Dysphagia

Ultrasonographic measurement of masseter muscle thickness associates with dysphagia in institutionalized elderly individuals.

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Abstract:	Background & Aims The prevalence of dysphagia increases in elderly individuals and it is disproportionately higher in nursing home residents. The main objective of this study was to assess the relationship between the thickness of the masseter muscle measured by ultrasonography and the presence of dysphagia in a group of institutionalized elderly people. As a secondary objective, we aimed to establish cutoff points of masseters thickness to identify elderly individuals at risk of dysphagia. Methods Cross-sectional study of all residents from 3 nursing homes. All individuals underwent ultrasonographic measurements of left and right masseters muscle thickness (MMT) and were classified according to the presence of dysphagia assessed by both the EAT-10 screening questionnaire and the volume-viscosity swallow test (V-VST). Results 469 patient (69% women, mean age 84.7 y) were recruited. Dysphagia was present in

	41.6% and 26% of individuals according the EAT-10 and V-VST respectively. Multivariate logistic regression showed that 1 mm increase in MMT reduced by 21% the risk of dysphagia according to the EAT-10 tool and by 30% using the V-VST after adjusting for age, sex, MNA score, and BMI. We next used receiver operative characteristics (ROC) to identify cutoff points of MMT to detect dysphagic individuals according to either EAT-10 or V-VST. Conclusions the thickness of the masseter muscle in relaxation measured by ultrasonography is reduced in elderly individuals with dysphagia and can be useful to inform clinical decisions in geriatric settings
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Ultrasonographic measurement of masseter muscle thickness associates with dysphagia in institutionalized elderly individuals.

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ABSTRACT

Background & Aims: The prevalence of dysphagia increases in elderly individuals and it is disproportionately higher in nursing home residents. The main objective of this study was to assess the relationship between the thickness of the masseter muscle measured by ultrasonography and the presence of dysphagia in a group of institutionalized elderly people. As a secondary objective, we aimed to establish cutoff points of masseters thickness to identify elderly individuals at risk of dysphagia.

Methods: Cross-sectional study of all residents from 3 nursing homes. All individuals underwent ultrasonographic measurements of left and right masseters muscle thickness (MMT) and were classified according to the presence of dysphagia assessed by both the EAT-10 screening questionnaire and the volume- viscosity swallow test (V- VST).

Results: 469 patient (69% women, mean age 84.7 y) were recruited. Dysphagia was present in 41.6% and 26% of individuals according the EAT-10 and V-VST respectively. Multivariate logistic regression showed that 1 mm increase in MMT reduced by 21% the risk of dysphagia according to the EAT-10 tool and by 30 % using the V-VST after adjusting for age, sex, MNA score, and BMI. We next used receiver operative characteristics (ROC) to identify cutoff points of MMT to detect dysphagic individuals according to either EAT-10 or V-VST.

Conclusions: the thickness of the masseter muscle in relaxation measured by ultrasonography is reduced in elderly individuals with dysphagia and can be useful to inform clinical decisions in geriatric settings

KEYWORDS: swallowing, mastication, severe dependency, malnutrition, ROC

Introduction

Aging is accompanied by a series of pathophysiological changes that negatively affect the functionality of the individual. Among those changes there are reductions in muscle mass and strength that negatively affect deglutition [14] . The normal swallow process includes three phases, an oral, pharyngeal and esophageal phase. Aging is often accompanied by reduced chewing functionality, a key component of the oral preparatory phase of the swallow. Impaired chewing jeopardizes the ability to safely form or move a bolus from the oral cavity to the esophagus (i.e. dysphagia) [7] . In turn, dysphagia contributes to frailty, aspiration pneumonia, malnutrition, and dehydration, ultimately increasing mortality [9] .

The prevalence of dysphagia increases in elderly individuals and it is disproportionately higher in nursing home residents [25] . Thus, prevalence rates of 44 % have been described in a geriatric acute care unit in Spain [6] and over 60% in people living in institutionalized settings in Taiwan [17] . However, prevalence data in the literature is highly variable as consequence, among others, of participant selection or assessment tools [reviewed in [2]]. To adequately address the impact of dysphagia in institutionalized elders it is of paramount importance to identify at-risk individuals. Several tools have been developed for the screening the risk of dysphagia and establishing a clinical diagnosis [reviewed in [22]]. Screening tools are basically questionnaires, such as the Eating Assessment Tool (EAT)-10, and the Sydney Swallowing Questionnaire (SSQ), while diagnosis tools such as the Volume-Viscosity Swallowing Test (V-VST) or videofluoroscopy evaluate the efficacy, and safety of the whole swallowing process. Despite its important repercussions few studies have evaluated the alteration of the oral phase, specifically the muscles involved in chewing process. Tongue muscle mass was reduced in patients with sarcopenic dysphagia [21] and geniohyoid muscle cross-sectional area was associated jaw-opening strength, and duration of swallowing sound

[1] . However, no study has investigated the association of the masseters muscles and dysphagia thus far.

The size of the masseter muscle can be determined by different imaging techniques such as magnetic resonance imaging (MRI), computerized axial tomography (CT) or ultrasound. As both MRI and CT present some problems of availability, cost portability and radiation (CT), ultrasound may be a suitable alternative.

The main objective of this study was to assess the relationship between the thickness of the masseter muscle measured by ultrasonography and the presence of dysphagia in a group of institutionalized elderly people. As a secondary objective, we aimed to establish cutoff points of masseters thickness to identify elderly individuals at risk of dysphagia.

Materials and methods

Study subjects

We performed a cross-sectional study of all residents from 3 nursing homes in Zaragoza (Spain) between February 2019 and August 2019. Of a total of 602 patients, 485 agreed to participate and, after applying the exclusion criteria, the final study population was 468 individuals. Those excluded had masseteric hypertrophy or bruxism (n=2), tumor interventions or mandibular surgeries (n=11), nasogastric tube (n=6), or severe intercurrent diseases (n=8). All participants, or their legal representatives, gave their informed consent to be included. The study protocol was approved by the management of the three geriatric centers and by the local ethical committee (Ethical Committee for Clinical Research of Aragon, CEIC-A, ref # C.P. - C.I. PI19 / 135).

Masseter muscle thickness measure

The ultrasonographic determinations were performed with the patient supine in a relaxed position. Subjects were instructed to maintain minimal interocclusal contact. Recordings were performed using a 7.5 MHz linear transducer connected to Edan DUS 60 ultrasound scanner (Edanusa, CA, USA).

The transducer was positioned perpendicular to the external edge of the muscle, between the intertragic fissure and the oral commissure, parallel to the Frankfort plane, exerting medium pressure and applying a generous layer of transducer gel. Measures were taken from the thickest area of the muscle approximately near the plane of occlusion. A line was drawn from the cortex of the mandibular ramus to the inner part of the fascia (Figure 1). 3 measurements for each masseter (left and right) were taken by the same observer at 5 minute intervals and the results averaged. The thickest side, either left or right, was reported as masseter thickness for each individual.

Dysphagia assessment

Patients, or their caregivers if needed, completed the Spanish- language validated version of the screening questionnaire EAT- 10 [5] . Scores of 3 or higher were consider abnormal and suggestive of dysphagia [4] .

The volume- viscosity swallow test (V- VST) was used to test the individuals' ability to swallow boluses of different volumes and viscosities as previously described [28] . Briefly, the V- VST was designed to identify clinical signs of impaired efficacy (labial seal, oral and pharyngeal residue, and piecemeal deglutition), as well as impaired safety of swallow (voice changes, cough and decrease in oxygen saturation ≥3%). Patients who had one or more signs of impaired efficacy and/or safety of swallow was considered as having dysphagia

Diet and dependency.

Diets habitually consumed by the patients were categorized by texture into regular diet, soft diet or smooth pureed, according to [8] . Patients were also screened using the mini-nutritional assessment (MNA) test [13] . Activities of daily living (ADL) were evaluated by the Barthel Index [19] , a higher number reflecting a greater ability to function independently.

Statistical analysis.

Chi-square and Student's t-test were used to compare categorical and continuous variables respectively. The association between continuous variables was tested by Pearson's correlation coefficient (r). Multivariate logistic regression was used to analyze the association of masseters thickness and dysphagia adjusted by confounding variables.

The areas under receiver operating characteristic (ROC) curves were computed with the trapezoidal rule. We then calculated the optimal cutoff points to identify individuals with dysphagia according to the Youden Index (the maximum sum of sensitivity and specificity). Data were analyzed using R version 3.1.3 (http://www.r-project.org) and the required packages. P values < 0.05 were considered significant.

RESULTS

Patient characteristics

A total of 469 elderly people (68.9% women) participated in this multicentric study. Subjects´ ages ranged from 61 to 108 years. No sex differences were observed in age or BMI (Table 2). The average measure performance in activities of daily living was 38 according to the Barthel Index indicating severe dependency. An even more reduced index in women reflected a greater inability to function independently in females compared to males. Women also scored lower on the MNA questionnaire and more women than men were found to experienced dysphagia according to both EAT-10 questionnaire and V-VST. Associated with this increased prevalence of dysphagia more women than men required modifications in their diets; an ~ 48 % of women had either soft or smooth pureed diets vs. ~36% of men. Overall, ~ 45% of our patients required texture-modified diet (29.4% pureed and 15.1% soft diet). Those prescribed texture-modified diet were more vulnerable and with high prevalence of dysphagia. Thus, 87% and 75% of those precising texture-modified diets had dysphagia according to V-VST or EAT-10 diagnoses respectively. In contrast, only 30% and 23% of individuals without special diets were diagnosed with dysphagia according to V-VST or EAT-10 respectively.

The masseter muscle thickness (MMT) measured by ultrasonography showed significant differences according to age and sex. Men had thicker both left (L) and right (R) masseters compared to women. Interestingly, significant differences were found between the left and right MMT in women ($p=0.045$) but not in men. For the sake of clarity, the thickest masseter will be used henceforth to represent MMT for each individual. A significant inverse correlation was found between age and MMT ($r= - 0.27$, $p<0.001$). Conversely, masseter thickness was positively associated with BMI ($r=0.52$, $p<0.001$), Barthel index ($r=0.75$, $p<0.001$), MNA score ($r=0.59$,

p<0.001) and the texture of the diets in the order of thicker muscles on regular diet > soft diet > pureed diet (Supplemental Table 1). Those associations occurred in both men and women.

Association of MMT with dysphagia

Next we investigated the association of the left and right MMT with the screening tool EAT-10 and the clinical bedside assessment method V-VST in the detection of dysphagia. According to the EAT-10 tool and compared to non-dysphagic individuals, the median MMT was reduced an ~19% in dysphagic females (5.52 vs 6.75 mm, p<0.001) and ~26% in males (5.52 vs 7.52 mm, p<0.001) (Figure 2A). When we used the V-VST as criterion of dysphagia the median R-MMT decreased an ~25% in dysphagic females (5.00 vs 6.71 mm, p<0.001) and ~28% in males (5.34 vs 7.44 mm, p<0.001) compared to their non-dysphagic counterparts (Figure 2B).

Subsequently, we tested the strength of the association of MMT with dysphagia by logistic regression. Unadjusted (raw) models showed that reduced odds for dysphagia were associated with increased masseter thickness (Table 2). Once the model was adjusted for age, sex, MNA score, and BMI our analyses indicated that each 1 mm increase in MMT reduced by ~21 % the risk of dysphagia according to the EAT-10 tool and by ~35 % using the V-VST.

Cutoff values of MMT for clinical evaluation of dysphagia.

We used receiver operative characteristics (ROC) analysis to examine the sensitivity and specificity of MMT to predict dysphagia, according to the EAT-10 screening tool and the diagnostic method V-VST. Figure 3 depicts ROC curves plotting the sensitivity and specificity for left and right masseters thickness and sex. The areas under the ROC curves (AUC-ROC) for the prediction of dysphagia based on the EAT-10 tool were 78.5 and 74.3% for men and women respectively (Fig.

3A). In a similar fashion AUC-ROCs according to V-VST were 84.0 and 80.4% for men and women respectively (Fig. 3B).

Lastly, we calculated the optimal cutoff points using the Youden Index (the maximum sum of sensitivity and specificity) to identify dysphagic individuals according to either EAT-10 or V-VST. Interestingly, identical cutoff points of appeared using both methods. The best predictive values for having dysphagia in women were 6.3 and 6.6 mm for women and men respectively..

DISCUSSION

In this study we observed a significant negative association between the thickness of masseter muscles and the presence of dysphagia. We also found that variations of MMT may be explained by differences on age, sex, type of diet, nutritional status (MNA), and BMI. Nevertheless, in our models, the relationship with dysphagia and MMT remained after adjusting these parameters.

In frail elderly people, oral phase dysfunction may produce inadequate bolus formation, oral transit time delay, and large amounts of residue in the oral cavity after swallowing, resulting in dysphagia [21] . Oral phase dysfunction is tightly dependent on the initial mastication process [24] and oral sensorimotor alterations were associated with dysphagia in long- term care older residents [27] . It is hence clear that a relationship does exist between mastication and dysphagia. Indeed, MMT has been already associated with chewing efficiency [20] suggesting that evaluating MMT may inform swallowing function and dysphagia in elder individuals.

Our data showed a somehow reduced thickness of the masseter than those found in previous studies. Multiple studies have analyzed the thickness of the masseter since the pioneering studies of Kiliaridis and Kälebo in 1991 [15] , Bakke et al in 1992 [3] , and Raadsheer et in 1994 [26] . However, many of them had a small sample size or were performed in young and healthy individuals. Recently Umeki et al [31] analyzed 774 participants with an average age of 73.5 years and a masseteric thickness of 11.4 mm. Another large study also in the Asian population conducted by Yamaguchi et al [33] including 139 participants with a mean age of 75 years and a masseter thickness of 11.6 mm. Although the last 2 studies were performed in older individuals they are not quite comparable with our population. Our participants had a mean age of 84.7 y and we,

and others, have observed a decrease in the thickness of the masseter muscle with age [3, 15, 26] . One of the main contributions of this study is the measurement of the masseter in a group of very aged institutionalized European population. An alternate explanation for the disparate MMT might be that our elders have a high a greater degree of impairment according to the Barthel index. This study has been carried out in Spanish public nursing homes, where a high level of dependence is required for admission. Dysphagia was negatively associated with Barthel Index in Japanese elderly people living at home and receiving home nursing care [11] . Our study may reflect those findings into European elderly individuals living in nursing homes with a high prevalence of dependence.

We also found a significantly higher MMT in men when compered to women, which is consistent with what was found in previous reports [3, 15, 26] . Likewise, we observed a direct association between BMI and MMT corroborating previous studies of Satiroğlu et al in Turkish population [29] and Umeki et al in elder Asian individuals [31] .

Differences in MMT were highly associated with the texture of the diet. Solid foods may be modified to compensate limitations in elderly patients with dysphagia [12] . Accordingly, the proportion of nursing home residents receiving those modified diets ranged between 26 and 67%, according to a 2017 review [23] . The severe dependency index observed in most of our patients may explain, at least partially, the high rates of dysphagia and their high use of texture-modified diets. It is worth noting that a diminished texture of the food may influence negatively the functional capacity of the masseter muscles. Thus, Shimizu et al [30] noted that texture-modified diets were associated with decreased skeletal muscle mass index and functional independence measure scores. Likewise, Yamaguchi et al [32] observed a relationship of skeletal muscle mass, and tooth loss with masseter muscle thickness. We posit that functional deterioration in geriatric

patients might create a vicious circle in which some patients with sarcopenic dysphagia receive a texture-modified diet that further worsens their oral swallowing phase.

Sarcopenic dysphagia might underlay the association between atrophy of the chewing muscles such as masseter and dysphagia [10]. This sarcopenic dysphagia is consequence of a decrease in generalized global muscle mass which ultimately causes reduced lingual strength and decreased mass of the masticatory muscles [16]. Studies in Japanese elders with similar age than our patients have reported reduced strength of the tongue in patients with dysphagia secondary to aging and sarcopenia [18, 34]. However, to the best of our knowledge, this is the first study in European population showing an association of dysphagia with reduced thickness of a key chewing muscle such as the masseters.

Diagnosis of dysphagia might be difficult in patients with severe dependency as they may not be able to answer questionnaires or undertake other diagnostic tests. Ultrasonographic evaluation of MMT can therefore become a valid surrogate marker of dysphagia. However, along with the development of the technology of MMT measurement it is also necessary to provide cutoff points for the diagnosis of dysphagia. ROC curves shown that MMT was highly specific for the diagnosis of dysphagia making this technique a suitable screening method for this condition. Similar high specificity and moderate sensitivity have been reported using the tongue muscle area to diagnose sarcopenic dysphagia in older individuals [21].

This study has some limitations. Because of its cross-sectional design we cannot establish a causal relationship between the decrease in the thickness of the masseter muscle and the diagnosis of dysphagia. Secondly, we have only investigated muscle thickness but not its functionality (chewing

strength). Future studies are hence warranted to establish and clarify the relationship between the thickness of the masseter muscle the presence of swallowing problems. Whether or not this tool will be useful beyond older institutionalized individuals with severe dependency remains to be tested too.

Despite these limitations, the measure of the masseter muscles is a simple, fast, and non-invasive procedure that can be useful for the assessment of the first phase of swallowing and the screening of dysphagia in institutionalized elders with a high degree of dependence. We conclude that the thickness of the masseter muscle in relaxation measured by ultrasonography is reduced in elderly individuals with dysphagia and can be useful to inform clinical decisions in geriatric settings.

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Statement of autorship.

AS-P, MG-F, EF-L, JP-N, AS-L, and ET-A designed the study and collected the data. AS-P, MG-F, and JMA-M analyzed the data. AS-P, MG-F, and JMA-M wrote the manuscript. All authors approved the final manuscript and take public responsibility for the content of the article.

Conflict of Interest Statement

The authors declare that they have no conflict of interest

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Table 1. Characteristics of the population according to the studied variables and sex.

variables	[ALL]	female	male	p
	N=469	*N=325*	*N=144*	
Age (years)	84.7 (7.68)	85.0 (7.62)	84.0 (7.79)	0.168
BMI (kg/m^2)	24.4 (5.79)	24.6 (6.29)	24.1 (4.45)	0.315
Barthel index	38.1 (33.3)	31.8 (30.7)	52.5 (34.4)	<0.001
MNA score	19.6 (5.02)	19.0 (4.95)	20.9 (4.93)	<0.001
Diet				0.025
Regular Diet	260 (55.4%)	168 (51.7%)	92 (63.9%)	
Soft Diet	71 (15.1%)	57 (17.5%)	14 (9.72%)	
Smooth pureed	138 (29.4%)	100 (30.8%)	38 (26.4%)	
R-MMT (mm)	6.33 (1.57)	6.07 (1.50)	6.90 (1.57)	<0.001
L-MMT (mm)	6.13 (1.51)	5.85 (1.42)	6.76 (1.53)	<0.001
max-MMT	6.47 (1.56)	6.21 (1.49)	7.06 (1.57)	<0.001
Dysphagia				
EAT-10	195 (41.6%)	148 (45.5%)	47 (32.6%)	0.012
V-VST	122 (26.0%)	94 (28.9%)	28 (19.4%)	0.041

BMI: Body mass index, MNA: Mini Nutritional Assessment, RMMT: Right masseter muscle thickness, LMMT: Left masseter muscle thickness, EAT-10: Eating assessment Tool-10. V-VST: Volume-viscosity swallow test, p: p-value for sex differences.

Continuous variables are expressed as mean (standard deviation)

Categorical data were expressed as the incidence (percentage)

Table 2. Masseter muscle thickness as predictive factors of dysphagia analyzed by logistic regression models.

Dysphagia	OR (raw)	OR (model1)	OR (model2)	OR (model3)
EAT-10	0.49 (0.41-0.57) p<0.001	0.49 (0.41-0.58) p<0.001	0.59 (0.48-0.71) p<0.001	0.79 (0.64-0.97) p=0.026
V-VST	0.38 (0.31-0.47) p<0.001	0.38 (0.30-0.47) p<0.001	0.48 (0.38-0.61) p<0.001	0.65 (0.50-0.84) p=0.001

Data are expressed as odds ratios (OR) and 95% confidence intervals. EAT-10: Eating assessment Tool-10. V-VST: Volume-viscosity swallow test.

Raw: unadjusted model

model 1: Model adjusted by age and sex

model 2: Model adjusted by age, sex, and body mass index.

model 3: Model adjusted by age, sex, body mass index, and MNA score.

Figure 1. Measure of masseter thickness in an ultrasonography image. Examples of different muscle thickness. Measures were taken in the thickest area of the muscle between the cortex of the mandibular ramus to the inner part of the fascia

Figure 2. Masseters thickness by sex and the presence of dysphagia according to the EAT-10 (A) or V-VST (B) tools.

Boxes represent interquartile ranges (between the 25th and 75th percentiles), whiskers represent the range, and lines within boxes represent the median.

*, $p < 0.001$

Figure 3. Receiver-operating characteristics (ROC) curves representing the discriminant performance of the masseters thickness for identifying dysphagia according to to the EAT-10 (A) or V-VST (B) tools. The cutoff points correspond to the best trade-off between specificity and sensitivity (in parentheses).

AUC: Area Under the Curve.

Figure 1

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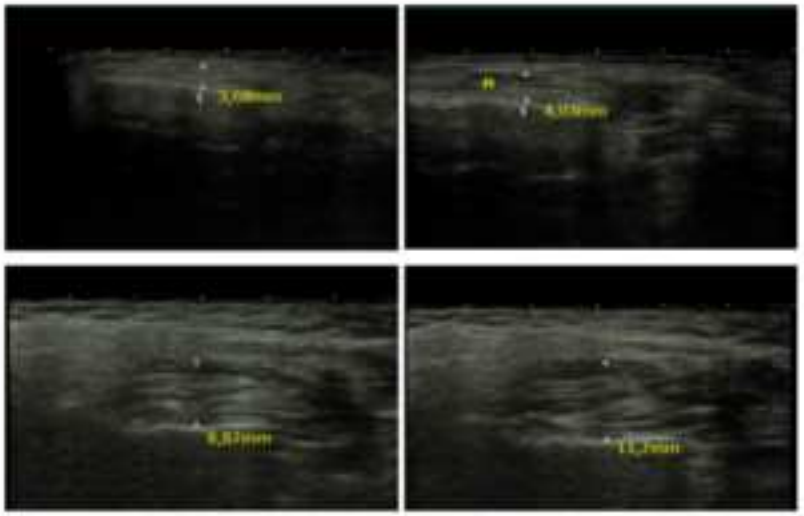

Figure 2

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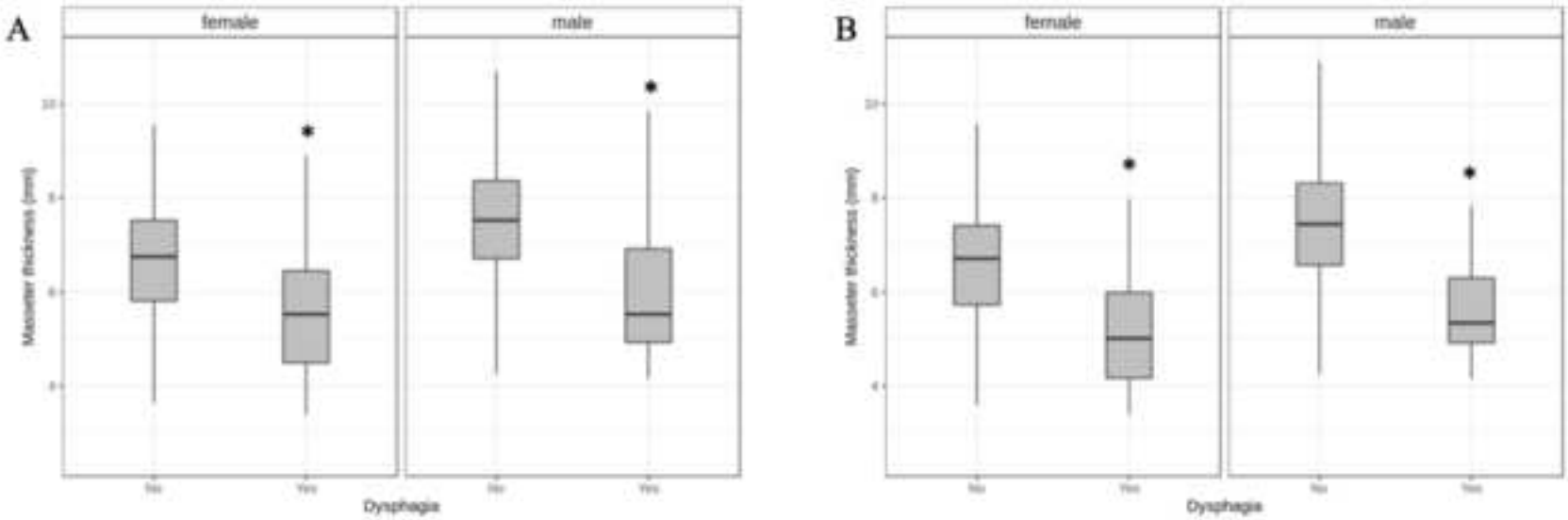

Figure 3

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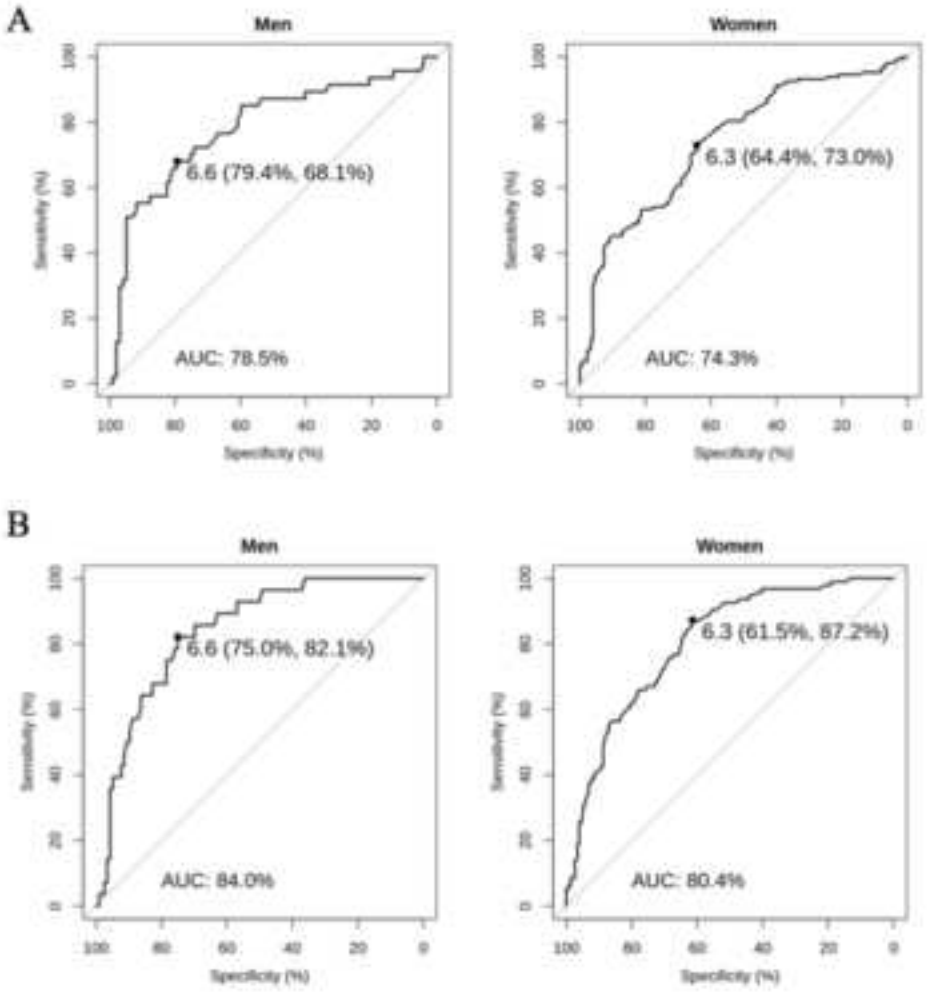

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