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Whole body shapes and fit problems among overweight and obese men in the United States

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Abstract

Purpose – The purpose of this study was to explore body shapes among overweight and obese men and examine fit issues based on the current ASTM sizing standards related to the categorized body shapes.

Design/methodology/approach – The SizeUSA data and the additional data extracted using the ImageTwin (TC2-19) software were used. To categorize body shapes, principal component (PC) analysis with varimax rotation, hierarchical cluster analysis for an elbow method and K-mean cluster analysis were employed. Comparing the categorized body shapes and ASTM sizing charts, a cross-tabulation was performed to test associations between fit analyses for top and bottom for the body shape groups. Furthermore, an analysis of variance and pairwise comparison were performed to identify differences in mean values of size drops between two body parts across the different body shape groups.

Findings – Using a three-dimensional (3D) body scanning technology and 3D virtual avatars, three body shapes for overweight and obese men emerged: Rectangle-curvy, bottom hourglass-hip tilt and top hourglass-straight shapes. Further, overweight and obese male consumers are not likely to find a perfect fit from apparel companies who developed their sizing charts based on the men's and big men's ASTM standards. Notably, the big men's ASTM sizing standard did not work for most overweight and obese men the United States.

Originality/value – Despite the notable increase in the US population that is overweight and obese, most overweight and obese men have had fit problems due to the differences in their body shapes as compared to the standardized body shape used in the current sizing system. The results of this study suggest apparel companies who are targeting overweight and obese male consumers in the United States updating their sizing systems in order to solve fit problems.

Keywords Apparel fit, 3D body scanning, Body shape, Fit problems

Paper type Research paper

Of all adults in the United States over the age of 20, 71.6% are considered overweight (31.8%) or obese (39.8%), with Body Mass Indexes (BMIs) of 25–29.9 and over 30, respectively (Center for Disease Control and Prevention, 2016). Experts predict that the proportion of obese adults will grow to nearly half (49.2%) by 2030 if current trends continue (Healy, 2019). Despite the notable increase in the US population that is obese, apparel companies have tended to use a limited sizing system developed from a standardized body shape. This system provided a perfect fit for an extremely limited segment of the population with a BMI of less than 25 and/or similar body shape to a standardized version. Because the current apparel industry provides a satisfactory sizing system for particular body shapes (Song and Ashdown, 2013), those with other shapes have experienced issues of ill-fitting attire.

The limited sizing system has caused clothing fit issues among women who wear plus-size exercise apparel (Christel and O'Donnell, 2016). Similarly, overweight and obese men are likely to have fit problems due to the differences in their body shapes as compared to the

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standardized body shape used to develop the current sizing system. To reduce the fit problems, better designs for plus-size consumers require understanding their body shape (Buttnet *et al.*, 2019). Song and Ashdown (2013) found that fit issues related to body shape. The problems of clothing fit among overweight and obese male consumers in the United States provide a starting point to explore how their body shapes look and what fit issues they have experienced based on the current sizing system.

Previous research has employed a three-dimensional (3D) body scanning technology to facilitate body shape categorizations and identify body shapes and fit issues. This technology allowed researchers to obtain accurate body measurements (e.g. Song and Ashdown, 2011). In another study, researchers used a 3D body scanner to categorize men's body shapes (Shin *et al.*, 2011). They identified four body shapes among 3,686 male participants from SizeUSA data (i.e. slim, heavy, slant inverted triangle and short round top) (Shin *et al.*, 2011). However, because Shin *et al.*'s body shape categorization included a broader age range (18–66) and underweight men (BMIs of 18.5 or less), there remains a need to explore and categorize body shapes of overweight and obese men. Although numerous researchers have conducted studies using 3D body scanning technology, primarily on women's body shape categorizations (e.g. Song and Ashdown, 2011) and overweight and obese men's lower body shape categorizations in South Korea (Lee and Shu, 2011; Lee *et al.*, 2020), it is also critical to classify men's whole body shapes to identify how well the current ASTM sizing systems satisfy overweight and obese men in the United States. Thus, the purpose of this study is to explore body shapes among overweight and obese men and examine fit problems based on the current ASTM sizing standards related to the categorized body shapes. The following three research questions guide this study:

RQ1. What are the body shapes among overweight and obese men in the United States?

RQ2. How well does each identified body shape for overweight and obese men align with the current ASTM sizing standards?

RQ3. How do problems of fit differ across body shapes based on current ASTM sizing standards?

Exploring the whole body shapes and identifying fit issues across the categorized body shapes provides implications for researchers and apparel companies who are interested in overweight and obese male consumers: Researchers and apparel companies need to consider various body shapes among overweight and obese male consumers and try to update the current sizing system through developing new patterns depending on the body shapes.

Literature review

3D body scanning technology

The 3D body scanning technology is a promising way to generate accurate body measurements automatically and quickly (Daanen and Psikuta, 2018; Song and Ashdown, 2010). Organizations such as SizeUK, SizeKorea and SizeUSA have used 3D body scanning technology to collect anthropometric body data. These data have helped the apparel industry acquire up-to-date body measurements of their target markets to provide garments with a better fit (Shin *et al.*, 2011). Anthropometric data also have been used in research studies to identify different body shapes in the current population to (1) provide a better fit or (2) create mass customizations through 3D body scanning technology (Kim, 2014; Pleuss *et al.*, 2019; Saeidi, 2019; Shin *et al.*, 2011; Song and Ashdown, 2011).

Three-dimensional body scanning technology is a promising way to improve apparel fit and size issue with mass customization (Senanayake and Little, 2010; Sohn *et al.*, 2020). Mass customization can benefit plus size target market once their body shape scrutinized by the industry (Hudson and Hwang, 2020). Custom specifications by individuals or apparel companies can be applied to the overall pattern-making process with using 3D body scan technology in order to create a mass-customized clothing (Loker, 2007). Although mass customization can improve apparel fit by considering every variation of body shapes, it would be very difficult, costly and time consuming as a total transformation of business operations system is required (Liu *et al.*, 2020).

The collection of body measurements using the 3D body scanning technology yields several benefits; it is fast, accurate and non-invasive and can generate a 3D body avatar for use in virtual prototyping (Song and Ashdown, 2015; Sayem, 2017; Daanen and Psikuta, 2018, Saeidi, 2019). Additionally, the technology can generate missing or new data after the body scanning session (Song and Ashdown, 2011) and provides a new approach to body shape categorization analysis (Song and Ashdown, 2011; Kim, 2014; Choi and Nam, 2010). Finally, this tool can help individuals to assess and improve an outdated sizing system (Shin *et al.*, 2011; Xia and Istook, 2017).

Using the 3D body scanned data, Simmons *et al.* (2004) developed the Female Figure Identification Technique (FFIT) to categorize female's body shapes from the front view based on six girth measurements, which were bust, waist, hip, high-hip, stomach and abdomen. Nine body shapes were identified for female in the United States: Hourglass, bottom hourglass, top hourglass, spoon, rectangle, diamond, oval, triangle and inverted triangle (Simmons *et al.*, 2004). Later, Sokolowski and Betencourt (2020) modified FFIT formulas for plus sized women. However, researchers pointed out the limitations of the FFIT. For example, according to Parker *et al.* (2021), the FFIT was unauthoritative because of inconsistent placement of body measurements and missing shoulder-to-shoulder measurement to categorize body shapes. Song and Ashdown (2011) noted a limitation of the FFIT in that width/depth measurements need to be included in addition to girth measurements to fully define the lateral body shape.

To overcome the limitations of earlier body shape categorization methods, Song and Ashdown (2011) used 3D scan data to develop an objective categorization method for classifying the lower female body shape using principal component and cluster analyses. Categorizations were based on multi-view, two-depth measurements generated from the original SizeUSA data. Kim (2014) used 3D scan data to examine the anthropometric characteristics of 2,950 women and then categorized their body shapes. Four different shapes emerged, including the Obese A-Shape, Overweight Y-Shape, Obese H-Shape and Normal S-Shape. The 3D body scan data have also enabled researchers to categorize lateral body shapes, and Choi and Nam (2010) integrated both visual assessment and statistical analysis to classify the upper lateral body shapes of 246 women.

3D body scanning technology has made it possible for researchers to assess the current sizing system (Shin *et al.*, 2011) and provide ways to generate up-to-date sizing information for a new system (Xia and Istook, 2017) that fits the body measurements of individuals in the current population. Shin *et al.* (2011) used 3D scan data to assess the current sizing system by comparing size drops in SizeUSA scan data with drops in the men's ASTM size chart. They found that the current men's sizing system was developed for a "regular" body shape. However, there are various body shapes within a size range, so it is necessary to develop an updated sizing system that accommodates all body types. Xia and Istook (2017) developed a way to create a sizing system by implementing multivariate statistical analyses. Then, the researchers tested the feasibility of the generated sizing system on the SizeUSA dataset (n = 6,308 female subjects) and found that the body shape information was critical for developing and updating the sizing system, which is ultimately beneficial for improving garment fit.

Body shapes among men in the United States

Shin *et al.* (2011) used the SizeUSA dataset (3,686 male scans) to categorize the shapes of men's upper body based on drop value and BMI. Through factor analysis, the researchers extracted four factors for body shape categorization: girth, height, torso length and slope degree. According to cluster analysis results, four different body shapes were identified, which include Slim Shape (SS, 31%), Heavy Shape (HS, 26%), Slant Inverted Triangle Shape (SITS, 34%) and Short Round Top Shape (SRTS, 9%). Based on drop value and BMI, the SS group was categorized based on the height factor and fit into the tall body shape of the menswear fitting category. The HS body shape group encompassed overweight and obese participants with an average BMI of 31.78, characterized by the girth and torso factors. This group described either the big and tall or athletic body shape categories. The SITS group classification was based on three factors (girth, height and shoulder slope degree), and described the regular body shape of ASTM D6240 standard for menswear sizing. Finally, the SRTS group contained overweight and obese participants with an average BMI of 32.89, which described portly and stout body types.

Saeidi (2019) categorized the lower body shape of 1,420 men, aged 18–35 with a normal BMI, using the SizeUSA dataset. An Exploratory Factor Analysis (EFA) approach was utilized to determine crucial factors for body shape categorization and identified that girth, height, length and depth. Finally, three different lower body shapes emerged from the *K*-mean cluster analysis, and Saeidi arrived at flat-straight, moderate and curvy-straight shapes.

Previous studies regarding obese body shape categorization were conducted on the SizeKorea dataset to categorize the lower body shape (Lee and Shu, 2011; Lee *et al.*, 2020). Lee and Shu (2011) examined major physical changes that happen in the lower body shape of middle-aged overweight and obese men with BMI of at least 25 and waist circumference of 34 inch or more. They found that as overweight and obese men get older, "their waist and stomach slowly curved into a circular and flat body type due to their obesity". Lee *et al.* (2020) used scripted-based 3D body measurement software to categorized lower body shape of abdominal overweight and obese men. Three-dimensional body scan of 173 men aged 35–64 were used. Three lower body shape groups were identified based on a K-means cluster analysis and ten PCs: "flat abdomen but buttocks-developed obesity type", "abdomen and buttocks–developed obesity type with vertical thighs" and "buttocks-drooped obesity type with tilted thighs" (Lee *et al.*, 2020, p. 12). Reviewing the relevant literature (Lee and Shu, 2011; Lee *et al.*, 2020; Sheldon, 1940; Shin *et al.*, 2011; Saeidi, 2019) on men's body shape categorizations revealed a notable gap in overweight and obese men's whole body shape classifications, as no research could be uncovered in the realm of whole body shapes of overweight and obese men in the United States.

Fit analysis among men in the United States

Fit is a crucial factor in consumer satisfaction, but it's not easy to achieve due to the fact that diverse body shapes result in varying fit preferences (Alexander *et al.*, 2005; Shin *et al.*, 2011). Preferences might include how the garment drapes on the body, the comfort of the garment and how consumers perceive the fitting of the garment (Pisut and Connell, 2007). Two individuals within the same size category may have different body shapes; this difference in shape is primarily based on how and where fat is distributed on the body. Two people with the same circumference measurement may have a different distribution to the front and back of body fat, resulting in the need for different shaped pattern blocks to achieve a proper fit (Hlaing *et al.*, 2013; Petrova and Ashdown, 2008). However, there are no such golden standards for determining the best fit for each body shape because an individual's perception of fit is influenced by many different factors (e.g. gender, size, age, culture, style, trend and more) (Pisut and Connell, 2007). Thus, there have been two ways to assess apparel fit, subjectively and objectively. We focused on reviewing studies on subjective and objective fit analyses for men in the United States as follows.

Subjective fit. Subjective fit is based on the assessment of either a consumer or expert judge's opinion or both. Understanding fit problems from a consumer's perspective is challenging, as it may be difficult for them to verbalize their fit expectations and needs

(Ashdown, 2007). To measure fit preferences, scholars have developed a fit evaluation scale to understand consumer's definitions of proper fit. Among limited researches of men's fit preferences, Chattaraman *et al.* (2013) developed a scale to measure fit preferences of male consumers on jeans, khakis, dress shirts and polo shirts. The authors found that male consumers' fit preferences were subject to various factors, including age, body size and BMI. Individuals may vary in their fit criteria, but the authors also found that men with higher BMIs prefer a looser fit for their jeans, dress shirts and polo shirts; as men's BMIs increased, they also preferred higher waistlines (Chattaraman *et al.*, 2013). Later, Stewart *et al.* (2014) used the developed scale by Chattaraman *et al.* (2013) to examine men's fit preferences in outdoor performance clothing. In their study, overweight men tended to frequently mention about the fit of their pants in the crotch, seat and hip areas, as well as the fit and sizing inconsistencies of their shirts (Stewart *et al.*, 2014). Recently, Guo and Istook (2021) developed a 7-point scale of perceived fit preference from wearers (from −3: terrible to 3: excellent). Although the scale (Guo and Istook, 2021) was developed to evaluate dresses, it can be used to measure perceived fit preference for other types of clothing for men.

Sindicich and Black (2011) examined fit issues of men's ready-to-wear clothing as it related to sizing and overall body composition. The researchers found that larger men experienced a wide range of fit issues in choosing and wearing business clothing and that heavier men had difficulty finding a suit that fit both their chest and waist measurements (Sindicich and Black, 2011). The researchers related the origin of some fit issues to sizing and grading practices but speculated that the source of other issues might have related to variation in body types.

Despite the scarcity of studies for men's subjective fit analysis in the United States, a recent study of Sohn *et al.* (2020) on fit analysis among Korean male consumers was conducted to compare virtual fit and actual fit of the customized jacket. In the study, fit evaluations were rated using 5-point scale for a total of 16 categories including overall fit, length at three sites (i.e. jacket, sleeve and collar), width at five sites (i.e. shoulder, back, hem, sleeve and collar), circumferences at four body areas (i.e. neck, chest, waist and upper arm), shoulder angle and front and back armhole (Sohn *et al.*, 2020).

While many researchers have concentrated on evaluating physical aspects of clothing fit, Shin and Damhorst (2018) discovered that consumers evaluate apparel fit in three dimensions: physical, aesthetic and functional. Physical aspects of fit (i.e. tightness and length) were consistent with numerous prior researches, however individuals identified aesthetic and functional aspects of fit as new and important components when evaluating clothing fit (Shin and Damhorst, 2018).

Objective fit. Objective fit assessment refers to the relationship between the garment and the body. Objective fit is more accurate and standardized than subjective fit is; it also provides more quantitative information and is less prone to influence from personal criteria (Yu, 2004). Traditionally, researchers invited two or more garment experts to conduct objective fit evaluation (e.g. Ashdown *et al.*, 2006). Later, Guo and Istook (2021) used the scale of subjective fit preference developed in the study to objectively evaluate garment fit by experts in both live and photographed fit evaluation processes.

With the technological advancement of 3D body scanners that provides reliable objective fit evaluations (Wu *et al.*, 2011), measurements extracted from the national sizing survey data using 3D body scanners were compared with those in the ASTM size charts to assess objective fit (e.g. waist circumference discrepancies between the 3D body scanning data and the size charts). However, although numerous studies have been undertaken to evaluate objective fit for women, an only study has been conducted to evaluate objective fit among men in the United States. Shin *et al.* (2018) compared the SizeUSA data with the ASTM size chart to examine fit issues for big and tall men. The researchers analyzed data from 301 big and tall men with heights greater than 71.5 inches and weights greater than 215 pounds.

They found that the majority of big and tall men (86.4%) struggled to find the correct fit of a pair of pants for a suit based on the ASTM size chart (Shin *et al.*, 2018).

Using a 3D software, a virtual objective fit evaluation was conducted to visually evaluate the fit of jeans on the 3D virtual avatars created based on body measurements from the SizeUSA data for men in the United States. Saeidi (2019) examined the linkage between body shape and apparel fit using actual 3D models, virtual prototyping and fit analysis to evaluate the fit of jeans using basic block patterns on different body shapes. The researcher found that each body type experienced different fit problems specific to their respective body shapes. Importantly, using shape-driven block patterns to achieve a proper fit could accommodate the needs of the various body types (Saeidi, 2019). A further review of the literature yielded no specific research and only yielded limited findings related to the fit of overweight and obese men's clothing issues.

Method

Sample selection

Men with a BMI of 25 or higher and between 18 and 55 years of age were included in the study. Considering this study focusing on categorizing body shapes and related apparel fit issues, BMI metric following Center for Disease Control and Prevention's guideline on identifying overweight and obese population (Center for Disease Control and Prevention, 2021) was used to classify the population and figure out their body shapes. Furthermore, researchers noted that "the BMI provides a reliable indicator of body fat" (Song and Ashdown, 2011, p. 920). Because men over 55 years tend to show different body changes, such as, losing weight because of the testosterone hormone (Shah and Villareal, 2017), we included men until 55 years of age. All data collected from the SizeUSA dataset included 1,818 useable participants.

The SizeUSA data account for the most recent and large-scale anthropometric dataset in the United States. The SizeUSA data were collected using 3D whole-body scanners that are highly efficient, valid and reliable at obtaining a large number of body measurements (Xia *et al.*, 2018). Following previous studies on body shape categorization using the SizeUSA data (e.g. Song and Ashdown, 2011), the additional data (e.g. side seam, width, and depths) in the ImageTwin (TC2-19) software were extracted (i.e. widths and depths) in addition to the original 200 body measurements. Further, drop values for widths, girths (e.g. full girths, front and back arcs) and depths between two body parts (e.g. chest to waist, top hip to waist and hip to waist) were calculated.

Data analysis

In the body shape categorization process, we followed prior research (Song and Ashdown, 2011; Lee *et al.*, 2020). To answer RQ1, principal component (PC) analysis with varimax rotation was used to categorize body shapes. Then, *K*-mean cluster analysis was conducted to specify the possible number of body shapes for overweight and obese men in the United States. In addition, hierarchical cluster analysis for an elbow method was also used to ensure the number of clusters identified through K-mean cluster analysis. To compare group differences in PC values and body characteristics in each PC dimension (dependent variables, DV), a multivariate analysis of variance (MANOVA) and an analysis of variance (ANOVA) with post hoc multiple comparison were conducted.

To compare the sizing system among categorized body shape groups to answer RQ2 and RQ3, we used both ASTM sizing standards for men (D6240/D6240M-12) (ASTM International, 2012) and big men (D8077/D8077M-16) (ASTM International, 2016). Based on a formula for fit tolerance (Simmons *et al.*, 2004), an appropriate size for each of five body parts (back shoulder-length, and four girth measurements on the chest, waist, top hip and hip) were determined for each sizing standard. Values of ideal sizes on the chest, waist, top hip and hip were calculated.

Analyses were performed for the top and bottom based on the sizing charts in each sizing system. For tops, a perfect fit, "0," was recorded when there were no differences in sizes between chest and waist; a bad fit, "1," was recorded for differences in sizes. For bottoms, a perfect fit was recorded as "0" when sizes in all the three areas (i.e. waist, top hip and hip) were identical; "1" was recorded as a bad fit when there were differences in sizes. For both tops and bottoms, "2" was recorded if one did not fall into the sizing system. For RQ2, to compare in fit issues in each sizing system (i.e. tops in men's size, tops in big men's size, bottoms in men's size, bottoms in big men's size) (DVs) among body shape groups, cross-tabulation with chi-square test was performed. To answer RQ3, ANOVAs and post hoc tests (i.e. Tukey HSD and Games-Howell) were performed to identify differences in mean values of size drops between two body parts (DVs) (e.g. differences between tops' size based on chest measurement and tops' size based on waist measurement) across the different body shape groups. All the analyses were performed in SPSS. In addition, G*Power 3.1 software was used to test one-way between group ANOVAs to determine the minimum number of the required sample size and post hoc power analyses.

Results

Sample characteristics

Participants' ages were well balanced throughout four age groups, including from 21.5% to 29.4% for each group. For ethnicity, about a half of the participants were White or European Americans (n = 812, 45%) followed by Blacks or African Americans (n = 390, 21.5%), Hispanic or Latino (n = 197, 10.8%), Asian or Asian American (n = 112, 6.2%) and others (n = 134, 7.4%). According to BMI values, about 62% of participants were overweight (n = 1,125), and 38% were obese (n = 693) (see Table 1).

Based on the power analysis using G*Power 3.1 software (Faul *et al.*, 2020), the sample size (n = 1,818) was sufficient to test one-way between-group ANOVAs, exceeding the minimum number of the required sample size (n = 1,548) to achieve the power of 0.95 for an effect size of 0.1 (a = 0.05, number of groups = 3).

RQ1: Body shape categorization

Principal component analysis. Ninety-six body measurements (i.e. 55 raw measurements and 41 drop values) were included in a bivariate correlation analysis. After deleting medium to high correlations with the weight as suggested by Song and Ashdown (2011), 20 measurements (i.e. five raw measurements and 15 drop values) were included in a principal component (PC) analysis. Several PC analyses were performed to reduce unnecessary measurements. Ultimately, four PCs were identified with eigenvalues of 1.0 and above, accounting for 77.8% of the variation among eight variables: PC1—Shoulder to chest front silhouette (i.e. chest width, front shoulder width), PC2—Buttocks prominence (i.e. back depth: hip to waist, buttocks angle), PC3—Chest to hip front silhouette (i.e. width: chest to waist, width: hip to waist) and PC4—Abdomen prominence (i.e. front arc: top hip to waist, front arc: hip to waist) (see Table 2).

Cluster analyses. Two cluster analyses, K-mean and hierarchical cluster analyses, were used to specify the ideal numbers of body shapes for overweight and obese men in the United States. K-mean cluster analysis was performed using the optimal number of clusters with four PCs to categorize body shapes. We experimented with two-to four-cluster models to double-check the optimal number in the hierarchical cluster analysis. When conducting

	f	%	M	SD
Age				
18–25	399	21.9		
26–35	460	25.3		
36–45	535	29.4		
46–55	424	23.3		
Ethnicity				
White or European American (Non-Hispanic)	812	44.7		
Black or African American (Non-Hispanic)	390	21.5		
Asian or Asian American	112	6.2		
Hispanic or Latino	197	10.8		
Other	134	7.4		
BMI				
Overweight (BMI of 25.0–29.9)	1125	61.9		
Obese (BMI of 30.0 and above)	693	38.1		
Height in inch			68.92	3.38
Weight in lbs			203.49	35.71
Chest circumference			44.55	3.84
Waist circumference			40.33	4.82
Hip circumference			42.63	3.78
Chest width			15.16	1.11
Waist width			13.63	1.40
Hip width			15.32	1.16
Buttocks angle			20.01	3.25

Table 1.
Sample characteristics

Component	Eigenvalue	Rotated sums of squared loading % of variance	Cumulative %
1	2.055	25.683	25.683
2	1.752	21.895	47.578
3	1.327	16.584	64.162
4	1.091	13.636	77.797

Note(s): The total amount of variations in the sample is 8

Table 2.
Total variance explained from PCA

hierarchical cluster analysis, Ward's method on the four PCs was used to obtain a coefficient of an agglomeration schedule. The optimal number of clusters was three based on the subtracted value 1,818 from 1,815, considering that the coefficients' gap between 1,815 and 1,816 was much higher than the previous coefficient gaps. Thus, three clusters were confirmed to be the ideal number (Cluster 1: $n = 401$, 22%; Cluster 2: $n = 743$, 41%; Cluster 3: $n = 674$, 37%). In the three-cluster mode, with no correlation among four PC values, MANOVA was not performed. Instead, a one-way ANOVA for each PC value was performed. Because Levene's test was significant at $p < 0.05$ level for all four PC values ($F = 12.39$–40.15), equal variance was not assumed. Thus, Welch's F-test with Games-Howell post hoc multiple comparison was performed instead of other post hoc comparisons (e.g. Bonferroni correction). The ANOVA results showed the overall F for each of four PC variables was statistically significant and ranged from 69.77 to 1123.50 (see Table 3). The results of ANOVAs and Games-Howell post hoc tests for the three body shape groups showed significant differences between pairs of the body shape groups for four PCs. For PC1 (shoulder to chest front silhouette), BS3 had a comparatively wider shoulder and chest (0.28) among the three groups, followed by BS1 (0.06) and BS2 (−0.29). For PC2 (buttocks prominence), BS2 (0.61) had the most prominent buttocks followed by BS1 (−0.17) and BS3 (−0.58). For PC3 (Chest to hip front silhouette), BS3 (0.60) had a comparatively narrower hip width than chest width, followed by BS1 (−0.23) and BS2 (−0.42). Finally, for PC4 (Abdomen prominence), BS1 (1.48) had the most prominent abdomen while BS2 (−0.41) and BS3 (−0.43) had a similar level of a prominent abdomen.

Differences across body shapes. We used MANOVA with the post hoc test of eight one-way ANOVAs to test the differences across the three body shape groups. Because the sample size for each group was different, Levene's test was significant at $p < 0.05$ level for all eight variables meaning unequal variances ($F = 3.47–91.75$) across the groups. As a result, the Welch statistic was used to interpret F-test, and Games-Howell post hoc multiple comparison was performed.

MANOVA results showed that ($F_{\text{Wilk's Lambda}}$ (16, 3616) = 334.02, $p < 001$, $\eta^2 = 0.60$). According to the results of the one-way ANOVA, the F_{Welch} (ranging from 38.15 to 532.82) were statistically significant, meaning that the values of the eight variables differed significantly across the three body shape groups. As shown in Table 4, the mean and standard deviation of eight variables were compared across the three body shape groups.

PCs for cluster analysis	Body shape group BS1 (n = 401)	BS2 (n = 743)	BS3 (n = 674)	F_{Welch}	η^2
PC1: Shoulder to chest front silhouette	0.06^b (1.13)	-0.29^c (0.85)	0.28^a (0.98)	69.77***	0.07
PC2: Buttocks prominence	-0.17^b (1.01)	0.61^a (0.81)	-0.58^c (0.78)	403.62***	0.28
PC3: Chest to hip front silhouette	-0.23^b (1.10)	-0.42^c (0.75)	0.60^a (0.89)	275.13***	0.22
PC4: Abdomen prominence	1.48^a (0.74)	-0.41^b (0.55)	-0.43^b (0.60)	1123.50***	0.62

Note(s): Means were ranked by ^{a}, ^{b} and ^{c} ordered by its magnitude. Standard deviations were in parentheses under mean values
BS1: Rectangle-curvy shape, BS2: Bottom hourglass-hip tilt shape, BS3: Top hourglass-straight shape
***$p < 0.001$

Table 3. Mean and standard deviation of PC for three body shape groups

Variables for cluster analysis	BS1	Body shape group BS2	BS3	F_{Welch}	η^2
PC1: Shoulder to chest front silhouette					
Width: chest	15.38^a (1.24)	14.78^b (0.91)	15.44^a (1.11)	86.57***	0.08
Width: shoulder	17.16^a (1.07)	16.80^b (0.92)	17.21^a (0.97)	38.15***	0.04
PC2: Buttocks prominence					
Back depth drop: hip-waist	1.40^b (0.67)	1.95^a (0.57)	1.29^c (0.51)	288.37***	0.23
Buttocks angle	19.33^b (4.48)	22.39^a (3.86)	17.78^c (4.00)	249.43***	0.21
PC3: Chest to hip front silhouette					
Width drop: chest-waist	1.45^b (0.77)	1.20^c (0.63)	2.13^a (0.79)	302.67***	0.25
Width drop hip-waist	1.41^c (1.12)	1.68^b (0.72)	1.97^a (0.76)	50.00***	0.06
PC4: Abdomen					
Front arc drop: hip-waist	2.31^a (0.82)	0.81^c (0.60)	0.98^b (0.66)	532.82***	0.44
Front arc drop: top hip-waist	1.50^a (0.52)	0.71^b (0.44)	0.60^c (0.43)	441.33***	0.37

Note(s): Means were ranked by ^{a}, ^{b}, and ^{c} ordered by magnitude. Standard deviations were in parentheses under mean values
BS1: Rectangle-curvy shape, BS2: Bottom hourglass-hip tilt shape, BS3: Top hourglass-straight shape
***$p < 0.001$

Table 4. Mean and standard deviation of three body shape groups on eight body measurements

According to the Games-Howell post hoc analysis, chest and shoulder widths were higher in BS1 and BS3 than in BS2. For the back depth drop value from hip to waist and buttocks angle, BS2 had the highest values, followed by BS1 and BS3. Concerning width drop from chest to waist, BS3 had comparatively wider chest than waist compared to BS1 while BS2 had a comparatively narrower chest than waist when compared to BS1. For the width drop value from hip to waist, BS3 had a comparatively wider hip than waist when compared to BS2, followed by BS1. The front arc drop from hip to waist and from top hip to waist showed abdomen prominence. BS1 had the largest drop values for both (i.e. from hip to waist and from top hip to waist) across the three groups. BS3 had a more prominent abdomen in the hip area than in the waist when compared to BS2, while BS2 had a more prominent abdomen in the top hip area than in the waist area as compared to BS3.

Finalized body shapes. Using the PC analysis, cluster analyses and comparisons across the three body shape groups, concerning the four PCs associated with the eight variables, the names of the three body shape groups were determined. As shown in Figure 1, front and side silhouettes were drawn based on mean values of width measurements in the chest, waist and hip levels for the front body silhouette. The same approach applied to that of the side seam, front X and back X measurements in the chest, waist, abdomen and hip levels for the side-body silhouette.

Then, the front and side silhouettes for each body shape were overlapped with images of 3D virtual body models created using the CLO 5.2 software (CLO Virtual Fashion Inc, 2020). The CLO software allowed users to adjust the 3D virtual body models using body measurements of heights, circumferences (i.e. girths) and length (CLO Virtual Fashion Inc, 2020). To create the 3D virtual avatar for each body shape group, we used mean values of the girth (e.g. neck base, chest, waist, top hip and hip), height (e.g. chest, waist, top hip, hip and crotch) and length (e.g. center front neck to waist, center back neck to waist and across the shoulder) measurements. Based on the process of body shape categorization and visual analysis of the silhouettes and 3D virtual body model, three body shapes for overweight and obese men emerged, including rectangle-curvy, bottom hourglass-hip tilt and top hourglass-straight.

RQ2: Fit analysis for tops and bottoms based on ASTM sizing system

We used sizes for each body part (i.e. chest, waist, top hip and hip) based on circumference values in each body area by using the fit tolerance formula for the men's and big men's ASTM sizing system. For tops, a perfect fit was achieved when there were no differences in chest and waist sizes. Any differences in size between chest and waist were considered fit problems in tops if they choose tops based on their chest size. For bottoms, three different areas (i.e. waist, top hip and hip) in sizes were used to determine whether one would achieve a perfect fit or fit problems when they chose their pants sizes based on their waist sizes. When sizes in all three

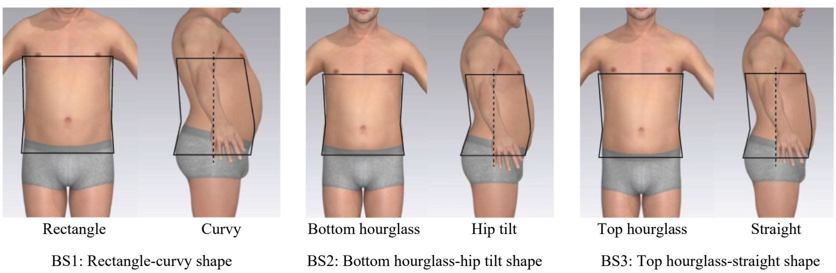

Figure 1.
Whole body shape names with images of 3D Avatar from CLO software

areas were identical, we considered it a perfect fit with bottoms. Any difference in sizes between the two body areas were indicative of the subjects having fit problems.

According to the crosstab analysis shown in Table 5, all chi-square values were significant at the $p < 0.001$ level (ranging 29.85 to 124.06). The results indicate that fit analysis (perfect fit, fit problems and NA) associated with different body shape groups. Men with BS1 ($n = 87$, 21.7%) and BS3 ($n = 178$, 26.4%) tend to find a perfect fit with tops more easily than BS2 ($n = 125$, 18.6%) in men's size. About 80% of men with BS2 (597) would have fit problems with tops in the men's size. In big men's size, men with BS1 ($n = 81$, 20.2%) would be more likely to find a perfect fit with tops than the other two groups (BS2: $n = 77$, 10.4%, BS3: $n = 71$, 10.5%). For bottoms, men with BS1 ($n = 8$, 2.0%) would have more difficulty to find a perfect fit in men's size than those with BS2 ($n = 63$, 8.5%) and BS3 ($n = 71$, 10.5%). However, this sizing standard would give men the most fit problems with bottoms for all the three groups (BS1: $n = 346$, 86.3%, BS2: $n = 644$, 86.7%, BS3: $n = 565$, 83.8%). The big men's sizing system tends to give the least perfect fit with bottoms to men with BS1 ($n = 8$, 2.0%), BS2 ($n = 5$, 0.7%) and BS3 ($n = 11$, 1.6%). Men with BS1 ($n = 121$, 30.2%) would have most fit problems with bottoms for big men's size compared to those with BS2 and BS2, although BS1 has the highest number of subjects whose body size for the bottoms applied to big men's size.

	Body shape group			
	BS1	BS2	BS3	χ^2
Tops in men's size				
Perfect fit	87	125	178	53.72***
	21.7%	16.8%	26.4%	
Fit problems	271	597	459	
	67.6%	80.3%	68.1%	
NA	43	21	37	
	10.7%	2.8%	5.6%	
Tops in big men's size				
Perfect fit	81	77	71	124.06***
	20.2%	10.4%	12.6%	
Fit problems	119	75	92	
	29.7%	10.1%	13.6%	
NA	201	591	511	
	50.1%	79.5%	75.8%	
Bottoms in men's size				
Perfect fit	8	63	71	44.72***
	2.0%	8.5%	7.8%	
Fit problems	346	644	565	
	86.3%	86.7%	83.8%	
NA	47	34	38	
	11.7%	4.8%	6.7%	
Bottoms in big men's size				
Perfect fit	8	5	11	29.85***
	2.0%	0.7%	1.6%	
Fit problems	121	165	115	
	30.2%	22.2%	17.1%	
NA	272	573	548	
	67.8%	77.1%	76.6%	

Note(s): NA: Not applicable, BS1: Rectangle-curvy shape, BS2: Bottom hourglass-hip tilt shape, BS3: Top hourglass-straight shape
***$p < 0.001$

Table 5. Fit analysis for tops and bottoms based on men's and big men's ASTM sizing system among three body shape groups

RQ3: Differences in fit problems across the body shape groups based on ASTM sizing system

Because there were different numbers of the sample who fit to each sizing system, we performed ANOVA separately for each sizing system. According to the results of Levene's test, except for the tops in men's size ($F = 2.80, p = 0.06$), other DVs had unequal variances across the groups with significant at $p < 0.05$ level ($Fs = 4.79$–139.78). Thus, for tops in men's size, we performed ANOVAs with Tukey HSD post hoc tests while the Welch statistic and Games-Howell post hoc tests were performed for other DVs. Size differences between the body and the ASTM sizing standard in the chest, waist and hip areas were analyzed to compare how fit problems for tops and bottoms differ across the body shape groups (see Table 6). For tops in (big size) men, men with BS3 have a 0.42 (0.85) size looser fit in their waist areas while men in the other two body shapes would have a 1.05–1.45 (0.31 -0.33) size tighter fit in their waist areas when they select the size based on their chest sizes. ANOVA results showed that size differences in tops for both men [$F = 154.03, p < 0.001$] and big men [$F_{Welch} = 18.46, p < 0.001$] sizes across three body shape groups.

For bottoms in men's size, all the three body shapes would have looser fit on top hip (0.50–0.59 sizes) areas, which were not different across three body shape groups [$F_{Welch} = 0.96, p > 0.05$]. Additionally, in the hip areas, BS2 and BS3 would have less loose fit (1.60 and 1.62 sizes) than their right hip size compared to BS1 with 2.27 size looser in the hip area when they choose pants based on their waist sizes [$F_{Welch} = 7.39, p < 0.001$]. In big men's size, men with BS2 would have tightest fit on top hip (2.30 size) followed by BS3 (2.15 size) and BS1 (1.48 sizes), which were different across three body shape groups [$F_{Welch} = 16.00, p < 0.001$]. Men with BS2 would have more fit problems with bottoms due to a 1.18 size tighter fit in the hip area than for men with BS3 and a 0.37 size tighter in the hip area when they choose the bottoms based on their waist size. Men with BS1 would have a 0.65 size looser fit in the hip area in big men's size. This finding indicates that all three body shape groups were the difference in fit problems in hip areas [$F_{Welch} = 20.13, p < 0.001$] (see Table 6).

Power analysis for post hoc tests. Post hoc power analyses were also conducted to lessen Type II errors using the G*Power software (Faul *et al.*, 2020). Based on the values of mean,

Table 6. Mean and standard deviation of size differences based on ASTM sizing system among three body shape groups

		Body shape group BS1	BS2	BS3	$F(F_{Welch})$	η^2
Tops in men's size						
Chest-waist	*M*	-1.05^b	-1.45^c	0.42^a	154.03^{***}	0.15
	SD	2.16	1.91	2.03		
Tops in big men's size						
Chest-waist	*M*	-0.31^b	-0.33^b	0.85^a	$(18.46)^{***}$	0.12
	SD	2.10	1.65	2.10		
Bottoms in men's size						
Top hip-Waist	*M*	-0.54^a	-0.59^a	-0.50^a	(0.96)	0.001
	SD	2.10	1.35	1.21		
Hip-waist	*M*	-2.27^b	-1.60^a	-1.62^a	$(7.39)^{***}$	0.02
	SD	3.13	1.85	1.78		
Bottoms in big men's size						
Top hip-Waist	*M*	1.48^b	2.30^a	2.15^a	$(16.00)^{***}$	0.05
	SD	1.75	1.40	1.46		
Hip-waist	*M*	-0.65^c	1.18^a	0.37^b	$(20.13)^{***}$	0.10
	SD	2.77	2.10	1.90		

Note(s): Means were ranked by a, b, and c ordered by its magnitude
BS1: Rectangle-curvy shape, BS2: Bottom hourglass-hip tilt shape, BS3: Top hourglass-straight shape
$^{***}p < 0.001$

standard deviation and sample size for each group, the effect size was calculated. Then, the calculated effect size, total sample size, the number of groups and a value of 0.05 were entered to get the value of power. All post hoc power analyses were over 0.8 meaning that it is acceptable according to the power guidelines (Aberson, 2011).

Discussion and conclusions

Three body shapes were categorized for overweight and obese men in the United States (RQ1): Rectangle-curvy shape, bottom hourglass-hip tilt shape and top hourglass-straight shape. Three body shapes were categorized and named based on four factors: two factors of front silhouettes (e.g. shoulder to chest front silhouette and chest to hip front silhouette) and two factors of side silhouettes (e.g. abdomen prominence and buttocks prominence). Front body silhouette was somewhat consistent with other studies of women's body shapes, namely, Kim (2014), who identified the obese A-shape, overweight Y-shape and obese H-shape). For the side lower body silhouette, it also aligned with the previous study on women's lower body shapes (e.g. Song and Ashdown, 2011: curvy shape, hip tilt shape and straight shape). Furthermore, two factors of side silhouettes (i.e. abdomen prominence and buttocks prominence) were consistent with findings in Lee and Shu (2011)'s study on overweight and obese men's lower body shapes in South Korea. Lee *et al.* (2020) also used the two factors of side silhouette to differentiate three body shape groups among overweight and obese Korean male consumers, which were flat abdomen/developed buttocks, developed abdomen/buttocks with vertical thighs and drooped buttocks with tilted thighs. The consistent results confirm that the two factors of side silhouette are the most important factors to differentiate body shapes in overweight and obese male population. Thus, the three identified whole body shapes in overweight and obese male consumers showed important variations that need to be accommodated by apparel companies.

Interestingly, across body shape groups, the increased back curvature was observed based on the substantial difference in length measures between the center back to waist and center front to waist. This difference caused them to have a rounded upper back shape. Some studies have supported an increase in the posterior thoracic angle among obese subjects when compared to their normal weight counterparts (e.g. González-Sánchez *et al.*, 2014), which may result from fat accumulation in the belly area. This body change was also evident among older women, and researchers suggested changing garment patterns to accommodate physical changes and to avoid fit issues (e.g. shorten the back) (Ashdown and Na, 2008). For overweight and obese men, however, due to their prominent belly, the product developers and designers should carefully change the pattern.

The results of this study supported the discrepancy in fit issues between the body shapes and the current ASTM sizing standards (RQ2). This result indicated that the current ASTM sizing standards did not meet the needs of the overweight and obese male population in the United States. Overweight and obese men may experience more fit problems with bottoms than they do with tops in both sizing standards (i.e. men's and big men's sizes). The findings of this study are consistent with previous research in finding that a good fit in pants is harder to achieve than in other clothing categories (Petrova and Ashdown, 2008). Given the low percentages of perfect fit among both standards, overweight and obese male consumers are not likely to find a perfect fit from apparel companies who developed their sizing charts based on the ASTM standards. Notably, the big men's ASTM sizing standard does not seem to work for most overweight and obese men the United States. Considering various body shapes in overweight and obese male consumers, negative fit issues in existing ASTM sizing standard were expected, but there would be potential ways to improve their apparel fit.

The results of this study are unique in providing objective fit issues for each body shape group among overweight and obese male consumers in the United States in terms of the size differences in specific body areas (RQ3). For men's size, those with BS2 had more fit problems for tops because of fat accumulation in the waist area compared to the chest area. For bottoms in men’s size, those with BS1 had higher differences in size (two sizes) due to fat accumulation in the waist area compared to the hip area. However, the other body shapes (BS2 and BS3) also had a large difference in sizes (1.6 sizes). For bottoms in big men’s size, only BS1 had the same fit problems (looser fit in the hip area) while BS2 and BS3 tended to have a tighter fit in their hip areas when they choose bottoms based on their waist sizes. The results implied that there would be different fit needs in terms of sizes in each body parts in each body shapes of overweight and obese male consumers.

This study contributes literature for body shape and fit analysis studies using 3D body scanning technology for the overweight and obese male population in the United States. Especially, there have been limited studies to categorize the whole body shapes in overweight and obese population in the United States. Although two studies (Lee and Shu, 2011; Lee *et al.*, 2020) focused on obese men’s lower body shapes in South Korea, this study first attempted to categorize the whole body shapes in overweight and obese men in the United States. By following the proven body shape analysis method from the previous studies (Song and Ashdown, 2011; Lee *et al.*, 2020), this study confirmed that the method can apply to body shape categorization in the focused population (i.e. overweight and obese population) in providing differentiations from all dimensions, front and side silhouettes. Furthermore, this study contributes to studies on objective fit analysis in relation to body shapes by providing empirical results of fit analysis in terms of tops and bottoms compared to ASTM sizing standards.

Since body shape categorization was used to provide critical information for better clothing sizing, patterns and fit (Lee *et al.*, 2020), this study also provides practical implications for apparel product developers in the United States: The sizing systems need updating to achieve better fit and accommodate different body shapes in overweight and obese men. This study can play a key role in providing body shape and fit information for apparel companies who are targeting overweight and obese male consumers in the United States. For different body shape groups, apparel companies can minimize fit issues by developing a shape-driven block pattern for tops and bottoms (Saeidi, 2019; Song and Ashdown, 2011). Considering those populations who need to engage in an active lifestyle to reduce health risks due to fat accumulation, apparel companies for exercise apparel should carefully consider updating their sizing chart for overweight and obese men in the United States.

Limitations and future studies

We used the SizeUSA dataset; however, future research could include other anthropometric datasets to categorize body shapes. Further, focused on the US population, but future studies could include other national datasets to generalize body shape categories at a global level and compare differences in body shapes in various countries.

We used BMI to classify overweight and obese males following the guideline by Center for Disease Control and Prevention (2021). This may have caused us to include muscular people as being overweight and obese. Future studies could include waist-to-height ratio that may be a better screening tool for adult health risk factors related to being overweight and obese (Gibson and Ashwell, 2011) to identify body shapes related to health among overweight and obese population.

We focused on the population up to 55 years old. Older populations who are overweight and obese need to be included for body shape categorization studies. Older people are likely to have body changes in terms of gaining body fat and undergoing posture changes (i.e. a curved upper back) throughout the aging process (Ashdown and Na, 2008). They become important target consumers in exercise apparel consumption because they are interested in staying healthy and having an active lifestyle with enough buying power.

Lastly, as a starting point, we categorized body shapes and conducted an objective fit analysis. Consumers reported their fit perceptions differently based on their age and body size (Chattaraman *et al.*, 2013; Pisut and Connell, 2007), and other factors, such as culture, gender, style and trend (Pisut and Connell, 2007). Future studies can compare the subjective fit analysis of how their perceived fit is different from the objective fit analysis based on body measurements and the sizing chart.

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