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Comparison of Garment Sizing Systems

Adriana Petrova[1] and Susan P. Ashdown[2]

Abstract

Reflecting two ways of impacting a garment sizing system-by modifying the body sizing table, and by modifying the ease amounts added (at bust and hip only), 4 garment sizing systems presenting the combinations of a standard (ASTM D5585-95R01) or a modified body sizing table, each with constant or size-dependent ease amounts across sizes, were compared by testing their relative (as opposed to absolute) performance in fit tests with 81 study participants. Test garments (princess style jackets), sizes 2-16, were manufactured for each system (32 garments). Each participant was photographed in the best-fitting size garment from each system. Three fit experts ranked the 4 garments by fit for each study participant. Statistical analysis indicated better overall performance of systems based on size-dependent ease (but not within each size group) and of the modified table (significantly better for participants with small hip-bust drop and not significantly for participants with large drop).

Keywords

sizing, pattern grading, fit

In the era of mass-produced clothing, garment sizing is the method used to create ready-to-wear garments meant to fit a range of people in the population. Yet, market research shows that consumers are frequently dissatisfied with the fit of clothing, which leads to high volume of returns of merchandise and financial losses for the manufacturers (DesMarteau, 2000; Reich & Goldsberry, 1993). Research has found that a major factor for the problems experienced with garment fit is the inadequacy of the sizing standards currently in use in the United States. For example, Newcomb and Istook (2004) analyzed data from the 2003 SizeUSA anthropometric study (http://www.sizeusa.com/) and found that the body shapes targeted by the ASTM (American Society for Testing and Materials) sizing standards for juniors (ASTM D6829-02), misses (ASTM D5585-95R01), and women over 55 (ASTM D5586-01) are not the body shapes most commonly found in the U.S. population.

Related to garment construction and therefore to garment fit and garment sizing is the critical concept of ease—the amount of fabric added over and above the body dimensions to provide for comfort and fit. Ease amounts are generally determined by fitting a garment. It has been suggested by practitioners as

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well as researchers (Gordon, 1986; Petrova, 2007; Petrova & Ashdown, 2008) that ease amounts ought to vary with size, the larger sizes usually requiring larger ease amounts. However, the standard garment sizing practice utilizes methods that effectively add constant ease amounts across all sizes.

Seeking to improve the fit of ready-to-wear garments for the Misses population, in a previous study (Petrova, 2008), the researcher proposed two ways of changing the current garment sizing practice—(a) by modifying the standard body sizing table ASTM D5585-95R01 and (b) by using size-dependent, as opposed to constant, ease amounts across the garment sizes. Four garment sizing systems presenting the combinations of a standard (ASTM D5585-95R01) or a modified body sizing table, and constant or size-dependent ease amounts across sizes, were constructed. In the study presented here, the researchers test the effects of the changes proposed to garment sizing practice by comparing the four systems described above. This was accomplished by fit testing actual garments manufactured according to the rules of each of the systems on a sample of study participants representative of the misses population segment.

Background and Justification

Body Sizing and Garment Sizing

In the process of sizing garments, the dimensions of each garment in a set of garments of different dimensions, or sizes, are developed with the purpose of having that set fit (nearly) all persons in a specified target population. The problem of defining the garment dimensions is understandably related to the dimensions of the body for which a garment is made. For a single person, the relation between garment and body, or garment fit, is found empirically through adjusting the garment to fit the body thereby finding the differences between garment and body dimensions, or the so-called garment ease. The ease values can be used to construct garment patterns from body dimensions, as the garment dimensions would be calculated by adding the corresponding ease amounts to the body dimensions. Garment sizing becomes related to body sizing—the process of segmenting the population into size groups of similar body dimensions so that the single garment created for that size group can fit all the people in the size group. Garment sizing can be viewed as comprising of two major components—(a) the body sizing system on which it is based and (b) the method of adding garment ease in each size, which is done in the process of grading (i.e., scaling up and down) the garment patterns in order to construct the garments of different sizes.

A body sizing system is usually derived from anthropometric data of the targeted population. First, the ranges of values of the body dimensions that are most relevant to garment construction, or key dimensions, are divided into groups by size intervals, so that the members of each size group have similar body dimensions. The rest of the body dimensions in a size group are calculated using regression equations based on the key dimensions as predictor variables (O'Brien & Shelton, 1941). All dimensions are tabulated for each size to form a body sizing system. Two of the important characteristics of a body sizing system are the drop and the intersize interval or grade of the system. The drop is a relationship (usually the circumferential difference) between two key dimensions. The intersize interval is the value of the differences between sizes for the key dimensions. The intersize interval of the system can vary across sizes—it may be smaller for the smaller sizes and increase for the larger sizes. The point of change in the intersize interval is called the break. Different body sizing systems need to be developed for different types and styles of garments (Gordon, 1986; International Organization for Standardization, 1991; Koblyakova, 1980; Winks, 1997) because key dimensions for a system need to be relevant to the construction of the specific garment and also need to describe the body shapes in the targeted population adequately. For example, the key dimensions for a waist-length jacket and for a pant clearly need to be different—bust circumference and arm length may be selected as key dimensions for the jacket, while hip and inseam may be selected for the pant.

Once the body sizing system is developed, the full range of garment sizes is created by developing grade rules and applying them to a base-size garment pattern constructed to fit the company's fit model—a person who embodies one of the sizes in the body sizing table and represents the targeted population in terms of body shape. Koblyakova (1980) describes three distinct methods of pattern grading—the group method, the ray method, and the proportional method. In the proportional method, the vertical and horizontal intervals of the body sizing table are applied to the construction points of the pattern to be graded. Therefore, in this method the ease amounts included in the base-size pattern will propagate to all garment sizes, rendering the ease for all sizes the same. In the ray method, rays are drawn from a selected focus point to all construction points on the garment pattern and the size intervals are applied along the ray. Ease values in this method are also generally the same throughout the size range. In the group method, two patterns are developed for the sizes at extreme ends of the size range. The patterns are aligned, and analogous construction points are connected with lines. These lines are divided by the number of sizes between the end sizes plus one in order to find the construction points of the patterns of the "between" sizes. If the end patterns are developed with different ease amounts, the rest of the garment sizes will also have variable ease. The disadvantage of this method is the necessity to develop the patterns for the two end sizes, requiring two fit models at the extreme ends of the range—not an insurmountable obstacle but rarely practiced.

For reasons of practicality and cost-effectiveness, the proportional grading method has become most popular in the industry today. In the application of this method, garment sizing is based on an existing body sizing table and on the pattern for the initial prototype garment developed for the fit model. The fit model is fitted to refine the shape of the garment pattern, thereby identifying appropriate ease amounts for the fit model. Next, the pattern of the garment made for the fit model is graded proportionally using the increments (grades) of the company's body sizing system, and in the process giving all garment sizes the ease amounts established for the fit model. This practice of sizing garments has been challenged by the idea that garment ease may need to vary according to size rather than being constant for all sizes (Gordon, 1986; Petrova, 2007). The idea is rooted in the empirical establishment of variation in the ease amounts necessary for good garment fit with size (see Size Dependence of Wearing Ease section).

Another challenge to the practice of garment sizing is the fact that current body sizing standards have been found to be inadequate in describing the actual population in the United States (Newcomb & Istook, 2004). An analysis of the SizeUSA data (Petrova, 2008) showed that most women in the population, when identified by bust size and independently by hip size, did not fit the bust–hip proportions of the standard: more women have a hip–bust drop smaller than the 2.5 inch hip–bust drop of the ASTM sizing system. Further, it was shown (Petrova, 2008) that if the body sizing table were modified to increase bust circumference for each size by 1 inch, or effectively decrease the hip–bust drop from 2.5 to 1.5 inches, the distribution would become more symmetrical and women with matching bust and hip sizes in the new modified system will form the largest group. At the same time, the number of women in the combinations of hip sizes with bust sizes that are one size larger decreased and combinations of hip sizes with bust sizes that are one size smaller increased. Generally, a garment designed for matching bust and hip sizes would accommodate a body with smaller bust size for the same hip size better than a body with larger bust size for the same hip size because it would provide extra room in the bust in the first case but would be a little tight in the second case. Therefore, it was concluded that a garment sizing system based on a modified body sizing table ASTM D5585-95R01 with a hip–bust drop of 1.5 inches would have the potential to accommodate more people.

Size Dependence of Wearing Ease

The method of adding ease in garments is viewed here as one of the major components in a garment sizing system because it ensures the proper fit of the resulting garments. Wearing ease—the amount of fabric left over and above the body dimensions to provide for comfort and fit—is established through experience and common practice in the process of fitting a custom or prototype garment to a body.[1] The amount of appropriate ease is often expected to depend on the size and shape of the person as well as on his or her comfort perception. Practical guides to patternmaking and garment fitting often stipulate that more ease should be left for the larger sizes but only recommend a range of ease values rather than give exact values for each.

Some researchers have tried to quantify ease and provide a system of determining the appropriate ease values for the purposes of constructing well-fitted garment patterns. In their classic study, Kirk and Ibrahim (1966) suggested that skin stretch during physical activity should be considered when evaluating the performance of stretch fabrics for garment design. Skin stretch at the various body areas such as buttocks, back, elbow, and knee were given for various dynamic body positions and expressed as a percentage of the skin length in normal body position, thereby incorporating size dependence into the stretch amounts—the higher the value of the body dimension, the higher the stretch. In turn, the relation of the skin stretch to the fit of a garment proposed a relation between body size and fit of the garment.

Petrova, Ashdown, Loker, and Schoenfelder (2003) have used body scan technology to measure the changes in waist, hip, and thigh circumferences, and crotch length after sitting. The percentage change of the waist and hip circumferences after sitting have been found to increase with the body mass index (BMI) of the study participant, which is representative of the size of the participant. The percentage change of the crotch length was found to decrease with BMI and percentage change of the thigh circumference to stay the same with BMI. It should be noted that even a constant percent change would indicate increase in the sitting circumference with size.

While the connection between size and garment fit is somewhat indirect in the study of Kirk and Ibrahim (1966), other researchers link the body changes during a physical activity directly to the ease amounts accounted for the construction of garments. Koblyakova (1980) provides data on changes in the above-bust, bust, and waist circumferences during breathing for male and female athletes and nonathletes. The difference between the circumferences in a relaxed state and after taking a deep breath is used to calculate the minimum ease amounts necessary at the bust and waist for upper-torso garments directly. Again, the results are presented as percentages indicating the size dependence of the calculated ease amounts.

Petrova and Ashdown (2008) have also examined the ease in pants for size and shape dependences by investigating whether the percentage differences in the circumferences between the pant and the body at the waist, abdomen, hip and thigh changed depending on the size and shape of the study participant. No significant changes were found for the percent differences except for the size dependence of the hip circumference. However, an example for pant ease values at hip was calculated using a model where the percent pant-body difference was held constant with size. This model yielded increasing amounts for the wearing ease at hip with increasing sizes.

In a previous study (Petrova, 2008) the researcher investigated ease amounts' increase with size and provided regression equations for calculating these values based on a study of custom-fitted clothing. As has been noted, appropriate ease values depend on the type, style, material, and function of the garment. For example, the ease amount at the bust for a close-fitted special-occasion dress will certainly be different from the ease necessary for a work shirt for a job requiring a lot of arm movement and stretching. Ease amounts found for one style cannot be simply used for another; they must be transformed in some manner reflecting the new style, or a new study must be conducted to establish the correct wearing ease for the new style.

Testing of Fit

The fit of a garment, as the relation between a body and a garment, is described by five components—ease, grain, line, balance, and set (Erwin, 1949). All of these are evaluated interactively to determine the goodness of garment's fit. A traditional method of evaluating fit is through analysis of the wrinkles that occur in a garment that does not wrap properly around the body, that is, a garment that does not fit the body (Watkins, 1995). This method has been developed thoroughly for all garment areas. In this method, the direction, magnitude, and amount of wrinkles that can be caused by a specific problem in the garment fit are identified. Generally, three types of wrinkles or stress folds are identified—horizontal, vertical, and diagonal, and each type can indicate different problems, including insufficient, excess, or misplaced ease. Professionals are well trained to use wrinkle analysis in both static and dynamic body positions to recognize fit problems and to suggest garment alterations that would correct the problem.

Generally the methods for fit evaluation are qualitative, involving the subjective opinion of humans. Such methods include direct observation and description, participant's responses, and expert evaluations and ratings (Watkins, 1995). Because qualitative methods rely on subjective assessment, they lack precision and often are not communicated effectively (Yu, 2004). Methods to increase the reliability of subjective assessment have been developed. These include the use of a panel of judges as opposed to a single judge, careful definition of the criteria for fit evaluation, and training of the judges prior to the assessment (Meilgaard, Civille, & Carr, 2007).

Fit evaluation is more reliable when fit is captured through still photographs or video recordings because it can be reevaluated and objectively compared to the fit of other garments. McConville (1986) stated that using photographs in fit assessment is an "excellent means for documenting and illustrating findings." Video recordings also can be used successfully to document as well as analyze fit quantitatively by evaluating still frames of the recordings (Ashdown & Watkins, 1992; Kohn & Ashdown, 1998). Objective measures of fit also include wear testing (McConville, 1986), imaging using Moire optics, algebraic evaluation of fit through linear, cross-sectional, and volume indexes, clothing waveform analysis, and pressure evaluation using pressure gauges to assess clothing fit (Yu, 2004). To determine whether the fit measured in an objective fit evaluation is good or bad, criteria for goodness of fit for the garment being studied must be established first. This is done by combining an objective method with a subjective method and matching the data of the objective evaluation to the results of the human assessment of fit, which, it should be noted, is based on cultural and social norms of the time, as well as common practice of the apparel industry. Fit preference of the wearer of the garment is an additional factor, but this is generally not considered at this level of analysis.

Fit testing to assess the fit of a single garment is related to but different from fit testing a complete garment sizing system. Fit testing of sizing systems should be performed by testing the garments in the sized set on a number of participants but since this requires considerable time, effort, and money, this type of testing is rarely performed in the apparel industry. Instead, the common practice in the industry is to fit only the fit model in order to develop the base pattern of the garment (Ashdown & O'Connell, 2006; Bougourd, 2007; Bye & LaBat, 2005).

Fit testing of a garment sizing system can be done in two different ways: (a) by testing the fit of the garments in the size set on a selected group of fit models, each one representing the dimensions of one of the sizes tabulated in the body sizing table used to develop the garment sizes (Ashdown & O'Connell, 2006; Bougourd, 2007) or (b) by testing the fit of one garment from each size on a number of participants representing the targeted population as a whole (Ashdown, Loker, Schoenfelder, & Lyman-Clarke, 2004; Gordon, 1986; Loker, Ashdown, & Schoenfelder, 2005; McConville, 1986; Watkins, 1995). The first method may perfect the patterns of the sized set for each body size in the body sizing table, but it cannot evaluate the performance of a sizing system for the whole population. The second method involves numerous participants and may present logistical problems, but it does indeed test the garment sizing system against the full range of body types and shapes in the population.

These methods of testing garment size sets should not be confused with the assessment of the accommodation rate of a body sizing system. Accommodation rates assess the number of people in the population or in the target market who can be expected to be fitted by a body sizing system based on a comparison of body measurements to the body chart that forms the basis for the body sizing system. Such assessment does not include a test of the garment-to-body relationship, which requires an actual test of garments from the sizing systems.

Research Objectives

In this study the performance of four garment sizing systems was assessed through comparative fit testing in order to investigate possible solutions to the aforementioned challenges to the current garment sizing practice in the United States. The four garment sizing systems were developed (Petrova, 2008) by modifying the current garment sizing method in two ways: (a) two of the sizing systems were based on the standard body sizing table ASTM D5585-95R01 and two of the systems were based on the modified body sizing table ASTM D5585-95R01 and (b) for each of these different body sizing tables two of the systems were graded using constant ease determined for a fit model and two systems were graded using size-dependent ease amounts calculated from a test of the ease values in custom-fitted garments. For ease of reference, the four systems were labeled as SS (standard ASTM D5585-95R01 graded with constant ease), SE (standard ASTM D5585-95R01 graded with size-dependent ease), MS (modified ASTM D5585-95R01 graded with constant ease), and ME (modified ASTM D5585-95R01 graded with size-dependent ease).

In order to establish which sizing system would perform best, garments from the full range of all four garment sizing systems were fit tested on a sample of women in the size range of the body sizing table ASTM D5585-95R01. The fit testing methodology developed for this study employed a set of photographic records of garment fit for each participant. Based on the photographs, three fit experts performed wrinkle analysis and ranked the garments from the different systems by fit. Fit ranking data were analyzed statistically. Usually fit testing of a garment sizing system is done in order to evaluate its true performance in terms of how many people in the population it can accommodate with well-fitted clothing. This study was designed to compare the performance of each of the garment sizing systems with respect to each other as opposed to measuring the actual performance of individual systems. By comparing the garment sizing systems rather than evaluating them, a direct assessment of the performance of the introduced modifications to the standard garment sizing method was conducted. This method of comparative fit testing of one garment sizing system against another on the same sample of participants is the best way of comparing the performance of sizing systems. No previous example of comprehensive comparison of sizing systems has been reported in the literature. The following hypotheses were tested in this experiment:

1. A garment sizing system based on size-dependent ease grading (SE and ME) will perform better overall than a garment sizing system based on constant ease grading (SS and MS).
2. A garment sizing system based on a modified body sizing table ASTM D5585-95R01 defined with a hip–bust drop of 1.5 inches (3.8 cm; MS and ME) will perform better overall than a garment sizing system based on the standard body sizing tables ASTM D5585-95R01 with a hip–bust drop of 2.5 inches (6.4 cm; SS and SE).
3. A garment sizing system based on a modified body sizing table ASTM D5585-95R01 defined by a hip–bust drop of 1.5 inches (3.8 cm; MS and ME) will perform better than a garment sizing system based on the standard body sizing tables ASTM D5585-95R01 with hip–bust drop of 2.5 inches (6.4 cm; SS and SE) for women with hipbust drop values between 0 (0 cm) and 2 inches (5.1 cm).
4. There will be no difference in the performance of a garment sizing system based on a modified body sizing table ASTM D5585-95R01 defined by a hip–bust drop of 1.5 inches (3.8 cm; MS and ME) and a garment sizing system based on the standard body sizing tables ASTM D5585-95R01

with hip–bust drop of 2.5 inches (6.4 cm; SS and SE) for women with hip–bust drop values between 2 (5.1 cm) and 4 inches (10.2 cm).

Methodology

Test Garments

The test garment style was a collarless, unlined V-neck princess style jacket hemmed 2 inches below the hip, with princess seams crossing the armscye, a contoured center back seam, small shoulder pads, and short one-piece sleeves.

Using patterns developed in previous work (Petrova, 2008), eight test garments were constructed in the size range 2–16 for each sizing system SS, SE, MS, and ME (32 garments total). The jackets were made from stable medium-weight cotton twill fabric (250 g/m^2, or 7.4 oz/yd^2) in neutral color. Shrinkage tests were performed in a home-laundering machine to determine the number of times the fabric needs to be prewashed in order to eliminate the effects of residual shrinkage at subsequent laundering.

Jackets of the same size from the four different sizing systems differed in bust and hip measurements by amounts as small as 3 mm (1/8 inches). Great precision was required at all stages of marking, cutting, and construction to accurately capture these small differences in the test garments. Fabric was spread evenly in one ply on a large table and secured with weights to prevent it from moving or twisting. The stitching line for each garment pattern shape was traced separately onto the fabric using a fine-point pen. As each panel was cut, seam allowances were clipped and serged at width of 3/8 inches. Stitching was done exactly on the seam line marked with the fine-tipped pen. Any deviation from the seam line on either side of the seam was repaired by ripping the incorrect portion of the seam and redoing it.

Snap buttons were used for the front jacket closure because they can be installed at a specified place with great precision. Unlike regular buttons, which can move sideways within their buttonholes, snap buttons form a stable point-to-point closure thus maintaining the precise torso dimension of the jacket during the fitting.

The edges of the jacket (at neckline and front closures, jacket hem, and sleeve hem) were finished with facings, which were stabilized with lightweight nylon woven interfacing. Two color-coded ribbon labels—one designating the garment sizing system and second designating the size of the jacket, were attached on the inside of the jacket at the center back neckline.

Study Participants Recruitment

Participants were recruited in the size range 2–16 of the standard body sizing table ASTM D5585-95R01. Participants were recruited at three sites—a small city in a northeastern state of the US and in two small cities in a Southern state of the US. Recruitment was done through calls for participation in an electronic newspaper of a local university, flyers, and announcements in a newspaper in the local community, email announcements and calls to the customers of a local fabric store, as well as contacts to participants from previous studies.

Testing Procedures

Prior to testing, consent for participation was sought from each participant in accord with the procedures of the institutional review board. Each study participant was asked to change into standard test garments (stretch top and leggings[2]), which were donned over the participant's regular underwear and body shaping undergarments. Participants' ages were recorded, and height, weight, bust, and hip circumferences were taken manually. Participants with long hair were instructed to tie their hair up to prevent obstruction of the jacket neckline in the photographs. All participants wore their shoes for the fit tests.

Jackets of different sizing systems and sizes were given to the participants for the trials. The order of the tested garment sizing systems was randomized for each participant to prevent any systematic patterns resulting from changes in body posture or kinesthetic aftereffects that might occur during the testing. The jacket that fit the participant best in the bust–waist–hip area of the torso was selected within each garment sizing system. To test the acceptability of the fit in the bust and chest area in an active position, each participant was asked to raise and flex her arms, assuming a driving position. The final jacket sizes were selected with consultation between the researcher and the participant. Participants did not know what garment sizes they were testing.

Once a garment was selected, front, right side, and back black-and-white photographs of the participant wearing the garment were taken in standard conditions. The participant stood behind a white line drawn on the floor approximately 1.5 m (5 ft) in front of a digital photo camera stationed on a tripod. By adjusting the zoom function on the camera, each participant was photographed only between the chin and the thigh levels, capturing only the image of the jacket. A black screen was set behind the participant. The lights in the room were dimmed and only the flash of the photo camera illuminated the participant. The participant was asked to stand in her usual relaxed posture, with her hands brought slightly away from the body so that the hip of the jacket would not be obstructed. The standard conditions of the photo shoot ensured equal presentation of the garments in the photographs (see Figure 1), which were used for fit evaluation. Upon completion of the study, participants were given a tote bag as a thank-you gift and were given a chance to enter a lottery drawing for the distribution of several $30 gift cards.

Fit Evaluation

Fit evaluation was completed by fit experts who were professionals in the area of apparel design and construction and had at least 10 years of experience in teaching patternmaking and fit. Three judges evaluated the fit of the jackets using electronic forms set up in Microsoft® Excel®, one form for each participant (see Figure 1). The forms contained three photographs of the participant in each of the four jackets from the different sizing systems. Jackets were labeled as Jackets 1, 2, 3, and 4 rather than by sizing system and size, thereby maintaining "blind judging." Short instructions to the judges were given on the form; a longer list of instructions was sent prior to sending the forms via e-mail. For each participant judges ranked (rank 1 being best, rank 4 being worst), the four jackets by the overall fit in the bust–waist–hip area—the areas where the sizing systems were different. The electronic form was designed to warn the judge if any of the jackets were not ranked or if any two jackets were ranked the same (preventing judges from giving any two jackets the same rank). Jackets were presented on the form in a random order that did not match the order in which the participant tried the jackets and also randomized the order of the jackets from the different systems. After completing the evaluations, the form was saved and e-mailed back to the researchers for analysis.

Data Analysis

The rankings given by the judges were extracted from the Excel forms and entered into SPSS v.11.0 along with participants' body measurements, age, and the jacket sizes used from each garment sizing system. The hip–bust drop was calculated for each participant as the difference between the hip and bust circumferences. The rankings given to a jacket from a specified garment sizing system by each of the three judges were added up to form a cumulative rank for the jacket from that system. The ranking from each judge varied from 1 (best fit) to 4 (worst fit). The sum of the rankings of all three judges for a jacket in each system formed cumulative rankings for the jacket and varied from 3 (highest ranking from all three judges) to 12 (lowest ranking from all three judges). To assess each judge's reliability, intraclass correlation reliability coefficients were calculated in SPSS.

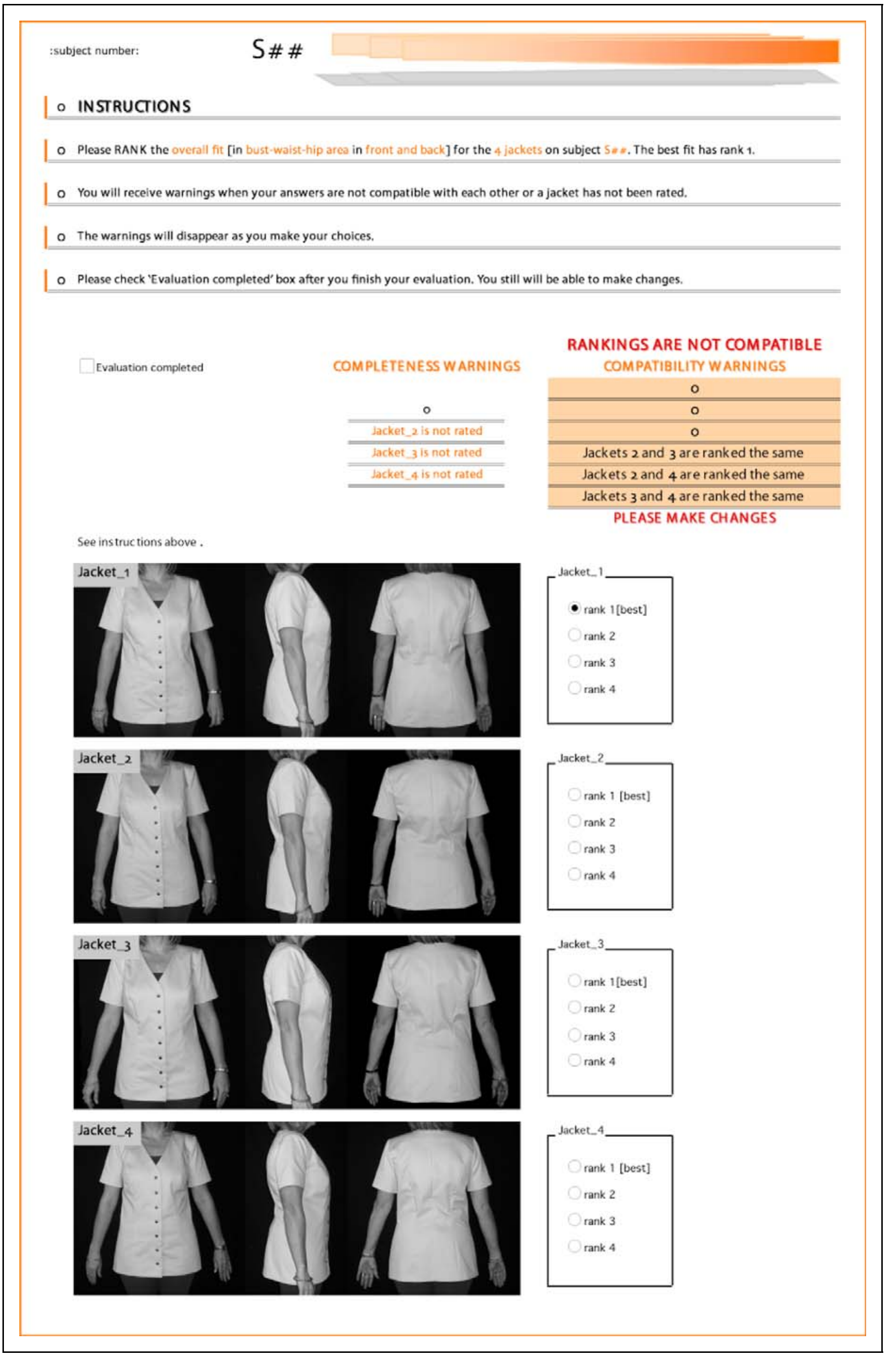

Figure 1. Digital form (produced in Microsoft® Excel®) used for fit evaluation of jackets for one participant.

The frequencies of the rankings for each garment sizing system were calculated for the individual rankings from each judge and for the cumulative rankings from all three judges, and median, mode, and percentiles were calculated. A nonparametric sign test was selected to perform comparison of the overall performance of the garment sizing systems because (a) data were ordinal and (b) the differences between rankings were not normally distributed. For paired sets of data (paired by participant), the sign test counts how many times a condition (a garment sizing system) is ranked as better than another condition (another garment sizing system) and determines whether the difference is significant. The sign tests were repeated for each garment size and for each drop group.

Results and Discussion

Study Participants Sample Description

Eighty-one Caucasian women in the age range 26–55 were recruited. Their bust measurements ranged from 82.9 cm to 110.0 cm and hip measurements ranged from 91.5 cm to 112.0 cm. The height of the participants was between 160.0 cm and 172.0 cm. Only one participant exceeded the range of the standard body sizing table ASTM D5585-95R01 by bust but she was accommodated by the jackets in the largest size and was retained in the study. Participants were distributed among the three sites as follows: 24 participants at site 1, 54 participants at site 2, and 3 participants at site 3. Seventy-two of the participants used the same size jacket in all garment sizing systems. Seven participants used the same size in systems SS and SE but one size smaller in systems MS and ME. One participant used the same sizes in systems SS, SE, and MS and one size smaller in system ME. One participant used the same sizes in systems SE, MS, and ME and one size larger in system SS. The distribution of the participants by size was skewed towards the larger sizes. The hip–bust drop for the sample ranged from -3 cm (-1.18 inches) to 17.5 cm (6.89 inches), with mean of 6.3 cm (2.48 inches) and standard deviation of 4.9 cm (1.93 inches). Participants were separated by their hip–bust drop value into nine groups (see Table 1) with intervals of 1 inch (2.54 cm) with midpoint value of the hip–bust drop ranging from -3.8 cm (-1.5 inches) for Group 1 to 16.5 cm (6.5 inches) for Group 9. Group 4 included hip–bust drop values of 1 to 2 inches, with a midpoint of 3.8 cm (1.5 inches), representing the drop of the modified ASTM D5585-95R01. Group 5 included hip–bust drop values of 2 to 3 inches, with a midpoint of 6.4 cm (2.5 inches), representing the drop of the standard ASTM D5585-95R01.

Overall Performance of the Garment Sizing Systems

Table 2 presents the frequencies of the individual and cumulative rankings of the garment sizing systems SS, SE, MS, and ME, where rank 1 means best fit and rank 4 means worst fit. Because there is a lot of uncertainty in fit evaluations, the reliability of a single judge was expected to be low: reliability for a single judge was 0.51 for the SS, 0.40 for SE, 0.37 for MS, and 0.35 for the ME garment sizing system. Using three judges increased the reliability of the evaluation, the average measure intraclass correlation coefficient being 0.76 for the SS, 0.66 for SE, 0.64 for MS, and 0.62 for the ME garment sizing system. Using more judges or training them may have increased the reliability of the evaluation.

Table 1. Midpoint of the Drop and the Number of Participants in Each Hip–Bust Drop Group

	Drop Group									
	1	2	3	4	5	6	7	8	9	Total
Midpoint of drop in group[a]	−3.8	−1.3	1.3	3.8	6.4	8.9	11.4	14.0	16.5	
Number of participants in group	1	8	11	15	12	17	7	8	2	81

[a]Measurement in centimeters

Table 2. Frequencies of Individual and Cumulative Rankings of Garment Sizing Systems SS, SE, MS, and ME and Statistics of the Cumulative Rankings

		Garment Sizing System			
	Rank	SS	SE	MS	ME
Ranking by					
Individual: Judge 1					
	1	15	17	18	31
	2	17	19	25	20
	3	21	17	21	22
	4	28	28	17	8
Individual: Judge 2					
	1	10	18	22	31
	2	13	26	21	21
	3	24	16	23	18
	4	34	21	15	11
Individual: Judge 3					
	1	12	15	22	32
	2	14	17	27	23
	3	17	29	16	19
	4	38	20	16	7
Cumulative: all judges					
	3	5	7	6	15
	4	2	4	9	6
	5	6	2	6	13
	6	6	8	12	8
	7	4	16	11	15
	8	6	10	13	11
	9	14	13	7	7
	10	11	7	10	2
	11	14	6	4	3
	12	13	8	3	1
Statistic					
Average		8.9	7.9	7.2	6.2
Median		9	8	7	6
Mode		9[a]	7	8	3[a]
Percentiles					
	25	7	6	5	4
	50	9	8	7	6
	75	11	10	9	8

Note. a. Smallest of multiple modes

However, this study relied on judges' previous experience of evaluating fit and only general instructions about the focus of the study on the fit of the garments at the bust and hip were given to the judges.

A general pattern of the frequencies of the ratings presented in Table 2 can be traced as follows: The jackets from system SS are given rankings indicating best fit (rank 1) the fewest times and are given rankings indicating worst fit (rank 4) most frequently. On the other hand, the rankings of the jackets from system ME indicate best fit most frequently and worst fit the fewest times. This pattern is not evident for the system SE even though the number of times when SE is ranked as better fitting (ranks 1 and 2) seems less than the number of times it is ranked as worse fitting (ranks 3 and 4). In reverse, system MS appears to have been ranked as better fitting (rank 1 and 2) more than it has been ranked as worse fitting (ranks 3 and 4). These patterns in the rankings imply that, overall, the garment sizing system SS may be the worst one and system ME may be the best one in providing good fit for the sample.

The above patterns also imply the order of the four sizing systems in providing good fit for the sample: The number of times each system has been ranked as rank 1 (best) shows that systems are ordered by their performance from worst to best as SS, SE, MS, and ME. The number of times each system has been ranked as rank 4 (worst) puts the systems in the same order. The number of times a system has been ranked as rank 2 or 3 does not present any clear pattern.

Table 2 also presents the mean, median, modes, and percentiles for the cumulative rankings for each of the garment sizing systems. The order of the sizing systems from worst to best as SS, SE, MS, and ME suggested by the frequencies is supported by the order established by the means of the cumulative rankings of 8.9, 7.9, 7.2, and 6.2, respectively, by the medians of 9, 8, 7, and 6, respectively, as well as by the cutoff values for the 25th, 50th, and 75th percentiles. Sizing system SS had a double mode at rank 9 and rank 11, system SE has a mode at rank 7, MS at rank 8, and ME has a double mode at ranks 3 and 7. The modes of the cumulative rankings place system SS as worst and ME as best performing garment sizing system with no clear distinction between systems SE and MS.

A nonparametric Friedman test for the cumulative rankings of the systems was carried out to investigate the order of the systems. Only participants who wore the same size jacket in all four systems ($n = 72$) were included in this analysis. The Friedman test ordered the systems as SS, SE, MS, and ME, with mean ranks of 3.10, 2.78, 2.29, and 1.83, respectively. Friedman's chi-square was $\chi^2(3, N = 72) = 40.838$, $p < .001$, showing that there are significant differences between some of the four garment sizing systems.

The established order of the sizing systems supports Hypothesis 1 that systems based on size-dependent ease (systems SE and ME) will perform better than systems based on constant ease (systems SS and MS). Overall, the better performance of systems based on the modified body sizing table ASTM D5585-95R01 (systems MS and ME) is in support of Hypothesis 2 that systems designed for smaller hip–bust drop will perform better because they accommodate participants with smaller drop better, while providing participants with larger drop with extra bust ease, which, unless excessive, generally is evaluated as acceptable fit.

To test which systems performed significantly different from each other, a pairwise comparison of ratings of the garment sizing systems was carried out using the nonparametric sign test[3] for paired data for the cumulative rankings of the systems (see Table 3). Comparisons were made separately for the participants that used the same garment size in both compared systems and those that used different sizes in the two compared systems. The first system in the pair is named System 1 (S_1) and the second system in the pair is named System 2 (S_2). For each pair of sizing systems the cumulative ranking for S_1 is subtracted from the cumulative ranking for S_2. When the difference S_2-S_1 is less than zero ($S_2 - S_1 < 0$), the cumulative ranking for S_2 is smaller than that for S_1, indicating that S_2 performed better for this participant, i.e. the jacket from system S_2 provided better fit. If the difference $S_2 - S_1$ is equal to zero ($S_2 - S_1 = 0$), the cumulative rankings for both systems are the same for this participant and both systems S_1 and S_2 performed the same. If the difference $S_2 - S_1$ is larger than zero ($S_2 - S_1 > 0$), the cumulative ranking for S_2 is larger than that for S_1, indicating that S_1 performed better for this participant. These differences are evaluated and counted for all participants. The sign test compares the number of counts indicating that S_1 performed better, the number of counts indicating that the systems were the same, and the number of counts indicating that S_2 performed better, and indicates whether the differences in these counts are significant. The pairwise comparisons shown in Table 3 reveal that for the groups of participants who wore the same size in both compared systems, the system SE performs better than SS but not significantly, MS performs significantly better than SE, ME performs significantly better than MS, ME performs significantly better than SS, MS performs significantly better than SS, and ME performs significantly better than SE. Overall, the rank order of the performance of the systems from worst to best is SS, SE, MS, and ME, though the difference between SS and SE was not significant leading to a rejection of

Table 3. Comparison of Performance of Pairs of Garment Sizing Systems by Cumulative Ranking of the Systems

	Pair of Compared Garment Sizing Systems $S_1..S_2$					
	SS..SE	SE..MS	MS..ME	SS..ME	SS..MS	SE..ME
Participants used same size in S_1 and S_2						
Total number of participants	80	74	80	72	73	73
Number of participants when						
S_2 has lower ranking	43	44	48	56	52	54
S_1 and S_2 have same ranking	6	4	4	4	1	1
S_1 has lower ranking	31	26	28	12	20	18
System with better performance	SE	MS	ME	ME	MS	ME
Significance	0.201	0.042	0.029	0.000	0.000	0.000
Participants used larger size in S_1						
Total number of participants	1	7	1	9	8	8
Number of participants when						
S_2 has lower ranking	0	0	0	0	0	0
S_1 and S_2 have same ranking	0	0	0	1	0	1
S_1 has lower ranking	1	7	1	8	8	7
System with better performance	SS	SE	MS	SS	SS	SE
Significance	–	0.016	–	0.008	0.008	0.016

Note. Comparison results significant at $p \leq 0.05$ are highlighted.

Hypothesis 1 for the pair of systems SS and SE. The overall performance of system ME was significantly better than that of system MS, thus supporting Hypothesis 1 for the pair MS and ME. The number of participants who wore different sizes was low, especially for the pairs SS and SE, and MS and ME, thus preventing the statement of statistically significant results for this group of participants.

Performance of the Garment Sizing Systems by Size

Table 4 presents the results of the comparison between constant ease and size-dependent ease systems, or pairs SS and SE, and MS and ME, carried out by repeating the sign test within each size group, again, comparing only participants who wore the same size in both systems. The trend in rankings shows that systems SE and ME may be performing better for the larger sizes (10, 12, 14, and 16), while in most cases systems SS and MS perform better for the small sizes, probably due to the fact that systems SE and ME provided less ease in this size range and, as mentioned earlier, less ease generally was evaluated as providing worse fit than more ease. However, the small sample size across the size groups and the skewness of the sample toward the larger sizes do not allow inferences about statistical significance of the results.

Performance of the Garments Sizing Systems by Drop

The effect of modifying the drop of the standard body sizing table of ASTM D5585-95R01 from 2.5 (6.4 cm) to 1.5 inches (3.8 cm) was evaluated through comparison of the performance of systems SS with MS and systems SE with ME by repeating the sign tests (see Table 5) for each of the nine drop groups. The results present a trend for systems MS and ME to perform better than systems SS and SE, respectively, for almost all drop groups. However, most of the results were not significant; because the sample showed a large variation in drop value the size of each drop group was small thus preventing any definitive conclusions about the systems' performance by drop group.

Table 4. Comparison of Performance of Garment Sizing System SS With MS and SE With ME by Cumulative Ranking for Participants Within Each Drop Group. Only Participants Who Used the Same Garment Size in Both Compared Systems are Included.

	Garment Size							
	2	4	6	8	10	12	14	16
SS..SE								
Total number of participants	1	3	6	12	17	18	16	7
Number of participants when								
SE has lower ranking	0	0	4	4	8	11	12	4
SS and SE have same ranking	1	1	1	0	2	1	0	0
SS has lower ranking	0	2	1	8	7	6	4	3
System with better performance	–	SS	SE	SS	SE	SE	SE	SE
Significance	–	0.500	0.375	0.388	1.000	0.332	0.077	1.000
MS..ME								
Total number of participants	1	3	8	11	20	16	15	6
Number of participants when								
ME has lower ranking	0	2	3	3	14	11	10	5
MS and ME have same ranking	0	0	1	1	1	0	1	0
MS has lower ranking	1	1	4	7	5	5	4	1
System with better performance	MS	ME	MS	MS	ME	ME	ME	ME
Significance	–	1.000	1.000	0.344	0.064	0.210	0.180	0.219

To evaluate the effect of hip–bust drop on system performances, the comparison was carried out for two subgroups of the whole sample that had hip–bust drop values closer to those of the standard and of the modified body sizing tables: drop groups 3 and 4 were combined into group "small drop"; drop groups 5 and 6 were combined into group "large drop." The results of the comparisons of systems SS with MS, and SE with ME for the small and large drop groups are also presented in Table 5. For the combined group "small drop" the comparison of the garment sizing systems shows that systems MS and ME performed significantly better than systems SS and SE, respectively, thus supporting Hypothesis 4. Improved performance was expected because the modified systems MS and ME were designed for a body proportion with smaller hip–bust drop value and were expected to accommodate those participants better. For the combined group "large drop" the comparison of the garment sizing systems shows that systems MS and ME appear to have performed better but not significantly better than systems SS and SE, respectively. This finding suggests that, in support of Hypothesis 5, systems MS and ME may be performing better, the same, or worse than systems SS and SE, respectively. This result was expected as the systems SS and SE are designed for a larger drop and may accommodate participants with large drop better, but systems MS and ME, by providing more ease at the bust, may be providing the same or better fit than that of SS and SE.

Remarks on the Fit of the Jacket

It should be noted that in this experiment only two dimensions—bust and hip— were subject to testing. The tested garment grading systems differed only along bust and hip, and by extension along the waist, where a pattern was modified to create a smooth outline along the side seam, preserving the proportion of the jacket. The interactions between the various dimensions and especially the interactions between horizontal and vertical dimensions greatly affect the fit of a standard sized jacket onto a specific participant. While participants may belong to a certain size group by the key dimensions of bust and hip, the intrasize variation along key and/or other body dimensions causes a

Table 5. Comparison of Performance of Garment Sizing System SS With SE and MS With ME by Cumulative Ranking for Participants Within Each Garment Size. Only Participants Who Used the Same Garment Size in Both Compared Systems are Included

	Drop Group								
	1	2	3	4	5	6	7	8	9
SS..MS									
Total number of participants	1	7	11	15	10	16	4	7	2
Number of participants when									
MS has lower ranking	0	6	9	12	7	9	2	7	0
SS and MS have same ranking	0	0	0	0	0	1	0	0	0
SS has lower ranking	1	1	2	3	3	6	2	0	2
System with better performance	SS	MS	MS	MS	MS	MS	–	MS	SS
Significance	–	0.125	0.065	0.035	0.344	0.607	1.000	0.016	0.500
SE..ME									
Total number of participants	1	7	10	15	10	17	4	7	2
Number of participants when									
ME has lower ranking	0	5	8	12	7	11	4	6	1
SE and ME have same ranking	1	0	0	0	0	0	0	0	0
SE has lower ranking	0	2	2	3	3	6	0	1	1
System with better performance	–	ME	ME	ME	ME	ME	ME	ME	–
Significance	–	0.453	0.109	0.035	0.344	0.332	0.125	0.125	1.000

	Small drop	Large drop
SS..MS		
Total number of participants	26	26
Number of participants when		
MS has lower ranking	21	16
SS and MS have same ranking	0	1
SS has lower ranking	5	9
System with better performance	MS	MS
Significance	0.003	0.230
SE..ME		
Total number of participants	25	27
Number of participants when		
ME has lower ranking	20	18
SE and ME have same ranking	0	0
SE has lower ranking	5	9
System with better performance	ME	ME
Significance	0.004	0.124

Note. Comparison results significant at $p \leq 0.05$ are highlighted.

standard size garment to fit differently on each participant. For example, the height variability of shoulder-to-bust, bust-to-waist, and waist-to-hip heights within a size group can lead to a vertical mismatch between the garment bust and hip levels and the body bust and hip levels. A jacket that fits well against the bust of a participant may not fit the waist and the hip of that participant if she is shortwaisted and has a small waist-to-hip height. In this case, the high-hip level of the jacket will fall at the hip of the participant and even if the body and garment hip circumferences were appropriate to one another, the jacket would not fit the body properly. In such case it is likely that a jacket with larger waist, that is therefore larger in the high hip area, may be able to accommodate the variation in height by having more room for the jacket to slide over the hips and provide satisfactory garment fit. Of the compared garment sizing systems, the systems MS and ME provide a larger waist because of the larger bust circumference. Therefore, it is conceivable that having a larger waist is one of the reasons that the systems MS and ME performed better than the systems SS and SE.

Another example of interactions between garment dimensions is the interaction between shoulder width and bust circumference ease. When comparing garments of systems SS and SE, and MS and ME, respectively, many participants commented that the garment which had less bust ease felt roomier in the shoulders. As participants were not aware of the differences between the jackets they relied on their subjective feeling to assess the fit of the jackets. Even though they generally could not feel the difference in the jackets that had less ease in the bust area specifically, the interaction between the bust and shoulder area led participants to believe that there was more room in the shoulder area even though this was not the case. For the pairs SS and SE and MS and ME, the dimensions in the shoulder and arm area of the jackets were the same.

While such differences are acknowledged, it is important to stress that the aim of the experiment was to see whether the small differences introduced by the different garment sizing systems would make a difference for the overall performance of systems for the whole sample of participants rather than concentrating on the ability of a jacket of specific size to fit a specific person. The differences in garment dimensions between jackets from different sizing systems but within the same size, while very small, were able to provide differentiation in the garments' fit discernible to the experts evaluating the fit of the jackets.

Conclusions and Future Work

This work presented an experiment designed to compare the performance of four garment sizing systems: SS—using standard body sizing table and constant ease grading, SE—using standard body sizing table and size-dependent ease grading, MS—using modified body sizing table and constant ease grading, and ME—using modified body sizing table and size-dependent ease grading. A sized set of garments was constructed for each system and tested on participants. Each participant identified the best-fitting size jacket from each system and was photographed in each of the four jackets selected. Using traditional wrinkle analysis, three judges independently evaluated jacket fit by looking at the black-and-white photographs. Since the goal of the test was to compare the performance of the systems (rather than evaluate it absolutely), judges ranked the fit of four jackets that each participant had on from best to worst. Analysis of the rankings' frequencies showed that by overall performance the systems ranked as ME, MS, SE, SS, from best to worst. As expected, the systems MS and ME, being based on the modified body sizing table with smaller hip–bust drop performed better for participants with smaller hip–bust drop. However, these systems performed the same as systems SS and SE for the participants with large hip–bust drop, perhaps because the additional ease that the systems MS and ME provided due to the larger bust circumference (though generally larger than needed) was still evaluated as good fit. The overall better performance of systems MS and ME may also be attributed to the fact that the increased bust dimension of the garment also led to an increase in the waist dimension of the garment allowing the garment to accommodate the intrasize variability of the vertical and circumferential dimensions of the torso better. The overall better performance of the systems SE (not significant) and ME (significant) with respect to systems SS and MS, respectively, indicated that the size-dependent ease grading method has the potential to produce better results in fitting the size range than does the constant ease grading method. This finding was not supported for individual size groups, which may be attributed to small sample size within each group.

It would be preferable to increase the reliability of the judges by increasing the number of fit experts evaluating the fit of the jackets. If possible and economically feasible, a pretest should be done to determine the number of judges to be used as this may vary with the style and complexity of the tested garment. Experiments on comparing sizing systems also need to be performed with larger number of study participants. It should be noted that the experiment described here reflected modifications along only two garment dimensions. Future work should focus on introducing size systems that modify more garment dimensions simultaneously.

The methodology for comparing sizing systems used in this work was not intended to evaluate the absolute performance of each sizing system but to compare sizing systems that differ in a certain way, effectively testing the effect of a modification introduced to a sizing system. Despite the small differences in garment dimensions among the four sizing systems, the results are reassuring. The researchers conclude that the devised methodology for comparing sizing systems is successful and can be used for other garments and systems.

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Notes

1. Another type of ease is design ease, which relates to the design of the garment and is not considered in this research study.
2. The same test garments were used in determining the ease amounts appropriate for the jacket.
3. The sign test is equivalent to the Friedman test when there are only two repeated measures.

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Bios

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