ABSTRACT

Relational growth or oral and pharyngeal structures with vocal-tract length during the first two decades of life as visualized with MRI and CT studies.

Houri K. Vorperian, Shubing Wang, Moe K. Chung, Reid B. Durschb, Michael Schimek, Lindell R. Gentry & Ray D. Kent

Waisman Center, Department of Biostatistics, Biostatistics & Medical Informatics, University of Wisconsin - Madison

INTRODUCTION

The pharyngeal cavity and nasal cavity play a critical role in the development of the speech motor system. Anatomical and physiological changes over the course of development are attributed to neural maturation of speech motor control. However, the role of anatomic growth of speech production structures in the oral and pharyngeal regions has not been studied in a concerted manner. This study addressed this gap in the literature by investigating the development of soft-tissue and bony vocal tract (VT) structures in the oral and pharyngeal regions. VT measurements were secured from 645 imaging (CT or MRI) in males and females aged birth to 220 months (mean age = 92 months). Measurements were secured from sagittal, coronal, and axial planes. Measurements were secured at the level of the hyoid bone, the soft palate, the hard palate, the lips, the tongue, and the mandible. These measurements were compared to a (i) sequential age distribution reference method and (ii) a method that determined structural changes in the VT using all available age points. VT structures were compared among males and females. Statistical analysis was performed to assess the extent to which the different VT structures contribute to VTL.

METHODS AND PROCEDURES

Subjects: A total of 645 boys and 600 girls from birth to 220 months (mean age = 92 months) were included in the study. The subset of 600 girls included in the study was age- and sex-matched to the subset of 645 boys. The study was conducted according to the Declaration of Helsinki and approved by the Institutional Review Board.

Image Acquisition and Data Exaption: Subjects were identified as 600 girls and 645 boys aged birth to 220 months from a large, prospective sample. Measurements included oral and pharyngeal measurements (VT measurements) secured from sagittal, coronal, and axial planes. Measurements were secured at the level of the hyoid bone, the soft palate, the hard palate, the lips, the tongue, and the mandible. These measurements were obtained from a standardized method outlined in the Materials and Methods section.

Statistical Analysis: Linear dimensions of the upper airway were calculated for each age and sex group. The correlation coefficients between each variable and VTL were calculated. The following linear regression model was used:

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \epsilon \]

where \( Y \) is the dependent variable (VT measurement), \( X_1, X_2, \ldots, X_k \) are the independent variables (VT measurements), \( \beta_0, \beta_1, \ldots, \beta_k \) are the coefficients, and \( \epsilon \) is the error term.

RESULTS

A total of 645 subjects (males and females) were measured in this study. The results of the statistical analysis are presented in Figures 2 to 9. Three illustrative examples are shown in Figures 2-7, which demonstrate the relationship between the different VT structures and VTL. Figure 2 shows the developmental changes in the relational growth of VT structures in the oral and pharyngeal regions with vocal tract length (VTL). Figure 3 shows the extent of relational growth of the palate with VTL. Figure 4 shows the extent of relational growth of the lips with VTL. Figure 5 shows the extent of relational growth of the tongue with VTL. Figure 6 shows the extent of relational growth of the mandible with VTL. Figure 7 shows the extent of relational growth of the hyoid bone with VTL.

DISCUSSION / MAJOR FINDINGS

The findings of this study indicate that most VT structures examined contribute to VTL, i.e. assess relational growth of the different VT structures with VTL. Such findings can help address questions of whether structures that are important to speech motor control should be incorporated into theoretical constructs on motor speech development in children. The increased variability associated with the developmental dispersion of VT structures highlights the importance of understanding the role of anatomic growth in the development of speech production structures.

Figure Legends

Figures 2-9. Measurements of VT structures with respect to VTL for males and females. Figures 2-7 display the relational growth of oral and pharyngeal structures in the oral and pharyngeal regions with VTL for males and females. Figures 2-7 also display the extent of relational growth of oral and pharyngeal structures in the oral and pharyngeal regions with VTL for males and females.