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Effect of Wearing Cervical Headgear on Tongue Pressure

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Abstract. *The purpose of this study was to examine whether wearing cervical headgear affected tongue pressure on the lingual surface of mandibular incisors, with particular attention to suprahyoid muscle activity. Tongue pressure was recorded using a miniature pressure sensor without cervical headgear and with two cervical headgears with traction forces of 500 and 1200 g, respectively. Electromyographic activity of suprahyoid muscles and respiratory-related movement were recorded simultaneously. Wearing cervical headgear significantly affected tongue pressure and suprahyoid muscle activity in the short-term. A significant increase in tongue pressure was observed in association with an increase in traction force from 500 to 1200 g, whereas no significant difference in suprahyoid muscles activity was seen between these force levels. These results suggest that wearing cervical headgear increases tongue pressure on the lingual surface of mandibular incisors, and this increase in tongue pressure may result from changes in the electromyographic activity of suprahyoid muscles to maintain adequate pharyngeal patency.*

Index words: Cervical Headgear, Suprahyoid Muscle, Tongue Pressure, Upper Airway.

Introduction

Cervical headgear (CHG) is commonly used in orthodontic practice to restrain maxillary growth, to distalize molars and to reinforce anchorage (Proffit, 1992). It has also been suggested that CHG may facilitate mandibular growth. Graber (1966) described the reflexive mandibular thrust against a threat to upper-airway patency associated with the use of the CHG and appraised its beneficial influence on mandibular growth. However, no quantitative data were shown. Baumrind *et al.* (1983) also reported enhanced mandibular growth in a CHG sample. In a series of studies, Hiyama and co-workers (1997a,b, 1998, 1999) investigated the effects of a CHG on electromyographic (EMG) activities of the jaw, tongue and neck muscles, as well as on upper-airway structure, head posture, and mandibular position. They demonstrated that the subject's head was ventrofelexed (Hiyama *et al.*, 1997b), the upper-airway dimension was narrowed anteroposteriorly (Hiyama *et al.*, 1998), and the mandibular position was displaced anteriorly (Hiyama *et al.*, 1999) by wearing a CHG. They surmised that these changes in head posture and upper-airway structure may be due to changes in the EMG activities of several muscles surrounding the mandible induced by wearing the CHG (Hiyama *et al.*, 1997a).

Recently, we investigated the effect of changes in the breathing mode and body position on tongue pressure and the genioglossus EMG activity (Takahashi *et al.*, 1999). Changes in body position significantly affected tongue pressure during oral respiration. Moreover, genioglossus EMG activity varied significantly with different breathing modes and body positions. Hiyama and co-workers (1997a) demonstrated that genioglossus EMG activity was increased when a CHG was worn, and considered that this increase was a compensatory activation for the compromised upper-airway. Considering these findings, it is possible that the increased genioglossus EMG activity caused by wearing a CHG may affect tongue pressure on the lower incisors.

Although the genioglossus muscle is the principal muscle to dilate the upper airway in the anteroposterior direction, there are other suprahyoid muscles that contract to move the hyoid bone anteriorly (van Lunteren and Strohl, 1986; van Lunteren, 1990; Weigand *et al.*, 1990a,b). Indeed, it has been reported that wearing a CHG resulted in significant anterior displacement of the hyoid bone (Hiyama *et al.*, 1998). This forward migration of the hyoid bone would be elicited by activation of not only the genioglossus muscle but also other suprahyoid muscles.

The purpose of this study was to examine whether wearing a CHG affected tongue pressure on the lingual surface of mandibular incisors, with particular attention to its relationship to suprahyoid EMG activity.

Materials and Methods

Subject

Ten subjects were screened initially and three subjects with skeletal Class III were excluded. Consequently, this study was carried out in seven healthy males with a mean age of 26·8 ± 1·8 (mean ± SD) years. None of the subjects had an

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ongoing respiratory infection or were taking any medication known to affect muscle activity. All of the subjects had complete dentition with the exception of the third molars and no skeletal abnormality. Each subject had an acceptable overjet and overbite. Informed consent was obtained from each subject before the study.

Recording

As described elsewhere (Takahashi *et al.*, 1999), pressure from the tongue on the lingual surface of the lower anterior teeth was measured by a pressure sensor (PS-A type, Kyowa Co., Tokyo, Japan) incorporated in a lingual flange of a custom-made intraoral appliance made of silicon rubber impression paste (Exafine putty type, GC Co., Tokyo, Japan). The output of the transducer was affected by temperature at a rate of 0·1 per cent/°C. The thickness (*c.* 1 mm) of the appliance (Gould and Picton, 1962, 1963) and the location of the transducers were carefully standardized. The sensitivity of the sensor was calibrated immediately before and after each experimental session.

A pair of surface electrodes was placed mid-sagittally on median skin of the submental region to record mass potentials of the EMG activity of suprahyoid muscles. A neutral electrode was placed on the right ear lobe. Respiratory movement of the chest wall was simultaneously recorded by an inductance band (TR-751T, Nihon-Kohden, Tokyo, Japan).

Protocol

After bonding a double-buccal tube to the buccal surface of the maxillary first molar on both sides, two CHGs were adjusted for each subject. The lengths of the neckbands were adjusted to give total traction loads of 500 and 1200 g, respectively. These traction loads were chosen so as to clearly detect any effect of variation in CHG force on tongue pressure.

The subjects sat in a reclining chair with a headrest in an upright position without wearing a CHG and were instructed to remain awake with both eyes open, to keep the Frankfort plane parallel to the floor, and to maintain an intercuspal position and quiet nasal breathing during the recording session. Three minutes after insertion of the intra-oral appliance and placement of the electrodes, simultaneous recording of respiratory movement, tongue pressure and suprahyoid EMG activity was carried out for the following 3 minutes. Recording sessions were repeated twice with traction loads of 500 (CHG_{500}) and 1200 g (CHG_{1200}). EMG signals were amplified, band-pass filtered at 30 Hz to 1 kHz, full-wave rectified, and integrated. After conversion of the signals through an A/D converter (Maclab/8S, ADinstruments, Castle Hill, Australia), they were stored in a personal computer (Macintosh Performa 5270, Apple Computer, Cupertino, CA, U.S.A.) for data analysis. Signals from the pressure sensor were amplified with pre-adjusted and calibrated gains, and stored in the same manner as the EMG signals.

Data Analysis

Consecutive recordings of tongue pressure and suprahyoid EMG activity for 30 seconds were averaged with a time constant of 200 ms. The average EMG amplitude in each subject was normalized to the control condition. A Friedman test followed by Dunn Procedure were used to compare the tongue pressure and suprahyoid EMG activity among three sessions; without a CHG, and with the CHG_{500} and CHG_{1200}. A Spearman rank test was used to determine the correlation between the rate of change in suprahyoid EMG activity and tongue pressure. the amplitude of EMG activity and tongue pressure in each subject with CHGs was normalized to values without a CHG, respectively. Accordingly, two points were plotted for each subject; from control to with the CHG_{500}, and from control to with the CHG_{1200}. Statistical significance was established at the 5 per cent level.

Results

Figure 1 shows a typical simultaneous recording of chest wall movement, tongue pressure on the lingual surface of the mandibular incisors, and suprahyoid EMG activity in a subject. A marked increase in suprahyoid EMG activity was observed with the CHG_{500} and CHG_{1200}. Tongue pressure showed respiratory-related cyclic oscillation with a maximum value during expiration and a minimum value during inspiration without the CHG, as we reported in our previous study (Takahashi *et al.*, 1999). This cyclic oscillation in tongue pressure was observed in seven subjects.

In all seven subjects, negative pressure was recorded without the CHG. Since we were interested in positive tongue pressure to examine a possible linkage to suprahyoid EMG activity, these negative values were regarded as 0 g/cm^2 for the data analysis. When negative pressure occurs, the tip of the tongue does not touch the surface of the pressure sensor.

The change in tongue pressure caused by wearing a CHG is illustrated in Figure 2. Tongue pressure without a CHG was 1·6 ± 1·29 (mean ± SD) g/cm^2, while it increased to 3·46 ± 1·93 g/cm^2 with the CHG_{500} and 5·61 ± 2·04 g/cm^2 with the CHG_{1200}, respectively. Significant differences were found among all three conditions. Thus, wearing a CHG significantly affected tongue pressure.

The change in suprahyoid EMG activity caused by wearing a CHG is illustrated in Figure 3. Suprahyoid EMG activities with the CHG_{500} and CHG_{1200} were 132 ± 26·8 per cent and 134 ± 39·5 per cent, respectively when compared with the control. Significant differences were found between control and with the CHG_{500}, and between control and with the CHG_{1200}. The difference between CHG_{500} and CHG_{1200} was not statistically significant.

Figure 4 shows the relationship between the rate of change in suprahyoid EMG activity and tongue pressure. As suprahyoid EMG activity increased, the tongue pressure also increased. There was a significant positive correlation ($P = 0{\cdot}033$) between these two variables.

Discussion

To our knowledge, this is the first study to demonstrate the effect of wearing a CHG on tongue pressure exerted on the lingual surface of the mandibular incisors. Our results show that wearing a CHG significantly increased tongue pressure.

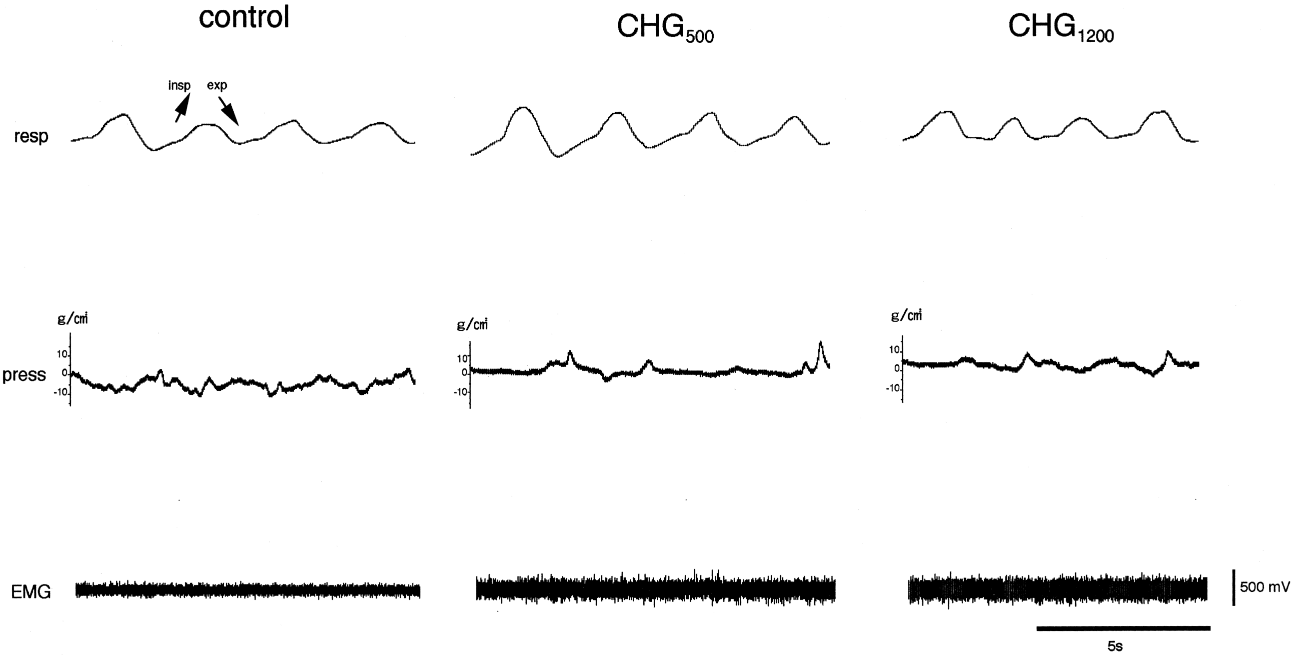

FIG. 1 A typical simultaneous record of chest wall movement (*resp*), tongue pressure on the lingual surface of mandibular incisors (*press*), and suprahyoid EMG activity (*EMG*). The vertical bar represents 500 mV for suprahyoid EMG activity. The horizontal bar represents 5 seconds. Abbreviations: *insp*, inspiration; *exp*, expiration, *control*; recording without a CHG, *CHG₅₀₀*; recording with the CHG_{500}, *CHG₁₂₀₀*; recording with the CHG_{1200}.

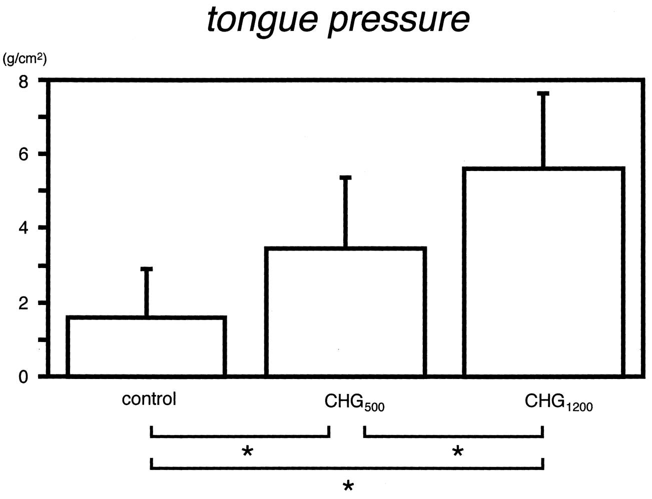

FIG. 2 Comparisons of tongue pressure among three recording sessions. * Significant at the 5% level.

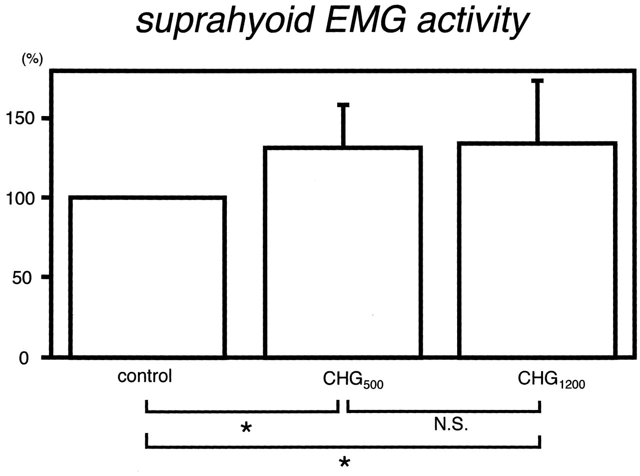

FIG. 3 Comparisons of suprahyoid EMG activity among three recording sessions. Suprahyoid EMG activity with both the CHG_{500} and CHG_{1200} was normalized to the value without a CHG (*control*). * Significant at the 5% level. NS: not significant.

In addition, wearing a CHG also increased suprahyoid EMG activity. Thus, it is likely that the increase in tongue pressure caused by wearing a CHG resulted from changes in suprahyoid EMG activity to maintain a patent pharyngeal airway. In the present study, we used CHGs with two different loads; 500 and 1200 g. A cervical traction force of 500 g is used for clinical application, while 1200 g is not. Significant anterior displacement of the hyoid bone occurs with a CHG with a traction force of 700 g (CHG_{700}; Hiyama *et al.*, 1998). Hiyama and co-workers (1998) noted that the pressure exerted by a neckband of the CHG might account for this displacement. It was likely that the CHG_{1200} would affect the position of the hyoid bone more than a CHG_{700}, since the effect would be exaggerated by the greater traction force.

Wiegand *et al.* (1990a,b), and van Lunteren and Strohl (1986; van Lunteren, 1990) pointed out the important role of the geniohyoid muscle in maintaining pharyngeal patency. Since the submental surface electrodes would have mainly detected geniohyoid EMG activity due to its close proximity to the electrodes, we speculate that the increased suprayoid EMG activity in the present study when the subject wore a CHG was mainly due to an increase in geniohyoid EMG activity. On the other hand, Hiyama and co-

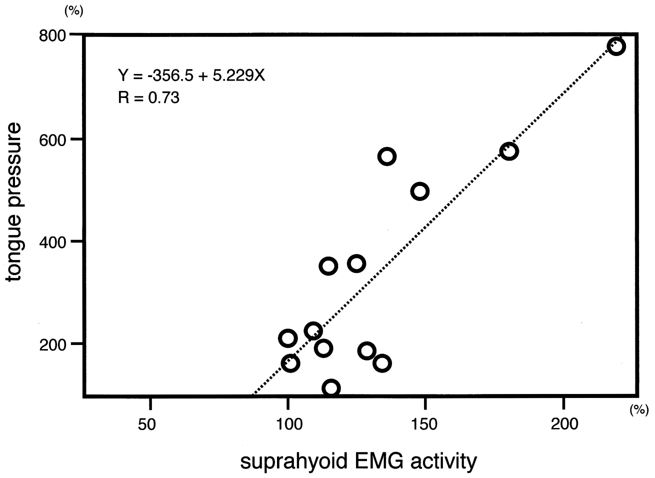

FIG. 4 Relationship between rate of change in suprahyoid EMG activity (abscissa) and tongue pressure (ordinate). Tongue pressure and suprahyoid EMG activity with both the CHG$_{500}$ and CHG$_{1200}$ were normalized to those without a CHG. The broken line indicates a regression line.

workers (1997a) reported a significant increase in the genioglossus EMG activity by wearing a CHG. This leads us to believe that the increase in tongue pressure caused by wearing the CHG$_{500}$ is the summed EMG activities of both the genioglossus and geniohyoid muscles to maintain upper-airway patency. Interestingly, a significant difference in tongue pressure between with the CHG$_{500}$ and with the CHG$_{1200}$ was observed in the absence of any significant change in the suprahyoid EMG activity between these conditions in the present study. In contrast, Hiyama and coworkers (1997a) reported that the change in genioglossus EMG activity caused by wearing the CHG$_{1200}$ was greater than that caused by wearing the CHG$_{500}$. Since the genioglossus muscle runs in uppermost part of suprahyoid muscles, its EMG activity might be hardly detectable in the present study. This may explain why no significant difference in suprahyoid EMG activity was observed between the two traction conditions. It is probable that the increase in tongue pressure from the CHG$_{500}$ to the CHG$_{1200}$ can be explained by variation in genioglossus EMG activity alone. A more detailed study is needed to clarify the distinct effect of several suprahyoid muscles on the maintenance of upper-airway patency. It is likely that the traction force affects not only cervical soft tissue, but periodontal mechanoreceptors of molars. There are some studies about interactions between masticatory muscles activity and mechanical stress to periodontal receptors for incisors and canines (Yamada *et al.*, 1985; Kamata 1994; Türker *et al.*, 1994; Yang and Türker, 1999), but not for molars. There is a likelihood that the distal force on the molars delivered by the CHG reflexively modulates changes in tongue pressure and suprahyoid EMG activity.

Concerning dentoalveolar changes caused by the use of a CHG, there have been few studies on changes in the inclination of mandibular incisors (Cook *et al.*, 1994; Hans *et al.*, 1994; Keeling *et al.*, 1998). Keeling and colleagues (1998) studied the dental changes after early Class II treatment with a CHG, and found that a CHG produced no significant labial tipping of mandibular incisors, as previously reported (Cook *et al.*, 1994; Hans *et al.*, 1994). However, in these studies, subjects used a CHG or high-pull headgear in combination with a biteplate (Keeling *et al.*, 1998) or a multibracket appliance (Cook *et al.*, 1994; Hans *et al.*, 1994), which may significantly alter any change in inclination of mandibular incisors that might occur during treatment with a CHG alone. Therefore, it remains unclear whether the increase in tongue pressure caused by wearing a CHG alters the dentoskeletal morphology. In our study, the subjects were told to maintain an intercuspal position during recording to avoid the influence of changes in mandibular position, which occurs with the use of a CHG (Hiyama *et al.*, 1999). However, it is unlikely that the mandibular position of orthodontic patients would always be in an intercuspal position when they wear a CHG. If the chin drops against the chest with the use of a CHG, the anteroposterior upper-airway dimensions *may* be restricted unless a reflexive response occurs to keep the upper-airway open (Graber, 1966). Anterior displacement of the mandible in association with the activation of upper-airway-dilator muscles may take place. We speculate that if recording was performed in the resting mandibular position, subjects with narrow upper airway might show greater tongue pressure than those with wide upper airway.

With regard to skeletal changes caused by using a CHG, it has been demonstrated that both a functional appliance, and a CHG or high-pull headgear facilitate mandibular growth in growing children (Keeling *et al.*, 1998). In contrast, Tulloch *et al.*, (1997, 1998) reported no enhancement of mandibular growth with headgear compared with an untreated control group of children with Class II malocclusion. However, a combination type of headgear was used in these studies (Tulloch *et al.*, 1997, 1998) and a high-pull headgear by some of the patients in the study by Keeling *et al.*, (1998). Since combination headgear includes a headcap, it has a different mechanism than a CHG, which might be relevant to tongue pressure or muscle activity. Therefore, the findings of their studies (Tulloch *et al.*, 1997, 1998; Keeling *et al.*, 1998) are not completely comparable with those in previous studies (Hiyama *et al.*, 1997a,b, 1998, 1990).

In the present study, sample size was small and the changes were observed in the very short term. Longer-term studies, probably on patients undergoing actual treatment, are needed to clarify whether the increase in tongue pressure caused by the use of a CHG persists, and also whether it is associated with increased mandibular growth, with or without proclination of mandibular incisors. Özbek and coworkers (1998) demonstrated that the use of functional-orthopedic devices increased upper-airway dimensions in growing children with skeletal Class Ii malocclusions. In the study of Özbek *et al.* (1998), subjects with smaller upper-airway dimensions before treatment responded better than those with larger upper-airway dimensions before treatment. Therefore, whether increased tongue pressure affects dentoskeletal morphology may depend on factors such as variations in upper-airway dimensions at the beginning of treatment. Since the anteroposterior dimension of the upper airway continues to increase until at least 18 years of age (Taylor *et al.*, 1996), disruption of such normal growth of the pharynx may induce so-called catch-up growth of the mandible in certain subjects with reduced upper-airway dimensions.

Conclusions

1. Wearing CHG significantly affected tongue pressure and suprahyoid muscle activity in the short term.
2. A significant increase in tongue pressure was observed in association with an increase in traction force, whereas no significant difference in suprahyoid muscle activity was seen between force levels.
3. The increase in tongue pressure may result from changes in the EMG activity of suprahyoid muscle to maintain adequate pharyngeal patency.

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