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DETECTION OF ADENOID HYPERTROPHY AND NASAL OBSTRUCTION USING MEL-FILTER BANK

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Abstract. *Acquired immunity to pharyngeal tonsil lymphoid tissue hypertrophies improves during childhood. Identifying and treating pharyngeal tonsil hypertrophy at an early stage is essential because hypertrophied tissues may occur sleeping and breathing disorders. Therefore, we propose a non-invasive method for detecting pharyngeal tonsil hypertrophy using speech. In an acoustic analysis, the symptoms of adenoid hypertrophy and nasal obstruction are found to be similar, making their discrimination challenging. In addition, it is necessary to consider the effects of nasal obstruction or not in a nasal cavity with an adenoid. This study focuses on the frequency response caused by adenoid hypertrophy and nasal obstruction as different transfer function characteristics are expected. Adenoid hypertrophy and nasal obstruction change the shape of the vocal tract – which is an acoustic tube – affecting the resonance and anti-resonance frequencies. This paper describes an experiment investigating the effects of adenoid hypertrophy and nasal obstruction using a Mel-filter bank. The results confirmed that changes in the Mel spectrum are due to adenoid hypertrophy and nasal obstruction.*
Keywords: Adenoid hypertrophy, Nasal obstruction, Transfer function, Mel-filter bank

1. **Introduction.** Pharyngeal tonsil lymphoid tissue, called an adenoid, hypertrophies as acquired immunity improves during childhood [1]. Adenoid hypertrophy culminates in growth between the ages of 4 and 6, and subsequently atrophies. However, hypertrophy has been observed in some cases even after the atrophy duration has passed, leading to stenosis between the nasal cavity and epipharynx. The stenosis of the nasal cavities inhibits nasal breathing and leads to chronic oral breathing [2]. Chronic oral breathing during the early stage of childhood has been considered to result in a long face and malocclusions [3,4]. In addition, hypertrophy is one of the leading causes of sleep apnea syndrome (SAS) [5]. The cure rate of adenoidectomy and tonsillectomy, including among obese patients aged 2 to 18 years, was 75% to 100% [6]. Therefore, early detection and surgical treatment of hypertrophy are essential to avoid developmental delay and deterioration in quality of life [7].

Cone-beam computed tomography (CBCT) and roentgenographic cephalometry are conventional methods for diagnosing adenoid hypertrophy [8]. Although these methods provide accurate measurements, they involve radiation exposure [9]. To address these

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issues, we proposed a non-invasive method for finding adenoid hypertrophy through speech analysis [10]. Previous studies have proposed a detection method for adenoid hypertrophy when a subject utters the Japanese nasal /N/ sound into a microphone [2,10]. A detection rate of approximately 82% or higher was achieved, demonstrating the effectiveness of the proposed method. However, this method focuses only on adenoid hypertrophy. Thus, the effect of a concomitant nasal obstruction in the nasal cavity must also be considered [11]. The combined rate of sleep-disordered breathing and allergic rhinitis in children is 40.8% [12], and there is often overlap between adenoid hypertrophy and various other causes [13]. The results of this study confirm the discriminability of adenoid and nasal obstruction using a Mel-filter bank for the transfer functions of three-dimensional models.

This paper is organized as follows: Section 2 describes the transfer function of the three-dimensional model and Section 3 describes experiments using the Mel-filter bank. Finally, in Section 4, we summarize this paper and suggest directions for future work.

2. **Transfer Function of the Three-Dimensional Model.** Adenoid hypertrophy and nasal obstruction affect the resonance and anti-resonance frequencies because they change the spectrum envelopes of the speech sound [14]. The vocal tract, including the oral and nasal cavities, is an acoustic tube. In this study, the transfer functions of three-dimensional models, created using a three-dimensional printer, were measured. Figure 1 shows a cross-sectional view of a three-dimensional model. These models were used in an experiment where four conditions (0, 10%, 80%, and 90%) were applied to determining the obstruction rate from adenoid hypertrophy, and three conditions (0, 80%, and 100%) were applied to determining the obstruction rate from nasal obstruction.

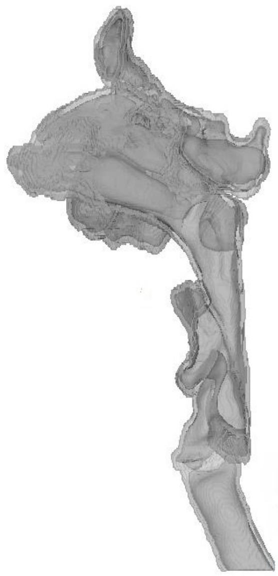


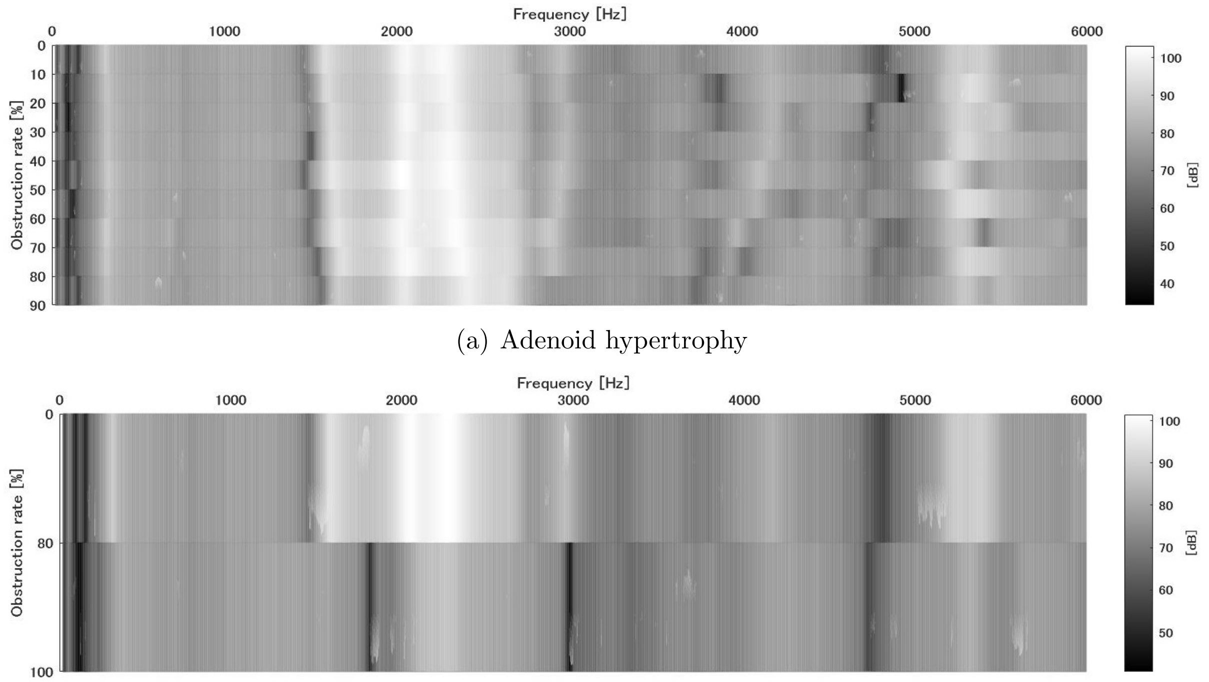
FIGURE 1. Cross-sectional view of the three-dimensional model

3. **Extraction of Features Using Mel-Filter Bank.** In this study, the measured transfer functions of three-dimensional models were compressed using a Mel-filter bank. The effects of the adenoid hypertrophy and nasal obstruction or not that provided the obstructive conditions as a percentage of the cross-sectional area of the tube were confirmed.

3.1. **Mel spectrum and Mel-filter bank.** The Mel scale is a human sensory scale that considers the human perception of pitch. The frequency at the Mel scale is called the Mel frequency, and the frequency and Mel frequency have a logarithmic relationship on the frequency axis. A triangular filter arranged within the logarithmic frequency is called a Mel-filter bank. Sufficient knowledge about the rough spectrum shape in speech analysis is also important and Mel-filter bank is used to extract acoustic features [15]. In this paper, the spectrum is compressed into the Mel spectrum using the output of a 30-channel Mel-filter bank.

3.2. **Experiment conditions.** This experiment was performed in an anechoic room to measure transfer functions accurately. The TSP signal was from a sound input into a three-dimensional model from a speaker installed on the glottis side of the model. The output sound was then received by a microphone installed on the nostril side of the three-dimensional model. The TSP (time-stretched pulse) is commonly used in impulse response measurements of audio systems and room acoustics. An AP525 (Audio Precision, Inc.) was used for recording and analysis, with a sampling frequency of 48 kHz and a quantization size of 16 bits. The signal was swept from 20 Hz to 20 kHz during a 1 s period and synchronous averaging was conducted 100 times.

3.3. **Results and discussion.** Figure 2 shows the transfer function of each three-dimensional model. Figure 2(a) shows that spectrums with troughs near 1.7 and 2.3 kHz are approximately 100 Hz higher as the obstruction rate increases owing to adenoid hypertrophy. The peaks occur at approximately 3 kHz between 0 and 80% obstruction of the models; however, these peaks become a trough at 90% obstruction. This behavior at 90% obstruction is attributed to the fact that the vocal tract, which is a single tube, behaves like a bifurcated tube with glottis and nostril sides owing to the increased obstruction rate caused by the adenoid hypertrophy.

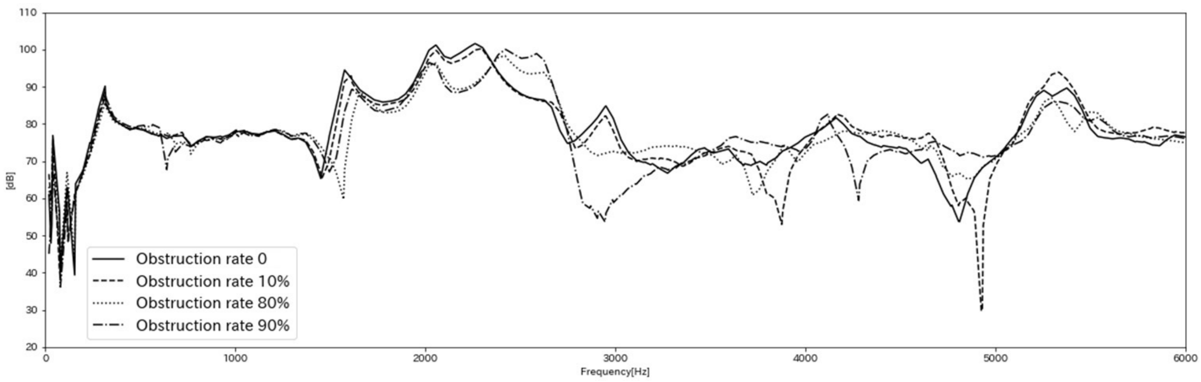


(a) Adenoid hypertrophy

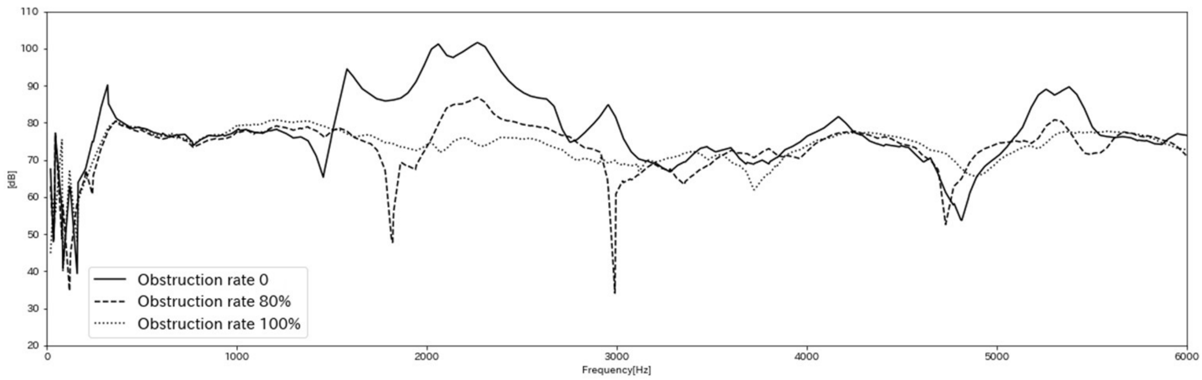
(b) Nasal obstruction

Figure 2. Three-dimensional transfer function

Figure 2(b) shows that troughs occur at approximately 2 and 3 kHz when the obstruction rate from nasal obstruction is 80%. This finding is expected to be used as an effective parameter for detection of nasal obstruction or not. Figure 3 shows the transfer function expressed along frequency-magnitude axes. To understand the overall trend of the transfer function, the transfer function was changed using a Mel-filter bank, as shown in Figure 3. Figure 4 shows the Mel spectrum changed using this bank. Figure 4(a) shows that

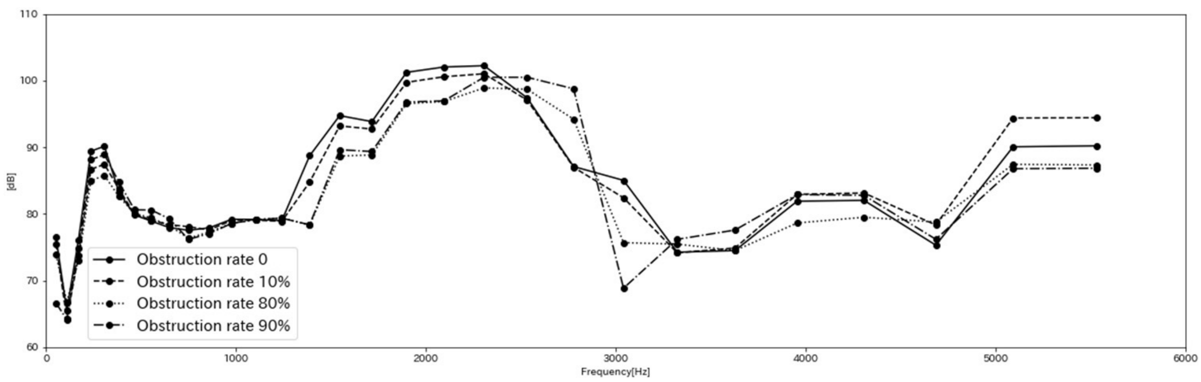


(a) Adenoid hypertrophy

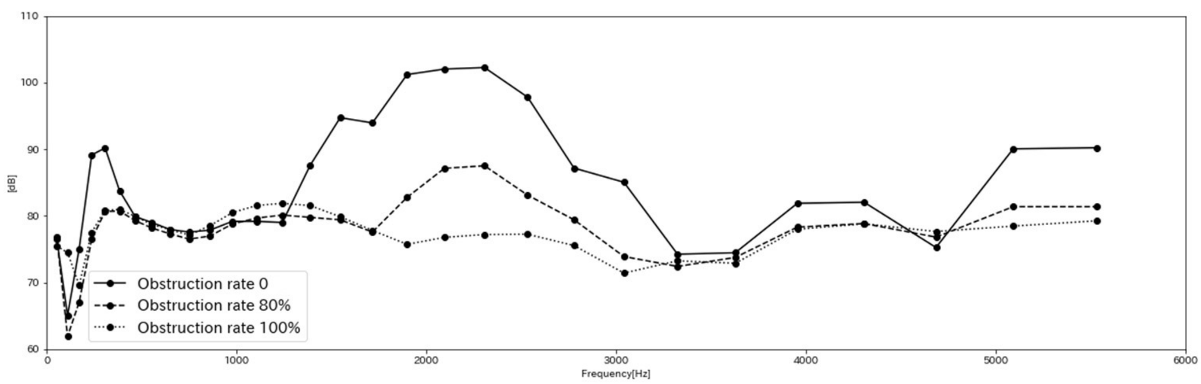


(b) Nasal obstruction

FIGURE 3. Transfer function



(a) Adenoid hypertrophy



(b) Nasal obstruction

FIGURE 4. Mel spectrum

when the obstruction rate of the adenoid hypertrophy is 90%, the level of resonance from approximately 1.5 to 2 kHz decreases, and the resonance is reversed at approximately 3 kHz. Figure 4(b) shows that the level of resonance from approximately 1.5 to 3 kHz decreases as the obstruction rate increases. These results indicate that it is possible to detect adenoid hypertrophy and nasal obstruction or not using the Mel spectrum as the feature parameters.

4. **Conclusion and Future Work.** In this paper, transfer functions of three-dimensional models were measured using a Mel-filter bank and the results confirmed the changes in the obstruction rate owing to adenoid hypertrophy and nasal obstruction. The results obtained and depicted in Section 3 confirmed changes in the frequency characteristics in the Mel spectrum because of adenoid hypertrophy and nasal obstruction or not. These changes in the Mel spectrum are expected to be used as a parameter to discriminate between adenoid hypertrophy and nasal obstruction.

In a future study, we will confirm their effects when observed concurrently and accurately examine a three-dimensional model with an oral cavity. In addition, we will try to establish a method for achieving a more robust detection of adenoid hypertrophy.

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