CHAPTER 2.

REVIEW OF LITERATURE

The current study was anthropometric in nature as it involved taking body measurements of men for trousers. The review of literature for the present study has been divided into three parts:

2.1 Anthropometric Studies

2.2 Sizing Studies

2.3 Global Sizing Surveys.

2.1 ANTHROPOMETRIC STUDIES

Anthropometric Studies are related to anthropometry or taking body measurements for a small sample size normally carried out by individuals

Patel (1963) studied the measurements of ninety-eight children in the age group of four to seven years. The children were grouped into three groups based on their height and weight and thirty-three measurements were taken. It was found that measurement had a relation upon weight and height. As these increased all other measurements increased as well. The investigator made muslin garments and tried on the children. She concluded the following from her study-
• Proposed system of sizing of garments was dependant upon height and weight.
• 18 measurements were used to provide well-fitted garments.
• Ease was needed as follows – chest -15cms; shoulder length – 1cms; Armhole – 3 cms; shoulder to back – 1 cms; shoulder-to-shoulder front – 3 cms and total crotch 6 cms.
• Due to the big stomach children have, the centre front was lowered by 1 cms.

Gupta (1968)\textsuperscript{51} studied the measurements of two hundred women from M.S. University of Baroda having bust measurements of 83 to 87 centimeters and adapted the basic block to make patterns for different styles of nightclothes. Subjects from all age groups above 15 years of age were included in the study. 69 measurements were taken with the help of locally procured instruments like the measuring tape, silver chain, marking pencil etc. The data was tabulated and analyzed and the findings were divided into four parts. When all the 69 measurements were considered only 52 subjects could be placed in any one of the groups. Thus, when only 32 important measurements were taken into account the investigator was able to place 114 subjects in definite groups. The other 86 subjects were placed in mixed groups that had a combination of measurements. Besides the 114 proportionate figure types the other women were placed in one of the other seven figure type categories.

Marathe (1968)\textsuperscript{76} measured three hundred infants, hundred in each group – 1) five to ten days old. 2) Three months. 3) Six months. The investigator analyzed the data in three different ways in an attempt to find out the best way to determine infant sizes for drafting patterns for infant garments. In the first method the mean was calculated from the actual raw measurements. In the second method each measurement range was found and divided approximately into two equal halves – the upper and the lower half. Eight measurements could not be clearly fixed in the upper or lower groups and were treated separately. In the third method each measurement was divided into four quartiles for all the three age groups so that the overlapping could be clearly noted.
It was found that in the first method, because the range was so large it did not serve the purpose of giving clothes that would fit well for a specific group of babies.

In the second method only 50-55 percent of the babies could be grouped in either of the groups, lower or upper.

It was found that 66 percent of the babies could be grouped using the third method. The percentage of babies which over lapped at various age levels was examined and dealt with separately.

The sizes for the babies who were above or below average were also obtained. **Mitter (1968)** studied the measurements of 200 women of the Maharaja Sayajirao University of Baroda. In all 68 measurements were taken plus the weight. Besides height and weight, the measurements were classified into lengths, girths, neck measurements and shoulder measurements.

The age range was 15-38 years with the majority falling in the range of 18-20 years.

Post segregation, only 32 important measurements were taken. Three groups were formed—small, medium and large. Majority (97) of subjects fell in the medium group, seven subjects were in the small group and 10 subjects in the large group.

Based on the mean of the three groups i.e. small, medium and large for each measurement was calculated. In all ten figure types were discovered. The investigator adapted the basic blocks based on her findings and recommended suitable necklines.

**Rajor (1968)** measured 100 infants of ages nine months to twelve months in order to recommend proper sizing to manufacturers of infant clothing. Twenty-five measurements of the infants could be placed in either of the two groups – either the upper or the lower, or the larger or smaller groups. The data analysis revealed that 47% of the nine-month babies were in the smaller group and 44% in the larger group. Only 9% were in the third group that had combined measurements.

48% of the twelve-month babies were in the smaller group and 44% in the larger group. 8% were in the group with combined measurements.

The investigator concluded that thirty three percent of the nine-month babies were in the smaller group with a mean weight of 5.85 kilograms, fifty five percent
in medium with an average weight of 7.35 kilograms and twelve percent in the larger group with 8.85 kilograms. Nine percent of the twelve month old babies an average weight of 5.85 kilograms in the smaller group; seventy four percent had a mean weight of 7.35 kilograms in the medium group and seventeen percent with a mean weight of 8.85 kilograms in the larger group.

Singla (1968) measured 100 children of three years of age, 50 boys and 50 girls so as to group the measurements into different size groups for making patterns and garment construction. Forty-seven measurements were taken and the data tabulated. It was found that 38% were in the smaller group: 39% in the larger group and 23% included subjects who had some measurements in-group one and some measurements in group two. The ranges for all the measurements were divided into four quartiles. It was found that majority of the subjects measurements were in the middle of the two quartiles. Out of the 100 subjects, 37% subjects had all their measurements in one particular quartile. 41% were in the middle of two quartiles. 10% had all their measurements in the third and fourth quartile. 6% had their measurements distributed in all four quartiles. Different basic blocks were made and tried on children. The investigator thus concluded that since the block fitted most of the children well she could use that for all the adaptations and recommended different paper patterns for children who were small, medium and big.

In a study by Satsangi (1970), 300 boys in the age groups of 14, 15 and 16 years enrolled in ten high schools in Baroda City, were measured. 57 measurements were included in this schedule. The average weight was observed in the range of 28-52 kgs. In the 14 year age group the average weight was 35 kgs, in the 15-year age group it was 40 kg, and in the 16-year age group it was 45 kgs. The height ranged from 150-170 cm, wherein 155 cms was the average height for 14-year age group, 155 cms was the average height for 15-year age group and 160 cms was the average height for the 16-year age group. It was observed that weight, armpit and hip girth measurements fell into five sections because the range for weight was 29-50 kgs, for armpit girth it was 63-87 cms and hip girth it was 68-92 cms. This pattern was followed for all other girth
measurements, thus dividing the range into five groups A, B, C, D and E. A proposed system of boy’s body measurements based on intervals of height and armpit girth measurements, height and hip measurements required for upper and lower garments respectively was finalized on the basis of twelve figure types for 300 adolescent boys.

Taneja (1970) measured two hundred preadolescent girls ranging in age from ten to twelve years. In all 64 measurements were taken and recorded in the schedule which also included background information like age, The two hundred subjects were divided into three age groups of ten, eleven and twelve years. The total range for weight was divided into different sections with a class interval of 5 kilograms. Total range for bust girth measurement was divided into different classes with a class interval of 5 centimeters. It was found that weight and bust girth measurements fell into four sections. The total range for height was from 118 to 142 centimeters, with a class interval of 5 centimeters. Total range was divided into five sections. Same pattern was followed for linear measurements. Total range was divided into five sections. It was observed that the girls in the group grew more rapidly between eleven and twelve years of age than between ten and eleven. None of the subjects in the 10-year-old age group were in the heaviest and tallest group. Similarly none of the twelve year old girls were in the lightest and shortest group. The eleven-year girls were distributed in all four-weight groups and in all five-height groups.

In a study by Agarwal (1971), the body measurements of three hundred boys of seven, eight and nine years of age enrolled in different schools in Baroda were taken. In all Seventy Three measurements were taken and the background information like age, The boys were divided age wise into three groups – seven, eight and nine. The weight of the boys ranged from 13 to 27 kilograms and the bust girth from 48 to 62 centimeters. These two were divided into groups keeping a class interval of 5 kilograms for weight and 5 centimeters for bust girth. It was found that weight and total bust girth measurements could be divided into three
groups. So the other girth measurements were also divided into three groups A, B and C.
The total range, 113 - 132 centimeters for height was divided into different divisions keeping a class interval of 5 centimeters. The linear measurements were divided into four sections.
It was observed that growth increment between eight and nine years was more than between seven and eight years. Less than 10 boys of seven years and nine years were found in the last and first groups respectively. Eight-year-old boys were distributed in all the groups for all the length and girth measurements.
The data further revealed that the girth measurements could be divided into ten figure types. This distribution showed that two groups had very small frequencies, which could be combined with the nearest group. Finally eight figure types were obtained.

Alimichandani (1971)\(^5\) studied the body measurements of 300 women between the ages of 25 and 50 years staying in different parts of Baroda. The data obtained was analyzed and categorized based on similarities in body types to standardize the body measurements for women in order to make well fitting garments. 79 measurements were taken with the help of measuring tape, scale marking pencil and wooden calipers. Several body landmarks were located with the help of marking pencils. The total ranges for bust girth, hip girth and weight were divided into six groups making the interval of 5 cms and 5 kilograms.
When the bust girth was compared with lengths above the waist and the hip girth was compared lengths below the waist the overall picture showed that the majority of the subjects with small bust girth had short lengths above waist and with small hip girths had short lengths below waist and vice versa. Same pattern was observed when bust girth was compared with girths above waist and hip girth was compared with girths below waist. It was seen that majority of the subjects with large bust girth had large girths above waist and with large hip girth had large girths below waist. No relation was found between shoulder slope and bust girth. When the ranges of bust girth, waist girth and hip girth were compared, it was seen that bust girth was 15 centimeters more than waist girth and 10 centimeters less than hip girth.
It was thus concluded that the difference between bust and waist could be same, more or less than 15 centimeters. Similarly the difference between bust girth and hip girth could be same, less or more than 10 centimeters. Not a single subject had bust girth more than hip girth.

Kuruvilla (1971) measured 1000 girls in the age group of fifteen and twenty five years. The weight and 66 other measurements were taken, as well background information such as age were recorded on the schedule. The bust girth was kept constant, the first group being 70, the second 75, the third 80 and the fourth being 85 centimeters. Relation between the bust girth, and the girth and length measurements above the waist were found. The relation between the front cage and the waist girths with the bust was found. Relation between the back cage and the waist girths were found keeping the back bust girth as constant. The height and the all the length measurements were divided into five groups. The shoulder slopes were divided into 8 groups, as the range was too large. The neck depth was divided into three groups. The height was in five groups of 145,150,155,160 and 165 centimeters. The hip girth was divided into four groups of 80,85,90 and 95 centimeters.

Lamba (1971) measured 300 girls in the ages of seven, eight and nine in order to standardize measurements for ready to wear clothing for young girls. The measurement schedule included 73 measurements for each of the subjects along with their background information like age. The total range for weight was divided into different groups with a class interval of 5 kilograms, similarly the total girth at bust level and hip level were divided into different groups keeping the class interval as 5 centimeters.

It was found that the subject’s weight, bust girth and hip girth was divisible into three groups; weight range being 13-27 kilograms, bust girth range 48-62 centimeters and hip girth range was 53 to 67 centimeters. The pattern was followed for all other girth measurements keeping class intervals.

The total height ranging from 108 to 127 centimeters was divided into four sections with an interval of 5 centimeters. The range for back length from highest shoulder point to waist level being 24 to 31 centimeters was also divided into four
sections with a class interval of 2 centimeters. It was observed that the length and girth measurements from highest shoulder point to ankle level, from cervical and neck base to waist level for all subjects were divided into ten figure types with an adjustment of one to two centimeters. It was observed that in this group girls grow more rapidly between eight and nine years rather than seven and eight years of age.

Patrick (1971) studied the anthropometric measurements of 300 girls ranging from thirteen to fifteen years of age. 100 subjects in each age group were measured from different schools in Baroda (Gujarat), Moradabad (Uttar Pradesh) and Bhiwani (Haryana).

The total range for weight and height was divided into different classes with a class interval of five kilograms and five centimeters respectively. Similarly the total range for bust girth measurement was divided into different classes with a class interval of five centimeters. It was found that weight and bust girth fell into four groups because the range for weight was 28 to 47 and for bust girth it was 63 to 82. The range for back length from highest shoulder point was divided into different classes with an interval of three centimeters.

The linear measurements were divided into four groups. Fifteen combinations with four groups of girths and four groups of length measurements were found. These were taken as fifteen figure types. It was found in some of these that the number of subjects was less than five. These were included in the next nearest group to have regular growth pattern, and thus finally eleven figure types were formed.

Thus the proposed system for girls body measurements (thirteen to fifteen years) based on intervals of height and bust girth were proposed.

Chanchani (1972) measured 500 children between the ages of three and four years in order to standardize their measurements. Two hundred and fifty boys and two hundred and fifty girls of three to four years of age residing in Baroda were measured. Seventy measurements along with the background information such as age were included in the measurement schedule.
The total ranges for all measurements were divided into three groups - A, B and C with varying class intervals. It was found that for all the subjects’ weight, chest girth and hip girth were divisible into three groups. Weight range was 11 to 16 Kilograms with two kilograms interval. Chest girth ranged from 47 to 52 centimeters with a class interval of two centimeters and the hip girth 47 to 55 centimeters with a class interval of three centimeters. The total range for height, which was 82 to 108 centimeters, was divided into three groups, with a class interval of nine centimeters.

The ranges for front and back length from the highest shoulder point to waist level were divided into three groups with a class interval of two centimeters.

Finally seven figure types were obtained for both boys and girls. After statistical analysis it was observed that there was not much difference between the boys and girls. However in most of the cases the boys concentrated more than the girls in the higher range groups. Based on the seven figure types, a proposed system of body measurements for three to four year old children was put forward.

Mathur (1972) measured five hundred newborn infants ranging from five days to ten days. 250 boys and 250 girls were measured. In all 39 body measurements were taken. The infants were divided into three groups according to their ranges with different class intervals. Data showed that all girth and length measurements were in the same group with an adjustment of two centimeters. It was found that the boys were larger than the girls in all measurements. Nine combinations were obtained from the data. Nine figure types were taken. Finally seven to eight figure types were formed.

Paul (1972) measured five hundred infants between the ages of one to two years. 68 measurements were taken. The range for boys and girls was the same. Data showed that some children were small, some large, some light, some medium and some heavy. Hence each measurement was divided into three groups. The data for the boys and girls was tabulated separately. In both cases the majority of the subjects were in the middle group, but in the case of boys,
more subjects were in the larger group and less in the smaller group as compared to girls. Though the number of boys in the larger group were more, there was not much significant difference between the measurements of the boys and girls after finding out the mean. It indicated that the growth pattern was almost the same for boys and girls. All linear and girth measurements were divided into nine figure types. The researcher recommended seven figure types.

Vijaylakshmi (1972)\textsuperscript{119} measured 250 boys and 250 girls of two to three years of age. The entire range of measurements was distributed according to three girths and three length groups formed adjusting up to two centimeters on either side. The total range for weight was eight to thirteen kilograms. Weight was divided into three groups with a class interval of two kilograms. 47.7\% of the total subjects weighed between 10-11 kilograms. The mean weight for the total sample was 10.39 kilograms.

The total range for height was 70 to 87 centimeters. This range was divided into a class interval of six centimeters. The height of 44.8\% was between the range of 82 and 87 centimeters. The mean height for boys and girls indicated that boys are taller than girls. The mean height for the total sample was 80.36 centimeters. Seven combinations with three groups of girth and three groups of length measurements were formed. The system of girls and boys body measurements based on intervals of height and chest girth was proposed.

In a study by Subramanian (1974)\textsuperscript{111}, 350 men in the age group of twenty and twenty eight years from different hostels of Baroda were measured. The instruments used were weighing scale, Level Square, measuring tape; stainless steel linear scale, L scale, steel chain, marking pencil, vernier caliper, protractor, and ribbons.17.42\% were 23 years old and 5.14\% were 28 years.29.43\% were short, 31.14\% were medium, and 39.43\% were tall in height. 29.71\% of the total sample was 43-47 kg, 29.14\% were 48-52 kgs, 25.42 \% 53-57 kg, and 15.71\% were 58-62 kg in weight.
According to girth at armpit level it was found that 14.2% were 73-75-77, 28.5% were 78-80-82, 42.8% were 83-85-87 and 14.2% were 88-90-92.
The total waist girth found was categorized into four groups- 97 men were of 58-63 cms, 175 men of 64-69 cms, 66 men of 70 – 75 cms and 12 men of 76-81 cms. The total hip girth was 76-81 cms for 73 men, 82-87 cms for 164 men, 88-93 cms for 93 men and 94-99 cms for 20 men.

In a study by Patel (1975), the body measurements of three hundred boys of four, five and six years of age were taken, in Baroda and Palanpur. Background information such as age, were recorded as part of the study.

A total of sixty-one measurements were taken. The total ranges for all measurements were divided into four groups A, B, C and D, with varying class intervals. It was found that for all the subjects height and total girth at armpit level were divisible into four groups. Height range being 94 to 117 centimeters with six centimeters class interval. Total girth at arm –pit level ranged from 49 to 56 centimeters with two centimeters class interval. The pattern of dividing the total range into four groups A, B, C and D was followed for all other girth and length measurements having different class intervals. Thus all girth and lengths were divided into four groups.

The boys of four years were in groups A, B, C. None of them were in D.Where as the boys of six years were in groups B, C, D and none were in the shortest or smallest group A. But the boys of five years of age were in all groups Vis; A, B, C and D. This showed that the there was a pattern of growth and development of various parts of the body specific to the age.

400 class IV employees from different institutions of Maharaja Sayajirao University were measured by Singh (1975) in order to make uniforms comfortable and smart. Measurements were taken at different girth levels. The total range for height was from 149 to 172 centimeters. It was divided into three groups. Short from 149 to 172 cms, medium from 157-164 cms, and tall from 165-172 cms with a class interval of 8cms.30% of the subjects were short,
43.25% had medium height and 26.75% were tall. All other length measurements were also divided into three groups.
The total range for weight was from 38 to 61 kgs. This was divided into three classes from 38 to 45 kgs, 46 to 53 kg and 54 to 61 kgs with a class interval of 8 kgs. 44% had least weight, 39.50% had weight in the second column and 16.50% had maximum weight.
Thus with every 1 cm rise in height there was an increase of 1 kg in weight. 3% of the subjects were short and fat and 5.75% were tall and thin.
The girth at armpit level ranged from 73 to 92 cms. The subjects were distributed according to the bust measurements – 75, 80, 85 and 90 cms. The range for hip girth was from 73 to 97 cms. All the girths above the hip girth were divided into four groups. On comparing girth at armpit level and hip girth, it was noticed that either the two were same or the hip girth was 5 to 10 cms more than the former.
The data was analyzed and used by the investigator to provide better fitting uniforms for the employees.

300 girls of ages four, five and six were measured in Baroda (Gujarat) and Jullundur (Punjab) in a study undertaken by Walia (1975). Each age group had a sample of 100 subjects each. 63 measurements were taken in all. It was found that the total ranges for all measurements were divided into four groups A, B, C and D.
In almost all the cases the six year olds concentrated towards the bigger groups and the four year olds towards the smaller groups. After analysis it was found that although the measurements were divisible into four groups the subjects virtually fell into three groups. Thus they formed short, medium and tall groups. Some of the tall subjects in the four-year-old group went as far as the medium of the six year olds, and the smaller six-year-old girls were almost the same size of the medium four year olds.

Gogoi (1976) measured 300 preadolescent boys in the age group of 10-11 years from six different schools and analyzed the data and divided the sample
categories based on similarities in the body types. The background information of the respondents was also recorded. The boys were divided by age into two age groups – 10 and 11 years. It was found that total range of 123 to 142 centimeters for height was divided into four divisions keeping a class interval of 5 centimeters. The range 123 to 137 centimeters for ten-year-old subjects and the range 128 to 142 centimeters for eleven-year-old subjects could be divided into three class intervals. Heights fell into four sections and the total range for all the lengths was divided into sections 1, 2, 3 and 4.

Total weight range from 18 to 32 kilograms was divided into three groups with a class interval of five kilograms. The total chest girth measurements were also divided into three groups. Thus, the ten and eleven year old subjects were divided into short, medium and tall groups according to their total range of measurements.

Kamala (1976), measured one hundred and fifty twelve-year-old and one hundred thirteen year old boys studying in various schools in Baroda. The total range for weight was divided into different groups making a class interval of five kilograms. Similarly the total girth at armpit level and hip level were divided into different groups keeping the class interval as five centimeters.

Weight, girth at armpit level, waist and hip girth measurements were divided into three groups; weight range being 23-37 kilograms; girth at armpit level range 58-72 centimeters and hip girth range 63-77 centimeters. The same order was followed for all other girth measurements keeping class intervals, thus three groups A, B, and C were formed based on the above. The total range for height 133-152 centimeters was divided into four groups with an interval of five centimeters. The height range for twelve-year-old fell into the first three groups and for thirteen year olds in the last three groups.

The subjects belonging to three different weights and three different height groups for each group were finalized. A system of body’s measurements based on the interval of height and armpit girth measurements and a height and hip measurement required for upper and lower garments respectively was finalized.
In an Anthropometric survey by Croney (1973-1974), 317 women studying in the London School of Fashion were measured. This was undertaken to provide up-to-date information on the body measurements of young women intending to make fashion their career. The sample was taken from the whole student population of the London College of Fashion. The results related to 311 subjects, and the age distribution in single year classes; the age range was narrow, just over 71% being either 18 or 19 years of age. In ethnic origin, 92% of the sample was European. Despite this evidence of heterogeneity there appeared to be no reason to exclude the Non-European because the sample was typical of many contemporary student populations in Western Europe.

18 body measurements were taken and the results were given in terms of range, mean and standard deviation for each variable, together with values for the 5th and 95th percentile. A correlation matrix was calculated for all the variables and the study was completed by a factor analysis.

Patterson et al (1983) studied one hundred and fourteen white and ninety-one black women volunteers from Tallahassee, Florida, to determine if elderly ambulatory women were adequately represented in the garment sizing system. Thirty-three body measurements were taken on each subject, whose ages ranged from 65 to 96, with a mean of 73.912. Statistical analysis of these 33 measurements used descriptive statistics, t-tests, Pearson Product Moment Correlations, factor analysis, partial correlations and multiple regressions. Of the 33 measurements 25 were significantly different from the body measurements of the O’Brien and Shelton 1941 study. All the existing sizing systems were based on that study. Among those found to be dissimilar, were bust, waist, abdominal extension, and hip girth measurement. The statistical analysis yielded body measurements that could be used as key indices for reliably predicting other body measurements. From these indices, five alternate sizing systems were developed: height/weight, height/bust; weight/waist height; bust/waist height, and abdominal extension/waist height. One horizontal and one vertical measurement were selected for each sizing system.
Goldsberry et al (1996)\textsuperscript{48}, sponsored by the Institute for Standard Research and the Apparel Industry undertook the first large-scale body measurement database specifically for women of age 55 and older. Part 1 examined differences in body measurements between the new database and the Voluntary Product Standard PS 42-70 database. Data collection and computing methodologies were pilot tested in Arizona with 469 subjects who were 55 years of age and older. State project coordinators and data collectors in 38 states were recruited and provided training during the two day workshops conducted in 24 regional locations. Measurements of a total of 6,652 ambulatory women representing 38 states were included in the final analysis. A specially designed computer program sorted subjects by size based on the same bust, height, and weight criteria as those used in the PS42-70 database. For the analysis subjects were classified into 7 figure types (Junior Petite, Junior, Misses Petite, Misses Tall, Women and Half Size. in 6-10 sizes each. Using T-tests compared mean differences of each size within each figure type. Significant differences between the current older woman’s body measurements and the PS 42-70 database across the sizes and figure types were abdominal-extension, waist, and sitting –spread, armscye, bust-height, back width, chest width, hip and hip arc. Some measurements (e.g. hip – height, inseam, cervical-height, waist-arc, abdominal –arc and weight) tended to be generally greater than those of the PS 42-70 with a few exceptions in some figure types. Depending on the sizes and figure types, other measurements varied in both directions from the PS 42-70. It could be expected that women 55 and older would have difficulties buying clothing that fitted well. Thus it was critically important that the new database be used to develop improved sizing for women 55 and older.

Visual observation suggested that distinct differences in physical characteristics existed between Asian and Western country people. Nakanish et al, (1999)\textsuperscript{85} compared young Japanese and Caucasian American male students on a variety
of anthropometric characteristics and located and quantified the magnitude of physical differences between the two races.

Twenty young Japanese male subjects who were born and raised in Japan were randomly selected from Asian University exchange students (age: mean \( \pm \) SD=19.7-1.8 years). Twenty Caucasian American male subjects, who were born and raised in America, were also randomly selected at Central Washington University (age: 21.1 – 2.1 years). All these data concerning the Japanese were collected within 10 days after their arriving at the United States to minimize the effect of acclimatization. It was found that Americans were significantly taller and heavier than the Japanese, and every specific limb length of the Americans was significantly longer than the Japanese. As for limb girths, every girth measurement was significantly greater for the Americans. The ratio of the sitting height to standing height for the Japanese was significantly larger than that for the Americans. The average height and weight for the Americans were 180.6 cms and 78.6 kg respectively, while the Japanese averaged 171.8 cm and 62.1 kg respectively. Although the sample size was small in study the average height and weight values suggest that the samples in the study represented the general young populations of each country.

The difference in sitting height (1.8 cm) was much smaller than that in the standing height (8.8 cms). The ratio of sitting height to total height was significantly different between the Japanese and the Americans. These observations indicated that the difference in the standing height was due primarily to the effect of leg length. Concerning the sitting height to standing height ratio, the values reported were similar to those found in 1962. Japanese =54.4%. Americans =52.1%. This suggests that the ratio has not changed over 35 years.

The ratio of total arm length to height was also significantly different between the two races. The Caucasians have longer upper and lower extremities relative to their height than the Japanese.

Limb lengths and girths were all significantly larger for the Americans. The greatest differences for the limb length and girth were found for the calf (18.3%) and biceps (17.3%) respectively. It was also found the Americans have a larger upper extremity than the Japanese. With respect to length to girth ratio, there was no significant difference between the two groups.
Though the physique of the Japanese has changed tremendously as a result of Westernized diet and life style during the last three decades and it has been hypothesized that the body shape of the Japanese may eventually approach that of the Americans and Europeans, the present findings suggested that there were still clear differences in anthropometric characteristics between the Japanese and Americans which may be due to effects of genetics.

Kang et al (2001)\textsuperscript{62}, analyzed how approximately the sizing of domestically produced children’s wear compared to children’s sizes, based on an anthropometric survey conducted in 1998. The study compared the extent of growth between age groups with the difference in sizing systems used by manufacturers.

The study focused on children aged 4 to 12 years who were divided in two groups, primary students and toddlers. Seven sizes were selected; bust, waist and hip, height, back neck to waist, sleeve length and waist to ankle.

They found that –Bust girth- growth started to appear at 6 years of age. By 10 years girls surpassed boys due to the influence of secondary sexual development.

Waist girth– at age 5 girls’ waist girth was smaller than boys. The investigators suggested that from this age onwards there should be separate pattern of sizing for each sex.rather than a unisex sizing.

Hip Girth – Boys were smaller than girls and the difference increase from the age of 10 onwards.

Crotch length – girls’ crotch length became longer from age 7 onwards- and continued to dominate from then onwards.

Chest width, back width, and shoulder width grew consistently by .5cm or 1.5 cms ages 3 to 13 years. Sleeve length also grew relative to height. No distinctive differences between the sexes. However girls stopped growing by age 14 while boys kept growing till age 18.

Girls shoulder slope was steeper than the guys and the right side was much steeper than the left. The bust, waist and the hip differed from ages 5-6 and became properly developed to each sex from ages 9-10.
While the investigator compared the measurements over four years four sizes showed an increase over the previous years. The difference of height, bust and waist appeared at about 6 years old and showed a difference previously at 5 years. The measurements of bust, waist and hip sizes were different in 1997 and 1979. The size gaps between the two surveys started at about 6 years of age and became clearer as the children grew older. The measurements taken in 1998 were similar to the measurements of older groups in 1979.

The investigator found that over 70% of the companies applied exactly the equal increments between the sizes of clothes. However in reality the actual body increases in body sizes is irregular. Clothing sizes did not reflect actual increments in body size between age groups. The investigator concluded that the existing sizing system used by the children’s apparel companies was unsuitable and recommended a new sizing system.

Anon, (2007) in the article published on the earliest anthropometric studies in U.S, reported that Clothing size designation served as a communication among manufacturers, salesman and consumers. The development of clothing sizing systems has been dated from 1901 when the United States Government established the National Bureau of Standards (NBS), a non-regulatory agency for the purposes of measurement standardization in science and industry. According to the article, in 1921, the first report on an US anthropometric survey with clothing sizing conducted on approximately 100,000 men during demobilization at the end of the First World War were published. Again, during 1937-1941 a US survey of clothing sizes for approximately 1,47,000 boys and girls conducted across the USA was published.

Anon, (2007), published an article by O'Brien and Sheldon on study of development of sizing standard “CS 215-58” in 1941. The study did not result in a sizing standard until the 1950’s. In 1958, the U.S. Department of Commerce issued a new commercial standard known as CS 215-58 based on the 1939 study. This standard used four classifications of women (Misses, Women’s Half Sizes and Juniors). Three height groups (Tall, Regular and Short), a bust measurement and three hip types (Slender, Average and Full) to classify sizes.
The sizes were based on bust measurement, height group, and drop value (difference between hip and bust circumference) and yielded over 20 sizes for use by the apparel industry. However, this standard was only voluntary, meaning that manufacturers did not have to follow it. They could either revise it to fit their needs, use it as it was created, or disregard it entirely. In addition, it was based on the study by O’Brien and Shelton, and thus suffered from the same inadequacies that the study had. Due to these problems, women of the 1950’s and 1960’s attempted to get around a growing size problem by using corsets and girdles to mold their bodies to the shapes of the clothing produced.

Anon, (2007) in an article published on the development of Sizing Standard “PS 42-70” reported that despite the problems on the earlier sizing systems, the next step in the history of sizing standards did not occur until 1971, when the U.S. Department of Commerce released a new voluntary standard, known as the PS 42-70. This standard is basically a revision of the previous standard CS 215-58, but did not include modifications based on a health survey performed by the National Center For Health Statistics in 1962. This survey indicated that U.S. adults were taller and heavier than they were in 1940. Thus, the bust girth was increased by one grade interval per size code for all figures. Other changes from the CS 215-58 included the elimination of “Slender” and “Full Hip” options for all figure types as well as the elimination of the “Tall option in the juniors and Women figure types (U.S. Department of Commerce).

Even with all these changes to the CS 215-58 standard, the new PS 42-70 standard was still voluntary and based on the 1939 study by O’Brien and Shelton. According to the report no problems with the sizing systems had been confronted.

Ashdown et al (2008), studied changes that occur in women as they age, in their posture and bilateral symmetry that affect the fit of clothing. These changes have been documented in many studies. Anthropometric measures made in previous studies, however, were limited to linear measurements (circumferences
or lengths) and included only one angle, the shoulder slope. In this study, the authors took detailed measurements using a 3-D body scanner to validate previous studies and more precisely quantify body changes in older women. They compared upper-body measurements of 40 women aged 19-35 to those of 40 women aged 55+. Using these measurements, they quantified the differences in posture and the differences in the amount of bilateral variation between the older and younger women. Nineteen upper-body angles, 16 linear measurements, and one proportional measurement were included in the study. Of the 36 body measurements taken, 21 measurements were significantly different between the two groups of women.

Ariadurai et al (2009) developed a size chart based on the anthropometric measurements of 160 Sri Lankan Children between the ages of 5 and 12. For the purpose of this study the height was taken as the base measurement and the size chart developed for seven size groups. They measured 76 boys and 84 girls. Their height and the three primary body measurements, namely chest girth, waist girth and hip girth were measured. They divided the population into eight equal class intervals based on heights ranging from 113.8 cms to 153.7 cms disregarding the age of the child. Based on the average measurements obtained the three body measurements at height measurements of 116,122,128,134,140,146 and 152 cm were determined and basic measurement charts obtained. The study revealed that the chest, waist and hip girth measurements of boys were higher than that of girls. However, though the chest measurements of both boys and girls at 116 cms height was the same at 152 cms height the chest measurement of boys was 6 cms higher than that of the girls. The trend was also observed in the waist measurement where the difference of 1 cm at 116 cm was 3 cm at 152 cm height. However, in the case of hip measurements, the difference of 3 cm at 116 cm came down to 1 cm at 152 cm height.
Universiti Teknologi Mara (UiTM) Shah Alam (2009)\textsuperscript{149} conducted an anthropometric survey to measure 2,100 young Malaysians from the three major races. The volunteers were randomly chosen between the ages of seven and seventeen and were randomly picked from 29 schools in four urban and rural districts of Selangor. Fifty different body measurements, from head to toe were taken for each subject using the ISO body measurement standard. Four trained measurers took the measurements.

Fifty-two different body parts of each girl (51 for boys) were measured, resulting in almost 107,100 measurements. The results based on the sample population, that at 17 the tallest boy measured 184.4 cms and the tallest girl, 170.6 cms. The average height for the male participants was 143.2 cms and the average weight 42.2 kilograms, and for the females the average height was 140.6 cms and the weight 39.3 kilograms.

Measurements of chest/bust, waist and hip girth in relation to height division (short, medium and tall) revealed four generalized body types. Four basic shapes for females (apple, banana, pear and hourglass) and males (rectangle, inverted triangle and trapezoid). On an average, the girls aged seven to twelve had a banana or tubular shape while those aged between thirteen and seventeen had pear shape. Boys in both age brackets had rectangular shape. Based on this a new sizing system was developed.

\section*{2.2 SIZING STUDIES}

The following studies reported are pertaining to fit issues, which are very specific and done with a purpose to either identify a fit problem or to find a solution for the existing fit problem. Some of the studies here, are based on older anthropometric surveys in order to compare with the recent global surveys.
The Bureau of Home Economics took fifty-five measurements of several thousand women. Partial correlations with age held constant were computed for a representative group of 4,128 of the women. The correlations among twenty-nine of these variables served as the basis of the study undertaken by Heath (1952)\textsuperscript{52}. By a combination of the multiple-group and the centroid method of factoring, five factors were extracted. After twenty-nine rotations, simple structure was evident, and the factors were interpreted as bone length, size of joints, and circumference below the waist, circumference of extremities, and circumference above the waist. The intercorrelations of the primaries were computed, and two second-order factors were extracted. It was found that one of them was primarily related to the growth of fatty tissue and the other to the development of the bones.

Salusso (1982)\textsuperscript{139} classified the adult body form variation in relation to the U.S. Standard for apparel sizing, the Principal Component Sizing System. The researcher found variations within height intervals along a linear-to-lateral body type continuum. Consumers, producers and distributors of adult female apparel in the United States agree that an adequate apparel sizing standard is essential to efficient apparel production. To be adequate, PS 42-70, the standard currently used in the US should be accurate as a classification system for body form variation, easily used within the apparel production process, and understandably labeled. The efforts to improve the current sizing standards have been focused on obtaining current database. However, a sizing system is based on the database and method used to structure body form variation in that database. The researcher developed an empirical method for structuring a sizing system, which yielded a more efficient classification system than PS 42-70.

The database for this study was the 1977 survey of the 1330 U.S. Army women with 60 measurements per subject. Subjects varied in body size, regional distribution, race and age. After discriminate analysis of race and age effects, the sample was limited to subjects who were White or Black and between 17 – 35 years old. A review of the apparel sizing, body form classification and multivariate
statistics yielded classification methodologies applicable to classification of body form variation. Initial examination of PS 42-70 as a classification system for the sample revealed poor proportioning of lengths and upper body breadths. Fifteen principal components were used to summarize trends in body form variation. Principal components 1 and 2, laterality (fullness) and linearity (length) were selected to describe body size and type. Parallel cluster analyses of variation within categories defined by laterality and linearity components and categories defined within the PS42-70 showed lower body laterality and upper body linearity to be common variations among groups homogenous in overall size.

The experimental method was developed around relationships between magnitude of laterality and linearity components. The Principal Component Sizing System, PCSS resulting from this method structured variation within height intervals along a linear-lateral body type continuum. Qualitative and quantitative comparisons of PS 42-70 and PCSS as classification systems showed the later to be numerically more efficient and adequate.

Hogge et al (1988) compared the preferences, perceived availability and fitting problems of selected ready-to-wear garments for elderly and non-elderly men living in northern Colorado. The participants were 50 males, 65 years of age and older, and a contrast group of 50 males, 30-50 years of age. A Clothing Preference Interview Schedule was developed, adapted from a Clothing Needs of Elderly Women Questionnaire by Hogge and Baer, to obtain data from the participants. Inferential statistics were computed to investigate relationships or differences that existed between responses of the elderly and non-elderly men. More men from the elderly than non-elderly group found garments in their preferred sizes and colors in the local stores. Men in both groups expressed various preferences for fiber content of selected clothing items. However, the older men had a greater acceptance of man-made fibers. The common fitting problem of both groups with shirts and jackets was sleeve length. When purchasing clothing, the most important factor for both groups was fit. Design/style was ranked as second by the non-elderly and eighth by the elderly men who
ranked durability and price higher than the non-elderly men did. Thus the researcher concluded that fit was the most important factor while buying clothing.

Giddings et al (1990), studied eighty-nine black males and 94 white males between the ages of 18 and 30 and determined whether (1) the two groups differed in their ability to obtain properly fitting pants, (2) differences existed in their anthropometric morphology, and (3) a pants pattern could be developed that would fit the group with the greater difficulty. Results from the pants fit questionnaire indicated that the black males needed pants alterations more often than the white males. An analysis of the anthropometric data revealed a difference between black males and white males for various body measurements. She developed pants pattern to fit the average measurements of the black group. The fit of the pants was evaluated on a body with the average measurements. A panel of judges gave the pants an overall good rating on fit. The researcher concluded that the bodies of the white and black males being different, different patterns had to be developed for good fit.

Tam (1991), investigated clothing for females with Downs’s syndrome. Down’s syndrome patients generally have non-standard features. The investigator gathered a database of dimensions of 200 Down’s syndrome females in Hong Kong aged 15 years and above. The researcher investigated the fastenings, posture and ergonomic features, as the mental retardation affects their ability to dress/undress. From the information gathered the researcher established mannequins and size tables. Important outer garment types were identified and pattern construction rules developed for five major garment categories: skirt; culottes; slacks; blouses and casual jackets.

Workman (1991) investigated one of the factors in sizing variation – body measurement specifications for fit models. Every apparel company employs a different fit model and develops its own size charts. As a result, there are
widespread differences in sizing and fit of garments from various apparel manufacturers. She recommended that size charts need to be checked and revised every ten years to reflect changes in characteristics of the U.S. population. She specifically focused on determining the existent standards for size 8 and 10 fit models, compared body measurement specifications for size 8 with size 10, and compared current standards with those of 10 years previously to see if specifications had been revised. Data for the study was collected from 1976 and 1986 trade journal advertisements for size 8 and 10 fit models. Data were analyzed using a T-test. The results showed that the 1986 size 10 had significantly larger hip measurement specification than size 1986 size 8. The comparison of 1986 and 1976 specifications revealed only one difference – hip measurement specifications for the 1986 size 10 were significantly larger than for the 1976 size 10. She observed that the range of size variations were larger for the 1986 fit models than the 1976 models.

**Chun -Yoon et al (1993)**

reviewed the sizing systems developed in different countries – USA, Austria, England, Germany, Hungary, Japan and South Korea. On comparison of these sizing systems, the investigators found that the way of labeling garment sizes varied from one sizing system to another; most of the sizing systems classified figure types by height and drop value (the difference between hip girth and bust girth measurements) and the way of classifying garments and the key dimensions of the garments were slightly different in each sizing system. Thus recognizing the need greater uniformity, the International Organization for Standardization developed an international size labeling system. Many countries, including England, Japan, South Korea and Hungary revised their labeling systems and adopted the ISO system.

**Shen et al (1993)**

developed bodice patterns using photographic data, physical measurement and computer technology. The data was gathered for 12 female subjects. The data was used to develop the experimental methodology and a computer was used for generation of sloper patterns for the upper torso. The pattern was generated by conventional drafting methods as well. The researchers developed an evaluation scale, which had 25 fitting criteria; in order to compare the fits of the experimental drafted bodice and the conventional hand
drafted bodice. They found that for 12 of the 25 items on the scale, the experimental bodices were judged to have a better fit, for two items on the scale the hand drafted bodices had a better fit. No statistically significant differences were found for the remaining items on the fit scale. Thus the researchers concluded that this new method showed potential for providing accurate, quickly generated bodice patterns.

Chun-Yoon et al (1995)\textsuperscript{32}, initiated the investigation of consumers' preferences for various sizing systems, including a system with only a numerical code unrelated to body dimensions and several systems with various information on body dimensions. Throughout the study, a sizing system including information on body dimensions was called an \textbf{anthropometric size description system}. The major difference between an anthropometric size description system and the system used for most women's ready-to-wear garments is that the former designated garment size with measurements of key body dimension(s) (e.g., "size 8 for waist 28 inches"). An anthropometric size description system reduced the possibility of consumers purchasing unsatisfactory garments because of a misunderstanding about size. It did not completely eliminate the need to try on clothing because consumers with a 28-inch waist, for instance, had varied preferences in fit. However, the researchers believed that for at least some consumers, it eliminated uncertainty in initially finding the correct size. An anthropometric size description system reduced the return rate caused by consumers purchasing the incorrect size and also reduced damaged merchandise caused by frequent trying-on of garments. Thus, it contributed to greater profits for both manufacturers and retailers.

Ashdown et al (1996)\textsuperscript{125} studied the designing of better fitting apparel for older women. Clothes come in special sizes for wide women, short women and young women. However none are specially tailored for the older women whose body changes can include a forward head and neck angle, forward shoulder roll, back curvature, increase in girth and decrease in height. Clothes are made for the upright stance of the 17-35 year old and typically offer poor fit for the different body proportions found among older women. The reason according to Professor Ashdown was that women’s clothing sizes – including misses, women’s, petite,
junior and plus sizes were derived from a 1940s study of 10,000 women, of which only 2% were older than age 60. In fact 92% of the older women had fitting problems. Ashdown and Kohn studied the postural changes among older women and observed how these changes could be incorporated into suit jacket and blazers.

To analyze fit among older women, the researchers developed a nylon taffeta jacket with standardized slashes that pinpoint where the garment’s stresses were when worn. Slashes were cut in vertical, horizontal and diagonal directions to the grain. Twelve women between the ages of 55 and 65 - an age group often still in the workplace and needing business suits – were videotaped while wearing the slashed garment and an identical unslashed garment. Subjects answered a questionnaire about fit and size, and an expert panel analyzed the fit of the unslashed jackets on women. The video of the slashed garments was analyzed by the computer.

The computer objectively picked up very subtle stresses and the magnitude of the curvatures. Unlike most apparel designers, who tend to focus body dimensions such as circumference and length, they examined body stance, angles and proportions and relationships, such as how the shoulders and bust relate to one another. They used video image analysis computer programs – to detect postural changes in the back and shoulder curvature of older women. The researchers worked with a women’s apparel manufacturing company, Koret in California.

Chun-Yoon et al (1996) generated an anthropometric size-labeling system designating garment size with body measurements by selecting key dimensions for women’s ready −to-wear garments. Two different statistical analyses were used to select the key dimensions and the results showed that the key dimensions selected by both means of analysis were similar. In addition to the key dimensions that existed another dimension representing length or height was added. It was noted that bust dimension was key for all upper body garments and hip and waist circumferences were for all lower body garments. The other key dimensions that represented length or height were sleeve inseam length or
sleeve out seam length for long sleeve shirts, shoulder height or shoulder length for short sleeve or sleeveless shirts, crotch height for calf or ankle length pants and waist height for skirts.

**Feather et al (1996)**\(^{45}\), collected data from 503 female collegiate basketball players concerning body cathexis, body form, and garment fit satisfaction, uniform design preferences and demographic characteristics. Of the three areas of the body (upper, lower and total) players indicated that they were most dissatisfied with parts of the lower body. Being in uniform did improve their perception of their bodies. Satisfaction with garment fit parallels satisfaction/dissatisfaction with the body; the lower area creates the greatest garment fit problems. The type of body form had a significant effect on both uniform fit satisfaction and uniform body cathexis. Fit satisfaction was the highest with the ectomorph body form. The differences were inverse: as the body increased in size, the lower the degree of satisfaction with garment fit and the body. Uniform preferences for the jersey were a deep V – neckline, sleeveless, and the hip length with straight hemline and side vents. For the shorts, a baggy style with side v-vents at the hem, and an 11/2 or 2 inch elastic drawstring were selected.

**Beazley (1997)**\(^{16}\), explained how to undertake anthropometric surveys; first by reviewing previous surveys and size charts to select which measurements should be taken and appropriate equipment. The sample of persons to be measured was determined, the main constraint being the availability of time. The selections of measurements were made for the end use of constructing garment patterns by both direct and proportional measurement systems. Finally 10 measurements were selected and 100 young women between the ages of 18-28 years were measured. It was concluded that measuring the human body was not easy.

**Huck et al (1997)**\(^{59}\) designed coveralls for fire fighting, with special emphasis on sizing and fit to maximize wearer comfort and mobility, and also incorporated design features to help improve the functionality of the garment. The researchers used a structured functional apparel design approach to develop garment specifications. They also used literature reviews, market surveys and user inputs
for the development of the prototypes. They selected ten body movements and asked the subjects to fill out a wearer acceptability scale in order to determine their perceptions of fit and comfort. The results were encouraging for the new coveralls.

Anderson et al (1998), studied the nuances of fit as defined from the consumer’s perspective, developed instruments and methodologies to capture personal fit preferences of the consumers and translated consumer fit preference data into an expert system to be used in decision making involving fit. The objective focused on understanding consumer preferences relative to garment fit. The emphasis was on understanding how to translate these into apparel items that satisfactorily fit the diverse consumers. Factors including social ideals, apparel industry ideals, and perceptions of what constituted a good fit at specific body sites and personal attitudes towards body shape and size were explored. It was a three-fold process – first, understanding fit issues that involved comprehension of both physiological and the psychological aspects that produced the concept of fit in the mind of the consumer. Researchers at Nottingham Trent developed an interactive web site where global researchers, retailers, manufacturers and consumers could discuss various approaches to fit. These discussions formed the basis for the development of methodologies to understand fit preferences of consumers. Secondly, the project explored the role that fit played in the purchase decision process for apparel from the mind of the consumer. Final analysis of the information from focus groups was used to develop a research questionnaire for a national survey of women consumers of apparel products. The final phase was the development of an expert system to aid industry and consumers in decision making related to the fit of women’s apparel.

Ashdown (1998) studied the apparel sizing systems and found that most were based on one or two body dimensions and relied on assumptions about proportional body relationships to project other dimensions necessary to design the garment patterns. Garments from these systems did not fit a population with large variations in body proportions. Using non-linear optimization methods and anthropometric data of US Army women three multidimensional sizing systems
were derived that were designed to provide improved fit for women in the USA with much variation. The systems ranged from optimized linear system with regular grade to an unconstrained optimized system with a grade break at each size. The researcher found that optimized sizing systems compared favorably with D 5585-94 in their ability to accommodate variation in the population based on mathematical test of the aggregate loss of each system.

Beazley (1998)\textsuperscript{17} studied the formulation of sizing systems and body measurement tables. The data used was a survey of 100 young women in 1993 at Manchester Metropolitan University and 10 body measurements were taken. This illustrated the statistical analysis of body measurements, the formulation of sizing systems and body measurement tables. A review of previous surveys and their method of analysis were also undertaken. The main control measurements of height, bust, waist and hips denoted the size of the wearer and were obtained by correlation. Size ranges and intervals were obtained by normalizing the data and comparing the sizes young women bought and previous size charts. Sizing systems for five sizes 8 to 16 were suggested for three heights, short, medium and tall and bust fittings medium, small and very small. They retained the same proportion for the five sizes within each of the nine systems. A further system of changing proportion in girth measurements was developed from the survey of young women based on percentiles and bust fittings. The neck girth, which did not correlate strongly with any measurement, was analyzed separately. Two examples of body measurement tables covering 30 measurements were formulated to illustrate the procedure A comparison was made with previous tables. It was concluded that the body proportion had changed and the young women were taller and broader in the hips and waist.

Connell et al (1998)\textsuperscript{34}, developed body analysis standards based on body scan data relative to body shape, posture and weight for women ages 19-35. They also produced an expert system, which could be used to analyze body scans as a basis for realigning sizing and pattern development for specific target markets and developed virtual fit models based on body shapes and posture that occurred
in the population to enhance the fit of women’s apparel. They developed a set of nine body scan analysis scales. In the age group of 19-25 years a large percentage had an average, rectangular body shape and few had a full rectangular body shape. When shape and age were considered the pear shape was found to be the dominant shape in each age category.

McCulloch et al (1998)\textsuperscript{80} formulated a new approach for the construction of apparel sizing systems. As the first step in this novel process they defined efficient sizing systems based on a mathematical model of garment fit. Non-linear optimization techniques were then used to derive a set of possible sizing systems using multi dimensional information from anthropometric data. The method was illustrated by developing a sizing system designed for a dress shirt of a military uniform using anthropometric data from the US army. The results of the analysis showed that endogenous size assignment and selection of disaccommodated individuals, together with relaxation of the requirement of step wise structure resulted in substantial improvements in the fit of the garments. The investigators concluded that their methodology enabled the development of sizing systems that increased accommodation of the population, reduced the number of sizes in the system, and improved overall fit of individuals.

Beazley (1999)\textsuperscript{18} explained how size charts are developed for garments, evaluation of measuring equipment used and comparison of size chart body measurements with those proportionally derived by traditional formulae. There are different types of size charts; some are of body measurements for specific proportion and shape. Others are for garments including ease allowances, which vary according to the garment style and type of fabric. Size charts can be developed in three stages commencing with raw survey data, which is then rounded to the nearest 1 cm or .5 cm and finally ease is added for the finished garment. During the survey some measurements were repeated using different measuring equipment and compared so that the best-suited method was selected. The anthropometer was used for linear measurements, the measure tape for recording the contour surface of the body.
Turner et al (1999)\textsuperscript{117} in their study of computer systems for made-to-measure pattern production, found that the systems had the capability of determining default measurements for sets of customer measurements input to the system where one or more measurements are missing. They recommended the use of default formulae rather than mathematical interpolation of size charts. They found that default formulae, when applied to given size chart sets, enabled measurements to be determined efficiently over wide ranging customer sizes in both stature and girth. The specific default formulae for the German charts were derived for Regular and Outsize charts and also for the full range of Height categories and Bust to Hip relationships, thus catering to all sizes and shapes of customers.

Bond et al (2000)\textsuperscript{20} initiated development of a system for made to measure pattern generation with special reference to computer-aided design applications. Recognition of the relationship between body figuration and pattern construction was found to be important for clothing with good fit. The investigator studied the background of women’s sizing systems and the categorization of female figure types and proposed a new system of size codes and size charts.

Bradtmiller (2000)\textsuperscript{21} initiated the need for anthropometric data for people with disabilities. He outlined a program outlining those needs. While the height of doors etc is quite standard, people with difficulties exhibit anthropometric variability in things like reaches etc. One of the main problems in measuring people with disability is that there is no uniformity or standardization among measuring techniques. Hence comparison of data from different studies was not possible. The other problem was that though there were anthropometric studies done on able people it could not be used for disabled people. As it was difficult to get a sample size of over 20 individuals at any time and this being too small a size for any work, the researcher recommended a nationwide anthropometric survey of individuals with disabilities. The data collected included information on body sizes; reach capabilities, range of joint motion, strength and visual data.

Kind et al (2000)\textsuperscript{64} in their study measured the levels of satisfaction regarding retail attributes and fit amongst specialty size college women. The study was
based on the theory of retail satisfaction. Female students from nine
geographically diverse universities were part of the program. Of this 358
respondents were placed in three specialty groups based on height or clothing
size. Those who did not fit into these groups were placed in an average category.
The researchers found that the large size college females had significant
dissatisfaction to retail attributes; petite, tall and large size college females had
dissatisfaction with various apparel fit with the large size group being most
dissatisfied. The researcher recommended reevaluation of sizing standards or a
universal international sizing standard.

Otieno et al (2000) conducted an anthropometric survey of 618 female Kenyan
children aged from two to six years. The correlation coefficients of 33 parameters
were analyzed, which resulted in a centilong system based on height, outside leg,
chest and hip as the key dimensions. The measurements were then categorized
and size designated and used by the industry.

Tsang et al, (2000) studied kinanthropometry to define the physique of 49
Hong Kong –Chinese Fire Services recruits. Kinanthropometry is widely used in
predicting the secular trend in increased body size in and among different ethnic
groups worldwide. The research developed a standard to use in the physical
recruitment in the disciplined forces as well as for improving the basic
measurement scale of uniforms. The researchers found that the somatypes of the
studied disciplined personnel were distributed in the range of endomorphic
mesomorph. Significant correlation was observed between somatype
components and body girths and length measurements.

Workman (2000), examined information on body measurement specifications
for one prototype body used by women’s apparel manufacturers-fit models. She
investigated whether the fit model measurement specifications had changed
since 1986. Advertisements for sizes 8 and 10 fit models were collected from
1986 and 1997 trade publications in the apparel industry. She observed that the
1997 size 8 specifications for bust, waist and hips were larger than the 1986 size
8. In 1997, size 8 and 10 fit model specifications did not statistically differ. The
bust and waist of the 1997 advertisements either gave measurement with no size
designation or gave a size say 8, but gave no measurement specifications, which suggested that size 8 was the current sample size designation. While the fit model specifications had changed, the change appeared to have been accomplished by redesigning as a size 8 what was previously a size 10. She concluded that though technological advances had revolutionized how apparel is produced the aspect that has not changed was the customer’s perception of fit.

Ashdown et al (2001) developed a prototype mathematical process using body scan data to improve sizing systems for specific target market populations of an apparel firm. They quantified fit using measurements of the scanned body and body in clothing and evaluated consumer acceptance of the scanning process. The body scanner provided three-dimensional data of the human body. The data was analyzed using non-linear data such as surface area, volume or data from body slices that could comprehensively analyze the human body and address problems of garment fit.

Thirty female subjects aged 15-53 participated in the pilot study of body/apparel relationship using a set of ready to wear women’s trousers. The subjects donned a pair of test trousers in the correct size as determined on best fit from the range of sizes. The subjects were then placed in a set position for scanning using a body and foot positioner and scanned in test trousers. They then changed from the test trousers to Lycra shorts to be scanned in a minimally clothed state. Subjects were placed in the same position as they were for the first scan using the body and foot positioners and scanned for the second time. The sample ranged in age from 15 years to 53 years with a mean of 29 years. 73% was Caucasian, 17% Asian and 10% other. The sample was well distributed by age but highly educated compared to the general population. Sixty scans, thirty scans each in test trousers and in minimal clothing (lycra shorts), were made to comprise a database of matching sets of clothed and unclothed scans to establish garment fit dimensions. Of the 30 subjects, 57% were judged to be well fitted with the test pants and 45% were judged to experience poor fit in some dimension.
Subjects were generally comfortable with the scanning process. Subjects were most interested in using their body scans data for virtual try-on, to visually evaluate how particular garments would look on their body. Custom fit, fit prediction, co-design and use by a personal shopper also appealed to the consumers. Merged clothed and unclothed scans allowed visualization and analysis of the fit of clothing. Comparison of volumes taken of different sections of clothed and unclothed scans and area and shape analysis of slices of the merged scans were made for pants that fitted well and those that did not fit well.

Campbell et al (2001) applied the theory of product performance and consumer satisfaction to examine the instrumental and expressive outcomes associated with prototype trousers developed from the Canada Standard Sizing (CSS) size code M18 and the ASTM D5886 size code MP16. Instrumental outcomes were positive or negative judgments of a product based on consumers reactions to the physical aspects of a product. Expressive outcomes referred to positive or negative judgments based on consumer's personal or emotional reactions to a product. A convenience sample of 20 women aged 56 to 89 years participated in a two-week wear test followed by face-to-face interviews. The results showed that a) the participants measurements were similar to the ASTM MP 16 measurements; b) although participants were satisfied with the ASTM prototype trouser there was no significant difference in the overall satisfaction; c) participants tended to associate both prototype trousers with instrumental outcomes.

Istook et al (2001) studied all the 3D Body scanning systems that were available in the market and determined the underlying principles that allowed the systems to work. The ability to customize garments for fit is directly tied to the availability of a comprehensive, accurate set of measurements. The specifications of all the systems were compared in order to provide further research into the integration of these systems with the CAD pattern design or pattern generation technologies.
Kuruwita et al (2002) through an application of Statistical Data Mining, assigned a “Personal Code” to every individual that condensed all his/her measurements into a single value. The new code minimized the risk of misspecification and provided an alternative size regimen for ready-made garments. Measurements of the head, collar, sleeve, waist, length of leg, and foot were collected from 409 Sri Lankan Males in the age group of 21-28. The analysis showed that the highest correlation existed between the collar size and waist and that the waist accounted for much of the total variation. Based on the Principle Component Analysis it was seen that the first three components had meaningful descriptions of the shape and structure of the person. The investigators identified 18 different clusters as basis for a Personal Code. They classified a new individual to one of those clusters with ninety percent accuracy.

McKinnon et al (2002) examined the effect of subject positioning on the accuracy of body scan data. A body measurement system developed by the Textile Clothing Technology Corporation was used to acquire two scans from each of 72 subjects. The subjects were instructed to continue to breathe normally and stand with their feet shoulder-width apart. The two scans were compared and statistical analysis was performed to determine the precision of results and whether the lack of standardization affected the data. Physical measurements were also obtained from each subject and served as a basis for comparison to the scanned measurements. As physical measurements are accepted as true value, these were used to determine the level of accuracy of the scanned data. Three separate scans of 72 different subjects were taken at various levels of breathing and at various foot positions to determine the effect of the variables. The study indicated that that respiration and foot placement had a significant effect on body scan data. It was established that the scan data rendered by the software was precise but lacked accuracy when compared to physical measurements.

In 2002 the data from the anthropometric study of females in the late 1980’s obtained by The Navy Clothing and Textile Research Facility (NCTRF) in U.S. resulted in the a new sizing system for female sailors that incorporated three body types and lengths and size standards used by the apparel industry at that
time. In (2002) they further collected 38 clothing related anthropometric dimensions from a sample of 1,338 sailors. While taking their measurements the sailors also tried the existing 17 Naval uniforms so as to identify their specific size and it problems. The researchers evaluated the size and fit, and combined this information with the anthropometric data, information collected during the survey and the problems that the sailors experienced with the uniforms they were wearing. They identified the two body types. In addition the new sizing system solved problems observed during the size and fit evaluation as well. The researchers also developed same-size standards for each garment type to eliminate confusion of uniform size and established an idea of fit for each garment type.

Kinley (2003) studied the inconsistency that existed within size categories, and the difference in size of two different price points (expensive and inexpensive), and of two different types of labels (national and private) of women’s pants. The U.S. sizing system involved the use of a size code to direct customers to garments most likely to fit their body. For this the researcher measured the waist, crotch, and inseam of 1011 pairs of trousers. She observed inconsistency in each size category. The expensive pants were generally larger in measurements than the inexpensive pants but found little significant difference between national and private label merchandise except for sizes 4 and 6.

Simmons et al (2003) compared the body-scanning measurement extraction methods and terminology with traditional anthropometric methods. With the use of 3 D body scanners, body measurement techniques can be non-contact, instant and accurate. A total of 21 measurements were chosen as being critical to the design of well fitting garments. The body scanners were analyzed for availability of information, willingness, company cooperation and relevance to applications in the apparel industry. On each of the 21 measurements, standard measurement procedure was identified for three different scanners – TC², Cyberware and SYMCAD. Of the 21 measurements in the study, the TC² scanner was the scanner that had the most measures identified for the study and also had the capability of producing more applications specific to the garment Industry.
Ashdown et al (2004)\textsuperscript{12} used multiple measurements derived from scan data evaluation of size range, measurement specification and grading rules to get better fitting pants designed for a specific female target market. Two hundred and fifty five women were selected in the age group of 34-55 years in Misses 4-16 and women’s 14-24 sizes. Participants were scanned twice, once in minimal clothing and the second time in the best fitting size of test pants, selected by the researchers to fit at the hip. Software was used to merge, align and clean the scan data and to provide 3D visualizations of the scan data.

The visualizations of the scans showed the stress folds, distorted areas of the silhouette and the areas of misfit. Post scanning the data was processed.\textsuperscript{13} Critical fit locations were identified and overall back and front ratings were given. A panel of three experts assessed the fit of the pants using the scans. Twenty-six participants were scanned in more than just one size of pants if it seemed there was a question about which size fit best at the hip. The final sample size was 203 scans. The sample included 155 Misses size participants across seven sizes and 48 Women’s size participants across six sizes. There were less than 10 participants in each of the Women’s sizes to draw conclusions for the localized areas. Hence only the Misses sample was considered. As the scans could be rotated, the judges identified areas that fit most participants such as the front waist placement, hip front, and thigh front and back and the areas of more frequent misfit such as the waist front, crotch, back and overall back. Hip ratings were acceptable in most participants and the crotch back was clearly the worst rated area indicating a general pattern making problem. The overall poor ratings for the back compared to the front were also due to the misfit in the crotch back. The waist front and back ratings indicated that the pants fit less than half the participants acceptably being either too large or too small. On the other hand fit at the thigh was rated high for most participants. Thus the base pattern adjustments were made accordingly.

They also found more Acceptable fitting pant waists in sizes 4 and 6 and a larger number of Marginal and Unacceptable ratings for the waist in sizes 12, 14 and 16. The results were similar for the abdomen.
These results identified the size categories where the sizing system can be improved.

Loker et al (2004) studied the interest consumers had in the scan process, in being scanned, and in allowing retailers and manufacturers to use their scan data crucial to the commercial success of these applications. Two related studies were conducted. First, 203 female participants aged 35 to 55 were surveyed after they were scanned and viewed their scanned images on the computer monitor and in a movie file. For 22 of these participants, an observer also recorded their verbal and nonverbal responses to the scan process and viewing their scan. Although general acceptance of scanning was very high, women who were married and had over $100,000 household income were significantly less comfortable with some aspects of the body scan process. Observations of participants’ verbal, facial, and bodily expressions found some participants to be unsettled and unprepared for interactions with the unfamiliar yet personalizing technology.

Newcomb et al., (2004), studied the inadequacies of ASTM sizing standards at meeting the needs of consumers in three target groups, segmented by age – juniors, Missy and over 55. The size USA data, ASTM measurement data and the Body Shape Analysis software were used, to compare the body shapes that emerged in each group. The body measurements were translated into body shapes. Then the Size USA data containing measurements from 6300 women from all over the USA were retrieved and sorted by age into the above three groups. The stomach, hip, bust, high hip and waist measurements were extracted and processed using the FFIT for apparel software. However the results obtained were a preliminary indication of the body shapes that actually dominated the sizes studied. As the size USA was a representative of the population distribution of the US, this was extrapolated to describe the entire population. Finally graphs were produced showing the body shapes targeted by each ASTM standard, which were then compared to graphs showing the actual body shapes that predominated each group. The results were analyzed for each of the groups separately.

JUNIORS – After processing the ASTM through the FFIT it was shown that the measurements related to the hourglass figure. Thus the patterns made using ASTM
would best fit consumers with an hourglass figure. While the body shapes that predominate in the actual U.S. population showed the following- 52.9% of the samples were rectangular in body shape, 13.6% with spoon shape, 12.5% with hourglass body shape.

MISSY- Similarly the results from the ASTM measurements clearly targeted the hourglass figure, while the measurements from size USA revealed that 80% of the entire population was composed of people with rectangle, spoon or inverted triangle shape. The hourglass figure was only 8%.

OVER 55- This showed that the ASTM measurements fitted people with the spoon shaped body the best followed by the rectangle shape. Was also quite close to the size USA distribution as both primarily target rectangle and spoon shaped bodies. However clothes produced using the over 55 ASTM measurements would only fit 30% of the population.

The above study showed clearly why the clothes did not fit the population properly. It was found by the researcher that the Size USA provided more accurate details of the US population body measures than the earlier studies.

Simmons Et Al (2004) studied the sizing standards used in the United States. She observed that the body measurements used in the design and development of clothing was established from identified "best practices" of the industry. However the industry as a whole had not adopted a single system of clothing sizing. The retailers and the manufacturers used their own sizing systems as a differential advantage of their product in the market. All sizing systems were based on the myth that humans had mathematically proportional bodies and that they grew in proportional ways. In addition, the shapes and proportions of the population had changed from previous generations. So a variety of issues impacted the inability to fit the current American customer.

Mass customization methodologies provided customized fit of apparel, however alterations were extremely difficult. The researcher concluded that optimal customization could occur only if garments were made for each figure type. The researcher-developed software that could use 3D body scan data to define the shape of women. The researcher categorized the body types based on the measurements of bust, waist and hip, and the bust to waist ratio as compared to the hip to waist ratio as follows-
**Hourglass figure** – a small difference in the comparison of the circumference of hip and bust and the ratios of their bust to waist and hip to waist were almost same.

**Bottom hourglass** – larger hip circumference than bust circumference and the ratios of their bust to waist and waist to hip were significant enough to produce a definite waistline.

**Top Hourglass** – subjects had large bust circumference compared to the hip circumference and the ratios of the bust to waist and hip to waist were significant enough to produce a waist.

**Spoon** – larger circumferential difference in the hips and bust and bust to waist ratio is lower than the hourglass shape and the high hip to waist is great. This person had a shelf at the waist. The waist tapered from the bust yielding a waistline but starting at the waist going down the high hip and hip project straight out to the side, and not tapering.

**Rectangle** – Bust and hip measures were fairly equal and the ratios of the bust to waist and hip to waist were low, thus leaving no discernible waistline.

**Oval** – characterized by having several rolls of flesh around the midsection area, and the midsection appeared to be larger than the rest of the body

**Triangle** – larger hip circumference than bust and the ratio of the hip to waist was small. There was no defined waistline.

Of the 222 subjects, 40% were bottom hourglass, 22% hourglass, 17% spoon, 15% rectangle, and 4% oval.

This study helped ratify female body shapes and helped in future sizing for women based on their body shapes.

In a study by Simmons et al, (2004) on Female Figure Identification Technique for Apparel, she observed that the industry as a whole had not adopted a single system of clothing sizing. She also observed that clothing sizes used were based on biased studies that were decades old. She focused on determining whether the existing sizing systems used in the USA actually met the needs of the female population and developed sub groups that could aid in description of their various shapes. A sample size of 254 women was used. 21 measurements were taken which were then compared with the standard measurements and the best fitting standards closest to the subject’s body size.
was calculated. This was done in three ways: Percentage Difference, Tolerance Difference and Weighted Tolerance Difference.

PERCENTAGE DIFFERENCE - calculated the closest size based on the percentage difference between the subject's measurement and the standard. The least difference in value would be the Best Fit.

TOLERANCE DIFFERENCE – for each measurement a tolerance limit was given. The standard tolerance used in the industry was taken and then used. The closest was taken as the Best Fit.

WEIGHTED TOLERANCE - formula was developed to calculate the degree to which a measurement was out of tolerance with the standard. The least degree of difference was taken as the best fit.

The Best Fit results were as follows-

PERCENTAGE DIFFERENCE RESULTS - the standard that provided the best fit for over 44% of the subjects was the CS215-58 database. Despite the fact that 93% of the subjects measurements were greater than 5% larger than the standard.

Based on the above results, the researcher found that the past and current sizing standards were significantly insufficient at describing the body shapes and sizes of most of the subjects. Inconsistencies existed in more than 50% of the measurements compared within the size that was considered the best fit.

The researcher found that many subjects did not fit into earlier shape categories and thus created newer categories. In all nine shape categories were created which were hourglass, bottom hourglass, top hourglass, spoon, rectangle, oval, triangle and inverted triangle.

**Stock et al (2004)** factors associated with misconceptions of body shape for 1,1681 first year University students from Germany and Lithuania. They rated perception of body shape on a five-point scale. Multifactor logistic regression showed that the German students perceived themselves as being fatter than their BMI suggested compared to their Lithuanian peers. This was a big problem for the University students in Germany.

**Vinicus et al (2004)**, in their study, described the growth pattern of Japanese descendants in Sao Paulo, Brazil. Cross sectional data from 1297 subjects were
obtained from eight middle and upper middle class schools. The comparison between Japanese and European ancestry revealed lower mean values of weight and height throughout the growth period in the Japanese subjects. But these statistics were significant only after the beginning of adolescence. Boys of European ancestry were significantly taller from age 15 and heavier from age 17, while the European girls were significantly taller and heavier from ages 14 and 15. At age 17, the mean weight and height of Japanese boys was 64 kilograms and 170.4 cms while the European boys mean weight was 68.8 kilograms and height was 176.2 cms. For Japanese girls the mean weight and height were 52 kilograms and 160.4 cms, while the European girls were 56.1 kilograms and 164 cms.

Alexander et al (2005)\textsuperscript{4} explored the relationship between body type and fit preferences with body cathexis, clothing benefits sought by consumers, and demographic profiles of consumers. The majority of respondents were between the ages 18 and 28, affluent Caucasian Americans, with an hourglass body type, who had a family income of $85,000 or more and shopped in department or boutique/specialty stores. Significant associations were found between body cathexis (satisfaction with head/upper body, lower body, height, weight and torso) and body shape. The degree of satisfaction with different body parts depended on the body type of the individual. The level of satisfaction with head/upper body, height and torso did not vary by body type. No significant differences were found between fit preferences and body type for lower body garments. The researcher concluded that understanding the fit preferences of female consumers helped apparel companies to produce and meet demands for comfortable and well fitting clothes for women.

Chan et al (2005)\textsuperscript{25} investigated the prediction of shirt patterns for different body sizes using multiple linear regressions. A total of 29 pattern parameters from men’s tailor made shirt and 34 body parameters obtained from a body scanner were designed for analysis. Multiple Linear Regression was applied to examine the underlying relationship between shirt pattern parameters and body measurements. Compared with formulae from the pattern expert, the prediction of shirt pattern from MLR was greatly improved.
McRoberts (2005)\(^{137}\) investigated the fit and design with figure types and the variations for petite women, five feet four inches or under and between the ages of 20-49 years. She observed that only a very small offer was available for the petite sector in the domestic market. Other factors that contributed to this was the sizing systems based on outdated anthropometric data gathered in the 1930’s, rising obesity that led to an array of figure type variations ranging from apple shaped to pear shaped women as opposed to hourglass shapes that were popular earlier. Using proprietary database, patterns were developed, muslins created and the fit of the muslins on live models assessed by a panel of judges. Statistical analysis showed a sample in distribution most similar to the size 16 petite of the voluntary product standard PS 42-70, a pear like silhouette supported by the literature. This suggested that the prototypical pattern resulted in improved fit as compared to the pattern based on the earlier standards. The researcher concluded that that most respondents in this category did not have the figure types catered to by the industry and suggested new sizing standards.

Meunier et al (2005)\(^{138}\) analyzed the accuracy and precision of two dimensional, image based anthropometric measurements with traditional anthropometry. The accuracy was estimated using a database of 349 subjects (male and female) who were also measured traditionally and the precision was estimated through repeated measurements of both a plastic mannequin and a human subject. Six dimensions were selected because of their relevance to clothing sizing. The dimensions were: stature, neck, circumference, chest circumference, waist circumference, and hip circumference and sleeve length. The overall results did not indicate the presence of large systematic errors in the image-based system when compared to the manual measurements.

Schofield (2005)\(^{99}\) researched the relationship between grading, sizing and anthropometric data. Historically grading preceded size charts. She analyzed forty size charts for women’s clothing and the corresponding anthropometric research. She identified four structural assumptions that did not match the anthropometric research and developed criteria that were applied to upper torso measurements. Only 17% of the measurements were found useful for grade rule formation. The researcher compared the grade rules to size intervals from

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concurrent sizing standards and found that eleven of the thirty-eight grade rules corresponded to body measurements and six did not match the related size interval. The researcher recommended new measurements for grade rules.

Ashdown et al (2006) studied and compared the reliability and validity of trained paraprofessional judges responses and expert judges responses in a garment fit test. The study addressed the relationships among participant’s body and garment measurements; participant’s perceptions of garment fit and fit assessments of the trained and expert judges. Paraprofessional judges participated in fit training sessions. Judges assessed fit from the videotapes of the participants in test jackets, and made second assessment two weeks later. T-tests for paired samples were run for reliability between judge’s first and second evaluations. The trained paraprofessional judgments were equally reliable as the expert assessments. Validity was measured by comparing the differences of participant’s body measurements and test jacket measurements and the judges and the participants fit assessments of the test jacket. None of the measures (judge’s responses, subject’s responses, measurements) showed a very high level of agreement in fit assessment.

Ashdown et al (2006) studied the sophisticated new technologies available to the apparel industry to create automated custom-fitted clothing that would be within reach of apparel companies to successfully implement custom fit. This study explored issues in setting up a custom apparel patternmaking process using 3D body scanning and software designed to automate patternmaking. Questions related to measurement reliability and validity, data and knowledge needed to create and test required system variables, and fit preference issues were addressed in this study. A system for generating custom-fitted outerwear jackets was developed for an industry collaborator, Log House Designs, and tested on ten participants. The fit of the prototype custom jackets was compared to the fit of a set of ready-to-wear jackets. Seven of the ten participants preferred the fit of the prototype custom jacket; the remaining three were equally satisfied with both jackets. She concluded that new technology helped in developing better fit of garments.
Chattaraman et al (2006) examined the relationship between physical and psychosocial attributes of the body, and aesthetic attribute preferences in clothing. Building upon a clothing comfort model, she determined whether women’s aesthetic response to apparel was related to their body size, body cathexis and body image and provided insight into underlying patterns of similarity in their response. An Internet survey was administered to a random sample of 199 female undergraduate students. The results indicated that body image and body cathexis had a negative linear relationship with aesthetic preference in styling, implying that lower body image and body cathexis correlate with preference for greater body coverage through clothing and vice versa. Body size showed a positive linear association with styling preferences, implying that increase in body size correlated with preference for greater body coverage in clothing and vice versa.

Chi et al (2006) checked the validity of measurements of dynamic postures recorded by a body scanner. Measurements between various anatomical landmarks were taken both manually and using a 3D body scanner and the validity of the measurements assessed when dynamic postures were adopted. Mechanical measurements of changes in the body surface dimensions were compared with figures produced by the body scanner for both the standard natural posture and for five dynamic postures, which should be accommodated while designing high fashion garments. The researcher found that though the body scanner collected data almost instantaneously and without physical contact with the target surface, the readings taken in respect of the dynamic postures, showed significant variations from manually taken measurements. The discrepancies were 6.8 cms over a 16 cms distance. Thus the researcher concluded that the 3D Body scanner was best suited for taking measurements in the natural anatomical posture. The scanner was not suitable for taking measurements of dynamic postures.

In a study by Connell et al (2006), the physical and social-psychological dimensions of demand for apparel by tween boys (aged 9-14) of those who are overweight and obese were investigated. Sizing options for adolescents are not based on any anthropometric data that reflect the body size and shape changes
driven by puberty. Thus once a set of measurements is established, grade rules for expanding to additional sizes seem to consider that the tweens get taller and heavier with each size but there is no data to back this. Apparel for this age group was usually produced by tweaking the measurements used for older people. Thus each company used a unique set of body measurements. The data was gathered from a sample of 40-50 boys and their mothers through questionnaires and focus group discussions. The segments of younger (9-11) and older (12-14) tweens were divided into normal and plus size groups based on calculation of Body Mass Index (BMI). This study developed a foundation for sizing standards based on actual data for the emerging market.

Faust et al (2006)\(^{44}\) studied the weaknesses in women’s ready to wear size standardization charts, originating not only in the obsolescence of the data base but also in the non adherence of order initiators to the suggested standard sizes. Trouser manufacturers were selected so as to cover a full price range spectrum. The manufacturers confirmed the usage of the same measurements for all product lines. In store measurements were also done. Garments were chosen at random from the selection offered in store and measured systematically. The specifications provided by the order initiators, the standard measurements prescribed, and the garment measures were all measured. The investigators found that the order initiators did not adhere to the standard size charts and the garment manufacturers were incapable or unwilling to produce garments that meet the order initiators specifications. The researcher emphasized that the industry had to be forced to adhere to standardized size charts.

Salusso et al (2006)\(^{97}\) examined the Principal Component Sizing System (PCSS) methodology as an alternative approach to advancing the mathematical efficiency and effectiveness of apparel sizing for women 55 and older (Salusso-Deonier, 1982). The 1994 American Society for Testing and Materials (ASTM) national body measurement database for women 55 and older was classified using the PCSS method (ASTM, 2001). PCSS-55+ had a thickness-by-length structure similar to the current domestic sizing system. Only 25 sizes were needed to encompass the same range as compared to the 55 sizes within the
current sizing standard. The PCSS method correctly classified 95% of subjects within 25 size categories and demonstrated potential as an alternative method for creating a simplified and marketable apparel sizing systems. The investigator concluded that with appropriate methods and databases, revision of US. Apparel sizing for women of all ages could provide long awaited valid and reliable sizing.

Schofield et al (2006)\textsuperscript{100} investigated the relationships of sizing, body shapes, and pattern shape to pants fit for women 55 and older. She designed Test pants in two shape options (full/flat seat) in five sizes produced and tested them on 178 participants in five states. The Sizes were developed using ASTM D5586-94 data. Both the participants and experts evaluated the fit. It was observed that the participants with flatter seat shape were significantly more satisfied with fit at the hip which indicated that the introduction of a shape variable improved satisfaction with fit for population segments with equivalent body shape variations. Experts were more critical, and identified areas of variation that were not addressed in the study. Results highlighted the complexity of fit. The variations in body size, shape, proportion and posture made creation of effective ready-to-wear sizing systems with a practical number of sizes difficult. The researcher suggested provision of good fit which included creating sizing for a subset of mature women and developing custom fit methods.

Strydom et al (2006)\textsuperscript{110} studied the problems that the South African clothing Industry experienced with regard to body measurements needed for the manufacture of well fitting clothes. The researchers observed that problems of fit could not be addressed without reliable body measurements. They conducted a postal survey among the South African retailers and manufacturers, and included the entire population in it. The postal survey was succeeded by personal interviews. They used purposive sampling to identify 13 respondents according to set criteria. The results indicated that for a large proportion of vertical, horizontal and circumference measurements there were no international descriptions as to how the measurements were to be taken. The problems were related to land marking as to how and where the respondents should take their measurements.
Chen (2007)\textsuperscript{28} evaluated the fit of basic garments on ten Taiwanese students who represented various figure characteristics. Post scanning, the body measurements with additional functional ease were manually entered into the computer to generate the block patterns. The patterns generated were used to make basic garments worn by the subjects for fit evaluation. The researcher found that the ease tolerance allowed by the system had to be revised and additional measurements had to be included to get a good fit. It was also observed that students who exhibited multiple figure variation complicated the fitting problems. For example, sloped shoulder subjects with narrow shoulders and forward stance generated the problem of extra fabric gathering at the shoulder tips as well as looseness at the upper chest. The researcher used 3D body scanners combined with computer aided design systems for the above.

Chunga et al (2007)\textsuperscript{30} developed sizing systems for Taiwanese elementary and high school students. The anthropometric data of 7800 students covering their ages from 6-18 years for both genders was used in the study. The two-stage cluster analysis was used for the classification of figure types. The size charts were developed based on the morphological characteristics of each figure type. Twelve sizing systems were established systematically by age group (elementary-, junior high-school and senior high-school students), gender (male and female) and garment type (upper and lower garments). The coverage rate of the developed sizing systems was over 85%, and the number of sizing groups of each system was less than 36. In addition, an index of aggregate loss of fit was used to validate the size charts, and the results showed that all the developed size charts had a good fit. Moreover, the developed sizing systems were compared with the Korean Standards, and a similar trend was found.

Hsu et al (2007)\textsuperscript{56} developed of size-charts, using a cluster-based data mining approach. The database used was the anthropometric data of adult females in Taiwan. The advantages of using a data mining cycle are that a higher percentage of the population could be covered using fewer sizes. Since anthropometric databases need constant updating the size charts proposed could also be renewed using data mining. Owing to outdated and incomplete size charts for adult females in Taiwan, a large anthropometric database was created.
Direct anthropometric measurements were performed on each of the 986 females. 11 anthropometric variables were identified which included 7 linear and 4 girth measurements. The major anthropometric variables were bust girth, waist girth, hip girth, neck girth, bust width, back width and shoulder width. The others were body height, cervical height, arm length and back waist length. The most important factors were found to be girth and height for garment making. The total coverage rate of the size charts reached 95.8% with the total number of size groups being 58. The size charts were simple and easy to understand size labels to describe body dimensions enabled consumers to quickly find suitable clothes. They also provided the percentage of females within each size group, for every body type, as well as the distribution of body types.

**Hsu (2007)** studied the bust to waist girth ratio approach for identifying female body shapes. By applying the proposed approach, body shapes could be accurately classified to develop body measurement charts. He studied the anthropometric measurements of 542 Taiwanese females in the age group of 18-24 years. 44 anthropometric variables were measured using females with various careers. Post analysis the study identified 12 anthropometric variables commonly used for upper body clothing manufacture. These included six linear measurements and six girth measurements. The girth and height factor were identified as the two critical factors. The findings provided the important framework for the development of body measurement charts. The population was classified into three stature categories and four body shapes and new measurement charts were developed. The body measurement charts had a high coverage rate of 94.87%. The nine-body measurement charts included 35 sizing accommodation groups. It was observed during the study that Taiwanese females between 18-24 years of age tend to have medium and full bust body shapes in the measurement charts.

**Kim et al (2007)** presented a new methodology to generate basic patterns of various sizes and styles using three-dimensional geometric modeling method. The geometry of a garment was divided into the fit zone and the fashion zone. The geometry of the fit zone was prepared from 3 D body Scan data so that its size and shape could be modified in a parametric manner. The fashion zone was
modeled using various parameters characterizing the aesthetic appearance of garment silhouette so that the users could design various garments intuitively. Database management system for garment shape templates were developed so that the users could design various garments ranging from basic items to fancy items. Flat pattern projection algorithm was developed to make flat patterns considering the physical properties as well as producibility of garments.

Klerk et al (2007)\textsuperscript{66} studied the early-adolescent female consumer’s expectations and evaluation, as well as the satisfaction relating to the fit, as a dimension of the quality of her clothes. They used a structured questionnaire for collecting data. Their subjects were 120 13-year-old young female consumers known in the study as the early – adolescent female.

It was found that the young consumer was not only concerned about the functional aspects of fit but also about the emotional effect. It was further found they did not have the expertise and knowledge and the cognitive skills that could enable them, during the evaluation phase of the decision-making process, to realistically evaluate this very important dimension of the quality of clothes, with the main purpose of giving functional comfort and emotional pleasure during post purchase experience. Thus they were mostly dissatisfied with the fit of their clothes.

Kwok et al (2007)\textsuperscript{69}, presented anthropometric measurements of 42 premature infants nursed in the neonatal intensive care unit in Hong Kong. Birth information, including maturity, age, gender, birth weight and present weight, were recorded. About 13 body size measurements, including stature, hand girth, armscye girth, chest girth, arm length, max girth, abdomen girth, hand length and foot length were measured for each infant. Using these data, body size distribution, the correlation between each body size measurement, and linear regressions of weight and stature with other body size measurements were analyzed. The researchers found that the weight and stature of premature infants were the most desirable and significant size parameters for the development of measurement charts for premature infants.
Lee et al (2007)\textsuperscript{72} compared body shape between 6300 USA and Korean women. They analyzed the distribution and proportion of body shapes of the two countries and compared the differences of body shape according to age. They used the measurement data from the Size USA and Size Korea and evaluated the body shapes using the Female Figure Identification Technique. The samples were defined by shape and comparisons were made by the distribution according to age and country through statistical analysis. The investigators found that the largest shape category was the rectangle in both countries, but the distribution within each shape category for Korean women was different from that of the USA women. More body shape categories were found in the USA women than in the Korean Women. In addition, most body shape categories had different body proportions when comparing the USA and Korean women. The USA women had the higher measurements in the waist, high hips, and hip height and the larger measurements in the bust, waist, high hip and hip circumference. It was found that the subjects had over 50.2”of hip circumference, over 10” larger hips than bust circumference and over 15.5” larger hips than waist circumference. This study could impact the development of international sizing standards that could have significant impact on brands producing product for a variety of international consumers.

Pisut et al (2007)\textsuperscript{94} investigated the fit preferences of female consumers in the USA based on the relationship between their fit preferences, body cathexis, fit problems, and personal profiles. 1026 females in the ages of 19-54 were asked to respond to a questionnaire that was mailed to them. The questionnaire was used to evaluate consumer preferences for individual garment categories (jackets, pants, skirts, blouses and jeans) relative to the respondent’s personal profiles, body shapes and body cathexis. Eighty percent of the sample reported two or more areas of the body where fit problems occurred. One third of the respondents altered up to 25 percent of Ready To Wear clothes. Semi-fitted preferences for clothing were reported most often. A significant relationship was found between women who scored high on the body cathexis scale and those who desired more fitted clothing. Body shapes were fairly evenly distributed.
among all age categories, except for the 19-35 year old respondents who had an hourglass silhouette.

The investigators recommended that for this young consumer clothes should be specifically sized according to the measurements and figure proportions of the consumer.

Shin et al (2007)\textsuperscript{140} investigated the fit issues related to the current apparel pants and sizing system for diverse consumers, identifying body shape differences among ethnic groups. A total of 1335 women (misses figure type 2-20) were selected for the study. This figure type category is commonly used for adult women of average proportion and height. First the body dimension differences among ethnic groups were examined with a single factor analysis of variance. Second, the fit of pants and jeans for the diverse consumers within the same size category was examined with the current standard sizing system, ASTM D5585 for adult female Misses figure type sizes 2-20. Three cases were programmed within a database; when each consumer selects a size for a pair of jeans based on 1) waist size: 2) Hip size; 3) waist height.

The results were analyzed with fit comparison plots. She observed that current jean consumers were radically diversified in the US and globally as well. The study revealed that ethnic groups had different fit problems and significant body shape differences. Even within the same figure type size category, a variety of body dimensions existed in each ethnic group. According to the fit problem assessment in this study, consumers within the same body figure type size category did not find the right fit of the pants and jeans within the current sizing system. Half of the female consumers did not find a garment to fit based on waist height (pants length) because the current sizing systems overlooked the effect of diverse consumers. The researcher suggested standardizing organizations to modify current sizing systems for diverse ethnic consumer groups as a demographic factor so that apparel companies could provide better quality of fit for their consumers in the global and local market.

Daanen et al (2008)\textsuperscript{38} studied two methods of producing skirts based on 3D whole body scans. They linked 3D whole body scans to manufacturing techniques to allow mass customization of clothes. Three women were scanned with an accurate 3D whole body scanner. They derived a set of relevant ID
measures automatically from the scan. The measures were incorporated in a skirt pattern and the skirt was made of denim material. The second method was based on triangulation of the scanned waist-to-hip. The points in the 3D scan were first converted to triangles and these triangles were thereafter merged with neighboring triangles of similar orientation until about 40 triangles remained. These triangles were then sewn together to form a skirt. The researchers found that the fit of the 3D patchwork skirt was much better than the fit of the skirt generated by the ID measures. They found that in the latter case, two of the three skirts were too wide because the scan derived hip circumference exceeded the manually derived values. This study was the first to report a direct conversion from 3D scan to clothing without the interference of clothing patterns.

**Mason et al (2008)** studied the role that Kenyan female consumers sizing and fit knowledge played in the problems experienced when selecting apparel. They studied 201 female teachers from Nairobi, Eldoret and Kisumu in the ages of 25-55 years. Most Kenyan female consumers experienced problems in getting the right size of apparel while more than 90% were unsatisfied with the fit of their clothes. The consumers were ignorant about their own body dimensions as well as the size labels on ready-made apparel. Hence they blamed their bodies as well as the apparel companies for their problem. The researcher concluded that the Industry should not use size label information that is not clear, informative and understandable.

**Petrova (2008)** used three-dimensional body scanning technology to analyze fit of women's pants and to measure garment ease at various locations. She constructed special test pants with adjustable Velcro sections to provide custom fit for each study participant. Twenty-four subjects, ages 35 to 55, represented three body shape groups (straight, medium, curvy) determined by the hip-to-waist circumferences ratio, and four size groups covering Misses size range 4 to 16. Scans of the subject wearing minimal clothing and of the same subject wearing the test pant, adjusted by the researchers for best fit in a standing position, were compared. The differences between the pant and body scans (ease) were determined for circumference, slice area, surface area, and volume measurements at various locations and analyzed for size and shape
dependence. Decrease in percent ease differences with increasing size was observed for several variables; no clear dependence on shape was found. She proposed the use of size dependences for pattern grading with grade intervals variable by size and body location.

**Coruh (2009)** studied the ergonomics of jeans and the discomfort areas for the wearer of the product and proposed design changes in the patterns. The study was conducted in 1170 university students, 614 females and 556 males. 430 preferred low waist jeans, 705 normal waists and 35 preferred high waist. The four factors the researcher focused on were – discomfort of tightness, discomfort of stepping up stairs, discomfort of strain and discomfort of opening waist on the back. The researcher observed that women experienced discomfort where the waist opened at the back more than men. This was a cause of low consumer satisfaction. No correlation was observed between the height of the respondents and other factors. There was no correlation observed between the discomforts of stepping up the stairs, strain and weight. The participants who preferred high waist jeans experienced discomfort of tightness, stepping up stairs and strains more than the participants who preferred normal and low waist jeans. The opening of the jeans at the back was experienced more in the respondents who wore low waist jeans as compared to normal waist. The researcher recommended redesigning of the jeans patterns in order to overcome the problem of the opening at the waist at the back.

**Hsu (2009)** developed a data-mining framework based on two –stage cluster approach to generate useful patterns and rules for standard size charts. The researcher conducted an empirical study in the apparel industry to support his manufacturing decision for production management and marketing with various customers needs. Since anthropometric database must be repeatedly updated standard size charts can also be updated continuously using data –mining.

**Mpampa et al (2010)** derived a new method for the development of sizing systems for the mass customization of garments. The new method was derived by following the basic statistical analysis on the anthropometric data, which were supported by an iterative mass customization model, which introduced
satisfaction performance indices. This was applied successfully to an anthropometric data consisting of 12,810 Greek men. By this method the researcher was able to balance the number of sizes to be produced (production costs) and the percentage satisfaction of consumers. This method was used for male shirts, trousers and coats and could be applied other garment categories and target populations as well.

### 2.3 GLOBAL SIZING SURVEYS

These surveys are carried out which are backed and sponsored by the governments of their respective countries and supported by industry partners and academicians. These are large-scale studies and takes years to complete. They cover all age groups, ethnicities and the entire geographical regions. These studies are commercial and are sold to apparel companies who want to make use of the body dimensions.

In the paper published by Bharadwaj et al, (1986)\(^9\) reports on the anthropometric data collected on 4400 Indian Army Personnel and the utilisation of the same in evolving size rolls for the trousers and shirts. A bivariate frequency distribution of abdominal circumference and abdominal height indicated that the data could be grouped into 14 sizes and such grouping could provide good fitting trousers to 92.52% of the troops. For shirts, the bivariate frequency distribution of chest circumference and arm length grouped army personnel again into 14 sizes. Such grouping encompassed 84.22% of the personnel studied. An extra large size was provided for those not covered in the 14 sizes. For the study, 95 army officers clothing measurements essential for their good fitting trousers and shirts were taken along with the relevant body measurements. A stepwise linear regression analysis was also carried out to predict clothing measurements from body measurements. The regression equations were used to work out the
dimensions of the trousers and shirts for different sizes from the classified anthropometric data.

In (1998)\textsuperscript{127} the Computerized Anthropometric Research and Design Laboratory at Wright–Patterson Air Force Base in conjunction with industrial partners did an anthropometric survey of the Civilian Population called the Civilian American and European Surface Anthropometry Resource or CAESAR\textsuperscript{TM}.

The goal of CAESAR\textsuperscript{TM} was to represent the anthropometric variability of men and women, ages 18-65 in the United States and Europe. The approach was to start with the United States, the NATO member nation with the largest population, followed by the Netherlands, whose population contains the tallest people in the NATO on the average and Italy whose population contains some of the shortest people in the NATO. The sample size was 4000 for the United States and 2000 each for the other two countries. At least 10 Geographic States in the United States were surveyed from April 1998 to early 2000. Netherlands and Italy was done in late 2000. The data collection method was standardized and documented so that the database could be consistently expanded and updated.

The Department of Trade and Industry and Leading British retailers and academics undertook a collaborative UK National Sizing Survey in July (2001)\textsuperscript{134}. Over 1.5 million measurements were taken from more than 11,000 people across the UK using the (TC) 2 body scanners – a revolutionary three-dimensional scanning method. Volunteers were chosen across three national regions to represent both genders across seven age groups from 16 to 95 years taking into account the ethnicity and socio-economic factors. The important results were –

- All the measurements for women had increased compared to the 1951 data.
- Women in the UK were taller than the women in the USA.
- Based on BMI calculations it was found that 12\% of the women and 6\% men were underweight; 50\% women and men were normal; 38\% women and 44\% men were overweight or obese.
The Size USA survey, (September 2003) was an anthropometric research to gather measurements of the U.S. population. 10,000 subjects were scanned, grouped into gender, six age groups and four ethnicities obtained enormous information including zip code, annual household incomes, marital status, lifestyle, education, employment etc.

Salient findings of the study were –

- That the population had grown taller and heavier but were growing heavier than taller and the existing grade rules did not reflect this trend.
- People got larger as they grew older.
- Black women were larger than white and Hispanic women of similar ages.
- Waists increased the most with age.
- Women’s hips were larger than their bust, and hence were more pear shaped.
- Men’s chests are larger than their hips.

On completion of the above study (Size U.S.A. Survey) a comparative study was carried between the findings of Size U.S.A. and Size U.K. the findings revealed that -

- People in the UK were taller and larger than they were in the 1950’s.
- Men in the U.K were shorter and weighed less than the men in the US.
- Women in the U.K were taller and weighed less than women in the U.S.
- Young men had more muscle tone than older men regardless of their weight.
- Many people did not know their body measurements.

Anon, (2003) An American consultant mapped the vital statistics of Indian Women through an anthropometric study for a standard fit and size of the salwar – kameez, with the idea to mass-produce this traditional dress. The study was conducted for apparel manufacturer and exporter TCNS Clothing for its “W” range of salwar – kameez. About 2000 women in 40 metros were measured in India to analyze the shape and size of the salwar kameez. This study enabled the planned sizes to suit 96% of the population.
Anon, (2004)\(^{143}\) reported that the representatives from the clothing industry met at the second **National Sizing Forum in Melbourne** on May 11, 2004, with the purpose of undertaking a valid anthropometric study, which could be used as a new Standard for the Sizing of Women's Clothing.

The anthropometric study was needed for the following reasons-

1) The body range in every country is likely to be different. Relative body proportions vary with ethnic background, number of generations in a different country, nutritional status, gender and age.

2) The clothing Industry requires to know the average dimensions for Australians as a whole, plus the distribution and frequency of the different size dimensions and ages.

3) As a person's size varies from the average not all dimensions will change at the same rate. For example, a person more slender than average is likely to have arms that are proportionately shorter. Likewise, a person larger than the average is likely to have an upper- arm girth that is more than proportionately larger than the average. When the garment is designed it is done for the average of the target group and scaled up and down to fit the different sizes within the group.

4) As people age, gravity has more effect on some measurement points than others. Points such as the distance from the collarbone to the maximum breast point, or from waist to maximum hip girth tend to move slowly towards the ground. This has an effect on how clothing should be cut for those target groups if it is to fit and drape properly.

5) Garment designers need information on many more body measurements than would be used in a sizing scheme. A sizing scheme indicates the dimensions of the body that a garment is intended to fit.

6) The end result would be a set of standardized measurements, which the Industry used.

Anon, (2005)\(^{6}\) reported that the **Size Mexico Survey** was a result of the growing U.S. Hispanic population that was becoming a burden for the retailers. Whether the Hispanic consumer was the same shape and size as the traditional U.S. consumer, or whether the Hispanic consumer was the same as the Hispanic
living outside the US, was determined by research. Over 1000 scans were collected from a survey conducted at Guadalajara Mexico and compared and contrasted to the Size USA data. Researchers evaluated the body shapes of females in Mexico and compared them to the US Mexican Population and the US population.

The results showed that –

- The U.S women were taller and the hourglass shape was more prominent than in Mexico.
- Women in the U.S had bigger bust, waist, hip, thigh and calf measurements than young Mexican women. However with age the waist measurement of the Mexican women surpassed the waist measurements of the women in the U.S.
- However there appeared to be little difference in size and shape between the U.S. Mexican women and the Mexican women.

Ujevic et al, (2005)\textsuperscript{118} in a paper reported that more than twenty distinguished experts of different profiles took part in the realization of the project “Croatian Anthropometric System”. More than 200 mainly young people conducted Field anthropometric measurements across all Croatian countries and in the city of Zagreb. At the end of 2005, the project had encompassed 30,000 subjects from birth to the age of 82 years divided into 53 age groups or .67% of the total population. This was the first systematic anthropometric measurement in the Republic of Croatia based on ISO standards. The earlier measurements were conducted on only one area and on a smaller sample in 1961/62, which was the basis of the standardized system being currently used in the Republic of Croatia.

Grandys (2006)\textsuperscript{133} reported in a paper that the Polish Committee for Standardization, Polish Federation of Apparel and Textiles and Polish Chamber of Fashion and Industry Chambers, were undertaking the anthropometric study of the Polish population. The previous survey undertaken in Poland was in 1970 which was a joint project undertaken by the Research and Development Centre’s for the Clothing Industry, Knitwear Industry, Footwear Industry and the Polish Academy of Sciences in Warsaw. The results of this study were published in the
early eighties in the form of tables and giving the body dimensions of the Polish population. About 33-37 characteristics were made available to describe the body type. However this study was proved to be outdated as the body of the new generation of Poles was very different to the study - the generation was taller and better built. Hence new Anthropometric studies were a must. This was conducted using a 3 D body Scanner. The scientists at the Warsaw Technical Institute had developed a computer aided body measurement method. They scanned 20,000 people of both sexes.

Anon (2006)\textsuperscript{126} reported that Avalon who are the global size and fit expert in collaboration with the Institute Francais du Textile et de l'Habillement (IIFTH) created the Standard French sizes for the apparel industry. The study, conducted by the IFTH in 2006, included more than 11,500 scans of French citizens from 37 different sites in France, thus providing a powerful insight on how to improve fit for the French body for apparel brands both in France and outside. It was found largest percentage (20.6\%) of French females corresponded to a French size 40, and the largest percentage of men also corresponded to a Men’s size 40.

In a study by Gupta et al (2006)\textsuperscript{50} an algorithm was developed based on the Linear Programming approach developed specifically to cluster a given population data into homogenous body size groups. The theoretical efficiency was demonstrated on an anthropometric database of 1900 Indian women in the age group of 18-35 years. The mathematical tool developed is flexible enough to be adapted for use for mass production as well as mass customization of garments. It is extremely versatile in that specific garment size tables can be developed. The degree of fit desired at each body dimension as well as the body dimensions used as the basis of clustering can be changed with ease. It is also a great tool for inventory management as it gives exactly the number of people covered by each cluster thus giving the manufacturer and the retailer the choice of deciding how many pieces to make in each style and in what sizes

Anon (2006)\textsuperscript{143} reported on Australia's first large scale 3D body scanning project that was undertaken by the Australian Defense Force in conjunction with
the University of South Australia. The age group for the anthropometric study was 17-29. Two comprehensive anthropometric surveys were conducted in Australia since 2002. Both were undertaken as private ventures. In 2002, the National Size and Shape Survey of Australia measured 1408 volunteers. This data was however not accepted as a standard representation of the women of Australia.

Zheng et al, (2007) analyzed nude breast measurements from 456 subjects aged between 20 and 39. The investigators proposed a new bra sizing system for Chinese women. Since 1935, the bra sizing system was based on bust girth and under bust girth. Women's breast is however very complex 3D geometry, while the existing system was based on just two girth measurements and was not suitable for categorization of breast size for bras. The new system used under bust girth and the breast depth width ratio as the classifying parameters. They were identified through principal K-means cluster analysis as the two most critical parameters out of 98 measurements obtained from 3D body scanning and 5 supplementary manual measurements as well as other relevant breast parameters including breast angles, distance, width, thickness, volume and curvature.

Catan (2008) reported the largest study of its kind; Spain undertook the full-body laser scans of more than 10,000 women and compared the resulting three-dimensional measurements with clothes on the high street. The study found that women had three body types; a “cylinder”, in which the top, middle and bottom were broadly aligned, “hourglass” and “pear shaped”. About a third of the women fell into each category, though they tended to move from being cylinders to pears, as they got older. Women between the ages of 19 and 30 had the hardest time finding clothes that fit, mainly because they were too tight or small. Instead of European dress sizes such as 38,49 or 46, Spanish women will have new sizes, including measurements for height, hips, waist and bust. Once this new measurement system is successful, the men will be scanned in Spain.

The first traceable data on the anthropometric survey done in Australia was in 1926 when 6000 women were measured. This was the L9, AS1344 standard
developed at the request of the Apparel Manufacturers Association. Five figure types were defined via a scientific classification of body types: big abdomen, heavy bust, big hips, sways back and average proportions.

Anon (2008)\textsuperscript{132} reported that Alvanon, who are the global size and fit expert, announced the most extensive collection of body scan research in China. Over 28,000 people were scanned in four regions of the country at various urban retail shopping centers. The scanners captured 45 measurements per person, resulting in the largest body measurement study ever performed in China.

The research highlighted that
- Even where the average height in China was similar to the Western body stature, the core body shape in China was significantly smaller and more homogenous than in the markets of the U.S and Europe.
- Men have similar average heights in China and the U.S. but have dramatically different average chest and waist measurements as well as differences in average weight and body mass.
- Women in China have much narrower variances in bust, waist and hip measurements than those in the U.S.

One of the most dramatic statistics from China shows that over a span of a decade (1992-2002)
- The average height of children (2-18) increased by almost 1.5", nearly twice as high as the increase among U.S. children.
- While adults in China, at any given height, look quite different from adults in the West, children’s body shapes and sizes are converging at a very rapid rate.
- Average Chinese female Height 5’4”; Weight 125 pounds; Chest 31”; Waist 28” and Low Hip 35”.
- Average U.S. Female Height 5’4”; Weight 155 pounds; Chest 37”; Waist 34” and Low Hip 42”.
- Average Chinese Male Height 5’8”; Weight 145 pounds; Chest 35”; Waist 31” and Low Hip 36”.
- Average U.S. Male Height 5’9”; Weight 191 pounds; Chest 41”; Waist 37 and Low Hip 41”. (25)
Anon (2009) reported that the **Size Canada Project was started in** March 2008 and scheduled for completion by May 2009. Various companies in Canada had expressed interest in acquiring data on the shapes and sizes of Canadians in order to better understand the sizing requirements of the Canadian market. The last female sizing standards were established in 1958 and were based on an already two-decade-old American Survey.

- Most measurement charts described the female body using only three body measurements (bust, waist and hip circumference), which was truly insufficient to truly capture the specificity of a human body. Thus a large number of consumers did not “fit” the existing standard size charts.

- Often consumers left feeling confused about their actual size and frustrated by the inconsistent fits. Size Canada was conducted across the country, with a projected sample size of approximately 6000 men and women selected from about 10 major cities and representative of the Canadian population distribution in terms of age, ethnicity etc.