“Verification and quantification of surface electromyographic (EMG) activity of the masseter muscle”
Background

MIDDLE EAR MUSCLE CONTRACTION PROJECT

ELECTROMYOGRAPHY

STUDY PURPOSE
This study is part of a larger project studying the middle ear muscle response.

The middle ear muscle response is a commonly observed reflex in response to non-acoustic and acoustic stimuli (Moller, 1983).

Potentially serves as a protective mechanism for the ear (Fletcher et al., 1960).

Surface EMG recordings will be made from a number of muscle systems of the head, neck, and upper extremities during behavioral and reflexive tasks.
Electromyography (EMG)

- Allows direct measurement of electrical activity that a muscle emits during contraction.
- Can be recorded at skin surface or within muscle belly.
- Can be used in a variety of research and clinical settings.

Konrad (2006)
The Role of EMG in The Current Study

- Focuses on the EMG recordings from the sensor placed onto the skin over the face of the masseter muscle during a biting and chewing task.
- The masseter muscle is an essential muscle of mastication, elevating the jaw during biting and chewing tasks (Gilroy, MacPherson, & Ross, 2012).
- This is a muscle that has undergone extensive study pertaining to its role in chewing and speech tasks (e.g. Green et al., 1997; Moore, 1993; Smith & Ringel, 1988).
Monitoring of the Masseter Muscle

- The masseter muscle is being monitored during the behavioral (control) and reflexive tasks for many reasons
  - Shared innervation with the tensor tympani muscle (Mukerji, Windsor, & Lee, 2010).
  - Potential to elicit a middle ear muscle response has been recorded (Moller, 1983).

- Precise onsets and offsets of when the masseter muscle contracts and relaxes need to be established
  - Establish timing and magnitude of a standard (i.e. control) motor task (biting and chewing activity)
  - Examine for possible relations between masseter activation and middle ear muscle responses
Study Purpose

- Develop an algorithm for automated identification, quantification and characterization of the biting and chewing related EMG activity of the masseter.
- Provide descriptive statistics for biting and chewing behaviors from a group of study participants.
- Validate this control task and quantify the consistency of the EMG recordings within and across the participants involved.
Methods

PARTICIPANTS

INSTRUMENTATION

PROCEDURE

ALGORITHM DATA ANALYSIS
Participants

- Drawn from a larger pool of participants in the middle ear project.
- Inclusionary criteria must be met to participate in the experimental visit where the EMG recordings take place.
- 11 participants were excluded from the current study because they didn’t meet the inclusionary criteria.
- 3 participants were not included due to the presence of facial hair obstructing the EMG recording.
- 5 participants were excluded due to insufficient signals, not following directions, or three bite/chew sequences could not be visually identified in the signal.
- 28 total participants were used in this study.
- Ages for all participants ranged from 18-40 years
- 26 females, 2 males
Instrumentation

EMG Recording
- Delsys Bagnoli 8 channel EMG system
- Delsys 3.1 double differential electrode
- Gain setting: 1000

Middle Ear Recordings
- Etymotic ER10X

Data Acquisition
- A-D Conversion NI-4499 (44.1 KHz SF, 24 bit)
- Dell 7910 Workstation
- Matlab with DAQ Toolbox with custom written software
Procedure

- Locate the masseter muscle by palpating the area while the participant clenched and relaxed their jaw.
- Prepare skin surface for EMG sensor placement.
- Place the sensor onto the skin surface.
The Bite and Chew Control Task

- Assurances must be made for proper placement of the EMG sensors and for validation of EMG recordings by having the participant complete controlled tasks.
- A set of standardized instructions for the bite and chew task are provided.
- Observations are made to verify the quality of the EMG recording.
- After the sensors are placed, the ER10X probe is placed into the ear.
The purpose of creating this algorithm was to find the onsets and offsets of masseter activity during the biting and chewing task.

This algorithm was created in MatLab.

The algorithm goes through a series of steps to identify the onsets and offsets of masseter activity.
Step 1: Generate an RMS signal of EMG data

- Method for conditioning the raw EMG signal to better measure the amplitude of the masseter response

- Root Mean Square (RMS)
  - Square the data
  - Take an average (mean) of the data over the time window (50 ms)
  - Take a square root of the averaged data
RMS Overlay on a Raw EMG Bite and Chew Sequence

- **Raw Emg Signal**
- **RMS Function**

**Voltage (mV)**

**Time (Seconds)**

- From 29 to 37 seconds.
Step 2: Segmenting the Bite and Chew Sequence

- An interactive program is then used to segment out each bite and chew sequence to avoid measurement of inappropriate data
  - The first event in the sequence was flagged as a bite and the rest of the signals in the sequence were flagged as a chew
- After each bite/chew sequence is identified, the algorithm then runs through each sequence separately to identify onsets and offsets
Interactive Segmentation of the Bite and Chew Sequence

Bite/Chew Sequence 1

Bite/Chew Sequence 2

Bite/Chew Sequence 3
Step 3: Setting the 75\textsuperscript{th} Percentile and Finding Midpoints

- A 75\textsuperscript{th} percentile is used to determine the onsets and offsets of major masseter activity.
- Anytime the EMG signal passed over the 75\textsuperscript{th} percentile threshold, it was identified.
- The midpoints between offsets of one event and the onsets of the next are measured and marked.
- These midpoints became the boundaries for the window that the individual events were extracted from.
75th percentile Threshold and Midway Point of an RMS Signal

- **RMS Function**
- **75th percentile threshold**
- **Midway Point**

Voltage (mV)

Time (seconds)
Step 4: Extract Individual Event and Set 5% Threshold

- The individual events are then extracted out of the data from the window created by midpoints.
- A threshold was then determined that was 5% of the total peak value.
  - Anytime the data ascended through the 5% threshold, it was flagged as an onset.
  - Anytime the data descended through the 5% threshold, it was flagged as an offset.
Single Chew Event with 5% of Peak Threshold

- Individual RMS Chew Event
- Onset of Chew
- Offset of Chew
- 5% of Peak Threshold

Voltage (mV) vs. Time (seconds)
Step 5: Extracting Variables From the Data

After each event was labeled, the algorithm then extracted the following variables from each bite and chew series for each participant and placed them into an excel file:

- Duration of the bite and chew
- Emg_min: Minimum amplitude for each bite and chew
- Emg_25: The 25th percentile amplitude
- Emg_50: The 50th percentile amplitude
- Emg_75: The 75th percentile amplitude
- Emg_max: The max amplitude or the peak
- Emg_int: The area underneath the curve of each bite and chew
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Results

Descriptive Bite Statistics

Descriptive Chew Statistics

Algorithm Accuracy for Bite Events

Algorithm Accuracy for Chew Events
Bite Events: Descriptive Statistics

- Averages (mean) were taken of each variable extracted from the bite data
  - Mean Duration: 1.2 seconds
    - Range of duration values: 0.91-1.45 seconds (s)
  - Mean 50\textsuperscript{th} percentile: 48.8 microvolts (\(\mu V\))
    - Range of 50\textsuperscript{th} percentile values: 44.3-58.23 \(\mu V\)
  - Mean Peak Value: 104.2 \(\mu V\)
    - Range of peak values: 85.1-128.9 \(\mu V\)
  - Mean Area Under Curve (Integral): 54,428.53 \(\mu Vs\)
    - Range of integral values: 42,321.1-73,387.6 \(\mu Vs\)
Chew Events: Descriptive Statistics

- Averages were taken for each of the variables extracted from the data
  - Mean Duration: 0.44 seconds
    - Range of duration values: 0.29-0.82 seconds
  - Mean 50th Percentile: 54.9 µV
    - Range of 50th percentile values: 25.5-90.13 µV
  - Mean Peak Value: 118.7 µV
    - Range of peak values: 68.5-162.8 mV
  - Mean Area Under Curve (Integral): 25,170.2 µVs
    - Range of integral values: 12,465.7-49,708 µVs
Discussion of Statistical Results

- Typically, the bite events had a longer duration than the chew events.
- The bites also had a larger integral value than the chews.
  - The bite events had a larger area underneath them than the chew events.
- The chew events had more variability in the amplitudes of their signals than the bite events.
  - Greater range was observed for the chew events in both the 50\textsuperscript{th} percentile values and the peak values.
The algorithm was able to correctly identify the offsets and onsets of bites in 77% of bite events.
The algorithm was able to correctly identify the offsets and onsets of chews in 95% of chew events.
The algorithm was more successful in correctly identifying the chew events than the bite events for various reasons.
Algorithm Errors with Bite Events

- The bite signals were more variable in morphology than the chew signals.
  - Bite events looked very different across participants, but the chew events were consistently very similar looking across participants.
- The algorithm would occasionally identify two events within one bite event, thus incorrectly identifying the first chew onset
  - This was typically due to the signal dropping below the 5% threshold requirement (offset) and then rising back up (onset) during the bite event
Algorithm errors with the bite events:

- Late identification of the bite onset
  - Could be a 75\textsuperscript{th} percentile threshold issue
- Early identification of the bite offset
  - Signal drops below the 5\% threshold, denoting an offset.
  - The pause between that offset and the next potential onset would be less than the duration requirement of 200 ms.
  - This results in the algorithm not counting the onset of the next event
Algorithm Errors with the Chew Events

- The algorithm would occasionally not identify a chew event due to pause duration issues
  - The pause between the offset of the previous chew and the onset of the current chew was less than 200 ms, so the current chew was ignored

- Some of the chews in the signal would consist of two short events within the single chew
  - This lead the algorithm to separate the chew into two events and only count the second event, resulting in a late onset identification of the single chew event
Algorithm Error: Incorrect Chew Onset and Offset

Chew Event that the Algorithm Didn't Identify

Correct Chew Onset

Correct Chew Offset

Voltage (mV)

Time (seconds)
Discussion

Research Limitations

Summary of Results

Implications for the Future
Research Limitations

- This algorithm requires an interactive process of visually segmenting out the bite and chew sequences.
  - This can lead to variability in the identification of onsets and offsets between user.
- The algorithm isn’t 100% robust and can incorrectly mark onsets and offsets of the bite and chew events or miss them entirely.
  - This can result in incorrect comparison between the onset of masseter activity and the onset of a middle ear muscle response.
Summary of Algorithm Accuracy Results

- Accuracy for identifying bite events: 77%
- Accuracy for identifying chew events: 95%
- Errors with the bite events
  - Incorrectly identifying two events within one bite onset
  - Late identification of bite onset
  - Early identification of bite offset
- Errors with the chew events
  - Not identifying a chew event at all
  - Separating a chew event into two separate events and only marking the onset of the second event, resulting in a late identification of the chew onset
Implications for the Future

- Algorithm variables may need to be adjusted to better identify onsets and offsets of masseter activity
  - Pause duration requirement of 200 ms may need to be changed
  - 75th percentile could be adjusted
- Most of the issues arose from identification of the bite events
  - May need to create a separate criteria for the bite events
    - Integral requirements
    - Duration requirements
Since the bites are so variable across participants, the larger project may want to solely use the chew events as a reference to masseter activity. This way, the comparison between masseter activity and the middle ear response will be a more consistent measurement.
References


Continued...


