J Oral Res
research in oral sciences

Review

Tongue strength as a clinical feature of oral health in neurological patients: A Systematic Review.

La fuerza lingual como una característica clínica de la salud oral en pacientes neurológicos: Una Revisión Sistemática.

Exequiel Plaza-Taucare.[1]
Diego Dornelles-Bilheri.[2]
Renata Mancopes.[3]
Angela Ruviaro Busanello-Stella.[2]

Affiliations:
[1]Departament of Human Communication and Oral Motor Disorders. University of Talca, Chile.
[2]Human Communication Disorder Program, Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brazil.
[3]Swallowing Rehabilitation Research Lab, University Health Network – Toronto, Canada.

Corresponding author: **Exequiel Plaza -Taucare.** Departamento de Ciencias de la Comunicación Humana y Trastornos Oromotores. Facultad de Ciencias de la Salud. Universidad de Talca, Avenida Lircay s/n Talca, Chile. E-mail: **eplaza@utalca.cl**

Receipt : 10/05/2020 Revised: 05/17/2021
Acceptance: 08/30/2021

Abstract: Objective: Current oral health assessment has a comprehensive view of the relationship between hard and soft tissues of the mouth as seen by orthodontics and prosthodontics in a healthy population. Despite knowing the influence this relationship has on functional outcomes such as swallowing and mastication, motor evaluation of soft tissue such as the tongue is still scarce. This lack of knowledge is even greater in individuals with a neurological condition. In this sense, the measurement of lingual strength has been addressed by some research as a key element accompanying oral rehabilitation in healthy populations. Acknowledging the importance of tongue strength in oral biomechanics, the Iowa Oral Performance Instrument (IOPI) has become a gold standard instrument. The purpose of this article was to search for scientific studies on tongue strength using the IOPI as a research tool in populations with neurological conditions, to know about its inclusion in the clinical practice and comprehensive oral health rehabilitation in this population. **Material and Methods:** A systematic search in five major databases was carried out based on the PRISMA Protocol. Searches were conducted in the PubMed, Medline, Lilacs, Web of Science and MedCarib databases including articles from 2007 to 2020. To generate the search in each database, three main constructs were developed: (1) "tongue strength IOPI"; (2) "Swallowing Disorders"; (3) "Neurological Diseases". **Results:** 152 studies were identified, 14 were included in the final review. The PEDro scale showed great heterogeneity in the level of evidence between the studies with only 5 RCTs and only two of them on lingual strength training. **Conclusion:** The IOPI was used mainly to measure tongue strength and only 36% as a clinical training device, which could contribute to improving oral health. The stroke was the most represented (79%).IIIISU.

Keywords: *tongue, muscle strength; oral health, oral; swallowing; nervous system disease; IOPI.*

Cite as: Plaza-Taucare E, Dornelles-Bilheri D, Mancopes R & Busanello-Stella ARR. Tongue strength as a clinical feature of oral health in neurological patients: A Systematic Review.
J Oral Res 2021; 10(4):1-14.
Doi:10.17126/joralres.2021.055

Resumen: Objetivo: La evaluación actual de la salud bucal tiene una visión integral de la relación entre los tejidos duros y blandos de la boca según se observa en práctica de la ortodoncia y la prostodoncia en la población sana. Apesar de conocer la influencia que tiene esta relación en resultados funcionales como la deglución y la masticación, la evaluación motora de los tejidos blandos como la lengua es aún escasa. Esta falta de conocimiento es aún mayor en personas con una condición neurológica. En este sentido, la medición de la fuerza lingual ha sido abordada por algunas investigaciones como un elemento clave que acompaña a la rehabilitación oral en población sana. Reconociendo la importancia de la fuerza lingual en la biomecánica bucal, el *Iowa Oral Performance Instrument (IOPI)* se ha convertido en un instrumento estándar de medición. El propósito de este artículo fue buscar estudios científicos sobre la fuerza lingual en pacientes neurológicos utilizando el IOPI como herramienta de investigación, para conocer su inclusión en la intervención clínica y rehabilitación integral de la salud bucal en esta población. **Material y Métodos:** Se realizó una búsqueda sistemática en cinco grandes bases de datos basada en el Protocolo PRISMA. Las búsquedas fueron realizadas en las bases PubMed, Medline and Lilacs, Web of Science y MedCarib incluyendo artículos desde 2007 al 2020. Para generar la búsqueda en cada base de datos, se desarrollaron tres constructos: (1) "tongue Strength IOPI"; (2) "Swallowing Disorders"; (3) "Neurological Diseases". **Resultados:** Se identificaron 152 estudios, 14 se incluyeron en la revisión final. La escala PEDro se evidenció gran heterogeneidad en el nivel de evidencia entre los estudios con sólo 5 RCT y únicamente dos de ellos sobre entrenamiento de fuerza lingual. El IOPI se utilizó principalmente para medir la fuerza lingual y sólo en un 36% como dispositivo de entrenamiento clínico, lo cual pudiese contribuir a mejorar la salud oral. **Conclusion:** El ACV fue el más representado (79%). Se necesita adicionar evidencia sobre el entrenamiento de la fuerza lingual en individuos con afecciones neurológicas como la enfermedad de Parkinson dada la creciente prevalencia reportada por la literatura científica.

Palabra Clave: *lengua; fuerza muscular; salud oral; deglución; enfermedades del sistema nervioso; IOPI.*

INTRODUCTION.

Prosthodontic rehabilitation acknowledges that as swallowing is a complex process, tongue functioning is crucial in restoring deglutition along suitable prosthesis.[1] In order to swallow, an individual triggers a complex activity of voluntary and involuntary actions that requires adequate coordination of the oropharyngeal and esophageal neuromuscular structures in order to maintain the nutritional status and airways protected.[2,3] Motor skill of the tongue and maintenance of natural dentition or prosthodontics rehabilitation is necessary also for an adequate masticatory function.[4] A swallowing disorder focused on the oral phase of the process implies an unsatisfactory muscular performance of the tongue based on its biomechanical functioning[5,6] and consequently the difficulty of propulsion of the alimentary bolus.[7]

In this context, the measurement of tongue strength has been approached by some studies, most of them in a healthy population,[8] where oral health care involving a transdisciplinary approach consisting of dental and medical professionals might be important, but has not been studied in detail in patients with neurological conditions.[9] This indeed justifies the need to evaluate tongue strength as a useful indicator of oral fuction10 that might help to understand its relationship with swallowing in neurological population.[11] Likewise, the influence on lingual muscle strength training is a relevant aspect to be investigated, as demonstrated in a study with laboratory rats, which showed that moderate exercise seems to be beneficial for muscles such as the tongue.[12] In addition, dentist can improve oral rehabilitation of a patient by incorporating orofacial myofuctional therapy involving the tongue.[13]

Further analysis of the relationship between tongue pressure and neurological problems may contribute to elucidate the mechanisms underlying tongue motor control during swallowing. Terms such as “strength” and “pressure” are mentioned as key variables in studies that aim to evaluate the tongue muscular performance instrumentally where the tongue pressure exerted on a surface, in this case on the palate, is measured in kilopascals kPa.[14,15]

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

It is important to note that the neurological conditions included in the search for review was an option of the authors based on their prevalence and the disturbed oral health status associated to dysphagia as seen in clinical setting, which has been documented by scientific literature.[16] So, in cerebrovascular accident CVA, for example, disturbance of swallowing is a frequent finding, with an estimated occurrence of 76% and a reduction in tongue force directly and negatively impacting the propulsion of the bolus.[17-19] In this context, a positive effect of muscular endurance training was observed on the strength and accuracy of the tongue pressure of this population.[20] In the case of subjects with Parkinson's disease (PD), the physiopathology of the disease[21,22] produces variations in tongue force and movement that may also determine difficulty in oral transit or bolus propulsion towards the pharynx.[23,24] Similarly, in subjects with traumatic head injury (TBI)[25-28] oral motor disorders, such as dysphagia, have been identified as secondary alterations. Moreover, Alzheimer's disease (AD) is found associated with swallowing dysfunction due to progressive neurodegenerative disorder.[29-30] There is evidence that dysphagia is highly prevalent in these populations, affecting 8% - 80% of CVA patients, 11% - 60% of PD patients, 91% of elderly patients with community-acquired pneumonia, and approximately 30% of brain-injured patients.[31]

Other neurological diseases such as Amyotrophic Lateral Sclerosis (ALS)[32] are also characterized by limited movement, decreased muscle strength[33] and abnormal tongue movement, making swallowing difficult and ineffective.[34] Another neurological disease that can affect muscle performance and cause swallowing disorder is Multiple Sclerosis (MS).[35,36]

Since tongue strength is an important aspect to be studied, the Iowa Oral Performance Instrument IOPI has emerged, among other devices, as a tool for its measurement.[37] The IOPI is a pressure transducer device used to measure tongue function variables. It made it possible to identify that maximum isometric tongue pressure for healthy young and middle aged persons is 63 kPa and 56 kPa for older people. This review focuses on tongue strength, where the IOPI is this clinical instrument most widely used in published studies worldwide. In the IOPI the maximum tongue strength and peak pressure during swallowing can be obtained by measuring the maximum isometric pressure (MIP) exerted by the tongue against the palate in an air-filled bulb that connects to a battery operated amplifier, conditioning circuit signal and digital voltmeter, displaying the peak pressure on a kilopascals (kPa) digital reading.[38,39] Thus, in order to provide up-to-date information on the IOPI tongue strength training and assessment in a broad spectrum of neurological conditions, this systematic review aimed to seek scientific evidence on the use of the IOPI as a research tool in subjects with neurological diseases.

MATERIALS AND METHODS.

The search strategy and eligibility criteria were based on the elaboration of a systematic review protocol which followed the recommendations of the report protocol for systematic reviews and PRISMA meta-analysis.[40] The procedures were performed in three phases considered for the search and selection of articles, namely, Identification, Screening and Eligibility phase. Two researchers independently conducted the search and analysis of the studies (EP and DB), and a third (AB) was consulted when there was disagreement in the analysis.

Identification

The purpose of this first phase was to identify the scientific evidence devoted to the study of tongue strength using the IOPI as a research tool in adult subjects with neurological diseases. For this purpose, searches were conducted in the PubMed, Medline and Lilacs, Web of Science and MedCarib databases including articles from 2007 to 2018.

To generate the search in each database, three main constructs were developed:

(1) "tongue strength IOPI";

(2) "Swallowing Disorders";

(3) "Neurological Diseases". The terms were selected using as criteria the frequency that appears in articles related to the thematic area of the study. Each construct included a series of keyword associations using the Boolean OR operator.

Thus, the first construct was composed by combining the following terms: "Tongue strength" AND "IOPI" OR "Iowa Oral Performance Instrument". The second

by the terms: "Deglutition" OR "Deglutition disorders" OR "Dysphagia". Finally, the third construct included the terms: "Neurologic" OR "Stroke" OR "Parkinson's disease" OR "Traumatic brain injury" OR "Alzheimer" OR "Amyotrophic lateral sclerosis" OR "Multiple sclerosis". The search was incorporated into the association between the three constructs, this time using the boolean operator AND.

The language of the articles was limited to English, Spanish and Portuguese; In the case of the PubMed database, the age group of the population studied was over 19 years old. We did not include dissertation papers and theses, as well as literature reviews and event annals. The duplicate articles were then eliminated and, considering the breadth of the initial search, the results were further refined by taking into account the information presented in the title, abstract and keywords.

Screening

The purpose of this second phase was to review the content of abstracts and titles found in the initial search to identify those potentially eligible for further full-text analysis. Based on the search terms, studies excluded were those that:

(1) did not include a device for measuring tongue strength;

(2) did not report research within the scope of the objective of this systematic review;

(3) were not done in humans.

Following, the full text of the potentially relevant articles was obtained, taking as reference the above criteria. Then, the agreement between the evaluators regarding their selection was evaluated.

Eligibility

The purpose of this third phase was to conduct a thorough analysis of the articles included in the previous review. This time, the Inclusion Criteria established for this research were considered:

(1) to present use of the IOPI as an instrumental device;

(2) include tongue strength assessment or training;

(3) be written in English, Spanish or Portuguese;

(4) consider subjects with neurological disorders as defined in the search terms;

(5) be available online.

In addition, the exclusion criteria were considered:

(1) present a device in the study and tongue strength therapy other than the IOPI;

(2) include subjects with severe orofacial or dental structural changes.

After reading the articles in full, the following data were extracted: Names of the authors, year of publication, country where the study was conducted and modality of use of the IOPI instrument (evaluation or training). Additionally, it detailed how the evaluations and training with the IOPI were. Furthermore, the PICO Statement (Population, Intervention, Comparison and Outcome) was conducted to identify relevant information from the studies in addition to other key data (Table 1).

Then, the final studies were analyzed based on the PEDro scale and then, as there was not enough methodological and statistical data, it was not possible to provide a meta-analysis.

Cronbach's α value, sensitivity, specificity of measurement and the size effect value (Cohen´d) were not possible to consider for further statistical analysis due to the lack of information reported in the reviewed studies.

RESULTS.

The initial search by the researchers responsible for this phase produced a total of 152 abstracts (PubMed= 30; MEDLINE=107; Lilacs=5; Web of Science=10; Med Carib=0). There was 100% agreement in the search performed. Of the 152 abstracts obtained in the initial search, duplicate items were removed (n=33), leaving a total of 119 articles. Of these, 48 were excluded according to the criteria defined in the screening phase. There was 90% agreement between the two initial researchers in the selection of those articles. In the eligibility phase, 71 articles were then evaluated with the inclusion and exclusion criteria.

After this, 57 studies were discarded, leaving only 14 to be included in the final review. There was 100% agreement between the researchers. Figure 1 shows the selection flowchart obtained according to the proposed Systematic Review Protocol. Identification and relevant information of the studies based on the PICO Statement (Population, Intervention, Comparison and Outcome) plus other relevant information was identified.(Table 1)

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

Table 1. PICO Statement and additional characteristics of the studies reviewed.

Authors, Year and Country	Study Design Gender	Population Neurological Condition	Population Iopi Use	Intervention	Intervention Objective	Comparison of Intervention of IOPI Protocols	Results And Outcomes
Stierwalt et al.,[42] (2007) United States	Cross-sectional study	50 Total: 15 Males 35 Females	CVA, TBI	Evaluation	To add measures of lingual function to the existing literature by providing information on a group of individuals with oral dysphagia, and establish a comparison between these two groups.	--- --- ---	A reduction in tongue strength was found in the group of individuals with dysphagia. The findings provide evidence that, in this group, the weakness of the tongue coincided with signs of dysphagia. Justification for lingual strengthening protocols is proposed. The greater strength of the tongue was found in men than in women and in younger groups.
Robbins et al.,[43] (2007) United States	Prospective cohort study	10 Total: 5 Males 5 Females	CVA	Training	To examine the effects of tongue exercises on the recovery of stroke patients	Eight-week program, performing 10 repetitions, three times a day, three days a week.	All subjects significantly increased isometric and swallowing pressures. There was a reduction in penetration for liquids. Two subjects increased their intake of food volume.
Yeates et al.,[44] (2008) Canada	Cases Study	3 Males	1 CVA 1 TBI 1 Tumor	Training	To test an experimental therapy protocol with the IOPI as feedback. The tongue pressure training protocol emphasizes exercises for strength and precision.	10 sets of six tongue pressure exercises against the palate, during 24 sessions.	Increased isometric strength of the tongue, improved production of tongue pressure, better bolus control in videofluoroscopy and better functional dietary intake by oral route. Results indicate that, for these three adults with dysphagia, tongue pressure training was beneficial in improving instrumental and functional aspects of swallowing.
Easterling et al.,[45] (2013) United States	Cross-sectional study	23 Total: 11 Males 12 Females	ALS	Evaluation	To determine the pattern of neurodegenerative alteration in (1) isometric tongue strength and spontaneous saliva swallowing, (2) saliva production and (3) forced vital capacity in ALS patients.	--- --- ---	A pattern of compensation levels was identified in the isometric strength of the tongue and in the control of saliva. This may be associated with the ALS patient's ability to compensate with less viscous consistencies when swallowing. Tongue pressure measuring devices can be used in conjunction with the clinical swallowing examination.

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

Steele et al.,[46] (2013) Canada	Cases Study 2 Females	6 Total: 4 Males	TBI	Training	To measure the results of the treatment of tongue pressure in a group of six adults with chronic dysphagia after acquired brain injury.	24 sessions, 60 tongue pressure tasks, arranged in blocks of six, with a minimum rest period of 10 seconds.	Improvements were observed in post-treatment measures of tongue pressure and laryngeal penetration - aspiration. No improvement was seen with regard to pharyngeal residues.
Park et al.,[47] (2015) Korea 6 Males 9 Females	Randomized controlled blind-simple study.	15 Total	CVA	Training:	To evaluate the effectiveness of a structured resistance training program for the tongue, in order to improve the function of swallowing in patients with stroke and dysphagia.	Six weeks, five times a week, five sets of 10 trials per day. Minimum rest period of 30 seconds.	The study confirmed that tongue resistance training is an effective intervention for stroke and dysphagia patients, offering improved ongue muscle strength and overall improvement in swallowing.
Kim et al.,[48] (2016) Korea	Randomized study with a control group	18 Total: 11 Males 7 Females	CVA subacute	Evaluation	To evaluate the effect of conventional tongue resistance training against the palate on tongue strength in swallowing function in dysphagic stroke patients.	--- --- ---	This study demonstrated the efficacy of the tongue resistance training against the palate in increasing the muscular strength of the tongue and improving the swallowing function in patients with post-stroke dysphagia.
Byeon[50] (2016) Korea	Randomized study. Pre-post-test control group	48 Total: 14 Males 24 Females	CVA	Evaluation	To investigate the effect of orofacial myofunctional exercise in improving the muscle strength of the cheek, tongue and lips, and the diadochokinetic rate in patients with dysphagia.	--- --- ---	Orofacial myofunctional exercise is effective in the rehabilitation of swallowing function in the oral phase in patients with dysphagia, improving muscle strength and the rate of orofacial response.
Lee et al.,[51] (2016) Korea	Cross-sectional study	96 Total: 45 Males 51 Females	CVA	Evaluation	To assess the relationship between tongue pressure and different aspects of swallowing function in the oral phase.	--- --- ---	The findings indicate that tongue pressure seems to be closely related to swallowing function in the oral phase in post-stroke patients.

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

Steele et al.,[18] (2016) Canada	Prospective, randomized, parallel allocation study.	14 Total: 9 Males 5 Females	CVA	Evaluation	To compare the results of two traditional language resistance training protocols. The first emphasized pressure time patterns in the gradual pressure release and saliva swallowing tasks. The second protocol emphasized strength and precision in generating pressure on the tongue palate and did not include swallowing tasks	--- --- ---	Tongue strength can be improved with resistance training for individuals with tongue weakakness after a stroke. Pressure resistance training of the tongue appears to be effective in reducing fine fluid residues in the valleculae.
Oliveira et al.,[52] (2017) Brazil	Cross-sectional analytical observational study.	31 Total: 17 Males 14 Females	CVA	Evaluation	To evaluate if factors such as time of onset and type of stroke, severity and the degree of dysphagia were associated with tongue strength of stroke patients.	--- --- ---	The presence of dysphagia was shown to be statistically associated with tongue pressure. Dysphagic post-stroke patients had lower values for anterior and posterior tongue pressure, than those without dysphagia.
Oh et al.,[53] (2017) Korea	Control study, pre-post-test	8 Total	CVA	Evaluation	To investigate the effect of neuromuscular electrical stimulation on strength and lip closure in patients with dysphagia after stroke.	--- --- ---	Lip strength and lip closure function showed significant improvement. This study demonstrated that neuromuscular electrical stimulation is useful for improving lip strength and closing function.
Pitts et al.,[55] (2018) United States	Cross-sectional study.	28 Total: 17 Males 11 Females	PD	Evaluation	To determine whether the lingual pressures in PD are: (a) reduced, (b) reflect the medication status or (c) are consistent with the self-reported diet and swallowing function.	--- --- ---	The strength of the tongue was significantly reduced and did not differ depending on the medication. Measures of tongue strength and swallowing pressure can serve as clinical indicators for further evaluation of dysphagia zand promote early diagnosis of dysphagia in PD.

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

Moon et al.,[57] (2018) Korea	Preliminary randomized clinical trial, single blind	16 Total: 7 Males 9 Females	CVA subacute	Training	To investigate the effects of tongue strength and tongue accuracy on swallowing function and quality of life in patients with subacute stroke and dysphagia.	IOPI training of tongue strength and precision for 30 minutes, twice a day. Five times a week for eight weeks.	The group that received training with IOPI showed a significant recovery of Maximum sometric Pressure in comparison with the control group. The suggestion was to incorporate this training as part of the rehabilitation of dysphagia in patients with subacute stroke.

CVA: Cerebrovascular accident. **TBI:** Traumatic brain injury **ALS:** Amyotrophic lateral sclerosis. PD: Parkinson's disease. **----:** Non-training using IOPI.

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

Table 2. PEDro scale for assessment of revised articles.

Scale Items	Random Allocation	Concealed Allocation	Similar prognostic indicators	Blinding of all subjects	Blinding of therapist	Blinding of assessors	Measures of key outcome in more than 85% of subjects	Analysis by intention to treat	Between-group statistical comparison	Measures of precision and variability
Stierwalt et al.,[42] (2007)	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Robbins et al.,[43] (2007)	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Yeates et al.,[44] (2008)	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Easterling et al.,[45] (2013)	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes
Steele et al.,[46] (2013)	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Park et al.,[47] (2015)	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes
Kim et al.,[48] (2016)	Yes	No	Yes	Yes	No	No	Yes	No	Yes	Yes
Byeon[50] (2016)	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes
Lee et al.,[51] (2016)	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Steele et al.,[18] (2016)	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes
Oliveira et al.,[52] (2017)	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Oh et al.,[53] (2017)	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes
Pitts et al.,[55] (2018)	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Moon et al.,[57] (2018)	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes

From the 14 selected articles, five used the IOPI as an instrument for lingual strength training, while nine used the instrument as a device for assessing tongue strength and endurance. In all studies, a total of 366 individuals with neurological conditions assessed or treated with the IOPI were found. Only four diseases, of the six surveyed, were identified in the reviewed studies. No studies were found on patients with AD and MS. From the total participants of the studies, 7.6% were persons with PD and 6.2% were individuals with ALS.

The performance of tongue strength in stroke was the most studied. Of the 14 studies, 43% were carried out in Korea, 29% in the United States, 21% in Canada and 7% in Brazil. All articles were also analyzed using the PEDro Scale58 in order to obtain a better methodological assessment. (Table 2)

Studies using the IOPI training research showed large sample variability in number of subjects and limited blinding process. Studies that used the IOPI mostly as a tool to evaluated lingual strength showed greater complexity in terms of randomization and

inclusion of a control group, which is reflected in score obtained by three studies in the PEDro scale.

In all studies, we found a total of 366 individuals with neurological conditions evaluated or treated using the IOPI. Only four diseases out of the six surveyed were identified in the reviewed studies. No studies were found on AD and MS patients. The performance of tongue strength in stroke was the most studied. Maximum isometric pressure (MIP) is used as a standard measure for tongue strength assessment.

DISCUSSION.

Tongue strength assessed against palate pressure is identified as a key aspect in the oral swallowing phase, as previously elucidated.[41] The authors of the analyzed studies followed this premise and stated a relationship of swallowing disorders with elderly subjects, undermining their oral health.[42-46] This reasoning is pertinent, since a better tongue function based on biomechanical lingual performance training offers a new perspective for treating individuals with dysphagia.[47,48]

This may be of fundamental importance when the clinical condition is related to the age factor and thus may potentiate the decrease in tongue strength and increase the risk of dysphagia and oral disturbances.[49] Four studies in this systematic review.[42,50,51,52] provided information on tongue function measurements in individuals with oral dysphagia. This information is considered relevant because it comes from the four investigations with larger samples of subjects in which the IOPI was used as an evaluation tool.

The four studies were conducted in stroke patients and were able to establish a significant association between reduced tongue strength and the presence of altered swallowing. Although therapies were not performed with this device as a training tool, results supported the benefit of strength and tongue resis tance training in stroke dysphagic patients.[46,48,50,53]

The option to standardize the assessment proce-dures with the IOPI allows an adequate comparative analysis of findings showing maximum isometric pressure as the gold standard measure and tongue position in the anterior palate as the optimal position associated with swallowing requirements, even in studies with samples from less than 20 subjects or case studies.[46,48,52] The use of classical protocols[54] allows researchers in the analyzed studies to provide information that can be reliably and homologously interpreted using measurements such as maximum isometric pressure, resistance and accuracy of lingual movement. This is possible despite the already ob-served heterogeneity of the studied neurological groups and may help future designs of therapies that include tongue strength training.[47]

The level of evidence in this area of knowledge still needs development. From the 14 reviewed studies just 5 were randomized clinical trials as evidenced in the PEDro Scale, and only 2 of them were on tongue strength training. In the case of a study with PD patients[55] who measured the tongue pressure with the IOPI, as in the stroke studies,[18,47,51] it was established that the tongue force was significantly associated with the presence of muscle biomechanics alteration in patients with concomitant dysphagia.

This study makes an additional, but not least, contribution by noting that lingual performance does not vary with the patient's medication status but does influence overall oral health. The latter is established as an important contribution to similar research with PD patients, because it relativizes the influence factor of medication on tongue strength tasks.[55] Standardized kPa measurements for tongue strength, such as MIP, help to better understand research findings, especially in those studies with small number of participant and high clinical condition heterogeneity in their samples.[44,53] In addition, execution variability, whether in assessment and training programs, may interfere with study results, and a fixed protocol of sessions provides a better understanding of the effect of the programs,[56] as observed in four of the five studies involving the IOPI therapy.[43,44,47,57]

Despite the variability in the proposed tongue strength training programs,[43,44,46] it was observed that most participants in the reviewed studies received training programs ranging from 6 to 8 weeks and the sessions were held at 3 to 5 days a week, which meets recent literature recommendations for tongue training program.[57]

Protocols for training using the IOPI[43,44,47,57] reflect much of what the first studies proposed by Robbins in 2005, and because of their reliability most of them

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

remain almost unchanged.[54]

In terms of measurements, the maximum isometric tongue pressure seems to have a diagnostic value for oral dysphagia, which goes in the same direction as that established in another study.[47] In addition, in the analyzed studies, MIP´s were taken directly from the IOPI digital readings in each of the three controlled trials.[47,50,57] This procedure, as described in the IOPI manual, was tested and demonstrated strong intra- and inter-rater reliability.[56]

Most of the evaluation and training of tongue strength using the IOPI was conducted in sessions supervised by the researcher, so no evidence of double-blind design was found. Only two of the five tongue training studies were randomized,[47,57] so blinding was important to prevent bias in treatment effects.[48] In most of the reviewed studies, allocation of subjects undergoing training exercises was not randomized either, which could have helped in a more reliable interpretation of the results. In this sense, there are recommendations for conducting research with more homogeneous samples as possible and the use of randomized controlled investigations to determine treatment efficacy.[49] In terms of tongue strength assessment and training measures, MIP is established as the gold standard for researchers involved in studies aimed at assessing tongue strength and endurance performance. This was observed in the study that included six patients with acquired head injury with chronic dysphagia. This group of subjects completed 24 tongue pressure resistance training sessions for a total of 11 weeks - 12 weeks. Strength and accuracy were key parameters where later improvements were observed in post-treatment measures of tongue pressure in conjunction with decreased laryngeal penetration verified with fluoroscopic examination.[18]

With regard to the results found in the present study on tongue training in neurological patients, the already available research reporting a relationship between age and tongue strength in healthy individuals clearly does not fully apply for individuals with clinical conditions, but constitutes an important referential base where the MIP decreases with age[47,48,55] In addition, tongue strength has not being well evaluated in terms of the effects on mixing ability of masticatory functions.[59]

The results of tongue strength in terms of maximum isometric pressures were consistent and showed increased tendencies in lingual strength in all evaluations performed with the IOPI. On the other hand, in studies with the IOPI as a training tool, additional data should be collected to better understand the positive findings shown. This can be observed in two selected therapy studies,[44,46] which surveyed nine CVA and TBI patients, which, besides being small samples, showed a tendency to increase tongue strength throughout the training program. It is noteworthy that the literature states that performance in the development of tongue strength may not be linear and identifying a trend may be a challenge for researchers.[51]

In the five studies found on training with the IOPI, three were exclusively on stroke, one exclusively on TBI and one with three different diseases. In the latter, despite the variability of the subjects, the authors observed progress patterns that may reflect the tendency obtained by using the training program. Thus, it should be clear in these situations the limitation that case studies can generate in terms of generalizations and associations of techniques and outcomes.[23,48] Two studies conducted in Korea[53,57] have generated research that tends to establish a relationship with swallowing process when the facial or hypoglossal nerve is injured by a stroke, where the muscles of the tongue, cheek and lips weaken, causing problems in both the oral preparatory phase and the oral phase. Although this review is focused on the lingual muscle, the comprehensive view of the potential use of measurements obtained with the IOPI can be considered as a contribution to new research lines and better integration of oral muscle pressure measurements.[60]

From the 14 studies reviewed, it was possible to conclude that tongue strength can be reliably assessed by the use of the IOPI. Studies in individuals with neurological conditions are still scarce and even more so when the IOPI is used as a training tool. This situation determines that the study in the terms that was accomplished, allowed only carrying out a systematic review and not a meta-analysis. Only one study[18] had values, such as Cohen's effect size range, that could aid a more robust analysis of articles that met the review criteria.

This reinforces the fact that studies with larger and homogeneous populations should be carried out. In terms of the amount of neurological conditions studied, it is clear that there is still little reported evidence from studies with other diseases than CVA and TBI involving outcomes related to tongue strength and the relationship with the biomechanics involved in swallowing.[48] This review supports the fact that despite the limited evidence published since 2007, there are positive effects on swallowing by using the IOPI in tongue strength training, with CVA being the most studied neurological condition.

Authors of reviewed articles conclude that providing further extended evidence on other neurological populations and a search for a better understanding of the role of tongue strengthening programs on biomechanics of deglutition should be the aim for future research. This apply especially to Parkinson's disease that is currently, the leading source of global disability, and the fastest growing neurological degenerative disorder in the world from all neurological disorders.[61] None of the studies included latino participants, and this is remarkably important now that It has been reported that for the period 1990-2016, Parkinson's prevalence increased by 19.9% in Chile, placing it as the Latin American country that registers the greatest increase in prevalence of this pathology.[62]

The most frequent use of the IOPI has been mainly as an instrument to evaluate tongue strength performance before and after any intervention. The outcomes of the few studies found on interventions establish a positive effect of using the IOPI on tongue training.

CONCLUSION.

There is still limited amount of evidence on the effects of using the IOPI as a research tool in subjects with neurological conditions undermining their oral health, being those with CVA the most studied.

The use of the IOPI has been mainly as a tool for evaluation more than for tongue strength training in this population. Studies with larger and homogeneous samples and higher level of evidence are still needed to increase knowledge on biomechanical performance as tongue strength in other prevalent neurological conditions such as Parkinson´s disease and ALS.

Conflict of interests: The authors declare not to have any conflicts of interest.
Ethics approval: Does not apply.
Funding: Self-financed.
Authors' contributions: EPT was responsible for the concept, design, collection, analysis of information and preparation of the manuscript and DDB was responsible for the design and analysis of information; RM was responsible for guiding the manuscript; ARB-S was responsible for project guidance and general orientation on the execution of the manuscript.
Acknowledgements: None.

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

REFERENCES.

1. Kharade P, Dholam K, Bachher G. Appraisal of Function After Rehabilitation With Tongue Prosthesis. J Craniofac Surg. 2018;29(1):41-44.
2. Mendell DA, Logemann JA. Temporal sequences of swallow events during the oropharyngeal swallow. J Speech, Lang Hear Res. 2007;50(5):1256–71.
3. Robbins J, Hamilton JW, Lof GL, Kempster GB. Oropharyngeal swallowing in normal adults of different ages. Gastroenterology. 1992;103(3):823–9.
4. Morita K, Tsuka H, Kato K, Mori T, Nishimura R, Yoshida M, Tsuga K. Factors related to masticatory performance in healthy elderly individuals. J Prosthodont Res. 2018;62(4):432-5.
5. Luchesi KF, Kitamura S, Mourão LF. Dysphagia progression and swallowing management in Parkinson's disease: An observational study. Braz J Otorhinolaryngol. 2015;81(1):24–30.
6. Nakazawa Y, Kikutani T, Igarashi K, Yajima Y, Tamura F. Associations between tongue strength and skeletal muscle mass under dysphagia rehabilitation for geriatric out patients. J Prosthodont Res. 2020;64(2):188–92.
7. Adams V, Mathisen B, Baines S, Lazarus C, Callister R. A systematic review and meta-analysis of measurements of tongue and hand strength and endurance using the Iowa Oral Performance Instrument (IOPI). Dysphagia. 2013;28:350–69.
8. Murakami K, Hori K, Minagi Y, Uehara F, Salazar SE, Ishihara S, et al. Coordination of tongue pressure production, hyoid movement, and suprahyoid muscle activity during squeezing of gels. Arch Oral Biol. 2020;111:104631.
9. Obana M, Furuya J, Matsubara C, Tohara H, Inaji M, Miki K, Numasawa Y, Minakuchi S, Maehara T. Effect of a collaborative transdisciplinary team approach on oral health status in acute stroke patients. J Oral Rehabil. 2019;46(12):1170-6.
10. Yajima Y, Kikutani T, Tamura F, Yoshida M. Relationship between tongue strength and 1-year life expectancy in elderly people needing nursing care. Odontology. 2017;105(4):477–83.
11. Robbins JA, Levine R, Wood J, Roecker EB, Luschei E. Age effects on lingual pressure generation as a risk factor for dysphagia. Journals Gerontol - Ser A Biol Sci Med Sci. 1995;50A(5):257–62.
12. Ma D, Shuler JM, Kumar A, Stanford QR, Tungtur S, Nishimune H, Stanford JA. Effects of Tongue Force Training on Bulbar Motor Function in the Female SOD1-G93A Rat Model of Amyotrophic Lateral Sclerosis. Neurorehabil Neural Repair. 2017;31(2):147-56.
13. Świder K, Matys J. Complete dentures for a patient after a stroke by means of orofacial myofunctional therapy: A clinical report. J Prosthet Dent. 2018;120(2):177–80.
14. Hirota N, Konaka K, Ono T, Tamine K, Kondo J, Hori K, Yoshimuta Y, Maeda Y, Sakoda S, Naritomi H. Reduced tongue pressure against the hard palate on the paralyzed side during swallowing predicts Dysphagia in patients with acute stroke. Stroke. 2010;41(12):2982-4.
15. Park HS, Oh DH, Yoon T, Park JS. Effect of effortful swallowing training on tongue strength and oropharyngeal swallowing function in stroke patients with dysphagia: a double-blind, randomized controlled trial. Int J Lang Commun Disord. 2019;54(3):479–84.
16. Furuya J, Suzuki H, Tamada Y, Onodera S, Nomura T, Hidaka R, Minakuchi S, Kondo H. Food intake and oral health status of inpatients with dysphagia in acute care settings. J Oral Rehabil. 2020;47(6):736-742.
17. Yoon WL, Khoo JKP, Rickard Liow SJ. Chin tuck against resistance (CTAR): New method for enhancing suprahyoid muscle activity using a shaker-type exercise. Dysphagia. 2014;29(2):243–8.
18. Steele CM, Bayley MT, Peladeau-Pigeon M, Nagy A, Namasivayam AM, Stokely SL, Wolkin T. A Randomized Trial Comparing Two Tongue-Pressure Resistance Training Protocols for Post-Stroke Dysphagia. Dysphagia. 2016;31(3):452-61
19. Hewitt A, Hind J, Kays S, Nicosia M, Doyle J, Tompkins W, Gangnon R, Robbins J. Standardized instrument for lingual pressure measurement. Dysphagia. 2008;23(1):16-25.
20. Kim JH, Choi JW, Lee SH, Cho YS. Difference in tongue strength using visual feedback in healthy adults. J Phys Ther Sci. 2017;29(12):2075–6.
21. Chen H, Burton EA, Ross GW, Huang X, Savica R, Abbott RD, Ascherio A, Caviness JN, Gao X, Gray KA, Hong JS, Kamel F, Jennings D, Kirshner A, Lawler C, Liu R, Miller GW, Nussbaum R, Peddada SD, Rick AC, Ritz B, Siderowf AD, Tanner CM, Tröster AI, Zhang J. Research on the premotor symptoms of Parkinson's disease: clinical and etiological implications. Environ Health Perspect. 2013;121(11-12):1245-52.
22. Braak H, Del Tredici K, Rüb U, De Vos RAI, Jansen Steur ENH, Braak E. Staging of brain pathology related to sporadic Parkinson's disease. Neurobiol Aging. 2003; 24(2):197–211.
23. Kanna SV, Bhanu K. A simple bedside test to assess the swallowing dysfunction in Parkinson's disease. Ann Indian Acad Neurol. 2014;17(1):62–5.
24. Clarke CE, Gullaksen E, Macdonald S, Lowe F. Referral criteria for speech and language therapy assessment of dysphagia caused by idiopathic Parkinson's disease. Acta Neurol Scand. 2009;97(1):27–35.
25. Takizawa C, Gemmell E, Kenworthy J, Speyer R. A Systematic Review of the Prevalence of Oropharyngeal Dysphagia in Stroke, Parkinson's Disease, Alzheimer's Disease, Head Injury, and Pneumonia. Dysphagia. 2016;31(3):434–41.
26. Chan V, Zagorski B, Parsons D, Colantonio A. Older adults with acquired brain injury: A population based study. BMC Geriatr. 2013;13(1):1.
27. Feigin VL, Barker-Collo S, Krishnamurthi R, Theadom A, Starkey N. Epidemiology of ischaemic stroke and traumatic brain injury. Best Pract Res Clin Anaesthesiol. 2010;24(4):485–94.
28. De Medeiros Correia S, Morillo LS, Filho WJ, Mansur LL. A deglutição nas fases moderada e grave da doença de Alzheimer. Arq Neuropsiquiatr. 2010;68(6):855–61.
29. Sato E, Hirano H, Watanabe Y, Edahiro A, Sato K, Yamane G, Katakura A. Detecting signs of dysphagia in patients with Alzheimer's disease with oral feeding in daily life. Geriatr Gerontol Int. 2014;14(3):549-55.
30. Zhang TM, Yu SY, Guo P, Du Y, Hu Y, Piao YS, et al. Nonmotor symptoms in patients with Parkinson disease: A cross-sectional observational study. Med (United States). 2016;95(50):e5400.
31. Panebianco M, Marchese-Ragona R, Masiero S, Restivo DA. Dysphagia in neurological diseases: a literature review. Neurol Sci. 2020 Nov;41(11):3067-3073.
32. González-Garza MT, Martínez HR, Caro-Osorio E, Cruz-Vega DE, Hernández-Torre M, Moreno-Cuevas JE. Differentiation of CD133 + Stem Cells From Amyotrophic Lateral Sclerosis Patients Into Preneuron Cells. Stem Cells Transl Med. 2013;2(2):129–35.

33. Sandstedt P, Littorin S, Johansson S, Gottberg K, Ytterberg C, Kierkegaard M. Disability and contextual factors in patients with amyotrophic lateral sclerosis - A three-year observational study. J Neuromuscul Dis. 2018;5(4):439–49.
34. DePaul R, Brooks BR. Multiple orofacial indices in amyotrophic lateral sclerosis. J Speech Hear Res. 1993;36(6):1158–67.
35. Marrie RA, Cohen J, Stuve O, Trojano M, Sørensen PS, Reingold S, Cutter G, Reider N. A systematic review of the incidence and prevalence of comorbidity in multiple sclerosis: overview. Mult Scler. 2015;21(3):263-81.
36. Holtbernd F, Deppe M, Bachmann R, Mohammadi S, Ringelstein EB, Reilmann R. Deficits in tongue motor control are linked to microstructural brain damage in multiple sclerosis: A pilot study. BMC Neurol. 2015;15(1):190.
37. Arakawa I, Igarash, K, Imamura Y, Müller F, Abou-Ayash S, Schimmel M. Variability in tongue pressure among elderly and young healthy cohorts: A systematic review and meta-analysis. J Oral Rehabil, 2021;48(4): 430-48
38. Gingrich LL, Stierwalt JAG, Hageman CF, Lapointe LL, Lieshout V, Falls C. Generated by the Anteromedian and Posteromedian Tongue by Healthy Young Adults. 2012;4388:960–73.
39. Yamanashi H, Shimizu Y, Higashi M, Koyamatsu J, Sato S, Nagayoshi M, et al. Validity of maximum isometric tongue pressure as a screening test for physical frailty: Cross-sectional study of Japanese community-dwelling older adults. Geriatr Gerontol Int. 2018;18(2):240–9.
40. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA; PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 2;350:g7647.
42. Hirota N, Konaka K, Ono T, Tamine K, Kondo J, Hori K, et al. Reduced tongue pressure against the hard palate on the paralyzed side during swallowing predicts dysphagia in patients with acute stroke. Stroke. 2010;41(12):2982–4.
42. Stierwalt JAG, Youmans SR. Tongue measures in individuals with normal and impaired swallowing. Am J Speech-Language Pathol. 2007;16(2):148–56.
43. Robbins J, Kays SA, Gangnon RE, Hind JA, Hewitt AL, Gentry LR, Taylor AJ. The effects of lingual exercise in stroke patients with dysphagia. Arch Phys Med Rehabil. 2007;88(2):150-8.
44. Yeates EM, Molfenter SM, Steele CM. Improvements in tongue strength and pressure-generation precision following a tongue-pressure training protocol in older individuals with dysphagia: Three case reports. Clin Interv Aging. 2008;3(4):735–47.
45. Easterling C, Antinoja J, Cashin S, Barkhaus PE. Changes in tongue pressure, pulmonary function, and salivary flow in patients with amyotrophic lateral sclerosis. Dysphagia. 2013;28(2):217–25.
46. Steele CM, Bailey GL, Polacco RE, Hori SF, Molfenter SM, Oshalla M, Yeates EM. Outcomes of tongue-pressure strength and accuracy training for dysphagia following acquired brain injury. Int J Speech Lang Pathol. 2013;15(5):492-502.
47. Park JS, Kim HJ, Oh DH. Effect of tongue strength training using the iowa oral performance instrument in stroke patients with dysphagia. J Phys Ther Sci. 2015;27(12):3631–4.
48. Kim HD, Choi JB, Yoo SJ, Chang MY, Lee SW, Park JS. Tongue-to-palate resistance training improves tongue strength and oropharyngeal swallowing function in subacute stroke survivors with dysphagia. J Oral Rehabil. 2017;44(1):59–64.
49. Easterling C. Management and Treatment of Patients with Dysphagia. Curr Phys Med Rehabil Reports. 2018;29(6):213–219.
50. Byeon H. Effect of orofacial myofunctional exercise on the improvement of dysphagia patients' orofacial muscle strength and diadochokinetic rate. J Phys Ther Sci. 2016;28(9):2611–4.
51. Lee JH, Kim HS, Yun DH, Chon J, Han YJ, Yoo SD, Kim DH, Lee SA, Joo HI, Park JS, Kim JC, Soh Y. The Relationship Between Tongue Pressure and Oral Dysphagia in Stroke Patients. Ann Rehabil Med. 2016;40(4):620-8.
52. Oliveira GD de, Valentim AF, Vicente LCC, Motta AR. Fatores associados à pressão de língua em pacientes pós-acidente vascular cerebral. Audiol - Commun Res. 2017;22(0):1870–1.
53. Oh DH, Park JS, Kim WJ. Effect of neuromuscular electrical stimulation on lip strength and closure function in patients with dysphagia after stroke. J Phys Ther Sci. 2017;29(11):1974–5.
54. Robbins JA, Gangnon RE, Theis SM, Kays SA, Hewitt AL, Hind JA. The effects of lingual exercise on swallowing in older adults. J Am Geriatr Soc. 2005;53(9):1483–9.
55. Pitts LL, Morales S, Stierwalt JAG. Lingual pressure as a clinical indicator of swallowing function in Parkinson's disease. J Speech, Lang Hear Res. 2018 ;61(2):257–65.
56. Clark HM, Solomon NP. Age and sex differences in orofacial strength. Dysphagia. 2012;27(1):2–9.
57. Moon JH, Hong DG, Kim KH, Park YA, Hahm SC, Kim SJ, Won YS, Cho HY. Effects of lingual strength training on lingual strength and articulator function in stroke patients with dysarthria. J Phys Ther Sci. 2017;29(7):1201-4.
58. Cashin AG, McAuley JH. Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. J Physiother. 2020:66(1): 59.
59. Watanabe D, Yoshida T, Yokoyama K, Yoshinaka Y, Watanabe Y, Kikutani T, Yoshida M, Yamada Y, Kimura M, Kyoto-Kameoka Study Group. Association between Mixing Ability of Masticatory Functions Measured Using Color-Changing Chewing Gum and Frailty among Japanese Older Adults: The Kyoto-Kameoka Study. Int J Environ Res Public Health. 2020;17(12):4555.
60. Smaoui S, Langridge A, Steele CM. The Effect of Lingual Resistance Training Interventions on Adult Swallow Function: A Systematic Review. Dysphagia. 2020;35(5):745-61.
61. Dorsey ER, Sherer T, Okun MS, Bloem BR. The Emerging Evidence of the Parkinson Pandemic. J Parkinsons. Dis.2018;8:S3–S8.
62. 2016 Global, regional, and national burden of Parkinson's disease, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. Neurol. 2018; 17:939–953

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