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Measurement of the Thickness of Submental Muscles by Ultrasonography in Healthy Children

ABSTRACT

Background: Submental muscles are vital for swallowing as they are responsible for hyolaryngeal elevation. This study aimed to determine the normative values of submental muscles in healthy children.

Methods: The thickness of the digastric muscle, the thickness of the mylohyoid muscle, and the thickness of the geniohyoid muscle were measured in 218 (124 boys and 94 girls) healthy children by the ultrasonography. Correlation analysis of the thickness of the digastric muscle, the thickness of the mylohyoid muscle, and the thickness of the geniohyoid muscle with gender, age, height, weight, and body mass index were performed, and median values were determined in preschool, school, and adolescent age groups.

Results: No significant differences were found in median height, weight, body mass index, the thickness of the digastric muscle, the thickness of the mylohyoid muscle, and the thickness of the geniohyoid muscle values of the males and females ($P > .05$). There were highly significant mild to moderate positive correlations of age, height, weight, and body mass index with the thickness of the digastric muscle, the thickness of the mylohyoid muscle, and the thickness of the geniohyoid muscle parameters ($P = .001$, $r = 0.26$-0.58). The thickness of the digastric muscle was 4.3 mm, 4.5 mm, and 5.4 mm in the preschool, school, and adolescent groups, respectively. In the preschool, school, and adolescent groups, the thickness of the geniohyoid muscle was 4.8 mm, 5.35 mm, and 6.25 mm, respectively. The thickness of the mylohyoid muscle was found as 1.6 mm, 1.9 mm, and 2.3 mm in preschool, school, and adolescent groups, respectively.

Conclusion: Submental muscles that perform hyolaryngeal elevation can be easily evaluated with the ultrasonography. Knowing the normative thickness values of submental muscles according to age groups in children will contribute to the diagnosis of atrophy or hypertrophy in these muscles. It can also be used in the follow-up of dysphagia treatment.

Keywords: Children, dysphagia, submental muscles, swallowing, ultrasonography

INTRODUCTION

Dysphagia is a clinical condition that defines swallowing difficulty, which causes extensive morbidity ranging from dehydration and malnutrition to recurrent pneumonia. It is estimated that dysphagia or swallowing difficulty in adults is present in about 40% of individuals; this rate increases to 64% in patients with stroke.[1] In adults, the cause may be congenital, as well as acquired disorders such as stroke, head and neck cancer, traumatic brain injury, and neurodegenerative diseases.[2] Infants and children experience swallowing problems due to behavioral, developmental, or neurological conditions, respiratory problems, gastroesophageal reflux, cleft lip, or palate.[3] Advances in medical technology have led to an increase in the survival of infants born prematurely or with low birth weight. These children often present with dysphagia due to either undeveloped sensorimotor swallowing mechanisms or common comorbidities associated with prematurity.[4] Children with cerebral palsy often present with dysphagia, as neurological disorders that occur due to abnormal prenatal brain development or birth trauma affect swallowing function.[5] Swallowing disorder symptoms in children may not be as pronounced as in adults. It may occur with symptoms such as projectile vomiting, choking, coughing, reluctance to suck or eat or

Emine Uysal[1]
Mehmet Öztürk[2]
Zuhal Bayramoğlu[3]
Mustafa Yasir Özlü[1]
Ömer Erdur[4]

[1]Department of Radiology, Selcuk University Faculty of Medicine, Alaeddin Keykubat Yerleşkesi Akademi, Konya, Turkey
[2]Divison of Pediatric Radiology, Department of Radiology, Selcuk University Faculty of Medicine, Alaeddin Keykubat Yerleşkesi, Konya, Turkey
[3]Department of Pediatric Radiology, Istanbul Faculty of Medicine, Istanbul, Turkey
[4]Department of Otorhinolaryngology, Selcuk University Faculty of Medicine Alaeddin Keykubat Yerleşkesi, Konya, Turkey

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Corresponding author:
Emine Uysal
Email: *druysalemine@gmail.com*
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present as silent aspiration without any symptoms. The risk of pneumonia increases 13 times in children with silent aspiration.[3]

Dysphagia is frequently seen in neuromuscular diseases due to mouth muscle weakness.[6] Several oral muscles play a role in the swallowing process. The tongue plays a role in creating a nutrient bolus and transporting the bolus to the pharynx.[7] The mylohyoid, digastric, and geniohyoid muscles (submental muscles) allow the hyoid to be displaced to the anterosuperior position during swallowing.[8] This movement allows the larynx to move up and forward to protect the airway and open the upper esophageal sphincter while swallowing.[9] As a result of hyolaryngeal elevation, the epiglottis tilts biomechanically to aid airway protection, and the upper esophageal sphincter opens and allows bolus transfer from the pharynx to the esophagus.[10,11] The contribution of epiglottic deflection to airway protection and the critical role of the upper esophageal sphincter in bolus transfer is compromised when hyolaryngeal elevation decreases.[12] Biomechanical events based on hyolaryngeal elevation make submental muscles a common target for many swallowing therapy techniques.[13,14]

The most commonly used methods to evaluate swallowing function are the fiberoptic endoscopic evaluation of swallowing (FEES) and videofluoroscopic swallowing study (VFSS).[15] However, exposure to radiation during the examination and the need to transport patients for the examination often limits the use of VFSS.[16] FEES does not contain radiation and is portable; however, it is less quantitative and invasive.[17] Ultrasonography (US) can be used to examine food movement during swallowing and morphometric examination of swallowing muscles. Compared to VFSS and FEES methods, the advantages of the US are that it does not contain radiation, is non-invasive, and is portable. Also, it is possible to use real food while evaluating swallowing function with the US. With these advantages, the US can be used as an ideal tool in diagnosing and following up patients with dysphagia.[15] The US has been used to examine tongue, larynx, and hyoid bone movement in studies conducted to date.[18-20]

The mylohyoid, digastric, and geniohyoid muscles (submental muscles) are responsible for hyolaryngeal elevation, which protects the airway and allows the upper esophageal sphincter to open.[9] Any deterioration or delay in this process causes aspiration.[21] For this reason, many swallowing therapy methods aim to strengthen the submental muscles.[13,14] With the US, these muscles can be easily visualized, and their thickness can be measured. However, very few studies evaluate mylohyoid, digastric, and geniohyoid muscles with the US, especially in children.[9] We did not find a study demonstrating the average thickness of the mylohyoid, digastric, and geniohyoid muscles in healthy children. Determining the normal thickness values of these muscles may help diagnose dysphagia due to submental muscle weakness. Normative thickness values can also be used to evaluate treatment response after swallowing therapy in children with dysphagia. This study aimed to determine the mean thickness values of mylohyoid, digastric, and geniohyoid muscles in healthy children. The relationship between muscle thickness and gender, age, weight, height, and body mass index (BMI) will also be evaluated.

MAIN POINTS

- The submental muscles are responsible for hyolaryngeal elevation, which protects the airway and allows the upper esophageal sphincter to open.
- TDGM, TMHM, and TGHM values do not differ between genders in healthy children.
- There is a significant positive correlation between TDGM, TMHM, and TGHM values with age, height, weight, and BMI in healthy children.

METHODS

Study Design and Patients

Approval was obtained from the Ethics Commitee of Selcuk University Faculty of Medicine ethics committee for this prospective study (Document date-number: 19.02.2020-2020/76). Written informed consent was obtained from the parents of all participants. Two hundred eighteen children (124 boys and 94 girls) who applied to the healthy pediatric outpatient clinic from April 2020 to August 2020 were included in the study. The subjects had no history of dysphagia or any illness that could affect swallowing. Also, participants were examined by a clinician experienced in evaluating swallowing function to confirm that there was no anatomical or functional pathology. Exclusion criteria were a history of disease that could affect swallowing function, abnormal findings of the swallowing examination, and abnormal US findings in the submental region. Participants with heterogeneity and solid or cystic lesions of the muscle's parenchyma were not included in the study. Children under 3 years were not included in the study since they would not stand still during the examination. Age, gender, height, and weight of the children were noted before the US examinations. BMI was calculated using BMI = weight (kg)/height (m)^2. The subjects were arranged into 3 subgroups by age as 3-6 years (preschool, n = 78), 7-12 years (school age, n = 90), and 13-17 years (adolescent, n = 50).

Ultrasound Technique

The US examinations were carried out using an Aplio 500 US system (Canon Medical System Corporation, Tustin, Calif, USA) equipped with a 10-MHz linear array transducer by an experienced pediatric radiologist. All US examinations were performed in the supine position with the comfortable, standard head and neck posture. During the examination, the participants were asked to keep their mouths closed. The gain, focal zone, pulse repetition frequency, and wall filter were set to acquire each participant's optimal image. The mylohyoid, digastric, and geniohyoid muscles with homogeneous echotexture without solid or cystic lesions were defined as normal. The thickness of the digastric muscle (TDGM) was measured from the upper to the lower boundary of the fascia at the thickest location of the right and left anterior bells. The average of the 2 values obtained for each participant was calculated and recorded as TDGM. The thickness of the mylohyoid muscle (TMHM) was measured from the upper to the lower border of the fascia, below the digastric muscle's measurement point on the right and left sides. The average of the 2 values obtained was calculated and recorded as TMHM. The thickness of the geniohyoid muscle (TGHM) was measured between the lower and upper border of the fascia at its widest location in the middle part (Figure 1).

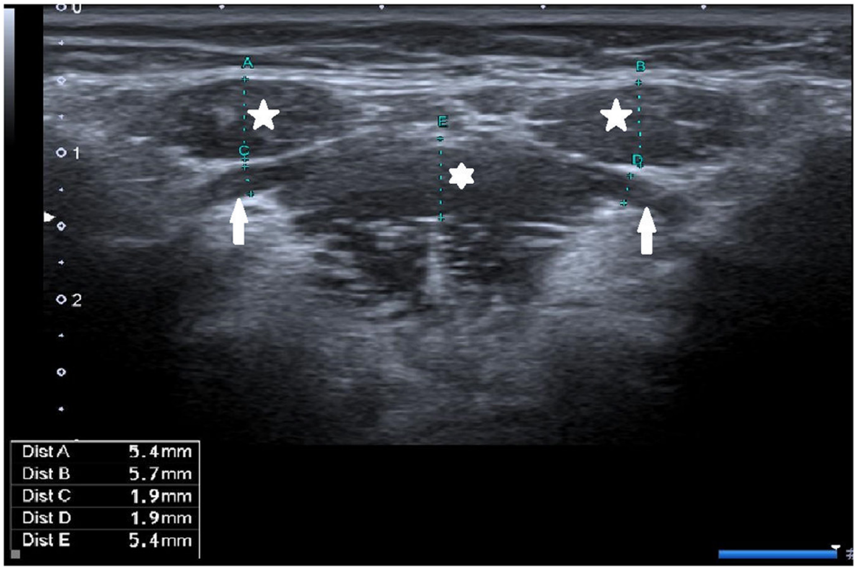

Figure 1. The grayscale ultrasonography image shows the thickness measurement of the submental muscles in a 13-year-old healthy child.
Five-pointed stars, digastric muscles; arrows, mylohyoid muscles; hexagram, geniohyoid muscle.

Statistical Analysis

All data were processed in Microsoft Office Excel and transferred to Statistical Package for the Social Sciences (SPSS) version 21.0 (IBM SPSS Corp.; Armonk, NY, USA) for statistical analysis. The distribution of the data was assessed with the Kolmogorov-Smirnov test paying attention to the skewness and kurtosis. Descriptive statistics of the data were expressed as median with interquartile range (IQR). Differences between median values of age, height, weight, BMI, and TDGM, TMHM, TGHM parameters among the gender groups were compared using the Mann-Whitney *U* test. Differences between median values of age, height, weight, BMI, and TDGM, TMHM, TGHM parameters among the 3 age groups were compared using the Kruskal-Wallis test. Correlation analysis of the age, height, weight, BMI with TDGM, TMHM, and TGHM parameters were tested with Spearman's correlation analysis. The scattered dot graphics were plotted for correlation of age with TDGM, TMHM, TGHM parameters (Figure 2). Variables were studied at the 95% CI with $P < .05$ accepted as statistically significant.

RESULTS

Descriptive statistics of the age, height, weight, BMI, TDGM, TMHM, and TGHM parameters in gender are given in Table 1. The median age value was significantly higher in girls compared to boys ($P = .042$). The median values of TDGM, TGHM, and TMHM in girls were 4.57 mm, 5.35 mm, and 1.95 mm, respectively, while in boys, it was 4.6 mm, 5.4 mm, and 1.9 mm, respectively. No significant differences were found in median height, weight, BMI, TDGM, TMHM, and TGHM values of the males and females ($P > .05$). Descriptive statistics of the height, weight, BMI, TDGM, TGHM, and TMHM parameters by age groups are shown in Table 2. There were statistically significant differences in median values of height, weight, and BMI between each age group comparisons. The median height, weight, and BMI values increase by age. The thickness of the digastric muscle was 4.3 mm, 4.5 mm, and 5.4 mm in the preschool, school, and adolescent groups, respectively. In the preschool, school, and adolescent groups, TGHM was 4.8 mm, 5.35 mm, and 6.25 mm, respectively. TMHM was found as 1.6 mm, 1.9 mm, and 2.3 mm in preschool, school, and adolescent groups, respectively. There were statistically significant differences in median values of TDGM, TMHM, and TGHM between each age group comparison. Median TDGM, TMHM, and TGHM values increase by age.

Correlation analysis of age, height, weight, and BMI values with TDGM, TMHM, and TGHM parameters are given in Table 3. There were highly significant mild to moderate positive correlations of age, height, weight, and BMI with TDGM, TMHM, and TGHM parameters ($P = .001$, $r = 0.26$-0.58). Figure 2 shows the correlation between TDGM, TMHM, and TGHM parameters with age. There were highly significant mild to moderate positive correlations of TDGM with TGHM ($P = .001$, $r = 0.42$), TGHM with TDGM and TMHM ($P = .001$, $r = 0.37$-0.42), and TMHM with TGHM parameters ($P = .001$, $r = 0.36$).

DISCUSSION

The incidence of dysphagia in children has been increasing in recent years.[4,22] Early treatment of dysphagia can reduce medical problems caused by aspiration pneumonia, malnutrition, and dehydration.[23] Therefore, early detection of dysphagia is essential for the success of the treatment. Videofluoroscopic swallowing study and FEES used in the diagnosis of dysphagia are methods that are difficult to apply in children and require special equipment.[17,23] The US is another objective diagnosis method that is relatively easy to apply. The advantages of the US are that it can be applied to bedridden patients and does not contain radiation.[24] Many studies indicate that the US can be used to evaluate swallowing function.[18-20,24,25] Lee et al[23] showed that hyoid bone displacement measured by the US showed a statistically significant correlation with VFSS findings. Therefore,

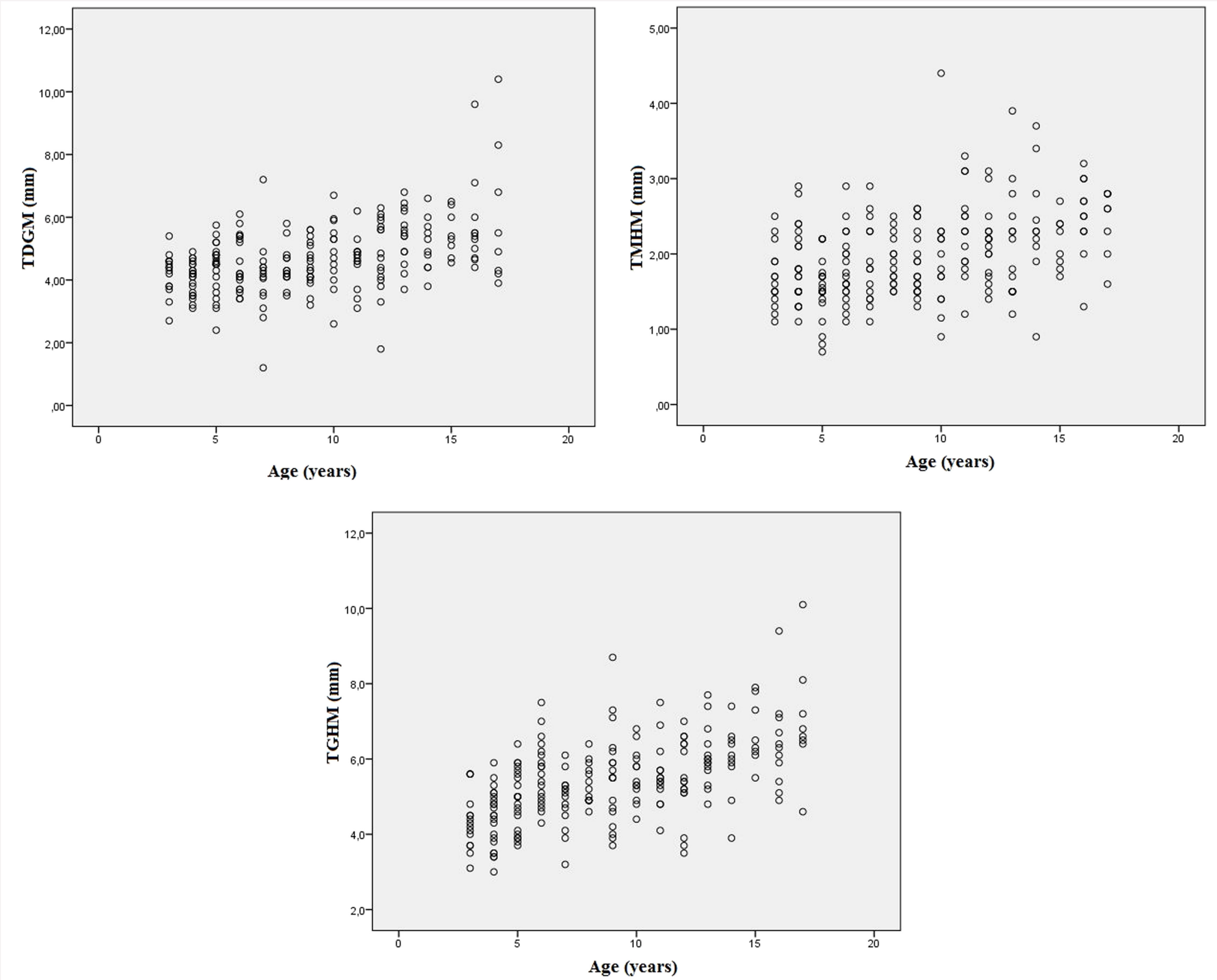

Figure 2. Scattered dot plots show the correlation of age with TDGM, TMHM, and TGHM.
TDGM, thickness of the digastric muscle, TMHM, thickness of the mylohyoid muscle; TGHM, thickness of the geniohyoid muscle.

Table 1. Descriptive Statistics of Age, Height, Weight, BMI, and TDGM, TGHM, TMHM Parameters by Gender Groups

	Descriptive Statistics			
	Median (Interquartile Range)			
Parameter	**Girls (n = 94)**	**Boys (n = 124)**	**All (n = 218)**	***P***
Age (years)	9 (6-13)	8 (5-12)	9 (5-12)	.042
Height (cm)	135.5 (120.7-158)	126.5 (110-155)	132 (115-156)	.17
Weight (kg)	31 (22-50)	26 (19.25-46.75)	29 (20-47)	.27
BMI (kg/m²)	17.53 (15.15-20.46)	17 (14.96-19.54)	17.35 (15.11-20.29)	.76
TDGM (mm)	4.57 (4-5.3)	4.6 (4.1-5.37)	4.6 (4.1-5.3)	.51
TGHM (mm)	5.35 (4.6-6.1)	5.4 (4.8-6.1)	5.4 (4.7-6.1)	.6
TMHM (mm)	1.95 (1.5-2.3)	1.9 (1.5-2.3)	1.9 (1.5-2.3)	.84

P values by the Mann-Whitney *U* test.
BMI, body mass index; TDGM, the thickness of the digastric muscle; TGHM, the thickness of the geniohyoid muscle; TMHM, the thickness of the mylohyoid muscle.

Table 2. Descriptive Statistics of Height, Weight, Body Mass Index, and TDGM, TGHM, TMHM Parameters by Age Groups

	Group 1 3-6 years (n = 78), Median (IQR)	Group 2 7-12 years (n = 90), Median (IQR)	Group 3 13-17 years (n = 50), Median (IQR)	*P*	
Height (cm)	110 (104-118)	137 (126.75-150)	162.5 (157.75-168)	**.001***	**1 vs. 2: .001′**
					1 vs. 3: .001′
					2 vs. 3: .001′
Weight (kg)	18.5 (16-22)	32.5 (26-42)	53 (47-65)	**.001***	**1 vs. 2: .001′**
					1 vs. 3: .001′
					2 vs. 3: .001′
BMI (kg/m^2)	15.19 (14.08-17.35)	17.36 (15.49-18.71)	20.63 (18.23-23.18)	**.001***	**1 vs. 2: .001**
					1 vs. 3: .001
					2 vs. 3: .001
TDGM (mm)	4.3 (3.77-4.7)	4.5 (4.08-5.22)	5.4 (4.6-8.6)	**.001***	**1 vs. 2: .046′**
					1 vs. 3: .001′
					2 vs. 3: .001
TGHM (mm)	4.8 (4.1-5.6)	5.35 (4.9-5.92)	6.25 (5.8-6.8)	**.001***	**1 vs. 2: .001′**
					1 vs. 3: .001′
					2 vs. 3: .001′
TMHM (mm)	1.6 (1.5-2.02)	1.9 (1.6-2.3)	2.3 (1.87-2.72)	**.001***	**1 vs. 2: .001′**
					1 vs. 3: .001′
					2 vs. 3: .001′

**P* values by the Kruskal-Wallis. ′*P* values by Mann-Whitney *U* tests. Bolded *P* values represent statistically significant results.
IQR, interquartile range; TDGM, the thickness of the digastric muscle; TGHM, the thickness of the geniohyoid muscle; TMHM, the thickness of the mylohyoid muscle.

they suggested that the US could be a helpful screening tool for patients with dysphagia.

The movement of the hyoid bone supplied by the suprahyoid and infrahyoid muscles plays a vital role in swallowing. In particular, the digastric, geniohyoid, and mylohyoid muscles help elevate the hyoid bone and open the upper esophageal sphincter during swallowing.[26] Since these muscles' functions are necessary for normal swallowing, knowing the muscles' average thickness values will help reveal pathologies such as atrophy and hypertrophy. In the current study, the thickness of these muscles was measured in healthy children, and it was revealed that muscle thickness was positively correlated with age, height, weight, and BMI. The thickness of the digastric muscle was 4.3 mm, 4.5 mm, and 5.4 mm in the preschool, school, and adolescent groups, respectively. Van Den Engel-Hoek et al[9] reported the digastric muscle thickness as an average of 6.3 mm in healthy children and young adults. The authors included 53 healthy individuals aged 5-30 years. The higher mean value of digastric muscle thickness in the higher age group compared to our study confirms the correlation of TDGM with age.

Table 3. Correlation Results of the Auxological Parameters with TGHM, TDGM, and TMHM Values

	TGHM		TDGM		TMHM	
	P	*r*	*P*	*r*	*P*	*r*
Age	**.001**	**0.56**	**.001**	**0.44**	**.001**	**0.41**
Height	**.001**	**0.55**	**.001**	**0.48**	**.001**	**0.38**
Weight	**.001**	**0.58**	**.001**	**0.55**	**.001**	**0.37**
BMI	**.001**	**0.5**	**.001**	**0.51**	**.001**	**0.26**

P values by Spearman's correlation analysis. Bolded *P* values represent statistically significant results.
BMI, body mass index; TDGM, the thickness of the digastric muscle; TGHM, the thickness of the geniohyoid muscle; TMHM, the thickness of the mylohyoid muscle.

In a study evaluating the movement of the geniohyoid muscle during swallowing in healthy adults, it was reported that the range of motion of the muscle and the duration of movement during swallowing significantly differed between men and women.[27] In this study, the authors did not provide any information about geniohyoid muscle thickness. Our study revealed that thicknesses of digastric, geniohyoid, and mylohyoid muscle do not differ between genders in children. In a thesis study, TDGM, TMHM, and TGHM values of 25 children with dysphagia were measured by the US before and after swallowing therapy and were significantly higher after therapy.[28] In this study, it was reported that the degree of hyoid elevation increased significantly after swallowing therapy compared to pre-therapy. As a result of their studies, the authors stated that the US could be used to measure submental muscle thickness and hyoid elevation in the evaluation of swallowing function.

We think that knowing the normative values of TDGM, TGHM, and TMHM according to age groups in healthy children will be helpful for dysphagia screening with the US. Therefore, in our study, it was aimed to measure the digastric, mylohyoid, and geniohyoid muscle thicknesses in healthy children and to reveal the average thickness values of these muscles for preschool, school, and adolescent age groups. In children with dysphagia, measuring these muscle thicknesses and comparing them with average values for age may help reveal the etiology of dysphagia. Additionally, it can be used to evaluate treatment efficacy in children receiving swallowing therapy.

The first of the limitations of the study is the limited number of participants. Second, children under the age of 3 were not included in the study, as they may not be immobilized during the US examination. Finally, since a single radiologist carries out the measurements, the inter-observer correlation cannot be evaluated.

The US is a portable, radiation-free, non-invasive, and relatively cheap tool to evaluate swallowing function. Another advantage is that the US is an easily tolerated method for children. Submental muscles that perform hyoid elevation can be easily evaluated with the US. Knowing the normative thickness values of submental muscles according to age groups in children will contribute to the diagnosis of atrophy or hypertrophy in these muscles. It can also be used in the follow-up of dysphagia treatment.

Ethics Committee Approval: Ethics committee approval was received from the Ethics Committee of Selcuk University Faculty of Medicine (Document date-number: 19.02.2020-2020/76).

Informed Consent: Written informed consent was obtained from the parents of all participants.

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Author Contributions: Concept - E.U., M.Ö., Ö.M.; Design - E.U., M.Ö., Ö.M.; Supervision - Ö.M., Z.B.; Resource - E.U., M.Y.Ö.; Materials - M.Y.Ö., Ö.M.; Data Collection and/or Processing - M.Ö., M.Y.Ö.; Analysis and/or Interpretation - Z.B., E.U.; Literature Search - M.Y.Ö., M.Ö., E.U.; Writing - E.U., M.Ö.; Critical Reviews - E.U., M.Ö., Z.B.

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