International Journal of Language & Communication Disorders

INT J LANG COMMUN DISORD, SEPTEMBER–OCTOBER 2015,
VOL. 50, NO. 5, 659–664

Short Report

Swallowing disorders in Parkinson's disease: impact of lingual pumping

Natalie Argolo†, Marília Sampaio†‡, Patrícia Pinho†, Ailton Melo† and Ana Caline Nóbrega†‡

†Division of Neurology and Epidemiology, Federal University of Bahia, Salvador, Bahia, Brazil
‡Department of Speech–Language Pathology, Health Sciences Institute, Federal University of Bahia, Salvador, Bahia, Brazil

(*Received April 2014; accepted December 2014*)

Abstract

Background: Lingual pumping (LP) is a repetitive, involuntary, anteroposterior movement of the tongue on the soft palate that is executed prior to transferring the food bolus to the pharynx, but we also observed LP when multiple swallows were taken. LP may be associated with rigidity and bradykinesia in patients with Parkinson's disease (PD). This phenomenon tends to be more prevalent in dysphagic PD patients, and its impact on swallowing dynamics remains poorly understood.
Objective: To evaluate how LP interferes with the oral and pharyngeal phases of the swallowing of foods of different consistencies and volumes.
Methods: We used videofluoroscopy to study the swallowing of 69 PD patients performing 10 swallows of barium mixed with foods of different consistencies and volumes.
Results: LP was associated with the unstable intra-oral organization of the bolus, the loss of bolus control, the pharyngeal retention of food and food entering the airway. This abnormal movement was also associated with a shorter oral transit time and was found to be more prevalent with food of thicker consistencies.
Conclusions: LP is associated with swallowing incoordination and with food entering the airway. Preventive measures to minimise the pulmonary or nutritional consequences of this behaviour are necessary.

Keywords: Parkinson's disease, deglutition disorders, lingual pumping.

What this paper adds?

What is already known on this subject?
Lingual pumping (LP) is a common finding in patients with Parkinson's disease, and may be associated with dysphagia and aspiration. However, the impact of LP on swallowing dynamics remains poorly understood.

What this study adds?
The data demonstrate that LP is associated with swallowing incoordination during the oral phase, the pharyngeal retention of food and the occurrence of food entering the airway, and that LP occurs more frequently with foods of thicker consistencies. The adoption of preventive measures, such as changing the consistency of food, may decrease the negative impact of LP, but additional studies of the management of LP in patients with Parkinson's disease should be performed.

Introduction

Among the numerous motor and non-motor consequences of Parkinson's disease (PD), dysphagia is the primary cause of mortality in PD patients (Wang *et al.* 2002). Swallowing disorders associated with PD include anterior escape, premature loss of bolus, oral and pharyngeal retention, multiple swallows, laryngeal penetration, and aspiration of food (Umemoto *et al.* 2010).

Lingual pumping (LP), also called festination of the tongue or lingual rocking, is a videofluoroscopic finding in approximately 75% of PD patients (Troche *et al.* 2007, Nóbrega *et al.* 2008). Ali *et al.* (1996) described LP as a repetitive, involuntary, anteroposterior

Address correspondence to: Natalie Argolo, Division of Neurology and Epidemiology, Rua Padre Feijó, 29 (4° floor) – Canela, Salvador – Bahia – Brazil CEP: 40.110–170; e-mail: nataliefono@gmail.com

International Journal of Language & Communication Disorders
ISSN 1368-2822 print/ISSN 1460-6984 online © 2015 Royal College of Speech and Language Therapists
DOI: 10.1111/1460-6984.12158

movement of the tongue on the soft palate that is executed prior to transferring the food bolus to the pharynx, but we also observed LP when multiple swallows were taken This abnormal movement may be associated with rigidity and bradykinesia, but its underlying pathophysiological mechanisms remain unclear (Bushmann *et al.* 1989). Among PD patients, LP is most frequently observed in those with dysphagia and food aspiration (Ali *et al.* 1996, Nagaya *et al.* 1998). However, the effects of LP on swallowing dynamics remain poorly understood.

During the oral phase of normal swallowing, the tongue performs a series of stereotyped but not invariant movements in synergy with the jaw to move the food bolus posteriorly (Steele and Van Lieshout 2008). During mastication, the tongue moves the bolus coordinately, placing the bolus on the teeth for chewing and lifting the bolus from the teeth as they close upon the bolus. The bolus is then mixed with saliva and replaced on the teeth using a repetitive rotary tongue movement until a manageable consistency is reached (Logemann 2007). In PD patients, the lingual movements are fewer and slower than normal, and several authors have described involuntary movements during swallowing in PD patients (Van Lieshout *et al.* 2011, Ali *et al.* 1996, Leopold and Kagel 1996).

We hypothesized that abnormal involuntary movements, such as LP, could alter the swallowing process and result in an uncoordinated intra-oral organization of the bolus, which could affect the pharyngeal phase of swallowing, resulting in post-swallowing residue and aspiration of food. Another hypothesis is that this incoordination could lead to increased oral and pharyngeal transit times due to the difficulty of initiating the swallow. In addition, food boluses of different consistencies and volumes that demand different lingual motor efforts could affect the occurrence of LP. Therefore, the aim of this study was to evaluate how LP interferes with the oral and pharyngeal phases of swallowing depending on the consistency and volume of food.

Methods

Patients

Consecutive idiopathic PD patients who presented at the Ambulatory Movement Disorders Clinic of the Federal University of Bahia were enrolled and subjected to a videofluoroscopic study of swallowing (VSS). PD diagnoses were made by a certified neurologist in accordance with United Kingdom Parkinson's Disease Brain Bank (UKPDBB) guidelines (Gibb and Lees 1988). The exclusion criteria were as follows: the existence of other neurological diseases, psychiatric or cognitive disorders; head and neck cancer; and severe dysphagia (that prevents the completion of the examination with food samples of all consistencies and volumes). The majority of the patients included in this study took levodopa and were evaluated during the 'on' state of medication.

This study was approved by the local ethics committee of Bahia and was conducted according to the guidelines of the Helsinki Declaration (1964). All patients signed an informed consent form before any procedure was conducted.

Assessments

For VSS evaluations, the subjects were seated in a lateral position and instructed to eat 5, 10 and 20 ml of a suspension of thin fluid (barium mixed with water at a 1:1 ratio) and thick fluids (pure barium); 5, 10 and 15 ml of barium paste composed of barium mixed with Nestlé® natural yoghurt at a 2:1 ratio; and half a biscuit dipped in barium (solid). These evaluations were performed using an edible radiopaque barium sulphate agent (Bariogel® 100%).

The following visuo-perceptual parameters of the VSS analyses were examined:

- The type of intra-oral bolus organization, which was divided into closed (i.e. the bolus is positioned above the tongue dorsum), open anterior-restricted (i.e. the bolus is positioned anterior to the tongue), open expanded (i.e. the bolus is positioned anterior to and above the tongue), prolonged (i.e. the bolus is spread above the tongue from its tip to the soft palate) and unstable (i.e. the bolus exhibits an oscillating positioning with or without intra-oral food spill) (Yamada *et al.* 2004).
- The loss of bolus control, as determined by the occurrence of premature loss of bolus into the oral sulci or the pharynx before the onset of swallowing (Ali *et al.* 2006).
- Start site of the pharyngeal phase, defined as the location of the contrasted material when laryngeal elevation occurred (tongue base, valleculae, ariepiglotic fold, pyriform sinuses or pharyngo-oesophageal transition).
- Multiple swallows, defined as more than three hard swallows after posterior bolus propulsion.
- Piecemeal deglutition, in which the bolus was fractionated into many swallowing units.
- Retention on the tongue or in the pharyngeal recesses, in which the contrasted material remained in the valleculae or the pyriform sinuses, on the posterior pharyngeal wall or in the pharyngo-oesophageal transition zone after the first swallow was performed.
- Food entering the airway, which was defined as the laryngeal penetration and/or aspiration of the contrasted material.

During the examination, when multiple swallows or piecemeal deglutition were observed, only the first swallow in the series was analysed for each bolus.

The temporal parameters included the oral transit time (OTT), which was defined as the period from the first anteroposterior movement of the tongue until the head of the bolus passed through the mandibular angle, and the pharyngeal transit time (PTT), which was defined as the period from when the bolus tail passed the mandibular angle until it passed through the cricopharyngeal region (Troche *et al.* 2007). OTTs of up to 2 s were considered to be normal, except in the case of solids, when OTTs as long as 18 s were considered normal to account for the mastication period. In all cases, a PTT longer than 1 s was considered to be abnormal (Logemann 2007).

Statistical analyses

The data were analysed using R software, version 3.0.2. Descriptive values are presented as the mean ± standard deviation (SD). Cochran–Mantel–Haenszel tests were used to evaluate the association between LP and the qualitative data for swallowing while controlling for food consistency and volume. Marginal logistic regression was performed for the following two analyses: the LP and food consistency and the LP and food volume. Subsequently, the results of the latter analysis were corrected using the Holm–Bonferroni method for multiple comparisons. The analysis between LP and temporal parameters was performed using marginal log-linear regression.

Results

Of the 71 patients enrolled in this study, 69 completed the VSS protocol. Prior to the examinations, all patients had a history of ingesting food of all consistencies through their mouths without any restrictions or having to use an alternative pathway. During the VSS studies, two patients experienced severe aspiration of food of one or more consistencies, which prevented them from completing the examination with all the food consistencies and volumes investigated in this study. These two patients were excluded from the study and referred for speech therapy. The study population included 44 men and 25 women; the mean age of the study participants was 63.36 ± 11.62 years. The mean disease duration was 7 ± 5.2 years; the mean Hoehn & Yahr stage was 2.3 ± 0.9. Thirteen patients (18.84%) exhibited LP. The swallowing assessments of 69 patients resulted in 690 swallowing events (10 per patient), 52 (7.54%) of which involved LP.

Table 1 presents the associations between LP and swallowing abnormalities. The occurrence of LP was associated with the unstable positioning of the food bolus, the loss of bolus control with food spillage into the anterior sulci and the floor of the mouth, retention in the pharyngo-oesophageal transition zone and food entering the airway.

No association was observed between LP and lingual tremor ($p = 0.7151$).

With respect to the duration of deglutition, LP was associated with a shorter OTT (a mean value of 4.22 ± 6.85 ms in PD patients without LP versus a mean value of 2.47 ± 2.64 ms in those with LP; $\mathrm{Exp}(\beta) = 0.58$; $p = 0.0031$). However, no significant association between LP and PTT was detected (a mean value of 0.857 ± 0.911 ms in PD patients without LP versus a mean value of 1.005 ± 1.007 in patients with LP; $p = 0.545$).

When we investigated the occurrence of LP with respect to food consistency, we noted that the likelihood of LP increased with increases in food consistency. The thick fluid was associated with a 2.89-fold increase in LP when compared with the thin fluid ($p = 0.0297$), and barium paste increased the occurrence of LP 3.57-fold compared with the thin fluid ($p = 0.0088$) (figure 1). No significant differences in LP were observed between the paste material and the thick fluid, the solid food and the thin fluid, the solid food and the thick fluid and the solid and the paste material ($p = 0.7483$, 0.6789, 0.2491 and 0.2616, respectively).

Using marginal logistic regression analysis, no association was detected between the occurrence of LP and food volume. For thin fluids, the comparisons of LP between 5 and 10 ml, 5 and 20 ml, and 10 and 20 ml yielded *p*-values of 1, 0.57 and 0.57, respectively. For thick fluids, these *p*-values were 1, 0.16 and 0.16, respectively. For food paste, the comparisons of LP between 5 and 10 ml, 5 and 15 ml, and 10 and 15 ml yielded *p*-values of 0.71, 0.48 and 0.32, respectively. We did not perform this analysis with solid foods because only one volume using this consistency was tested.

Discussion

The data reveal that LP is associated with swallowing incoordination during the oral phase, pharyngeal retention of food and food entering the airway. The results also demonstrate that LP was more frequent with food of thicker consistencies.

According to the findings, LP increased the occurrence of unstable positioning of the bolus above the tongue prior to its propulsion to the pharynx. As a result, mostly intraoral leaks occurred, and food was transferred into the pharynx in an uncoordinated manner. Because LP interferes with the coordination of tongue movements for the correct propulsion of the bolus, LP also increases bolus retention in the pharyngeal recesses after swallowing and can contribute to laryngeal penetration and/or aspiration of food in PD patients. Nagaya

Table 1. Associations between lingual pumping and swallowing abnormalities

Swallowing abnormality		Lingual pumping Absent (%)	Lingual pumping Present (%)	*p*-value
	Closed	47.20	24.49	
Type of intra-oral bolus organization	Open anterior restricted	11.71	8.16	
	Open anterior expanded	12.24	14.29	0.0161*
	Prolonged	12.06	12.24	
	Unstable	16.78	40.82	
Loss of bolus to anterior sulci	Absent	89.50	73.08	0.0017*
	Present	10.50	26.92	
Loss of bolus to lateral sulci	Absent	95.45	90.38	0.1473
	Present	4.54	9.62	
Loss of bolus to mouth floor	Absent	79.00	61.54	0.0053*
	Present	21.00	38.43	
Posterior loss of bolus	Absent	69.94	57.69	0.0936
	Present	30.56	42.30	
Start site of the pharyngeal phase	Tongue base/valleculae	77.90	71.15	0.2186
	AEF/PS/PET	22.10	28.85	
Multiple swallows	Absent	44.98	36.54	0.4378
	Present	55.02	63.46	
Piecemeal deglutition	Absent	76.18	69.23	0.2188
	Present	23.82	30.77	
Retention on tongue	Absent	95.14	94.23	0.8608
	Present	04.86	05.77	
Retention in vallecula	Absent	79.62	75.00	0.8958
	Present	20.38	25.00	
Retention in PS	Absent	93.57	86.54	0.2043
	Present	06.43	13.46	
Retention in AEF	Absent	98.59	96.15	0.5268
	Present	01.41	03.85	
Retention in PET	Absent	95.61	80.77	0.0001*
	Present	04.39	19.23	
Food entering the airway	Absent	95.14	88.46	0.0287*
	Present	4.86	11.54	

Note: AEF, aryepiglottic fold; PS, pyriform sinus; PET, pharyngo-oesophageal transition. *Significant statistical difference ($p < 0.05$).

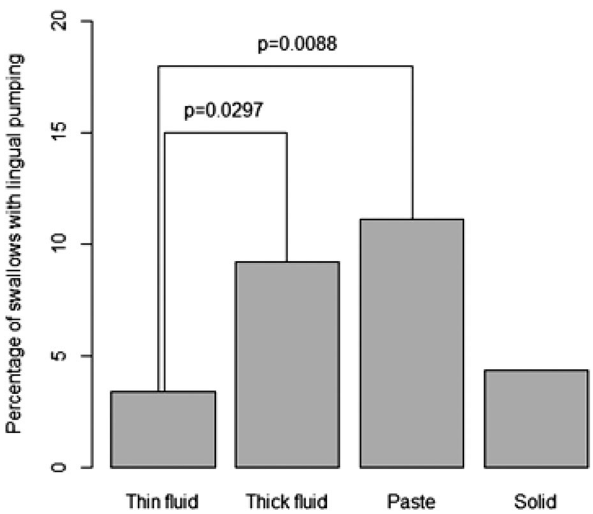

Figure 1. Percentage of swallows involving lingual pumping according to the consistency of the food.

et al. (1998) performed VSS studies in PD patients and reported repetitive tongue pumping only in the group exhibiting aspiration. The results thus confirm that LP can interfere with both the oral and pharyngeal phases of swallowing, including the organization of the bolus within the oral cavity, bolus transfer to the pharynx and the mechanisms of airway protection.

Concerning the impact of LP on the duration of swallowing, the occurrence of LP was associated with lower OTTs in our study. This result may be explained by the accelerated motion of the tongue during this activity, which can result in more rapid but less coordinated deglutition. Troche *et al.* (2007) reported a positive correlation between the number of lingual pumps and OTT. In our study, we did not quantify the number of lingual pumps; our analysis consisted only of identifying whether each individual exhibited LP.

With respect to the relationship between LP and food consistency, Troche *et al.* (2007) observed a higher number of lingual pumps with thicker foods in PD patients, which is consistent with our results. The lack of resistance to the flow of thin liquids may reduce the extent of oral manipulation required, whereas more tongue movement may be required to move thicker liquids within the oral cavity, which could thus demand a larger amount of motor energy. Moreover, bradykinesia can cause a loss of motor energy and can predispose PD patients to the onset of LP when eating food of thicker consistencies (Hallett 2011).

Logemann *et al.* (2008) reported that reductions in the aspiration of thin liquids occurred most frequently with honey thick liquids followed by nectar thick liquids and highlighted the importance of managing the consistency of food to reduce the chance of aspiration in dysphagic patients. In our study, the occurrence of aspiration was also observed to be greater with thin liquids than with thick liquids and pastes. In contrast, the occurrence of LP exhibited the opposite trend, increasing in frequency as the consistency thickened. The strongest association between LP and aspiration occurred with the thick liquid consistency. However, it is important to emphasize the fact that the thick fluid material we used consisted of pure barium that was not diluted with water (as was the thin liquid) or mixed with yoghurt (as was the material of the paste consistency), which could have led to more pronounced rheological characteristics, such as adhesion, and increased the difficulty of swallowing this substance.

One interesting finding of our study was the observed reduction in the occurrence of LP with solid foods. This result may be explained by the high levels of oral manipulation that mastication requires. In addition, the masticatory movements may require different types of motor control that may reduce the appearance of this abnormality. Hiiemae and Palmer (1999) have described the technique of food movement within the oral cavity during its processing as a 'push–pull' system in which food is pushed backward using a 'squeeze-back' mechanism and is intermittently pulled forward by the bodily movement of the tongue. This food-movement process, when associated with the constant contact between the tongue and hard palate, is likely to promote constant sensory input that affects motor performance.

Dantas *et al.* (1990) analysed the effects of bolus variables on the oral and pharyngeal phases of swallowing and reported that the magnitude of the anterior movement of the tongue base during swallowing increased linearly with increasing bolus volume. Although movements of larger amplitude can increase the extent of kinaesthetic feedback and larger food volumes can result in better sensory input, we hypothesized that increasing food volume would reduce the occurrence of LP (Van Lieshout *et al.* 2011). However, in our study, the 20-ml volume was offered in a cup, and most of the patients did not consume the entire 20 ml at once. Thus, we cannot determine the exact volume ingested, making such an analysis unfeasible.

It is interesting to note that most of our patients had PD with low Hoehn & Yahr staging, and it is possible that changes in the ability of patients to move their tongue may begin in the early stages of PD. Van Lieshout *et al.* (2011) also reported changes in the lingual movement abilities of PD patients during the early stages of disease, but further studies should be conducted to clarify the relationship between the severity of dysphagia and the severity of PD.

We also must stress that we observed lingual tremors in some patients, but the tremors were not associated with LP. Moreau *et al.* (2007) studied oral festination during orofacial diadochokinetic tasks and reported an association between oral festination and the festination of gait, but not with the freezing of gait or peripheral tremors. The authors concluded that oral festination shares the same pathophysiology as disorders of gait and that tremors and festination may arise through different mechanisms.

With respect to the management of LP, we did not find any studies that evaluated the effect of treatments on reducing LP. Furthermore, the effect of drugs or deep-brain stimulation (DBS) on LP remains poorly studied. Cantiniaux *et al.* (2014) reported that levodopa and DBS did not improve the velocity or the rhythm of speech. The reported effects of levodopa on swallowing are also inconsistent (Menezes and Melo 2009). Although there is a strong association between festination of gait and festination of speech, the relationships of these variables with LP during swallowing have not been established, and it is difficult to predict whether these interventions might alleviate LP in PD patients.

Understanding the neurophysiological mechanisms underlying LP is necessary to define the optimal therapeutic interventions to reduce this symptom. More studies investigating the effects of levodopa and DBS on LP are necessary to clarify the mechanisms involved in the neurological control of the tongue and swallowing in PD patients. In addition, studies of preventive measures, such as changing the consistency and/or volume of food or the adoption of tools that facilitate better organization of the bolus, should also be conducted.

Because LP is associated with swallowing incoordination and food entering the airway, it may increase morbidity and mortality in PD patients. However, more studies are necessary to clarify the role of this repetitive tongue movement in swallowing and the mechanisms associated with its occurrence. Recognition of this alteration and its potential effects on the morbidity of PD patients may lead to the elucidation of optimal treatments for LP in this population.

Acknowledgement

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

ALI, G. N., WALLACE, K. L., SCHWARTZ, R., DECARLE, D. J., ZAGAMI, A. S. and COOK, I. J., 1996, Mechanisms of oral–pharyngeal dysphagia in patients with Parkinson's disease. *Gastroenterology*, **110**, 383–392.

BUSHMANN, M., DOBMEYER, S. M., LEEKER, L. and PERLMUTTER, J. S., 1989, Swallowing abnormalities and their response to treatment in Parkinson's disease. *Neurology*, **39**, 1309–1314.

CANTINIAUX, S., VAUGOYEAU, M., ROBERT, D., HORRELOU-PITEK, C., MANCINI, J., WITJAS, T. and AZULAY, J. P., 2010, Comparative analysis of gait and speech in Parkinson's disease: hypokinetic or dysrhythmic disorders? *Journal of Neurology, Neurosurgery and Psychiatry*, **81**, 177–184.

DANTAS, R. O., KERN, M. K., MASSEY, B. T., DODDS, W. J., KAHRILAS, P. J., BRASSEUR, J. G., COOK, I. J. and LANG, I. M., 1990, Effect of swallowed bolus variables on oral and pharyngeal phases of swallowing. *American Journal of Physiology*, **258**, G675–G681.

GIBB, W. R. and LEES, A. J., 1988, The relevance of the Lewy body to the pathogenesis of idiopathic Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, **51**, 745–752.

HALLETT, M., 2011, Bradykinesia: why do Parkinson's patients have it and what trouble does it cause? *Movement Disorders*, **26**, 1579–1581.

HIIEMAE, K. M. and PALMER, J. B., 1999, Food transport and bolus formation during complete feeding sequences on foods of different initial consistency. *Dysphagia*, **14**, 31–42.

LEOPOLD, N. A. and KAGEL, M. C., 1996, Prepharyngeal dysphagia in Parkinson's disease. *Dysphagia*, **11**, 14–22.

LOGEMANN J., 2007, Swallowing disorders. *Best Practice and Research Clinical Gastroenterology*, **21**, 563–573.

LOGEMANN, J. A., GENSLER, G., ROBBINS, J., LINDBLAD, A. S., BRANDT, D., HIND, J. A., KOSEK, S., DIKEMAN, K., KAZANDJIAN, M., GRAMIGNA, G. D., LUNDY, D., MCGARVEY-TOLER, S. and GARDNER, P. J. M., 2008, A randomized study of three interventions for aspiration of thin liquids in patients with dementia or Parkinson's disease. *Journal of Speech, Language and Hearing Research*, **51**, 173–183.

MENEZES, C. and MELO, A., 2009, Does levodopa improve swallowing dysfunction in Parkinson's disease patients? *Journal of Clinical Pharmacy and Therapeutics*, **34**, 673–676.

MOREAU, C., OZSANCAK, C., BLATT, J.-L., DERAMBURE, P., DESTEE, A. and DEFEBVRE, L., 2007, Oral festination in Parkinson's disease: biomechanical analysis and correlation with festination and freezing of gait. *Movement Disorders*, **22**, 1503–6.

NAGAYA, M., KACHI, T., YAMADA, T. and IGATA, A., 1998, Videofluorographic study of swallowing in Parkinson's disease. *Dysphagia*, **13**, 95–100.

NÓBREGA, A., RODRIGUES, B., TORRES, A., SCARPEL, R., NEVES, C. and MELO, A., 2008, Is drooling secondary to a swallowing disorder in patients with Parkinson's disease? *Parkinsonism and Related Disorders*, **14**, 243–245.

STEELE, C. M. and VAN LIESHOUT, P. H. H. M., 2008, The dynamics of lingual–mandibular coordination during liquid swallowing. *Dysphagia*, **23**, 33–46.

TROCHE, M. S., SAPIENZA, C. M. and ROSENBEK, J. C., 2007, Effects of bolus consistency on timing and safety of swallow in patients with Parkinson's disease. *Dysphagia*, **23**, 26–32.

UMEMOTO, G., TSUBOI, Y., KITASHIMA, A., FURUYA, H. and KIKUTA, T., 2010, Impaired food transportation in Parkinson's disease related to lingual bradykinesia. *Dysphagia*, **26**, 250–255.

VAN LIESHOUT, P. H. H. M., STEELE, C. M. and LANG A. E., 2011, Tongue control for swallowing in Parkinson's disease: effects of age, rate, and stimulus consistency. *Movement Disorders*, **26**, 1725–1729.

WANG, X., YOU, G., CHEN, H. and CAI, X., 2002, Clinical course and cause of death in elderly patients with idiopathic Parkinson's disease. *Chinese Medical Journal (English Edn)*, **115**, 1409–1411.

YAMADA, E. K., SIQUEIRA KO, D. E., XEREZ, D., KOCH, H. A. and COSTA, M. M. B., 2004, The influence of oral and pharyngeal phases on the swallowing dynamic. *Arquivos de Gastroenterologia*, **41**, 18–23.