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Short Communication

Palatal activity in voicing distinctions: a simultaneous fiberoptic and electromyographic study*

Fredericka Bell-Berti

Haskins Laboratories, New Haven, Conn. and Department of Communication Sciences and Disorders, Montclair State College, Upper Montclair, New Jersey, U.S.A.

Hajime Hirose

Haskins Laboratories, New Haven, Conn. and Research Institute of Logopedics and Phoniatrics, Faculty of Medicine, University of Tokyo, Tokyo, Japan

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Abstract: A preliminary study of both EMG activity and palatal movement measurements is reported. Simultaneous fiberoptic motion pictures of the nasal surface of the soft palate and electromyographic recordings from the levator palatini muscle were obtained for one speaker of American English. Frame-by-frame measurements of the motion pictures and computer-processed EMG signals were analyzed to provide data about the relationship between velar height and EMG potential strength and the time course of the EMG activity and soft palate movement.

In order to determine the relationship between the strength of electromyographic (EMG) potentials and an articulator's displacement, measures must be made of both and compared. Our immediate aim was to provide simultaneous measures of EMG potentials and velar height to provide evidence for (or against) the assumption that different EMG activity levels, for minimally contrastive items, may be used as indicators of differences in articulator displacement. Berti & Hirose (1971) and Bell-Berti (1973; in press *a*) reported differences in the magnitude of EMG potentials of muscles in the velopharyngeal region between voiced and voiceless stop consonant production that were interpreted as reflecting different degrees of articulator displacement. A preliminary investigation was undertaken of the relationship between the level of levator palatini EMG potentials and the vertical displacement (height) of the velum. We assumed the levator palatini to be the muscle primarily responsible for palatal elevation (Lubker, 1968; Fritzell, 1969; Bell-Berti, in press *b*) and that we were dealing with a simple one muscle–one parameter system, although contraction of the levator palatini also results in posterior movement of the velum.

Procedures

Since this was a preliminary study, only one subject was used. The subject was one of three who served in a more complete EMG investigation of velopharyngeal function (Bell-Berti, 1973), and was selected for this study for two reasons: first, she showed clearly

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different patterns of EMG activity for minimal utterance pairs in a muscle whose function could be readily observed (the levator palatini, which raises the soft palate); and second, her nasal cavity was large enough to permit insertion of a fiberoptic endoscope to view the soft palate.

An inventory of eight nonsense disyllables was used. They contained oral–nasal and nasal–oral consonant contrasts in medial position. The nasal consonant was always /m/, the stop consonants were /b/ and /p/, the vowels were /i/ and /ɑ/. The same vowel occurred in both syllables of an utterance. Each utterance type began with /f/ and ended with /p/, to avoid lingual coarticulation effects, provide clear oscillographic records of the beginning of the first and end of the second vowels, and insure initial and final oral articulation. A randomized list of the eight utterances was repeated 10 times during the experiment.

Bipolar hooked-wire electrodes of the type described by Hirose (1971) were inserted into the levator "dimple" on the oral surface of the soft palate. The EMG potentials were recorded onto magnetic tape, and were later rectified and integrated (with a 25 ms integration time constant), computer-sampled (at 5 ms intervals) and averaged using the system described by Port (1971; Kewley-Port, 1973). Eight to ten tokens of each utterance type were averaged. The point in the utterances chosen for averaging the tokens was the acoustic boundary (determined from an oscillographic record) between the nasal and medial stop consonants, and is the zero point on the abscissa in the figures.

A fiberoptic endoscope (Sawashima & Hirose, 1968; Sawashima & Ushijima, 1971; Ushijima & Sawashima, 1972) was inserted into the subject's right nostril and positioned to provide a view of the nasal surface of the soft palate as it was raised and lowered. A narrow grid of thin plastic film was placed along the floor of the nasal cavity to aid identification of palatal movement (Fig. 1). Motion pictures of each of the ten repetitions of the utterance list were taken through the fiberscope at 60 frames/s. Synchronization marks, corresponding to the first and last frames for each list, were recorded on the EMG data tape. Frame-by-frame measurements of the vertical displacement of the soft palate were made for each of the repetitions of each utterance type included in the EMG average. The units of measurement of palatal height were arbitrary. The palatal height measurements were then averaged for each frame of each token of each type.

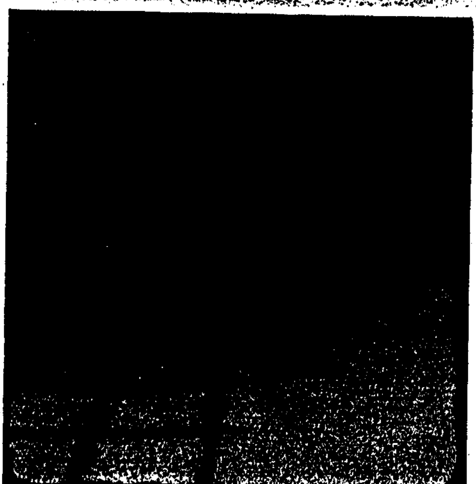

Figure 1 One frame showing the thin plastic grid in place on the nasal surface of the soft palate.

Results

In comparing the EMG activity of the levator palatini and the height of the soft palate, changes in EMG activity regularly preceded changes in palatal height, as expected. However, the temporal separation between peak EMG activity and peak palatal height was not constant. There was a separation of about 60 ms between peak EMG activity and peak palatal height for /b/ in /fibmip/ (Fig. 2, bottom) while the delay was on the order of 110 ms for the /b/ in /fimbip/ (Fig. 2, top).

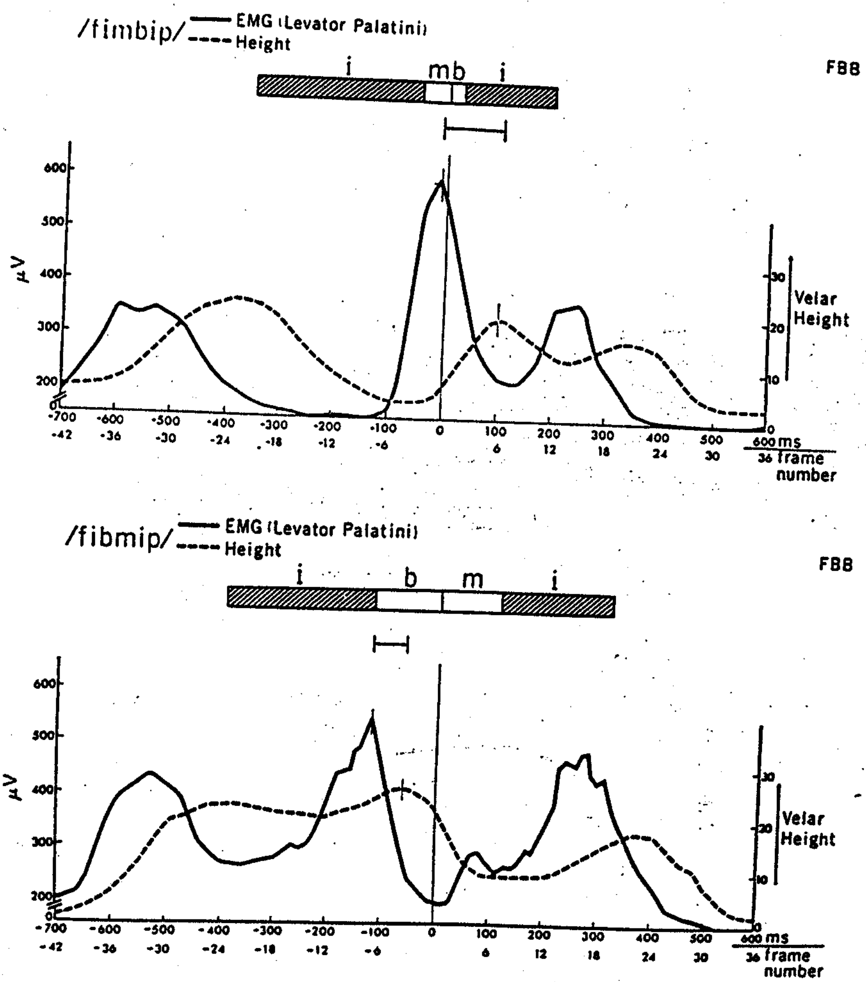

Figure 2 Comparisons of levator palatini EMG activity and velar height for the utterances /fimbip/ (top) and /fibmip/ (bottom).

In addition to differences in the time-lag between peak EMG activity and peak palatal height, we found differences in the size of the increase in palatal height and the corresponding increase in EMG potential. There was a greater increase in, and a greater peak of, EMG activity for stops following nasals than for stops following vowels (Fig. 3, top). Palatal height, on the other hand, had a somewhat different pattern. Although the increase in palatal height was greater for stops following nasals (i.e. the /b/ in /fimbip/), the absolute height reached by the soft palate might be higher for stops following vowels (i.e. the /b/ in /fibmip/) (Fig. 3, bottom).

We can summarize these points by comparing four measurements made of the data (Table I). First, the time-lag between peak EMG activity and peak palatal height for stops

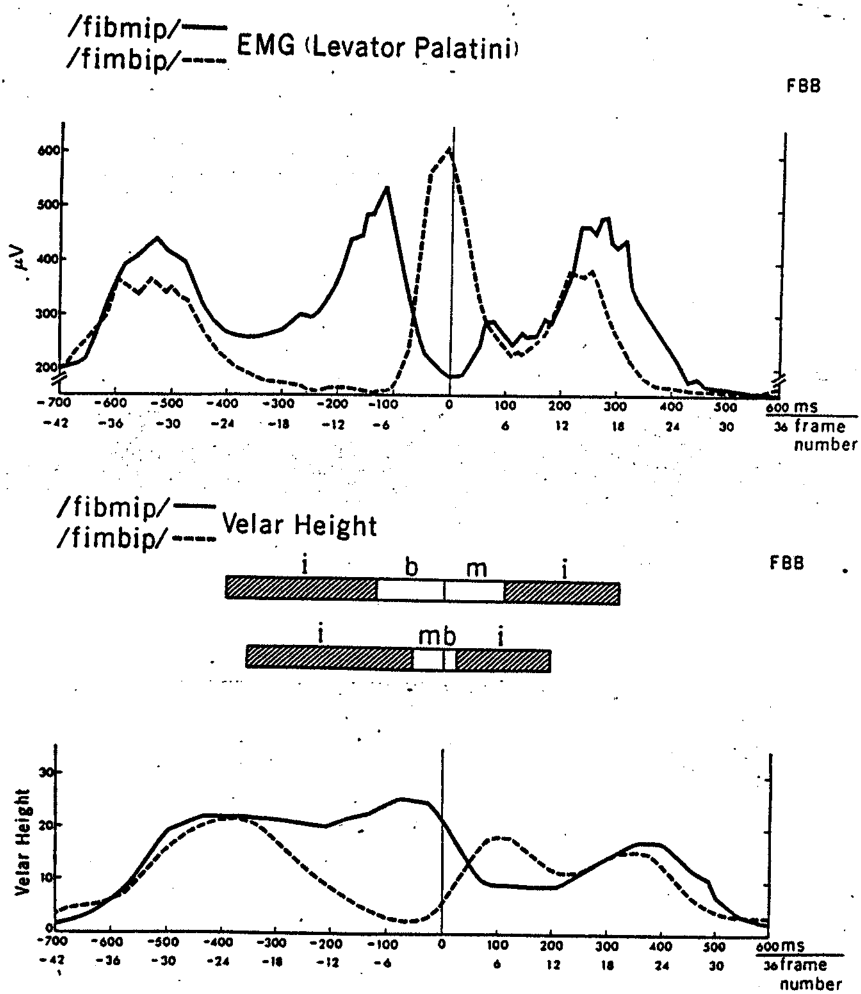

Figure 3 Comparisons of levator palatini EMG activity (top) and velar height (bottom) for the utterances /fibmip/ and /fimbip/.

was greater when the stop followed a nasal than when the stop followed a vowel. This may be a function of the increased work-load applied to the levator palatini when the palate must be raised from a lower position through a greater distance. Second, there was a greater average increase in EMG activity for stops following nasals than for stops following vowels. Third, there was a greater increase in palatal height for stops following nasals than for stops following vowels, although the absolute height of the palate might be greater for stops following vowels. This apparent discrepancy becomes comprehensible

Table I

	1 Time-lag EMG-Height	2 EMG increase	3 Height increase	4 Base line height
Oral/nasal	95 ms	177 μV	4	13·5
Nasal/oral	130 ms	348 μV	13·5	1·5

when one considers the starting point against which the increase in palatal height is measured. That is, the palate starts from a very much lower position, and must move through a very much greater distance to close the velopharyngeal port sufficiently to prevent nasal coupling, when the stop followed a nasal than when it followed a vowel.

A Pearson *r* computed between increases in palatal height and EMG potential was 0·84 ($P < 0{\cdot}005$). Given equal starting points, the greater the EMG activity the greater will be the height of the soft palate.

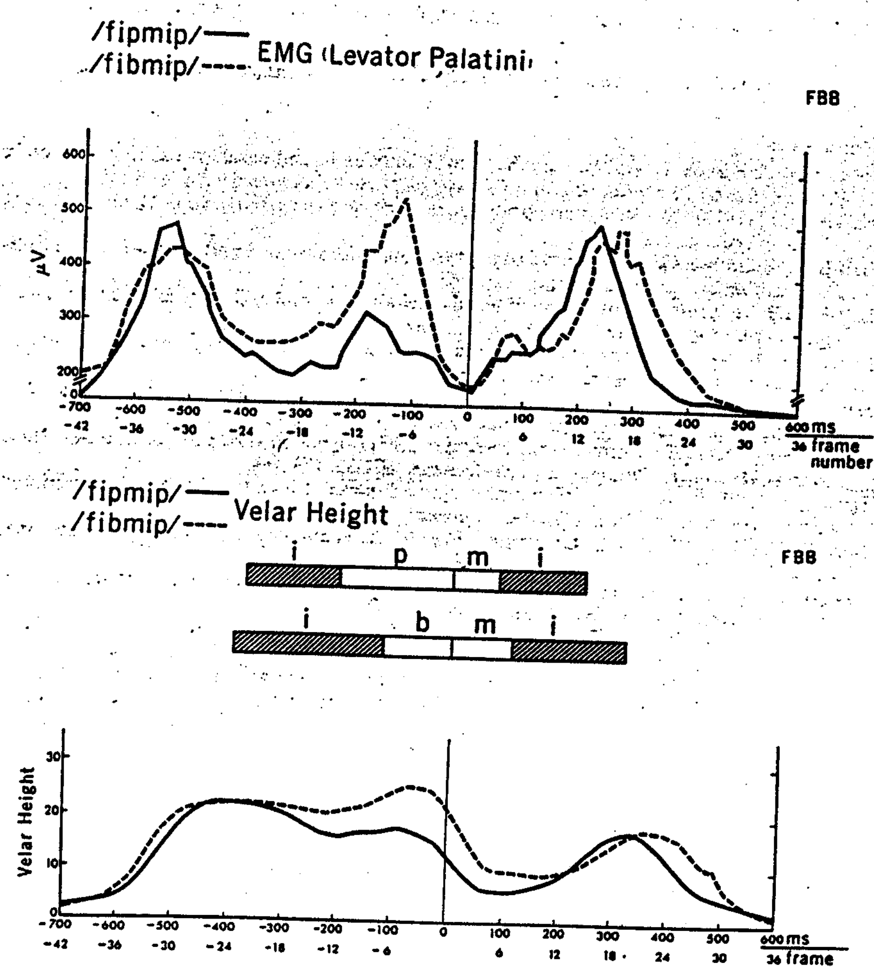

Figure 4 Comparisons of levator palatini EMG activity (top) and velar height (bottom) for the utterances /fipmip/ and /fibmip/.

Conclusion

Although there is no obvious constant relationship between absolute velar height and the absolute magnitude of the EMG signal for an articulation, there is a strong correlation between the size of the increase in EMG potential and the size of the change in velar height. That is, the larger the increase in EMG potential, the greater will be the corresponding increase in velar height. This conclusion is supported by the data displayed in Fig. 4. The EMG activity is greater for the /b/ (in /fibmip/) than for the /p/ (in /fipmip/) (Fig. 4, top). The height of the soft palate reflects this difference in EMG activity: the palate is higher for the /b/ utterance than for the /p/ utterance in the region of the medial stop consonants, while the height curves are similar in those regions where the EMG curves are similar.

This preliminary investigation, then, supports the view that for minimal utterance pairs increases in EMG potential should be interpreted as reflecting increases in velar height. Reports of other data (Berti & Hirose, 1971; Bell-Berti, 1973, in press *a*), where different EMG potentials were recorded for voiced and voiceless stop cognates (in similar phonetic environments), may be interpreted as reflecting differences in the velar height and, therefore, in the size of the pharyngeal cavity for those stop articulations.

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