Associations Between Body Measurements, Age, And BMI to Determine Body Asymmetry Among Women

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Keywords: Female anthropometry, body asymmetry, BMI, age

Introduction: Body contour, posture, proportion, and symmetry affect the fit of clothing. Patternmakers develop patterns based on one side of body, assuming the other side would be symmetrical (Armstrong, 2013). However, human body is not perfectly symmetrical due to heredity, growth patterns, lifestyles, diet, disease, and age (Kim et al., 2010). All these factors can impact the proportion of body and the way clothing fits on individuals. Body asymmetry can cause fitting problems, and discomfort (Liechty et al., 1985). Pattern experts such as Liechty et al. (1985) and Armstrong (2013) recommended pattern alteration for figures with considerable variations between left and right side of bodies. However, currently there is no guidelines or suggestions about the asymmetrical variations for each body measurements except for shoulder slope and side waist to hip suggested by Armstrong (2013). According to Liechty et al. (1985), length, width, and circumference measurements between the left and right sides of the body should be checked and if they vary considerably, patterns must be altered where necessary to improve fit. In the previous studies, fit assessment of garments made from the body measurements from both sides resulted in improved fit and acceptable balance as compared to the fit of the same garments that were designed based on one body side (Forstenhausler & Baytar, 2020; Kim et al., 2010; Pei et al., 2019). The other studies that examined body asymmetry associations with age, body mass index (BMI), gender, and ethnicity were mainly related to genetic variations, sexual selection, physical health and anthropology, and developmental stability and their results were inconsistent. (Livshits & Kobyliansky, 1989; Manning, 1995; Milne et al., 2003; Ruff & Jones, 1981; Schell et al., 1985; Wilson & Manning, 1996). Therefore, the present study aimed to find the associations among length-related body measurements with age, and BMI.

Methods: There is no asymmetric threshold in the context of apparel production except for waist to hip length (>1/8 inch) and shoulder slope (>1/8 inch) that as suggested by Armstrong (2013). Therefore, we defined asymmetry as "if the differences between left and right body measurements are predominant on one side, the distribution was skewed either to the right or the left", which was formulated as (|Mright -Mleft| =Md). Five hundred and twenty out of 6,814 subjects with varying age and BMI were randomly selected from SizeUSA for data analysis. Eleven length-related body measurements (i.e., shoulder height, armscye height, thigh height, knee height, mid tight height, calf height, side neck to ground, side waist to floor, side neck to bust, bust to waist, and waist to hip) from each subject were imported to an Excel file. Principle Component Analysis (PCA) was applied to transform several possibly correlated variables (11 length measurements) into a smaller number of principal components (PCs). Also, each subject's BMI was calculated with the Adult BMI Calculator provided by Center for Disease Control and Prevention (CDC) (CDC, 2020). For data analysis, descriptive statistics with correlations at 95%

confidence level by using Pearson Correlation Coefficients, one-way ANOVA, and t-test were conducted in IBM Statistical Package for Social Sciences (SPSS) 27.

Results: The majority (25%) of the female participants were 18-25 years old, followed by the age ranges of 26-35 (18%), 36-45 (18%), 46-55 (15%), 66 and older (14%), and 56-65 (9%). The participants' race were diverse. White/ Non-Hispanic (50%), Black/African American (18%), Other (13%), Asian (7%), Non-Hispanic Mexican (6%), and Mexican American (5%). Based on BMI, participants were divided into four weight statuses: Underweight (24%, n=126), Normal (13%, n=67), Overweight (28%, n=146), and Obese (35%, n=181). The results from PCA showed substantial correlation among length related measurements (KMO= .662, p= .000). Also, it was observed that 70.52% of variations among these measurements was explained by four PCs. Each PC should have a minimum of three variables in practice. If a component had less than three variables, the component could not be retained since it did not have enough indicator variables. Therefore, PC2 and PC3 which had less than three variables were removed from data analysis. PC1 and PC4 that included eight variables were considered as key measurements for data analysis. There was not any significant mean difference between length-related measurements and subjects' age groups (df= 5, p> .05). We found a significant positive association between shoulder height (r (520) =.109, *p*=.013), side neck to the front ground (r(520)=.139, *p*=.002), side neck to bust (r (520) =.139, *p*=.002) measurements and BMI groups. With increasing BMI, the differences between these left and right measurements increased. The result of the t-test at shoulder height among BMI groups showed significant mean differences compared with what was identified (1/8 inches) (df=519, *p*= .00). Skewing was mainly towards the left shoulder. The skew for the healthy weight group (Md= -.19 inches, SD=.44) was larger, followed by the overweight (Md=-.148 inches, SD=.44), and obese group (Md= -.12 inches, SD=.47). The underweight group showed less skewing compared to the other groups (Md= -.09 inches, SD=.38). At side neck to front ground and side neck to bust, we found significant mean differences between BMI groups (F= 3.9, *p*=.009). The post hoc tests showed that these differences are mainly related to the underweight groups compared with the overweight and obese groups. the healthy weight (Md= .001, SD=.24) and underweight (Md= .017 inches, SD=.27) groups had skewing toward right. In contrast, overweight (Md= -.08 inches, SD=.32) and obese (Md= -.038 inches, SD=.29) groups showed skewing towards the left side. We did not observe additional significant mean differences between other measurements and subjects' BMI.

Conclusion and Discussion: The results from this study showed that asymmetric variations at shoulder height, side neck to front ground, and side neck to bust, were significantly different among the four BMI groups. With the increasing BMI, the differences between these left and right measurements increased. But no significant mean differences were observed in terms of the subjects' age groups. This study had several limitations. Only women's body measurements were evaluated, and future studies should look at men's data as well. For analysis, SizeUSA database, which was collected 20 years ago, was used. It may not be a good representative of current women's population in the U.S, therefore a newer database would give an updated information on the most current body asymmetry. The database did not provide information if these women were right/ left-handed, or their exercise routines etc. while this information could help with data analysis. Further studies are required to define asymmetry thresholds for different body measurements in the context of apparel production. Nonetheless, our findings highlighted the importance of developing block patterns that accommodate women's body features for pattern makers and for mass customization processes. Besides, software programmers can utilize the result to improve virtual avatar-alteration systems that allow manufacturers to customize patterns for women with asymmetric variations.

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