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Evaluation of chewing ability in cerebrovascular accident and Parkinson's disease

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Purpose: Chewing problems are a major and prevalent issue in populations with neurological pathologies including cerebrovascular accident (CVA) and Parkinson's disease (PD). We measured habitual solid chewing performance in patients with CVA or PD and compared it to that of normal older adults to identify differences in chewing ability between groups.

Methods: Measures of habitual solid chewing in 32 patients with CVA, in 35 patients with PD, and in 217 normal older adults were compared. Data on the chewing duration, frequency, and rate were collected using a solid chewing task (SCT). We also analyzed the relationships between dentures, number of teeth, and SCT outcomes.

Results: The chewing duration in the PD group was significantly longer than the normal group ($p<0.05$). Chewing frequency and rate were not significantly different among the three groups. Results can be explained by rigidity and bradykinesia in orofacial structures in the PD group. No significant differences between the PD and CVA groups may be partly explained by the diverse location and size of the CVA lesion compared to the PD. Dentures and the number of teeth were not significantly correlated with SCT outcomes.

Conclusions: Chewing impairment remains the area of development for research and rehabilitation, and SCT may help to assess oropharyngeal dysphagia and to identify therapeutic interventions.

Keywords: Cerebrovascular accident, Parkinson's disease, Chewing duration, Chewing frequency, Chewing rate

INTRODUCTION

Chewing or mastication is an essential process for breaking down food for safe and efficient swallowing [1,2]. Jaw movements, including opening and closing, contribute to the rhythmicity and coordination of mastication [3]. A central pattern generator in the brainstem is responsible for this coordination and rhythmicity of jaw movements, controlling the rhythm and tempo of jaw opening and closing and the sequences of muscle activity [3,4]. The chewing process is completed in coordination with movements of the tongue, jaw, cheek, soft palate, hyoid bone and masticatory muscles to place and process the food [5]. Concurrently, saliva is secreted to help convert the food into a soft, coherent, and moistened structure suitable for swallowing [1]. Because the chewing process and bolus manipulation involve a variety of structures, we can expect oropharyngeal dysfunction in terms of swallowing during chewing. Impaired chewing ability

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can increase the possibility of airway invasion.

At the beginning of a chewing sequence, the mechanical characteristics, shape, and size of the food largely determine the amount of jaw muscle activity and movement trajectories required [6,7]. Sensory inputs from these bolus properties initiate jaw opening, and the consequent motor output is adjusted by sensory feedback during the chewing process. The periodontal mechanoreceptors and muscle spindles in the jaw closing muscles are the main contributors to sensorimotor regulation during chewing [1,7]. Chewing is important because chewing problems result in poor eating quality, malnutrition, and reduced quality of life [8].

Chewing problems are a major and prevalent issue in populations with neurological pathology [9]. Cerebrovascular accident (CVA), which is considered a leading cause of death and acquired disability [10], is characterized by a neurological deficit attributed to an acute focal (or global) disturbance of cerebral function of vascular origin, including ischemic and hemorrhagic stroke [11,12]. The lesion's size and the cerebral structures, including sensory and motor cortical representation areas, central nervous system (CNS) pathways, and motor neuron pools of the cranial nerves in the brainstem, affected by stroke may result in orofacial impairment and affect chewing [13-16]. Impaired masticatory performance in patients with stroke may result from reduced tongue force, impaired oral sensitivity, facial asymmetry, and reduced lip force [15,17]. In addition, chewing efficiency, as reflected by maximum bite and restraining lip forces, is significantly lower in the stroke group than in the control group, and loss of teeth is closely related to chewing efficiency [17].

Parkinson's disease (PD), another neurological disease associated with chewing problems, is characterized by resting tremor, bradykinesia, rigidity, and postural instability due to basal ganglia pathology [18]. In patients with PD, orofacial musculature, including the lip and tongue musculature, and involuntary mandibular movements can be influenced by tremor and rigidity. This orofacial musculature in PD that is affected by tremor and rigidity may cause orofacial pain, temporomandibular joint discomfort, cracked teeth, and dental attrition. It may also result in difficulties in controlling and preserving dentures [19,20]. In addition to the difficulties in controlling the bolus in the mouth and reduced tongue movement, bradykinesia causes slowness in chewing in patients with PD [21-23].

We would like to measure habitual solid chewing performance in patients with CVA or PD and compare it to that of normal older adults in order to identify differences in chewing ability in natural eating situations between groups. The aims of this study were to determine whether 1) the chewing ability in the CVA and PD groups, measured using chewing duration, frequency, and rate during a habitual solid chewing task (SCT), is different from that in the normal group and 2) teeth-related variables, including loss of teeth and denture, are associated with SCT performance in the three groups. Therefore, we hypothesized that chewing ability in the disease populations would be significantly different from that in the normal population. Moreover, there would be significant differences in chewing ability between the CVA and PD groups. We additionally hypothesized that teeth-related variables would be associated with SCT performance.

METHODS

Participants

We recruited 284 participants, including 217 normal older adults (95 men, 122 women) who were over 65 years of age (mean ± standard deviation [SD] = 75.75 ± 5.25, range 65–90 years), 32 patients (25 men, 7 women) with CVA (mean ± SD = 71.91 ± 7.22, range 60–87 years), and 35 patients (17 men, 18 women) with PD (mean ± SD = 68.37 ± 6.46, range 57–84 years) from May 2018 to November 2020 at three senior community centers, the Pohang Stroke and Spine Hospital, and PD support community (Korea PD Association, KPDA). This study was approved by the Severance Hospital Institutional Review Board (IRB No. 4-2018-0113, 4-2019-1138) and the Pohang Stroke and Spine Hospital IRB (IRB No. PSSH0475-201806-HR-003). Informed consent was obtained from all subjects involved in the study.

Inclusion criteria for normal older adults (normal group) were as follows: individuals over 65 years of age who did not have a history of dysphagia or head and neck or neurological diseases. The CVA and PD groups included patients who self-reported a history of CVA or PD, respectively, without a history of any other neurological disease and were taking appropriate medication at the time of SCT evaluation.

Self-reported demographic information, including age, sex, medical history, years of education, denture status, and number of teeth, were collected. An older adult requires twenty teeth for normal Korean meals [24], and individuals with more than 20 teeth had significantly higher chewing efficiency than that of individuals with fewer than 20 teeth in a previous study [25]. We excluded participants who had fewer than 20

natural teeth and did not have dentures. Participants who had more than 20 natural teeth or those who had fewer than 20 natural teeth and dentures were included.

All participants had normal cognitive function as measured using the Korean Mini-Mental Status Examination [26] and were able to follow the instructions of the SCT. All participants provided written informed consent for the collection of data for the study. The participant characteristics are shown in Table 1.

Solid chewing task

After providing demographic information, the participants performed the SCT. To assess chewing function, participants were instructed to chew on a slice of a commercially available cracker (IVY™, Haitai Inc.; 4.6×4.6 cm, 3.29 g). We used crackers for the chewing task because one of the crucial steps in the modified barium swallow study is to evaluate a piece of cracker (i.e., a solid texture) coated with barium [17]. The hardness of the crackers was measured using a rheometer (Model Compac-100II; Sun Scientific, Japan) (Figure 1) and it was 5.09E+05 g/cm^2. A rheology graph report is presented in Figure 2.

Participants were instructed to chew the cracker at the same speed as if they were eating at mealtime (i.e., habitual chewing rate). They kept silent while chewing and were instructed

Table 1. Participant characteristics

Variable	Group		
	Normal	CVA	PD
Sex			
Men (N)	95	25	17
Women (N)	122	7	18
Age (yr)			
Mean (SD)	75.75 (5.25)	71.91 (7.22)	68.37 (6.46)
Range	65–90	60–87	57–84
Education (yr)	11.41	1.75	3.11
Dentures			
Yes	79	14	7
No	138	16	28
Number of missing teeth	2.75	3	2.47
K-MMSE	26.98	24.44	27.94

CVA, cerebrovascular accident; PD, Parkinson's disease; N, number of participants; SD, standard deviation; K-MMSE, Korean version of the Mini-Mental State Examination.

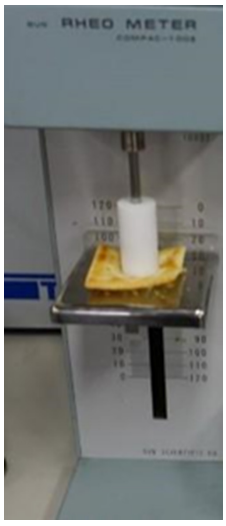


Figure 1. Rheometer (Model Compac-100II) (Sun Scientific, Japan) measuring the hardness of a cracker.

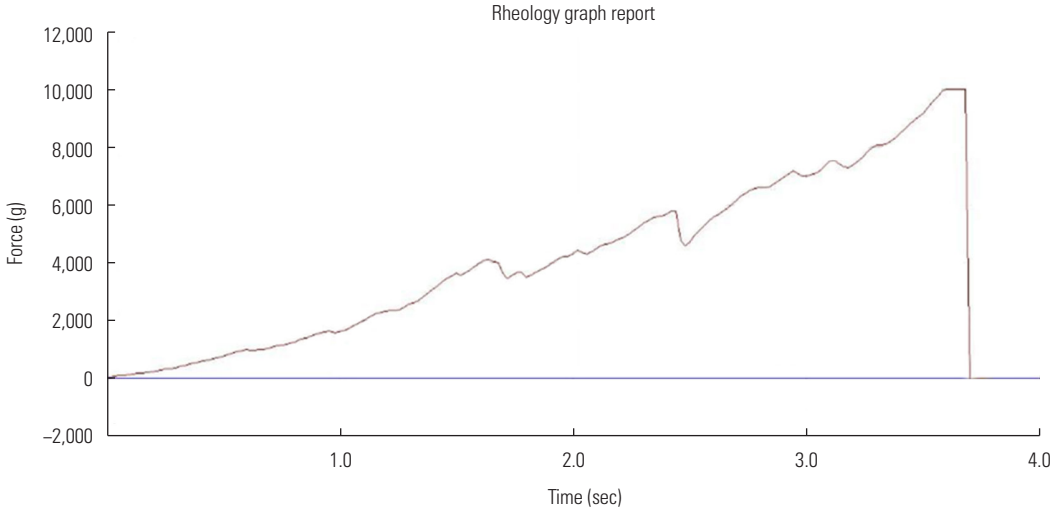


Figure 2. Rheology graph of the hardness of the cracker over time during measurement.

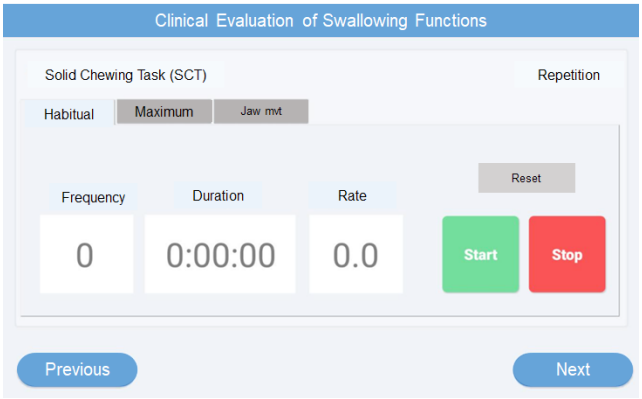


Figure 3. A screen of a tablet application for chewing duration, frequency and rate.

to produce an "ah" sound for 3 seconds immediately after completing the last chewing cycle to indirectly identify signs of aspiration. All participants did not show signs of aspiration. Chewing outcomes were measured by either way: 1) The chewing durations were measured using a timer and the chewing frequencies were counted with a manual counter and recorded on a scoring sheet, or 2) The chewing duration and frequency were measured using a tablet application (Figure 3). The measurement began once chewing was started. "Chewing rate" was calculated by dividing the number of jaw movements by chewing duration in seconds.

Data analysis

Data were analyzed using SPSS Statistics 25 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to analyze the demographic information of the participants. A one-way analysis of variance was used to identify differences in the chewing duration, frequency, and rate of SCT between the normal, CVA, and PD groups. Post-hoc analysis was performed using a Tukey's honest significant difference test. Additionally, we analyzed the relationships between dentures, number of teeth, and SCT outcomes using Pearson's correlation.

RESULTS

SCT outcomes

The duration of the SCT was longest in the PD group, followed by the CVA and normal groups. The PD group took more time to chew a piece of cracker than the CVA and normal groups did. For normal older adults, the mean chewing duration was 49.78±24.74 seconds. The mean chewing duration for patients with CVA was 59.05±27.97 seconds. For patients with PD, the mean chewing duration was 64.12±33.80 seconds (Table 2). The chewing duration was significantly different between the PD and normal groups ($p<0.05$) (Figure 4).

Table 2. Chewing duration, frequency, and rate during a solid chewing task in the normal, CVA, and PD groups

Outcomes	Normal	CVA	PD
Duration (s)			
Mean (SD)	49.78 (24.739)	59.05 (27.97)	64.12 (33.803)
Range	19–222	19–131	21–159
Frequency			
Mean (SD)	63.64 (32.475)	68.97 (23.89)	75.61 (36.00)
Range	23–286	31–144	36–170
Rate (Frequency/Duration)			
Mean (SD)	1.30 (0.300)	1.27(0.35)	1.24 (0.30)
Range	0.59–2.47	0.57–1.98	0.68–1.94

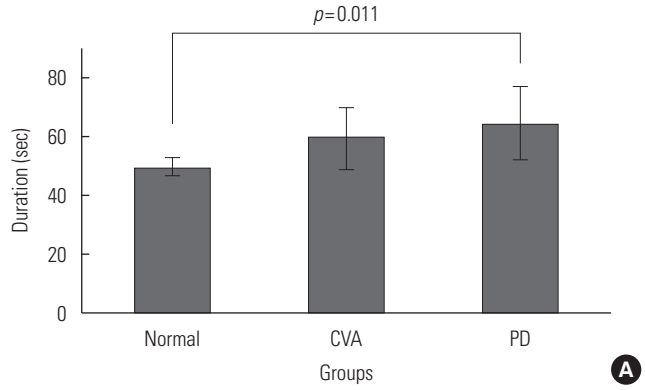
CVA, cerebrovascular accident; PD, Parkinson's disease; SD, standard deviation.

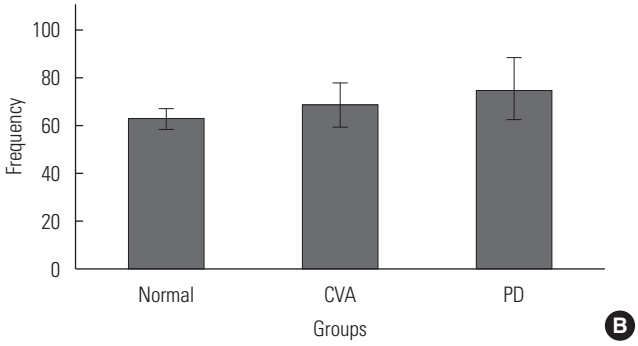
The chewing frequency during the SCT was highest in the PD group, followed by the CVA and normal groups. The PD group chewed a piece of cracker more frequently than the CVA and normal groups did. For normal older adults, the mean chewing frequency was 63.64±32.48. The mean chewing frequency for patients with CVA and those with PD was 68.97±23.89 and 75.61±36.00, respectively (Table 2). However, the number of jaw movements between groups was not significantly different ($p>0.05$) (Figure 4).

The chewing rate during the SCT was lowest in the PD group, followed by the CVA and normal groups. The PD group chewed a piece of cracker more slowly than the CVA and normal groups did. For the normal group, the mean chewing rate was 1.30±0.300 times/seconds. The mean chewing rate in the CVA group was 1.27±0.35 times/seconds, and it was 1.24±0.300 times/seconds for the PD group (Table 2). However, the chewing rate did not differ significantly between groups ($p>0.05$) (Figure 4).

Relationships between dentures, number of teeth, and SCT outcomes

Dentures and the number of teeth were not significantly correlated with SCT outcomes, including chewing duration, frequency, and rate. However, chewing duration was positively correlated with chewing frequency ($r=0.843$, $p<0.01$) and negatively correlated with chewing rate ($r=-0.271$, $p<0.01$). Chewing frequency was positively correlated with chewing rate ($r=0.241$, $p<0.01$) (Figure 5).





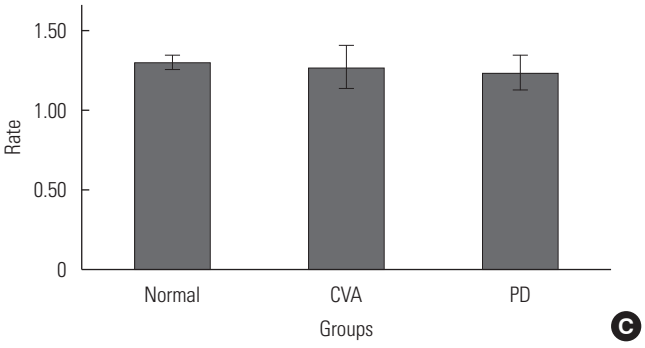
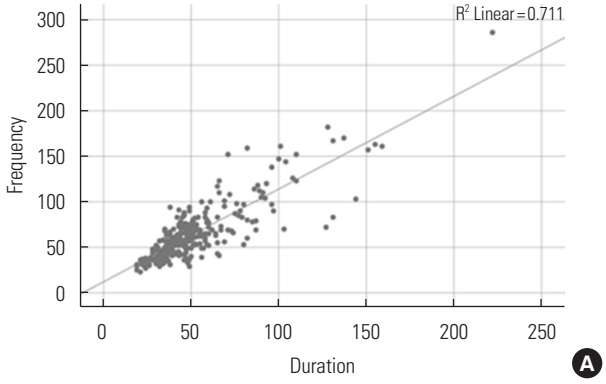
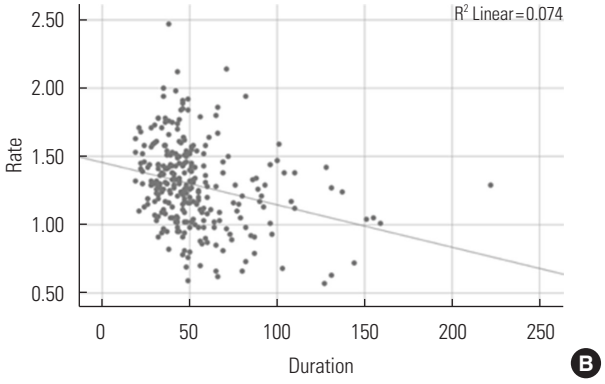


Figure 4. Post-hoc analysis of chewing duration, frequency, and rate of solid chewing task in the normal, cerebrovascular accident (CVA), and Parkinson's disease (PD) groups. (A) The chewing duration in the PD and normal groups was significantly different ($p<0.05$); (B) The number of jaw movements was not significantly different between groups ($p>0.05$); (C) Chewing rate was not significantly different between groups ($p>0.05$). (Error bars indicate 95% confidence intervals). CVA, cerebrovascular accident; PD, Parkinson's disease.





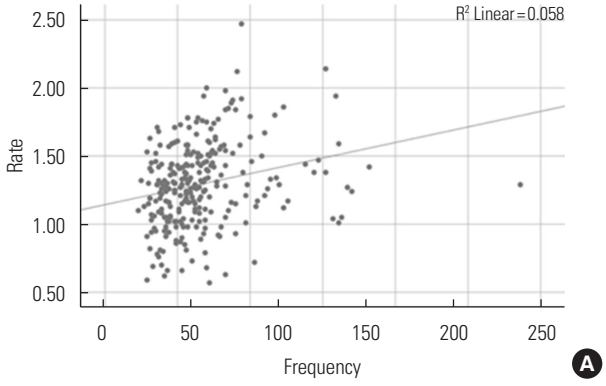


Figure 5. Relationships between dentures, number of teeth, and outcomes in the solid chewing task. (A) Correlation between chewing frequency and duration: $r=0.843$, $p<0.01$; (B) Correlation between chewing duration and rate: $r=-0.271$, $p<0.01$; (C) Correlation between chewing frequency and rate: $r=0.241$, $p<0.01$.

DISCUSSION

To our knowledge, this is the first study to compare chewing performance between normal older adults, patients with CVA, and patients with PD. The SCT outcomes demonstrated that the PD group chewed a piece of cracker more slowly and took more time to chew than the other groups did. This can be explained by rigidity and bradykinesia in orofacial structures during chewing in patients with PD [27]. Chewing is a part of the oral stage of the swallowing process and involves mastication and mixing of the bolus with saliva for optimal swallowing [5,28]. Chewing continues until all of the bolus is prepared for swallowing [5,28]. However, owing to rigidity and bradykinesia, the time taken to chew a piece of cracker becomes prolonged, and impairments in the oral stage of swallowing affect the pharyngeal stage of swallowing, which can increase the risk of aspiration. Wakasugi et al. [29] investigated oral impairments in patients with PD and showed that prolonged oral transit time reflected poor lingual control and decreased range of motion of the tongue in PD, resulting in dysphagia. Chewing duration was the only SCT outcome that could differentiate the normal group from the PD group.

In contrast, patients with CVA did not show any significant differences in SCT outcomes compared to those in the other two groups. We hypothesized that a neurological deficit associated with the swallowing pathway in CVA may have resulted in poorer chewing ability in these individuals than in those in the control group. However, unlike that in reports indicating impaired masticatory performance in stroke patients [15,17], the quantitative SCT measurements were not significantly different between the stroke and control groups. This result may be explained by three factors. First, the location and size of the lesion in this study might be different from those in previous studies [15,17], although little is known about chewing function in patients with CVA. For example, in a previous study, a paramedian (PM) lesion in the lower or middle medulla affected the location of the medially situated nucleus of the hypoglossal nerve, which is responsible for tongue function [30]. This PM lesion caused difficulties in manipulating and maintaining the bolus, preventing premature spillage into the pharyngeal cavity [30]. However, compared to extensive unilateral or bilateral PM lesions, narrow unilateral PM medullary lesions are not likely to lead to dysphagia due to tongue dysfunction, because the lesion does not affect the location of the hypoglossal nucleus [31]. Consistently, dysphagia commonly occurs due to medullary and pontine lesions [30], but orofacial dysfunctions differ between pontine and medullary lesions depending on the damaged nuclei of cranial nerves associated with chewing, particularly the facial and trigeminal nuclei located in the pons and hypoglossal nucleus situated in the medulla. In addition, the corticobulbar tract is involved in the oropharyngeal stages of swallowing, such as spillage and laryngeal elevation [32]. Thus, lesions in the cortex may also influence chewing function. In this study, we found that the CVA group showed impaired SCT outcomes compared to the control group.

Second, compared to previous studies, this study had fewer patients with lesions at sites involved in orofacial functions [15,17]. We included all patients regardless of the presence of facial palsy, but previous studies focused only on CVA patients with facial palsy. Clinical symptoms according to disease severity, such as the level of facial asymmetry, lingual palsy, and soft palate dysfunction, may influence SCT outcomes [30,33]. Lastly, methodological differences may have influenced our results. Previous studies [15,17] identified that chewing efficiency, physiologically measured based on maximum bite force and maximum restraining lip force, was severely impaired in patients with stroke compared to that in controls. However, this study included behavioral measurements such as the chewing duration, frequency, and rate to compare chewing performance. Differences in methodology may have yielded results that show no significant differences between the CVA and control groups.

We also found that there were no correlations between SCT outcomes, dentures, and number of teeth. The chewing ability of older adults naturally deteriorates [9,34,35]. Chewing problems may arise due to a number of reasons, including sarcopenia of the masticatory muscles, loss of teeth, and use of dentures in older adults [9,34-37]. Bilodeau-Mercure et al. [34] also demonstrated that the accuracy of orofacial functions involved in chewing declines with aging. It is widely known that individuals with missing teeth and/or dentures have significantly poor chewing ability [9,34-37]. In this study, however, we included participants who were able to eat normal Korean meals and had more than 20 natural teeth or dentures in order to identify the differences in SCT performance between groups. We can explain the lack of correlations between SCT outcomes, dentures, and number of teeth to be a result of the inclusion criteria.

Despite the valuable insights gained from the comparison of habitual SCT outcomes, this study had some limitations. In terms of inclusion criteria, we did not collect data on medical

history, such as disease duration or severity, and lesion information, in the disease populations. In addition, we assessed chewing frequency using a manual digit counter and visual observation. Although an earphone-type chewing-count measurement device or a sensor at the masseter muscle to count mastication movements is an available objective measure, manual counting is a feasible and convenient tool in a clinical setting. Further study using a SCT in the oldest-old population might identify chewing clinical variables such as loss of teeth and denture.

CONCLUSIONS

We measured habitual solid chewing performance in patients with CVA or PD and compared it with that of normal older adults. Chewing impairment remains the area of development for research and rehabilitation. SCT may help to assess and predict oropharyngeal dysphagia, and to identify therapeutic interventions in a clinical setting. Further study would be necessary to determine whether other measures in chewing efficiency could be used to distinguish the normal group from the disease populations, and how to apply study results to dysphagia rehabilitation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

1. Almotairy N, Kumar A, Trulsson M, Grigoriadis A. Development of the jaw sensorimotor control and chewing - a systematic review. Physiology & Behavior. 2018;194:456-465.
2. Fulks BA, Callaghan KX, Tewksbury CD, Gerstner GE. Relationships between chewing rate, occlusion, cephalometric anatomy, muscle activity, and masticatory performance. Archives of Oral Biology. 2017;83:161-168.
3. Lund JP, Kolta A. Generation of the central masticatory pattern and its modification by sensory feedback. Dysphagia. 2006;21: 167-174.
4. Lund JP. Mastication and its control by the brain stem. Critical reviews in Oral Biology and Medicine: an official publication of the American Association of Oral Biologists. 1991;2:33-64.
5. Matsuo K, Palmer JB. Anatomy and physiology of feeding and swallowing: normal and abnormal. Physical Medicine and Rehabilitation Clinics of North America. 2008;19:691-vii.
6. Gaszynska E, Godala M, Szatko F, Gaszynski T. Masseter muscle tension, chewing ability, and selected parameters of physical fitness in elderly care home residents in Lodz, Poland. Clinical Interventions in Aging. 2014;9:1197-1203.
7. van der Bilt A, Abbink JH. The influence of food consistency on chewing rate and muscular work. Archives of Oral Biology. 2017; 83:105-110.
8. Baba K, John MT, Inukai M, Aridome K, Igarahsi Y. Validating an alternate version of the chewing function questionnaire in partially dentate patients. BMC Oral Health. 2009;9:9.
9. Woo J, Tong C, Yu R. Chewing difficulty should be included as a geriatric syndrome. Nutrients. 2018;10:1997.
10. Dai R, Lam OL, Lo EC, Li LS, Wen Y, McGrath C. Orofacial functional impairments among patients following stroke: a systematic review. Oral Diseases. 2015;21:836-849.
11. Sacco RL, Kasner SE, Broderick JP, Caplan LR, Connors JJ, Culebras A, et al. An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013;44:2064-2089.
12. The World Health Organization MONICA Project (monitoring trends and determinants in cardiovascular disease): a major international collaboration. WHO MONICA Project Principal Investigators. Journal of Clinical Epidemiology. 1988;41:105-114.
13. Kimoto K, Ono Y, Tachibana A, Hirano Y, Otsuka T, Ohno A, et al. Chewing-induced regional brain activity in edentulous patients who received mandibular implant-supported overdentures: a preliminary report. Journal of Prosthodontic Research. 2011;55: 89-97.
14. Onozuka M, Fujita M, Watanabe K, Hirano Y, Niwa M, Nishiyama K, et al. Mapping brain region activity during chewing: a functional magnetic resonance imaging study. Journal of Dental Research. 2002;81:743-746.
15. Schimmel M, Ono T, Lam OL, Müller F. Oro-facial impairment in stroke patients. Journal of Oral Rehabilitation. 2017;44:313-326.
16. Takada T, Miyamoto T. A fronto-parietal network for chewing of gum: a study on human subjects with functional magnetic resonance imaging. Neuroscience Letters. 2004;360:137-140.
17. Schimmel M, Leemann B, Herrmann FR, Kiliaridis S, Schnider A, Müller F. Masticatory function and bite force in stroke patients.

Journal of Dental Research. 2011;90:230-234.
18. Poewe W, Seppi K, Tanner CM, Halliday GM, Brundin P, Volkmann J, et al. Parkinson disease. Nature Review Disease Primers. 2017;3:17013.
19. Dirks SJ, Paunovich ED, Terezhalmy GT, Chiodo LK. The patient with Parkinson's disease. Quintessence International (Berlin, Germany: 1985). 2003;34:379-393.
20. Friedlander AH, Mahler M, Norman KM, Ettinger RL. Parkinson disease: systemic and orofacial manifestations, medical and dental management. Journal of the American Dental Association (1939). 2009;140:658-669.
21. Ertekin C, Tarlaci S, Aydogdu I, Kiylioglu N, Yuceyar N, Turman AB, et al. Electrophysiological evaluation of pharyngeal phase of swallowing in patients with Parkinson's disease. Movement Disorders. 2002;17:942-949.
22. O'Day C, Frank E, Montgomery A, Nichols M, McDade H. Repeated tongue and hand strength measurements in normal adults and individuals with Parkinson's disease. The International Journal of Orofacial Myology. 2005;31:15-25.
23. Solomon NP. Assessment of tongue weakness and fatigue. The International Journal of Orofacial Myology. 2004;30:8-19.
24. Yunhap News. The minimum number of teeth for a healthy old age… "10 each above and below." https://namu.news/article/1118513. Accessed March 29, 2021.
25. Helkimo E, Carlsson GE, Helkimo M. Chewing efficiency and state of dentition. A methodologic study. Acta Odontologica Scandinavica. 1978;36:33-41.
26. Kang Y, Na DL, Hahn S. A validity study on the Korean Mini-Mental State Examination (K-MMSE) in dementia patients. Journal of the Korean Neurological Association. 1997;15:300-308.
27. Albuquerque LC, Silva HJ. Jaw movement in people with Parkinson's Disease. Características do percurso da movimentação mandibular dos diferentes tipos de Doença de Parkinson. Codas. 2016;28:193-196.
28. Sasegbon A, Hamdy S. The anatomy and physiology of normal and abnormal swallowing in oropharyngeal dysphagia. Neurogastroenterology and Motility. 2017;29:10.1111/nmo.13100.
29. Wakasugi Y, Yamamoto T, Oda C, Murata M, Tohara H, Minakuchi S. Effect of an impaired oral stage on swallowing in patients with Parkinson's disease. Journal of Oral Rehabilitation. 2017;44:756-762.
30. Kim H, Chung CS, Lee KH, Robbins J. Aspiration subsequent to a pure medullary infarction: lesion sites, clinical variables, and outcome. Archives of Neurology. 2000;57:478-483.
31. Kim JS, Kim HG, Chung CS. Medial medullary syndrome: report of 18 new patients and a review of the literature. Stroke. 1995;26: 1548-1552.
32. Moon HI, Kim GS, Lee E. Is the location of white matter lesions important in the swallowing function of older patients with mild stroke? Dysphagia. 2019;34:407-414.
33. Kim H, Kim YB, Lee KH, Chung CS, Robbins J. Dysphagia characterized by aspiration subsequent to pontine stroke. Journal of Medical Speech-Language Pathology. 2007;15:161-172.
34. Bilodeau-Mercure M, Kirouac V, Langlois N, Ouellet C, Gasse I, Tremblay P. Movement sequencing in normal aging: speech, orofacial, and finger movements. Age (Dordrecht, Netherlands). 2015;37:9813.
35. Naka O, Anastassiadou V, Pissiotis A. Association between functional tooth units and chewing ability in older adults: a systematic review. Gerodontology. 2014;31:166-177.
36. Grigoriadis A, Johansson RS, Trulsson M. Temporal profile and amplitude of human masseter muscle activity is adapted to food properties during individual chewing cycles. Journal of Oral Rehabilitation. 2014;41:367-373.
37. Gaszynska E, Kopacz K, Fronczek-Wojciechowska M, Padula G, Szatko F. Electromyographic activity of masticatory muscles in elderly women - a pilot study. Clinical Interventions in Aging. 2017; 12:111-116.