

Shear wave elastography of the submandibular gland in healthy individuals

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Abstract

Objectives: Shear wave elastography is a rapidly evolving new technique. The purpose of the present study was to determine the sonoelastographic features of the submandibular glands in healthy individuals.

Methods: We conducted a cross-sectional study of 45 healthy individuals, whose submandibular glands were studied using shear wave elastography. The stiffness of both submandibular glands was measured and its relationships with the age, sex, body mass, body mass index (BMI), and height of the participants were assessed.

Results: The participants had a mean age of 31.82 ± 5.53 years, a mean height of 158.30 ± 7.16 cm, a mean body mass of 57.83 ± 8.84 kg, and a mean BMI of 22.99 ± 2.72 kg/m². The mean shear elastic modulus of the right and left submandibular glands were 18.02 kPa and 19.09 kPa, respectively. Positive correlations were found between the elasticity of the right submandibular gland and the anthropometric parameters.

Conclusion: The elastic modulus of the submandibular glands has been determined in healthy individuals and the data generated can serve as a reference for future studies of pathological conditions of these structures.

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Keywords

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Introduction

The submandibular glands (SMG) are major salivary glands that produce saliva, a watery fluid that contributes to various phases of digestion and contains antibacterial substances that serve as a first-line of defense against infection. Diseases affecting the SMGs range from minor inflammatory diseases to benign and malignant neoplasms. Inflammation is a common factor in several important SMG disorders, such as sialadenitis, sialolithiasis, and autoimmune disorders, including Sjogren's disease.¹ During the last 20 years, the surgical treatment of some SMG pathologies has evolved towards gland preservation. Although imaging of the SMGs using computed tomography and magnetic resonance imaging is useful, there is a need for a dynamic real-time tool for the localization of some tumors.² Because of its anatomical location, the SMGs are readily amenable to ultrasonographic examination, which represents a cheap, portable, non-invasive, and well-established means of diagnosing and monitoring the therapy of SMG pathologies. In addition, ultrasonography can be used to guide needle biopsies and for therapeutic aspiration.³

Shear wave elastography (SWE) is a modern, rapidly growing imaging tool that measures the degree of deformation of the underlying tissues and provides complementary information regarding tissue elasticity to that obtained using conventional ultrasonography.¹ This is achieved by the emission of several pulses from a transducer and the measurement of the velocity of the

shear waves, which is used to estimate the degree of tissue stiffness, in kilopascals, using the Young modulus formula. The main advantages of SWE are its reproducibility, operator-independence, semi-quantitative output, and utility for the qualitative evaluation of tissue elasticity in the absence of manual compression artefacts. Its principal disadvantage is that the pressure applied to the tissue of interest by the operator's hand can alter its elasticity, which can result in some inaccuracy. A second type of elastography, strain-type elastography, involves the application of gentle pressure, making it operator-dependent, and yields semi-quantitative and qualitative stiffness estimates.⁴⁻⁶ SWE is also used for the morphological assessment of the liver, breasts, thyroid gland, and musculoskeletal system.⁷ We believe that the proper application of this method requires knowledge of normal values, to permit the setting of cut-off limits for the accurate discrimination of abnormal stiffness values. Most of the published studies have generated normative SMG elastography data in healthy participants as part of an assessment of all the soft tissues of the neck. However, in the present study, we aimed to characterize the sonoelastographic features of the SMGs alone.

Methods*Participants*

We conducted a cross-sectional study that was approved by the institutional review

board of Prince Sattam bin Abdulaziz University (PSAU/COM/RC/IRB/p/69). Healthy adults were recruited at a university hospital between March and April 2020, from whom written informed consent was obtained. The inclusion criteria were that the participants were healthy and between 24 and 49 years old. The exclusion criteria were neck surgery, sialadenitis, sialolithiasis, and having undergone head or neck irradiation. The sex, age, body mass, body mass index (BMI), and height of each of the participants were recorded.

Technique. Both SMGs were examined using an L18-4, MHZ linear-array transducer and an EPIQ Elite SW 5.0.1 ultrasound system (Philips, Bothell, WA, USA). Each gland was examined three times by two radiologists with 10 years' experience of ultrasonography. The participants were scanned in the supine position with their neck extended and their head tilted in the opposite direction to the ultrasonographer. Each participant was scanned three times, with the probe being removed from the skin between

measurements, to assess intra-observer repeatability. A thick layer of gel was used and minimal pressure was applied using the transducer, to minimize the induction of artifacts. To increase the reliability of the stiffness values obtained, a confidence map was used to mask areas with values below a defined confidence level. After identifying an SMG, the “elasto” mode was activated and the probe was held stationary for 5 s, with a 2-mm diameter region of interest (ROI) circle placed 5 mm from the upper surface of the gland. After viewing the color map, real-time shear wave images were recorded, with color coding. The values obtained were the median elasticity (MED), maximum elasticity (MAX), and average elasticity (AVG), which were recorded in kilopascals. The color scale was mapped to a range of 0 kPa to 200 kPa, and the spectrum of colors used ranged from blue for softer tissues to red for stiffer tissues (Figure 1).

Statistical analysis. Statistical analysis was performed using Statistical Package for

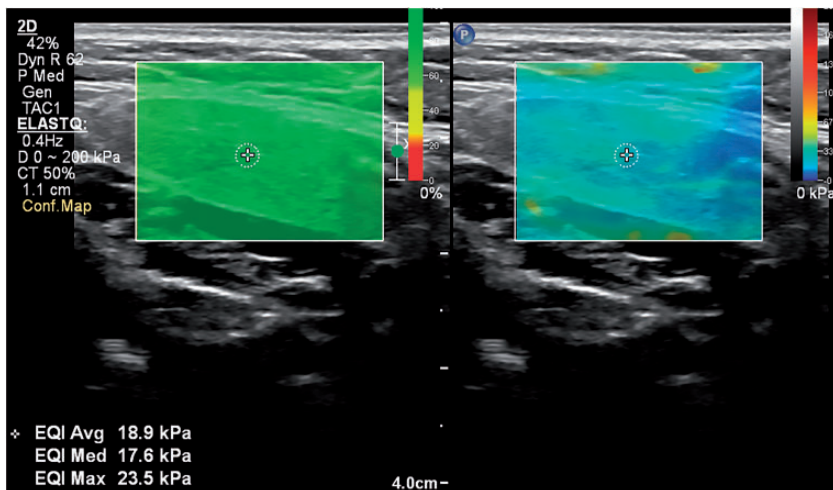


Figure 1. Shear wave elastography of the right submandibular gland. A confidence map is shown on the left and a color map on the right, in which blue indicates softness and red firmness of each part of the gland. The stiffness of the gland was measured in kPa.

the Social Sciences version 21 software (IBM, Inc., Armonk, NY, USA). A sample size of 40 was calculated to be required. The data are presented as mean \pm standard deviation (SD) and range. The independent sample *t*-test was used to assess the difference between the mean elasticity of the right and left SMGs. The relationships between the mean elasticity of the two glands and the age, height, body mass, and BMI of the participants were assessed using Pearson's correlation coefficients.

Results

We examined 90 submandibular glands in 45 healthy adult participants (38 women and 7 men) with a mean age of 31.82 ± 5.53 years (range 24 to 49 years), a mean height of 158.30 ± 7.16 cm (range 144 to 178 cm), a mean body mass of 57.83 ± 8.84 kg (range 43 to 84 kg), and a mean BMI of 22.99 ± 2.72 kg/m² (range 18.50 to 30.90 kg/m²). The intra-observer reliability calculation yielded an overall intra-class correlation coefficient of 0.82. The mean shear elastic moduli of the right and left SMG glands were 18.02 ± 6.65 kPa (range 9.19 to 32.93 kPa) and 19.09 ± 5.65 kPa (range 9.82 to 31.50 kPa), respectively, which were not significantly different. In addition, there were no significant differences in elasticity between the sexes. With the exception of a positive correlation between

SMG elasticity and BMI ($p > 0.05$), there were no correlations between anthropometric parameters and the elasticity of either gland (Table 1). Example ultrasonographic images of an SMG are shown in Figure 1.

Discussion

We studied the SMGs of healthy participants using quantitative SWE and evaluated the relationships of elasticity with height, body mass, BMI, and sex. During the last 10 years, several studies have evaluated the use of SWE for the assessment of salivary gland pathology, on the basis that both neoplastic and inflammatory lesions cause changes in their stiffness.⁸ The results of these studies suggested that malignant neoplasms are stiffer than benign neoplasms³ and that the salivary glands of patients with Sjogren's syndrome and other chronic inflammatory disorders are stiffer than those of healthy patients.^{1,3,9}

There are several potential confounding factors to be considered when performing SWE of the salivary glands. First, they are in close proximity to the skin and subcutaneous tissues, which permits the transfer of local stress artifacts to the salivary glands, and second, their close proximity to bones may result in stress inhomogeneity.¹⁰ Arslan *et al.*¹¹ reported stiffnesses of 18.3 ± 3.9 kPa and 17.1 ± 3.7 , respectively, for the right and left SMGs, which were

Table 1. Correlation analysis of the relationships between anthropometric parameters and the elasticity of the submandibular glands

Parameter	Right SMG		Left SMG	
	<i>P</i>	Coefficient	<i>P</i>	Coefficient
Age	0.906	0.018	0.896	-0.020
Body mass/kg	0.334	0.147	0.577	0.085
Height/cm	0.151	-0.218	0.994	0.001
BMI	0.038	0.311*	0.579	0.085

*Correlation is significant at the 0.05 level (2-tailed).
SMG = submandibular gland; BMI = body mass index.

similar to the values obtained in the present study (18.02 ± 6.65 kPa and 19.09 ± 5.65 kPa, respectively). However, in three other studies, lower stiffness values were obtained: Herman *et al.*⁸ obtained 11.0 ± 3.4 kPa, Arda *et al.* obtained 10.92 ± 3.1 kPa in men and 11.9 ± 3.1 kPa in women, and Bhatia *et al.*^{3,12} obtained a value of 11.3 kPa. In addition, two other studies reported slightly higher values: Elbeblawy *et al.* obtained a value of 12.2 kPa and Ogura *et al.*^{1,13} obtained values of 12.4 ± 4.2 kPa in men and 13.8 ± 5.1 kPa in women. Finally, Kaluzny *et al.*¹⁴ obtained substantially higher values, recording a mean elasticity of 22.4 kPa.

We found no relationship between SMG elasticity and sex, which is consistent with the findings of previous studies.^{8,12,15} With respect to laterality, Herman *et al.*⁸ found that the right SMG had a higher mean stiffness than the left SMG, which was explained by the ultrasonographer being on the right side of the participants during the examination. In contrast, in the present study, there was no difference between the stiffness of the glands, which is consistent with the findings of Mantsopoulos *et al.* and Badea *et al.*^{15–17} There were no correlations between anthropometric parameters and the shear moduli of the SMGs in the present study, except for BMI, which positively correlated with the shear modulus of the right SMG.

The differences in the stiffness values obtained in the present and previous studies may be explained by several factors. For example, differing equipment may yield different values, the elasticity values for the same organ may vary with BMI or age,¹⁸ and different populations may have SMGs of differing stiffness. It has been suggested that the stiffness of the central and peripheral parts of the glands differs, although one previous study did not identify such a difference.¹⁶ With respect to the stiffness of pathological SMGs, some previous studies have shown slight increases in stiffness in the presence of chronic inflammation. Benign lesions have

been shown to have variable increases in elasticity, and this wide range of stiffness values renders SWE of limited use for the assessment of benign SMG lesions.^{6,31} However, malignant neoplasms are associated with significant increases in gland stiffness, as demonstrated by Wierzebecka *et al.*,¹⁹ who reported a mean stiffness for benign tumors of 88.7 ± 48 kPa and a mean stiffness for malignant tumors of 146.3 ± 104.7 kPa.

The present study had several limitations. First, the small sample size reduces the accuracy of the elasticity data. Second, the sample contained a large majority of women. Third, we did not measure the elasticity of pathological SMGs. Finally, the diameter of the ROI used for the measurements was only 2 mm. Therefore, further larger studies should be conducted that include participants with a range of pathologies, to increase the validity of the measurements.

Conclusion

We believe that the SMG stiffness data obtained in the present study provide a reference for the evaluation of stiffness in future studies of patients with gland pathologies.

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Author contributions

MB designed the study, conducted the literature search, and was the major contributor to the drafting, writing, and editing of the manuscript. AS, EN, HE, and AB assisted with the interpretation of the data. AA, KM, and SS participated in the study design. RH supervised the study. All the authors read and approved the final version of the manuscript.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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