

Examining crotch lengths at the trochanterion plane by using 3D body scanning to suggest considerations for improving sizing of absorbent underwear panels and pads

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Introduction: Women's underwear garments typically include a crotch panel, which is an extra layer of fabric attached inside of the garment, taking the shape of the perineal region and extending over the orifices to absorb or wick moisture away from that area (LaBat & Ryan, 2019). Therefore, this panel, or other absorbent products such as hygienic pads that are attached to this panel to take in urine leakage and vaginal or period discharge should be properly sized based on the size of the body to provide comfort to the wearer (LaBat & Ryan, 2019). Previous studies found that age, BMI, and race were important factors for developing fitted patterns at the crotch area (Song & Ashdown, 2011). In a comparative study of trouser patternmaking methods, it was found that front and back crotch lengths and crotch width should be increased with aging to provide comfort (Lim & Cassidy, 2017). The same study examined the crotch length differences between Asian and Western women and found significantly longer crotch length in the Asian cohort. Anthropometric data related to underwear sizing and fit for women is very limited, and information on optimum positioning of the crotch panel from anterior to posterior planes is not available. Due to the limited number of studies about the size of crotch length, the main purposes of the present study were to better understand (1) the sizing of women's underwear as well as commercial hygienic pads (i.e. sanitary pads and panty liners), and (2) the correlations between the length of crotch panel among women with varying age, size, BMI, hip measurements, and race.

Methods: A multi-method approach was used to address the goals of this study. Upon receiving an IRB approval, a Qualtrics survey was conducted via Amazon MTurk to better understand female consumers' experiences with commercial hygienic pads. Participants self-reported their panty sizes, weight, and height, and hygienic pad sizes. To measure crotch lengths, a total of 544 3D body scans of North American women (aged 18-45) from CAESAR database were used. Trochanterion was determined as the body landmark to set a baseline when extracting the measurements. To extract data related to crotch length at the trochanterion plane, and anterior to posterior depth, profile silhouettes were captured from the CEASAR database. Adobe Illustrator was used to connect the front and back side lines. FreeCAD was used to get absolute crotch coordinates, which were used to detect and measure front, back, and total crotch's lengths in Adobe Illustrator. Seven body measurements (i.e., height, front and back curve lengths, total curve length, anterior-posterior length, max-hip girth, and depth) were compared based on participants' BMI, race, and age to analyze the correlations among the variables. Descriptive statistical analyses, regressions, ANOVA and Pearson's correlation tests at 95% confidence level were conducted in SPSS 25.

Results: One hundred and seventy useable survey responses were collected from women aged 18 years and older. Most of the participants were 24-29 years old (32%), followed by 30-35

years old (31%) and 42-47 years old (9%). Participants' racial categories were White/ European American (44%), Asian/ Asian American (41%), Black/ African American (9%), American Indian or Alaska Native (3%), Native Hawaiian or Other Pacific Islander (3%). Based on BMI (Center for Disease Control and Prevention, 2020), participants were divided into four groups: normal (50%), underweight (22%), obese (15%), and overweight (12%). Sixty five percent of the participants indicated the use of sanitary pads, followed by both sanitary pads and panty liners (20%), and panty liners (12%). The reasons for their use were hygienic protection (26%), menstrual protection (23%), feeling fresh all day (23%), protection before/ after menstruation (16%), and bladder leak protection (10%). In terms of the length of sanitary pads, 43% of the participants reported using Long, followed by Regular (37%), and Extra-long (20%). There was no statistical difference among the participants' race categories and their preferred size of sanitary pads ($p=0.89$). Analysis of the participants' panty sizes showed a significant positive relationship with respect to their age and BMIs. Participants older than 42 years (62%) selected larger sizes (i.e., L, XL, and 2XL) as compared to the participants younger than 42 years old. There was a small positive correlation with the increase in age and increase in sizes ($r(289) = .259, p<.001$). There was a medium positive correlation between participants' panty sizes and their BMI ($r(289) = .393, p<.001$). As BMIs increased, panty sizes increased. The average age for the use of Regular size sanitary pad was 31.59 (SD=9.21), Long was 33.15 (SD=9.21), and Extra-long was 34.45 (SD=8.81). With increasing age, participants used larger sanitary pads. There was a low positive relationship between participant's age and use of larger sanitary pad size ($r(292) = .116, p= .047$). With increasing BMI, participants reported use of longer sanitary pads. There was a low positive relationship between participant's BMI and sanitary pad size ($r(292) = .216, p<0.001$). No statistically significant mean differences were found between race groups and the size of sanitary pads ($p= .122$).

The 3D body scan database was consisted of White/ European American (74.8%), Black/ African American (12.3%), Asian/ Asian American (10.5%), and other (2.4%). Age ranges were divided into three groups 18-25 (23.2%), 26-35 (40.3%), and 36-47 (36.6%). Seventy two percent of the participants were in the normal BMI category, whereas 16.7% was overweight; 7.4% was obese; and 3.9% was underweight BMI category. Six lower-body measurements (i.e., front crotch-curve length, back crotch-curve length, total crotch-curve length, max-hip girth, anterior-posterior length, and crotch depth) indicated significant positive correlations with BMI ($r(542) = .294-.847, p = .000$). On the other hand, race did not show any significant correlations with four lower-body measurements (i.e., back crotch-curve lengths, max-hip girth, anterior-posterior length, and crotch depth) ($r(542) = -.061--.020, p=.153-.636$). However, race significantly indicated negative correlations with the front crotch-curve length ($r(542) = -.128, p = .003$) and total crotch-curve length ($r(542) = -.091, p= .033$). Based on the one-way ANOVA results, four lower-body mean measurements (i.e., front crotch-curve length, back crotch-curve length, total crotch-curve length, max-hip girth) and the mean measurement of height indicated significant differences among the four racial groups ($F(3, 540) = 6.653-20.765, p = .000$). Significantly, the Black/African American population had the largest means at the three lower-body measurements for which the statistical results were front crotch-curve length (M=21.1,

SD=3.64), total crotch-curve length (M=45.01, SD=5.84), and max-hip girth (M=106.05, SD=10.28). In contrast, the Asian/Asian American population had the smallest mean measurements at the two lower-body measurements of back crotch-curve length (M=21.61, SD=2.07) and max-hip girth (M=95.54, SD=5.57). The women aged 42 and older had significantly longer front crotch-curve length (M=20.68, SD=3.73), back crotch-curve length (M=24.16, SD=2.57), and total crotch-curve length (M=44.70, SD=5.31) as compared to the women who were under 42 (M=19.44, SD=3.11), ($t(83.780) = -2.669, p = .009$); (M=22.96, SD=2.46), ($t(542) = -3.790, p = .000$); and (M=42.42, SD=4.82), ($t(542) = 3.639, p = .000$), respectively. Moreover, the older female group was significantly larger at the max-hip girth measurement (M=105.75, SD=9.88) than the younger female group (M=101.20, SD=8.18), ($t(83.557) = -3.669, p = .000$).

Discussion and Conclusion: The results from the survey and 3D body scan analyses confirmed the relationship between crotch length and women's BMI, hip measurements, age, and race. Anterior-posterior crotch length, max-hip girth, and crotch depths were becoming longer and larger among individuals with obese weight status. Moreover, these measurements, especially back crotch length and max-hip girth, significantly increased as women became older. Our findings contradicted with the ones reported by Lim & Cassidy (2017) and would make a valuable contribution to the body of knowledge on the sizing of women's underwear and hygienic products. Our results can also help the apparel industry and the feminine hygiene product markets develop better fitting products aging in mind.

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