Comparing Body Sizing Standards to Their Referenced Data Sources: The Case of ASTM D4910 Standard Tables of Body Measurements for Infants

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Introduction. Textiles and apparel have routinely played a key role in the protection of infants, with modern strategies focused on thermoregulation within the near environment (Tourula et al., 2011; Golden et al., 2021), accuracy of fit (Kwok et al., 1997, 1998; Kwok et al., 2007; Deng et al., 2011; Haar et al., 2013), and flammability regulations (Ahrens, 1977; Clark-Esposito, 2018; Government Publishing Office, 2021). Anthropometric-based body sizing standards underpin the successful execution of each strategy. Thus, to support infant protection efforts within textiles and apparel, this study aimed to provide a method for testing the coherence between a body sizing standard and its referenced data sources, with the analysis of *ASTM D4910 Standard Tables of Body Measurements for Infants* as an example. The body-garment relationship (BGR) theory, specifying spatial relationships between body and pattern components (Gazzuolo, 1985; Carufel & Bye, 2020), was chosen as the theoretical foundation for this study and guided the discussion.

Method. The six versions of ASTM D4910 were used as the primary data sources in this case study. Qualitative content analysis of the body measurement definitions enabled targeted quantitative statistical comparisons between the referenced data source's anthropometric data and the standard's size-specific measurement values. Only definitions shared across all six versions and the referenced data sources were analyzed, while referenced data sources were only used if they provided specific data on infants: the number of subjects per age category, the body measurement mean for each age category (μ), and the standard deviation of the mean.

Seven data sources were referenced in total, with three to five referenced per version. Of the seven, only three provided the specified infant data (Snyder et al., 1975; Snyder et al., 1977; Kuczmarski et al., 2002). Content analysis was performed to identify the body measurement definitions that share a consistent meaning across all six versions of D4910. These definitions were then summarized on key components; for instance, height was summarized as "straight distance from top of head to bottom of feet; infant lying down." Summarized definitions were compared to the final three data sources' body measurement definitions to determine the final comparable body measurements used for hypothesis testing.

Hypotheses were tested to determine if the D4910 body measurement value for a size was statistically significantly different from the referenced data source's anthropometric mean for the corresponding age group (H_0: Reference data source μ = ASTM D4910 measurement value). A one-sample *t*-test with $p \leq 0.05$, Cohen's *d* effect size ($d \geq 0.8$), and 95% confidence interval were performed for all 120 statistical comparisons between D4910 and the final three referenced data sources. In line with previous comparisons of American voluntary product sizing standards to an anthropometric database (e.g., Patterson & Warden, 1983-84; Goldsberry et al., 1996), it was hypothesized that the referenced data source's anthropometric data were not used to develop the standard's sizing system (H_A: Reference data source $\mu \neq$ ASTM D4910 measurement value).

Results. Content analysis of D4910 revealed that overall, the number of measurements per standard increased over time, from 32 in 1999 to 69 in 2019. The additional measurements in D4910-19 segment the body in a more detailed manner (e.g., -08/13 had elbow and wrist girths, while -19 had elbow, forearm, wrist, and hand girths). Thirty-two body measurements were listed by all six versions, with 23 definitions retaining a consistent meaning from 1999 to 2019. The final three data sources had 36 (Snyder et al., 1975), 34 (Snyder et al., 1977), and three (Kuczmarski et al., 2002) measurements, respectively. The following seven measurements retained a consistent meaning between D4910 and the final three referenced data sources: head girth and height (all three), chest girth, waist girth, thigh girth, and shoulder width (Snyder et al., 1975; Snyder et al., 1977), and hip girth (Snyder et al., 1977).

Of the 120 statistical comparisons made between the final three referenced data sources and D4910, 79% rejected the null hypothesis. Of these rejections, 85% had $p < 0.000$ and 67% had Cohen's $d > 0.8$, indicating a large difference between the values. Of the rejections, 67% of the D4910 values were larger than their upper confidence interval values and 12% were smaller than their lower confidence interval values. A total of 22% of the D4910 values fell within their 95% confidence intervals; however, none of the D4910 values exactly matched with those of the referenced data source. Lastly, the 59 hypotheses for the major girths (i.e., chest, waist, hip, and thigh) were universally rejected at $p \leq 0.05$; 97% had $p < 0.000$, 92% had Cohen's $d > 0.8$, and in all 59 instances, the D4910 value was larger than the upper confidence interval value.

Discussion. The results indicated that the null hypothesis could be rejected in general: ASTM D4910 body measurement values were not derived from the referenced data sources' anthropometric data. This presents a major concern for infant apparel producers, as the use of D4910 may result in garments that are typically too large for infants at key girths across all age ranges. This may also lead to issues related with meeting federal regulations for 'snug-fit' outlined in *16 CFR Chapter II, Part 1615 – Standard for the Flammability of Children's Sleepwear: Sizes 0 through 6X (FF 3-71)* (Government Printing Office, 2021).

To assist infant apparel producers in developing accurate sizing systems and well-fitting basic blocks, it may be beneficial to apply the BGR theory for analyzing the relationships between the infant body and infant pattern-making practices. Two possible research avenues include: (a) which body measurements should be included in the body sizing standard? and (b) what mathematical formulas accurately describe the infant body? Since infants have different body proportions and components than adults (e.g., infant arms and legs are the same length at birth, infants have 270 bones while adults have 206) (Crelin, 1973), their sizing systems must reflect their unique needs. The analytical and dimensional components of the BGR theory cover how to generate operational definitions for garments and bodies (Gazzuolo, 1985; Carufel & Bye, 2020), which may help determine which body measurements must be taken from infants to make, grade, and fit garments. The visual and physiological components of this theory cover how to compare garments and bodies (Carufel & Bye, 2020), which may help generate mathematical formulas to describe relationships between infant body components, thereby updating current sizing system predictive models.

Conclusion. This case study utilized a novel method for testing the coherence between a body sizing standard and its referenced data sources, providing an easily accessible, holistic body sizing standard assessment method. Study findings lead to numerous opportunities for deeper understanding of infant body sizing practices, such as (a) a BGR theory-driven list of functional measurements for infant apparel, (b) a survey of infant apparel industry sizing practices, and (c) an apparel-oriented anthropometric survey of infants to update D4910. The major limitation of the study – the use of only measurements that retained consistent meanings across all sources – also suggests a research opportunity in the statistical comparison of body measurement values for variations of a single body measurement definition. For example, would arm length or girth values taken with the arm bent significantly differ from arm length or girth values taken with the arm straight? In conclusion, the findings of this case study set strong foundations for the necessity of a critical dialogue among apparel industry stakeholders regarding sizing system generation, specifically body measurement selection and sizing system formulas.

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