J Oral Res
research in oral sciences

ARTICLE

MASTICATORY FUNCTION ACCORDING TO BODY MASS INDEX. PART I: KINEMATIC ANALYSIS USING DIFFERENT FOOD TEXTURES.

Función masticatoria según índice de masa corporal. Parte I: análisis cinemático utilizando diferentes texturas de alimentos.

Constanza Farfán.[1,2]
Camila Venegas.[1,3]
María Florencia Lezcano.[1,2]
Ramón Fuentes.[1,2]

AFFILIATIONS:
[1]Dental School, Research Centre for Dental Sciences (CICO), Universidad de La Frontera, Temuco, Chile.
[2]Department of Integral Adults Dentistry, Dental School, Universidad de La Frontera, Temuco, Chile.
[3]Master program in Dentistry, Dental School, Universidad de La Frontera, Temuco, Chile.

CORRESPONDING AUTHOR:
Ramón Fuentes Fernández. Centro de Investigación en Ciencias Odontológicas Facultad de Odontología, Universidad de La Frontera Avenida Francisco Salazar # 1145, Temuco, Chile. Phone: (56-45) 2596902. E-mail: ramon.fuentes@ufrontera.cl

CITE AS:
Farfán C, Venegas C, Lezcano MF & Fuentes R.
Masticatory function according to body mass index. Part I: kinematic analysis using different food textures.
J Oral Res.2022;11(1):1-12.
doi:10.17126/joralres.2022.005

ABSTRACT:

Introduction: Chewing is a learned orofacial function, important in the nutrition process of most mammals. It has been described that it can vary according to the characteristics of the individuals and the characteristics of the food. The aim of this study was to compare the kinematic cha-racteristics of mastication in subjects with different body mass index (BMI), including foods of different hardness in the analysis.

Material and Methods: A cross-sectional observational study was conducted. The mastication of 3.7 g of peanut (soft food) and 3.7 g of carrot (hard food) was compared among three study groups formed according to BMI: normal weight (BMI 18.5-24.9), overweight (BMI 25-29.9) and obese (BMI ≥30); each with 7 participants. The kinematics of the masticatory movement were assessed with a 3D Electromagnetic Articulograph, the characteristics analyzed were number of masticatory cycles, masticatory frequency, speed and area of the cycles.

Results: No significant differences were noted among the study groups for the number of masticatory cycles, frequency or speed in the two foods studied. It was observed that when chewing carrot, the horizontal area of the masticatory cycles was significantly larger in the obese than in the overweight group. However, when chewing peanuts, this parameter did not present significant differences among the different groups. A comparison of the characteristics of mastication of the two foods revealed that the carrot chewing presented a significantly greater masticatory frequency and speed than the peanut chewing.

Conclusion: This study demonstrated that food hardness influences the kinematic characteristics of mastication more than BMI, noting that hard foods are masticated faster and more frequently than soft foods and that masticatory frequency tends to increase with BMI.

KEYWORDS:

Body mass index; Obesity; Overweight; Mastication; Biomechanical Phenomena; Food.

Received: 06 May 2021 | **Accepted:** 07 November 2021 | **Published online:** 28 January 2022

ISSN Print 0719-2460 - **ISSN Online** 0719-2479. **www.joralres.com/2021**

RESUMEN:

Introducción: La masticación es una función orofacial aprendida, importante en el proceso de alimentación de la mayoría de los mamíferos. Se ha descrito que esta puede variar de acuerdo a las características de las personas y las características de los alimentos. El objetivo de este estudio fue comparar las características cinemáticas de la masticación en sujetos con diferente índice de masa corporal (IMC), incluyendo alimentos de diferente dureza en el análisis.

Material y Métodos: Se realizó un estudio observacional de corte transversal. Se comparó la masticación de 3,7 g de maní (alimento blando) y 3,7 g de zanahoria (alimento duro) entre tres grupos de estudio formados según el IMC: normopeso (IMC 18,5-24,9), sobrepeso (IMC 25-29,9) y obeso (IMC ≥30); cada uno con 7 participantes. La cinemática del movimiento masticatorio se evaluó con un Articulógrafo Electromagnético 3D, las características analizadas fueron número de ciclos masticatorios, frecuencia masticatoria, velocidad y área de los ciclos.

Resultados: No se observaron diferencias significativas entre los grupos de estudio para el número de ciclos masticatorios, frecuencia o velocidad en los dos alimentos estudiados. Se observó que al masticar zanahoria, el área horizontal de los ciclos masticatorios fue significativamente mayor en el grupo de obesos que en el de sobrepeso; Sin embargo, al masticar maní, este parámetro no presentó diferencias significativas entre los diferentes grupos. Una comparación de las características de masticación de los dos alimentos reveló que el masticado de zanahoria presentó una frecuencia y velocidad masticatoria significativamente mayor que el masticado de maní.

Conclusión: Este estudio demostró que la dureza de los alimentos influye en las características cinemáticas de la masticación más que el IMC, observando que los alimentos duros se mastican más rápido y con mayor frecuencia que los blandos y que la frecuencia masticatoria tiende a aumentar con el IMC.

PALABRAS CLAVE:

Índice de Masa Corporal; Obesidad; Sobrepeso; Masticación; Fenómenos Biomecánicos; Alimentos.

INTRODUCTION.

Clinical nutrition is the discipline concerned with the prevention, diagnosis and management of nutritional changes, body composition and metabolic changes related to diseases and conditions caused by the lack or excess of nutrients.[1] The eating disorders this discipline treats include overweight and obesity, defined as excessive accumulation of fat, which can be a key risk factor in the development of numerous chronic diseases.[1,2]

Therefore, a nutritional evaluation is essential to detect individuals at risk. For this, different objective indicators have been developed. The body mass index (BMI) is a simple indicator of the relation between weight and size that is frequently used to identify overweight and obesity. It is currently the most used indicator and has been recommended by the WHO due to its simplicity and low cost.[3]

Mastication is a learned orofacial function with relevant implications in the harmonic development of the stomatognathic and craniofacial systems.[4] It is a complex process that involves the repeated opening and closing of the jaw, secretion of saliva and the mixture of food with the tongue.[5] In the attempts to understand the different factors that contribute to the development of masticatory function (MF), different quantifiable variables that allow its objective analysis have been examined, including masticatory performance, maximum bite force (MBF), the electrical activity of superficial muscles of mastication and masticatory kinematics, with this last one referring to the analysis of characteristics like speed, frequency and area of the masticatory cycles in the three spatial planes.[6-9]

Each of these evaluations uses specific equipment and methods to analyze the variables under study. The quality of MF has been investigated in relation to obesity through the evaluation of different para-

 ISSN Print 0719-2460 - ISSN Online 0719-2479.

meters —*e.g.*, number of teeth present, number of teeth with untreated caries and number of restored teeth— demonstrating that obesity is associated with a deteriorated dentition.[10,11] In addition, cross-sectional studies indicate that a deficient masticatory performance is associated with obesity.[12,13]

Different test foods have been used to study mastication, from natural foods with variable textures and compositions —*e.g.*, peanut, banana, carrot, prototype granola.[14,15]— to synthetic materials with standard characteristics, such as chewing gum and bag-ged silicone like Optosil.[6,16,17] Which have been used for masticatory efficiency and performance studies, as well as for the kinematic analysis of the mastication.[12,16]

Roasted peanuts are considered a good representative of soft foods, and raw carrots of hard foods, and both are considered appropriate test foods for the study of mastication.[18] It has been observed that natural food-texture and hardness interfere in some of the kinematic parameters of mastication.[17] The literature emphasizes the need to include dentists in multidisciplinary teams involved in the treatment of patients with obesity, and to study associated MF and its variability in depth.[17]

Accordingly, our purpose was to compare the kinematic characteristics of mastication in fully dentate subjects with different BMI, including foods of different hardness in the analysis.

MATERIALS AND METHODS.

An exploratory study was carried out. The movement of the jaw during mastication of foods with different hardness was analyzed in subjects with different BMI.

Statement of Ethics

The present study was approved by the Scientific Ethics Committee of the Universidad de La Frontera (Ethics Committee Approval No. 039_19).

All volunteers were informed of the nature of the study and, in conformity with the World Medical Association's Declaration of Helsinki (2008), voluntary informed consent was obtained in writing from the volunteers prior to participation.

Sample and Eligibility Criteria

Convenience sampling was applied to gather 21 participants (14 males and seven females, 22.9 years of age ± 3.5 years), seven participants per group who were classified according to BMI (kg/m^2) as: Normal weight (BMI 18.5-24.9) (four females and three males), Overweight (BMI 25-29.9) (seven males) and Obese (BMI ≥30) (three females and four males).

The analysis was performed with the group of subjects that we were able to recruit. The following inclusion criteria were applied: males and females over 18 years of age, under no current pharmacological treatments, with continuous and complete maxillary and mandibular dental arch (up to second molar), with Angle Class I and no orthodontic devices. Subjects with oral injuries that made correct mandibular movement difficult, such as angular cheilitis, traumas or cankers, were excluded.

Participants allergic to either of the test foods (peanut or carrot) and subjects with signs or symptoms of temporomandibular joint (TMJ) disorders were also excluded. For the identification of these signs and symptoms, a clinical screening and examination recommended by the American Academy of Orofacial Pain was applied (1993).[19] A temporomandibular joint diagnosis by a specialist in temporomandibular disorders was not included.

Anthropometric Measurements

BMI (Eq. 1) was assessed using a clinical scale to measure weight in kg and a measuring rod to measure the height in m.

BMI [kg/m^2]=(weight [kg])/(height [m])^2[1]

Test Food

Two food types were used for this study. Each participant on each occasion was given 3.7 g of raw carrot chopped into 1 cm^3 cubes (Figure 1A) and 3.7 g plain peanuts (Figure 1B).[14,16]

Participants chewed each food on three different occasions with a two minute pause between each round; during the break the subjects drank water to remove possible residues from the oral cavity; the peanuts were the first to be chewed, then the carrot; this order was maintained in all subjects.

Recording Protocol for Masticatory Movements

A 3D electromagnetic articulograph (Carstens Medizinelektronik, Bovenden, Germany; 3D-EMA AG501) was used to register masticatory movements. Four of its sensors were fixed to the participant's skin with a biocompatible adhesive (Epiglu®, Meyer Haake, Germany). These sensors were attached on the following points of the head of the participant: skin point of the right (1st) and left mastoid (2nd), glabella (3rd) and on the mucosa of the mandibular inter-incisor midline (4th). The first three sensors were placed to define a reference system attached to the head of the participant, which allows obtaining the movement of the mandible relative to the skull.[9]

The recording of masticatory movements begins with the participant in the maximum intercuspation position (MIP), with the test food located between the tongue and palate, the participant is asked to chew freely, without indicating a side of preference or number of masticatory cycles.

The recording ends when the first swallow begins. This recording is repeated three times for each food, in the same session, with two minutes of rest between each repetition.

The kinematic characteristics evaluated were: area (mm^2) of each masticatory cycle on the frontal, sagittal and horizontal planes, the speed of ascent and descent of the mandible (mm/s) and masticatory frequency (cycles/min).

Data Processing

The data were recorded, labeled and transferred to a personal computer. All recorded data were processed using scripts developed with MATLAB (The MathWorks, Inc., Natick, MA, USA). The parameters calculated were: number of masticatory cycles performed until first swallowing, masticatory frequency in cycles per minute, area defined by the projection of each masticatory cycle on frontal, sagittal and horizontal planes, and speed of the mandible during masticatory cycles.

Statistical Analysis

The data were arranged on an OpenOffice Calc (Apache Software Foundation, Los Ángeles, USA) spreadsheet; IBM SPSS Statistics software (IBM, New York, USA) (version 27.0) was used to conduct the statistical analysis.

A descriptive analysis of the data was performed, for which the average and its respective standard deviation were determined. The Shapiro-Wilk test was applied to test normality. For comparisons between types of food, the T-test for related samples (normal distributions) or the Wilcoxon test (samples with no normal dis-tributions) was applied.

Pearson correlation between masticatory frequencies associated with both types of test-food and between masticatory frequency and BMI were obtained. The Kruskal-Wallis nonparametric test was ap-plied for comparison between the different BMI groups. The Mann-Whitney U test was applied post hoc. A type I error of up to 5% (p=0.05) was accepted.

RESULTS.

Table 1 to Table 3 show the mean values and standard deviation of the obtained data along with the results of the comparisons carried out. Table 1 and Table 2 indicate the differences among the three BMI groups —normal weight, overweight and obese— with peanuts as test food (Table 1) and with carrot as test food (Table 2). The differences between the chewing of peanut and carrot without considering the variable BMI are indicated in Table 3.

Following, the main findings regarding the kinematic characteristics analyzed —number of masticatory cycles, masticatory frequency, speed of the opening and closing movement of the jaw, area of the masticatory cycles on the frontal, sagittal and horizontal planes— are presented.

Number of Masticatory Cycles

The number of masticatory cycles did not present significant differences among the three groups of different BMI, nor when comparing between the two foods used (peanut and carrot).

Pasticatory Frequency

No statistically significant differences were found for this variable when compared between the three

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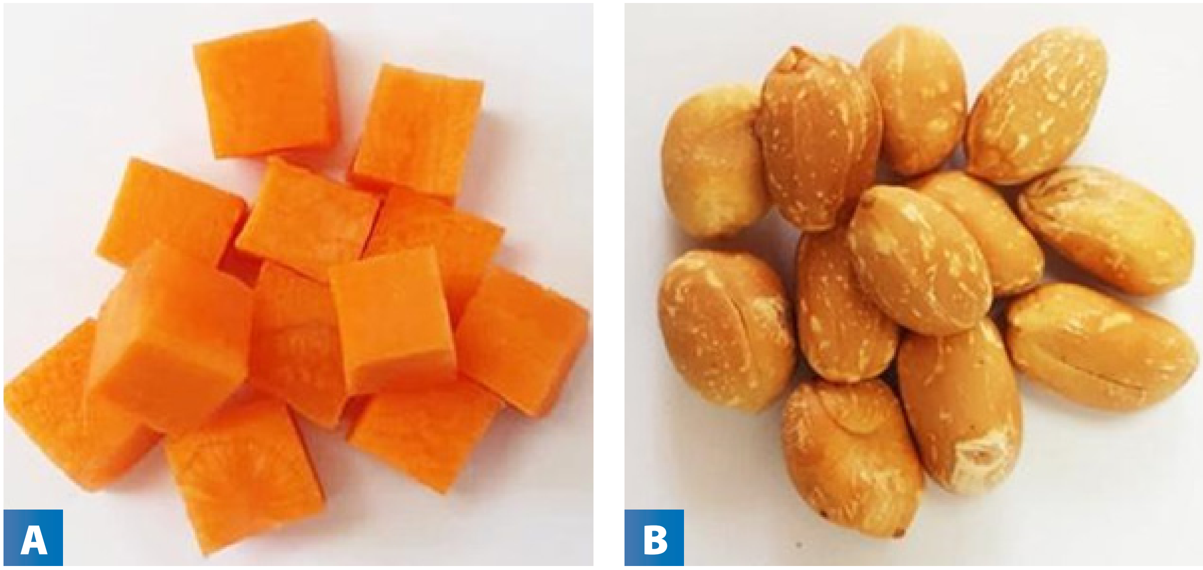
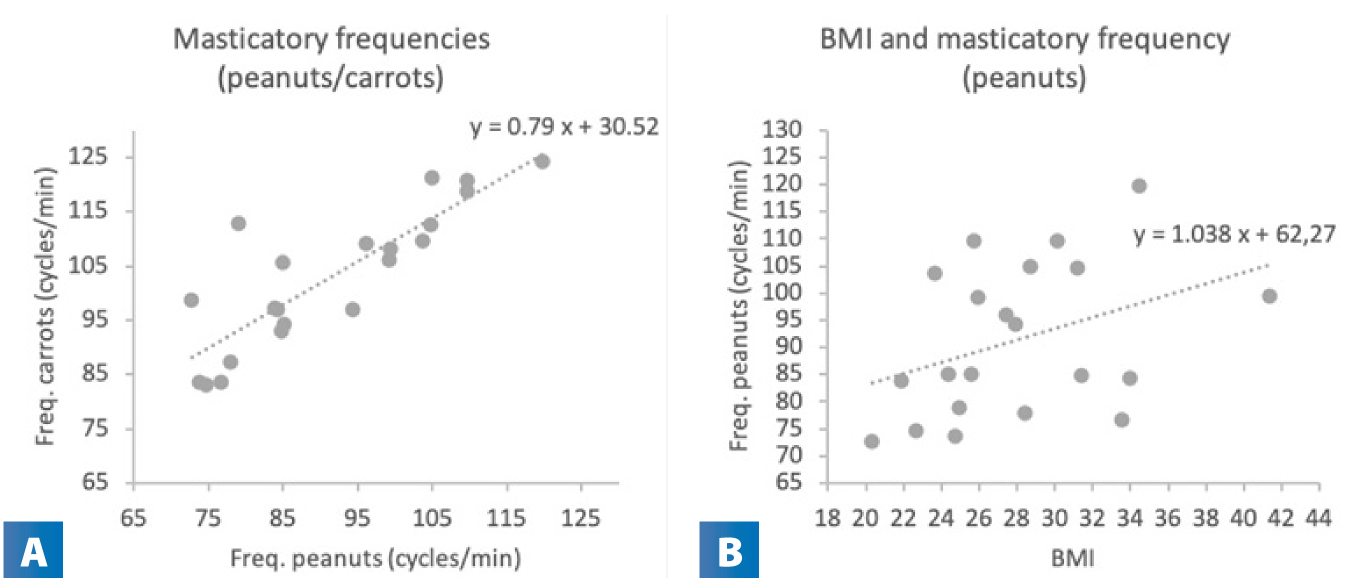
Figure 1. Test foods used in the procedure.



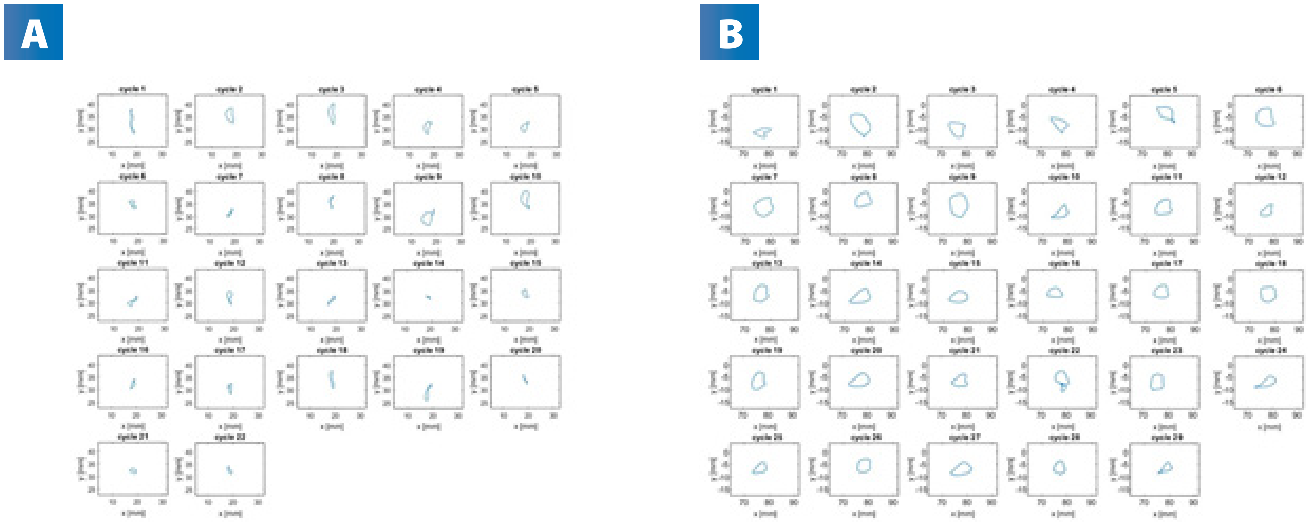
A: Carrots in 1 cm^3 cubes. **B:** Peanuts.

Figure 2. Masticatory frequency associated with peanuts/carrots and masticatory frequency associated with peanuts.



A: Linear relationship between masticatory frequencies associated with peanuts and carrots as test foods. **B:** Linear relationship between BMI and masticatory frequency associated with peanuts as test food.

Figure 3. Representation of masticatory cycles in the horizontal plane while chewing carrot.



A: Overweight participant. **B:** Obese participants, a larger area of the masticatory cycle is observed in the horizontal plane in the obese group when chewing a hard food like carrot.

Table 1. Kinematic Characteristics of Mastication Associated to Peanuts as Test Food.

CATEGORY	n	AGE (YEAR) MEAN ± SD, (RANGE)	NUMBER OF CYCLES	MASTICATORY FREQUENCY (MEAN± SD)	CYCLE AREA (MEAN± SD, MM²)			SPEED (MEAN± SD, MM/S)	
					FRONTAL	SAGITTAL	HORIZONTAL	ASCENT	DESCENT
Normal	7	23 ± 2.7 (20-28)	26±8	81.81±10.81	39.48±8.26	11.29±6.84	9.63±4.18	54.56±10.02	55.08±11.53
Overweight	7	22.1 ± 3.5 (18-28)	29±7	95.31±10.98	26.81±7.63	12.28±3.06	5.20±3.07	57.00±9.99	54.12±8.79
Obese	7	23.6 ± 3.6 (19-29)	26±9	97.02±15.66	33.94±12.84	10.02±5.31	9.42±5.16	63.02±12.36	61.67±12.75
p-value		0.75	0.06	0.06	0.24	0.09	0.34	0.32	

Comparison of the average values of the kinematic characteristics of mastication: number of cycles, masticatory frequency, area of the masticatory cycles sagittal and horizontal frontal plane and the speed of opening and closing of the mouth, during peanut chewing in the three study groups. *$p<0.05$.

Table 2. Kinematic Characteristics of Mastication Associated to Carrots as Test Food.

CATEGORY	n	AGE (YEAR) MEAN ± SD, (RANGE)	NUMBER OF CYCLES	MASTICATORY FREQUENCY (MEAN± SD)	CYCLE AREA (MEAN± SD, MM²)			SPEED (MEAN± SD, MM/S)	
					FRONTAL	SAGITTAL	HORIZONTAL	ASCENT	DESCENT
Normal	7	23 ± 2.7 (20-28)	26±10	98.718±12.93	36.25±9.97	10.31±2.22	8.98±5.16	63.55±11.69	63.64±14.66
Overweight	7	22.1 ±3.5 (18-28)	30±9	104.82±12.71	28.06±9.63	10.38±3.34	5.239±3.60*	62.07±10.91	59.89±9.93
Obese	7	23.6 ±3.6 (19-29)	25±6	105.64±14.99	42.91±13.86	10.59±4.18	13.51±5.83*	70.75±10.77	68.71±9.42
p-value		0.37	0.71	0.16	0.87	0.02	0.33	0.17	

Kinematic characteristics of mastication: comparison of the average values of: number of cycles, masticatory frequency, area of the sagittal and horizontal frontal plane masticatory cycles and the speed of opening and closing of the mouth during carrot mastication in the three study groups. *$p<0.05$.

ISSN Print 0719-2460 - ISSN Online 0719-2479.

Table 3. Kinematic Characteristics While Associated with the Mastication of Peanuts and Carrot.

CATEGORY	NUMBER OF CYCLES	MASTICATORY FREQUENCY (MEAN± SD)	CYCLE AREA (MEAN± SD, MM²)			SPEED (MEAN± SD, MM/S)	
			FRONTAL	SAGITTAL	HORIZONTAL	ASCENT	DESCENT
Test food	27±7.65	91.38±13.91	33.41±10.76	11.20±5.12	8.09±4.51	58.20±10.92	56.96±11.12
Peanut	27±8.24	103.06±12.95	35.74±12.41	10.43±3.18	9.24±5.84	65.46±11.25	64.08±11.59
Carrot	27±8.24	103.06±12.95	35.74±12.41	10.43±3.18	9.24±5.84	65.46±11.25	64.08±11.59
Peanut/Carrot = p	0.84	0.01	0.39	0.49	0.19	0.01	0.01

Comparison of the average values of the kinematic characteristics of mastication: number of cycles, masticatory frequency, area of the sagittal and horizontal frontal plane masticatory cycles and the speed of opening and closing of the mouth, between peanut and carrot mastication. *$p<0.05$.

groups when chewing peanut ($p=0.06$) (Table 1) or carrot ($p=0.37$) (Table 2). However, when comparing peanut and carrot che-wing, it was found that the number of chewing cycles per minute was significantly higher for the carrot than for peanuts ($p=0.01$) (Table 3).

Masticatory frequency associated with peanuts and masticatory frequency associated with carrots were moderately correlated (r=0.667, $p=0.01$) (Figure 2A). With peanuts as test food, masticatory frequency and BMI were weakly correlated (r=0.376, $p=0.04$), (Figure 2B). However, with carrots as test food no significant correlation was observed (r=0.19, $p=0.20$).

Average Area of Masticatory Cycles

A comparison of the areas of masticatory cycles on the frontal, sagittal and horizontal planes between test foods revealed no statistically significant differences (Table 3). Significant differences were only found between obese and overweight when chewing carrot, with a significantly larger horizontal area of masticatory cycles in obese subjects ($p=0.02$), (Figure 3 and Table 2).

Speed of the Mandible During Mastication

The speed of the mandible during mastication did not present significant differences among the BMI groups. However, when comparing this variable between test foods it was noted that the speed to chew carrot was significantly faster than to chew peanut ($p=0.01$).

DISCUSSION.

In this study, the kinematic characteristics of mastication were evaluated in participants with different BMI using representative hard and soft foods (carrot and peanut). It was found that the analyzed kinematic characteristics had no considerable variations according to BMI; these findings agree with results from other studies that have reported that the number and duration of masticatory cycles do not differ according to the BMI of the participants.[13,20]

Another interesting result within the present study is that when chewing soft foods, masticatory frequency (cycles per minute) was positively correlated with BMI. This was not confirmed for hard foods, it could be due to the limited sample size analyzed and the limited range of BMI associated with it.

Flores-Orozco *et al.*,[6] reported that obese subjects eat faster than subjects with normal weight, which supports our results regarding masticatory frequency. It is important to emphasize that these studies carried out their evaluations by counting masticatory cycles by simple observation and measuring time with a chronometer. The inherent subjectivity of those methods imply low reliability.

The method applied within the present study is based on electromagnetic articulography, which offers objective measurements with high accuracy.[21] Other studies have evaluated chewing speed in relation to BMI based on questionnaires, reporting that people who tend to eat faster have a higher BMI than those who eat more slowly.[22,23]

However, the design of these studies does not allow inferring a causal relationship. Speed is considered an important parameter to evaluate the relationship between mastication and obesity, given that it has been shown that eating more slowly with higher number of masticatory cycles can increase diet-induced thermogenesis through orosensory stimulation.[24]

The latter imply an increase in the energy output associated with eating, which is why it has been inferred a possible link between mastication and the tendency to obesity.[24] Several authors have made attempts to define masticatory behavior with different food hardnesses.

In this way Veyrune *et al.*,[17] studied mastication in subjects with different BMI and their behavior associated with foods with different characteristics. They reported that parameters such as number of cycles and masticatory frequency vary and depend on the hardness of the foods. Those results are supported by ours, since we found that when chewing carrot, there is a significantly greater masticatory frequency and speed than when chewing peanuts.

However, there were no significant differences in terms of the number of cycles necessary to crush either of the two foods. Another important variation detected was that the horizontal area of the masticatory cycles in the obese group was significantly larger than the overweight group when chewing carrot. This is another result that supports the idea that food hardness is a determining factor in the variation of some kinematic characteristics of mastication and that it probably also has a different effect in relation to BMI.

A change in the food hardness did not generate any change in the MF of those with normal weight, but generated differences between the obese and overweight groups. Further research is needed to fully understand the influence of food hardness on masticatory kinematics and its relation to obesity. Randomized clinical trials have also been conducted. Schnepper *et al.*,[25] reported on the intervention in eating habits of groups seeking to lose weight, mostly overweight individuals.

This was done through sessions in which certain eating habits of the participants were adjusted. Different types of food were provided in these sessions, such as carrots, bread and the favorite meal of each participant. After the intervention, the participants adopted a conscious and effective mastication that resulted in a significant reduction in BMI. This supports the idea of conducting further studies to generate new knowledge on the association between mastication, BMI and the characteristics of foods with the purpose of defining masticatory habits that could contribute to the prevention and treatment of obesity in the population.

Guidelines on masticatory habits and food preference could be indicated by dentists to favor a balanced nutritional state.[12] Among the limitations of this study, we can mention the use of a reduced number of foods to evaluate mastication, one to represent hard foods (carrots) and another to represent soft foods (peanuts).

The number of participants included in the study is also limited. For future studies, a larger sample with a wider range of BMI must be considered to obtain more conclusive results. Among the limitations of this study, we can mention the use of a reduced number of foods to assess chewing, one to represent hard foods (carrots) and another to represent soft foods (peanuts), the use of carrots in cubes, since not being an isotropic food, the samples chewed in each repetition may have different textural characteristics.

Also, the small sample size for each group, which negatively affects the statistical power of the study. Laterotrusive and protrusive guides were not considered, so our results may be influenced by possible alterations of the guides. Controlling for variable bias will be considered in future research.

ISSN Print 0719-2460 - **ISSN Online** 0719-2479.

CONCLUSION.

Our results suggest that food hardness is a determining factor in the modification of the kinematic characteristics of mastication. Hard foods are chewed with greater speed and frequency than soft foods in the population studied, regardless of BMI.

However, it was observed that when chewing a hard food like carrot, BMI did influence the kinematic characteristics analyzed, since the obese group presented a significantly wider movement in the horizontal plane than the overweight group. Masticatory frequency tends to increase with BMI.

Conflict of interests:

There is no conflict of interest to be declared.

Ethics approval:

The study was approved by the Scientific Ethics Committee of the Universidad de La Frontera, approval number: 039_19

Funding:

This manuscript was financed by project DI19-0039, Research Office, Universidad de La Frontera.

Authors' contributions:

All authors contributed to the execution of the study and writing of the manuscript.

Acknowledgements:

The authors have received support from the Research Office, Universidad de La Frontera. This work is part of the project DI19-0039. Camila Venegas thanks CONICYT-PFCHA/Magíster Nacional/2020 – Folio: 22201829.

REFERENCES.

1. Cederholm T, Barazzoni R, Austin P, Ballmer P, Biolo G, Bischoff SC, Compher C, Correia I, Higashiguchi T, Holst M, Jensen GL, Malone A, Muscaritoli M, Nyulasi I, Pirlich M, Rothenberg E, Schindler K, Schneider SM, de van der Schueren MA, Sieber C, Valentini L, Yu JC, Van Gossum A, Singer P. ESPEN guidelines on definitions and terminology of clinical nutrition. Clin Nutr. 2017; 36(1):49-64. doi: 10.1016/j.clnu.2016.09.004.
2. WHO. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser. 2000;894:i-xii, 1-253. PMID: 11234459.
3. Burrows RA, Díaz N, Muzzo S. Variaciones del indice de masa corporal (IMC) de acuerdo al grado de desarrollo puberal alcanzado. Rev Med Chil. 2004 Nov;132(11):1363-8. doi: 10.4067/s0034-98872004001100004. PMID: 156 93198.
4. Moya MP, Marquardt K, Olate S. Caracterización de la Función Masticatoria en Estudiantes Universitarios. Int J Odontostomat. 2017; 11(4): 495-499.
5. Watanabe Y, Hirano H, Matsushita K. How masticatory function and periodontal disease relate to senile dementia. Jpn Dent Sci Rev. 2015; 51(1): 34–40.
6. Flores-Orozco EI, Tiznado-Orozco GE, Osuna-González OD, Amaro-Navarrete CL, Rovira-Lastra B, Martinez-Gomis J. Lack of relationship between masticatory performance and nutritional status in adults with natural dentition. Arch Oral Biol. 2016 Nov; 71:117-121. doi: 10.1016/j.archoralbio.2016.07.008. PMID: 27494213.
7. Lepley CR, Throckmorton GS, Ceen RF, Buschang PH. Relative contributions of occlusion, maximum bite force, and chewing cycle kinematics to masticatory performance. Am J Orthod Dentofacial Orthop. 2011 May;139(5):606-13. doi: 10.1016/j.ajodo.2009.07.025. PMID: 21536203.
8. Santos AC, Silva CA. Surface electromyography of masseter and temporal muscles with use percentage while chewing on candidates for gastroplasty. Arq Bras Cir Dig. 2016;29 Suppl 1(Suppl 1):48-52. doi: 10.1590/0102-6720201600S10013. PMID: 27683776; PMCID: PMC5064256.
9. Fuentes R, Dias F, Lezcano MF, Álvarez G, Farfán C, Astete N, Arias A. Application of 3D electromagnetic articulography in dentistry: mastication an deglutition analysis. Protocol report. Int J Odontostomat. 2018; 12(1): 105-12.
10. Katagiri S, Nitta H, Nagasawa T, Izumi Y, Kanazawa M, Matsuo A, Chiba H, Miyazaki S, Miyauchi T, Nakamura N, Oseko F, Kanamura N, Ando Y, Hanada N, Inoue S. Reduced masticatory function in non-elderly obese Japanese adults. Obes Res Clin Pract. 2011 Oct-Dec;5(4):e267-360. doi: 10.1016/j.orcp.2011.03.005. PMID: 24331130.
11. Passeri CR, Andrade JA, Tomal KT, Pracucho EM, Campos LP, Sales-Peres SH. Masticatory function of obese candidates to bariatric surgery from distinct socioeconomic classes. Arq Bras Cir Dig. 2016;29 Suppl 1(Suppl 1):53-58. doi: 10.1590/0102-6720201600S10014. PMID: 27683777; PMCID: PMC5064279.
12. Sánchez-Ayala A, Campanha NH, Garcia RC. Relationship between body fat and masticatory function. J Prosthodont. 2013 Feb;22(2):120-5. doi: 10.1111/j.1532-849X.2012.00937.x. PMID: 23107352.
13. Isabel CA, Moysés MR, van der Bilt A, Gameiro GH, Ribeiro JC, Pereira LJ. The relationship between masticatory and swallowing behaviors and body weight. Physiol Behav. 2015;151:314-9. doi: 10.1016/j.physbeh.2015.08.006. PMID: 26253216.
14. Al-Omiri MK. Muscle activity and masticatory efficiency with bilateral extension base removable partial dentures with different cusp angles. J Prosthet Dent. 2018 Mar;119(3):369-376. doi: 10.1016/j.prosdent.2017.05.001. Erratum in: J Prosthet Dent. 2020 Dec;124(6):822. PMID: 28645664.
15. Farfán C, Coaquira-Quispe JJ, Lezcano MF, Arias A, Navarro P, Fuentes R. Análisis Cinemático de la Masticación de una Granola Prototipo en Contraste con la Masticación de Maní. Int. J. Odontostomat. 2020; 14(2): 198-204.
16. Gonçalves TM, Vilanova LS, Gonçalves LM, Rodrigues Garcia RC. Effect of complete and partial removable dentures on chewing movements. J Oral Rehabil. 2014 Mar;41(3):177-83. doi: 10.1111/joor.12125. Epub 2013 Dec 23. Erratum in: J Oral Rehabil. 2015 Jan;42(1):81. PMID: 24372333.
17. Veyrune JL, Miller CC, Czernichow S, Ciangura CA, Nicolas E, Hennequin M. Impact of morbid obesity on chewing ability. Obes Surg. 2008 Nov;18(11):1467-72. doi: 10.1007/s11695-008-9443-9. PMID: 18368460.
18. Yurkstas AA. The masticatory act. A review. J Prosthet Dent. 1965 Mar-Apr;15:248-62. doi: 10.1016/0022-3913(65)90094-6. PMID: 14267314.
19. McNeill C. Temporomandibular Disorders. 2nd Ed. Chicago, American Academy of Orofacial Pain. Illinois, Quintessense, 1993.
20. Park S, Shin WS. Differences in eating behaviors and masticatory performances by gender and obesity status. Physiol Behav. 2015 Jan;138:69-74. doi: 10.1016/j.physbeh.2014.10.001. PMID: 25447481.
21. Savariaux C, Badin P, Samson A, Gerber S. A Comparative Study of the Precision of Carstens and Northern Digital Instruments Electromagnetic Articulographs. J Speech Lang Hear Res. 2017 Feb 1;60(2):322-340. doi: 10.1044/2016_JSLHR-S-15-0223. PMID: 28152131.
22. Sasaki S, Katagiri A, Tsuji T, Shimoda T, Amano K. Self-reported rate of eating correlates with body mass index in 18-y-old Japanese women. Int J Obes Relat Metab Disord. 2003 Nov;27(11):1405-10. doi: 10.1038/sj.ijo.0802425. PMID: 14574353.
23. Otsuka R, Tamakoshi K, Yatsuya H, Murata C, Sekiya A, Wada K, Zhang HM, Matsushita K, Sugiura K, Takefuji S, OuYang P, Nagasawa N, Kondo T, Sasaki S, Toyoshima H. Eating fast leads to obesity: findings based on self-administered questionnaires among middle-aged Japanese men and women. J Epidemiol. 2006 May;16(3):117-24. doi: 10.2188/jea.16.117. PMID: 16710080; PMCID: PMC7603906.