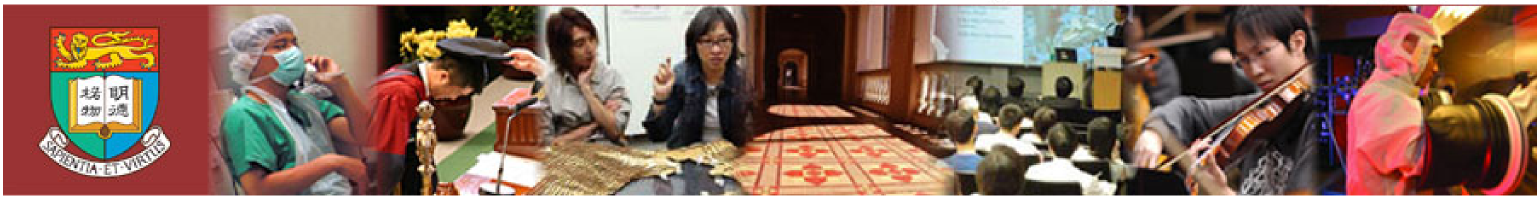

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Other Contributor(s)	University of Hong Kong.
Author(s)	Chan, Lai-ching, Connie
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Applications of surface electromyography in the assessment of hyperfunctional dysphonia

Chan Lai Ching, Connie

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Abstract

This study investigated the use of absolute and normalized surface electromyography (EMG) signals and their reliability (including within-block, within-day and between-days reliabilities) in assessing hyperfunctional dysphonia. Fourteen dysphonic individuals and 14 controls with normal voice participated in the study. Results revealed that hyperfuncational dysphonic speakers evidenced significantly greater absolute EMG values in orofacial site and both absolute and normalized values in thyrohyoid site during phonation. The reliability of surface EMG measurements decreases with the increase in time gap between the two assessments. Findings from the present study supported the use of normalized surface EMG as a tool for differentiating dysphonic from normal voices. Special precautions should be taken in using surface EMG in clinical settings in order to increase its reliability.

Introduction

Hyperfunctional dysphonia are characterized by hypertonicity of laryngeal muscle during phonation (Redenbaugh & Reich, 1989). According to Morrison et al. (1998), hyperfunctional dysphonic speakers often demonstrated palpable increases in suprahyoid muscle tension on phonation particularly in higher pitch ranges during singing, and during high vowels and phoneme transitions in connected speech. In addition, the authors stated that hyperadduction of vocal folds at the glottic or supraglottic level (or both) was also found in patients with hyperfunctional dysphonia. Other studies (Hirano, Koike, & Joyner, 1969; Redenbaugh & Reich, 1989) indicated that hyperfuncational dysphonic speakers demonstrated excessive muscle activities which were associated with abrupt phonatory initiations, excessively stiff vocal folds, high collision forces following vocal-fold adduction, and high medial compressive forces during vocal-fold closure. As characterized by the excessive muscle activities, hyperfunctional dysphonic patients can be studied by surface electromyography (EMG).

Surface EMG provides a non-invasive, objective method for measuring the physiological processes occurring during sustained muscular work. It measures the electric potential field evoked by active muscle fibers through the intact skin (Zwarts & Stegeman, 2003). Surface EMG has been used as augmented biofeedback in voice training (Prosek, Montgomery, Walden, & Schwartz, 1978; Yiu, Verdolini, & Chow, 2005). It also plays a role in the diagnosis of dysphonia (Hocevar-Bolterzar, Janko, & Zargi, 1998; Redenbaugh & Reich, 1989; Stemple, Weiler, Whitehead, & Komray, 1980).

Several authors have attempted to differentiate between dysphonic and non-dysphonic voices using surface EMG. Stemple et al. (1980) measured the muscle activities over the left thyroid lamina with a ground electrode on the right earlobe. They found that patients with vocal nodules exhibited significantly greater surface EMG levels than vocally healthy controls both at rest and reading aloud monosyllabic words. Hocevar-Bolterzar et al. (1998) investigated the surface EMG characteristics of different muscle groups of the lower face and anterior neck during silence and vowel production in both dysphonic patients and controls with normal voice. Their study revealed that patients with hyperfunctional dysphonia demonstrated significantly greater EMG activities in thyrohyoid, suprahyoid, orofacial, and lower facial muscle sites than the normal controls.

In the aforementioned studies, absolute EMG levels were obtained for comparing between groups of speakers. However, absolute EMG-level values are highly affected by anatomical and physiological variability such as muscle fiber membrane characteristics and motor unit discharge rates (D. Farina, Cescon, & Merletti, 2002; Redenbaugh & Reich, 1989). Other non-physiological properties such as the size, shape and placement of the electrodes can also affect surface EMG signals (M. Farina, Merletti, & Enoka, 2004). Therefore, comparing muscle activities across subjects, time, muscles and studies based on absolute EMG levels would be problematic. In view of this variability issue, normalization has been suggested as a solution. According to Dankaerts and colleagues (2004), EMG normalization is the process by which the magnitude of muscle activation is expressed as a percentage of that muscle's activity during a calibrated test condition. Examples of calibrated tests include at rest, maximal voluntary contraction and 50% maximal voluntary contraction. Redenbaugh and Reich (1989) compared the absolute and normalized EMG levels in assessing hyperfunctional dysphonia. They found that hyperfunctional dysphonic subjects demonstrated significantly higher absolute EMG levels than vocally healthy subjects in tidal breathing and different speech tasks including vowel prolongation and passage reading. The absolute EMG levels of each subject's vowel prolongation and passage reading were also used to derive proportions relative to his/her rest EMG, maximal EMG and 50% maximal EMG. Their results revealed that group differences remained significant after normalization relative to the maximal and 50% maximal EMG levels. Their study suggests that normalizing EMG signals can be a valid procedure to differentiate dysphonia and non-dysphonic voices. However, the reliability of the assessment procedure was not investigated in their study.

Establishing the reliability of an assessment procedure has significant clinical implications. It reveals whether the differences in performance over time in the same individual are due to the variability of the assessment procedure or a true change such as treatment effects (Mathur, Eng, & MacIntyre, 2005). Reliability reflects the degree of stability of a measurement, that is, similar results are obtained from assessing the same subject at different times using the same equipment (Van Dijk, 2000). It can be evaluated as short-, intermediate-, and long-term reliability with the use of different time frames (Knutson, Soderberg, Ballantyne, & Clarke, 1994). Other terms such as within-day and between-day reliability have also been used in the literature (Ng & Richardson, 1996). Previous studies of voluntary gross motor tasks using surface EMG suggest that, in general, the reliability of EMG measurements decreases with the increase in time gap between the two assessments. Higher reliabilities are obtained for within-day measurement than between-day measurement (Dankaerts et al., 2004; Hyun & Sherwood, 2005; Mathur et al., 2005).

The present study has two objectives. First, it aimed to investigate the use of absolute and normalized surface EMG signals in assessing hyperfunctional dysphonia. It was hypothesized that dysphonic individuals would demonstrate significantly greater EMG levels than non-dysphonic individuals. The second aim was to determine the reliability of surface EMG as a tool for assessing hyperfunctional dysphonia. The present study assessed two levels of short-term reliability of surface EMG in voice assessment including a few seconds time gap (i.e., within-block reliability) and a few minutes time gap (i.e., within-day reliability). The intermediate reliability was the between-day reliability. It was hypothesized that reliability of surface EMG measurements decreases with the increase in time gap between the two assessments.

Method

Participants

Fourteen dysphonic subjects (13 females and 1 male) diagnosed with different types of laryngeal pathologies caused by vocal hyperfunction and 14 control subjects with normal voice (13 females and 1 male) participated in the present study. All subjects were aged between 20 to 50 years old to avoid effects of puberty (under age 20) and aging (over age 50) (Colton & Casper, 1996). All subjects had no history of neck and chest surgery and any form of neurological disorders. They also had normal hearing that they passed the hearing screening tested at 30 dBHL for octave frequencies between 0.5 kHz and 8 kHz. The two groups of subjects were matched in age (within two years of age). The mean age of the dysphonic group was 30.83 years (SD = 9.99; range = 20.8 – 49.3 years) and that of the control group was 30.41 years (SD = 10.29; range = 20.7 – 49.5 years).

The dysphonic subjects were recruited from patients attending the Voice Research Clinic at the University of Hong Kong and Tung Wah Hospital Voice Clinic. Table 1 lists the types of laryngeal pathologies in the dysphonic group. Subjects in the control group were recruited from the general population in the community. All the control subjects had no history or current voice, speech and hearing disorder. All control subjects had healthy voice that no breathiness and harshness were perceived during daily conversation, which was confirmed by two final year speech therapy students.

Table 1. Distribution of laryngeal pathologies in the dysphonic group

Laryngeal pathology		Number of subjects
Vocal nodules		5
Vocal fold thickening		5
Vocal fold edema		3
Polyps		1
	Total	**14**

Equipments

The ADInstrument (PowerLab Unit, Model ML 780, with eight-channel Dual Bio Amp Model ML 135) was used for capturing surface EMG signals. Silver/ silver chloride electrodes (10 mm diameter) with Ten 20 conductive EEG paste were used in order to reduce the impedance at sites of electrode contact. The SCOPE software program (ADInstrument PowerLab) was used to display and analyze the surface EMG signals.

Procedures

Participants took part individually in the experiment. They were seated comfortably and electrode placement was achieved after the relevant skin surfaces were lightly cleaned with alcohol and abrasive skin prepping gel. A pair of electrodes was then placed on thyrohyoid and orofacial muscle sites. For the orofacial site (OF), the electrodes were positioned on either side of midline, with 1 cm from the corner of the mouth. For the thyrohyoid site (TH), electrodes were positioned on either side of 0.5 cm from midline, over the thyrohyoid membrane. Figure 1 shows the OF and TH sites and the placements of electrodes. These two muscle sites were selected based on the study by Hocevar-Bolterzar et al. (1998) which indicated that dysphonic patients demonstrated increased EMG activities in these sites. Yiu et al. (2005) also demonstrated that these two sites were able to capture relatively stable surface EMG signals. A dry-earth strap was then attached firmly around the participant's wrist. After these devices have been positioned, participants were asked to rotate their heads to ensure lack of movement artifact in the EMG recording.

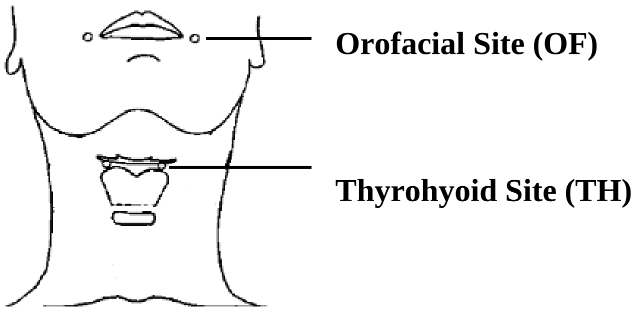

Figure 1. Placement of the surface EMG electrodes

Tasks

Surface EMG activities were measured from a non-speech task and three speech tasks. The non-speech task involved tidal breathing for 6 seconds. All the speech tasks were performed at the participant's own most comfortable pitch and loudness level:

1. Sustained vowel prolongation of /a/ for 6 seconds
2. Reading aloud the sentence /ba ba da gɔ gɔ/ (i.e., Father hits elder brother)
3. Reading aloud the standard passage 'The North Wind and the Sun'

Two non-speech maximal voluntary contraction tasks were also carried out for the normalization process.

1. Maximal voluntary contraction (MVC): To achieve the MVC for orofacial muscles, participants were asked to retract their lips at their maximum extent for 6 seconds. For the

thyrohyoid site, participants were asked to place the chin on a stationary platform and flex the neck by exerting a maximal downward force on the platform for 6 seconds.

2. 50% of the maximal voluntary contraction (50% MVC): Repeat the procedures for achieving MVC but subjectively embodied half the effort expended during the MVC for 6 seconds. Each participant was introduced with a self-rated scale: the force exerted for MVC was given an arbitrary value of ten units and the participant was required to exert a force of five units for the 50% MVC. A one minute rest was given between trials to avoid muscle fatigue.

One investigator conducted all testing. Each task was repeated five times to evaluate within-block reliability. All tasks described above were repeated after 30 minutes on the same day. This was to evaluate within-day reliability. The same procedures were repeated after 7-day-time with the same time of the day as Day 1 to evaluate the between-day reliability. The first testing day was referred to as Day 1 and the second testing day as Day 2. Figure 2 is the diagrammatic representations of the procedures.

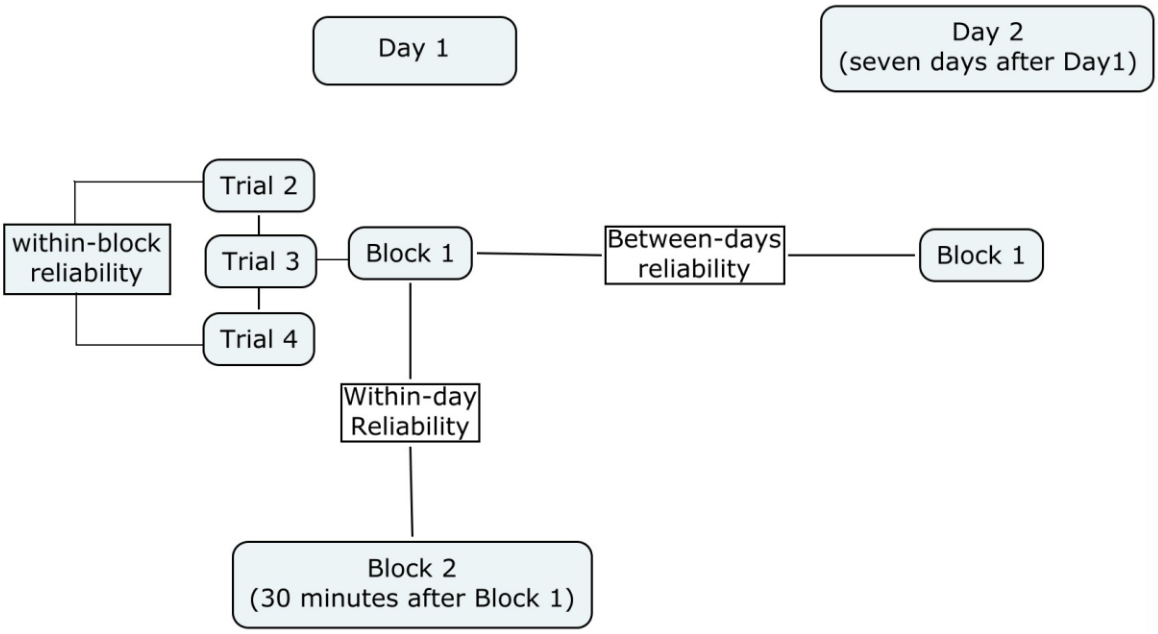

Figure 2. Flow of assessment illustrating different levels of reliability.

Data Analysis

Signal processing

Surface EMG signals collected from the thyrohyoid and orofacial sites were band-pass filtered at 10 to 500 Hz (Day, 2002). The middle two-second portion of EMG signal was extracted for the middle three trials (i.e., 2nd, 3rd and 4th trials) of tidal-breathing, sustained vowel prolongation, MVC and 50% MVC. For sentence and passage production, the whole portion of the production was analyzed. Signal amplitude, defined as the root-mean-square (RMS) voltage in microvolts, was computed for each segment using the SCOPE program.

Statistical analyses

Independent *t*-tests were performed to evaluate if there was any significant difference between the vocally healthy control and the dysphonic group. Because three *t*-tests were carried out on the EMG values obtained from each task, the p-level was adjusted to 0.017 (0.05/3) in order to minimize risks of Type I and Type II errors. Intraclass correlation coefficient (ICC) and standard error of measurement (SEM) were obtained to determine the reliability. According to Stratford (1989), ICC and SEM are the correlative measures of reliability. ICC is the ratio between the between-subjects variance and within-subjects variance, and it ranges from 0 to 1. When the within-subjects variance is relatively smaller than the between-subjects variance, it leads to a high ICC values which approaches one. Fleiss (1986) suggested that ICC values in the range of 0.75 to 1.0 are regarded as "good reliability". SEM illustrates the magnitude of fluctuations in the measurements that also reflects reliability of the measurement. SEM was calculated using the equation: $\mathrm{SEM} = S_X \sqrt{1 - \mathrm{ICC}}$ where S_x was the pooled standard deviation for all participants. For within-block, within-day and between-days, the SEM was expressed as a percentage of the grand mean by averaging SEM with the sum of means of the corresponding measures (i.e.,

%SEM). ICC and %SEM are the complementary measures of reliability. When the values of ICC are the same, the smaller the %SEM, the more reliable is the measure.

Inter- and intra-rater reliability for data extraction

Because data extraction of EMG values involved visual judgment on the EMG waveform, inter- and intra-judge reliability of the data extraction procedure had to be established. Twenty-five percent of the total number of EMG samples (i.e., 1344 samples) was repeated. They were analyzed by the investigator on a second occasion, two weeks after the first analysis. This was to evaluate the intra-rater reliability. These samples were analyzed by another examiner to evaluate the inter-rater reliability. When the values obtained on two occasions were within 0.5 μV, the segmented signals were considered to be agreed.

Results

Reliability measures of signal segmentation

The results of inter- and intra-rater reliability are shown in Table 2. The result showed quite good reliability for the two measures.

Table 2. Results of intra-rater and inter-rater agreement on data extraction based on two criterion levels.

	Difference < 0.5 μV
Intra-rater reliability	79.98% (1075/1344)
Inter-rater reliability	76.63% (1026/1344)

Differences between dysphonic and control groups

Table 3 and Table 4 list the group means and standard deviations of EMG measures obtained from orofacial (OF) and thyrohyoid (TH) sites respectively. For both the OF and the TH sites, there were no significant differences in the maximal voluntary contraction (MVC) and 50% MVC between dysphonic and control groups. For the OF site, the dysphonic group demonstrated significantly greater absolute sentence EMG level and absolute passage EMG level than the control. They also demonstrated significantly greater normalized sentence EMG level (50% MVC) and normalized passage EMG level (50% MVC) than the control subjects.

For the TH site, the dysphonic group demonstrated significantly greater absolute EMG values than the control group in all tasks except the absolute sentence EMG levels and absolute passage EMG levels. The dysphonic group also demonstrated significantly greater normalized EMG (MVC and 50% MVC) values in all tasks.

Table 3. Means and (standard deviations) of EMG absolute and normalized values for different speech and non-speech tasks obtained at the orofacial site.

Measures	**Dsyphonic Group Mean (SD)**	**Control Group Mean (SD)**	**p-level**
At rest			
Absolute level	7.60 (2.4)	7.35 (2.78)	0.80
Normalized EMG (AL/ MVC)	0.17 (0.09)	0.19 (0.31)	0.78
Normalized EMG (AL/ 50% MVC)	0.49 (0.24)	0.42 (0.33)	0.60
Vowel			
Absolute level	10.18 (2.55)	8.13 (2.96)	0.06
Normalized EMG (AL/ MVC)	0.21 (0.1)	0.17 (0.15)	0.35

Normalized EMG (AL/ 50% MVC)	0.63 (0.27)	0.44 (0.23)	0.06
Sentence			
Absolute level	32.82 (15.71)	19.29 (4.16)	0.007*
Normalized EMG (AL/ MVC)	0.68 (0.36)	0.44 (0.52)	0.18
Normalized EMG (AL/ 50% MVC)	1.93 (0.78)	1.04 (0.57)	0.002*
Passage			
Absolute level	36.14 (14.81)	20.29 (3.40)	0.002*
Normalized EMG (AL/ MVC)	0.73 (0.36)	0.41 (0.32)	0.02
Normalized EMG (AL/ 50% MVC)	2.16 (0.93)	1.06 (0.44)	0.001*
MVC	61.70 (39.72)	75.27 (49.74)	0.43
50% MVC	20.71 (12.8)	23.31 (12.79)	0.60

Note. * p< 0.017; AL = absolute level; MVC = maximal voluntary contraction

Table 4. Means and (standard deviations) of EMG absolute and normalized values for different speech and non-speech tasks obtained at the thyrohyoid site.

Measures	**Dsyphonic Group Mean (SD)**	**Control Group Mean (SD)**	**p-level**
At rest			
Absolute level	6.18 (1.83)	3.90 (1.37)	0.001*
Normalized EMG (AL/ MVC)	0.48 (0.35)	0.19 (0.11)	0.009*
Normalized EMG (AL/ 50% MVC)	0.87 (0.48)	0.42 (0.22)	0.005*
Vowel			
Absolute level	9.67 (2.57)	5.92 (2.06)	0.0001*
Normalized EMG (AL/ MVC)	0.68 (0.38)	0.27 (0.13)	0.001*
Normalized EMG (AL/ 50% MVC)	1.27 (0.55)	0.61 (0.31)	0.001*

Sentence			
Absolute level	19.93 (11.47)	12.91 (5.25)	0.05
Normalized EMG (AL/ MVC)	1.33 (0.86)	0.55 (0.28)	0.005*
Normalized EMG (AL/ 50% MVC)	2.38 (1.01)	0.22 (0.51)	0.001*
Passage			
Absolute level	20.74 (11.63)	14.24 (6.15)	0.08
Normalized EMG (AL/ MVC)	1.38 (0.74)	0.59 (0.29)	0.002*
Normalized EMG (AL/ 50% MVC)	2.46 (0.86)	1.31 (0.50)	0.0001*
MVC	19.22 (12.12)	30.50 (22.37)	0.11
50% MVC	9.54 (7.03)	12.82 (8.64)	0.28

Note. * $p < 0.017$; AL = absolute level; MVC = maximal voluntary contraction

Reliability analyses of surface EMG measure

Within-block reliability

The middle three trials (2nd, 3rd and 4th) of each task were obtained for evaluating within-block reliability. ICC and %SEM values for the absolute EMG level, normalized (MVC) and normalized (50% MVC) values of the OF and TH sites are listed in Table 5 and Table 6 respectively.

All of the measures of OF and TH sites of both speaker groups showed high to very high within-block reliability in both indices, of ICC and %SEM. For OF site of dysphonic groups, the ICC of absolute EMG level, normalized (MVC) and normalized (50% MVC) are with means 0.94, 0.87, and 0.95 accordingly; the %SEM of the three measures with means 3.41%, 6.98% and 3.46% accordingly. The OF site of control group shows similar results (ICC with means 0.94, 0.98 and 0.95 and %SEM with means 3.01%, 4.78% and 3.97% for the three measures accordingly). For TH site of dysphonic groups, the ICC of the three measures are with means 0.94, 0.93 and 0.90; %SEM with means 3.43%, 5.30% and 4.96% accordingly. Comparative results was found for the normal speaker with ICC means 0.97, 0.96 and 0.92; and %SEM means 4.01%, 3.52% and 4.61% for the three measures accordingly.

Table 5. Within-block intraclass coefficient (ICC) and percentage of standard error of measurement (%SEM) of the orofacial site

Measures	**Absolute**		**Normalized (AL/MVC)**		**Normalized (AL/ 50% MVC)**	
	ICC	**%SEM**	**ICC**	**%SEM**	**ICC**	**%SEM**
Dysphonic						
At rest	0.94	2.63	0.88	7.52	0.96	3.42
Vowel	0.95	2.00	0.87	6.40	0.91	4.50
Sentence	0.98	2.06	0.90	6.08	0.95	2.94
Passage	0.82	6.56	0.82	7.90	0.96	2.96
MVC	0.97	3.54	--	--	--	--
50% MVC	0.97	3.65	--	--	--	--
Mean	0.94	3.41	0.87	6.98	0.95	3.46
Control						
At rest	0.95	2.91	0.99	4.09	0.99	3.17
Vowel	0.92	3.72	0.97	4.98	0.93	4.87
Sentence	0.89	2.56	0.98	6.05	0.94	4.58
Passage	0.95	1.35	0.98	3.98	0.95	3.26
MVC	0.98	3.41	--	--	--	--
50% MVC	0.95	4.11	--	--	--	--

Mean	0.94	3.01	0.98	4.78	0.95	3.97

Note. AL = absolute level; MVC = maximal voluntary contraction

Table 6. Within-block intraclass coefficient (ICC) and percentage of standard error of measurement (%SEM) of the thyrohyoid site

Measures	**Absolute**		**Normalized (AL/MVC)**		**Normalized (AL/ 50% MVC)**	
	ICC	**%SEM**	**ICC**	**%SEM**	**ICC**	**%SEM**
Dysphonic						
At rest	0.87	3.86	0.96	5.09	0.92	5.74
Vowel	0.85	3.90	0.93	5.46	0.88	5.51
Sentence	0.98	2.97	0.92	4.05	0.90	4.77
Passage	0.97	3.08	0.89	6.61	0.90	3.82
MVC	0.97	3.79	--	--	--	--
50% MVC	0.99	2.98	--	--	--	--
Mean	0.94	3.43	0.93	5.30	0.90	4.96
Control						
At rest	0.96	2.48	0.97	3.74	0.94	4.39
Vowel	0.98	1.59	0.97	2.42	0.93	4.86
Sentence	0.99	1.47	0.95	3.99	0.90	4.64
Passage	0.91	4.48	0.95	3.94	0.89	4.55
MVC	0.98	3.17	--	--	--	--
50% MVC	0.98	2.91	--	--	--	--
Mean	0.97	4.01	0.96	3.52	0.92	4.61

Note. AL = absolute level; MVC = maximal voluntary contraction

Within-day reliability

ICC and %SEM values of within-day for the absolute EMG level, normalized (MVC) and normalized (50% MVC) values of OF and thyrohyoid TH sites are listed in Table 7 and Table 8.

Considering the OF site of dysphonic group, the ICC of absolute EMG level, normalized (MVC) and normalized (50% MVC) are with means 0.85, 0.74, and 0.77 accordingly; the %SEM of the three measures with means 6.60%, 12.96% and 10.34% accordingly. The OF site of control group shows results of ICC with means 0.80, 0.96 and 0.96 and %SEM with means 6.26%, 11.15% and 5.07% for the three measures accordingly. For TH site of dysphonic groups, the ICC of the three measures are with means 0.82, 0.86 and 0.54; %SEM with means 7.71%, 11.70% and 15.85% accordingly. For the normal speaker, results show that ICC are found with means 0.88, 0.72 and 0.86; and %SEM means 4.95%, 12.37% and 9.34% for the three measures accordingly.

Table 7. Within-day intraclass coefficient (ICC) and percentage of standard error of measurement (%SEM) of the orofacial site.

Measures	**Absolute**		**Normalized (AL/MVC)**		**Normalized (AL/ 50% MVC)**	
	ICC	**%SEM**	**ICC**	**%SEM**	**ICC**	**%SEM**
Dysphonic						
At rest	0.65*	9.62	0.67*	16.55	0.64*	16.56
Vowel	0.92	3.87	0.76	11.53	1.00	0.00
Sentence	0.71*	10.49	0.64*	15.35	0.73*	12.09
Passage	0.98	2.93	0.89	8.40	0.69*	12.70
MVC	0.96	5.13	--	--	--	--

50% MVC	0.87	7.54	--	--	--	--
Mean	0.85	6.60	0.74*	12.96	0.77	10.34
Control						
At rest	0.55*	11.84	0.88	25.55	0.88	12.73
Vowel	0.66*	9.56	0.97	8.18	1.00	0.00
Sentence	0.88	3.31	0.99	5.40	0.98	3.53
Passage	0.87	2.98	0.98	5.47	0.96	4.01
MVC	0.94	4.42	--	--	--	--
50% MVC	0.87	5.43	--	--	--	--
Mean	0.80	6.26	0.96	11.15	0.96	5.07

Note. * ICC < 0.75; AL = absolute level; MVC = maximal voluntary contraction

Table 8. Within-day intraclass coefficient (ICC) and percentage of standard error of measurement (%SEM) of the thyrohyoid site.

Measures	**Absolute**		**Normalized (AL/MVC)**		**Normalized (AL/ 50% MVC)**	
	ICC	**%SEM**	**ICC**	**%SEM**	**ICC**	**%SEM**
Dysphonic						
At rest	0.56*	10.91	0.89	12.25	0.62*	17.92
Vowel	0.70*	7.60	0.90	9.32	0.57*	14.92
Sentence	0.91	8.48	0.84	12.08	0.42*	16.77
Passage	0.98	4.00	0.81	13.13	0.54*	13.80
MVC	0.83	8.50	--	--	--	--
50% MVC	0.91	6.77	--	--	--	--
Mean	0.82	7.71	0.86	11.70	0.54*	15.85

Control						
At rest	0.55*	10.28	0.78	13.15	0.90	9.53
Vowel	0.89	6.26	0.44*	17.90	0.77	12.43
Sentence	0.95	4.11	0.82	10.04	0.87	8.80
Passage	0.99	2.09	0.85	8.40	0.90	6.59
MVC	0.94	3.62	--	--	--	--
50% MVC	0.96	3.34	--	--	--	--
Mean	0.88	4.95	0.72*	12.37	0.86	9.34

Note. *ICC < 0.75; AL = absolute level; MVC = maximal voluntary contraction

Between-days reliability

The between-days reliability results of OF and TH sites are listed in Table 9 and Table 10 respectively.

Considering the OF site of dysphonic group, the ICC of absolute EMG level, normalized (MVC) and normalized (50% MVC) are with means 0.75, 0.60, and 0.77 accordingly; the %SEM of the three measures with means 10.08%, 15.48% and 11.56% accordingly. The OF site of control group shows results of ICC with means 0.63, 0.74 and 0.80 and %SEM with means 10.79%, 25.85% and 13.78% for the three measures accordingly. For TH site of dysphonic groups, the ICC of the three measures are with means 0.75, 0.79 and 0.54; %SEM with means 11.24%, 14.33% and 17.45% accordingly. For the normal speakers, results show that ICC are found with means 0.82, 0.45 and 0.56; and %SEM means 8.81%, 20.19% and 15.34% for the three measures accordingly.

Table 9. Between-days intraclass coefficient (ICC) and percentage of standard error of measurement (%SEM) of the orofacial site.

Measures	**Absolute**		**Normalized (AL/MVC)**		**Normalized (AL/ 50% MVC)**	
	ICC	**%SEM**	**ICC**	**%SEM**	**ICC**	**%SEM**
Dysphonic						
At rest	0.61*	10.93	0.43*	20.74	0.50*	18.82
Vowel	0.81	5.01	0.48*	16.25	0.87	9.11
Sentence	0.68*	11.81	0.74*	13.18	0.83	9.48
Passage	0.59*	11.62	0.76	11.76	0.88	8.82
MVC	0.93	7.64	--	--	--	--
50% MVC	0.86	13.47	--	--	--	--
Mean	0.75	10.08	0.60*	15.48	0.77	11.56
Control						
At rest	0.25*	16.81	0.63*	44.27	0.80	18.46
Vowel	0.70*	8.95	0.84	15.45	0.83	12.10
Sentence	0.41*	9.44	0.67*	29.20	0.78	13.19
Passage	0.82	3.75	0.83	14.47	0.78	11.36
MVC	0.93	8.01	--	--	--	--
50% MVC	0.64*	17.75	--	--	--	--
Mean	0.63*	10.79	0.74*	25.85	0.80	13.78

Note. * ICC < 0.75; AL = absolute level; MVC = maximal voluntary contraction

Table 10. Between-days intraclass coefficient (ICC) and percentage of standard error of measurement (%SEM) of the thyrohyoid site.

Measures	**Absolute**		**Normalized (AL/MVC)**		**Normalized (AL/ 50% MVC)**	
	ICC	**%SEM**	**ICC**	**%SEM**	**ICC**	**%SEM**
Dysphonic						
At rest	0.55*	10.19	0.72*	20.30	0.56*	19.40
Vowel	0.68*	8.11	0.86	11.44	0.58*	16.62
Sentence	0.93	7.48	0.86	11.21	0.62*	15.47
Passage	0.83	11.82	0.73*	14.36	0.41*	18.29
MVC	0.65*	18.86	--	--	--	--
50% MVC	0.87	10.97	--	--	--	--
Mean	0.75	11.24	0.79	14.33	0.54*	17.45
Control						
At rest	0.93	4.29	0.50*	25.98	0.76	14.32
Vowel	0.51*	9.92	0.74*	16.12	0.69*	15.77
Sentence	0.86	6.70	0.18*	21.80	0.35*	17.41
Passage	0.83	7.85	0.36*	16.86	0.45*	13.86
MVC	0.91	10.81	--	--	--	--
50% MVC	0.87	13.31	--	--	--	--
Mean	0.82	8.81	0.45*	20.19	0.56*	15.34

Note. * ICC < 0.75; AL = absolute level; MVC = maximal voluntary contraction

Discussion

The present study had two main objectives. The first objective was to investigate the use of surface electromyography (EMG) to differentiate patients with hyperfunctional voice disorder from control subjects with normal voices. Three EMG measures, namely the absolute EMG levels, normalized data derived by maximal voluntary contraction, or MVC (i.e., ratio of absolute EMG level to MVC) and by 50% MVC (i.e., ratio of absolute EMG level to 50% MVC). Results revealed that dysphonic subjects demonstrated significantly greater EMG activities than non-dysphonic subjects. The second objective of this study was to determine the short-term reliability (i.e., within-block reliability and within-day reliability) and the intermediate reliability (i.e., between-days reliability) of surface EMG in assessing dysphonia. Results revealed that, as hypothesized, reliability decreased with the increase in time interval between the two EMG assessments.

Differences in surface EMG activities between the dysphonic and control groups

Both speaker groups were able to control the orofacial muscles and thyrohyoid muscles similarly at the maximum and moderate force levels, achieving comparable levels of EMG activity during the MVC and 50% MVC tasks at both muscle sites.

Orofacial (OF) site

Considering the OF site, hyperfuncational speakers in the present study evidenced significantly higher absolute EMG values (i.e., more tense) in sentence and passage reading than the control speakers. The significant increase in EMG levels in patients with hyperfunctional voice disorder might due to the generalized hyperfunction around the laryngeal region that leaded to increase in muscle activities around the lips and jaws. The result also suggested that the excessive muscle activities in OF sites might characterize hyperfunctional speakers only during speech tasks that involved more complicated muscle coordination such as sentence and passage reading. Speech task that involved relatively simple orofacial muscle coordination such as sustained vowel prolongation might not be able to differentiate between dysphonic and control subjects.

The present results revealed that for the OF site, normalized EMG values of sentence and passage reading by using MVC and 50% MVC were not able to differentiate dysphonic from normal controls in a sensitive manner. This might due to the reason that the maneuvers used in the present study to elicit MVC and 50% MVC (i.e., lips retraction) at the OF site might not be eliciting the true value. Thus, it is recommended for future study to determine the appropriate maneuvers.

Thyrohyoid (TH) site

Considering the TH site, vocally hyperfuncational speakers in the present study evidenced significantly higher absolute and normalized EMG values (by MVC and 50% MVC) at rest and during sustained vowel prolongation. The hyperfunctional speakers also demonstrated excessive muscle activities only in normalized EMG values (for both normalization by MVC and 50% MVC) for sentence and passage reading.

The excessive muscle activity during phonation in vocally hyperfunctional speakers might due to vocal misuse behaviors. Hyperfunctional speakers demonstrated significantly higher EMG levels at rest indicated that excessive muscle activity in the anterior-neck musculature may characterize the hyperfunctional speakers even when they are not speaking. This finding matched with that of Redenbaugh and Reich (1989) but not Hocevar-Bolterzar et al. (1998). Redenbaugh and Reich (1989) found that excessive muscle activities was shown in hyperfunctional speakers even when they are not speaking while Hocevar-Bolterzar et al. (1998) found that no difference was found between the EMG rest level of two speaker groups.

This suggested that surface EMG activities of TH site obtained from rest (i.e., tidal breathing) was not a sensitive way for differentiating dysphonic from control speakers.

Besides, as the vocally hyperfunctional speakers demonstrated significantly higher values in normalized EMG level (by using both MVC and 50% MVC) but not the absolute EMG levels in sentence and passage reading. These results suggested that normalized EMG values were more sensitive in identifying patients with hyperfunctional voice disorder. This might due to the fact that normalization minimizes anatomical and physiological variability between subjects (Redenbaugh & Reich, 1989). Thus, normalization was recommended in voice assessment in order to have a more sensitive result.

In summary, TH site is more promising than the OF site in differentiating vocally hyperunfunctional individuals from vocally healthy individuals. In addition, normalization is more promising than absolute EMG levels for comparisons.

Reliability analyses of surface EMG measures

According to the scale by Newell and Carlton (1985) concerning the level of reliability, the present study showed very high within-block reliability, high to very high within-day reliability and only moderate to high between-days reliability in both OF and TH sites.

The highest reliability was found for within-block reliability. The degree of reliability became lower for the within-day reliability, and the lowest for the between-days reliability. The decrease in reliability with the increase in time-gap might due to the re-application of the electrodes. Previous studies showed that EMG variables were highly affected by electrode location even when it was only a minor change in the position of the recording electrodes over the muscle (Dankaerts et al., 2004; D. Farina et al., 2002; Mathur et al., 2005). Both within-day and between-days measures required the re-location of electrodes. As no re-location of electrode was applied for within-block analysis, it is not surprised that its reliability was the highest. Although both within-day and between-days reliabilities required the re-location of electrodes, between-days reliability was lower than the within-day reliability. One of the main factors might be the uncontrolled intensity and pitch levels. In the present study, the subjects were asked to perform all the speech tasks with their most comfortable loudness and pitch levels. According to Hong, Ye, Kim, Kevorkian and Berke (1997), extrinsic laryngeal muscle activities change with pitch and vocal intensity levels. Thus, it was recommended for the future study to control the intensity and pitch levels of the subjects in order to reduce the confounding factors for determining the between-day reliability.

In summary, the reliabilities suggest that surface EMG can be quite reliable (consider the moderate-to-high between-days reliability).

Limitations of the present study

There are certain limitations in the present study that warrant further investigations. First, vocal intensity and pitch levels were not controlled for speech tasks. The subjects were asked to perform the speech tasks at their habitual pitch and loudness levels. Future studies should thus ask subjects to carry out speech tasks with pitch and intensity levels prescribed.

On the other hand, Redenbaugh and Reich (1989) pointed out that the surface EMG levels in male were generally higher than in female speakers no matter the speakers exhibited normal or vocal hyperfunctional behaviors. Unequal numbers of female and male participants were involved in this study. Equal number of females and males in each group should be used for future studies.

Conclusions and Clinical Implications

In conclusion, the results of the present study indicated that surface EMG measures of muscle activities could be used as a clinical tool for differentiating hyperfunctional dysphonic speakers. The use of thyrohyoid site and normalization of absolute EMG amplitudes were recommended.

Furthermore, the results showed that reliability of surface EMG measures increases with decrease in time gap between the two assessments. It was recommended that the assessment session for using surface EMG should be kept in a minimum duration in order to have a reliable result. In addition, as the between-days reliability was the lowest for all the three measures, special precautions should be taken when using surface EMG to evaluate the treatment outcome. For example, assessments should be done at the same time of the day. Checklist that ensures similar daily routines between the time-gap of the two assessments should also be given to patients for reducing variability in physical demands and mental stress so as to increase the between-days reliability.

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