Improved Apparel Sizing:  
Fit and Anthropometric 3-D Scan Data  
Susan Ashdown, Suzanne Loker, co-leaders (Cornell);  
Margaret Rucker (UC Davis)

One of the greatest challenges facing apparel companies today is to provide quality fit to a broadly defined target market. Two issues have limited the resolution of this problem:

- lack of data on fit characteristics of garments for different body sizes and shapes
- lack of current anthropometric data to describe the civilian population.

Three-dimensional body scan data have the potential to provide new insights into apparel sizing and fit issues. We are developing ways to objectively quantify and assess fit for a target market of a specific apparel firm through visual and statistical comparisons of objective measurements.

We are providing insight into body/apparel relationships using body scan data to develop research and analysis protocols that will improve apparel fit of existing firm sizing systems.

The 3-dimensional body scanner is a promising new research technology that will contribute to revolutionary changes in the conception, design, manufacture and distribution of apparel. Currently, the quantification of fit is complex and ambiguous; and objective methods, such as comparison of linear measurements, are inadequate. Body scanning provides multi-dimensional data that have the potential to provide new insights into sizing and grading systems. Our ultimate goal is to improve fit by adjusting existing sizing systems for specific target market populations of individual apparel firms.

Our research extends the research from our first NTC project (S01-CR01) by developing methodologies for applying a combination of fit and anthropometric population data to the problem of developing effective sizing systems for apparel products. We are developing protocols and analytical methodologies to garner the power of scan data to compare body measurements of standing and seated body scans. Data can be collected for target markets by gender, age and niche functional markets to collect measurements relevant to clothing fit when the wearer is in active positions. We are also linking our scan data set with the SizeUSA anthropometric data to establish it as statistically representative of the sample of the target market in the U.S. population.

Comparing Standing and Seated Scans

Following a pilot test to develop research protocols, 49 subjects in the target market, aged 34-55, were scanned six times in minimal clothing. Four scans were taken in the sitting position to capture all necessary breadth and thigh landmarks, and two scans were required to capture data and landmarks in the standing position [see figure]. The 3-D scans were transferred from the Human Solutions scan system to Innovmetrix’s Polywork’s software suite to set planes and create cross sections to align into one plane for measurement.

Seated/Standing Measurements by Body Type

The method for categorizing body shape that divided the study participants into the most distinct categories of body circumference and body breadth dimensions was Body Mass Index (BMI = mass/height^2 [kg/m^2]). Subjects were divided into normal, overweight and two obese groups (no underweight group) based on their BMI values. Increases in hip circumference in the seated position were significantly different among the four groups. The crotch length is the only measurement to decrease in the seated position, though with no significant differences among groups. Hip and crotch measurements, as well as significant differences in waist and thigh measurements, point to the difficult fitting issues when considering the variety of body positions and movements.

These results will be used to adjust existing patterns and pattern systems to improve fit for pants during wear in many positions. General conclusions are:

- Circumferences and breadths increase between the standing and seated position, while crotch lengths decrease.
- The data generally show greater differences in measurements as BMI increases.
- Significant differences occur at the hip circumference, waist breadth and thigh breadth.

Visual Analysis of Fit

We developed methods to visually analyze fit using 3-D scans of clothed subjects. Then, we determined the reliability of the fit ratings at different body areas to establish the number of judges needed for reliable results overall.

Using visual analysis of body scans, five judges rated 15 different lower body areas for the fit of women’s pants on 153 scans of women aged 35 to 54 years old [see figure]. Ratings for most body areas were reliable if fit parameters and the instrument scale were established and clearly defined for the judges. The judges’ alpha values were consistent overall, ranging from 0.757 to 0.859. We established that any combination of two judges would give the same fit analysis results. Ratings for most body areas indicated high reliability ranging from 0.737 to 0.912. Crotch ratings were less consistent, with front crotch rated at 0.680 and back crotch rated at 0.510. Based on the unreliability of the crotch area ratings, we concluded that different assessment methodology may be required for the crotch and other areas of misfit that are difficult to rate visually.

Scanning New Target Markets

We added scans representing new markets to our database:

- Girls ages 10-15: scanned during several on-campus events sponsored by the Cornell Cooperative Extension 4-H Office. The girls were scanned in the Human Solutions scanner in the standard position wearing a
Lycra scan suit over their underwear garments. These scans will be analyzed to develop a better understanding of this target market’s body shape, especially as compared to our older female scan data.

- **Men ages 25-55:** scanned at a local retail store with an industry partner, Joseph Aboubod, 120 men between the ages of 25 and 55 years were scanned using a [TC]² portable scanner.
- **Occupational clothing:** 18 subjects in California and 30 subjects in New York from three different occupational groups were interviewed, photographed and given questionnaires to complete. We will analyze the results to gain a better understanding of typical working positions and how fit issues may differ with common deviations from the standard anthropometric standing position.

**Next Steps**

We are currently exploring various methods for creating a mathematical model of fit. The first is an extension of our previous work using multinomial logistic regression to obtain an equation for acceptable fit. This method utilizes fit ratings and ease data. Another approach involves comparing ideal fit to population body measurements that have been found to be most important to apparel fit. This requires converting pant specifications into 3-D measures that are compared to 3-D body data. The goal is to evaluate the error which can be used to specify appropriate ease for good fit and apply the result to existing size specifications for apparel pattern development.

**Other Contributors:**

- **Graduate Students:** Kim Berman, Jia-Guo Cao, Eui Cho, Jennifer Cohen, Katie Dombek, Lindsay Lyman-Clarke, Adriana Petrova, Janine Szczepanski, Sanchit Tiwari (Cornell);
- **Undergraduate Students:** Luisa Avila, Arnab Bose, Katherine Buckner, Eve Cahill, Samara Fetto, Jessica Melendez, Natalie Walsh, Orren Wexler, Amanda Zheng (Cornell);
- **Staff:** Erica Carnrite, Fran Kozen.

**Industry Interactions:**

- 6 [Liz Claiborne, Invista, Shriners Children’s Hospital (Springfield MA, Buffalo Hospital, [TC]², Limited, TPC Hong Kong, Intellifit, Optitex];
- Other Non-NTC Academic Interactions: 2 [Univ. of Washington, Central Michigan Univ.]; Government: 2 [NASA, Natick Army Research Labs].

**Project Web Addresses:**

- [http://www.explore.cornell.edu/bodyscanner](http://www.explore.cornell.edu/bodyscanner)
- [http://www.ntcresearch.org/projectapp/?project=S04-CR01](http://www.ntcresearch.org/projectapp/?project=S04-CR01)

**For Further Information**


**Susan P. Ashdown**, a Professor of Textiles and Apparel at Cornell, joined the faculty in 1991. Susan earned a Ph.D. in apparel from the Univ. of Minnesota in 1991, a M.A. in textiles: apparel design from Cornell in 1989, and a B.A. in theater arts from Grinnell in 1971. Her research interests include anthropometrics: apparel sizing, fit and the perception of fit and 3D body scanning. S01-AC27, S01-CR01, S04-CR01* spa4@cornell.edu (607)-255-1929 [http://www.human.cornell.edu/che/bio.cfm?netid=spa4](http://www.human.cornell.edu/che/bio.cfm?netid=spa4)

**Suzanne Loker**, the J. Thomas Clark Professor of Entrepreneurship and Personal Enterprise in Textiles and Apparel at Cornell, joined the faculty in 1998 from positions at Univ. of Idaho, Univ. of Vermont, Kansas State and Washington State. She earned a Ph.D. from Kansas State in Educational Psychology in 1981, an M.A. from Syracuse in Clothing Design in 1973, and a B.S. from the Univ. of Wisconsin in Apparel Design in 1970. Suzanne's research interests include management of information and production technology, mass customization, applications of 3-D body scanning and socially responsible business practices. S01-CR01, S04-CR01*, s135@cornell.edu (607)-255-6204 [http://www.people.cornell.edu/pages/s135](http://www.people.cornell.edu/pages/s135)

**Margaret H. Rucker**, Professor of Textiles and Clothing at UC Davis, joined the staff in 1970. She earned a B.A. in psychology from DePauw Univ. in 1961 and a Ph.D. in organizational and consumer psychology from Purdue in 1969, then lectured in Management and Psychology at Univ. of Missouri. Peg was the 1997 International Textile and Apparel Association Educator of the Year. Her research interests include domestic and international trade and protective clothing development. S02-CD01, S02-CD02, S04-CR01 mhrucker@ucdavis.edu (530)-752-2018 [http://trc.ucdavis.edu/textiles/faculty/rucker_main.html](http://trc.ucdavis.edu/textiles/faculty/rucker_main.html)