Identification of the biomechanical response of the muscles that contract the most during disfluencies in stuttered speech

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Abstract
Purpose: Identify the head and neck muscles that contract most frequently during stuttering episodes using electromyography (EMG) sensors.
Method: 55 volunteers with stuttering and 30 individuals without stuttering, aged between 18 and 40, participated in the study. We recorded EMG signals from five facial and cervical muscles during speech tasks. The signals were processed and analyzed for mean amplitude and frequency activity in the 5-15 Hz range to identify significant activity differences among the selected muscles. Also, we excluded participants with motor difficulties or silver allergies from the study.
Results: Analysis of EMG signal amplitude revealed a higher average amplitude in samples obtained from disfluencies in the group of participants without stuttering, specifically in the depressor anguli oris muscle ($p < 0.05$). Furthermore, when examining the frequency range of 5-15 Hz, a higher average amplitude was observed in the zygomaticus major muscle for participants with stuttering ($p < 0.05$).
Conclusions: Muscle activity did not significantly correlate with stuttering episodes in most examined muscles. However, the depressor anguli oris muscle exhibited higher overall activity during speech with disfluencies in participants without stuttering. In contrast, we observed higher activity in the 5-15 Hz frequency range during speech with stuttering, specifically in the zygomaticus major muscle. These findings contribute to a better understanding of the muscle dynamics in stuttering and may guide the development of targeted therapeutic interventions to improve speech fluency.

Plain language summary
This research paper focuses on how the muscles in our face and neck behave differently in people who stutter compared to those who don't. Stuttering is a communication disorder involving disruptions, or "disfluencies," in a person's speech. We used a technique called electromyography, which records the electrical activity of muscles. Particularly, we looked at the activity in the general and 5-15Hz frequency range, which is a specific band of muscle activity. We found that in people who stutter, some muscles in the face and neck showed different activity patterns, especially when these individuals were in stressful situations or certain contexts. These findings can help us better understand what happens physically when someone stutters. This could potentially guide the development of new methods for diagnosing and treating stuttering in the future.

Introduction
Stuttering is a speech disorder that significantly affects the quality of life and communication abilities of people who suffer from it. Although it affects approximately 1% of the world's population (Carlo, 2018), its exact origins still need to be fully understood (Ruiz, 2005). Many researchers believe that the development of stuttering may involve central nervous system function and genetic and language learning factors (Smith, 2017). Therefore, researching the physiological mechanisms and neurological processes underlying stuttering can provide valuable insights to develop more effective treatment strategies and enhance our understanding of this condition.
One of the methods used to analyze stuttering in speech is electromyography, a technology already used to characterize the specific muscles that contract during speech. Electromyography (EMG) is a method commonly used to analyze stuttering in speech. This technique has proven valuable as an assessment tool in various fields, including medical research for understanding

speech motor control, rehabilitation for evaluating muscle function in speech therapy, ergonomics for studying occupational voice use, and exercise science for analyzing muscle activity during vocal exercises (Miller, 1979).

Electromyography (EMG) has been used to analyze muscle activity during speech and characterize contraction during stuttering. Several investigations on stuttering and analyzing EMG signals from facial and neck muscles have been performed, mainly in adults who stutter (AQT). These studies have used surface electrodes placed on the skin to acquire EMG signals and analyze parameters such as muscle activity amplitude, duration, and latency.

These studies have observed key trends and findings in the muscle activity of adults and children who stutter (AQT and NQT). Some research has found increased muscle tension in the orofacial muscles during stuttering (Lieshout et al., 1993; Freeman & Ushijima, 1978), while others have not established a significant relationship between muscle activity and stuttering episodes (Denny & Smith, 1992; McClean et al., 1984; Smith et al., 1996). In addition, lateralization and, thus, asymmetry of muscle activity in the muscles of the face (de Felício et al., 2007; Choo et al., 2010) and involuntary oscillations of muscle activity in the 5-15 Hz frequency band have been observed in some adults who stutter (Smith et al., 1993; Denny & Smith, 1992). However, in children who stutter, the same oscillations in the 5-15 Hz band have not been found, and the presence of tremors was low, concluding that there is no significant relationship between stuttering episodes and muscle activity (Walsh & Smith, 2013)

The study of electromyographic (EMG) analysis of facial and neck muscles in individuals with stuttering has been the subject of numerous investigations in the scientific literature. However, there needs to be more recent publications addressing this topic. Moreover, the findings of these studies have yet to provide clear or definitive conclusions regarding muscle activity related to stuttering due to the diversity of results obtained in different investigations. In the pursuit of understanding and treating stuttering, there is still much to be discovered about its underlying mechanisms. In this regard, identifying the most active head and neck muscles during stuttering using EMG sensors is a crucial step for optimizing the understanding and treatment of stuttering. The study of EMG signals in these muscles can provide detailed information on muscle activity, coordination, and motor control during speech production, which may help identify specific patterns of muscle activity and dysfunction in individuals with stuttering. This research has the potential to contribute significant evidence that supports and refines previously proposed theories of stuttering, which still need to be corroborated.

This study identifies which facial muscles have a more pronounced biomechanical response during stuttering. The muscle activity of the following muscles is analyzed: orbicularis oris, zygomaticus major, depressor anguli oris, sternocleidomastoid, and masseter in participants experiencing stuttering episodes in speech. In addition, this work performs a study comparing the muscle activity of group A (without stuttering) and group B (with stuttering), involving 55 volunteers between 18 and 40 years of age. Fluent and disfluent speech samples are collected in different speech environments, considering different types of disfluencies: repetitive, prolonged, and blocking.

This approach will allow us to identify specific patterns of muscle activity in different conditions. This study has the potential to significantly enrich and update the current knowledge on the physiology of stuttering, which in turn could favour the development of more effective therapies for people affected by this condition.

Method

Ethical Aspects

A document was drafted and sent to the Research Ethics Committee for Life Sciences and Technologies of the Pontificia Universidad Católica del Perú. The manuscript was accepted on July 15, 2022, and received the opinion number N° 004-2022-CEICVyTech/PUCP. It specified the number of participants in the study, a detailed description of the experimental protocol, inclusion and exclusion criteria, procedure for access and administration of the data obtained, analysis of the data obtained, biosafety measures, and informed consent.

Participants

Inclusion criteria in Group A participants

Group A comprised adults aged 18 to 40 without a language and/or speech difficulties diagnosis, such as language development disorders, stuttering, tachyphemia, tachykalemia, and phonological disorder.

Inclusion criteria in Group B participants

Group B comprised adults with stuttering episodes in their speech and will exclude those who presented difficulties and/or motor disability.

Exclusion criteria

We applied exclusion criteria for participants in both groups, excluding those participants who presented motor difficulties or disabilities, such as cerebral palsy, dyspraxia, motor apraxia, and other problems related to coordination, limited reach, reduced strength, unintelligible speech, and fine and gross motor difficulties. We applied these criteria to prevent these conditions from affecting the test performance and result interpretation. Additionally, we excluded individuals with known allergies to silver metal (Ag) to avoid potential adverse reactions to the study materials.

Sample size

The study considered the statistical variables of population, confidence level, and margin of error to determine the necessary sample size. According to previous studies (Carlo, 2018), the prevalence of stuttering in the population is 1%(p=0.01). Extrapolating this statistic to the Peruvian context, we estimated that around 137,790 people between 18 and 40 years old in Peru suffer from stuttering, considering a population of 33 million people and a specific population of youth and young adults of 13 million 779 thousand Peruvians (INEI, 2021).
To calculate the required sample size, the equation that applies for an infinite population was used (Camacho-Sandoval, 2008), considering a confidence level of 95% (Za=1.96) and a maximum permissible error of 3% (d=0.03):

$$n_0 = \frac{z_a^2 * p(1-p)}{d^2}$$

Where Za is the confidence level, p is the percentage prevalence of the population, and d is the maximum permissible error. These criteria ensure that the obtained sample adequately represents the population under study. We performed the necessary calculations and determined that a

minimum of 43 participants would be required. However, for this research, we used an optimal sample of 55 young people and young adults aged 18 and 40 with stuttering.
On the other hand, we anticipated minimal variability in the data collected from the control group, consisting of individuals without stuttering. Therefore, a sample size of 30 individuals without stuttering would be sufficient.

Selection of groups A and B

This research selected a sample size of 85 youth and young adult volunteers between 18- and 40 years old living in Lima, Peru. We divided the sample of 85 participants into two groups: Group A, which consisted of 30 participants without stuttering, and Group B, which consisted of 55 participants with stuttering.
We contacted group A participants through social networks and close circles of the researchers. We invited those who met the inclusion and exclusion criteria to participate in the research and addressed any doubts they had. For Group B participants, we reached out through open social networks and virtual support group pages dedicated to stuttering. Additionally, we published announcements and videos on the laboratory's official website (GIRAB-PUCP).

Selection of muscles and biomechanical variables

In this research, specific criteria were used for selecting the muscles to be evaluated in the participants with stuttering. Recurrence, surface area, size, and appropriate position of the muscles were considered. Based on these considerations, the orbicularis oris, zygomaticus major, depressor anguli oris, sternocleidomastoid, and masseter muscles were selected because of their relationship to previous EMG measurements in participants with stuttering or laryngectomy-related research (Lieshout et al., 1993; Freeman & Ushijima, 1978).
As for biomechanical variables, average amplitude and activity in the 5-15 Hz frequency band during stuttering were assessed, as these variables have been shown to provide valuable information about the onset and severity of stuttering. (Esperanza, 2020; Smith et al., 1993; Denny & Smith, 1992).

Materials and devices

- A Panasonic HC-V520M video camera with 16 GB internal memory and 720p resolution that was placed on a tripod and used to record the entire trial.
- A 64-bit laptop, 2.0 GHz processor, 2 GB of system memory, and 128 MB of graphics memory used for data collection through the EMGworks software.
- Delsys EMG sensors that made it possible to measure 5 different muscle groups using computational tools that facilitate data management and collection. It has a sampling frequency between 2148 Hz and 4296 Hz, a resolution of 16 bits, a battery life between 4-8 hours, and 8 sensors (27x37x13mm) for 8 different muscles or muscle groups.
- Nexcare Transpore 3M adhesive tape to ensure good contact between the EMG sensor and the skin.
- Disinfectant and exfoliating wipes to clean and exfoliate the test subjects' skin before attaching the sensors.
- Printed informed consent sheets detailing the relevant aspects of the test to which the subject was subjected.

Procedure

Before the experimental procedure

We scheduled a maximum of three appointments per day, with one-hour intervals, considering the availability of the participants, researchers, and speech therapist, as well as the battery life of the sensors. The goal was to avoid overcrowding in the space where we conducted the research data collection.

Before gathering the participants and researchers in the experimental environment, the researchers confirmed their vaccination status, having received all three (03) doses of the COVID-19 vaccine. To verify their COVID-19 vaccination status, the researchers requested potential participants to provide their vaccination records, whether in electronic or physical format. Researchers instructed all participants to complete a virtual COVID-19 symptomatology form three days before the appointment using the Google Forms platform. If any participant displayed symptoms, the researchers excluded them from the research.

As shown in Figure 1, the experimental environment covered an area of 15 square meters and featured two desks. The first desk served as a placement for the sensors, laptop, and other necessary accessories necessary for the experiment. The second desk for placing the informed consent form, as well as disinfection and cleaning items for the use of the participants. The researchers positioned the camera on the first desk, ensuring it focused on the chair where they conducted participant interviews. They securely mounted it using a tripod or base if space was available.

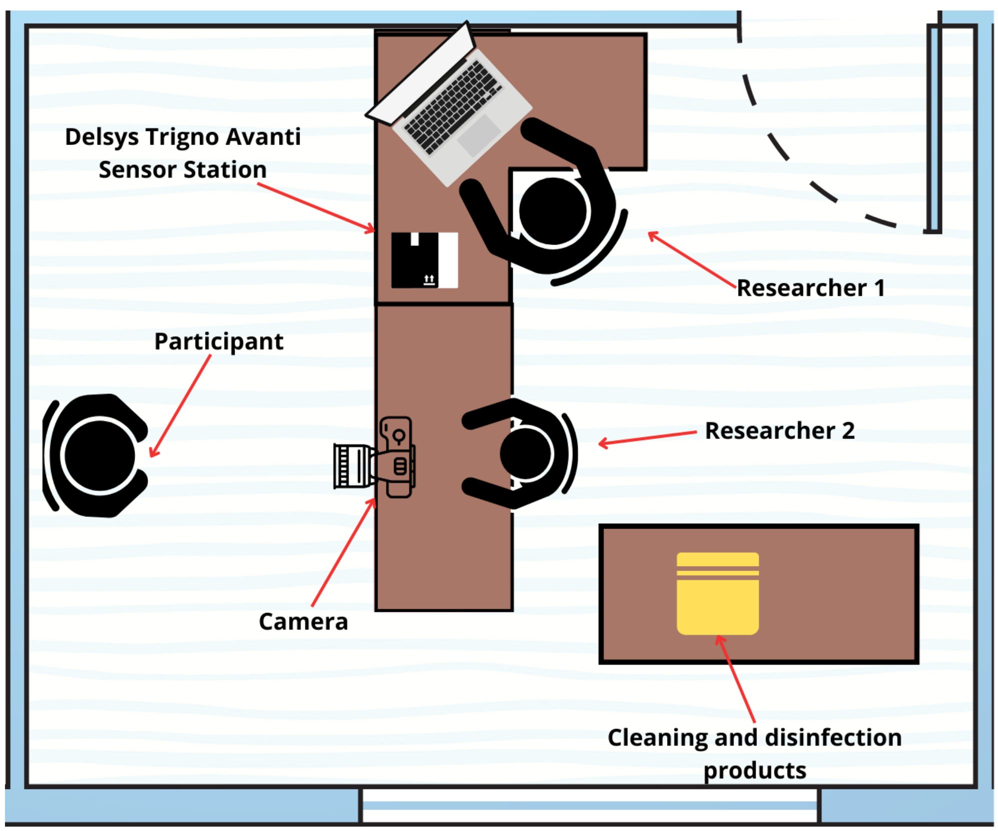

Figure 1. Own elaboration. Graphic illustration of the work area used for the tests.

The space where the data collection took place facilitated the free transit of the participants, had adequate ventilation and lighting, was cleaned correctly (including furniture, equipment, and accessories to be used), and the work tables were located in such a way as to guarantee a minimum physical distance of one meter between the participants. Before evaluating a new test subject, the instruments in contact with the previous test subject were disinfected using disinfectant wipes.
Before entering the classroom, all participants were asked to use alcohol gel and disposable paper towels for proper hand hygiene. Likewise, participants were always supervised to ensure they wore and adequately used their masks. Disinfectant wipes were used to clean the participant's face. Since the test subject had to remain unmasked during the test protocol, the investigators and the specialist always used double masks, face shields, and surgical gloves.

During the experimental procedure

With or without stuttering, participants signed an informed consent document to participate in the research. This was done in the classroom and as an initial part of the experimental procedure. One of the researchers oversaw handing out the documents to the potentially eligible participants for the research. The researcher made special emphasis on the fact that participation in this research is purely voluntary, that the person can withdraw from the study at any time without being affected in any way, and that the data collected are intended to be published for the scientific community without sharing personal data, and that there are no economic retributions for participating in the research.
Finally, the five Delsys EMG sensors were placed in the following muscles: masseter (E1); zygomaticus major (E2); sternocleidomastoid (E3); depressor anguli oris (E4); superior orbicularis superior (E5). The distribution of the sensors can be seen in Figure 2. It should be noted that a sixth sensor was used as a control in group B so that, when it was pressed, a signal peak was recorded each time a stuttering episode was detected, helping with the subsequent synchronization of the signal and the video. Likewise, when placing the EMG sensors, it was verified that the reference arrow of the sensor was aligned with the direction of the muscle fibers of the muscle to be analyzed. For better support and comfort of the test subject, the contact between the electrodes and the skin was ensured by Nexcare transpore 3M adhesive tape.

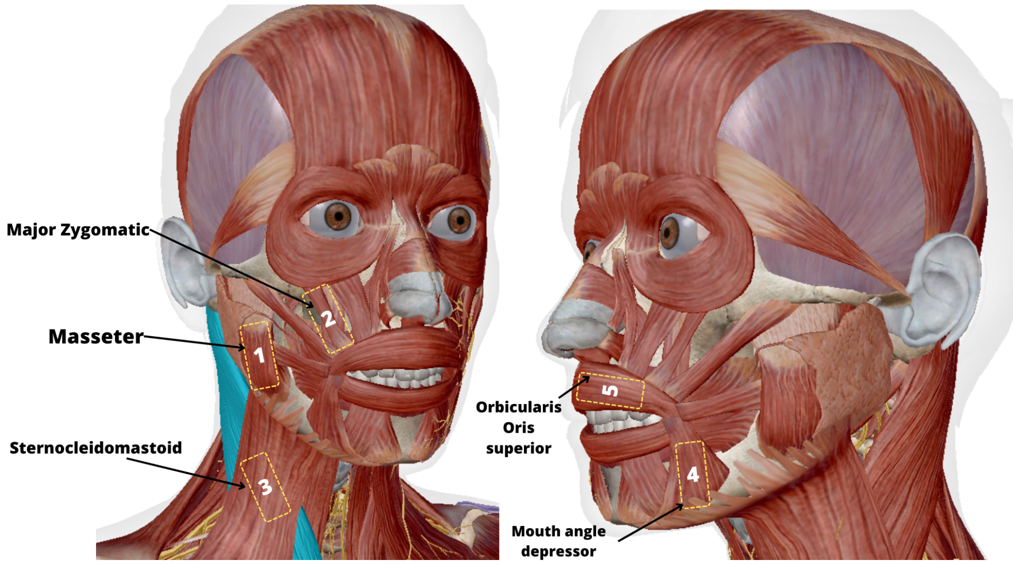

Figure 2. Graphic illustration of the distribution of the sensors around the face and neck, 1. Masseter, 2. Zygomaticus major R, 3. Sternocleidomastoid, 4. Depressor anguli oris, 5. Superior orbicularis oris.

The electrodes were placed, and the sensors synchronized with the EMG acquisition software, with a sampling frequency setting of 2148 Hz, a range of 11 mV, and a bandwidth of 20-450 Hz. After completing the software setup, the trial was initiated by turning on the chamber.
During the trial, four tests were performed: the first consisted of a spontaneous speech evaluation in which the participant was asked questions about his or her personal data, medical history, and educational background. The second test was a read-aloud of a text provided to the participant. The third test consisted of a telephone call to a trusted person to establish a casual conversation of approximately one minute. Finally, the fourth test focused on a brief presentation of roughly three minutes on any topic of interest to the participant.
After completing the tests, the camera and software recording was stopped to remove the sensors from the subject's face. Disinfectant wipes were provided for the subject's face, and the sensors were disinfected for later use.

Data collection

Samples of fluent speech and stuttering were collected from groups A and B. For each participant, 40 electromyography (EMG) signal samples with a duration of 1s were acquired during fluent speech. Similarly, all samples with the same period were extracted during disfluency speech.
To ensure the fluency of the speech samples, those containing any speech with disfluencies were excluded, and the selection of adjacent samples with a minimum time interval of 0.5s was avoided. On the other hand, speech samples with disfluencies were carefully selected so that these were contained partially or entirely within the time interval.

Data analysis

This study divided the collected data into 2 groups (A and B). For each participant in both groups, 5 EMG frames were acquired, corresponding to each muscle or muscle group, resulting in a total of 475 EMG frames to be processed. The "Delsys File Conversion Utility" tool was used to extract the EMG frames and convert them from .hpf to .mat format to perform the corresponding analysis. The EMG frames were between 650 and 1800 seconds long and operated on a millivolt (mV) scale. An EMG data sampling frequency (Fs) equal to 2149 Hz was set, a previously established value for data processing. A Nyquist frequency was also selected, which was used to calculate the signal's frequency spectrum.

Subsequently, two filters were designed; the first one consists of a low-pass FIR filter of order 20 with a cutoff frequency of 400 Hz to filter the EMG signal and eliminate the high-frequency noise. The second one consists of a FIR high-pass filter with a cutoff frequency of 20 Hz (Martinek et al., 2021) to remove low frequencies. The last one is a FIR band-reject filter to eliminate the 60 Hz interference and its harmonics, thus avoiding the ambient noise from the power grid.

The frequency spectrum of the filtered signal was calculated using the discrete Fourier transform (DFT), and the amplitude and power spectra were obtained. Then, the RMS envelope of the signal was found, and the rectified signal and the linear envelope were plotted. Finally, the RMS value of the signal was calculated and obtained.

The main objective of the data analysis is to evaluate muscle activity and the differences between muscles. For this reason, the biomechanical variable identified as the most important was the amplitude of the EMG signal because it is related to muscle activation and activity (Guzmán-Muñoz, 2018). In addition, a frequency analysis was performed in the 5-15Hz range to obtain the differences in muscle activity only considering a range of frequencies already identified as characteristic of disfluencies (Denny & Smith, 1992). The analysis was performed using Matlab software.

First, the analysis was run per participant; after applying a 60Hz noise filter to the signal, the amplitude of the EMG signal of the samples of fluent speech and speech with disfluencies was compared. For this purpose, the signal integral (IEMG) was performed, and the average was obtained for the speech and disfluencies samples. In the case of frequency analysis, the power spectral density was calculated for each of the samples, and the signal integral was calculated in the 5-15 Hz range; in addition, the total signal integral was obtained to calculate the percentage of muscle activity in the 5-15 Hz range concerning the total. This analysis was performed for each muscle in a participant, and the data obtained were stored in a format (.mat) for subsequent analysis.

Once the muscle activity data were obtained for each muscle and each participant, we proceeded to evaluate each muscle as a whole, that is, the data of all the participants as a whole, and thus establish in which of them there was a significant difference ($P < 0.05$) between fluent speech and speech with disfluencies. For each muscle to be evaluated, data were collected from each participant in group B for fluent speech and speech with disfluencies, and statistical analysis was performed. It was verified that the data complied with the requirements to perform the statistical t-student test of the Matlab statistics and machine learning toolbox, and the muscles that represented a significant difference were found. This procedure was repeated in the same way to compare group A vs group B disfluencies, group A vs group B fluent speech, and group A fluent speech vs group B disfluencies.

Results

Comparison between groups (A and B)

In both amplitude and frequency analysis, five specific muscles were evaluated: the depressor anguli oris (DAO), orbicularis oris (OO), masseter (M), sternocleidomastoid (S), and zygomaticus major (ZM).
In amplitude analysis, no significant differences were found for any muscle when comparing the signal amplitude between the fluent speech samples of both groups or when comparing the fluent speech samples of group A with the speech samples with disfluencies from group B. However, when comparing the disfluency speech samples of group A with the disfluency speech and fluent speech samples of group B, significant differences (p=0.0071 and p=0.0052 respectively) were found in the amplitude of the depressor anguli oris muscle, being higher in the case of group A by 214% compared to disfluency speech (Figure 3) and by 236% compared to fluent speech of group B.
As for the analysis of the activity in the frequency range 5-15 Hz, significant differences were found concerning the activity of the zygomaticus major muscle; this was higher in the samples of group B disfluencies than in the samples of group A fluent speech by 47% and that of disfluencies by 39% (Figure 4), corresponding to p=0.0004 and p=0.0041, respectively. Similarly, group B's fluent speech samples were more significant than group A fluent speech samples by 51% and disfluencies by 43%, corresponding to p=0.0001 and p=0.0016, respectively.

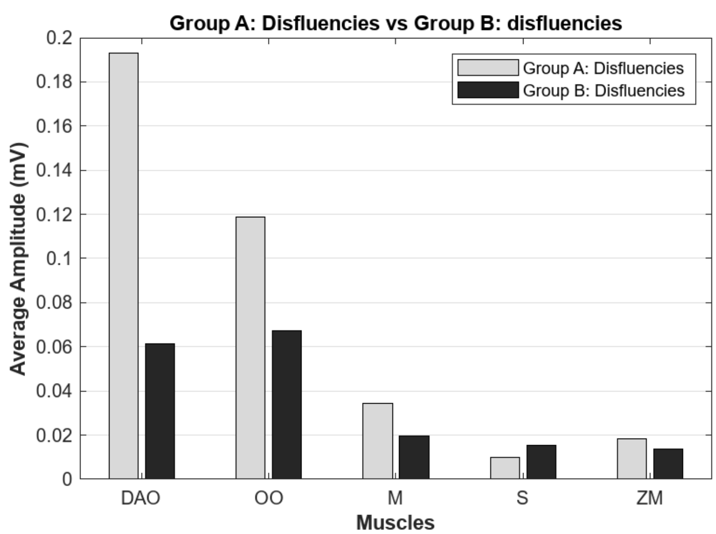

Figure 3. Comparison by muscle of the average amplitude between group A and group B disfluency speech.

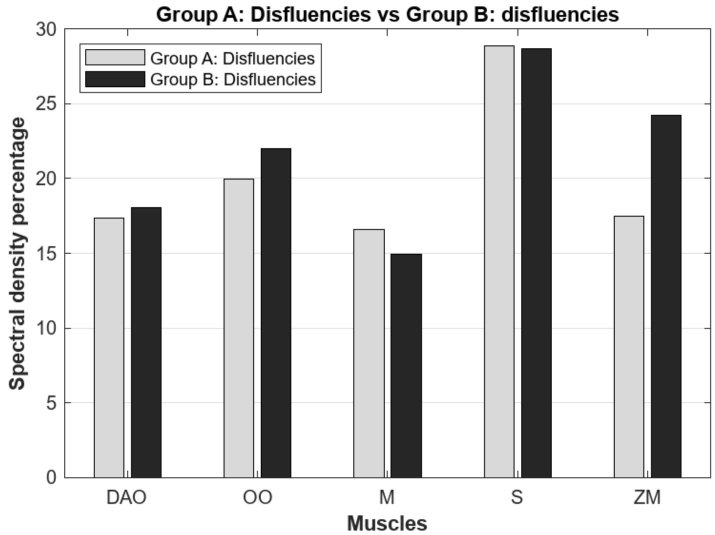

Figure 4. Comparison by the muscle of the percentage of spectral density 5-15 Hz between group B and group A speech with disfluencies.

Group A: Fluent speech and speech with disfluencies

In group A, a slightly higher average amplitude was found for the samples with disfluencies. However, no significant differences were found between fluent speech and speech with disfluencies (Figure 5). In the analysis of muscle activity at a frequency of 5-15 Hz, no significant differences were found in any muscle.

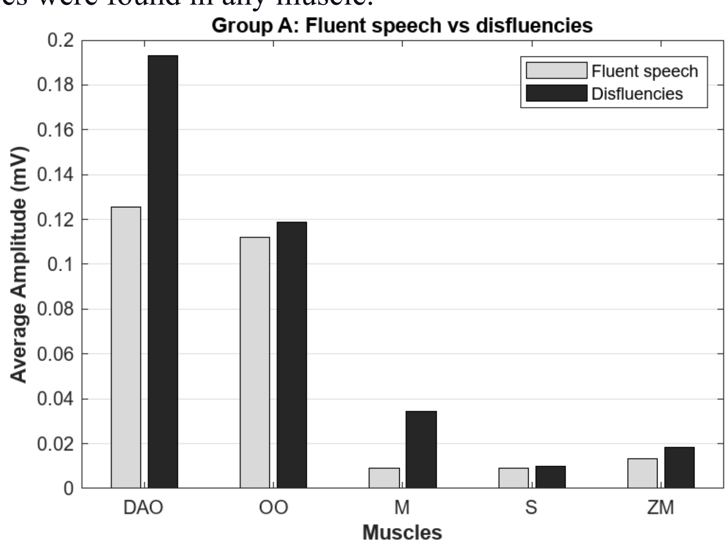

Figure 5. Comparison by the muscle of the average amplitude between the fluent and disfluent speech of group A.

Group B: Fluent speech and speech with disfluencies

In group B, no significant differences were found between the average signal amplitude of fluent speech or speech with disfluencies. For all muscles, a slightly greater amplitude was presented in the case of speech with disfluencies (Figure 6). In the analysis of muscle activity at a frequency of 5-15 Hz, no significant differences were found in any muscle.

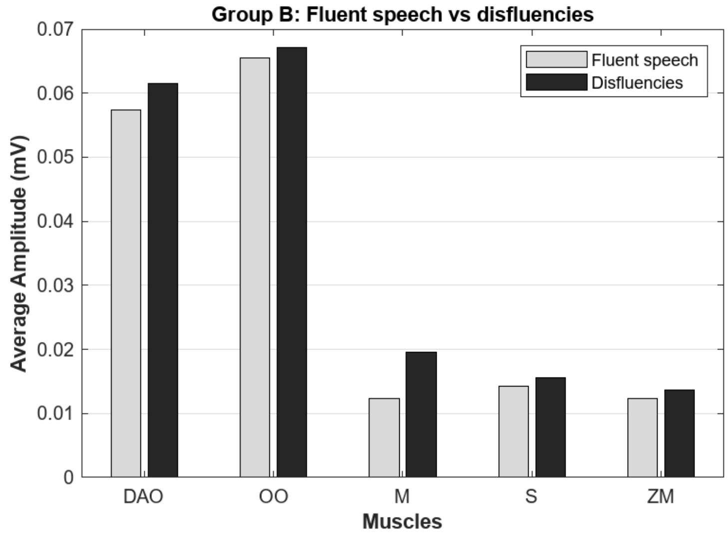

Figure 6. Comparison by the muscle of the average amplitude between the fluent and disfluent speech of group B.

Analysis in context

When the same analysis was performed, isolating the different phases of the test (personal data, reading, call, and exposition), slight variation was found in the results. The average amplitude calculated was broadly similar; however, in the case of the depressor anguli oris, the disfluency samples of group A presented a higher amplitude (p=0.0208) than the disfluencies of group B by 208% for samples collected during calls. Additionally, in the analysis of frequencies in the range of 5-15 Hz, in the case of speech in reading, it was found that when comparing the fluent speech of group A with the fluent speech and disfluencies of group B, the depressor anguli oris and masseter muscles presented a slightly greater muscle activity concerning the general analysis. Regarding the analysis of types of stuttering (repetitions, prolongations, blocks), it was found that, for repetitions, in the analysis of average amplitude, the zygomaticus major muscle had a significant difference (p=0.0311), where the disfluencies of group A presented greater amplitude than those of group B by 109%. In the case of the analysis of stuttering in prolongations, no differences were found in the patterns for the general analysis. In contrast, in the analysis of stuttering blocks, a higher average amplitude was observed for group B disfluencies compared to group A fluent speech (p=0.0422) in the sternocleidomastoid muscle, as speech with disfluencies presented a higher amplitude by 180% (Figure 7). Finally, the analysis at frequencies 5-15 Hz for blocks were similar and consistent with the overall analysis.

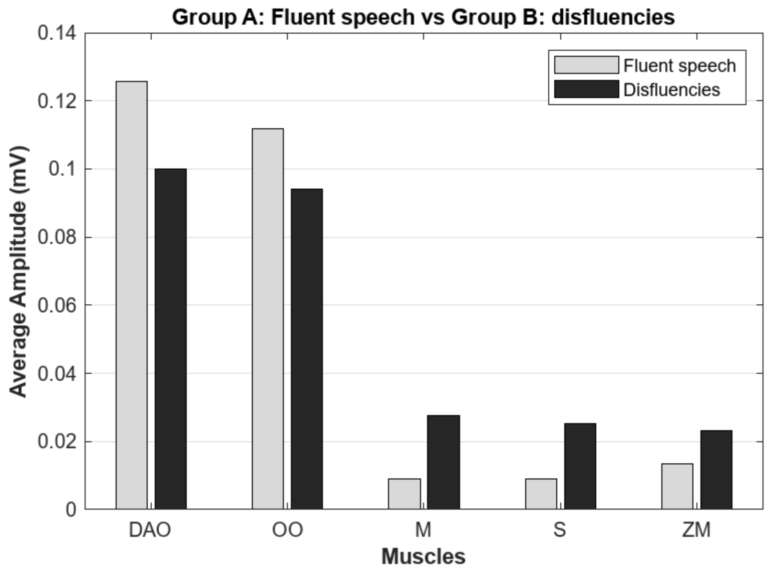

Figure 7. Comparison by the muscle of the average amplitude between the fluent speech of group A and disfluent speech with only stuttering blocks of group B.

Discussion

In this study, we evaluated the activation patterns of 5 facial and neck muscles in adults who do not stutter (Group A) and adults who stutter (Group B). The amplitude and activity analysis results in the 5-15 Hz frequency band were compared.

Comparison between groups (A and B)

In contrast to other studies, our results show no significant differences in EMG signal amplitude between the adult groups in most of the muscles examined. This suggests that the basic muscle activation patterns in adults who stutter and adults without stuttering are similar in amplitude and overall muscle activity.

However, significant depressor anguli oris muscle amplitude differences were observed when comparing group A disfluency speech samples with group B fluent speech samples and group A disfluency samples. These findings may contradict previous findings (Lieshout et al., 1993; Freeman & Ushijima, 1978) and indicate that, during stuttering, there may be less overall muscle activation in some muscles, such as the depressor anguli oris in adult stutterers. However, further research is needed to confirm this hypothesis.

Regarding the analysis at frequencies of 5-15 Hz, significant differences in the activity of the zygomaticus major muscle were observed in the 5-15 Hz frequency range. The activity was higher in group B compared to group A in all measurements, even between group B's fluent speech samples and group A disfluency speech samples. This result is consistent with some previous studies (Smith et al., 1993; Denny & Smith, 1992), where it is indicated that there is greater activity in the jaw, lip, and laryngeal muscles in that frequency band; however, unlike previous studies, the statistically significant difference was found only in the zygomaticus major muscle, while in the other muscles, there was greater activity by minimal difference.

Intragroup comparison: Fluent and dysfluency speech.

In group A, no significant differences in EMG signal amplitude were found between fluent and dysfluency speech samples. This finding is consistent with previous studies on disfluencies in adults who do not stutter (Denny & Smith, 1992; McClean et al., 1984; Smith et al., 1996).
On the other hand, in group B, we also found no significant differences in EMG signal amplitude between fluent and disfluency speech samples. These results are consistent with previous research that found no significant differences between the same study group (Smith et al., 1996). Additionally, the results contradict the hypothesis that adults who stutter have greater muscle activity in the facial muscles tested during stuttering episodes than in fluent speech.
Similarly, analysis at frequencies 5-15 Hz found no significant differences in comparing samples from the same fluent speech group and with disfluencies for either group. Similar to the amplitude analysis, the results show that, generally, in the same person, there is no difference in muscle activity between the disfluency samples concerning fluent speech in the 5-15 Hz frequency range.

Analysis of Stuttering in context

The frequency of stuttering episodes varied between individuals and circumstances. Participants reported experiencing more blocking and stuttering when calling acquaintances, possibly due to the stress generated by the situation and the associated head movement. Occasionally, telephone calls can generate stressful situations that produce signal disturbances.
A lower frequency of stuttering episodes was observed in participants in comfortable situations compared to more stressful ones. In addition, increased participants' stress levels were observed during speech pauses, resulting in a higher frequency and intensity of such pauses. These findings suggest that stress may play a crucial role in the occurrence and frequency of stuttering episodes. That context and environment may also influence the manifestation of these episodes in participants who stutter.
The results of the context signal analysis indicate a higher average amplitude in the zygomatic muscle compared to the general analysis during phone calls, during samples with disfluencies in group A compared to group B, which could be related to stress or nervousness in the conversation. Finally, in the analysis of different types of disfluencies in stuttering, it is noteworthy that a higher average amplitude was found in the EMG signal of the sternocleidomastoid muscle during blocks, presenting a significant difference compared to group A. Indicating a possible relationship between this muscle and blocks in stuttering.

Conclusion

In summary, this study suggests no significant differences in the amplitude and general muscle activity in most facial and neck muscles between adults who stutter and those who do not. However, significant differences were observed in the average amplitude of the depressor anguli oris muscle of samples with disfluencies in group A compared to samples from group B. In the analysis of muscle activity in the frequency range of 5-15 Hz, the zygomaticus major muscle presented significant differences, as the muscle activity was higher in group B samples than in group A. In addition, it is important to note that context and stress levels seem to influence the frequency and intensity of stuttering episodes. These findings provide useful information for identifying the muscles that exhibit greater activity during stuttering episodes, presenting new perspectives, or verifying previously found results. On a different note from previously found results, the urgency to continue research on this topic is highlighted by the continuous progression in the field of stuttering research.

Most importantly, the implications of these findings extend beyond the academic world. By shedding light on the distinct muscular activities that correlate with stuttering, the study paves the way for the development of innovative diagnostic and therapeutic methods. This understanding of stuttering at a physiological level could serve as a foundation for new interventions, focusing on the specific muscles with increased activity during stuttering. Consequently, this could potentially revolutionize the way stuttering is diagnosed and treated, offering those affected by this condition more effective and targeted therapeutic strategies in the future.

Conflict of Interest

There are no conflicts of interest.

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Author contributions

E. Marin and N. Unsihuay were both involved in data collection, recruitment of participants, as well as authoring the manuscript, however, their contributions diverged in specific areas. E. Marin played a role in data analysis and interpretation and N. Unsihuay specialized in signal processing. G. Paucar aided initially in data collection, recruitment of participants, had a significant role in the study's design, and was responsible for submitting the proposal for funding. V. Abarca offered valuable advisory services and supervision throughout the experiment's execution and the manuscript's writing process. Finally, D. Elias provided essential advisory support and facilitated the provision of equipment and tools necessary for the study.

Data availability statement

The data can be available by contacting Dante Angel Elias Giordano (girab@pucp.pe).

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Learning Outcomes

By examining the EMG signal activity of primary facial and neck muscles in stuttering and non-stuttering subjects, this study aims to facilitate several learning outcomes. It is anticipated that readers will be able to identify and define the key muscles monitored and the significance of the 5-15Hz frequency range used in EMG signal analysis (Knowledge). Furthermore, it is expected that readers will comprehend the implications of the observed differences in EMG activity between stuttering and non-stuttering subjects, and be able to articulate the impact of context and stress levels on the frequency and intensity of stuttering episodes (Comprehension). Through the application of this newfound knowledge, readers should be able to correlate these findings with potential real-world clinical or research contexts (Application). The capability to analyze the distinct EMG activities of the depressor anguli oris and zygomaticus major muscles is a further expected outcome of this study (Analysis). Finally, the study aims to enable readers to critically assess its methodology and findings and evaluate their implications for the broader understanding and treatment of stuttering, as well as compare these findings with previous research (Evaluation).