Exploring the Relationships of Grading, Sizing, and Anthropometric Data

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Clothing and Textiles Research Journal 2005 23: 13
DOI: 10.1177/0887302X0502300102

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Key Words

Anthropometry, Apparel Sizing, Clothing, Pattern Grading

Abstract

Grading is the process used to accomplish the sizing of manufactured clothing. The focus of our research was to question the belief that the foundation for grading is size measurements that are based on anthropometric data. Our review of literature established that grading preceded size charts. Forty size charts for women's clothing were examined for correspondence with anthropometric research. Four structural assumptions that did not match anthropometric research were identified. Criteria were developed and applied to upper torso measurements. Only 17% of the measurements were found useful for grade rule formation. Grade rules were compared to size intervals from a concurrent sizing standard. Eleven of 38 grade rules corresponded to body measurements, and 6 did not match the related size interval. New measurements for grade rules were recommended.

Sizing is the process used to establish a size chart of key body measurements for a range of apparel sizes. Sizing systems are sets of size charts, each chart created to serve one body type category of the population. Apparel manufacturers develop sizing systems with the goal of satisfying consumers' needs for apparel that fits. However, sizing systems used for U.S. women's clothing are not meeting the needs of customers. Strategies are being developed to address these concerns. "Size USA," a large-scale anthropometric study funded by industry, has gathered updated information on American body shapes and dimensions using body scanning. It is evident from this study that the apparel industry recognizes the problem and is searching for answers (De Lisser & Zimmerman, 2003).

Customers tend to blame themselves for difficulties in finding apparel that fits. Strait and Lawson (1994) concluded that "rather than attribute fit variations to manufacturers' sizing systems . . . a woman will perceive personal figure flaws as a reason for not fitting into the expected size number" (p. 133). LaBat (1990) also found that "when clothing does not fit, the consumer may perceive the cause as related to their body and not the clothing" (p. 43). Salusso (1995) suggested that "rather than conclude people's bodies are misproportioned, it is time to seek validity in sizing proportions" (p. 97). We propose that creating a new set of anthropometric measurements will not solve the fit problems of many women and that there are other factors that must be explored.

Grading is the process used by clothing manufacturers to produce garments in a range of sizes. Grading is a standard method of applying increases and decreases at points of a pattern to make the pattern larger or smaller. Practices and procedures of grading have changed little over the years and few researchers have focused on grading. If the grading process is flawed, the manufactured garments will not reflect the size charts. According to Moore, Mullet, and Young, "A grading system is developed from sizing specifications, and sizing specifications are derived from anthropometric surveys" (2001, p. 7). To accomplish the goal of creating garments in sizes that will fit people, grade rules used to create garments should be based on body measure-

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ments associated with a specific size. In turn, body measurements in size charts should be based on anthropometric data. However, we believe this process does not accurately describe grading practice.

To explore the relationships among grading, sizing, and anthropometric data, we focused on the following questions: (a) What is the historical relationship between size charts and grading? (b) Are existing size charts based on anthropometric data? and (c) Is grading practice based on size measurements? We included these methods: (a) augmentation of literature search with historical evidence from size charts, (b) documentation of practices revealed in an examination of size intervals from size charts, (c) examination of body measurements to determine whether they could be the basis of grading information, and (d) comparison of grading practice as defined by Price and Zamkoff (1974) with the 1970 U.S. sizing standard published by the U.S. Department of Commerce to determine whether body measurements have been used as the basis of grading information.

Except for national sizing systems that have been accepted as standards (known as sizing standards), there is little documentation of the process used to create size charts. There is even less documentation about the source of grading practices. Because of this lack of historical information, we used information that we gathered from size charts to corroborate and augment our review of literature in our search for the answers to our first two research questions.

Methods

Forty U.S. size charts for women's clothing dating from 1873 to 2000 were collected from retailers, dressmaking texts, published sizing standards, and apparel pattern companies (see Table 1). Attempts were made to obtain several charts from each decade. We limited ourselves to the measurements of the upper torso. The text from each source was examined for any methodology used in the derivation of the size chart(s). We included several 2000 charts because we thought any one retailer did not represent the market and we were trying to understand recent practices. All size charts differed from each other.

Table 1. Comparison of sizing charts from 1873 to 2000

Date	Sizing chart	Number of sizes	Range of bust circumferences in inches	
			Min	Max
1873	Butterick patterns (Bryk, 1988)	13	28	46
1882	Butterick patterns (Bryk, 1988)	13	28	46
1894	Ladies Standard Magazine (Bryk, 1988)	4	29	33
1897	Late Victorian Women's Tailoring (Holding, 1897/1997)	7	30	42
1902	Sears, Roebuck catalog	5	30	38
1902	Sears, Roebuck catalog patterns	6	32	42
1908	Ladies Tailor-Made (Gordon, 1908/1993)	17	21	50
1909	McCall's patterns (Bryk, 1988)	7	32	44
1910	Hopkins (1910/1990)	12	24	46
1917	Coates	14	32	37
1921	Butterick pattern #4251	7	32	38
1923	Woman's Institute of Domestic Arts and Sciences	11	30	50
1933	Woman's Institute of Domestic Arts and Sciences	9	34	50
1937	Woman's Institute of Domestic Arts and Sciences	11	30	50
1939	Kaplan & Kaplan	7	32	41
1943	N.Y. State Vocational and Practical Arts Assoc.	5	32.25	37.25
1947	Auditore	5	36.5	42.5
1949	Pivnick	7	33	42
1955	Gebbia	5	32.5	38
1955	Lapick	7	33	41
1955	Pivnick	7	33.5	42.5
1958	U.S. standard, CS 215-58, U.S. Department of Agriculture	9	30.5	43
1964	Simplicity patterns (Erwin and Kinchen)	11	31	50
1966	Mortimer-Dunn	8	30	44
1968	Rohr	9	32	48
1970	Mori	7	33	42.5
1970	U.S. standard, PS 42-70, National Bureau of Standards, U.S. Dept. of Commerce	9	31.5	44
1971	Tanous	7	30.5	40
1974	Scheier	6	34	40
1986	Butterick pattern – New sizing (Nastiuk)	8	30.5	40
1992	Butterick pattern #3001	10	30.5	46
1994	U.S. standard, D5585-94, American Society for Testing and Materials	10	32	44.5
1997	*E Style* catalog	10	35	51
1998	A major retailer	12	33	50.5
2000	*Eddie Bauer* catalog	11	32	46.5
2000	*JCPenney* catalog	12	30.5	46.5
2000	*L. L. Bean* catalog	9	33.5	45
2000	*Lands' End* catalog	9	33	44.5
2000	*Sears* catalog	9	31	43
2000	*Spiegel* catalog	7	33.5	41

We identified 30 measurements that were included in at least two size charts from descriptions, diagrams, drawings, or photographs that accompanied the size charts (see Table 2). Our size chart database was created by calculating the intervals between sizes for individual measurements of the

Table 2. Woman's Upper Torso Measurements from Size Charts (1873 - 2000) with Indication Whether Each Measurement Passes Criteria for Usefulness for Grading.

Circumference:	Arcs, from side seam to side seam:
1. Mid-neck, N-A, N-S	7. Front bust arc, US, N-L
2. Neck-base, US, N-A, N-S	8. Front above bust arc, N-L
3. Above bust, US, N-A, N-S	9. Back bust arc, N-L
4. Bust, US, N-A, N-S	10. Front waist arc, US, N-L
5. Waist, US, N-A, N-S	11. Back waist arc, N-L
6. Armscye, N-A, N-S	
Front width:	Back width:
12. Front shoulder width, G	15. Back shoulder width, G
13. Cross chest, US, N-L	16. Cross back, US, N-L
14. Bustpoint to bustpoint width, US, G	—. (Neck breadth, not used), G
Front length:	Back width:
17. Center front length, US, N-A, N-S	24. Center back length, US, N-S
18. Side neck to center front waist length, N-A, N-S	25. Side neck to center back waist length, N-A, N-S
19. Shoulder point to center front waist, N-A, N-S	26. Shoulder point to center back waist, N-A, N-S
20. Side neck to bustpoint length, US, G	27. Scye depth (nape to armhole height), US, G
21. Nape to bustpoint length, N-A, N-S	
22. Nape to center front waist length, US, N-A, N-S	
23. Shoulder point to side waist length, N-A, N-S	
Shared, front and back:	
28. Shoulder length, US, N-A, N-S	30. Side seam length, US, N-L
29. Shoulder slope angle, US	

Note. G = Measurement is useful for grading. N-A = Measurement is angled; it fails criterion 1. N-S = Measurement spans more than one cardinal point; it fails criterion 2. L = Measurement would be useful if had a related body landmark; it fails criterion 3. US = included in U. S. anthropometric survey measurement.

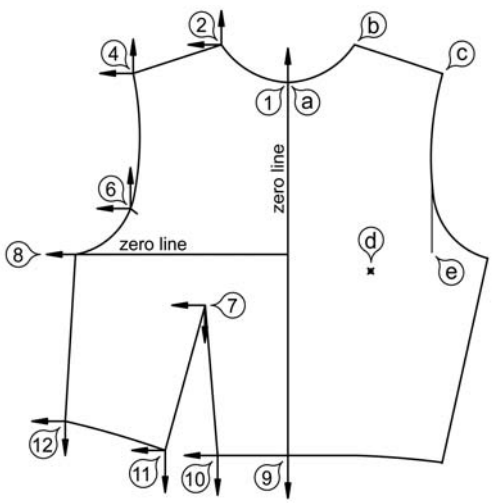

Figure 1. On the left side are cardinal pointsa for the front half of a basic bodice pattern. On the right side are body landmarks on the front of body: (a) suprasternale, (b) trapezius point, (c) acromium, (d) bust point, and (e) axilla.

[a]Number labels on pattern match numbers for cardinal point locations in Tables 3, 4 and 5.

upper torso and the difference between principal girths (bust, waist, and hip circumferences). We examined this data to determine whether the intervals were constant or followed any predictable pattern. We documented four assumptions used to create these size charts that were not based on anthropometric research.

Then, to establish the relationship between individual grade rules and sizing measurements, cardinal points of a pattern were matched to body landmarks. Cardinal points are the points on a pattern where grade rules are applied to expand or contract the pattern from one size to the next size (Taylor & Shoben, 1993). Landmarks, defined as sites on the body that serve as endpoints for measurements, are specifically located on a bony prominence or other physically definable point on the human body (see Figure 1 for the location of cardinal points on a garment and the landmarks on the front of the body). The corresponding measurements were examined to determine whether the intervals between measurements could be used as a source for grade rules. Three criteria were defined and applied: the measurement must (a) be either a horizontal or vertical measurement (related to the garment), (b) relate to only one cardinal point, and (c) be taken at an identifiable body landmark corresponding to a cardinal point.

Finally, a traditional set of grade rules was compared to size intervals from a single size chart in order to determine whether grade rules could be based on size charts. We chose the 1970 U.S. sizing standard for this determination because it was more complete than the 1994 U.S. sizing standard. The Price and Zamkoff (1974) text was chosen because it was often used in grading instruction and because it was published shortly after the 1970 U.S. sizing standard. The 1996 Price and Zamkoff text included the same grading information as the 1974 text. Both Price and Zamkoff mentioned size charts but did not include them. Our study was completed before the Moore, Mullet, and Young (2001) textbook was published.

The Historical Relationship Between Size Charts and Grading

Background

Kidwell (1979) identified the proportional dressmakers' systems developed between 1820 and 1840 as the earliest example of grading systems for women's clothing. These pattern-drafting systems provided a garment pattern in a range of sizes on a single piece of paper. All needed measurements on the bodice were calculated using different formulas, each a proportion of the original bust measurement. The dressmaker used one size of the pattern to construct a garment for an individual. An example of a pattern set created by a proportional dressmakers' system resembles a modern nested grade[1] from the United States. Both pattern sets reflect the use of two assumptions: (a) all elements of the pattern increase as the size increases, and (b) the bustpoint remains at a stationary level for all sizes. Proportional dressmakers' systems also reflect the assumption that a constant increase was used for all sizes at each cardinal point. Contemporary nested grades may use incrementally increasing values for the horizontal changes for sub-ranges of sizes (see forthcoming discussion of Assumption 4 for grades).

[1]A nested grade is created by laying out the set of pattern pieces of different sizes for a single pattern piece on one sheet of paper. In the U.S. nested grades for upper torso pattern pieces are lined up by matching the bust points or other central point.

A system for developing sizes for women's apparel became necessary when garments were no longer created specifically for individual women. The first size charts were developed for use with paper patterns. These charts were mass produced in the 1860s and published in women's magazines (Seid, 1989). Kidwell (1979) documented that all paper patterns of the 1860s were created using proportional dressmakers' systems of grading to create different sizes. A size was based on a single measurement. Bust circumference was used for blouses and dresses. Waist circumference was used for skirts. The body measurements for the garment pattern pieces were not related to a size chart. The success of the fit of the garment depended on the skill of the seamstress in adapting the pattern to the individual.

Beginning in the 1880s, individuals could order custom garments through the mail. Early garments, like paper patterns, were sized from one measurement. The garment pattern was created using the proportional dressmakers' system of grading based on bust measurement and was adapted to fit the individual (Cooklin, 1990).

The first fitted ready-to-wear garments for women were produced near the end of the 19th century. According to Cooklin, "They were usually very simple and cheap interpretations of the current fashions." He noted that "the women of the time who purchased ready-made clothes fully accepted the fact that substantial alterations would be required before the garments had any semblance of a reasonable fit" (1990, p. 4). Kidwell (1979) found that the sizing of ready-to-wear garments was based on proportional dressmakers' systems of grading. Cooklin described the system used to grade garments manufactured in the early 1920s as "proportionate grading" (1990, p. 5).

Findings

Sizing information is not the foundation for grading. Grading practice pre-dates publication of size charts by half a century. Grading systems in the form of proportional dressmakers' systems were in evidence before 1840. Of the eight size charts in our database dated before 1910, five charts used a single measurement per garment. The earliest size chart in our database with more than one measurement was

1894 Ladies Standard Magazine (Bryk, 1988), with bust, waist, and hip circumferences.

Documentation of grading methods post-dates these early size charts. The earliest source we identified to specify grading information was written by Auditore in 1947. Two others, Kirschner (1951) and Gebbia (1955), also included grading information. These publications preceded the publication of the first U.S. sizing standard in 1958. These individuals could not have based their grading practice on size charts derived from anthropometric data.

Relationship of Size Charts to Anthropometric Data

Background

Size charts based on more than one measurement were in use before the U.S. anthropometric survey was initiated by O'Brien and Shelton (1941) in 1939. When we examined the accompanying text, no information was given by any early source about the origin of the chart(s). Gordon (1908/1993) and Woman's Institute publications (1923, 1937) claimed to include average body measurements, but did not explain where or how averages were obtained and what population they represented. Size charts that existed before the availability of anthropometric data probably shared the same assumptions of human proportions that were the basis for early grading.

Kunick (1967) commented, "Our present-day sizing practice is the result of many years' growth by trial and error. Scientific method was never used for the purpose of sizing" (p. xv). Cooklin blamed deficient sizing of the 1940s on of the lack of large scale anthropometric surveys but noted that "with a few exceptions, the results of these surveys have had a limited effect on sizing systems used by the clothing industries throughout the world" (1990, p. 8). In 1995, Staples compared size charts used by companies who manufacture Misses' sized clothing. She stated, "In general there was a lack of knowledge of the derivation of the body dimensions from which company products were developed. When there was any knowledge, the source revealed was generally unscientific" (p. 99).

We found one example of a size chart based on measurement data. *E Style*, a catalog for African-American women, was created by a joint effort between *Ebony* magazine and *Spiegel* catalog. The sizing chart was based on "measuring hundreds of African-American women" (*E Style*, 1997, p. 3). Not only did the sizing chart use larger waist and hip sizes in proportion to bust sizes, but the changes between the sizes were not constant. *E Style* ended publication in the fall of 1998.

There have typically been three steps in creating a sizing system: (a) division of the population into categories (each to have its own size chart), (b) choice of a primary size interval for each chart, and (c) choice of intervals for remaining body measurements for each chart. The first step in the creation of a sizing system was to divide the population into categories of body types with similar characteristics. Each body type had a separate size chart. O'Brien and Shelton (1941), who conducted the first U.S. anthropometric survey, were not able to identify a single key body measurement that could be used to predict all other body measurements. They observed that the "bivariate distribution of the 10,042 women by girth of bust and stature shows that these two measurements are almost entirely unrelated" (p. 31). This finding shattered the foundation for the proportional dressmakers' systems and by extension modern grading systems. After analyzing the anthropometric data, they recommended that vertical measurements be controlled by dividing the population into three height classes. Horizontal measurements should be controlled by dividing the population into three weight classes. They recommended separate size charts for each of these resulting nine categories of women.

The first U.S. sizing system based on anthropometric data was the *U.S. Voluntary Product Standard CS 215-58* published in 1958 by the U.S. Department of Agriculture. Two control dimensions, height and hip circumference (not weight as recommended by O'Brien and Shelton, 1941), were used to divide the population into categories. However, the 1958 sizing standard was first divided into Misses, Women's, Half-size, and Junior body types. Body types were not included in O'Brien and Shelton's (1941) report. These categories were a continuation of common practice, not based on analysis of anthropometric

data. Only the Misses category was divided into nine categories: three height (regular, short and tall) by three hip categories (average, slender, and full). The total number of size charts developed was 20. The 1970 U.S. sizing standard and many other size charts used body types (Misses, Junior, Half and Women's sizes) to divide the population. These body types were apparently not based on research.

The 1958 U.S. sizing standard used three height categories for the Misses body type. However, the division by height did not distribute the Misses body type into three equal groups. Kunick (1967), the chief British researcher for the British anthropometric sizing study, criticized the U.S. standard for being "concerned mainly with providing the measurements for the sizes already produced by the American clothing industry, with a provision for . . . greater variation in stature" (p. 11). Cooklin reported that, unlike sizing standards from other countries, the distribution of the U.S. population into height categories for the 1970 standard was skewed "to provide the maximum size range which could be fitted adequately within one height category" (1990, p. 16).

To create an individual size chart for each category of the population, one body measurement must be selected as the primary sizing interval to divide the chart into sizes. Beazley (1998) stated, "A size chart is the artificial dividing of a range of measurements" (p. 67). The bust circumference was used as the size designation by all charts we located. With one exception, we found that all size charts before 1939 used 2-in. intervals in the bust measurement between sizes. For example, the size chart in the 1902 *Sears Roebuck* catalogue (1969) was divided into five sizes representing bust circumferences of 30, 32, 34, 36, and 38 in. respectively.

The 1970 and 1994 U.S. sizing standards, and most size charts since 1955, reflect the use of a stair-step interval for the bust, waist, and hip circumferences. These intervals are known as grades. The grade used by U.S. manufacturers has a 1-in. difference for small sizes, a 1.5-in. difference for medium sizes, and a 2-in. difference for large sizes. For example, a size chart using grades could be divided into sizes with bust circumference (in inches) of 30, 31, 32, 33, 34, 35.5, 37, 38.5, 40.5, and 42.5.

The next step was to choose appropriate intervals between sizes for the remaining body measurements (e.g., waist, center back length). We located several methods to select intervals between sizes in the literature. Beazley (1998) suggested that the mean and median value for all individuals measured in each size should be found for each measurement because "it is more convenient to have an easily recognizable difference between each size . . . [and then it is necessary to] round the intervals up or down" (p. 70). The British Joint Clothing Council (1957) used regression analysis on the British body measurement survey data to determine appropriate intervals for body measurements. In 1982, Salusso-Deonier developed the Principal Component Sizing System. She used this analysis method to prepare size charts for the Women 55 and Older body measurement data. For each measurement for each size category, she used the 75th percentile of the measurement of the individuals in that category (Reich & Goldsberry, 1996).

There is no documentation of the logic followed to determine the sizing intervals for the remaining measurements in the 1958 U.S. sizing standard. In 1970, the U.S. sizing standards were revised and published by the U.S. Department of Commerce with the cooperation of the National Bureau of Standards. *PS 42-70: Body measurements for the sizing of women's patterns and apparel* "was merely a massaging of the data using information from several sources to justify the data" (LaBat, 1987, p. 24). The calculations used to update some measurements were arbitrary and not related to anthropometric measurements. Thirteen size charts (for divisions of the population) were eliminated, leaving a total of seven charts.

The 1994 revision of the U.S. sizing standard, D 5585-94: *Standard table of body measurements for adult female misses figure type, sizes 2-20*, was published by the American Society for Testing and Materials. Its single chart was "derived from designer experience and market observations and cross-checked with available databases in the attempt to identify current customer characteristics and changing proportions and not from new nationwide anthropometric research" (ASTM, 1994, p. 1). No grading information was included.

Findings - Assumptions Evident in Size Charts

So little was written about the origins of size charts that we examined the charts themselves for answers. When we calculated the intervals that were used and compared similar patterns across charts we discovered several practices used to structure the size charts in our database. We noted that over time these practices became widespread. When we noted that they were contrary to published anthropometric research findings, we concluded that practices used to structure charts were in existence before anthropometric data was available. It is probable that there were advantages to the use of these practices that superseded the anthropometric research.

Our analysis of the size charts revealed four assumptions. We define the word assumption as a premise about a relationship between measurements of the body that is used in practice but has not been empirically tested. Each assumption reflects a practice evidenced in the early charts and that had reached widespread acceptance by the 1970s. The four assumptions were (a) the use of constant intervals between sizes for all measurements (within the grade), (b) the increase of all vertical measurements as size increases, (c) the use of constant differences between principal girths, and (d) the use of grades.

Sizing Assumption 1. Constant intervals between sizes for all measurements (within the grade). The use of a constant interval for the primary measurement, the bust circumference, is a convention that facilitated the organization of a size chart. Kunick justified this convention as "economy in the number of sizes" and further explained the use of constant intervals for other measurements by stating "consistency in size tables has a great advantage in practice because it enables a pattern grader to work to a standard difference between sizes, making memorization easy and frequent reference to a size chart unnecessary" (1967, p. 1).

The use of constant intervals for measurements was common in early size charts, but there were many exceptions. As many as five different values were used in one chart for intervals of a single measurement over the range of sizes. Several charts had measurements with intervals that alternated between values. For example, Woman's Institute of Domestic Arts and Sciences (1923) alternated between sizing intervals of ½ in. and 0 in. (no increase) for neck circumference. The 1958 U.S. sizing standard, based on the U.S. anthropometric survey, used constant intervals for only 85% of the measurements. The subsequent two U.S. sizing standards had constant intervals for all measurements in the charts. The use of constant intervals for measurements was not prescribed by the anthropometric data. The use of constant intervals increased over time. Of the 25 size charts in our database before 1970, only two had 100% use of constant intervals: 1939 Kaplan and 1947 Auditore. With two exceptions, the charts since 1955 used constant intervals for 90% or more of their measurements. Constant intervals were used without exception by all catalog size charts that were published in 2000 (Schofield, 2000).

Sizing Assumption 2. All vertical measurements increase as size increases. Cooklin stated that the grading system of early 1920s manufactured garments "was based on the theoretical assumption that there is a fixed relationship between length and girth measurements" (1990, p. 6). O'Brien and Shelton's (1941) research invalidated this assumption (see discussion above). Contrary to the practice recommended by analysis of the anthropometric data, we found that the values of vertical and length measurements increased as the girth dimensions increased in all sizing charts in the database. This change reflects an assumption that the larger a woman is, the taller she is, and vice versa. A woman whose height does not match her size category would have to choose between fitting her vertical or her horizontal measurements.

Sizing Assumption 3. The differences between the principal girths (hip minus bust and bust minus waist) is constant for all sizes. Recall that O'Brien and Shelton (1941) recommended subdividing each of three height categories into three weight categories. Instead, the 1958 U.S. sizing standard used three hip categories, defined by the difference between bust and waist circumferences. The slim and full hip categories were eliminated and eventually the medium hip category was the only offering. In 1990 Cooklin documented that the medium hip category, defined as hips being 2 inches greater than bust, represented only 47% of the U.S. popula-

tion. Cooklin commented that the use of one hip category only for each height group was justified because "an effective sizing system must cover the largest number of women with the smallest number of sizes" (p. 18).

Because the difference between the hip and bust was used to divide the 1958 U.S. sizing standard into size charts, we examined the differences between the hip and bust for all the size charts in the database. Beazley (1998) defined the difference between the hip and bust girths as the drop. For example, a hip circumference of 38 minus a bust circumference of 34 would be a 4 in. drop. The drop was calculated for all sizes for all size charts and the differences were then compared across charts. The difference between the bust and waist circumferences was also calculated. The percent of constant difference between principal girths was calculated for all charts to determine the acceptance of this practice over time.

The 1958 U.S. standard did not use constant differences between the principal girths within any of its three regular-height charts for the Misses category. However, our comparison of size charts revealed a clear tendency toward the increased use of constant differences between the principal girths (bust, waist and hip) for all sizes. The three early charts (i.e., 1894 *Ladies Standard Magazine*, 1910 Hopkins, 1917 Coates) had less than 20% agreement between bust, waist, and hip intervals. The 16 charts from 1921 to 1970 averaged 82% agreement. All 2000 charts had 100% agreement. A plausible explanation is that this simplification allowed manufacturers to reduce the total number of sizes produced. Although the use of constant intervals is now universally accepted, there is no agreement about the value of the difference between bust and hip and between bust and waist circumferences.

Sizing Assumption 4. The use of grades. In recent practice, U.S. size charts are subdivided into three groupings of sizes. The same interval is used between sizes for the principal girths of bust, waist, and hip. The convention is to use a 1-in. interval for small sizes, a 1 ½-in. interval for medium sizes and a 2-in. interval for larger sizes. The interval is known as the grade. We found no other values for grade intervals have been used in the United States.

No information could be found as to the origin of the use of grades. O'Brien and Shelton (1941) made no mention of the use of grades. The 1958 U.S. standard did not use 1 in. intervals and although it used 1½-in. and 2-in. intervals for the principal girths (bust, waist and hips), the intervals changed at different sizes. Only 9 of the 14 intervals (64%) of the waist and hip circumferences matched the bust interval. Lapick's chart (1955) was the first to use three grades, but he only had 82% agreement with intervals for bust, waist, and hips. The first size chart in our database to use three grades (1 in., 1½ in., 2 in.) and have 100% agreement between the bust, waist, and hip intervals was the 1970 U.S. sizing standard. All 2000 size charts in our database followed this practice except for the *Spiegel* catalog, which only used 1- and 1½-in. grades. However, there is no agreement as to which bust sizes are included in each grade.

The use of grades would have resulted in more sizes for smaller women. We analyzed the distribution of bust sizes for the women subjects in the 1941 anthropometric U.S. survey. We found 53% of these women had a bust circumference of less than 34 in., 29% were between 34 and 38 in., and 18% had a bust circumference greater than 38 in. By comparison, the measurements of the U.S. Army women (subjects of the 1988 ANSUR Anthropometric Survey) were distributed as follows: 29% had a bust circumference of less than 34 in., 56% were between 34 and 38 in., and 15% had a bust circumference greater than 38 in. We believe this shift in distribution of sizes over time indicates American women would be better served with more medium sizes than small sizes.

Summary. We identified four assumptions that have become common practice in developing size charts. None of these assumptions are supported by anthropometric research. Assumptions 1 and 4 probably evolved because they simplified the organization of size charts. Assumptions 2 and 3 probably allowed manufacturers to produce a smaller number of sizes thus reducing inventory and decreasing overhead. We conclude that the impact anthropometric data has had on size charts has been limited by reliance on these assumptions. This reliance has affected the organization of size charts as well as the values of individual measurements. Our next step was to determine whether it is possible to use existing size chart information to determine grade rules.

Is Grading Practice Based on Size Measurements?

The Criteria for Using Measurement Information for Grade Rule Formation

The purpose of grading is to create garment patterns in a range of sizes. Sizes are defined by body measurements. It is logical to assume that grade rules used to create garment patterns are derived from intervals between sizes. We tested this supposition by examining the upper torso measurements located in size charts. By examining grading methods we identified three criteria that are necessary for the formation of grade rules.

Criterion 1: Measurements must be horizontal or vertical as related to a garment. Current grading methods are based on a Cartesian graph. The first criterion was that the measurement must be either a horizontal or vertical measurement. For a measurement to be considered vertical, it must correspond with the vertical grainline of the garment pattern (e. g., center back length). For a measurement to be considered horizontal it must relate to the cross grain (perpendicular to the grainline) of the garment pattern (e. g., front bust arc). A diagonal measurement could be used if it can be divided into horizontal and vertical components. The diagonal line must be relatively straight on the pattern with a known angle. The length of the shoulder seam is the only measurement along a straight line that would appear to meet this criterion, since the shoulder angle is known. However, the angle of a shoulder seam on a pattern is not the same as the angle of a shoulder. No diagonal measurements from the body could be used for grade rule formation. Measurements on the surface of the body are appropriate if they follow the path of a garment. Center front length is a surface measurement but it does not follow the curved path of a garment. It is measured on the surface of the body between the breasts. This information cannot be used for grading.

Criterion 2: Measurement can not span 2 or more cardinal points. The second criterion was that the measurement could not span 2 or more cardinal points. When a measurement involves multiple cardinal points, the interval needs to be divided into grade rules for each point. Center back length is an example of a measurement whose interval must be divided into 2 grade rules: the vertical increase from center back waist to bust height, and the vertical increase from bust height to center back neck. There is no formula or procedure to determine what percent of the interval applies to each grade rule.

Criterion 3: Measurement must be related to a body landmark. The third criterion for a measurement to be useful for grade rule formation was that it must be taken at a landmark associated with a cardinal point. Anthropometric data collection requires explicit definitions of landmarks since the measurements must be reproducible (see Figure 1 for the location of landmarks on the upper torso). Few size charts included descriptions of how measurements were taken and many measurements were not related to identifiable body landmarks. We identified landmark(s) for each measurement where possible. Table 3 includes body landmarks with the related measurements for the front of the body.

Arc measurements, which effectively divide circumference measurements into front and back at the underarm and waist levels, would be useful for establishing grade rule information for the cardinal points at the side seam. Ten of the 19 size charts between 1930 and 1975 included arc measurements. No chart since 1975 has included arc measurements. Unfortunately, there are no body landmarks for a side seam. No source, including O'Brien and Shelton (1941), gave useful information on how to determine the location of body landmarks that relate to the side seam points of the garment. The circumference measurements are not useful measurements for grade rule information because there is no procedure or formula to divide the interval between the back and front grade rules. Common practice is to divide bust and waist increases equally between front and back garment pieces. This practice, although expedient, is contrary to both the 1958 and 1970 U.S. sizing standards.

In addition, locating and measuring the armscye is problematic. The axillas, the folds of skin in the front and back at the armpit, are the body landmarks used by physical anthropologists (Gordon et al., 1989). These landmarks are not used in collecting data for apparel sizing (see Figure 1 for the location of these landmarks). The cross chest width

Table 3. Cardinal Points, Landmarks, Existing Measurements and Recommended Measurements of the Front Bodice.

Cardinal Point Location on Pattern	Body landmark	Vert./ Horiz.	Existing Sizing Measurement and Comments	Recommended Measurement Needed Landmark and Comments
1. Center front	Suprasternale	V	Center front length, N-S Not garment measurement (between breasts).	Center neck to line between bust points
2. Shoulder, side neck	Trapezius point	H V	None Side neck to bust point, G Unstable location of bustpoint Full front length, N-A, N-S	Neck breadth
4. Shoulder point	Acromion	H V	Front shoulder width, G Full front side length, N-S Front shoulder slope, N-A, N-S	 Shoulder point to underarm level Landmark at underarm
6. Sleeve notch	Axilla not used	H V	Cross chest, G None	Landmark at sleeve notch Sleeve notch to underarm level Landmark at sleeve notch and underarm
7. Bust dart	Bustpoint	H V	Bustpoint to bustpoint breadth, G Unstable location of bustpoint U.S. grading practice assumes this is not needed.	 Underarm level vertical to bust point level (Negative if bust point above underarm level)
8. Underarm	None	H	Front bust arc, G	Landmark at underarm at side seam
9. Waist center	Waist general	V	Center front length, N-S	Center waist to line between bust points
10 &11. Waist dart	Waist general	HV	None	(None known)
12. Waist side	Waist general None	H V	Waist front arc, L Side length, L	Landmark at center waist Landmark at waist at side seam

Note. Numbers for cardinal point locations match number labels on pattern shown in Figure 1.
G = Measurement is useful for grading. N-A = Not useful, angled measurement. N-S = Not useful, spans more than one cardinal point.
L = Measurement would be useful if had a related body landmark.

and cross back width are measured to points that the measurer estimates as the sleeve notch location. No size chart indicated where these measurements were taken horizontally. A few of the charts specified the vertical distance from the center neck or shoulder. However, there is no agreement on that distance and distances appeared to be higher than the sleeve notch and certainly higher than the axilla locations. The cross chest width and cross back width would be useful measurements if the locations of the measurements could be clearly defined and were related to cardinal points. The bust point was a key landmark used in several measurements. However, the location of the bustpoint for an individual is inherently unstable and dependent on the brassiere worn.

Of the 30 measurements of the upper torso identified in our study, 18 (60%) failed to meet the first 2 criteria. The interval cannot be divided into its vertical and horizontal components or cannot be divided between cardinal points. Two critical measurements, bust and waist circumference, cannot be divided proportionally between front and back pattern pieces. Of the remaining 12 measurements, 5 require body landmarks that are not defined on the side of the body, the side length, the front and back bust arcs, and the front and back waist arcs. There are also two measurements, cross chest and cross back, that are not related to the existing body landmarks of the axilla. Table 2 shows all measurements and indicates which criteria were failed or whether the measurement would be useful for grading information.

In summary, based on our criteria, 5 out of 30 (17%) sizing measurements (scye depth, front and back shoulder widths, side neck to bustpoint, and bustpoint to bustpoint) could be useful for grading. Of these, only back shoulder width was commonly found in size charts in our database. Unfortunately, back shoulder width was not measured in the 1939 U.S. anthropometric survey. It was also not included in the 1958 and 1970 U.S. sizing standards. However, it did appear in the 1994 sizing standard. This fact is a further indication that size charts were not derived from anthropometric data. Two additional measure-

Table 4. Cardinal Points, Landmarks, Existing Measurements and Recommended Measurements of the Back Bodice.

Cardinal Point Location on Pattern	Body landmark	Vert./ Horiz.	Existing Sizing Measurement and Comments	Recommended Measurement Needed Landmark and Comments
1. Center back	Cervicale	V	Scye depth, G Center back length, N-S	
2. Shoulder side neck	Trapezius point	H V	None Full back length, N-A, N-S	Neck breadth Trapezius point to underarm height
3. Shoulder dart leg	Mid-shoulder	HV	None	(None known)
4. Shoulder point	Acromion	H V	Back shoulder width, G Full back side length, N-S, N-A Back shoulder slope, N-A, N-S	(Surface measurement would be best) Shoulder point vertical to underarm height
5. Shoulder dart point	None	HV	None	(None known)
6. Sleeve notch	Axilla not used	H V	Cross back, G None	Landmark at sleeve notch Sleeve notch height to underarm height Landmark at sleeve notch and underarm
7. Dart	None	HV	None	
8. Underarm	None	H	Back bust arc, G	Landmark at underarm at side seam
9. Waist center	Waist general	V	Center back length, N-S	Center waist to height of underarm Landmark at center waist and underarm
10 &11. Waist dart	Waist general	HV	None	(None known)
12.Waist side	Waist general	H V	Waist back arc, G Side length, G	Landmark at waist at side seam Landmark at side seam at waist and underarm

Note. Numbers for cardinal point locations match number labels on pattern shown in Figure 1.
G = Measurement is useful for grading. N-A = Not useful, angled measurement. N-S = Not useful, spans more than one cardinal point.
L = Measurement would be useful if had a related body landmark.

ments, cross chest and cross back, could be useful if they were related to the cardinal points in the armscye. Neck breadth has been used by anthropologists, but was not used in the 1941 U.S. anthropometric survey or in any size chart in our database. Neck breadth would meet all three criteria.

Cardinal Points Analysis

Cardinal points, the points on a garment pattern used for grading, were examined to determine whether there was a corresponding landmark and measurement (see Figure 1 for the locations of cardinal points and body landmarks). We identified 22 cardinal points for the basic bodice that are assigned a grade rule with vertical and horizontal components. For the 22 grade rules, there are a total of 38 grade rule components (see Table 3 for the details of the cardinal points for the front of the body and Table 4 for the back).

Only 7 of the 22 cardinal points (32%) were specifically related to body landmarks (i.e., one each at the suprasternale, bust point, and cervicale, and two each - front and back - at the trapezius point and acromion). The axilla has not been used to define the location of the armscye notch or related to cross chest and cross back measurements. Cardinal points on the side seam, the darts on the waist seam, and the back darts do not have related body landmarks. Therefore, the related measurements do not have definable reference points. Of the total 38 grade rule components, 16 had no related body measurement. Only 7 of the 17 front and 6 of the 21 back grade rule components had related body measurements that could be considered useful information for grade rule formation. However, measurements for 3 components, both back and front, did not have body landmarks (bust arcs, waist arcs, and side seam), leaving only 7 out of 38 components (18%) with useful body measurements.

Comparison of a Set of Grade Rules to a Size Chart

We compared the 1970 U.S. Sizing Standard intervals with the Price and Zamkoff (1974) grade rules for the cardinal points on the front bodice. Table 5 illustrates the comparison and indicates whether individual grade rules matched the related intervals.

Table 5. Comparison of 1970 U.S. Sizing Standard Size Intervals to Price and Zamkoff's (1974) Grade Rules for Bodice

Cardinal Point	Horizontal			Vertical		
	Size intervals		Grade rules	Size intervals		Grade rules
	Front	Back		Front	Back	
1. Center neck				N	1/8 S	1/8
2. Side neck	M	M	1/16	3/8 X	N	1/4
3. Back dart leg		N	1/8		N	1/8
4. Shoulder point	M	M	3/16	N	N	3/16
5. Back dart point		N	1/8		N	1/8
6. Sleeve notch	1/8 X	3/16 S	3/16	N	N	0
7. Dart point	1/8 S	N	1/8	N	N	0
8. Underarm	1/2 X	1/4 X	3/8			
9. Center waist				N	N	1/8
10 &11. Dart leg	N	N	1/8	N	N	1/8
12. Side waist	7/16 X	5/16 X	3/8	1/8 S	1/8 S	1/8

Note. Numbers for cardinal point locations match number labels on pattern shown in Figure 1.
S = grade rule matches size interval. X = grade rule does not match size interval. N = No measurement in 1970 Standard. M = measurement exists, but not in 1970 Standard.

A grade rule can have both a vertical and horizontal component. Cardinal points on the zero lines have only one component (see Figure 1 for the directions of the vertical and horizontal components of the grade rules at those points). There are a total of 38 grade rule components for the 22 cardinal points. Table 5 lists the 22 cardinal points with separate sections for horizontal and vertical grade rule components. The related size intervals from the 1970 U.S. sizing standard are given in separate columns for the front and back. Because the Price and Zamkoff (1974) grade rules are identical for front and back they are presented in one column.

We found that very few of the grade rules could have been based on body measurements. Of the 38 grade rule components, 27 (71%) grade rule components had no related anthropometric measurements. Of those 27 grade rule components, 14 (37%) relate to the cardinal points at dart points on bodice back and intersection of the three pairs of dart legs with the waist or shoulder seam. We found no measurements or landmarks that have been associated with these points.

We found that only 11 (29%) of 38 grade rule components had related measurements. Less than half, only 5 of those 11 grade rules, matched the size intervals. Body measurements with intervals that matched grade rules were the following: cross back, bust point to bust point, scye depth, and side seam length (applicable to grade rules on front and back). Body measurements with intervals that did not match grade rules were the following: cross chest, front and back bust arcs, front and back waist arcs, and side neck to bust point (see previous discussion under Criterion 3 for problems with these measurements). Shoulder width and neck breadth would be applicable to grading, but were not included in the original U.S. anthropometric survey. In all, 33 out of 38 grade rule components (87%) were not or could not be based on body measurement information. Table 5 shows the comparison between the sizing intervals and the grade rules.

Recommendations

In order to make the link between size charts and grading possible, we analyzed the needed grade points, with their related cardinal points and body landmarks. We recommend 21 measurements to be included in size charts. These measurements are listed in Tables 3 and 4 with the corresponding cardinal point and body landmark.

We found seven sizing measurements that could be used for grade rules if landmarks or measurement locations could be defined to match the cardinal points on a pattern. On the front of the upper torso, the measurements are cross chest, front bust arc, and waist front arc; on the back the measurements are cross back, back bust arc, and waist back arc; and serving both front and back, side length. The missing landmarks are sleeve notch location, center waist point, and underarm and waist points on the side seam.

We recommend seven new measurements for grade rule information: on the front, center neck to line between bust points, center waist to line between bust points, and front sleeve notch to underarm height; on the back, trapezius point to underarm height, back sleeve notch height to underarm height, and center waist to height of underarm; and serving both front and back, shoulder point vertical to underarm height. All new measurements require landmarks to be defined or new measurement locations to be used. We also recommend underarm level vertical to bust point level to document the change in height of the bust point across sizes.

Summary and Implications

We found evidence that grading practices predated sizing systems. Further, we found that sizing systems, even sizing standards that are derived from anthropometric surveys, are partially based on practices that have no basis in anthropometric research. Most sizing measurement information could not be used for grading. Apparently grading practice has precedence over body measurements in determining grade rules.

Existing grade rules have little basis in body measurements. Sized garments, created by the grading process, will not match the related body measurements in size charts. Similar research should be done on the measurements of the lower torso, arms and legs for women, and all measurements for men and children.

To provide adequate fit for women over a range of sizes, the grading process should reflect their body dimensions. Current methods of creating sized garments (grading) are not addressing the need for a good or even an adequate fit for many women. If grading has little basis in body measurements, then the actual sizes of manufactured garments are based on existing grading practices that originated before anthropometric surveys or sizing charts. Mass produced garments are not based on body measurements taken from women of varying sizes. The recommended body measurements needed for grading should be obtained in any future anthropometric research. This data should be tested as the basis of sizing charts and grading practice.

Sizing of clothing is an increasingly important issue. It should not be relegated to following outdated practice. The next step for researchers is to define and test the practices that are the primary basis for grading by applying real anthropometric data.

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