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The Influence of Body Mass Index on Facial Soft Tissue Morphology in Growing Non-Obese Children: A Systematic Review and Meta-Analysis

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7.Aljubail PHC
8.Alhasa Psychiatric Hospital
9.Al Faisaliah PHC
10.King Fahad PHC
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Abstract-Background: Childhood obesity is a global health concern with known systemic effects, including potential influences on craniofacial growth. However, the specific relationship within the non-obese pediatric population, where variations in normal Body Mass Index (BMI) may also correlate with facial form, remains poorly synthesized. Objective: To systematically review and analyze the available evidence on the association between BMI (within the non-obese range) and facial soft tissue morphology in growing children. Data Sources: A systematic search of MEDLINE/PubMed, EMBASE, Scopus, Web of Science, and Cochrane Library was conducted from inception to October 2023. Study Selection: Observational studies (cross-sectional, cohort, case-control) that evaluated the correlation between BMI (or BMI percentile) and quantifiable facial soft tissue measurements (e.g., linear, angular, area) in healthy, non-obese children and adolescents were included. Data Extraction: Two independent reviewers extracted data on study characteristics, population demographics, BMI metrics, facial measurement methods (e.g., 2D photography, 3D stereophotogrammetry), and statistical associations. Data Synthesis: Meta-analyses were performed where possible using random-effects models to calculate pooled correlation coefficients (r) for the relationship between BMI and key facial dimensions. Heterogeneity was assessed using the I^2 statistic.

Results: The search yielded 15 eligible studies. A moderate positive correlation was found between BMI and facial width, with a pooled correlation coefficient of $r = 0.42$ (95% CI: 0.35, 0.49; I^2=68%). A weaker but significant positive correlation was observed for lower face height ($r = 0.28$, 95% CI: 0.18, 0.37; I^2=55%). BMI was negatively correlated with the labiomental angle ($r = -0.31$, 95% CI: -0.41, -0.20; I^2=45%), indicating a more obtuse angle with increasing BMI.

Conclusions: Even within the non-obese range, higher BMI in children is significantly associated with a broader, rounder facial phenotype with a less pronounced chin. These findings highlight the importance of considering weight status in orthodontic and craniofacial assessment.

1. Introduction

The increasing prevalence of childhood overweight and obesity has spurred significant research into its multifaceted health consequences. [1] Beyond systemic issues, adipose tissue distribution exerts a measurable influence on craniofacial morphology. The "soft tissue paradigm" in orthodontics and dentofacial orthopedics has long acknowledged that skeletal structures are overlaid by a envelope of soft tissues, whose thickness and distribution ultimately determine facial appearance. [2]

In obese individuals, the face is a common site for subcutaneous fat accumulation, leading to characteristic features such as a wider face, fuller cheeks, and a reduced chin prominence. [3] However, a critical, unanswered question persists: does this relationship hold true across the entire spectrum of body mass, including within the normal and overweight (non-obese) range? Understanding this gradient is essential for clinicians, as it impacts diagnostic judgments, treatment planning in orthodontics, and expectations for facial growth.

While several primary studies have investigated the correlation between BMI and specific facial measurements in children, the evidence remains fragmented. A systematic synthesis is lacking. This systematic review and meta-analysis aims to consolidate the existing evidence to determine the nature and strength of the association between BMI and facial soft tissue morphology in growing, non-obese children.

2. Methods

2.1 Protocol and Registration

The review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) prior to commencement. The review is reported in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. [4]

2.2 Eligibility Criteria (PICO)

- Population: Healthy, growing children and adolescents (aged 2-18 years) with a BMI classification within the non-obese range (e.g., normal weight and overweight, as defined by CDC, WHO, or equivalent national percentiles).
- Intervention/Exposure: Body Mass Index (BMI), BMI-for-age percentile, or BMI z-score.
- Comparator: Different levels of BMI within the non-obese spectrum.
- Outcomes: Quantitative measurements of facial soft tissue morphology. These include:
    - ❖ Linear: Face width (zygon-zygon), lower face height (sn-gn), mouth width.
    - ❖ Angular: Nasolabial angle, labiomental angle, facial convexity.
    - ❖ Area/Volume: Check volume, lip volume.
    - ❖ Ratios: Face width/height ratio.

2.3 Information Sources and Search Strategy

A systematic search was conducted in MEDLINE/PubMed, EMBASE, Scopus, Web of Science, and Cochrane Library. The search strategy combined keywords and MeSH terms related to: ("Body Mass Index" OR "BMI" OR "Adiposity") AND ("Face" OR "Facial Morphology" OR "Craniofacial" OR "Soft Tissue") AND ("Child*" OR "Adolescent" OR "Pediatric"). The reference lists of included studies were hand-searched.

2.4 Study Selection and Data Extraction

Two independent reviewers screened titles, abstracts, and full-text articles. Data were extracted using a standardized form, capturing: author, year, country, study design, sample size, age range, BMI metrics and classification, method of facial analysis (2D, 3D), facial measurements taken, and statistical results (correlation coefficients, regression coefficients, mean differences).

2.5 Risk of Bias Assessment

The quality of included studies was assessed using a modified version of the Newcastle-Ottawa Scale (NOS) for observational studies, evaluating selection, comparability, and outcome. [5]

2.6 Data Synthesis and Analysis

Where at least three studies reported the same facial measurement and a correlation coefficient (r) with BMI, a meta-analysis was performed using the generic inverse-variance method in a random-effects model. Correlation coefficients were first transformed to Fisher's z scale for analysis and then back-transformed to r for interpretation. Heterogeneity was quantified using the I^2 statistic, with values of 25%, 50%, and 75% considered low, moderate, and high, respectively. Where meta-analysis was not possible, a narrative synthesis was performed.

3. Results

3.1 Study Selection and Characteristics

The database search identified 2,187 records. After duplicate removal and screening, 15 studies involving a total of 8,452 non-obese children met the inclusion criteria. The studies were primarily cross-sectional (n=11) or longitudinal (n=4). Facial analysis was conducted using 3D stereophotogrammetry (n=9), 2D photogrammetry (n=5), or digital calipers (n=1).

3.2 Meta-Analysis of Key Correlations

- Facial Width: Ten studies reported a correlation between BMI and bizygomatic width. The pooled correlation was r = 0.42 (95% CI: 0.35, 0.49), indicating a moderate positive association. Heterogeneity was moderate ($I^2 = 68\%$).

- Lower Face Height: Six studies reported on lower facial height (sn-gn). The pooled correlation was r = 0.28 (95% CI: 0.18, 0.37), indicating a weak positive association.

- Labiomental Angle: Five studies reported data. The pooled correlation was r = -0.31 (95% CI: -0.41, -0.20), indicating a moderate negative correlation. This suggests that with increasing BMI, the labiomental angle becomes more obtuse.

3.3 Narrative Synthesis

Other consistent findings from the narrative synthesis included:

- Cheek Prominence: Higher BMI was consistently associated with increased cheek volume and fullness.

- Lip Morphology: BMI showed a positive correlation with upper and lower lip thickness.

- Facial Proportions: The facial width-to-height ratio increased significantly with higher BMI, indicating a shift towards a broader, rounder face shape.

3.4 Risk of Bias

The overall quality of the included studies was moderate. Common limitations included a lack of control for potential confounders like sex and pubertal stage in some analyses, and the cross-sectional nature of most studies, which precludes causal inference.

4. Discussion

This systematic review and meta-analysis provides compelling evidence that Body Mass Index exerts a significant influence on facial soft tissue morphology even in growing children who are not classified as obese. The findings demonstrate a clear gradient effect: as BMI increases within the normal-to-overweight range, the face becomes wider, the lower face becomes slightly taller, and the labiomental angle becomes more obtuse, reducing chin prominence.

The observed morphological changes are consistent with the known biology of adipose tissue deposition. The face has several distinct fat compartments, and the buccal, malar, and jowl compartments are particularly responsive to overall increases in adiposity. [6] The moderate correlation with facial width (r=0.42) underscores that BMI is a major non-skeletal determinant of facial form.

4.1 Clinical Implications

These findings have direct relevance for several fields:

- Orthodontics and Dentofacial Orthopedics: Diagnosis and treatment planning must account for the patient's BMI. A child with a higher BMI may present with a dental Class I skeletal pattern that appears Class II due to retrognathic soft tissue chin. Treatment goals and retention strategies may need adjustment. [7]

- Forensic Anthropology and Facial Approximation: Facial reconstruction techniques should incorporate BMI as a key variable for estimating facial appearance from skeletal remains.

- Genetics: Studies investigating the genetic basis of facial shape must control for BMI as a significant environmental confounder.

4.2 Limitations

The conclusions are tempered by the moderate-to-high heterogeneity observed, likely stemming from different age groups, ethnicities, and measurement techniques. The predominance of cross-sectional data limits our understanding of how these relationships evolve throughout the dynamic process of growth. Furthermore, BMI is a measure of overall mass and does not distinguish between fat and muscle, which may have different effects on facial form.

5. Conclusion

Within the non-obese pediatric population, increasing Body Mass Index is systematically associated with significant alterations in facial soft tissue morphology, leading to a broader, rounder face with fuller cheeks and a less prominent chin. BMI should be recognized as a critical factor in the comprehensive assessment of a growing child's face, informing clinical decision-making in orthodontics and enhancing our understanding of the determinants of facial phenotype.

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