Comparing Rectangle Body Shape Using Unsupervised Machine Learning Algorithms

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Background and Research Purpose: Consumer dissatisfaction with apparel fit and lack of standardization of sizing systems in the fashion and apparel industry is still an issue to solve. Heretofore, sizing systems assume that humans have mathematically proportional bodies, and the bodies grow in proportional ways (Simmons et al., 2004a). In addition, researchers have consistently chosen bust, waist, and hip girths as key body dimensions to classify female body size and shape (Ashdown, 1998; Salusso-Deonier et al., 1985; Simmons et al., 2004b). However, key dimensions can be different as per different sample populations and for different types of garments. Besides, precedent studies implied that considering body shape can contribute to better accuracy and fit performance in pattern making and developing sizing systems to cater to a large and diverse population (Newcomb, 2006; Simmons et al., 2004a, b; Song & Ashdown, 2011; Song & Ashdown, 2012; Xia, 2013). Therefore, this research aims to explore identifying potential key body dimensions other than bust, waist, and hip girths and grouping clusters for a specific body shape population. This research will apply cutting-edge unsupervised machine learning techniques to understand body dimension relationships and patterns better.
Rectangle shape category: Based on Simmon's (2002) Female Figure Identification Technique (FFIT©), SizeUSA female population database was classified into nine body shapes to reflect the differential proportions of the American population. Among the database, a subset of 2901 rectangle-shaped subjects (45.97%), which is the most predominant shape in all ethnicities (White, Black, Hispanic, and Other, which include Asians), was extracted to be analyzed. Rectangle body shape represents people whose bust and hip measurement values are fairly equal, and bust-to-waist and hip-to-waist ratios are low (Simmons et al., 2004a). It was found that the classification using FFIT© oversimplifies complicating body measurements by relying on only six body measurements (bust, waist, hip, high hip, stomach, and abdomen) (Simmons, 2002; Simmons et al., 2004).
Analysis Methods: Body measurements data of rectangle-shaped subjects from the SizeUSA database were analyzed using the following three steps. First, we used exploratory factor analysis (EFA) to consolidate many measurements into a smaller set of latent factors. As a result, 39 measurements were grouped into three body measurement factors (23 horizontal measurements, 11 vertical measurements, and 2 shoulder slope measurements). Second, we used the Finite Mixture Model (FMM) with the Expectation-Maximization (EM) algorithm to approximate complex probability densities, which present multimodality, skewness, and heavy tails of horizontal, vertical, and shoulder slope data. According to the result, 5 levels of rectangle body shapes were identified, as shown in Figure 1 and Table 1. Third, we explored how shoulder slope varies across ethnicities using 1-way ANOVA (Figure 2).

Result: Using FMM with the EM algorithm, the results show five levels of rectangle body shape patterns based on the frequency of horizontal, vertical, and shoulder slope measurements (see Figure 1). The *Square* group is characterized by the moderate measurement in all three categories (horizontal, vertical, and shoulder slope). The *Small Square* group is characterized by the low measurements in all three categories. The results suggest that these groups may have a comparatively small difference in horizontal and vertical circumferences compared to other groups. However, the Square group has a moderate shoulder slope while the Small Square group has a flat shoulder slope. The *Horizontal Rectangle* group is characterized by high horizontal and moderate vertical slopes with moderate shoulder slopes. This square group may have more extended widths compared to height.

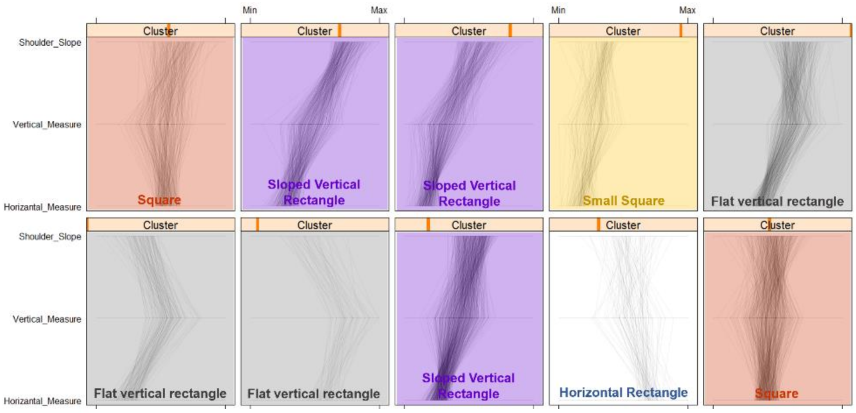

Figure 1 Groups of measure frequencies for 3 measurement factors

In contrast, *Slope Vertical Rectangle* and *Flat Vertical Rectangle* groups are characterized by low horizontal measurements and moderate vertical measurements. The results suggest that these groups may have slender body shapes compared to other groups, and high and low shoulder slopes sort the two groups. Furthermore, the 1-way ANOVA revealed that the shoulder slope measures of rectangle shape population significantly differ as per ethnicity group, as shown in Figure 2.

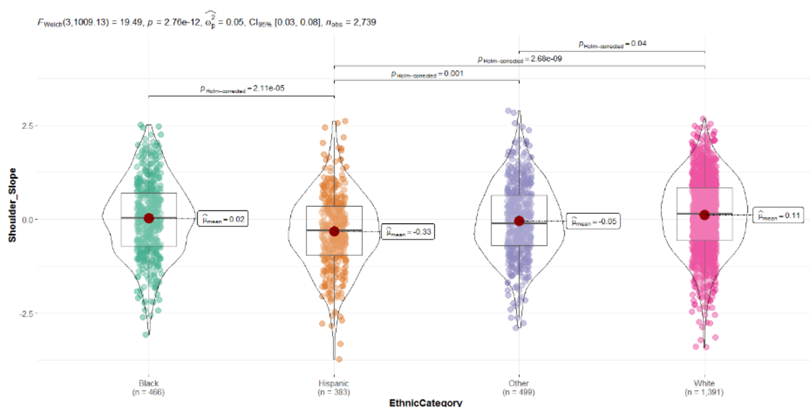

Figure 2 Violin plot of shoulder slope measurements

Conclusion: This study shows the value of EFA and FMM analysis to identify interaction patterns among 39 body measurements and categorize rectangle-shaped female subjects into different groups based on the frequency of horizontal and vertical measurements and the shoulder slant slope. The shoulder slope could be a potential key dimension to analyze the anthropometric data and develop a sizing system that enables the production of correctly sized clothing for the rectangle-shaped population. The future study will investigate how shoulder slope is related to the bust, waist, and hip measurements and their proportion.

References

Ashdown, S. P. (1998). An investigation of the structure of sizing systems: A comparison of three multidimensional optimized sizing systems generated from anthropometric data with the ASTM standard D5585-94. *International Journal of Clothing Science and Technology*. 10(5), 324-324

Newcomb, E. A. (2006). *Body shape analysis of Hispanic women in the United States*. (Doctoral dissertation, NC State University, Raleigh, United States). Retrieved from https://repository.lib.ncsu.edu/bitstream/handle/1840.16/1820/etd.pdf?sequence=1&isAllowed=y

Salusso-Deonier, C. J., DeLong, M. R., Martin, F. B., & Krohn, K. R. (1985). A Multivariate Method of Classif in Bod Form Variation for Sizing Women's Apparel. *Clothing and Textiles Research Journal*, *4*(1), 38-45.

Simmons, K.P. (2002). *Body Shape Analysis Using Three-Dimensional Body Scanning Technology*. (Doctoral dissertation, NC State University, Raleigh, United States). Retrieved from https://repository.lib.ncsu.edu/bitstream/handle/1840.16/5555/etd.pdf?sequence=1&isAllowed=y

Simmons, K., Istook, C.L. & Devarajan, P. (2004a). Female figure identification technique (FFIT) for apparel part I: Describing female shapes. *Journal of Textile and Apparel, Technology and Management*, 4(1), 1-16.

Simmons, K., Istook, C.L. & Devarajan, P. (2004b). Female figure identification technique (FFIT) for apparel part II: Development of shape sorting software. *Journal of Textile and Apparel, Technology and Management*, 4(1), 1-15.

Song, H. K., & Ashdown, S. P. (2011). Categorization of lower body shapes for adult females based on multiple view analysis. *Textile Research Journal*, 81(9), 914-931.

Song, H. K., & Ashdown, S. P. (2012). Development of automated custom-made pants driven by body shape. *Clothing and Textiles Research Journal*, *30*(4), 315-329.

Xia, S. (2013). *Sizing Systems Created Using SizeUSA Data for Three Body Shapes*. (Doctoral dissertation, NC State University, Raleigh, United States). Retrieved from https://repository.lib.ncsu.edu/bitstream/handle/1840.16/9807/etd.pdf?sequence=2&isAllowed=y