The Effect of Sound Intensity on Velopharyngeal Function in Normal Individuals

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Summary: Objective. Velopharyngeal closure is an important physiological process contributing to the normal function of speech and swallowing. The aim of this study was to analyze the influence of sound intensity on velopharyngeal function in normal individuals.

Materials and methods. Lateral cephalograms of 38 volunteers obtained at rest and during phonation of vowel /i:/ at both high and low sound intensity were carefully analyzed. The digital sound level meter was used to evaluate and record the sound intensity of the phonation process. The angular and linear parameters on the lateral cephalograms were then measured to reveal the correlation between sound intensity and velopharyngeal closure.

Results. All the angular parameter values measured in the study were significantly greater in high sound intensity condition. As for linear parameters, all values were found to be significantly larger at high sound intensity, except for the effective velopharyngeal length and the vertical velopharyngeal length. A multiple linear regression model was set up to describe the correlation between the sound intensity, the effective velopharyngeal length, and velopharyngeal closure. With the increase of sound intensity and the decrease of the effective velopharyngeal length, the width of velopharyngeal closure is enlarged.

Conclusions. As one of the characteristic features of sound wave, the sound intensity was found to affect the objectively measured parameters of velopharyngeal closure on lateral cephalograms.

Key Words: Velopharyngeal closure–Sound intensity–Lateral cephalogram.

INTRODUCTION

Velopharyngeal closure is responsible for directing the transmission of sound energy and air pressure in both the oral cavity and nasal cavity. The full closure of the valve contributes to the normal function of speech and swallowing.[1] The neuromuscular function and the anatomy of the velopharyngeal port, which is composed of soft tissues including the adenoids, pharynx, larynx, pharyngeal wall, velum, and underlying bony structures (maxilla, basicranium, and upper cervical spine), are critical factors in normal velopharyngeal mechanism. A failure of full closure of valve causes incomplete separation of the oropharynx from the nasopharynx and leads to dysfunction in speech and swallowing, which is termed as velopharyngeal insufficiency (VPI). Numerous etiologies, either congenital or acquired later in life, lead to VPI. The cleft palate is one of the most common congenital diseases associated with VPI. There are various methods to evaluate the velopharyngeal function, such as cephalometry, speech assessment, nasometry, nasoendoscopy, videofluroscopy, and magnetic resonance imaging.[2] Among these methods, lateral cephalometry is an accessible and practical method to evaluate velopharyngeal function. The cephalometry can be used to delineate factors such as excessive pharyngeal depth, movement of velum during phonation, and short velum that may contribute to VPI. Furthermore, it helps otolaryngologists better understand the anatomy before surgical treatment.[2–7]

The frequency and intensity are two of the most essential characteristics of the sound wave. In detail, the sound frequency determines the pitch whereas the sound intensity is defined as a dimensionless quantity measured in decibel (dB). Previous studies concentrated more on the choice of syllables when investigating velopharyngeal function.[8–12] Kuehn DP et al[8] suggested that nonnasal words were useful for evaluating the patient's ability to close the velopharyngeal port. Nonnasal words normally caused sustained velopharyngeal closure, with airborne sound exiting through the mouth only. Simpson RK et al[9] indicated that velopharyngeal stretch were different measured on cephalometric radiographs during the production of /alpha/, /epsilon/, /u/, and blowing. Smith BE et al[10] found that patients could exhibit a specific type of inconsistent velopharyngeal function. They exhibited velopharyngeal closing during /pa/ repetitions, but had openings during /pi/ repetitions. Bowman et al[12] proposed a greater velopharyngeal gap presented on lateral cephalograms when subjects with suspected VPI pronounced a vowel /i:/ than a sustained voiceless sibilant /s/. People in the absence of /s/ gap were observed with a small gap during the phonation of /i:/. It was reported that the /i:/ lateral cephalometric radiograph agreed better with the presumed VPI. Bowman et al suggested that the /i:/ lateral cephalometric radiograph better revealed velopharyngeal function. Therefore a number of investigations of velopharyngeal function were conducted by choosing the sustained phonation of vowel /i:/. Based on our own clinical experience, however, we found that one patient could present different features of velopharyngeal closure on cephalograms in the same syllable phonation. The sound intensity was assumed as a possible variable affecting velopharyngeal closure. However, there is no existing study regarding the effect of sound intensity on velopharyngeal function to the best of our knowledge. No criteria are proposed to standardize the sound intensity when velopharyngeal function studies are conducted.

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In this study, we applied the digital sound level meter (SLM) to evaluate the sound intensity during phonation. Lateral cephalograms during phonation at high and low sound intensity were obtained, respectively. The purpose of this study was to determine the effect of sound intensity on various objectively measured parameters of velopharyngeal closure on lateral cephalograms.

MATERIALS AND METHODS

Subjects

This study was ethically approved by the Ethics Committee of West China Hospital of Stomatology, Chengdu, China (WCHSIRB-ST-2013-129). A total of 38 volunteers, 20 males and 18 females, with mean age (range 21–28) and standard deviation of 24.86 and 2.12 years, were recruited in the study. All the subjects were in good health with no history of speech-language disorders, craniofacial anomalies, influenza, nasitis, or lesions in the head and neck regions within 4 weeks before the X-ray scanning. All the participants in the study were under optimized radiation protection.

Placement of SLM

The SLM (RS232, China) was connected to a laptop (S-VGN-S48CP/B, Sony, Japan) with the pre-installed software (*HANDHELD 2.0; Jinzhou, China*). Then the SLM was fixed by the tripod (CX-560, Nikon, Japan) in front of the lateral cephalogram equipment (OC200D, Instrumentarium Detal, Finland). The microphone of SLM was placed in front of the participant's mouth at the occlusal plane during the X-ray scanning. The horizontal distance between the microphone and the mouth was about 5 cm. (Figure 1) The vertical placement of SLM microphone was properly adjusted based on the height of each subject individually.

Background noise

The experiment was conducted at 7:00–10:00 PM in the Department of Oral Radiology, West China Hospital of Stomatology (Chengdu, China), to exclude the interference of environmental noises (eg, patients' footsteps, chats) in the daytime. Ambient noise and machinery sound were set as the background noise. A constant decibel value of background noise was achieved during each experiment.

Radiography evaluation

Lateral cephalograms were performed on all subjects at rest and during phonation of vowel /i:/ at both high and low sound intensity, respectively, with an Orthoceph OC200D (Instrumentarium Dental, Finland) at 85 kV, 13.0 mA. The main parts of OC200D consist of a cephalostat head, a CCD (charge-coupled device) camera, a secondary collimator, an ear rod with pin, and a nasion support with scale. Participants were required to remove all metal objects, such as eyeglasses, jewelry, oral appliances, and so on, from the head and neck area before X-ray scanning. Participants were guided to stand under the cephalostat. Then we adjusted the cephalostat to the proper height and introduced the ear rods to participant's external auditory meatuses to fix the head. The nasion support was set to the nasion to make sure the participant's Frankfurt Horizontal plane was parallel with the horizontal plane (Figure 1).

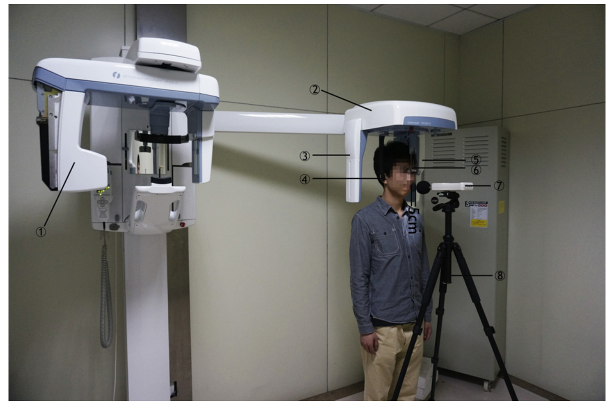

FIGURE 1. OP200 D main parts and the placement of SLM. The microphone of SLM is placed in front of the participant's mouth at the occlusal plane. The distance between the microphone and the mouth was 5 cm at horizontal level. ① Primary collimator selector ② Cephalostat head ③ Secondary collimator ④ Ear rod with pin ⑤ CCD camera ⑥ Nasion support with scale ⑦ SLM ⑧ Tripod.

The participants were trained to phonate vowel /i:/ at both high and low sound intensity before the lateral cephalometry scanning. They were taught to phonate vowel /i:/ at the low sound intensity level when the vibration of vocal folds could be felt by hand touch. For high sound intensity, participants were required to phonate the same vowel /i:/ in the same pitch at their maximum sound intensity. To ensure stable pitch across the two intensity conditions, an electronic tuner was applied to help train every participant to produce the sustained vowel /i:/ in the same pitch at high and low sound intensity before X-ray scanning. During each phonation, the sound intensity was identified and recorded.

Morphological features and parameters of velopharyngeal function of subjects were recorded and measured. Furthermore, SLM was used to evaluate and record the sound intensity of each phonation. The parameters measured in this research were described in the following.

Measurement

Cephalometric landmarks. Cephalometric landmarks were used to evaluate angular and linear parameters of velopharyngeal closure. N, nasion, was indicated the most anterior point of the junction between the frontal and nasal bones. S, sella, was the center of the sella turcica. ANS and PNS were the abbreviations for the anterior nasal spine and the posterior nasal spine, respectively. H was indicated the most convex point of the superior contour of the horizontal part of soft palate during phonation. PPW stood for the point where palatal plane extension intersected the posterior pharyngeal wall at rest, whereas PPW' was the point where palatal plane extension intersected the posterior pharyngeal wall during phonation. VPCs and VPCi were the superior and inferior point of velopharyngeal contact, respectively. U and U′, respectively, were the most