Individuals with Down syndrome (DS), who are born with an extra copy of chromosome 21 (Trisomy 21), experience high rates of cervical spine abnormalities. This developmental pilot study quantitatively compares the C-spine areas, using computed tomography (CT) images in the midsagittal plane, from individuals with Trisomy 21 against the TD trend line. See Figures 5 to 10.

1. Landmarking: Using CT scans, 3D landmarks were placed on the corners of the cervical bodies in the midsagittal plane using the sagittal (X), coronal (Y), and axial (Z) views to guide accurate landmark placement on C3-C7. Unit C5, C6 and C7 were cutoff from view. As seen in Figure 1, three landmarks were placed on C2, and 4 were placed on C3-C7, and used to calculate the area of each C-spine after the following pre-processing steps (2-4).  

2. Best Fit Plane: The least square best fit plane was found for the 3D landmarks of each vertebra. See Figure 2, blue plane.

3. Plane Rotation: The best fit plane was rotated until all x-coordinates were the same, resulting in a vertical plane in 2D. See Figure 3.

4. Point Rotation: All points were rotated on the best fit plane while maintaining the distance from each landmark to the centroid, creating a 2D polygon representing the midsagittal vertebra. See Figure 4.

5. Calculations and Plotting: The polygon area was calculated and these areas were plotted onto the TD trend line. The sex-specific TD growth trends were established in the Vocal Tract Development Lab (based on 130 TD CT scans; 46 females and 84 males). The blue polygon depicts the shape made after the points were moved onto the plane, without creating a 2D polygon with the blue landmarks depicts the shape that would have been made if the points were moved onto the plane, without regard to the plane.

V. DISCUSSION:

- Overall, the DS C-spine areas fell below the TD growth trend line, while the female DS C2 areas crossed the TD growth trend. Female DS vertebras had little growth from age 8-12 years. See Figure 5.

- The males DS C3-C6 areas were consistently below the TD growth trends; while this was also the case for the female DS C3-C6 areas, the difference in areas appear to increase from the TD growth trend during the course of development. Additionally, like C2, lack of substantial growth occurs in female DS vertebras from age 8-12 years, suggestive of developmental delay. See Figures 6-8.

- The male DS C7 areas were above the TD growth trend line, while female C7 areas crossed the TD growth trend. Compared to C2-C6, all DS C7 areas appear to correspond with the TD growth trend line. See Figure 10.

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