

Athletic Sizing Based on Performance

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Abstract

For many sportswear companies, the sizing of athletic garments follows the same guidelines as sizing for everyday casual garments. This research team feels this is not a precise way to size clothing for athletes as their body shapes tend to be different than that of the general population. Elite athletes' body shapes and sizes are similar depending on the sports they partake in. Proposed in this paper is a new sizing system for athletes based on athletic performance.

In order to appropriately create a size distribution for athletes, specific data on athlete body types and performance must be gathered. Researchers at NCSU have collected data sets to find these details by scanning athletes at a sprint triathlon in the Raleigh, North Carolina area. The research team chose to collect scans at a sprint triathlon because it is significantly shorter than a full triathlon, which will encourage people of all body types to participate, and because it allows for collection of data for running, swimming, and cycling.

Participants were scanned using the Vitus Smart XXL laser body scanner provided by Human Solutions. This is a laser-based body scanner made by Human Solutions Assyst AVM. The Vitus Smart XXL is ideal for this research because it uses the optical triangulation method with four separate lasers to find measurements that are accurate to +/- 1 mm. (Human Solutions, 2002). The scans taken after the race were compared to the athletes' finishing times. The sample of runners have been segmented into groups based on their finishing times. The scans within each group were averaged into one avatar with Human Solutions' Anthroscan Scan Database software. These avatars represent each group's average measurements. Each segment has a significantly different body type, which has been converted into measurements for sizing. By using this segmented population that were not adverse to body measurement we believe we can develop a more uniform sizing criteria that could then benefit other segmented groups.

Keywords Athletic, size, fit

1. Process and Methods

The ANTHROSCAN Survey Software is capable of statistical evaluation and analysis for very large data sets. Scans are saved as BLOB's (Binary large objects) directly in the database. The database table spaces hold scan measurement data, socio-demographic data and user defined data parameters. Common data import structures allow central data processing regardless of the scan location. The solution is characterized by three sections, a set up and definition section, a data management section for scan selection, and a report generation with an analysis section with statistic tools with graphical representation.

On August 17th, 2014 a team from Human Solutions and North Carolina State University's College of Textiles attended the Rex Wellness Sprint Triathlon in Raleigh, North Carolina to scan triathlon participants with a VitusSmart XXL body scanner. Each participant willing to be scanned went through a similar process: upon approaching the tent, they were asked to sign a consent form and complete a short survey of questions to gather information such as participant number, age, number of races run per year, and what race they are attending next. Once they stepped into the enclosed scanning space a researcher requested that they remove all loose-fitting clothing and stand on a short platform with their arms slightly away from the body. Researchers then began the twelve-second scan. At the conclusion of the scan, participants exited the scanning area and were welcome to take some of the pre-packaged refreshments provided for them.

The Rex Wellness Sprint Triathlon consisted of a 250 yard swim, a ten mile bike ride, and a 3.1 mile run. The start times of the race began at 7 a.m. and were staggered throughout the morning. Though the research team had originally intended to scan participants before the race, it was observed that participants were eager to spend their pre-race time preparing, stretching and watching others with earlier start times begin. The most active scanning period was the time after participants finished the race until the time that the awards ceremony began. During this period the researchers collected 83 scans. Four of these scans did not have useable scan data and five did not have useable finishing times, which left 74 complete scans for analysis. The total number of participants over 18 years old that finished the race is 341, therefore, 22% of available participants were sampled.

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2. Analysis

Of the 74 complete scans collected, 44 scans are of men and 30 are women. Their overall finishing times are fairly evenly spread, with men's times ranging from 50-85 minutes and women's times from 55-103 minutes (see Figures 1 & 2).

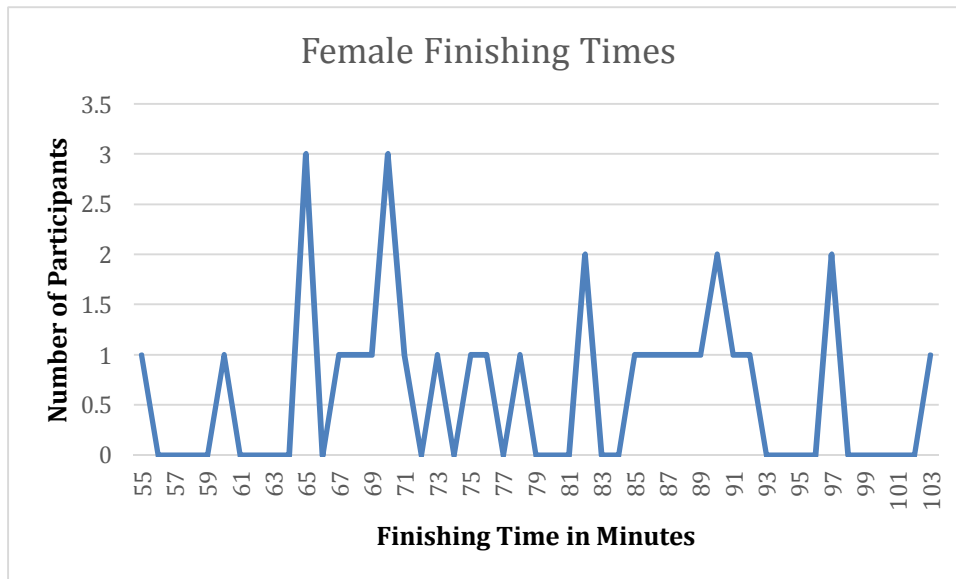


Figure 1: Female Finishing Times

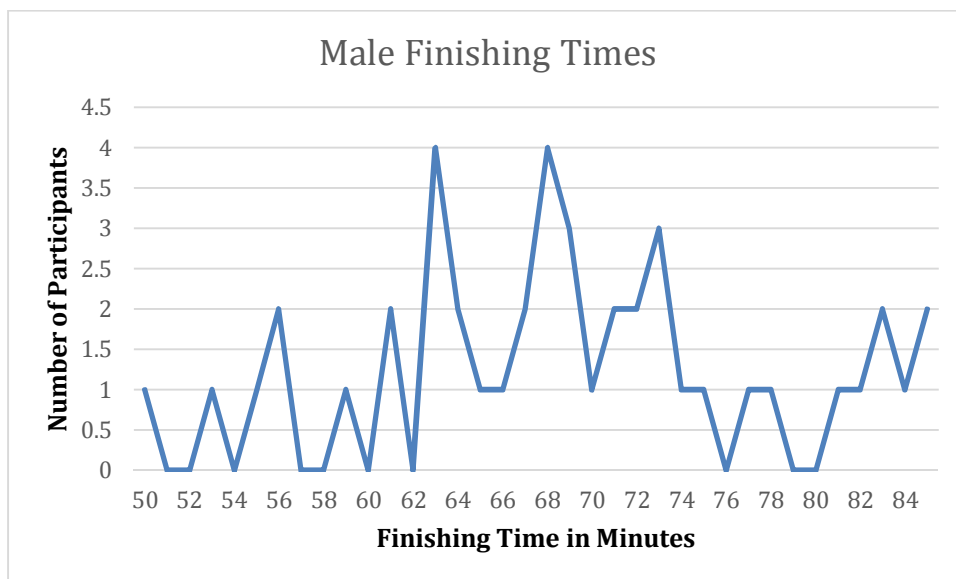


Figure 2: Male Finishing Times

Using an Anthroscan software to create average avatars, researchers compiled the scans of the top and bottom three finishers for both men and women. This software uses a PCA (principal component analysis) method, which analyzes each body part individually and compiles the results into one averaged avatar. Figure 3 shows the scans of the top three female competitors and their corresponding averaged avatar in gold.

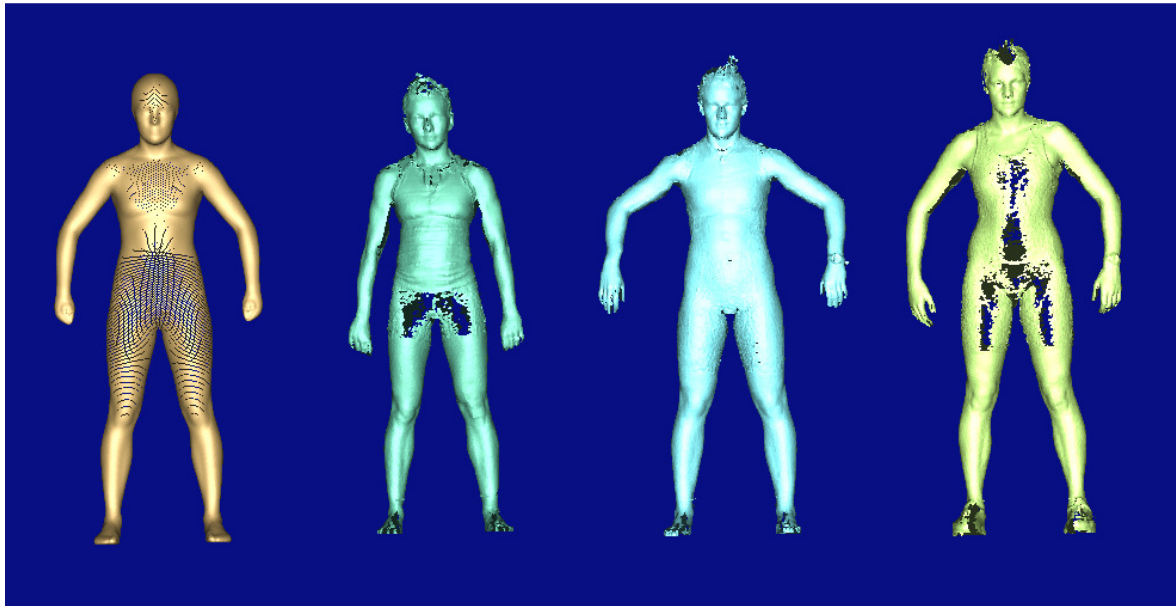


Figure 3: Average Body Data for Top 3 Finishing Females

Researchers used this avatar averaging tool to create several average body avatars that were measured and compared to demonstrate the differences in body types scanned at this event. The groups examined were the three males and three females with the fastest finishing times and the slowest finishing times. Figures 4-7 and tables 1-4 examine these avatars and their measurement differences.

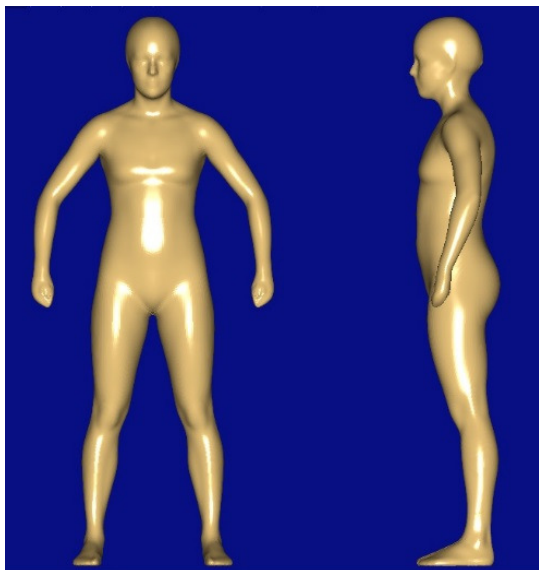


Figure 4: Top Three Finishing Females

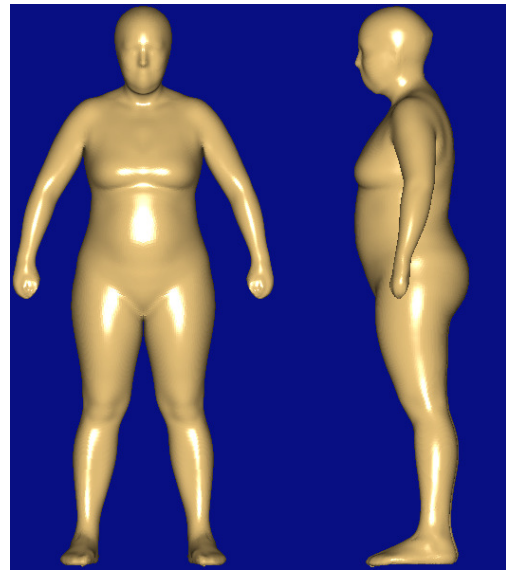


Figure 5: Last Three Finishing Females

Table 1: Top three women sample measurements

Measurement Names	Measurement IDs	Inch Measurements	Measurement Names	Measurement IDs	Inch Measurements
Body height (in)	10	63.95	Bust/chest girth (horizontal) (in)	4510	33.69
Head height (in)	20	9.39	Bust/chest girth (in)	4515	32.97
Neck height (in)	30	54.56	Underbust circumference (horizontal) (in)	4520	29.53
Distance neck to buttock (in)	40	21.79	Across back width (in)	5010	14.36
Distance neck-knee (in)	50	37.09	Across back width (armpit level) (in)	5020	13.95
Distance waist-knee (in)	60	23.26	Waist to buttock (in)	5080	8.14
Distance waistband-knee (in)	65	21.45	Distance waistband - buttock (in)	5085	6.15
Hip height (in)	95	30.21	Crotch length (in)	6010	28.45
Crotch height (in)	100	29.21	Crotch length, front (in)	6011	13.67
Knee height (in)	110	17.47	Crotch length, rear (in)	6012	14.78
Upper torso torsion (°)	996	0	Waist girth (in)	6510	27.94
Distance crotch to waistband (in)	997	9.59	Middle Hip (in)	6512	32.35
Neck diameter (in)	1010	4.65	High waist girth (in)	6515	27.94
Mid neck girth (in)	1510	12.71	Waist band (in)	6520	29.69
Neck at base girth (in)	1520	14.69	3D waist band (in)	6525	29.68
Head circumference (in)	1530	22.75	Waist to hip/thigh left (in)	7020	23.56
Torso width at waist (in)	2030	12.05	Waist to hip/thigh right (in)	7021	23.47
Total torso girth (in)	2510	57.89	High hip girth (in)	7510	31.04
Cross shoulder over neck (in)	3010	15.13	Buttock girth (in)	7520	36.06
Cross shoulder (in)	3020	16.83	Hip girth (in)	7525	37.34
Shoulder width left (in)	3030	5.32	Hip/thigh girth (in)	7530	36.9
Shoulder width right (in)	3031	5.1	Belly circumference (in)	7540	30.2
Shoulder angle left (°)	3910	27.3	Maximum belly circumference (in)	7545	30.72
Shoulder angle right (°)	3911	27	Arm length to neck back left (in)	8010	28.64
Across front width (in)	4010	13.19	Arm length to neck back right (in)	8011	28.67
Width armpits (in)	4020	13.61	Arm length to neck left (in)	8020	26.34
Bust points width (in)	4030	7.16	Arm length to neck right (in)	8021	26.25
Neck right to waist over bust (in)	4040	15.41			
Neck front to waist (in)	4050	11.94			

Table 2: Last three women sample measurements

Measurement Names	Measurement IDs	Inches Measurement	Measurement Names	Measurement IDs	Inches Measurement
Body height (in)	10	64.28	Bust/chest girth (horizontal) (in)	4510	40.69
Head height (in)	20	8.98	Bust/chest girth (in)	4515	40.65
Neck height (in)	30	55.3	Underbust circumference (horizontal) (in)	4520	36
Distance neck to buttock (in)	40	21.88	Across back width (in)	5010	16.26
Distance neck-knee (in)	50	37.49	Across back width (armpit level) (in)	5020	15.86
Distance waist-knee (in)	60	22.24	Waist to buttock (in)	5080	7.05
Distance waistband-knee (in)	65	21.5	Distance waistband - buttock (in)	5085	5.89
Hip height (in)	95	31.84	Crotch length (in)	6010	31.46
Crotch height (in)	100	28.12	Crotch length, front (in)	6011	15.16
Knee height (in)	110	17.81	Crotch length, rear (in)	6012	16.3
Upper torso torsion (°)	996	0	Waist girth (in)	6510	36.79
Distance crotch to waistband (in)	997	10.63	Middle Hip (in)	6512	41.29
Neck diameter (in)	1010	4.83	High waist girth (in)	6515	36.24
Mid neck girth (in)	1510	14.6	Waist band (in)	6520	37.86
Neck at base girth (in)	1520	16	3D waist band (in)	6525	37.85
Head circumference (in)	1530	23.55	Waist to hip/thigh left (in)	7020	25.19
Torso width at waist (in)	2030	17.65	Waist to hip/thigh right (in)	7021	25.19
Total torso girth (in)	2510	65.28	High hip girth (in)	7510	38.64
Cross shoulder over neck (in)	3010	16.32	Buttock girth (in)	7520	43.88
Cross shoulder (in)	3020	18.11	Hip girth (in)	7525	44.35
Shoulder width left (in)	3030	5.68	Hip/thigh girth (in)	7530	41.14
Shoulder width right (in)	3031	5.41	Belly circumference (in)	7540	37.71
Shoulder angle left (°)	3910	24	Maximum belly circumference (in)	7545	38.28
Shoulder angle right (°)	3911	24	Arm length to neck back left (in)	8010	28.16
Across front width (in)	4010	15.06	Arm length to neck back right (in)	8011	28.75
Width armpits (in)	4020	18.42	Arm length to neck left (in)	8020	25.73
Bust points width (in)	4030	7.96	Arm length to neck right (in)	8021	25.95
Neck right to waist over bust (in)	4040	17.65	Arm length to neck back right (in)	8011	28.75
Neck front to waist (in)	4050	13.66			

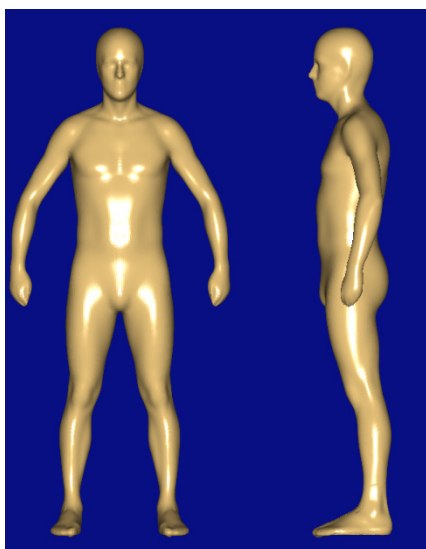


Figure 6: Top Three Finishing Males

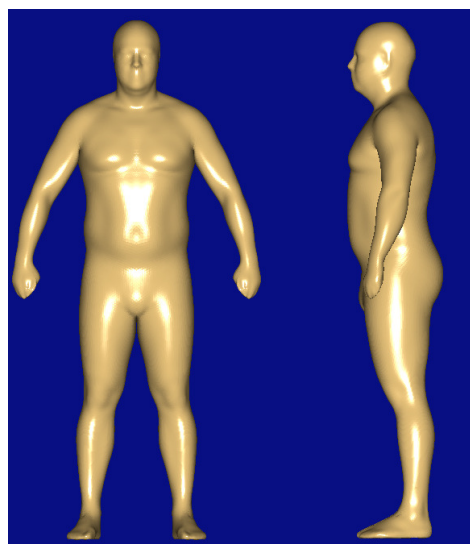


Figure 7: Last Three Finishing Males

Table 3: Top three men sample measurements

Measurement Names	Measurement IDs	Inch Measurements	Measurement Names	Measurement IDs	Inch Measurements
Body height (in)	10	70.29	Bust/chest girth (horizontal) (in)	4510	38.58
Head height (in)	20	10.1	Bust/chest girth (in)	4515	38.52
Neck height (in)	30	60.18	Underbust circumference (horizontal) (in)	4520	36.37
Distance neck to buttock (in)	40	24.7	Across back width (in)	5010	15.39
Distance neck-knee (in)	50	41.27	Across back width (armpit level) (in)	5020	14.84
Distance waist-knee (in)	60	25	Waist to buttock (in)	5080	8.55
Distance waistband-knee (in)	65	22.07	Distance waistband - buttock (in)	5085	5.5
Hip height (in)	95	32.93	Crotch length (in)	6010	31.88
Crotch height (in)	100	30.99	Crotch length, front (in)	6011	16.24
Knee height (in)	110	18.91	Crotch length, rear (in)	6012	15.64
Neck height front (in)	180	57.02	Waist girth (in)	6510	32.44
Upper torso torsion (°)	996	0	Middle Hip (in)	6512	33.08
Distance crotch to waistband (in)	997	9.47	High waist girth (in)	6515	32.97
Neck diameter (in)	1010	4.92	Waist band (in)	6520	32.54
Mid neck girth (in)	1510	14.36	3D waist band (in)	6525	32.54
Neck at base girth (in)	1520	16.52	Waist to hip/thigh left (in)	7020	24.3
Head circumference (in)	1530	23.7	Waist to hip/thigh right (in)	7021	24.3
Torso width at waist (in)	2030	14.72	High hip girth (in)	7510	32.65
Total torso girth (in)	2510	66.66	Buttock girth (in)	7520	37.43
Cross shoulder over neck (in)	3010	16.8	Hip girth (in)	7525	38.51
Cross shoulder (in)	3020	18.68	Hip/thigh girth (in)	7530	38.08
Shoulder width left (in)	3030	5.98	Belly circumference (in)	7540	32.6
Shoulder width right (in)	3031	5.92	Maximum belly circumference (in)	7545	32.63
Shoulder angle left (°)	3910	27.4	Arm length to neck back left (in)	8010	31.76
Shoulder angle right (°)	3911	26.8	Arm length to neck back right (in)	8011	31.78
Across front width (in)	4010	15.5	Arm length to neck left (in)	8020	29.32
Width armpits (in)	4020	16.2	Arm length to neck right (in)	8021	29.33
Bust points width (in)	4030	8.31			
Neck right to waist over bust (in)	4040	17.76			

Table 4: Final three men sample measurements

Measurement Names	Measurement IDs	Inch Measurements	Measurement Names	Measurement IDs	Inch Measurements
Body height (in)	10	69.99	Bust/chest girth (horizontal) (in)	4510	46.3
Head height (in)	20	9.27	Bust/chest girth (in)	4515	46.05
Neck height (in)	30	60.71	Underbust circumference (horizontal) (in)	4520	42.67
Distance neck to buttock (in)	40	25.06	Across back width (in)	5010	18.82
Distance neck-knee (in)	50	41.71	Across back width (armpit level) (in)	5020	18.72
Distance waist-knee (in)	60	25.1	Waist to buttock (in)	5080	8.86
Distance waistband-knee (in)	65	21.07	Distance waistband - buttock (in)	5085	4.42
Hip height (in)	95	33.1	Crotch length (in)	6010	36.93
Crotch height (in)	100	29.69	Crotch length, front (in)	6011	18.57
Knee height (in)	110	19	Crotch length, rear (in)	6012	18.36
Neck height front (in)	180	57.29	Waist girth (in)	6510	39.5
Upper torso torsion (°)	996	-0.1	Middle Hip (in)	6512	40.3
Distance crotch to waistband (in)	997	9.33	High waist girth (in)	6515	39.26
Neck diameter (in)	1010	5.61	Waist band (in)	6520	38.94
Mid neck girth (in)	1510	17.3	3D waist band (in)	6525	38.94
Neck at base girth (in)	1520	19.12	Waist to hip/thigh left (in)	7020	27.22
Head circumference (in)	1530	23.07	Waist to hip/thigh right (in)	7021	27.05
Torso width at waist (in)	2030	17.89	High hip girth (in)	7510	40.74
Total torso girth (in)	2510	73.94	Buttock girth (in)	7520	41.31
Cross shoulder over neck (in)	3010	18.14	Hip girth (in)	7525	42.17
Cross shoulder (in)	3020	20.61	Hip/thigh girth (in)	7530	41.16
Shoulder width left (in)	3030	6.09	Belly circumference (in)	7540	40.74
Shoulder width right (in)	3031	6.09	Maximum belly circumference (in)	7545	40.77
Shoulder angle left (°)	3910	26.7	Arm length to neck back left (in)	8010	32
Shoulder angle right (°)	3911	26.7	Arm length to neck back right (in)	8011	32.31
Across front width (in)	4010	17.17	Arm length to neck left (in)	8020	29.02
Width armpits (in)	4020	21.2	Arm length to neck right (in)	8021	29.33
Bust points width (in)	4030	9.53			
Neck right to waist over bust (in)	4040	19.23			

When researching the population of triathletes, researchers anticipated they would find samples to be very close in size across the spectrum. It is regularly argued in many sports texts, particularly *The Sports Gene* by David Epstein, that although training does a good deal for improving athletes, there are some people who absolutely have a genetic advantage over others in particular sports. Therefore, the research team expected to collect many scans from participants who were very tall and had narrow hips (Epstein, 2013). As can be seen from the average measurements of the top and bottom three finishers, the sample included a wide variation in body types. For example, the average waist girth of the top three females is 27.94 inches, while the average waist girth of the last three finishing females is 36.79 inches. For men the gap is slightly smaller, with the top three at 32.44 inches and the final three at 39.5; still a 7 inch difference.

The research team separated the men and women each into four size categories. The sizes are labeled Elite, Pro, Semi-pro, and Practiced. The sizes were determined by the athletes' finishing times with Elite sizes being the ones that finished fastest and Practiced sizes being the last finishers.

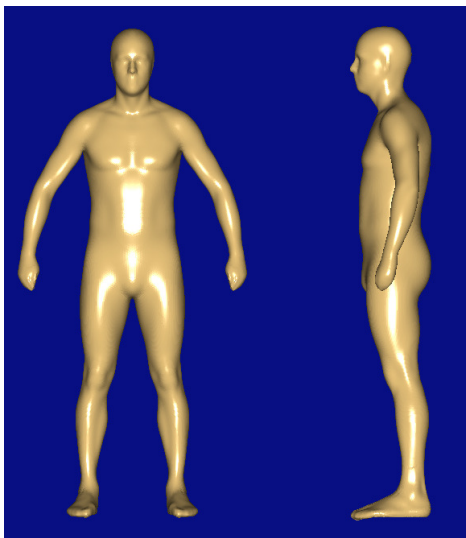
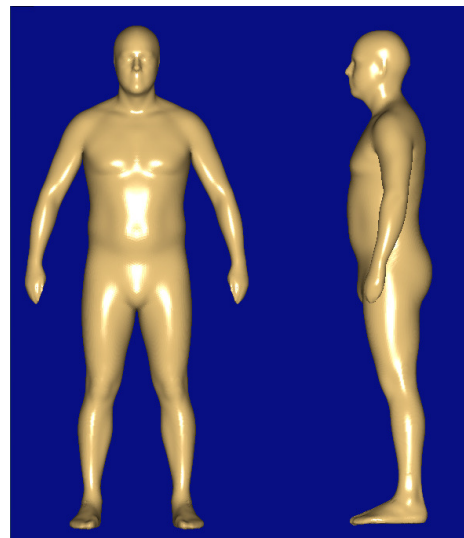
*Figure 8: Elite Male Size**Figure 9: Practiced Male Size*

Table 5: Elite Men Measurements

Measurement Names	Measurement IDs	Inch Measurements	Measurement Names	Measurement IDs	Inch Measurements
Body height (in)	10	71.02	Bust/chest girth (horizontal) (in)	4510	40.25
Head height (in)	20	9.57	Bust/chest girth (in)	4515	40.19
Neck height (in)	30	61.45	Underbust circumference (horizontal)	4520	37.21
Distance neck to buttock (in)	40	24.71	Across back width (in)	5010	16.38
Distance neck-knee (in)	50	41.87	Across back width (armpit level) (in)	5020	16.17
Distance waist-knee (in)	60	25.44	Neck to across back width (armpit level) (in)	5030	7.8
Distance waistband-knee (in)	65	22.87	Neck to waist center back (in)	5040	17.29
Hip height (in)	95	34.18	Waist to buttock (in)	5080	8.38
Crotch height (in)	100	31.9	Distance waistband - buttock (in)	5085	5.72
Knee height (in)	110	19.58	Crotch length (in)	6010	32.72
Neck height front (in)	180	58.38	Crotch length, front (in)	6011	16.45
Upper torso torsion (°)	996	0	Crotch length, rear (in)	6012	16.28
Distance crotch to waistband (in)	997	9.95	Waist girth (in)	6510	33.63
Neck diameter (in)	1010	5.13	Middle Hip (in)	6512	35.05
Mid neck girth (in)	1510	15.03	High waist girth (in)	6515	33.84
Neck at base girth (in)	1520	16.91	Waist band (in)	6520	34.5
Head circumference (in)	1530	22.96	3D waist band (in)	6525	34.5
Torso width at waist (in)	2030	13.84	High hip girth (in)	7510	34.58
Total torso girth (in)	2510	68.17	Buttock girth (in)	7520	38.96
Cross shoulder over neck (in)	3010	16.99	Hip girth (in)	7525	39.94
Cross shoulder (in)	3020	19.12	Hip/thigh girth (in)	7530	39.45
Shoulder width left (in)	3030	5.9	Belly circumference (in)	7540	34.44
Shoulder width right (in)	3031	6	Maximum belly circumference (in)	7545	34.53
Shoulder angle left (°)	3910	27	Arm length to neck back left (in)	8010	32.16
Shoulder angle right (°)	3911	27.1	Arm length to neck back right (in)	8011	32.2
Across front width (in)	4010	15.34	Arm length to neck left (in)	8020	29.58
Width armpits (in)	4020	16.17	Arm length to neck right (in)	8021	29.69
Bust points width (in)	4030	8.49	Arm length left (in)	8030	23.68
Neck right to waist over bust (in)	4040	17.95	Arm length right (in)	8031	23.69

Table 6: Practiced Men Measurements

Measurement Names	Measurement IDs	Inch Measurements	Measurement Names	Measurement IDs	Inch Measurements
Body height (in)	10	70.39	Bust/chest girth (horizontal) (in)	4510	43.13
Head height (in)	20	9.53	Bust/chest girth (in)	4515	43.13
Neck height (in)	30	60.86	Underbust circumference (horizontal) (in)	4520	39.86
Distance neck to buttock (in)	40	24.75	Across back width (in)	5010	17.47
Distance neck-knee (in)	50	41.61	Across back width (armpit level) (in)	5020	17.16
Distance waist-knee (in)	60	25.07	Neck to across back width (armpit level) (in)	5030	8.47
Distance waistband-knee (in)	65	21.58	Neck to waist center back (in)	5040	17.14
Hip height (in)	95	33.55	Waist to buttock (in)	5080	8.5
Crotch height (in)	100	30.62	Distance waistband - buttock (in)	5085	4.71
Knee height (in)	110	19.24	Crotch length (in)	6010	34.59
Neck height front (in)	180	57.62	Crotch length, front (in)	6011	17.51
Upper torso torsion (°)	996	0	Crotch length, rear (in)	6012	17.08
Distance crotch to waistband (in)	997	9.27	Waist girth (in)	6510	37.58
Neck diameter (in)	1010	5.58	Middle Hip (in)	6512	38.27
Mid neck girth (in)	1510	16.2	High waist girth (in)	6515	37.48
Neck at base girth (in)	1520	18.11	Waist band (in)	6520	37.55
Head circumference (in)	1530	23.41	3D waist band (in)	6525	37.55
Torso width at waist (in)	2030	17.47	Waist to hip/thigh left (in)	7020	26.51
Total torso girth (in)	2510	70.74	Waist to hip/thigh right (in)	7021	26.56
Cross shoulder over neck (in)	3010	17.73	High hip girth (in)	7510	38.53
Cross shoulder (in)	3020	19.9	Buttock girth (in)	7520	40.49
Shoulder width left (in)	3030	5.91	Hip girth (in)	7525	41.29
Shoulder width right (in)	3031	6.04	Hip/thigh girth (in)	7530	40.11
Shoulder angle left (°)	3910	27.1	Belly circumference (in)	7540	38.51
Shoulder angle right (°)	3911	26.8	Maximum belly circumference (in)	7545	38.54
Across front width (in)	4010	17	Arm length to neck back left (in)	8010	32.27
Width armpits (in)	4020	20.47	Arm length to neck back right (in)	8011	32.48
Bust points width (in)	4030	9.15	Arm length to neck left (in)	8020	29.35
Neck right to waist over bust (in)	4040	18.66	Arm length to neck right (in)	8021	29.61

For men, the Elite group contains the top 11 scans and the Practiced group contains the bottom 11 scans. Comparing again at waist measurements, the Elite group is now only 4 inches smaller than the Practiced group. The Elite group measurement changed only one inch after taking the top three competitors and adding and averaging together the next eight scans. The Practiced group's waist girth measurement changed almost two inches when averaging the next 8 scans with the bottom three. Though the spread has slightly decreased with the addition of more scans, this range of measurements is much more practical for creating a size run.

3. Results

This data has clearly shown that a new size run could be established with an adequate quantity of full 3D body scans from athletes. Figures 10-14 demonstrate a comparison between the collected data and the data from the general population using the NHANES sizing survey. (NHANES, 2005) The following graphs show a comparison of waist girth to hip girth.

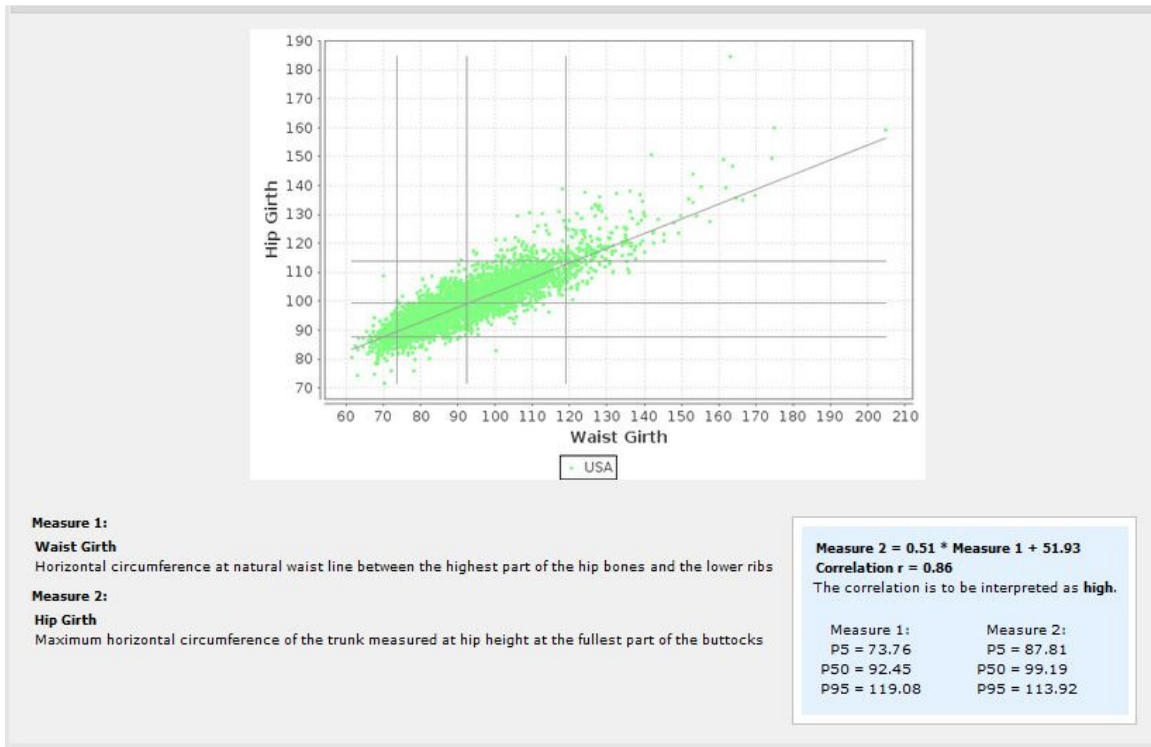


Figure 10: NHANES Male Results - Waist to Hip

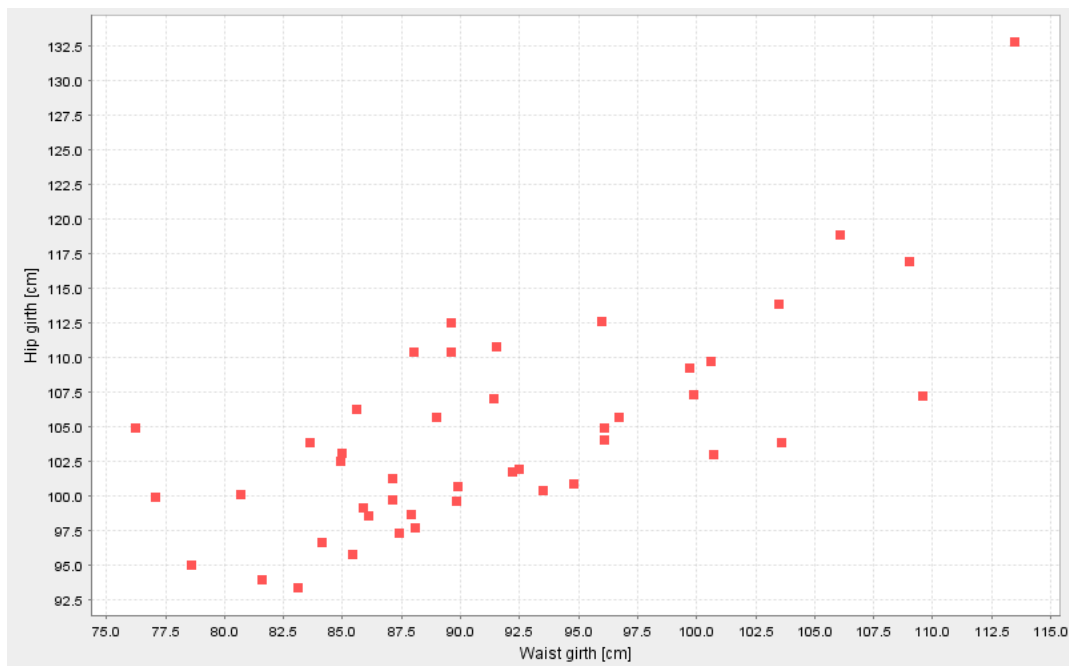


Figure 11: Athlete Scanning Male Results - Waist to Hip

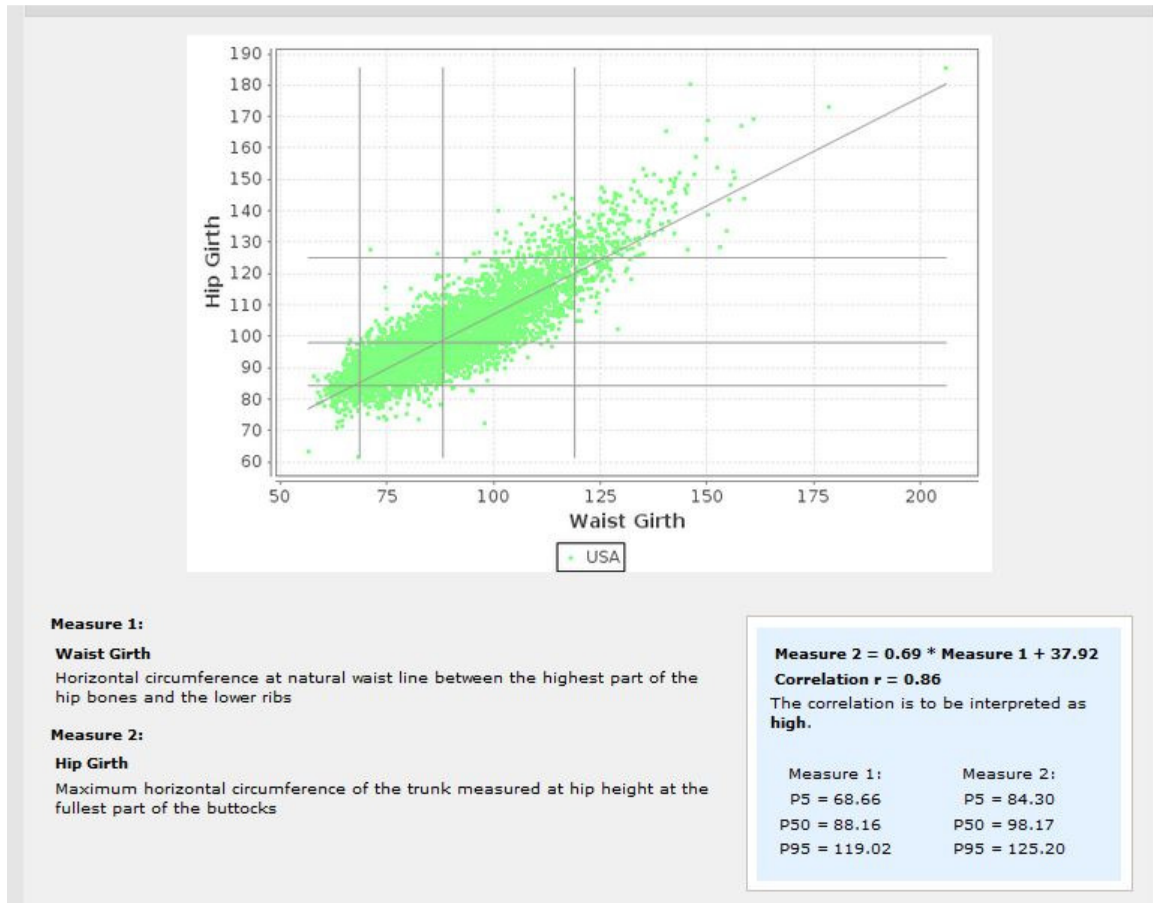


Figure 12: NHANES Female Results - Waist to Hip

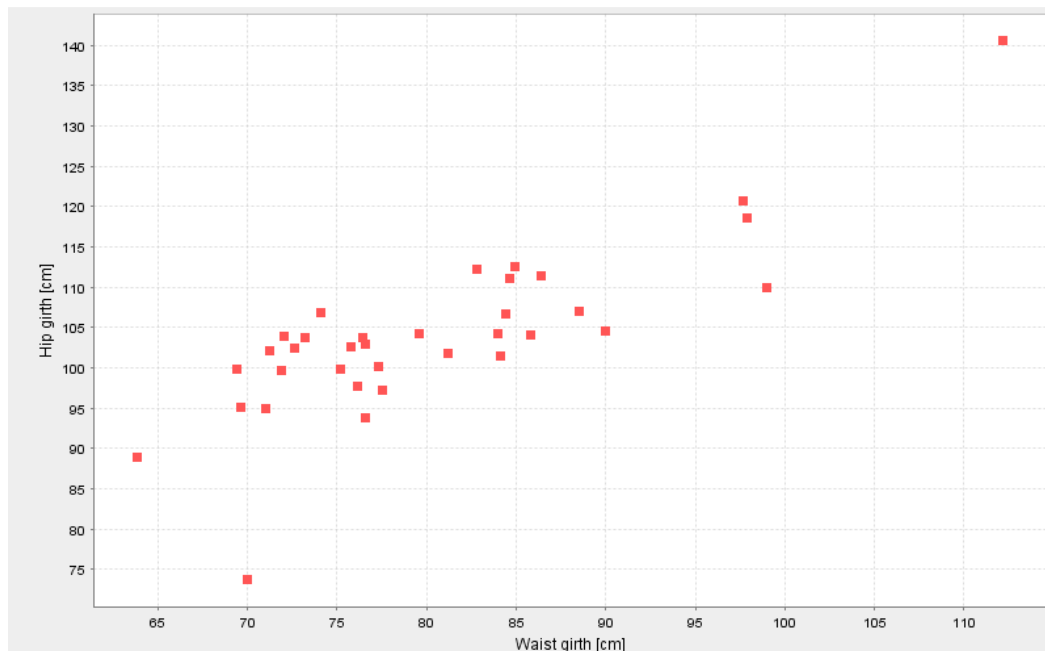


Figure 13: Athlete Scanning Female Results - Waist to Hip

As the graphs demonstrate, the data from this survey seem to follow a similar pattern to the data from the NHANES sizing survey. Unfortunately, the data collected is far too limited to definitively say what the overall differences are between athletes and the general population.

4. Conclusions

Many more of these experiments would need to be conducted in order to acquire a large enough database of scans to really change the method of sizing garments for athletes. Another opportunity for future research is to capture scans from several different sports or athletic groups to determine differences and similarities in body size and shape. Though the data collected in this survey can be applied to finishing times in several sports (the triathlon captured times for swimming, cycling, and running), there were not enough participants scanned to have true body differences in the top finishers for each category. The scans collected in this study will hopefully be just the beginning of a database of athlete body measurements.

References

Ackland, T, Kerr, D Schreiner, A. (1995) The elite athlete- assessing body shape, size, proportion and composition. *Asia Pacific Journal of Clinical Nutrition*. 4 (1); 25-9.

(2002) Vitus Smart XXL. *Human Solutions Assyst Avm*. Retrieved from http://www.human-solutions.com/fashion/front_content.php?idcat=139

Epstein, David. (2013) *The Sports Gene*. Penguin Group, LLC; New York, New York.

(2005) The national health and nutrition examination survey (NHANES). *National Center for Health Statistics: Center for Disease Control and Prevention, Hyattsville, Maryland*.