 18: 22-28.
14. Yoshimura N, Muraki S, Oka H, et al. Cohort Profile: Research on Osteoarthritis/Osteoporosis Against Disability study. Int J Epidemiol. 2010; 39: 988-995.
15. Yoshimura N, Muraki S, Oka H, et al. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab. 2009; 27: 620-628.
16. Takahashi K, Hashimoto K, Nakamura H, et al. The Study of the Facial Skin Temperature by Thermography after Gum Chewing -The Differences between Insulin Secretion Types. Journal of Japanese Society for Masticatory Science and Health Promotion. 2018; 28: 11-18.
17. Takahashi K, Hashimoto K, Nakamura H, et al. Thermography-Measured Facial Temperature Affects Masticatory Ability. Oral Health Dental Sci. 2019; 3: 1-5.
18. Kato H, Furuki Y, Hasegawa S. Observations on the main occluding area in mastication. J Jpn Soc Stomatognath Funct. 2000; 9: 57-64.
19. Tochikura J, Shiga H, Kobayashi Y. Functional differences between chewing on habitual chewing side and chewing on non-habitual chewing side -Masticatory movement function, masticatory muscular activity, and masticatory efficiency when chewing gumi-jelly. Journal of Japanese Society for Masticatory Science and Health Promotion. 2000; 9: 57-64.
20. Whipp BJ, Davis JA, Torres F, et al. A test to determine parameters of aerobic function during exercise. J Appl Physiol. 1981; 50: 217-221.
21. Yamada E, Katoh H, Miyamoto K, et al. Frequency Analysis of Surface Electromyogram of Rectus Femoris Muscle Using Wavelet Transform during Incremental Exercise -Changes in Frequency Characteristics before and after IEMGT. Physical Therapy Japan. 2003; 30: 357-361.
22. Murakami M, Katou J, Yamabe H, et al. Effect of Bicycle Ergometer Training on Oxygen Uptake Kinetics and Exercise Capacity in Patients with Cerebrovascular Disorder. Physical Therapy Japan. 2002; 29: 152-155.
23. Tabira K, Harada T, Yamamoto J, et al. Characteristics of incremental and high intensity constant load exercise tests on exercise physiology from the view point of oxygen uptake. J Jp Soc Resp Care Rehab. 2014; 24: 252-257.
24. Susaki T, Sugama S, Tachino K, et al. Effect of Arm and Leg Ergometry on Respiro-circulatory Responses; Comparisons with Maximum Voluntary Exercise. J Exerc Physiol. 1994; 9: 183-186.
25. Haramura M, Takai Y, Yamamoto M, et al. Differences in cardiorespiratory and metabolic responses between body mass-based squat and lunge exercises with relation to muscular activity with relation to muscular activity level. Jpn J Phys Fitness Sports Med. 2017; 66: 101-110.
26. Greenspan SL, Bouxsein ML, Melton ME, et al. Precision and discriminatory ability of calcaneal bone assessment technologies. J Bone Miner Res. 1997; 12: 1303-1313.
27. Hans D, Dargent-Molina P, Schott AM, et al. Ultrasonographic heel measurements to predict hip fracture in elderly women: the EPIDOS prospective study. Lancet. 1996; 348: 511-514.
28. Park H, Togo F, Watanabe E, et al. Relationship of bone health to yearlong physical activity in older Japanese adults: cross-sectional data from the Nakanojo Study. Osteoporos Int. 2007; 18: 285-293.
29. Tsuda-Futami E, Hans D, Njeh CF, et al. An evaluation of a new gel-coupled ultrasound device for the quantitative assessment of bone. Br J Radiol. 1999; 72: 691-700.
30. Matsuda H, Takada K, Hashimoto K, et al. Examination of measuring the masticatory ability using gum. Journal of Japanese Society for Masticatory Science and Health Promotion. 2001; 10: 95-100.
31. Hayakawa I, Watanabe I, Hirano S, et al. A simple Method for evaluating masticatory performance using a color-changeable chewing gum. Int J Prosthodont. 1998; 11: 173-176.
32. Tanaka A, Shiga H, Kobayashi Y. Quantitative Evaluation of Mandibular Movements and Masticatory Muscular Activities by Analyzing the Amount of Glucose Discharge during Gumi-jelly Chewing. The Journal of the Japan Prosthodontic Society. 1994; 38: 1281-1294.
33. Manly RS. Factors affecting masticatory performance and efficiency among young adults. J. Dent. Res. 1951; 30: 874-882.
34. Ishiwara T. Masticatory Efficiency and Particle Size Distribution of Masticated Raw Rice. J Stomatol Soc Jpn. 1995; 22: 207-255.
35. MacDougall JDB, Andrew BL. An electromyographic study of the temporalis and masseter muscles. J Anat. 1953; 57: 37-45.
36. Berry DC, Yemm R. Changes in facial skin temperature associated with unilateral chewing. Oral Rehabil. 1974; 1: 127-129.
37. Hijiya H, Takada K, Yasuda Y, et al. A thermographic study on gum chewing effort. Japanese Journal of Oral Biology. 1990; 32: 93-102.
38. Christensen LV, Radue JT. Lateral preference in mastication: a feasibility study. J oral Rehabil. 1985; 12: 461-467.

39. Kazazoglu E, Heath MR, Muller F. A simple test for determination of the preferred chewing side. J Oral Rehabil. 1994; 21: 723-724.
40. Pond LH, Barghi N, Barnwell GM. Occlusion and chewing side preference. J Prosthet Dent. 1986; 55: 498-500.
41. Delport HP, De Laat A, Nijs J, et al. Preference pattern of mastication during the first chewing cycle. Electromyogr Clin Neurophysiol. 1983; 23: 491-500.
42. Teraoka K, Shinada K, Asaka T, et al. A Longitudinal Cohort Study on the Relation Between Physical Condition and Masticatory Ability in the Elderly. J Stomatol Soc Jpn. 1998; 65: 376-379.
43. Iwasaki H, Inaba R, Fujita S, et al. Relationship between Biting Force and Physical Fitness and Calcaneus Bone Density in Students of Women's Junior College. Jpn J Health Hum Ecol. 1996; 62: 3-12.
44. Miki H, Tanaka M, Kawazoe T. Multivariate analysis of the relation between occlusal status and bone mineral density in calcaneus. Journal of Osaka Odontological Society. 2003; 66: 63-71.
45. Nakasima A. An Analysis of Several Physiological Factors Influencing the Masticatory Function. J Kyushu Dent Soc. 1976; 30: 20-36.
46. Iwasaki H, Inaba R, Iwata H. Biting Force and Physical Fitness in Athletes. Japanese Journal of Hygiene. 1994; 49: 654-659.
47. Ikuo Ishiyama. The Relationship between Occlusal Force and Physical Fitness in Healthy Young Women. Journal of Japanese Society for Masticatory Science and Health Promotion. 2008; 18: 22-28.
48. Ono K, Ando H, Murai Y. Relevance of Masticatory Strength to Dietary Habits and Measurements of Physical Strength in Elementary School Students. Journal of Japanese Society of Shokuiku. 2017; 11: 181-188.
49. Iwasaki M, Yoshihara A, Miyazaki H. Association between Masticatory Performance and One-leg Standing Time with Eyes Open in Community-dwelling Elderly Women. J Dent Hlth. 2012: 62; 289-295.
50. Johnson AL, Hatfield HK. A study of the relation of dental conditions, biting force, and the hand grip, Dent. Cosmos. 1917: 59: 599.
51. Kanazashi M, Sakamoto H, Fujino H. The correlation between lower limb strength and vastus intermedius muscle and the significance of measurement of grip force in young healthy women. Japanese Journal of Health Promotion and Physical Therapy. 2014; 3: 173-176.
52. Okawa Y, Ueda S. The Disuse Muscle Atrophy in The Hemiplegic Patients The Muscle Weakness in The "Unaffected" Extremities. The Japanese Journal of Rehabilitation Medicine. 1988; 25: 143-147.