【総説】

嚥下表面筋電計測に影響を与える要因
：システマティックレビュー

ヴエン ティ ハン，柴本 勇

聖隷クリストファー大学大学院　リハビリテーション科学研究科

E-mail: 18dr02@g.seirei.ac.jp

FACTORS AFFECT SWALLOWING SEMG
: SYSTEMATIC REVIEW

Nguyen Thi Huu Hanh，Isamu Shibamoto

Seirei Christopher University, Graduate School of Rehabilitation Sciences

抄録

背景：表面筋電（sEMG）計測時に影響するファクターは，摂食嚥下リハビリテーションや評価のクオリティに影響する．本研究の目的は，咀嚼や嚥下中時の筋活動を計測する際の電極貼付部位，体または頭の位置の影響を調査することである．

方法：健常成人の咀嚼および嚥下中の筋活動について，（1）咬筋，舌骨上筋，舌骨下筋の筋活動の記録時の電極貼付部位，（2）頭部位置，体幹姿勢の筋活動計測への影響に焦点を当て調査した．

結果：検索結果として 396 の文献を抽出した．選定基準に従って選定した結果，最終的に 15 の英文献と和文献を特定した．電極貼付部位については，筋活動指標で高い再現性が示された．電極貼付部位は，（1）咬筋：頬骨からオトガイまでの距離の中央．（2）舌骨上筋群：オトガイから下顎角までの距離の 3 分の 1．（3）舌骨下筋群：甲状軟骨の前部突出部分で，前正中線の横 1cm．体幹と頭部の姿勢は，sEMG の結果に影響することがわかった．頸部角度 90 度で垂直在姿勢が筋活動への外因として影響が少なく望ましい計測姿勢であった．

結論：被験者間で sEMG が異なることが予測され，sEMG を用いる研究においては，電極貼付部位，体幹，頭部姿勢の変化によって結果に影響する可能性がある．電極貼付部位，体幹姿勢，頭部姿勢による影響を最小限に抑えるために，常に同一のプロトコルに組み入れ表面筋電計測を行う必要がある．

キーワード：表面筋電図（sEMG），嚥下活動，電極位置，体位，頭位

Key words：sEMG，swallowing activity，electrode position，body position, head position

I) Introduction

Surface electromyography (sEMG) has been used in swallowing-related research since the 1950s when Doty Robert and Bosma James conducted a study regarding reflex deglutition in animals[1]. Scientists proved the high correlation between sEMG and physiological movement when chewing or swallowing and the correspondence in the direction of the muscle groups in Videofluoroscopic swallowing study (VFSS)[2, 3]. Although dysphagia evaluation was mainly based on the result of instrumental equipment such as the VFSS or Fiberoptic endoscopic evaluation of swallowing (FEES), disadvantages of VFSS and FESS limits their usage in clinical assessment. In contrast, sEMG is a safe and portable instrument, non-invasive and inexpensive tool to use in dysphagia rehabilitation. However, sEMG signal can be affected by some factors and lead to changes in the signal result. The factors affecting sEMG record includes two groups: (1) Biological factors and (2) Technical factors. The biological factors affect the sEMG is in correlation with motor unit, containing (1) Muscle action: the task requirement, movement speed, and direction determine the motor unit recruitment (2) Muscle fatigue: this factor has a relationship with the density of muscle fiber. Type I and type II fiber are two types of the motor unit, and they are different in each individual (3) Energy metabolism and oxygen availability: plays an essential role in the regulation of MU recruitment and firing frequency[4, 5].

Technical factors that affect EMG include (1) Electrode placement (2) Inter electrode distance (3) Type of electrode[6]. While the biological factors are different and dependent on the subject physical condition and not influenced by external factors, technical aspects were showed to be able to be controlled. Using the same type of electrode and keeping the inter-electrode distance unchanged, identifying electrode position using the same method in all subjects helps eliminate the measurement bias. Electrodes need to be placed in parallel to the muscle fiber. The first step is to identify muscle position based on anatomy landmark. Although muscle groups related to chewing and swallowing is relatively small and lies just below the skin, the anatomy point that best reflects the muscle activity is still not consistent[7, 8]. Accordingly, the correlation between environmental factors and sEMG signal in the subject should be checked before assessing the sEMG pattern. Therefore, we conducted a systematic review to describe the effect of electrode position and body and head posture in the muscle activity during chewing and swallowing measured by using sEMG in healthy adults.

II) Methods

This review aims to answer the following questions: 1) Do small changes in electrode positions and head or body positions affect the signal of the muscle activity of the

masseter muscle, suprahyoid muscle and infrahyoid muscle recorded by the sEMG during chewing and swallowing movement? 2) Which is the appropriate protocol for conducting an experiment involved in using sEMG? A comprehensive literature search was carried out from July to December 2019 to find studies that mentioned information regarding using sEMG in the evaluation of chewing and swallowing and the difference in electrode placement, body and head positions. The studies reported about the repeatability of sEMG in different sections of measurement also being included in this systematic review. The search was conducted in both the English and Japanese language to minimize the bias due to language restrictions in only English. Databases searched for articles included PubMed and Cochrane (English language) and 医中誌 Web and CiNii (Japanese language). The keywords were surface electromyography, electrode position, head position, swallowing, 表面筋電図, 電極, 嚥下, 姿勢, 再現性, 変異. Key words were search in "All fields", with the example of searching query in PubMed was ((surface electromyography) AND (electro position)) AND (swallowing) and in 医中誌Web was (表面筋電図 AND 嚥下 AND 電極)

III) Results

1) Searching results

Records identified through database searching are 396 articles. Hand search for relevance studies resulted in 3 studies. The removal of duplicates resulted in 376 articles to analyze further. After that, titles and abstracts were then screened by using the question in table 1 includes details about healthy adult subjects aged over 18 and using sEMG to evaluate chewing and swallowing. Research must report the effect of electrode placement or head position on the results of sEMG. Because testing food also affects the outcome of sEMG, the study involved using different types of food testing other than water or saliva swallowing test or the same food were excluded from the systematic review. Figure 1 summarizes the yield of the literature search strategy. Table 1 consisted of exclusion criteria which were used for the preliminary screening process, including screening and eligibility process. After finishing the initial investigation for the studies, we had 15 studies to include in the final process. Using questions in table 2, the information in those articles were extracted and synthesized. Risk of bias in each article regarding participant selection, the detection of measurement, attrition or missing data and reporting of results were summarized in Table 3.

2) Characteristics of included studies and outcome measures

All 15 studies focused on young and healthy subjects. Mean age ranges from 19.9 ± 3.5 years old[9] to 32.5 ± 6.4 years old[10]. There were 4 studies focused on changes between electrode position and 12 studies

described the difference between body or head position during trials. For swallowing evaluation, all studies used the simple saliva swallowing test, or water swallowing test as an assessment method.

3) Electrode position and sEMG muscle activity

Most of the studies used the same protocol for suprahyoid muscle which was mentioned in the reviews of Pencherz H and Winneberg A, 1983; Winnberg et al., 1988 as placing the electrode on the skin close to the anterior surface of the digastric muscle on the left side[11, 12]. One study put the electrode on the skin on both sides of the midline under the chin. Especially, electrode was placed on the anterior submental surface over the right and left mylohyoid muscles, adjacent to the submental midline to examine only the mylohyoid forces[13]. Taro Okitsu et al. used various positions of the electrode to detect most effectively electromyogram of the suprahyoid when swallowing. Muscle activity was shown highest in the position of one-third of the distance from the mental protuberance to the mandible angle[14]. One study used a total of 42 electrodes to record muscle activity simultaneously. Integral values were compared by using the analysis method in considering other distribution of sEMG signals such as sex, age. The study results were in correspondence with the finding that the central regions delivered the most apparent sEMG signals[15]. One study examined the sEMG signal using maximum voluntary clench and showed that sEMG muscle activity in the masseter muscle had high reliability regardless of electrode position[16]. The other study investigated the reproducibility of the sEMG test and concluded that there was no significant difference in the recording peak amplitude within and across sessions[17]. That two studies identified the high reproducibility of the electrode placement for swallowing-related muscle activity recorded by sEMG. The position to recorded infrahyoid muscle activity was determined on the anterior prominent part of the thyroid cartilage, 1 cm laterally to the anterior median line[9, 18], or on the side of the sternohyoid muscle had the duration of infrahyoid muscle activity in studies of approximately 0.95s to 1.25s[10, 19].

4) Head or body position and sEMG muscle activity

Different head posture, as well as body positions were examined in twelve studies. Three articles studied the following works with head supported: standing, seated upright, supine and lateral decubitus. The former two studies proved that for the masseter muscle, the EMG activity in the supine position was significantly lower than in the standing and seated position ($p<0.05$)[20]. Moreover, in 2006, after adapting the sEMG results by age, gender, body position and jaw posture tasks, Miralles study showed that suprahyoid activity was unchanged in different body positions ($p=0.939$), but infrahyoid EMG activity was

higher in lateral decubitus position than in standing position (p=0.028)[9]. Interestingly, the latter study adjusted suprahyoid EMG activity by age, gender, breathing type and body positions but the study revealed that during swallowing there was no significant difference in muscle activity between body posture (seated upright p=0.840; lateral decubitus p=0.988)[21].

Two studies investigated the sEMG parameter of the suprahyoid muscle using a set of different body angles at 90°, 60°, 30° and supine 0°. One study stated that there was no significant difference between the positions in the rising time and peak amplitude of the sEMG (p>0.05), whereas, for the latency, duration and falling time, the difference of muscle activity between positions was observed (p<0.001)[22]. The other study described a significant difference in the muscle activity between the upright position and different position on the time from the start to the peak of the integrated suprahyoid EMG (p<0.05)[23].

The effect of head position or neck angle on sEMG muscle activity was reported in five studies. Masuda's study in 2001 using the head in the middle position, the forward direction and the extended position, proved that the average maximum amplitude of the sEMG is lowest in the central position [24]. The study using the head position in the median, flexion 40°, 20°, and extension 40°, 20° pointed out that there was a significant difference in the duration of sEMG in head-extended 40°. Additionally, in both suprahyoid muscle and infrahyoid muscle, the period of muscle activity in extension 40 ° was prolonged in comparison with the flexion 40° and median position (p<0.05). One study investigated the effect of neck angle on the mylohyoid muscle using three head position: habitual position (HP), forward head posture (FHP) and optimal posture (OP). The results revealed peak muscle activity significant difference between HP-FHP and HP-OP (p<0.05). Muscle activity was reported to be most effective in habitual position with the lowest peak amplitude. However, the definition of the details of posture was not well explained[13]. There are two studies that combined the changes in body posture and neck angle. One study proved that there was no significant difference in the duration between chair sitting position and the 30-degree trunk side bend with the neck kept straight position[25]. One study analyzed muscle activity using 10g of jelly swallowing test in ten positions. The ten postures were the chin-up and chin-down posture in every body angle of 120°, 90°, 60°, 30°, and 0°. The duration and amplitude of muscle activity were significantly shorter and lower in the chin-down position than in the chin-up position in some body angle (p<0.05)[18].

IV) Discussion

1) Electrode position and sEMG muscle activity

The anatomy landmark plays a vital role in electrode placement in sEMG research. For

measure masseter muscle activity, it was merely asking the subject to do a clenching movement to identify the masseter. On the other hand, in swallowing, the suprahyoid muscles and infrahyoid muscles are groups of different muscles that take responsibility for important events. Therefore, muscle activity of those groups are combinations from different muscles. The question is that where is the position reflecting the activity of the whole suprahyoid or infrahyoid muscles, which means where is the best position to evaluate suprahyoid and infrahyoid muscles activation.

The electrode position for recording the swallowing-related muscle has high reliability. For swallowing evaluation by sEMG, the electrode positions were identified in the 19th century in the very first work of German scientists Erb W. 1886 and Remak E. 1909 and were clarified by using anatomical correlates by Goodgold J in 1975[26]. Many studies used the same position which was described in the old articles with an undetailed explanation about the exact anatomy point to identify the electrode positions. Some scientists used to place the electrode on the anterior belly of the digastric to record muscle activity of the suprahyoid muscle[9, 22, 23]. However, how to identify the digastric muscle in humans is difficult and different between people. The two studies re-evaluated the position for electrode placement of Taro Okitsu and Zaretsky stated the method used to identify the electrode position for the masseter muscle, suprahyoid muscle and infrahyoid muscle[14, 15]. The studies of Sforza (2011) and Maggie-Lee Huckabee (2012) have proved that sEMG activity has high reliability regardless of electrode position. Those results can be interpreted as the advantage of the surface electrode that can receive signals from multiple motor units[16, 17].

2) Head or body position and sEMG muscle activity

Overall, a lot of studies proved that body posture or head posture does have a substantial effect on muscle activity recorded by sEMG. Regarding the conclusion about the relationship of the neck posture and sEMG muscle activity, the parameters of sEMG were significantly different between head positions, especially in the extension 40° position. It may suggest that for extension posture, the muscle was used more than average and affects the swallowing process. Moreover, in the two studies combined the change of body and head posture, the result was different between the group with stable head posture and the group with unstable head posture. Sitting in a chair or side bend did affect the sEMG muscle activity. Moreover, there were differences in chin-down and chin-up posture between body angulation and between the suprahyoid and infrahyoid muscle activity. Since the swallowing muscle activity recorded in flexion or extension posture or incline body position were significantly different between postures, for the recommendation of using

sEMG, during swallowing, the subjects should be instructed to sit upright in a habitual comfort position and encouraged to maintain the head in the midline posture until completion of the swallowing task.

3) Limitations

Several limitations should be considered when interpreting our results. First, to minimize the selecting bias, we tried to conduct this systematic review in both English and Japanese articles. However, since the reviewer was not an English native speaker nor Japanese native speaker, viewing the full-text articles was recommended together with reading this systematic review. Second, regarding the studies bias, some reports did not explain the experimental condition in detail, for example how the head postures were measured and the electrode position, so in this systematic review, we were not able to fully understand about the method of some articles. Third, some articles only present the filtered data after comparing between groups or adjusted data, the outcomes must be interpreted with caution.

V) Conclusion

Along with scientific developments, the researcher is focusing on developing measuring techniques using sEMG. This review provides a more comprehensive look at the influence of factors such as electrode position and head or body posture while recording the sEMG by identifying the high repeatability of using sEMG in chewing and swallowing evaluation. The anatomy landmark plays an important role in electrode placement. There was a recommendation to measure sEMG bilaterally and to follow a detailed protocol regarding the head and body position. The upright sitting position is an appropriate option for dysphagia evaluation and swallowing rehabilitation.

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Appendix

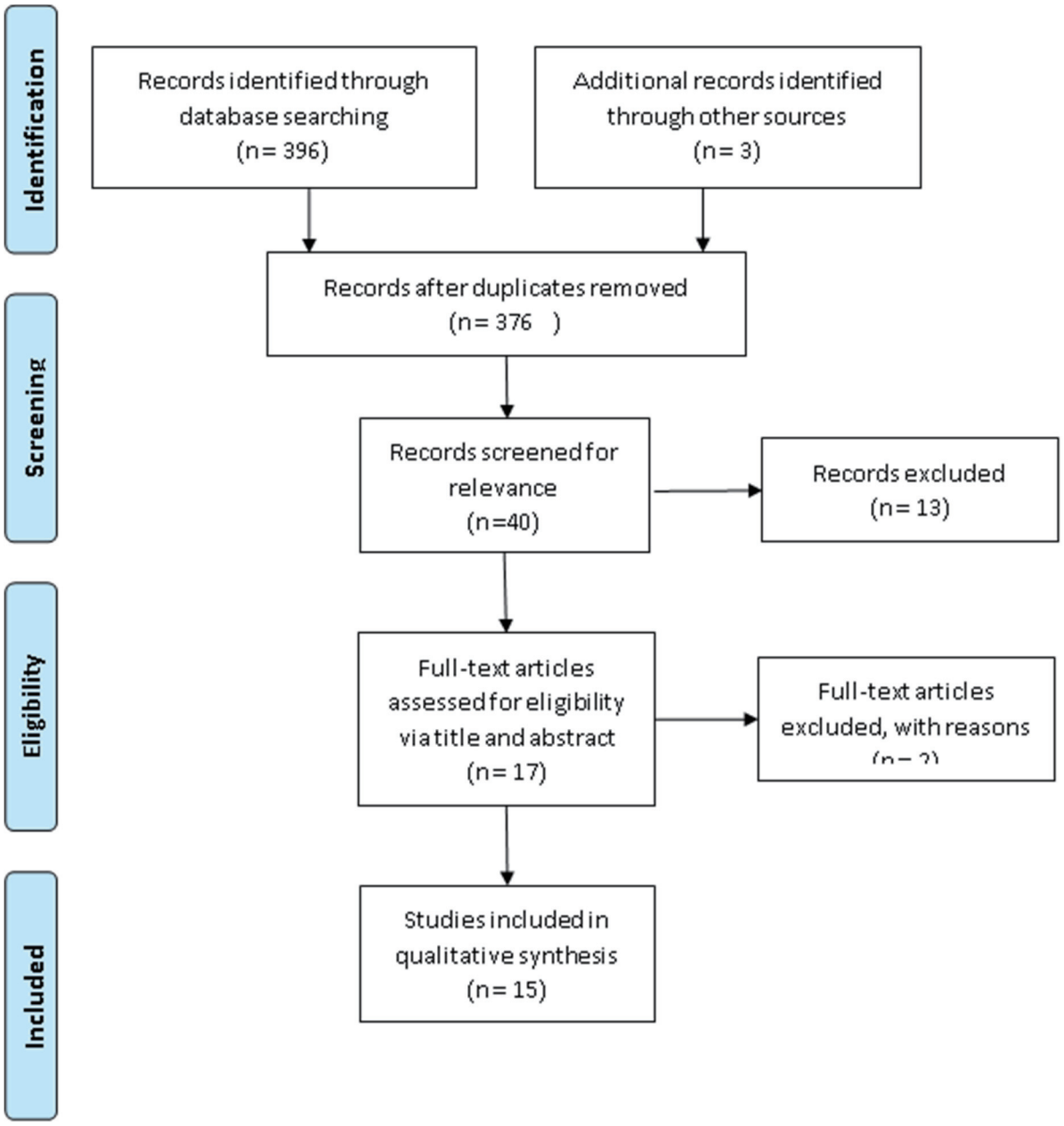

Figure 1: Summary of the yield of the literature search strategy according to the criteria laid out in the 2009 PRISMA guidelines for the systematic review.

Table 1: Exclusion Criteria for the screening of articles

Exclusion Criteria for the screening process
The study mentions other muscle instead of muscle activities of the masseter, submental group, or infrahyoid group.
The study used other types of EMG instead of surface electromyography.
The study focused on other groups of subject instead of healthy adults.
Exclusion criteria for eligibility
The study result focused on other conditions of muscle activity instead of on the difference of experimental condition.
The study used different experiment condition which affected the muscle activity instead of electrode position or head and body posture (For example different kinds of testing food.)

Table 2: Question used for analyzing final articles included in the review

The question used for the final analysis of included articles
What was the objective of the study?
What was the subject used in the study?
What is the author's definition of the electrode position OR the time in which the study occurred OR head or body position?
What kind of test was used?
What was the parameter of sEMG used for analysis?
How was the influence of different electrode position OR the time in which the study occurred OR head or body position on masseter, suprahyoid and infrahyoid muscle activity?
What was the author's conclusion?

Table 3: Risk of bias

Author	Year	Title	Risk of bias *	Type of bias
Taro Okitsu et al	1998	The Surface Electromyography on Suprahyoid Muscles during Swallowing.	+	No explanation of how to set up the head or body position
Zaretsky E et al	2017	Identification of the most significant electrode positions in electromyographic evaluation of swallowing-related movements in humans.	+	No information regarding detailed reported outcome on sEMG parameter
Sforza C et al	2011	EMG analysis of trapezius and masticatory muscles: experimental protocol and data reproducibility.	+	No information regarding detailed reported outcome on sEMG parameter
Maggie-Lee Huckabee et al	2012	Variability in Clinical Surface Electromyography Recording of Submental Muscle Activity in Swallowing of Healthy Participants.	-	
Miralles R et al	1998	Body position affects on EMG activity of sternocleidomastoid and masseter muscles in healthy subjects.	-	
Miralles R et al	2006	Body position and jaw posture effects on supra- and infrahyoid electromyographic activity in humans.	+	Unclear information regarding detailed reported outcome on sEMG parameter
De Mayo T et al	2005	Breathing type and body position effects on sternocleidomastoid and suprahyoid EMG activity.	+	No information regarding detailed reported outcome on sEMG parameter
Shiino Y et al	2016	Effect of body posture on involuntary swallow in healthy volunteers. Physiology and Behavior.	-	

Inagaki D et al	2007	Influences of body posture on the durations of oral swallowing in normal young adults.	-	
真寿田 三葉	2001	嚥下時の舌骨上筋群の活動に頸部のポジションが与える影響	+	Unclear explanation about the electrode position
乾　亮介	2011	頚部角度と舌骨上・下筋群の伸張性が嚥下筋の活動に与える影響について	+	No information regarding detailed reported outcome on sEMG parameter
乾　亮介	2012	Influence of Neck Position on the Activity of Pharyngeal and Neck Muscles during Swallowing – Examination by Surface Electromyography – (In Japanese)	-	
Holland T et al	2018	A preliminary study of the influence of sagittal plane neck alignment on mylohyoid activity during oropharyngeal swallowing: A surface electromyographic analysis.	+	Unclear explanation of the head posture
藤川純郎	2007	頚部の立ち直りが嚥下動態に及ぼす影響	+	Unclear explanation about the electrode position The vague description of the head posture
Sakuma T et al	2010	Relationship between ease of swallowing and deglutition-related muscle activity in various postures.	-	

（＊）participant selection, the detection of measurement, attrition or missing data and reporting of results

FACTORS AFFECT SWALLOWING SEMG: SYSTEMATIC REVIEW

Nguyen Thi Huu Hanh, Isamu Shibamoto

Seirei Christopher University, Graduate School of Rehabilitation Sciences

Abstract

Background: Factors during measurement with surface electromyography (sEMG) affect the quality of sEMG results in dysphagia screening and rehabilitation. This systematic review aims to summarize the position of electrode attachment and to investigate the effect of body and head postures on muscle activity during mastication and swallowing.

Methods: We examined the studies in healthy adults focused on (1) the electrode position of the masseter muscle, suprahyoid muscle and infrahyoid muscles and (2) the influence of head and body postures to muscle activity during mastication and swallowing.

Results: The search strategy produced 396 studies. Final searches identified 15 articles in both English and Japanese. Regarding the electrode position, muscle activity parameters were proved to have high repeatability. Recommendations for electrode positions are (1) Masseter muscle: The middle of the distance from the cheekbone to the mental angle; (2) Suprahyoid muscles: on the one-third of the distance from the mental protuberance to the mandible angle (3) Infrahyoid muscles: 1 cm laterally to the anterior median line on the prominent part of the thyroid cartilage. Although there were controversial between studies, body and head postures considerably influence in the sEMG result of swallowing muscles. Head in 90o position and upright sitting posture is recommended as having minimum impact on muscle activity.

Conclusions: Due to the variation of sEMG between subjects, those studies involved in muscle activity recorded by sEMG should have a reproducible and identical protocol to eliminate the influence of electrode position and changes in the body and head postures from sEMG.

Key words : sEMG, swallowing activity, electrode position, body position, head position