# Cloth Face Mask Fit and Function for Children: Sizing and Fit Analysis

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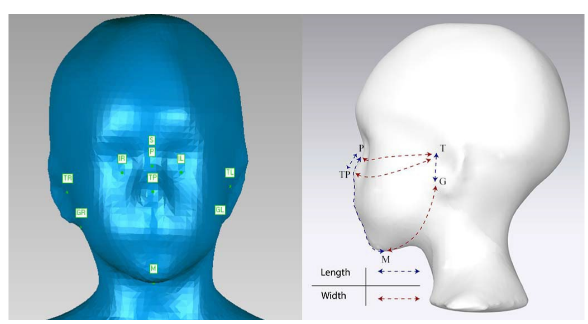
**Introduction:** Facemasks have been the predominant tool to reduce the transmission of the Covid-19 virus (Center for Disease Control and Prevention (CDC), 2022). They increase protection especially when they fit snugly and comfortably on the face (CDC, n.d.-a; Smart et al., 2020). Commercially available children's cloth masks range widely in material type, fabric structures, construction, layering, and shape. However, there is a lack of anthropometric data, and as a result lack of suggestions for sizing to provide the best facemask fit for children 4-6 years old. Several studies highlighted the important landmarks and measurements for developing fit of medical or pediatric face masks, but these findings have not been fully applicable to the clothing face masks for children (Amirav et al., 2014; Fu & Luximon, 2019; Seo & Han, 2017). Children's face and head proportions are significantly different than adults' proportions (Farkas et al., 1992; Lin et al., 2010). For instance, nose and eyes in addition to facial length, width, and volume increase from childhood to adulthood (Ferrario et al., 1998). Thus, face masks that are designed for adults and sized down for younger populations may not fit children as expected. Therefore, to provide a better cloth face mask fit, it is critical to design it based on children's anthropometric data. This study aimed to develop, test, and offer a method for the fit assessment of a new cloth face mask design for children 4-6 years old. The following research questions were raised: a) What are sizing and fit requirements for cloth face masks in children ages 4 to 6 years old? b) How does the improved mask design for children ages 4 to 6 years old fit?

**Methods:** Anthropometric data were collected from forty-four children's scan aged six years old by using the Size North America data set. Weight status and Body mass index (BMI) were calculated with the BMI percentile calculator for child and teen (CDC, n.d.-b). A total of 10 landmarks were selected based on the AATCC- M14 guideline (2020) to obtain information on the identifiable facial measurements related to the design of cloth face mask including: Tragion (T), Pronasal (TP), Menton (M), Infraorbital (I), Gonion (G), and mid-nose (P) (Figure 1). Then, distances between the landmarks were calculated. Landmarks were placed on the obj files with Geomagic Wrap 2021 software. As a result, 11 measurements were extracted and imported into an Excel file for data analysis. For data analysis, descriptive statistics with correlations at a 95% confidence level by Principal Component Analysis (PCA), K-means cluster sampling, and one-way

Figure 1. Landmark Placements



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ANOVA were conducted in SPSS 27. PCA with Varimax rotation was applied to transform several possibly correlated variables (18 facial measurements) into a smaller number of principal components (PCs). K-means cluster analysis was conducted to assign participants to the clusters. To analyze whether clusters were significantly different from one another, each face measurement was compared through a one-way ANOVA test. The findings from PCA and K- means cluster analysis suggested a sizing update for the cloth mask measurements to improve fit. Patterns were imported to Clo3D, after adjusting them in Optitex PDS, for subjective and objective fit analysis of the digital facemasks. Similar to the facemask design's silicon edges, the edge of the cloth facemask was sealed on the faces digitally by setting the skin offset to 0.00 mm. Two fit judges rated the fit of the simulated face mask on each scan at the nose and mouth levels through a 3-point Likert scale (1= not acceptable fit, 2= acceptable fit, 3= partially acceptable fit, i.e., too tight at either location). To quantify the gap (ease) between the mouth, nose, and the face mask, a vertical plane was set at the mouth, and nose levels, a cross-section was created, and the distance between nose and mouth from the inner layer of the face mask was measured in Geomagic Wrap 2021. Pearson's chi-squared test was used to determine whether there was a statistically significant association between fit and subjects' BMI, ethnicity, and sex.

**Results:** Of the forty-four scans, 57% of subjects were girls (N=25) and 43% of them were boys (N=19) with a diverse ethnicity including Non-Hispanic /White (N=16, 36%), Asian (N=12, 27%), African American/ Black (N=10, 23%), and Hispanic (N=6, 14%). Participants' BMIs were Underweight (7%, n=3), Healthy weight (61%, n=27), Overweight (16%, n=7), and Obese (16%, n=7). For sizing analysis, results from PCA and one-way ANOVA showed a statistically significant mean difference between M-G and M-T measurements and BMI ($df=3$, $p< .001$). Hence, BMI was considered as the main factor for categorizing participants. Based on the BMI, two clusters were found to be the best ones to represent the complexity among subjects. Although analysis of the key measurements between two clusters showed that width-related measurements were significantly different ($df=1$, $p<.001$), they were too small to be considered as a single size (5.00 mm). Therefore, the average mean was taken as a reference for improving the size of the cloth face mask ($M_{P-T}$= 113.45 mm, $SD_{P-T}$= 6.17 mm; $M_{T-TP}$=118.13 mm, $SD_{T-TP}$= 6.40; $M_{M-G}$= 90.41 mm, $SD_{M-G}$= 5.10 mm; $M_{T-G}$ = 33.03 mm, $SD_{T-G}$ =4.41 mm; $M_{P-TP}$= 20.90 mm, $SD_{P-TP}$= 2.35 mm; $M_{P-M}$= 103.74 mm, $SD_{P-M}$= 6.17 mm). Fit analysis showed that among 45% of subjects (N=20), the cloth face mask provided an "acceptable fit" at the nose and mouth levels. Ease amounts between nose, mouth and the inner layer of the face mask showed that on average, 12.65 mm (SD= 11.50 mm) gap at the nose, and 22.07 mm (SD= 8.90 mm) gap at the mouth level could provide an "acceptable fit". The subjects who received other ratings would need a larger size face mask to have better and comfortable coverage of the nose and mouth. Our results also indicated that in addition to the measurements, varied facial shapes such as prominent cheeks and nose, protrusive lips, and receding, or protrusive chin were important factors that impacted the fit of face masks.



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**Conclusion:** Our study highlighted the size and fit requirements for the design of cloth facemasks for children. Width measurements including P-T, T-TP, and M-G were found to be the most critical key measurements for developing a sizing strategy for a facemask. Additionally, BMI was found to be the main factor for identifying size range, indicating that children with higher BMIs need a sized-up facemask. Study findings also helped define "acceptable fit" for a child's cloth facemask as 22.07 mm ease at the mouth and 12.65 mm at the nose level. This study had a few limitations. Due to the pandemic, the improved cloth-face mask prototype was only tested on children's 3D scans. Therefore, subjects' feedback was not included in the fit evaluation process. Because of limited access to Size North America data, the number of scans used in this study was small. More research on children in different age groups would help with a better understanding of the facial variations and improving the fit of the facemasks. Since 20% of subjects had a tight fit at the nose and mouth, and 34% of subjects had a partially acceptable fit rate, future studies should also investigate face shape identification to further improve the mask design.



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