Comparison of Laryngeal Palpatory Scale (LPS), With Surface Electromyographic Measures in Patients with Muscle Tension Dysphonia

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Summary

Objectives: The aim of this study was to examine the laryngeal palpatory scale (LPS) to ascertain possible correlation with neck surface electromyography (sEMG).

Methods: Two otolaryngologists and one certified speech-language pathologist assessed 21 participants (seven women and 14 men; with a mean age of 42.8 years; ranged: 21 to 70 years) with muscle tension dysphonia (MTD) diagnosed with the current version of the LPS rating system. Consequently, relationships between LPS and objective measures of sEMG were evaluated using Spearman's rank correlation coefficient (r).

Results: The results show that there was a low to moderate between correlations, (statistically positive and significant in 10 correlations among the examined items/states).

Conclusions: In conclusion, low-moderate positive correlations between sEMG and LPS ratings were found with particular strength for LPS ratings of tightness and ratings made during dynamic tasks. Further investigations can provide useful evidence for researchers and clinicians to document treatment outcomes by using LPS and sEMG in patients with MTD and leading to the more standardized care and improved information about patient progress.

Key Words: Muscle tension dysphonia; Laryngeal palpatory scale; Test-retest reliability; Surface electromyography

INTRODUCTION

Muscle tension dysphonia (MTD) is a voice disorder characterized by excessive tension of the extra (para) laryngeal muscles.[1,2] In a study by Altman et al on 150 patients with MTD, 70% were reported to show neck muscle tension overactivity.[3] Supportably, a few studies reported extra laryngeal muscles hyper functionality in patients with MTD using surface electromyography (sEMG).[4,5] The increased muscle tension in patients with MTD has been attributed to many factors such as psychological and/or personality sources, vocal misuse factor or prolonged compensatory strategies developed by an underlying disease such as organic fold lesions, laryngopharyngeal reflux (LPR), and upper airway infection.[2] The exact reasons for increased laryngeal and extra laryngeal musculature overactivity in MTD patients is still a subject of debate.[1] Regardless of the unrevealed cause-effect connection between voice disturbance and excessive tension of the extra laryngeal muscles, the assessment of extrinsic muscle tension is a crucial element in the clinical assessment and diagnosis of MTD.[6]

Muscle tension in MTD can be assessed by using a number of different approaches. Historically,[1,]7, 8, 9, 10 perceptual voice assessment, palpation, laryngoscopy and videolaryngostroboscopy can be considered as subjective diagnosis methods whereas utilizing instruments such as electromyography, radiography and acoustic analysis pave the way for objective diagnosis of this pathological condition.[11] Laryngeal palpation is one of the most widely used methods to assess muscle tension and diagnosis of MTD. Laryngeal palpation has been applied in research and clinic surveys.[12,13] However, a significant issue is the subjectivity of the palpation rating techniques. Accuracy testing with more objective instruments such as sEMG may strengthen the validity and efficacy of the palpation methods.

The work of Redenbaugh and Reich[5] evaluated the relationship between sEMG and laryngeal/neck palpation ratings. They examined laryngeal/neck muscles tension during rest, phonation (vowel /i/), and reading tasks. One speech-language pathologist rated the tonicity of the ‘‘suprahyoid and infrahyoid muscles” on a 1–5 point scale. Seven vocally healthy subjects and 7 patients with MTD (3 contact ulcer, 2 vocal Fold nodules, and 2 laryngitis) were included in their study. The neck sEMG was recorded using only one electrode sited on the thyrohyoid membrane. The authors found a moderately high correlation between the palpation score and sEMG using the Pearson's correlations test. It seems that using only one located electrode is insufficient to understand the relationships between sEMG and clinical ratings of palpation. It is unclear why if the relationship between palpation and the single sensor was high, that the sensor would provide insufficient information. It seems a larger problem in that particular study is that they used raw voltage values instead of normalized sEMG percentages, lending to inaccurate methodology in processing. Redenbaugh and Reich[5] palpation method was published in 1989 and to our knowledge there is no information about the validity and reliability of the system.

The possible correlation between sEMG with current neck tension rating methods has also been investigated by Stepp and colleagues.[14] In a study Stepp *et al.*[14] explored the neck tension palpation tension rating systems of Angsuwarangsee and Morrison[15] (a four-point grading system based on the work of Lieberman[16] to document muscle tension severity of the suprahyoid, the cricothyroid, the thyrohyoid, and the pharyngolaryngeal muscles) and Mathieson *et al.*[17] (a palpatory rating system to document the resistance of the supralaryngeal muscle area, thyroid cartilage and sternocleidomastoid muscles using a 5-point grading scale. The laryngeal position in the vocal tract is also assessed on a four-point nominal scale) to determine whether the systems were correlated with sEMG in individuals receiving therapy for voice disorders. They examined 16 participants with vocal hyperfunction (MTD and vocal nodules). Neck muscle tension was examined during rest, reading, and spontaneous speech. The neck sEMG recording procedure was carried out placing three surface electrodes parallel to the muscle fibers of the (1) thyrohyoid, omohyoid, and sternohyoid muscles; (2) cricothyroid and sternohyoid muscles; and (3) sternocleidomastoid muscle. They found that the correlation between these grading systems and sEMG is generally low (Pearson's correlations: near zero or even negative). There is not enough information about validity and reliability of the Angsuwarangsee and Morrison[15] and Mathieson *et al.*[17] methods. In the study by Angsuwarangsee and Morrison Inter-rater and intrarater reliability of the Angsuwarangsee and Morrison scale were good with the exception of the pharyngolaryngeal muscle tension. However, Stepp *et al.*[14] found a low inter-rater reliability for these two scales except for the cricothyroid and pharyngolaryngeal assessments of the Angsuwarangsee and Morrison[15] scale.

Laryngeal palpatory scale (LPS) which introduced by Jafari *et al.*[18] is a novel valid and reliable instrument for assessing patients with MTD. The authors suggest that this scale is suitable for assessing anatomical structures influenced in MTD using a quantitative measurement. Authors reported moderate to almost perfect agreement for each single item, which indicates that the accompanying text behind the scale is appropriate to guide the examiners in the rating procedure. It is still unknown whether this new LPS correlates well with neck sEMG recordings which can help to determine the validity of the LPS. More objective instruments such as surface EMG may improve the utility of the palpation rating scales during treatment outcome measurement, especially when slight changes should be noticeable. Monitoring changes in neck tension in patients with voice disorders could lead to more standardized care and improved information about patient progress. Also, the LPS considered the left and right muscle behaviors of each muscle group, (except for the submental muscles), so it is necessary to consider all electrode recording location possibilities that correlate accurately with the current rating system. In the current study, LPS was used in comparison with neck sEMG collected from seven electrode recording locations during vocal behaviors to understand the degree of the correlation of LPS with neck sEMG.

MATERIALS AND METHODS

Participants

Two otolaryngologists and one SLP with more than 7 years of experience in the evaluation and treatment of voice disorders, identified MTD patients within the ear, nose and throat (ENT) department of Tehran University Hospital (Hazrat-e-Rasoul), as well as the ENT department of Iran University Hospital (Amir Alam) in Tehran, Iran. The group of participants consisted of 21 Patients with MTD and without evidence of laryngeal lesions or laryngeal neuropathology. The MTD patients were diagnosed based on case history, rigid videolaryngostroboscopy and auditory-perceptual voice evaluation. Inclusion criteria were: 1) aged 18 years or older; 2) not received voice therapy services; 3) no history of laryngeal surgery, and 4) no current or prior swallowing problems. Furthermore, participants were excluded if they had acute or chronic upper respiratory infection at the time of testing and a history of cardiac, pulmonary, or neurological problems.

Ethical consideration

The Ethics Committee of University of Social Welfare and Rehabilitation Sciences, Tehran, Iran, approved the study. A written informed consent was used before the study initiation to ensure participants understood the significance of participating in this study and they were free to withdraw at any time.

Laryngeal palpatory scale (LPS) technique

LPS[18] contains 45 items, categorized into three distinct subscales named “patient's symptomatic complaint”, “observation” and “palpation” (Appendix 1). LPS items were designed to evaluate symptomatic pain, posture, muscle condition, laryngeal and hyoid position, movement limitation and laryngeal space/gap reduction. The “Palpation” subscale contains four distinct categories: “muscle condition”, “laryngeal and hyoid position”, “movement limitation” and “laryngeal space/gap reduction”. “The muscle condition” category evaluates physiologic core traits such as increased extrinsic laryngeal muscle activation (“submental area” and “infrahyoid area” muscles) that keeps the larynx in a well-balanced and natural position. Additional indicators such as cricothyroid and SCM muscles were included to measure tension. Apart from the submental area muscles, LPS considers left and right muscle behaviors of each muscle group separately. Tenderness and tightness, which are both considered in the current scale, are the proposed factors to assess muscle condition (during both static and dynamic tasks). LPS is a 4-point Likert-type scale that paves the way to rate each item as follows: (0 = “absent”; 1 = “mild”; 2 = “moderate”, 3 = “severe”).[18]

Rater training

One certified speech-language pathologist who was specialized in assessment and treatment of patients with voice disorder assessed participants with MTD using the current version of the LPS rating system (Appendix 1). The rater had experience with laryngeal palpation and manipulation as a part of clinical practice prior to this study. At first, she was asked to read the LPS guideline text and she was trained in the correct use of the criteria as defined in the instruction text. The rating procedure for each patient lasted approximately 15 minutes.

Electromyographic techniques

To perform the sEMG, patients were recruited to the Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran. The sEMG recordings, in the current study were taken according to the most recent European standards.[19] Recording procedures were as follows: preparing the instrument, explaining the procedure to the patients, proper positioning of patients, cleaning the neck surface, electrode placement, and recording the sEMG signals. All sEMG signal recordings were made using the DataLOG, Biometrics Ltd. Preamplifier bipolar active electrodes (*Type NOS.SX230, Biometrics Ltd, UK*), with a fixed center-to-center interelectrode distance of 20 mm, recording diameter of 10 mm, built-in differential amplifier with sampling frequency of 1000 Hz, input impedance of 10^{15} Ω, common mode rejection ratio (CMRR) of 110 dB at 60 Hz, and bandwidth of 20–450 Hz. The magnitude of muscles activity was evaluated during vowel prolongation /i/ and counting tasks. Muscle activity (sEMG) was investigated in microvolts.

The clinician ensures that the participants are seated well back on the seat of the chair, that their spines are straight and that the heads are in a neutral position and with the knees and hips in 90° flexion. Participants were encouraged to relax their shoulders. To reduce skin input impedance and improve the quality of sEMG signal, careful skin preparation (including hair shaving, skin rubbing with alcohol and abrasion with fine sand paper) was used prior to electrode placement. (2-4).20, 21, 22 Moreover, no mobile phones or laptops were allowed, doors and windows were closed, and the ventilation system was turned off to reduce environmental noise.

The signals were recorded with seven bipolar Ag/AgCl surface electrodes. Electrode placement was carried out based on the instruction of the relevant clinical literature (2, 5-8).[20,]23, 24, 25, 26, 27, 28 The electrodes were considered as follows: (1) submental group muscles, (2) infrahyoidal left muscles, (3) infrahyoidal right muscles, (4) cricothyroid left muscles, (5) cricothyroid right muscles, (6) sternocleidomastoid left muscle, and (7) sternocleidomastoid right muscle. A measurement procedure was carried out to make sure the electrodes were placed correctly. An Example of electrode locations is shown in Figure 1 on one participant. Electrodes were placed beneath the chin, about 0.5 cm lateral to the submental midline (#1) as superior as possible; 1 cm lateral to the right and left neck midline, over the lamina of the thyroid cartilage (#2, #3); approximately 1 cm lateral to the neck midline, on the contralateral side of each other, on the gap between the cricoid and thyroid cartilages of the larynx (cricothyroid space) (#4, #5); with centered on the marked one third of the distance from the sternal notch to the mastoid process above the sternocleidomastoid muscles (#6, #7). To achieve this goal, the distance between the sternal notches to the mastoid process was divided into three equal parts following the suggestion of Falla *et al.*[27] A strap ground electrode was fixed around the right wrist joint. Electrode position #1 was placed unilaterally to record possibly the activity of the anterior belly of the digastric, mylohyoid, and geniohyoid musculatures, while electrodes positions #2 and #3 were placed bilaterally to record sternohyoid, thyrohyoid and omohyoid muscle activity. Electrode #4 and #5 were intended to be sensitive to the cricothyroid muscle group, which possibly contains cricothyroid and sternohyoid muscles. Electrodes positions #6 and #7 were placed bilaterally in order to record from sternocleidomastoid. Worth mentioning that the differences in the participants' laryngeal anatomy, neck size and musculature had an effect on the electrode placement. Electrodes were all placed by the first author.

FIGURE 1. Electrode positioning. The figure shows sEMG electrode locations as placed on patient RA.GH (male, age: 37).

Procedure

The sEMG recordings consisted of a couple of vocal assessments (prolongation of vowel /i/ and counting). Subjects were requested to prolong vowel /i/ at a habitual pitch and loudness. Each vowel was prolonged for almost 4 seconds and was produced three times, with intervals of more than 4 seconds between each these three trials (almost 10 second) to identify the onset of voicing. Next, the participants were requested to count from one to 10 in the manner similar to the prolongation of vowel /i/. This task was repeated and timed three times. Every task lasted for about 10 seconds with intervals of approximately 4 seconds in between.

An event marker was utilized and every time a visual and auditory trigger were used the button of event marker was pressed simultaneously. The participants were requested to start and finish each vocal assessment when this visual-auditory trigger were presented (Figures 2 and 3). To determine the signal integrity and any movement artifact, recorded signals were monitored after each recording had taken place and they were repeated if necessary. Intraclass correlation coefficient for each phonation task was measured. In the current study, for activity measurement, the sEMG data were calculated as the RMS for submental group muscles unilaterally, infrahyoidal muscles, cricothyroid muscles, and sternocleidomastoid muscles bilaterally during each test of vowel prolongation /i/and counting tasks. To reduce the sEMG data variability, activity measures were normalized to a reference contraction, in RMS (10).[28] The values of RMS were baseline corrected to the 500 ms of beginning rest period of the sEMG' recorded signal ((an average of 500 ms or scilence relaxation area plus 2 times of the standard deviation, within close range of auditory trigger and event marker).29, 30, 31 On the other hand, the RMS value of the EMG signals for each muscle group and during each phonation task were divided by the RMS value for the same muscles at rest.[32]

Statistical analysis

To measure the test-retest reliability, the intraclass correlation coefficient with mixed two-way effects model, absolute agreement type was calculated for the RMS of target muscles in patients with MTD. We used the benchmarks suggested by Landis and Koch (15)[33] as a guide for agreement: < 0.00 = poor, 0.00 – 0.20 = slight, 0.21 – 0.40 = fair, 0.41 – 0.60 = moderate, 0.61 – 0.80 = substantial and 0.81 – 1.0 = almost perfect. In addition, the standard error of measurement (SEM) was calculated as a measure of absolute reliability as follows: SEM= SD√ (1-ICC) (16).[34] The SEM is a measure of how much measured test scores are spread around a "true" score. The SEM is especially meaningful to a test taker because it applies to a single score and it uses the same units as the test.[34] Furthermore, Spearman's rank correlation coefficient (rs) is utilized to measure correlations between clinical ratings of various muscle groups of laryngeal palpatory scale and the normalized RMS sEMG from all possibly relevant electrode locations during /i/ vowel prolongation and counting. A *P*-value of < 0.05 was considered statistically significant. At first, the average values of the RMS of three trials of /i/ vowel prolongation and counting were calculated. The scores were entered into a research database (Microsoft Excel) and analyzed using SPSS 23.0 statistical software (SPSS, Inc., Chicago, IL). The significance of the correlation coefficient was categorized according to Munro[35] (17): 0.00 to 0.25 little if any correlation, 0.26 to 0.49 low correlation, 0.50 to 0.69 moderate correlation, 0.70 to 0.89 high correlation, and 0.90 to 1.0 very high correlation.

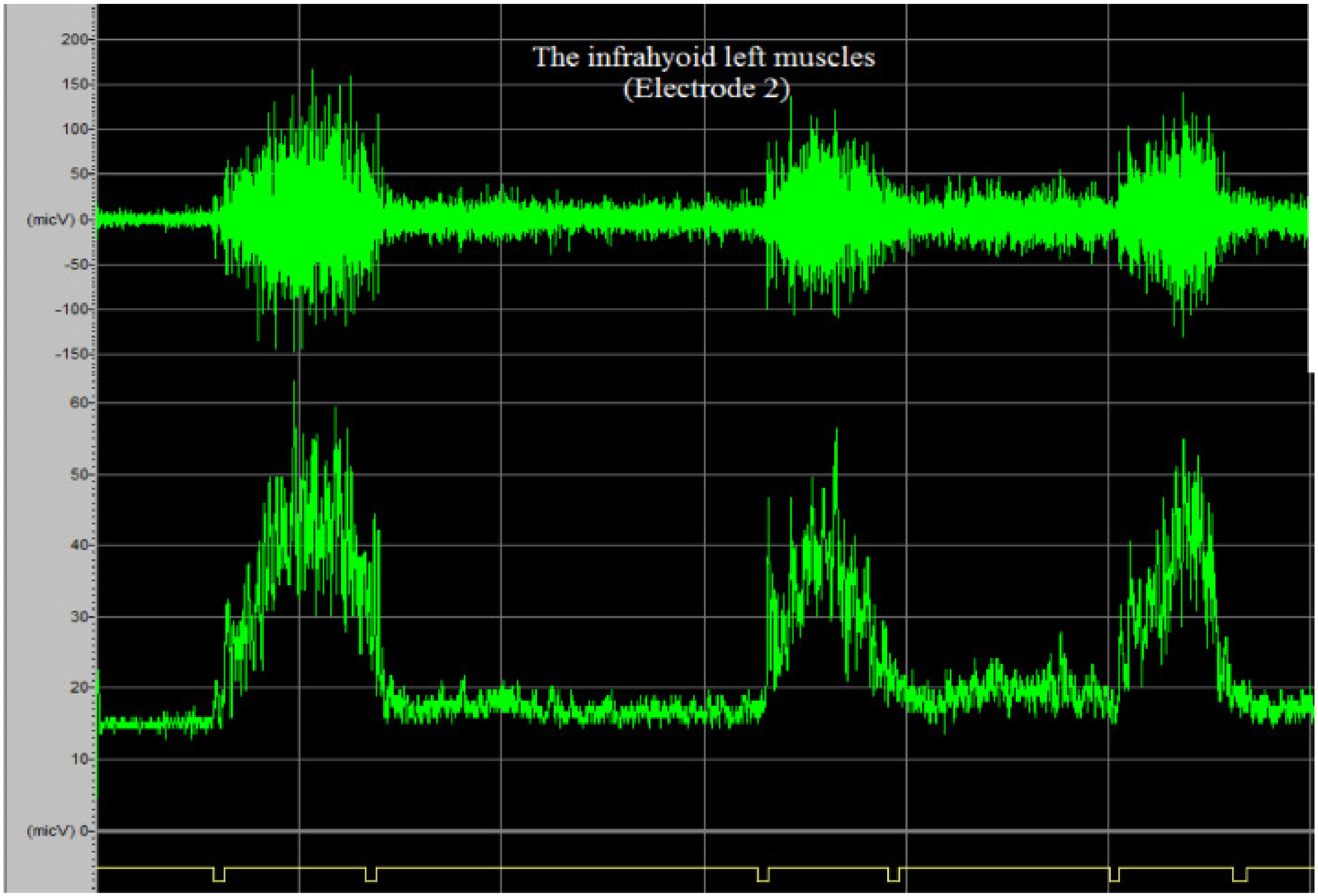

FIGURE 2. An example of the sEMG recording signals and RMS of the infrahyoid left (electrode 2) during vowel prolongation /i/, in case RA.GH (male, age: 37). Note: event marker is presented in the bottom of the figure.

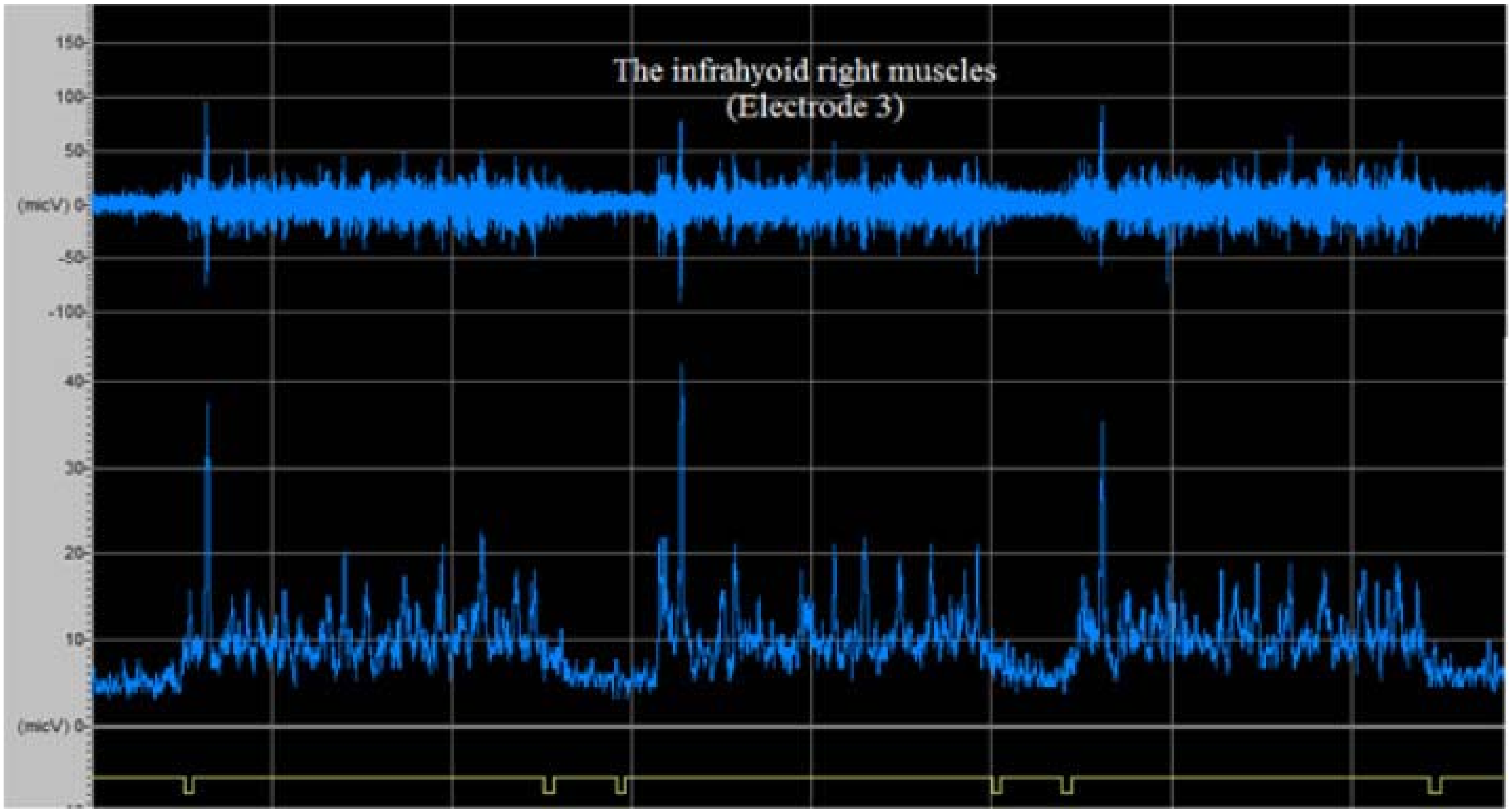

FIGURE 3. An example of the sEMG recording signals and RMS of the infrahyoid right (electrode 3) during counting in case AB.MO (male, age: 41). Note: event marker is presented in the bottom of the figure.

TABLE 1. Demographic Data and the Characteristics of the Subjects with Muscle Tension Dysphonia (MTD)

Subjects Identifier	Gender	Age	Duration of MTD (month)	Laryngoscopic/Stroboscopic Findings	Patients Main Complaints
AB.MO	Male	41.00	6	Antero-posterior shortening of the distance between the petiole and the arytenoids during phonation.	Hoarseness, pain, vocal fatigue, sore throat,
AB.AB	Male	27.00	36	Approximation of the false vocal folds	Hoarseness, vocal fatigue
AF.AL	female	45.00	24	Antero-posterior shortening of the distance between the petiole and the arytenoids during phonation.	Hoarseness, pain, vocal fatigue
AH.AB	Male	35.00	8	Presence of a gap between the vocal cords edges during phonation	Hoarseness, vocal fatigue, sore throat, pain, globus pharyngeus, Vocal strain
AL.AR	Male	47.00	5	Approximation of the false vocal folds	Hoarseness
AL.RO	Male	52.00	12	Complete sphincter-like closure of the supraglottis during phonation	Hoarseness, sense of a lump in the throat
AZ.ZA	female	59.00	4	Presence of a gap between the vocal cords edges during phonation	Hoarseness, sense of a lump in the throat
GH.EZ	Male	48.00	24	Antero-posterior shortening of the distance between the petiole and the arytenoids	Hoarseness, pain, discomfort, neck tightness,vocal fatigue, sore troat, sense of a lump in the throat
RA.GH	Male	37.00	4	Complete sphincter-like closure of the supraglottis during phonation.	Hoarseness, vocal fatigue, pain, Loss of pitch range,
HO.AG	Male	24.00	48	Antero-posterior shortening of the distance between the petiole and the arytenoids	Hoarseness, sore throat, globus pharyngeus, pain, sense of a lump in the throat
HO.SA	Male	27.00	3	Presence of a gap between the vocal cords edges during phonation	Hoarseness, globus, sense of a lump in the throat
IR.AB	female	48.00	48	Presence of a gap between the vocal cords edges during phonation	Hoarseness, pain, tightness in throat, laryngeal tenion
IS.KH	Male	58.00	12	Presence of a gap between the vocal cords edges during phonation	Hoarseness, vocal fatigue, limited vocal range, strained voice
MA.MO	female	21.00	8	Presence of a gap between the vocal processes during phonation	Hoarseness, globus, pain, laryngeal tension
MA.FE	female	53.00	2	Antero-posterior shortening of the distance between the petiole and the arytenoids	Hoarseness, globus pharyngeus, sense of a lump in the throat, loss of pitch range
MO.KA	Male	32.00	12	Presence of a gap between the vocal cords edges during phonation	Hoarseness, pain, unable to project voice, loss of pitch range
HO.NA	Male	70.00	1	Presence of a gap between the vocal cords edges during phonation	Hoarseness, vocal fatigue, sense of a lump in the throat
RE.SA	Male	35.00	12	Approximation of the false vocal folds	Hoarseness, globus, pain, sense of a lump in the throat,
SE.AL	female	52.00	12	Antero-posterior shortening of the distance between the petiole and the arytenoids	Hoarseness

MA.ES	Male	60.00	10	Approximation of the false vocal folds and antero-posterior shortening of the distance between the petiole and the arytenoids during phonation	Hoarseness, sore throat, sense of a lump in the throat, vocal fatigue
ZA.TO	female	28.00	40	Presence of a gap between the vocal cords edges during phonation	Hoarseness, vocal fatigue, globus

RESULTS

Patient characteristics

The MTD patient cohort consisted of seven women and 14 men; with an average age of 42.8 years (range 21 to 70). Patient characteristics include: gender, age, duration of MTD (month), stroboscopic findings, and main complaints are mentioned in Table 1.

Relative reliability

Test-retest reliability

The test-retest reliability values in patients with MTD are shown in Table 2. Almost perfect test-retest reliability was found for the RMS of target muscles during both the phonation of the sustained vowel /i/ and during counting (0.81–0.99).

Absolute reliability

The SEM

Table 2 shows the absolute reliability measures of the SEM for the sEMG data in patients with MTD. The highest value of the SEM was 1.26, obtained for the RMS of the infrahyoid left muscles group during the vowel /i/ prolongation. Furthermore, the lowest SEM was 0.08 was calculated for the RMS of the SCM right muscle in the /i/ vowel prolongation.

TABLE 2. Test-Retest Reliability and Absolute Reliability Measures for the RMS (normalized data) of the Submental Group, Infrahyoid Left, Infrahyoid Right, Cricothyroid Left, Cricothyroid Right, SCM Left and SCM Right Muscles During Vowel Prolongation and Counting in Patients With MTD

Tasks	**Muscles**	**Mean ± SD**			**ICC (CI (95%))**	**Mean ± SD**	**SEM**
		test	**Retest 1**	**Retest 2**			
/i/	Submental group	3.5±2.7	5.2±7.7	3.7±3.8	0.94 (0.87-0.97)	4.3 ± 4.2	1.02
	Infrahyoid left	3.3±2.7	3.6±3.02	4.5±4.4	0.81 (0.59-0.92)	3.7 ±2.9	1.26
	Infrahyoid right	3.8± 2.8	3.8± 2.8	4.1± 2.8	0.98 (0.96-0.99)	3.8 ± 2.7	0.38
	Cricothyroid left	4.8± 2.9	4.7± 2.6	5.1± 2.7	0.95 (0.89-0.98)	4.8 ±2.6	0.58
	Cricothyroid right	4.6± 3.2	4.6± 3.6	4.8± 3.7	0.99 (0.99-1)	4.7 ± 3.4	0.34
	SCM left	3.2± 2.3	3.3± 2.3	3.7± 2.4	0.99 (0.99-1)	3.3 ± 2.3	0.23
	SCM right	1.5± 0.8	1.6± 0.8	1.6± 0.9	0.99 (0.97-0.99)	1.5 ± 0.8	0.08
Counting	Submental group	7.3± 4.7	7.03± 4.6	7.6± 4.1	0.98 (0.97-0.99)	7.2 ± 4.4	0.62
	Infrahyoid left	4.1± 2.04	4.1± 2.4	4.6± 2.9	0.94 (0.87-0.97)	4.2 ± 2.2	0.53
	Infrahyoid right	4.8± 2.6	4.5± 2.3	5.04± 3.02	0.98 (0.95-0.99)	4.8 ± 2.5	0.35
	Ccricothyroid left	4.4± 2.5	4.3± 2.4	4.2± 2.09	0.95 (0.905-0.98)	4.3 ± 2.3	0.51
	Cricothyroid right	4.7± 3.1	4.9± 3.08	4.9± 2.3	0.96 (0.91-0.98)	4.8 ± 3.06	0.61
	SCM left	3.01± 2.05	3.08± 1.9	2.7± 1.5	0.98 (0.97-0.99)	3.07 ± 1.9	0.26
	SCM right	1.7± 1.6	1.7± 1.3	1.8± 1.4	0.98 (0.97-0.99)	1.7 ± 1.4	0.19

Correlation between laryngeal palpatory scale (LPS) and surface electromyography

Tables 3 and 4 show the Spearman's rank correlation coefficient (r) and *P* values between laryngeal palpation scale values and sEMG from all possible relevant electrode locations during vowel prolongation /i/ and counting. The sEMG from each electrode position was compared with relevant LPS muscles as follows: electrode 1 with submental group muscles, electrode two with infrahyoid left, electrode three with infrahyoid right, electrode four with cricothyroid left, electrode five with cricothyroid right, electrode six with SCM left and electrode seven with SCM right.

TABLE 3. Spearman Rank Correlation Coefficient between Various Muscle Groups of Laryngeal Palpatory Scale and the Normalized RMS sEMG From All Possible Relevant Electrode Locations During /i/ Vowel Prolongation

Relevant Electrode Locations	laryngeal Palpatory Scale Items		Correlation Coefficient	*P* value
Submental group	Static	Tenderness	0.22	0.32
		Tightness	0.33	0.13
	Dynamic	Tenderness	0.41	0.05
		Tightness	0.43*	0.04
Infrahyoid left	Static	Tenderness	0.25	0.26
		Tightness	0.28	0.21
	Dynamic	Tenderness	0.35	0.11
		Tightness	0.57**	0.006
Infrahyoid right	Static	Tenderness	0.37	0.09
		Tightness	0.42	0.05
	Dynamic	Tenderness	0.22	0.33
		Tightness	0.35	0.11
Cricothyroid left	Static	Tenderness	0.44*	0.04
		Tightness	0.27	0.22
	Dynamic	Tenderness	0.51*	0.01
		Tightness	0.56**	0.007
Cricothyroid right	Static	Tenderness	0.307	0.17
		Tightness	0.35	0.12
	Dynamic	Tenderness	0.47*	0.02
		Tightness	0.54*	0.01
SCM left	Static	Tenderness	0.29	0.19
		Tightness	0.28	0.21
	Dynamic	Tenderness	0.206	0.37
		Tightness	0.29	0.18
SCMright	Static	Tenderness	0.21	0.34
		Tightness	0.23	0.29
	Dynamic	Tenderness	0.29	0.19
		Tightness	0.31	0.16

Effects significant at $P < 0.05$ (*) and $P < 0.004$ (**) are noted.

TABLE 4. Spearman Rank Correlation Coefficient between Various Muscle Groups of Laryngeal Palpatory Scale and the Normalized RMS sEMG From All Possibly Relevant Electrode Locations during Counting

Relevant Electrode Locations	Laryngeal Palpatory Scale Items		Correlation Coefficient	*P* value
Submental group	Static	Tenderness	0.35	0.12
		Tightness	0.39	0.07
	Dynamic	Tenderness	0.38	0.08
		Tightness	0.45*	0.03
Infrahyoid left	Static	Tenderness	0.33	0.13
		Tightness	0.25	0.26
	Dynamic	Tenderness	0.29	0.19
		Tightness	0.201	0.38
Infrahyoid right	Static	Tenderness	0.37	0.09
		Tightness	0.33	0.13
	Dynamic	Tenderness	0.32	0.14
		Tightness	0.52*	0.01
Cricothyroid left	Static	Tenderness	0.25	0.27
		Tightness	0.33	0.08
	Dynamic	Tenderness	0.22	0.33
		Tightness	0.206	0.37
Cricothyroid right	Static	Tenderness	0.25	0.27
		Tightness	0.26	0.24
	Dynamic	Tenderness	0.32	0.14
		Tightness	0.46*	0.03
SCM left	Static	Tenderness	0.17	0.45
		Tightness	0.19	0.406
	Dynamic	Tenderness	0.24	0.29
		Tightness	0.12	0.58
SCM right	Static	Tenderness	0.26	0.23
		Tightness	0.13	0.56
	Dynamic	Tenderness	0.31	0.16
		Tightness	0.28	0.208

$*P < 0.05$.

The correlation coefficients (r) ranged from 0.12 to 0.56 (Tables 3 and 4). In particular, correlations between sEMG and palpation ratings were statistically significant between these 10 following electrode positions and LPSs items. Electrode position 1 (during vowel prolongation /i/), located on submental group muscles, and tightness rating of the submental group muscles (during dynamic procedure) of LPS ($r > 0.43$; $P < 0.05$). Electrode position 2 (during vowel prolongation /i/), located on infrahyoid left, and tightness rating of the infrahyoid left muscles (during dynamic procedure) of LPS ($r > 0.57$; $P < 0.001$). Electrode position 4 (during vowel prolongation /i/), located on cricothyroid left, and tenderness ratings of the cricothyroid left muscles (during static procedure) of LPS ($r > 0.44$; $P < 0.05$). Electrode position 4 (during vowel prolongation /i/), located on cricothyroid left, and tenderness ratings of the cricothyroid left muscles (during dynamic procedure) of LPS ($r > 0.51$; $P < 0.05$). Electrode position 4 (during vowel prolongation /i/), located on cricothyroid left, and tightness ratings of the cricothyroid left muscles (during dynamic procedure) of LPS ($r > 0.56$; $P < 0.001$). Electrode position 5 (during vowel prolongation /i/), located on cricothyroid right, and tenderness ratings of the cricothyroid right muscles (during dynamic procedure) of LPS ($r > 0.47$; $P < 0.05$). Electrode position five (during vowel prolongation /i/), located on cricothyroid right, and tightness ratings of the cricothyroid right muscles (during dynamic procedure) of LPS ($r > 0.54$; $P < 0.05$). Electrode position 1 (counting), located on submental group muscles, and tightness rating of the submental group muscles (during dynamic procedure) of LPS ($r > 0.45$; $P < 0.05$). Electrode position three (during counting), located on infrahyoid right, and tightness ratings of the infrahyoid right muscles (during dynamic procedure) of LPS ($r > 0.52$; $P < 0.05$). Electrode position 5 (during counting), located on cricothyroid right, and tightness ratings of the cricothyroid right muscles (during dynamic procedure) of LPS ($r > 0.46$; $P < 0.05$).

DISCUSSION

The main purpose of this study was to examine the novel laryngeal palpatory scale (LPS) to ascertain possible correlation with neck surface electromyography (sEMG), from all electrode recording location possibilities that correlate accurately with the current rating system.

The reliability of measurement can be considered a key indicator of measurement instrument quality which can help clinicians in the decision-making procedure.[36] Instrument reliability is indicated by its stability during multiple measurements.[37] Test-retest reliability refers to the repeatability of test scores at different moments in time which can be used to measure the reliability of biophysiological instruments such as EMG.[38] Reliable instruments strengthen the power of study to discover the differences and relationships. Thus it is essential to provide evidence for the reliability of repeated sEMG measurements before using it clinically.[39] In this study, the intraclass correlation coefficient (ICC) provides us with an estimate of relative reliability for consistency and agreement of successive measurements.[40]

According to the test-retest reliability findings, the current presented protocol was highly reliable for the measurement of the RMS of the submental group muscles, infrahyoidal left muscles, infrahyoidal right muscles, cricothyroid left muscles, cricothyroid right muscles, sternocleidomastoid left muscle, and sternocleidomastoid right muscles in the assessment of MTD patients in clinical settings and future research. Van Houtte *et al,*[25] measured the RMS of the suprahyoid, infrahyoid, and sternocleidomastoid muscles in both MTD and normal subjects. Participants were asked to sustain /a/ and /i/ vowels three times. They found that ICC for each phonation task was >0.90.[25] Reported RMS reliability of the examined muscles is consistent with the findings of the current study. In addition, Khoddami *et al.*[41] evaluated the reliability of surface electromyography (sEMG) in the assessment of patients with primary muscle tension dysphonia (MTD). All participants underwent evaluation of sEMG to record the electrical activity of the thyrohyoid and cricothyroid muscles. The root mean square (RMS) was one of the outcome measures which was obtained during /a/ and /i/ prolongation for test-retest reliability. They concluded that sEMG is a reliable tool to measure RMS (ICC=0/49-0/98).[41]

In the current study, the RMS were calculated for target muscles bilaterally, using multiple electrodes recording locations, which is the main different aspect compared to previous ones. Absolute reliability reflects the data variability of the repeated measurements for individuals, which can recommended as a supplemental procedure for the relative data to demonstrate measurement errors.[38,42] The standard error of measurement (SEM) is an example of measures with absolute reliability because the less SEMs vary, the higher the reliability and probably imply sensitivity to changes.[38] In the current study, the SEM for the RMS, was small in patients with MTD. The small SEMs confirmed the reliability of the activity domain measures of the submental group muscles, infrahyoid al left muscles, infrahyoid al right muscles, cricothyroid left muscles, cricothyroid right muscles, sternocleidomastoid left muscle, and sternocleidomastoid right muscles in the assessment of the patients with MTD.

The main aim of this study was to answer the question of whether the measured tenderness/tightness of the different muscle groups in the laryngeal palpatory scale (LPS) was correlated with RMS (normalized activity) recorded from all possible relevant electrode locations during the phonation of the sustained vowel /i/ and counting.

As results show, correlations between sEMG and laryngeal palpation rating scale (LPS) were generally low to moderate. The sEMG from each seven electrode positions (during vowel /i/ prolongation (Table 3) and counting tasks (Table 4)) were compared with relevant seven area muscles in LPS (evaluation of the tenderness and tightness during static and dynamic tasks (vowel /i/ prolongation and counting)). Electrode one with submental group muscles, electrode two with infrahyoid left, electrode three with infrahyoid right, electrode four with cricothyroid left, electrode five with cricothyroid right, electrode six with SCM left and electrode seven with SCM right. In particular, statistically positive and significant in LPS's 10 state/items can be seen among the existed items or possibilities (Tables 3 and 4). The results could be interpreted considering multiple factors. First, it seems that to be an effect of task on correlations, (see vowel /i/ prolongation (Table 3) and sEMG collected during counting (Table 4)). Obviously, more statistically significant correlations in vowel /i/ prolongation sEMG compared with sEMG were collected during counting. It may reflect more physical effort particularly during vowel /i/ extension sEMG, which possibly leaded to more significant and positive correlation results. Second, there does appear to be an effect of LPS task on correlations, with static LPS resulting in correlations that are evidently different to those for LPS collected during dynamic tasks. Dynamic LPS undoubtedly caused positive and significant relations in comparison to the static LPS. LPS examines muscle tenderness and tightness during both static and dynamic tasks. Data support the possibility that patients with MTD may reveal increased muscle tension mostly during dynamic tasks (phasic pattern of contraction). Third, regarding the findings, statistically significant correlation appeared during the evaluation of muscles tightness. The current scale considers the assessment of muscle condition, tenderness and tightness. Tenderness is considered as pain or discomfort when an area is touched, which can be tested by a clinician. During evaluation, light pressure is applied (about one third of the pressure needed during tightness evaluation) and tightness is defined as a pressure which gradually increases, until the muscle can be palpated firmly. It is therefore not surprising that the evaluation of muscles tightness is more decisive. It is also important to consider that tension is assessed by a clinician who is ideally calibrated for constant intra rater reliability, where a patient is not calibrated to pain across people. Pain is subjective and also can be related to experiences of pain and other psycho-emotional considerations.

Redenbaugh and Reich[5] evaluated the relationship between sEMG and laryngeal/neck palpation ratings. The authors found a moderately high correlation between the palpation score and sEMG using the Pearson's correlations test. Redenbaugh and Reich[5] reported results that are consistent with the results of the current study. On the contrary, Stepp *et al.*[14] found that the correlation between Angsuwarangsee and Morrison[15] and Mathieson *et al.*[17] grading systems and sEMG is generally low (Pearson's correlations: near zero or even negative). It seems that findings illustrated in the current study, were (to some extent) consistent with Stepp *et al.*[14] across the same situation of our measures. However, some measures were moderate in specific situations, like tightness more like Redenbaugh and Reich.[5]

The difference in results can most likely be attributed to the following factors: differences in research methodologies, the method of data collection, the participants' demographic characteristics, psychometric properties of the palpation rating system, the accuracy of palpation rating system, the issue of subjectivity or objectivity of the palpation methods and the degree of training and experience of raters.

Limitation of this study was not trying to re-rate a subject later with some kind of potential blinding (e.g., include patients without MTD to see the reliability of the clinician, or maybe include across several sessions).

It can also be considered that in the discussion of overlapping activities and cross talk in this area,[41] the previous work of coherence evaluation had shown that this phenomenon does not exist. But we cannot make this explicit now, and we consider this as a possibility and suggest that it can be used for future work and coherence evaluation, or using double differential electrodes, which are also very rare.

CONCLUSION

In the current study, we examined the relationship between LPS and neck sEMG collected from 7 electrode placements during vocal behaviors to understand the degree of correlation of LPS with neck sEMG.

This was primarily to answer the question of whether the measured tenderness/tightness of the different muscle groups in the laryngeal palpatory scale (LPS) correlated with RMS (normalized activity) recorded from all possible relevant electrode locations during vowel prolongation /i/ and counting. However, it is essential to provide evidence for the reliability of repeated sEMG measurements before using it clinically. To measure the test-retest reliability, the intraclass correlation coefficient was calculated for the RMS of target muscles in patients with MTD. According to the test-retest reliability findings, the current presented protocol was highly reliable for the measurement of the RMS of the submental group muscles, infrahyoid left muscles, infrahyoid right muscles, cricothyroid left muscles, cricothyroid right muscles, sternocleidomastoid left muscle, and sternocleidomastoid right muscles in the assessment of MTD patients in clinical settings and future research.

Consequently, an almost low to moderately positive correlation can be concluded between sEMG and the LPS rating system which mostly happened during evaluation of the muscles in LPS for tightness and especially during dynamic tasks. However, accuracy testing with other tools which are introduced to be a gold standard instruments such as GRBAS (a perceptual or auditory-acoustic assessment tool that addresses voice quality), as well as objective acoustic methods (to monitor changes in laryngeal position in patients with voice disorders) may increase the validity and utility of the LPS.

Eventually, based on the findings from this study, further investigations can provide useful evidence for researchers and clinicians to document treatment outcomes by using LPS and sEMG in patients with MTD.

Appendix A. Laryngeal palpatory scale (LPS)

LARYNGEAL PALPATORY SCALE (LPS)

Patient's name: …………………… Date: …………………

Item	Absent	Mild	Moderate	Severe
Patient's symptomatic complaint				
• Pain in the anterior/posterior neck during rest/speaking (pain area: ………….)	0	1	2	3
Observation				
• Habitual posture (head and neck, larynx, shoulders)				
A. Lateral view				
1 Head and neck extension	0	1	2	3
2 Geniohyoid pull (double chin)	0	1	2	3
B. Anterior and posterior view				
1 Head tilt (from midline: left or right)	0	1	2	3
2 Raised shoulders during rest/speaking (left, right or both)	0	1	2	3
3 Deviated larynx (from midline: left or right)	0	1	2	3
Palpation				
• Muscles condition				
A. Static				
*Tenderness				
1 Submental area	0	1	2	3
2 Infrahyoid area (left)	0	1	2	3
3 Infrahyoid area (right)	0	1	2	3
4 Cricothyroid (left)	0	1	2	3
5 Cricothyroid (right)	0	1	2	3
6 SCM (left)	0	1	2	3
7 SCM (right)	0	1	2	3
*Tightness				
1 Submental area	0	1	2	3
2 Infrahyoid area (left)	0	1	2	3
3 Infrahyoid area (right)	0	1	2	3
4 Cricothyroid (left)	0	1	2	3
5 Cricothyroid (right)	0	1	2	3
6 SCM (left)	0	1	2	3
7 SCM (right)	0	1	2	3
B. Dynamic (counting 1-10, vowel extension /i/)				
*Tenderness				
1 Submental area	0	1	2	3
2 Infrahyoid area (left)	0	1	2	3
3 Infrahyoid area (right)	0	1	2	3
4 Cricothyroid (left)	0	1	2	3
5 Cricothyroid (right)	0	1	2	3
6 SCM (left)	0	1	2	3
7 SCM (right)	0	1	2	3
*Tightness				
1 Submental area	0	1	2	3
2 Infrahyoid area (left)	0	1	2	3
3 Infrahyoid area (right)	0	1	2	3
4 Cricothyroid (left)	0	1	2	3
5 Cricothyroid (right)	0	1	2	3
6 SCM (left)	0	1	2	3
7 SCM (right)	0	1	2	3
• Laryngeal and hyoid position				
A. High position of larynx	0	1	2	3
B. High and back position of hyoid	0	1	2	3
• Movement limitation				
A. Limitation in lateral movement of larynx	0	1	2	3
B. Limitation in vertical movement of larynx				
1 Swallowing	0	1	2	3
2 Vowel extension /i/	0	1	2	3
3 Counting 1-10	0	1	2	3
C. Limitation in lateral movement of hyoid	0	1	2	3
• Laryngeal space/gap reduction				
A. Cricothyroid visor				
1 Static	0	1	2	3
2 Dynamic: /i/ in habitual, low, high pitch; pitch gliding; counting 1-10	0	1	2	3
B. Thyrohyoid				
1 Static	0	1	2	3
2 Dynamic: /i/ in habitual pitch; counting 1-10	0	1	2	3

Source: Reprinted from Ref. 18.

Abbreviation: SCM, sternocleidomastoid.

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