# The Importance of Anthropometric Data in Product Design

## INTRODUCTION

Anthropometry is a technique of measuring the human body in terms of dimensions, proportions, and ratios. Within the field of ergonomics, anthropometric data is extremely important in product design. Specifically, characteristics such as body size, strength, height, weight and range of motion are all considered when a product needs to be tailored to a particular user group. If no data is obtained or measurements are inaccurate, products may be designed in such a way that they are either unsafe or unpractical, which most likely would lead to a decrease in their sales. As a result, it is in the best interest of all companies to consider the appropriate anthropometric measurements when developing new products.

This report examines some of the human characteristics that are important when designing a stress ball for college students. In particular, 3 questions were examined:

> What are representative strength values, height and weight based on the population examined? What are the differences between men and women?
>
> What are the relationships between the anthropometric measures examined?
>
> What dimensions are recommended for the stress ball based on the data collected and other evidence?

## TEST PLAN

### Test Participants

One group of 12 participants, all of whom are currently enrolled in Ergonomics Laboratory 334 Section 003, was used for this study. Due to their class enrollment, all participants were volunteers and not-paid for their time.

Making up this group of participants were 8 women and 4 men who ranged in age from 20 to 22. Of the 11 right-handed and 1 left-handed participants, none claimed to have any hand injuries.

### Test Stimuli, Equipment, and Software

The test stimuli in this study were the protocols, or instructions for collecting data, that were used at each of the measurement stations. Since each participant had their height, weight, comfortable grip strength and maximum grip strength measured in this study, 4 different protocols were used. Each of the 4 protocols, plus a general introduction to the study, was written by the experimenter and all protocols were tested so they were as methodologically rigorous as possible. Summaries of each of the 4 protocols and the study introduction can be found in the Test Activities and Their Sequence section of this report.

The test equipment for this study included a Technasonic Weight Talker II scale, used to measure the weight of each participant, a model 0955 Invicta Plastics Limited standing anthropometer, used to measure the height of each participant and a model 5001 Grip A Takei Physical Fitness Test that was used to measure both the comfortable and maximum grip strength of each participant. In addition, a pencil and paper were used to record all participant data. No test software was used in this study.

**Test Activities and Their Sequence**

On October 25, 2005 from approximately 6:02 PM to 6:50 PM anthropometric measurements were taken on 12 participants in room G699 IOE at the University of Michigan Ann Arbor.

The study began with the experimenter giving a brief introduction of the study to each participant. After attaining the participant's first name and thanking them for their time, the participant was told the study was being conducted by IOE Balls Models, a company that produces stress balls. They were also told that by participating in the study, which consisted of taking 4 anthropometric measurements, they would be helping IOE Balls Models to design the most effective stress ball possible. Finally, after the participant was told the study was risk free, the participant was given the chance to express their questions and concerns to the experimenter. It is important to note that throughout this introduction process, the experiment maintained a positive demeanor.

The first station the participant visited was the weight station, which held the Technasonic scale. After the scale was turned on by the experimenter, the participant was asked to "remove their shoes and any excess clothing". Next, after the experimenter tapped the start button on the scale with their foot, the participant was instructed to "step on the scale and to remain standing up straight and as still as possible until the scale verbally acknowledged their weight". After the experimenter recorded the weight value, the participant was told they could "step off the scale and collect their personal items".

The second station the participant visited was the height station, which held the Invicta Plastics standing anthropometer. After the green measurement disk was placed at the maximum height of 207 cm by the experimenter and the participant had again taken off their shoes, the participant was asked to "stand with their feet on the green platform, as straight and as still as possible, with their back against the anthropometer". The experimenter then lowered the green measuring disk so it touched the top of the participants head and recorded the height value to the closest tenth of a centimeter. Upon completion of this task, the participant collected their personal items.

Next, the participant visited the grip strength station which was equipped with a Takei grip dynamometer to measure their comfortable and maximum grip strength. Comfortable grip was measured first by means of 3 trials. For each trial, after the experimenter had reset the dynamometer to a value of 0 by turning the center knob counterclockwise, the participant was told to grip the device with their "writing hand" to hold the dynamometer "downward and approximately 6 in away from the body ". Next, the participant was told to "slowly squeeze the device until slight pressure was felt in the palm of their hand and at that point to release their grip and hand the device to the experimenter". The experimenter then recorded the strength value to the nearest quarter of a kg and reset the device for the next trial. After the 3 comfortable grip strength trails were completed, the participant's maximum grip strength was measured. This was done by having the participant hold the device in the same manner, but instead instructing them to "exert full force on the device by squeezing their hands together (as if they were juicing a lemon)". After allowing the participant to exert force for 3 seconds, which was thought to allow enough time for build up to maximum force, the dynamometer was returned to the experimenter who recorded the maximum strength value to the nearest quarter of a kg.

Finally, before the participant left the study site, the participant was asked to provide their age and that value, along with the sex of the participant was recorded by the experimenter.

## RESULTS

Representative height, weight, comfortable and maximum grip strength values for the participants in terms of means and standard deviations are shown in Table 1. Values are shown in this format, because if one knows the mean and standard deviation of a characteristic, they can calculate percentiles values by using the appropriate z-score, which is important in product design. Table 1 also displays the means and standard deviations for the 4 measured characteristics for men and women participants separately. It is important to break the population into men and women subgroups, because in this case, women made up 2/3 of all participants which could skew the overall participant population statistics.

Table 1. Participant Anthropometric Data

| | Total Population | | Men | | Women | |
|---|---|---|---|---|---|---|
| Measurement | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation |
| Height (cm) | 165.6 | 10.2 | 172.0 | 10.8 | 162.4 | 8.9 |
| Weight (kg) | 68.0 | 12.0 | 68.5 | 8.0 | 68.0 | 14.0 |
| Comfortable Grip Strength (kg) | 10.25 | 5.00 | 11.00 | 7.50 | 9.75 | 4.00 |
| Maximum Grip Strength (kg) | 31.25 | 7.25 | 36.75 | 2.25 | 28.50 | 7.50 |

As can be seen from the table, the total participant population has a mean height of 165.6 cm, a mean weight of 68 kg, a mean comfortable grip strength of 10.25 kg and a mean maximum grip strength of 31.25 kg.

In terms of the differences between men and women, the 2 groups differ in each of the measurement categories. Looking at the mean values, it can be seen that the men participants in the study are an average of 9.6 cm taller and .5 kg heavier than the women participants. These findings support the idea that the average man is both taller and heavier than the average woman. Men participants also had a comfortable grip strength 1.25 kg larger than the women and had a maximum grip strength 8.25 kg larger than the women. Again, this data coincides with the idea that the average man is stronger than the average woman.

In order to determine the relationships between the anthropometric measures that were examined, the coefficient of determination was calculated for each possible measurement pair (6 total pairs). The coefficient of determination, or an R squared value, is an indicator of whether or not there is a good relationship between two variables. An R squared value of 1 indicates a perfect relationship while an R squared value of 0 indicates no relationship. Table 2 shows the R squared values for each measurement pair based off the data from all 12 participants.

Table 2. Coefficients of Determination for Anthropometric Measurements

| Measurements | R squared value |
|---|---|
| Height vs. Weight | 0.38 |
| Height vs. Comfortable Grip Strength | 0.17 |
| Height vs. Maximum Grip Strength | 0.46 |
| Weight vs. Comfortable Grip Strength | 0.05 |
| Weight vs. Maximum Grip Strength | 0.49 |
| Comfortable vs. Maximum Grip Strength | 0.06 |

As can be seen from above, the anthropometric measures examined in this study have very weak relationships with each other. The 2 strongest relationships are those between height and maximum grip strength with an R squared value of .46 and weight and maximum grip strength with an R squared value of .49. Since an R squared value of 1 means that two variables have a perfect relationship, these two relationships are only mediocre. In addition, the 2 weakest relationships are those between comfortable grip strength and maximum grip strength with an R squared value of .06 and weight and comfortable grip strength with an R squared value of .05. It is important to note that for this analysis, since the number of participants was small, the R squared values for the men and women subgroups were not examined. Furthermore, since all participants fell into an age range of only 2 years, age was not considered when determining the relationships between anthropometric measures.

In order to determine recommended dimensions for the stress ball, maximum and comfortable grip strengths of the participant population must be considered as well as hand breadth (which is the distance across the palm of a hand). Since a stress ball should be designed to comfortably fit in the hand of the maximum number of users, the $5^{th}$ percentile woman measurement will be used for hand breadth. Since this particular measurement was not obtained during the study, the measurement was obtained from the Eastman Kodak Company and was found to be 6.8 cm. With respect to grip strength, the stress ball should be designed so the $50^{th}$ percentile individual can compress the ball completely and the $5^{th}$ percentile woman can grip it comfortably. By using the mean and standard deviation values found above, as well as the percentile formula (percentile = mean + z*standard deviation), the $50^{th}$ percentile value for maximum grip strength was found to be 31.25 kg and the $5^{th}$ percentile woman comfortable grip strength was found to be 3.17 kg. Thus, in order to appeal the largest number of users, the stress ball should be designed so that it is 6.8 cm in diameter and made of a material that starts to compress at 3.17 kg of strength but does not completely compress until 31.25 kg of strength have been applied.

## CONCLUSIONS

After collecting anthropometric data from 12 participants, the data was analyzed in order to determine representative height, weight, comfortable and maximum grip strength measurements for young adults. From the data attained the mean values of these 4 measurement categories were 165.6 cm, 68 kg, 10.25 kg and 31.25 kg, respectively. Since these values are based of a small population, they most likely would change dramatically if more participants were measured.

Since it is important in product design to know the measurement differences between men and women users, participant data was separated by sex and reanalyzed. As can be expected, on average the men participants were taller, weighed more, and had higher comfortable and maximum grip strengths than women participants. However, since the number of participants was low, the difference between the values was reasonably small. In regards to weight, for example, the average man participant weighed only .5 kg more than the average woman, which is likely to be much less than the true difference in weight between men and women over a larger population.

In order to determine what kind of relationships existed between the tested anthropometric measures, R squared values were calculated for each of the measurement pairs. Since the 6 obtained R squared values ranged from .05 - .49, all well below the perfect R squared value of 1, it can be stated that no strong relationships existed between any of the 4 measures. Since this conclusion does not mirror ideal data where values such as height and weight would have a higher R squared value, the error can be attributed to the fact that the number of participants was small and the data was likely skewed.  Thus, if a larger participant population was tested, more complex relationships between height, weight, comfortable grip strength and maximum grip strength would likely be discovered.

In order make recommendations for the dimensions of the stress ball, both comfortable and maximum grip strength of the participant population had to be considered as well as hand size. Since this study did not measure the palm size of the participants, this data was obtained from an outside source. Next, the percentiles for which the different stress ball dimensions would be designed for were logically determined, and in this case were $5^{th}$ percentile women for hand breadth, $5^{th}$ percentile women for comfortable grip strength and $50^{th}$ percentile men/women for maximum grip strength. These percentile values were calculated using the percentile formula and the known population means and standard deviations. The obtained values lead to the recommendation that the stress ball that have a diameter of 6.8 cm and be made of a material that starts to compress at 3.17 kg of strength but does not completely compress until 31.25 kg of strength had been applied. It should be noted that the recommended dimensions would generate a stress ball that would be best suited for the study participants, but not necessarily for the larger population. In order to determine those dimensions, a larger scale analysis would need to be completed.

The results of this study might be challenged on the basis that the population tested was small and not random (all participants enrolled in the same course). Also, the fact that women and men were not equal in number could have greatly skewed the overall participant population statistics and thus the stress ball design dimensions. In addition, the protocols for each of the stations could have lead to error, since participants may have interpreted the instructions differently.  Finally, errors in manually reading the standing anthropometer and grip dynamometer, experimenter inconsistencies between participants, the fact the scale was not calibrated or checked for accuracy and individual participant differences could have lead to error as well.

In conclusion, anthropometric measurements are an important factor to consider when designing a product. By knowing mean values for the body size, strength, height, weight and range of motion of a target user group, companies can tailor product dimensions to best fit the group. Unfortunately, if these measurements are not taken into account, products may become either unsafe or hard to use, which of which are undesirable to consumers. As a result, in order to keep their products safe and useful for the broadest range of users, it is important for companies to design products using appropriate anthropometric data measures.