Genioglossi muscle activity in response to changes in anterior/neutral head posture

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Clinicians have acknowledged swallowing, tongue activity, and head posture as interdependent variables that must be concurrently examined. The purpose of this study was to evaluate genioglossus activity during swallowing, rest, and maximal tongue protrusion in two head positions (HPs) with a noninvasive recording device. Eight Angle Class I subjects were evaluated. Repeated measures were performed in a single session to record surface intraoral electromyographic (EMG) activity of the genioglossus muscles. Head position was measured in angular degrees from photographs. Three variables were measured in both the neutral-head position (NHP) and anterior-head position (AHP): (1) duration of genioglossus EMG during swallowing, (2) genioglossus EMG with the tongue at rest, and (3) genioglossus EMG during maximal isometric tongue protrusion. A Wilcoxin matched-pair signed-rank statistic was used for EMG analysis, and a paired sample *t* test statistic was used for head posture analysis. The angles measured for NHP and AHP within each subject were significantly different verifying two different head positions. Duration of swallowing was not significantly different between head positions. Resting genioglossus EMG and maximal isometric genioglossus EMG were statistically greater in the AHP. The data suggest that head positional changes may have an effect on genioglossus muscle activation thresholds. However, small differences in resting EMG activity between head positions suggests that the clinical significance needs further investigation. (AM J ORTHOD DENTOFAC ORTHOP 1993;103:39-44.)

Electromyographic (EMG) studies of the genioglossus muscle suggest that genioglossus activity varies with body postures,[1] head positions (dorsal/ventral flexion),[2] mandible positions,[3] and boluses of food.[4-6] This interrelationship may be partially explained by the functional role of the genioglossus muscle to maintain an adequate airway.[1,7] However, little is known about genioglossus activity in head postures that allow the eyes to maintain a horizontal gaze, such as an anterior head position. The purpose of this article is to evaluate genioglossus EMG activity during rest, swallowing, and maximal tongue protrusion in two head positions (HPs) with a noninvasive recording technique.

METHODS

Subjects

Eight normal adult subjects were identified from volunteers screened by a dentist and physical therapist. The study was approved by the human investigations committee and informed consent was obtained from all subjects participating in the study. All subjects who met the criteria were women. The age range for the eight subjects was 22 to 34 years with the mean age of 27.5 years (SD ± 4.3 years). Mean height was 162.8 cm (SD ± 4.06 cm) with a mean weight 54.39 kg (SD ± 4.22 kg).

Criteria for subject selection were chosen to eliminate variables that might alter muscle activity and interfere with normal function.[8] (See Table I).

Instrumentation

The equipment used for recording EMG of the genioglossus muscle was described in a previous report.[9] Recordings from both surface and fine wire configurations showed similar onset times, relative amplitude changes, and cessation times of EMG activity. Recording EMG activity of the genioglossus muscle with surface recording electrodes supported by an acrylic appliance was demonstrated to be valid.

In this study, EMG recordings demonstrated specificity by showing little contamination from other jaw muscles (Fig. 1). The secure fit of the appliance containing the recording electrode was checked inside the mouth of each subject. No appliance movement was acceptable when it was pushed anterior/posterior and pulled cephalad. The subjects were asked to occlude their teeth and purse their lips to ensure comfortable placement of the wires. The integrity of the insulation surrounding the recording wire was checked before and after each experimental session.

A photograph was used to measure HP in the sagittal

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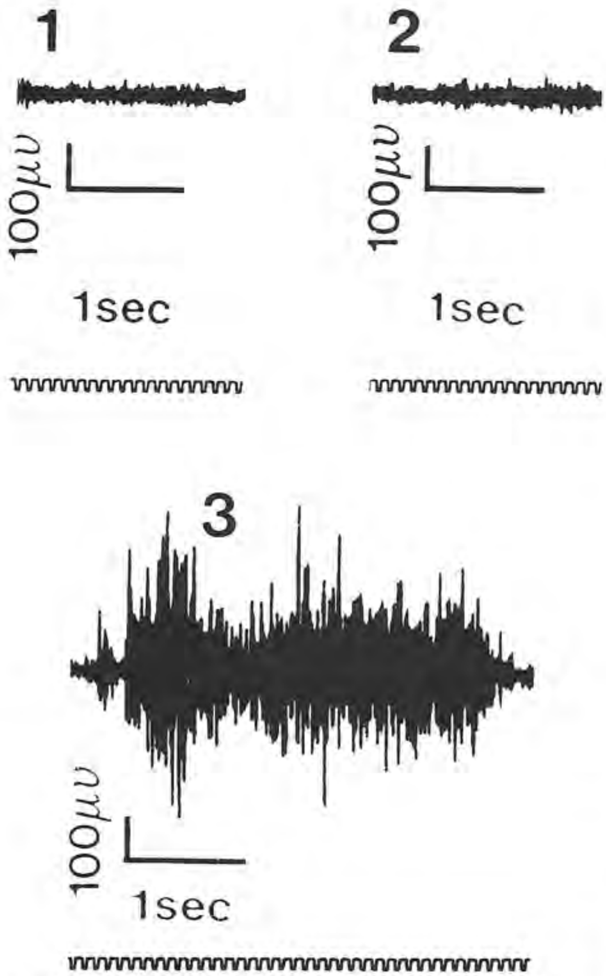

Fig. 1. Raw genioglossus EMG that was recorded from surface intraoral electrode during *(1)* tongue retraction, *(2)* resisted jaw opening, and *(3)* tongue rolling. The recordings demonstrate the specificity of the intraoral electrode.

plane. The camera was positioned to allow ample viewing throughout the trials including the marked tragus of the ear, a wooden dowel on the seventh cervical spinous process (C7), and a plumb line behind the subject. The camera position was held constant for each individual subject (Fig. 2).

Procedure

Genioglossus activity were measured in two different randomized HPs over three different types of tongue activity within the same subject. The two head positions consisted of neutral head position (NHP) and anterior head position (AHP). The three tongue activites were maximal protrusion, swallowing, and rest. The activities were chosen to identify the influence of HP on voluntary EMG activity, swallowing EMG activity, and baseline EMG activity of the genioglossus muscle.

First, maximal tongue protrusion was observed in randomized NHP and AHP. During maximal tongue protrusion each subject was asked to push their tongue against the lingual alveolar process of the maxillary incisors.[4] Subjects were allowed to practice while watching EMG activity on the oscilloscope before the data recordings. A 3-second sample was taken in the middle of the maximal protrusion trial.

Next, paired swallowing and resting EMGs were recorded in randomized NHP and AHP. Swallowing and resting genioglossus EMGs were recorded consecutively in the same randomized head position. Each recorded swallow was preceded by a water swallow to allow the subject to have residual fluid.

During each maximal tongue protrusion and swallow, a photograph of HP was taken simultaneously with the EMG sampling (Fig. 2). Rest periods of at least 30 seconds were given to the subject between each trial of maximal tongue protrusion and paired swallowing and resting EMGs.

Head position was rehearsed before experimental observations through demonstration and verbal commands. Both HPs were achieved by first having the subject walk in place, oscillate their head forward and back, and then gaze straight into a mirror to attain a neutral head position.[10] For AHP, subjects were given additional instructions to slump or round their shoulders forward, look straight ahead into a mirror, keep chin up, and bring the head maximally forward. The postural position of the mandible[11] was assumed by the subject to comfortably relax the jaw muscles before each recorded activity.

Measurements

Electromyographic activity was sampled during a 3-second period of maximal activity. Genioglossus EMGs were amplified (gain 1000, bandwidth 20 to 1000 Hz), rectified, integrated (time constant of 100 msec), and sampled at 20 Hz by a computer. Integrated EMG (IEMG) during swallowing was measured from a pen recorder tracing. A Wilcoxin matched-pair signed-rank test was used to test for differences of IEMG activity between the two HPs. All statistical tests used a probability level of $p < 0.05$. Median values for each set of trials were used for statistical calculation.

The angle formed between a horizontal line, perpendicular to a plumb line, bisecting C7, and a line passing through the tragus of the ear and C7 was measured from each photograph.[12] The angles were measured with a protractor. (See Fig. 2.) A paired *t* test was used to analyze HP data. Mean values for each set of trials were used for statistical calculation.

To address reliability of subject selection, four subjects were evaluated by two examiners. For measurements of HP angles, interrater reliability for three subjects and intrarater reliability on the remainder of the subjects were calculated with agreement of HP angles within $\pm 3°$.

RESULTS

First, mean HP angles were analyzed and were significantly different (Table II), thus confirming that the two HPs were different. The mean NHP angle was 50.5° ($\pm$SE 2.44°), the mean AHP was 25.5° ($\pm$SE 2.77°),

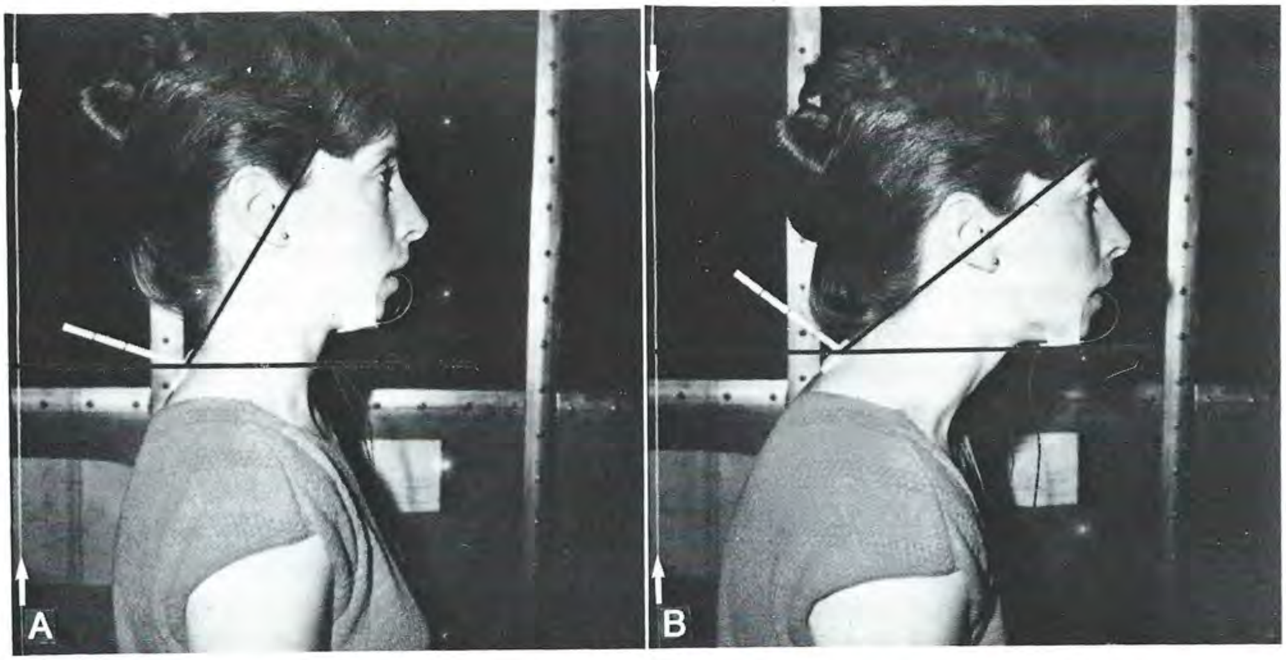

Fig. 2. Photograph taken of subject to measure head position from an angle formed by two lines: (1) bisects C7 and the tragus and (2) perpendicular to the plumb line and intersecting C7. **A**, Shows a neutral head position, and **B**, shows anterior head position. Two *white arrows* identify the plumb line.

Table I. Summary of subject selection criteria

1. Class I dental occlusion[21]
2. At least 24 real teeth
3. No extraneous cast restorations or cuspal coverages
4. No orthodontic treatment or occlusal equilibrations in the past year
5. One or less temporomandibular joint (TMJ) symptoms present[22]
6. No history of fractures, surgeries, or whiplash to the head and neck in the past year
7. No current symptoms of constant head or neck pain
8. No major hypomobilities or hypermobilities with passive cervical motion testing in the transverse and sagittal planes
9. Active cervical spine motion greater than 50% of the available range with no pain on passive overpressure
10. No tongue protrusion beyond the cutting edge of the teeth during swallowing
11. No adult-acquired tongue thrust swallow[23]
12. Nasal respiratory breather

and the mean difference between NHP and AHP was 25.5° (±SE 2.18°).

Median genioglossus data by group were identified: (1) Resting EMG was 6.51 μVsec in NHP and 7.98 μVsec in AHP (Table III). (2) Maximal tongue protrusion was 69.79 μVsec in NHP and 86.14 μVsec in AHP (Table IV). (3) Duration of swallow was 1.55 seconds in NHP and 1.43 seconds in AHP (Table V). Statistical differences were found between the two HPs for resting tongue activity and maximal tongue protrusion, whereas no statistical difference was found between HPs for the duration of swallowing. Typical examples of genioglossus EMG are demonstrated in Fig. 3, and complete data are presented in Fig. 4.

To test the specificity of the electrode and to dis-

Table II. Angle of head posture

Subject	*NHP (degrees)*	*AHP (degrees)*	*Difference (degrees)*
1	43	21	21
2	38.4	21.6	16.8
3	53.2	24.6	28.6
4	55.2	23.2	32
5	47	12.8	34.2
6	57.2	36.8	20.4
7	55.2	34.8	20.4
8	55.2	29.2	26
Mean	50.5	25.2	25.5
Standard deviation	6.9	7.84	6.17
Standard error	2.44	2.77	2.18

$p(t = 11.49) <$ significant at 0.001 level.

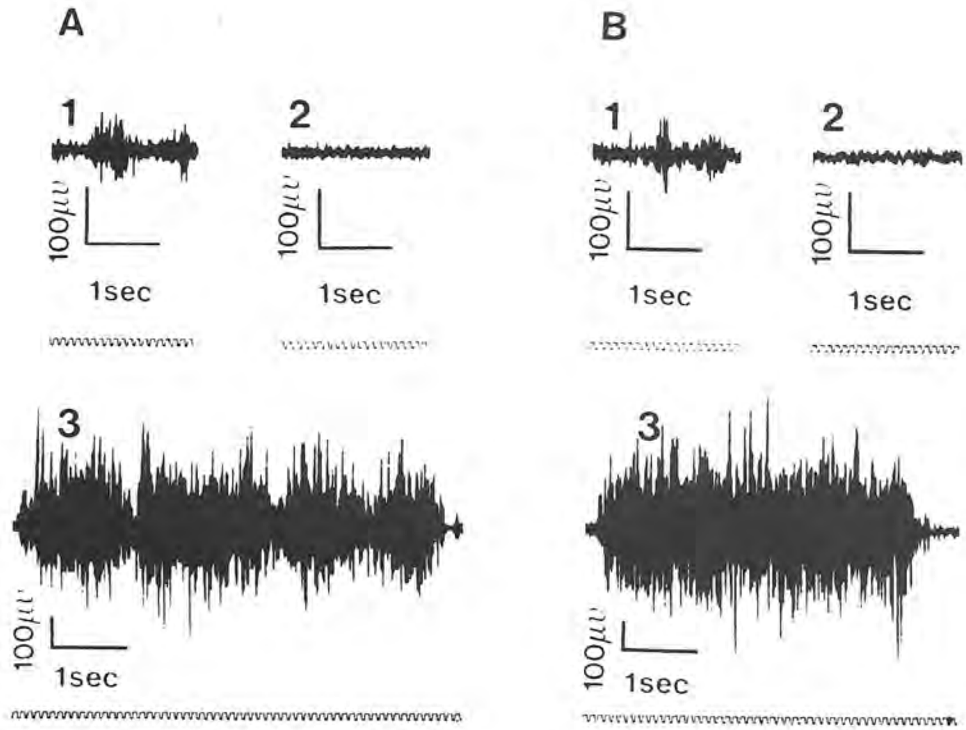

Fig. 3. Raw genioglossus EMG recorded with an intraoral electrode. Recordings of *(1)* swallowing, *(2)* resting, and *(3)* maximal tongue protrusion in NHP are shown in **A**, and in AHP are shown in **B**.

Table III. Resting genioglossus EMG median value for each subject's five trials with the range

Subject	*NHP (μVsec)*	*AHP (μVsec)*	*Difference (μVsec)*
1	6.55 (6.21-6.87)	6.67 (6.53-7.31)	−0.12
2	5.65 (5.02-8.26)	6.05 (5.92-9.13)	−0.40
3	9.19 (7.38-10.56)	8.45 (7.68-9.99)	0.74
4	6.97 (6.00-8.10)	8.32 (7.48-10.50)	−1.35
5	6.38 (5.88-8.10)	7.59 (7.16-7.81)	−1.21
6	7.53 (5.85-8.12)	8.62 (8.40-15.05)	−1.09
7	5.96 (5.05-6.42)	6.10 (5.44-7.01)	−0.14
8	6.46 (6.31-7.35)	9.42 (7.08-10.70)	−2.96

$p(T = 4) <$ significant at 0.05 level.

Table IV. Maximum genioglossus EMG median value for each subjects five trials with range

Subject	*NHP (μVsec)*	*AHP (μVsec)*	*Difference (μVsec)*
1	74.24 (69-82)	78.59 (70-87)	−4.35
2	59.76 (52-61)	81.21 (75-100)	−21.45
3	58.46 (50-81)	92.72 (51-99)	−34.26
4	125.12 (98-189)	126.69 (101-268)	−1.57
5	65.34 (64-72)	79.75 (72-82)	−14.41
6	80.69 (72-88)	91.06 (85-92)	−10.37
7	40.30 (30-53)	56.82 (48-82)	−16.52
8	133.66 (99-169)	215.01 (79-323)	−81.35

$p(T < 4) <$ significant at 0.01 level.

tinguish genioglossus activity from surrounding muscles, resisted mandibular opening, tongue retrusion, and tongue rolling were performed. Typical activity is shown in Fig. 1. Very little activity was observed from surrounding muscles, thus supporting observations from an earlier report.[9]

DISCUSSION

Statistically significant genioglossi EMG activity was found greater in AHP as compared with NHP dur-

Table V. Duration of swallowing EMG

Subject	NHP	AHP
	Seconds ± SD	Seconds ± SD
1	15.1 ± 2.6	13.0 ± 2.4
2	13.3 ± 1.0	13.0 ± 0.9
3	15.7 ± 2.8	15.9 ± 3.0
4	18.7 ± 2.6	20.2 ± 3.6
5	14.4 ± 1.4	13.7 ± 1.5
6	14.8 ± 1.7	10.5 ± 0.5
7	21.0 ± 1.7	19.5 ± 2.7
8	23.1 ± 1.1	25.0 ± 5.5
Mean	17.0 ± 1.1	16.6 ± 1.3

$p \mid T = -0.935 \mid > 0.381$ not significant at 0.05 level.

ing both maximal tongue protrusion and resting tongue activities. Previous research demonstrates changes in HP influence various components of the stomatognathic system including trajectory of jaw closure, tooth contacts, anterior lip tension, and initial tooth contacts.[13-18] The data from this study suggest that head positional changes, with eyes maintaining a horizontal gaze, may have an effect on genioglossus muscle activation thresholds. However, small differences in resting EMG activity between head positions suggests that the clinical significance needs further investigation.

Four possible hypotheses are proposed to explain the differences in genioglossus EMG for short-term alterations between NHP and AHP. First, considering HP has an immediate effect on the postural rest position of the mandible,[16,18-20] differences in head position related to genioglossus EMG may be due to altered proprioception. Both a change in genioglossus muscle spindle length and a change in temporomandibular joint mechanoreceptors may occur with altered head position. Second, head position may alter tongue position and the relationship of the structures of the posterior oropharyngeal cavity. Thus, HP may influence sensory receptors of cranial nerve IX and the superior laryngeal nerve to activate motor neurons responsible for airway maintenance. Third, head position influences tonic neck reflexes that are found to reflexively alter genioglossus activity.[2] Finally, the length of the genioglossus muscles may not be optimal in AHP, and biomechanical efficiency may be compromised.

Further research on the functional implications of anterior head position is needed to identify its impact on mastication and deglutition. Do the small but statistically significant changes observed in this study relate to functional disturbances involving the genioglossus muscle? In addition, further investigations are required to examine the long-term effects of anterior head position on the stomatognathic system and the mechanisms that control the changes in genioglossus activity.

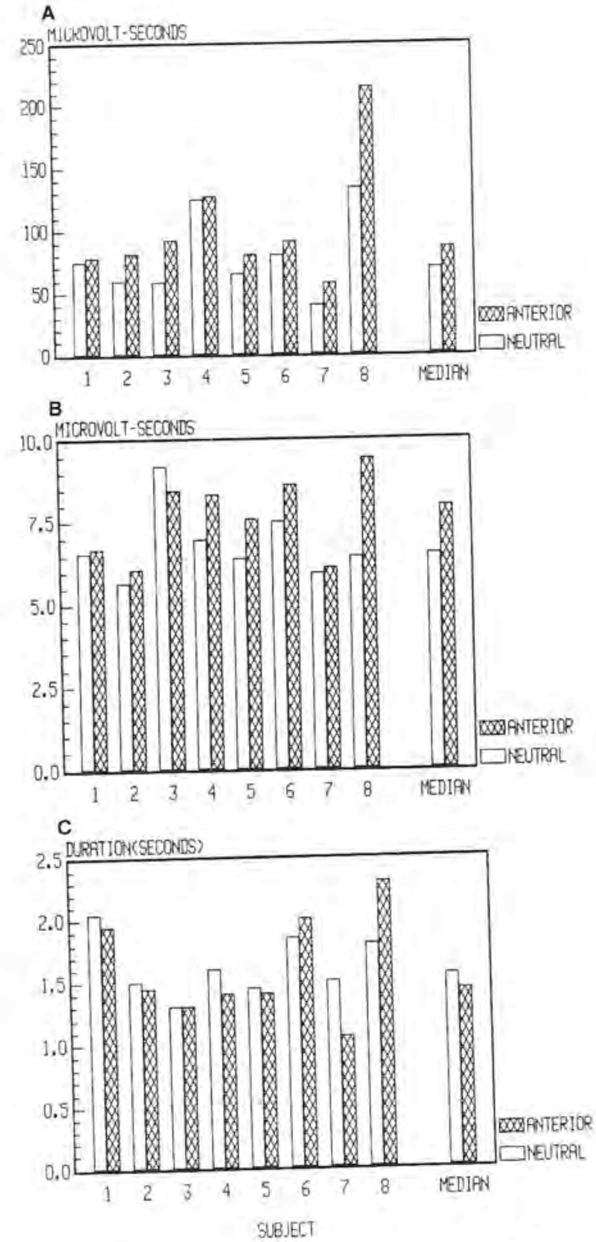

Fig. 4. Paired subject data bar graphs in NHP *(white bars)* and in AHP *(cross-hatched bars)*. **A**, Graph shows EMG activity during resting. **B**, Graph shows genioglossus EMG activity during maximal tongue protrusion. **C**, Graph presents duration of genioglossus swallowing activity in seconds. In graphs **A** to **C**, the first eight paired bars are for each subject and the pair on the far right is the median for all subjects.

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