U.S. ARMY NATICK SOLDIER RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER

Fit and Sizing Evaluation of a Prototype Female Body Armor System

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1. Introduction

Field reports and three studies (Refs. A – C) conducted to assess the fit and performance of the current Interceptor Body Armor (IBA) with the Improved Outer Tactical Vest (IOTV) for females indicate the need for better fit and function of body armor for female Soldiers. As a result, a research project was initiated by the Natick Soldier Research, Development, & Engineering Center (NSRDEC) for Product Manager Soldier Protective Equipment (PM SPE). The overall purpose of the project was to create a sizing system and body armor design offering improved fit, comfort, and performance of the body armor system (vest, front/back plates, and side plates) for female Soldiers, and increasing the overall number of females who are adequately fit with this system.

Using data from an anthropometric survey of 651 Army females conducted from 2006 through 2008 (Ref. D), a sizing system and design were developed and optimized to accommodate the most individuals in the fewest sizes. The sizing system uses a three inch sizing interval for Chest Circumference in order to provide a better fit than the 4 inch interval currently used. For length, a two inch sizing interval for Torso Length is used. Torso Length is a derived measurement using Cervicale Height and Waist Height, Omphalion to calculate a straight-line distance from the waist to the base of the neck. A length variable is needed because there is approximately a 4 inch range of variation in Torso Length to be accommodated. This cannot be done with a single length of vest or plate for a given size without compromising the fit and protection for half of the user population. It was determined that eight sizes would be needed to fit approximately 90% of Army females. The anthropometric data was then used to calculate design values for eighteen dimensions for each size, and initial patterns were developed. The result was a set of prototype IOTV-like garments and associated patterns with front, back and side plates that have been explicitly designed and sized based on the body size and shape of female Soldiers.

This report details the results of a fit and sizing evaluation of the prototype female body armor system. The objective of this field test was to validate the sizing and design on a sufficient number of female Soldiers. Based on the results, changes to the sizing or design would be recommended so that a final set of patterns could be developed. The goal of the overall project is to have a body armor system that provides at least an acceptable fit to 90% of female Soldiers, and that has a rate of predicted size being the best fitting size for 85% of female Soldiers.

The evaluation was conducted by the NSRDEC Design, Pattern, and Prototype Team, and the NSRDEC Anthropology Team. Data collection was done at several Army locations across the U.S. from September through December 2011. Coordination with cooperating units regarding female test participants, dates, and locations was arranged by the Operational Forces Interface Group (OFIG) at Natick.

2. Methods and Materials

A. Test Items

The items evaluated were eight sizes of ballistic protective vests with front, back, and side plates. The sizing and design of these vests were based on an analysis of anthropometric data of Army females. From that analysis, the Anthropology Team developed a sizing system using Chest Circumference and Torso Length (Figure 1) The eight sizes chosen are estimated to accommodate approximately 89% of Army females (Table 1). Clothing designers from the NSRDEC Design, Pattern, and Prototype Team created original patterns. The vests were manufactured by Creative Apparel Associates (Figure 2).

Sizes were assigned numeric identifiers to avoid confusion with the body armor sizes currently used by the Army (Figure 1). For three of the sizes the current Extra Small front and back plates were used. For the other five sizes, mock plates with modified height and width dimensions were made. These mock plates maintained the curvature of the current font and back plates and were weighted based on the aerial density of the current plates. For the side plates, the two smallest sizes used an existing SOF-used 6" x 6" plate. The other sizes used the USMC 8" x 6" plate (Table 2).

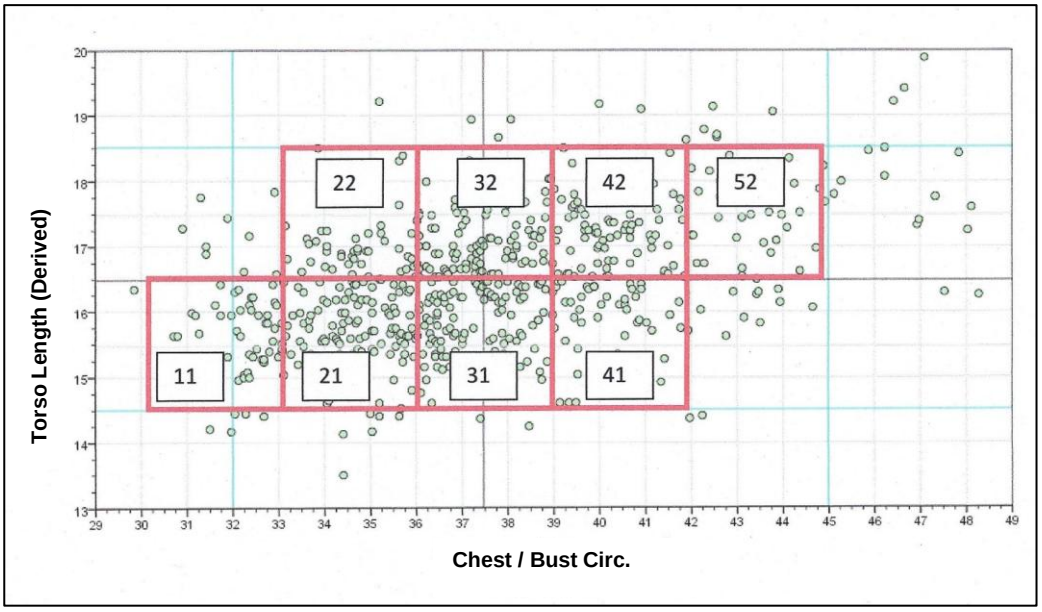

Figure 1. Eight sizes of female specific body armor.

Table 1. Expected Accommodation Rate for Developed Sizes

Size	Percent	Cumulative Percent
21	19.2	19.2
31	16.1	35.4
32	15.9	51.3
42	13.0	64.3
41	6.8	71.1
11	6.3	77.4
22	6.1	83.5
52	5.7	89.3
51	1.8	91.0
62	1.5	92.5
20	1.4	93.9
12	1.2	95.1
53	.8	95.9
43	.7	96.6
10	.7	97.3
63	.6	97.9
33	.5	98.4
72	.4	98.8
50	.3	99.1
23	.3	99.3
30	.3	99.6
61	.2	99.8
01	.1	99.9
40	.1	99.9
71	.1	100.0
Total	100.0	

Figure 2. Prototype female body armor vest

Table 2. Plate Sizing Per Vest Size

Size	Front/Back Plate	Side Plate
	Fit Tested	**Fit Tested**
11	current XS	6 x 6
21	current XS	6 x 6
22	13 x 7	8 x 6
31	current XS	8 x 6
32	13 x 7.5	8 x 6
41	11.5 x 8	8 x 6
42	13 x 8	8 x 6
52	13 x 8.5	8 x 6

The prototype design includes some unique features. There is an improved quick release with lever-activated buckles at the waist and shoulders. The front plate pocket is an exterior, side-opening, 3-D pocket. Strategically placed darts in the front panel mold and curve the panel and increase coverage at the side bust area. The shoulder straps are more adjustable and contoured to fit smoother on the female shoulder, and the yoke/collar is streamlined for improved fit and integration into neck area and under the top edge of the vest.

B. Locations and Dates

The fit and sizing evaluation was conducted at four different test sites; the Natick Soldier Systems Center, Natick, MA; the United States Military Academy, West Point, NY; the Massachusetts National Guard Joint Force Headquarters, Milford, MA; and Fort Benning, GA. The dates for each location, along with the number of Soldiers participating each day, are shown in Table 3.

Table 3. Test Dates and Locations with Test Participant Counts

		Location				
		Natick	USMA	Milford (MA NG HQ)	Ft. Benning	Total
Date	9/08/2011	6				6
	9/15/2011	1				1
	10/06/2011		31			31
	10/25/2011			17		17
	12/13/2011				32	32
	12/14/2011				19	19
	12/15/2011				15	15
Total		7	31	17	66	121

C. Sample

The final test sample included 121 female Soldiers. Of those, 61% were Active Duty, 14% were National Guard, and 25% were U.S. Military Academy Cadets (Table 4). The demographic and anthropometric data for the test sample are presented in the Results section.

Table 4. Sample Frequency by Component

	Frequency	Percent
Active Duty	74	61.2
National Guard	17	14.0
Cadet	30	24.8
Total	121	100.0

D. Fit Evaluation

Test participants arrived at the evaluation location wearing their uniform of the day. They completed a demographic information section on the data form (Appendix A) and removed the uniform outer shirt so that measuring and fitting were done wearing the T-shirt. Then the test participants were measured for the garment sizing variables of Chest/Bust Circumference, Waist Height - Omphalion, and Cervicale Height, and for design relevant variables of Neck Circumference-Base, Waist Circumference – Omphalion, and Stature. The measuring was done by a team of two trained anthropometrists using standard anthropometric techniques (Ref. E). The measurement team recorded each person's predicted size of vest based on the measurement values and the sizing tables.

Each test participant first tried on their predicted vest size. A team of two or three evaluators assisted with proper donning, assessed the fit, and, with input from the soldier, determined the overall acceptability of the predicted size. If the fit was not considered optimal, alternate sizes were tried on and evaluated. Finally, the evaluators determined a best-fit size for each individual. If none of the available sizes were considered a best-fit size, a rating of 'No Fit' was given.

Fitting was done while wearing the T-shirt to simulate the Army Combat Shirt (ACS), which is worn with body armor in an operational environment. A few of the test participants also tried their best fitting size vest over the ACU top and over an ACS provided by the evaluation team.

3. Results

A. Demographics

The demographic characteristics of the female Soldiers who participated in this evaluation are presented in Tables 5 – 8. Pay grades for the Active Duty and National Guard Soldiers ranged from E2 through O6 with the most frequent being E3 and E4. The most frequent MOS were 88M-Motor Transport Operator, 92A-Automated Logistical Specialist, and 92F-Petroleum Supply Specialist. There were 33 different occupational specialties included overall. Academy Cadets were counted as a separate category for these two variables. The average age was 25 years, with a range from 18 to 48. The average time in service was 4 years, 4 months, with a range from 3 months to over 26 years.

Table 5. Pay Grade Distribution

	Frequency	Percent
Cadet	30	24.8
E2	6	5.0
E3	24	19.8
E4	33	27.3
E5	12	9.9
E6	6	5.0
E7	4	3.3
E8	1	.8
O2	2	1.7
O3	2	1.7
O6	1	.8
Total	121	100.0

Table 6. MOS Distribution

	Frequency	Percent	Cumulative Percent
Cadet	30	24.8	24.8
88M	12	9.9	34.7
92A	12	9.9	44.6
92F	10	8.3	52.9
68W	6	5.0	57.9
42A	5	4.1	62.0
92Y	4	3.3	65.3
91B	3	2.5	67.8
91G	3	2.5	70.2
92W	3	2.5	72.7
15P	2	1.7	74.4
68K	2	1.7	76.0
88N	2	1.7	77.7
89B	2	1.7	79.3
91D	2	1.7	81.0
91J	2	1.7	82.6
92G	2	1.7	84.3
92R	2	1.7	86.0
16 other MOSs made up remaining 14%			

Table 7. Age & Time in Service

	N	Minimum	Mean	Maximum
Age (yrs)	120	18	25	48
Time in Service (yrs)	119	.25	4.3	26.17

Table 8. Race / Ethnicity

	Frequency	Percent
White, not Hispanic	60	49.6
Black, not Hispanic	34	28.1
Hispanic	10	8.3
Asian / Pacific Islander	6	5.0
American Indian / Native Alaskan	2	1.7
Mixed	7	5.8
Sub Total	119	98.3
No Data	2	1.7
Total	121	100.0

B. Anthropometry

Summary data for the one derived and six directly measured dimensions collected during the evaluation are presented in Table 9. Since having a wide range of variation was the most important consideration regarding the sample anthropometry, the approximate percentile values for the minimum and maximum of the fit test sample are also included. For all dimensions comparable to Ref. D, the range was at least from the 3rd percentile to the 97th percentile.

Table 9. Anthropometric Data Descriptive Statistics

	N	Min			Max			Mean		Std. D.	
		mm	in	%ile^	mm	in	%ile^	mm	in	mm	in
Chest Circumference	121	803	31.6	2nd	1164	45.8	97th	950.5	37.4	77.4	3
Torso Length*	121	359	14.1	n/a	469	18.5	n/a	416.1	16.4	21.4	0.8
Neck Circumference	120	319	12.6	n/a	418	16.5	n/a	369.5	14.5	17	0.7
Waist Circumference	120	645	25.4	1st	1142	45	98th	830	32.7	96.4	3.8
Stature	120	1511	59.5	3rd	1820	71.7	99th	1642.7	64.7	62.6	2.5
Cervicale Height	121	1282	50.5	3rd	1560	61.4	99th	1411.2	55.6	57.4	2.3
Waist Height(O)	121	891	35.1	2nd	1114	43.9	99th	995.1	39.2	50.3	2
* Cervicale Height minus Waist Height(O)											
^ Ref. D											

C. Size Distribution

The distribution of predicted sizes, based on measured size dimension values and the sizing table, included all eight sizes of vests developed for this evaluation. The most frequent were sizes 21, 31, and 32, which made up over 57% of the sample (Table 10). Approximately 6% of the test participants had a

predicted size outside of the range of the eight available sizes (Figure 3). Note that this distribution is specific to the fit test sample only and does not represent an Army tariff.

Regardless of the fit of the predicted size, over 99% of test participants had an acceptable fit in one of the eight sizes available (Table 11). Of those whose predicted size was one of the eight available, that size was also the best fitting size for 83% (Table 12).

Table 10. Predicted Size Frequency

Size	Frequency	Percent	Cumulative %
21	27	22.3	22.3
31	23	19.0	41.3
32	20	16.5	57.9
42	13	10.7	68.6
22	12	9.9	78.5
41	10	8.3	86.8
52	5	4.1	90.9
51	4	3.3	94.2
11	3	2.5	96.7
12	2	1.7	98.3
30	1	.8	99.2
62	1	.8	100.0
Total	121	100.0	

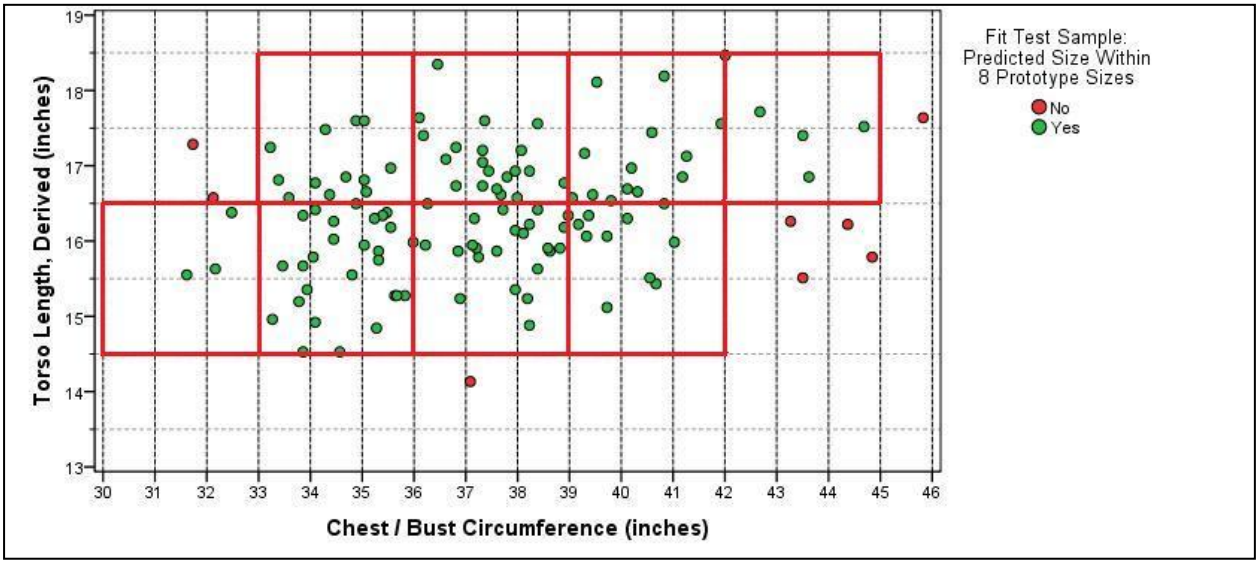

Figure 3. Predicted Size Distribution Plot

Table 11. Best Fit Size Frequency

Size	Frequency	Percent	Cumulative %
21	28	23.1	23.1
31	21	17.4	40.5
32	19	15.7	56.2
41	17	14.0	70.2
22	14	11.6	81.8
42	11	9.1	90.9
11	5	4.1	95.0
52	5	4.1	99.2
None	1	.8	100.0
Total	121	100.0	

Table 12. Predicted & Best Fit Size

	Frequency	Percent	Valid Percent
Predicted Size = Best Fit Size	92	76	**82.9**
Predicted Size NOT Best Fit	19	15.7	17.1
Total	111	91.7	100.0
Predicted Size Not Available	8	6.6	
Predicted Size Not Evaluated, Error	2	1.7	
Total	121	100.0	

D. Fit Evaluation

The overall fit evaluation ratings for all sizes selected based on the Soldiers' measurements for Bust and Torso Length (predicted size) are presented in Tables 13 & 14. Ratings shaded in red indicate areas where pattern changes may be needed for all sizes. The primary issues identified include the army scye area and the front and back plate locations. All other aspects rated 'OK' for at least 85% of the test sample.

The predicted size provided an acceptable fit for 88% of the test participants. There were 6% who predicted into a size that was not available as part of the evaluation. If only those who predicted into one of the eight available sizes are considered, the predicted size was acceptable for nearly 95% of test participants.

Complete ratings for each size are shown in Tables 15a through 16b. Ratings shaded in red indicate areas where pattern changes should be made to improve the fit of that size. Ratings shaded in yellow indicate areas where improvements can be made, but any changes should be carefully considered so that those rated 'OK' would not have their fit substantially altered. Two of the sizes (11 & 52) have very small samples (N=3) which may not represent the full range of variation for individuals who would predict into those sizes. Any fit issues for those sizes are also shaded yellow. Only very obvious trends in the fit ratings should be considered for pattern changes for those sizes.

Table 13. Overall Fit Ratings

Predicted Size Fit Ratings		Count	%
Neck	Too Big	0	0%
	OK	107	98.2%
	Too Small	2	1.8%
Chest	Too Big	4	3.7%
	OK	103	95.4%
	Too Small	1	.9%
Waist	Too Big	7	6.5%
	OK	99	92.5%
	Too Small	1	.9%
Shoulder Strap Length	Too Long	0	0%
	OK	102	100%
	Too Short	0	0%
Shoulder Strap Width	Too Wide	3	2.9%
	OK	92	89.3%
	Too Narrow	8	7.8%
Arm Scye	Too Big	61	59.8%
	OK	41	40.2%
	Too Small	0	0%
Front Vest Length	Too Long	6	5.4%
	OK	102	93.6%
	Too Short	1	.9%
Back Vest Length	Too Long	7	6.4%
	OK	101	92.7%
	Too Short	1	.9%
Overall Fit	Acceptable*	105	86.8%
	Not Acceptable	6	5%
	Size Not Available	8	6.6%
	Size Not Evaluated	2	1.7%

*Acceptable = 94.6% if size available & evaluated

Table 14. Overall Plate Size & Location Ratings

Predicted Size Fit Ratings		Count	%
Front Plate Length	Too Long	5	4.6%
	OK	99	90.8%
	Too Short	5	4.6%
Front Plate Width	Too Wide	0	0%
	OK	93	85.3%
	Too Narrow	16	14.7%
Front Plate Location	Too High	0	0%
	OK	11	10.1%
	Too Low	98	89.9%
Back Plate Length	Too Long	4	3.7%
	OK	103	94.5%
	Too Short	2	1.8%
Back Plate Width	Too Wide	0	0%
	OK	91	84.3%
	Too Narrow	17	15.7%
Back Plate Location	Too High	0	0%
	OK	28	25.7%
	Too Low	81	74.3%
Side Plate Length	Too Long	8	7.3%
	OK	80	73.4%
	Too Short	21	19.3%
Side Plate Width	Too Wide	0	0%
	OK	109	100%
	Too Narrow	0	0%
Side Plate Location (v)	Too High	2	1.8%
	OK	107	98.2%
	Too Low	0	0%
Side Plate Location (h)	Forward	5	4.6%
	OK	104	95.4%
	Back	0	0%

Table 15a. Fit Ratings by Predicted Size (11 – 31)

		Predicted Size							
		11		**21**		**22**		**31**	
		N	%	N	%	N	%	N	%
Neck	Too Big	0	0%	0	0%	0	0%	0	0%
	OK	2	66.7%	27	100%	12	100%	20	95.2%
	Too Small	1	33.3%	0	0%	0	0%	1	4.8%
Chest	Too Big	0	0%	0	0%	0	0%	1	4.8%
	OK	3	100%	26	100%	12	100%	20	95.2%
	Too Small	0	0%	0	0%	0	0%	0	0%
Waist	Too Big	0	0%	1	3.8%	0	0%	2	9.5%
	OK	3	100%	25	96.2%	11	100%	18	85.7%
	Too Small	0	0%	0	0%	0	0%	1	4.8%
Shoulder Strap Length	Too Long	0	0%	0	0%	0	0%	0	0%
	OK	3	100%	25	100%	10	100%	19	100%
	Too Short	0	0%	0	0%	0	0%	0	0%
Shoulder Strap Width	Too Wide	0	0%	1	4%	1	10%	1	5%
	OK	2	66.7%	21	84%	9	90%	18	90%
	Too Narrow	1	33.3%	3	12%	0	0%	1	5%
Arm Scye	Too Big	3	**100%**	15	**60%**	4	**44.4%**	12	**60%**
	OK	0	0%	10	40%	5	55.6%	8	40%
	Too Small	0	0%	0	0%	0	0%	0	0%
Front Vest Length	Too Long	0	0%	0	0%	3	25%	0	0%
	OK	3	100%	27	100%	9	75%	21	100%
	Too Short	0	0%	0	0%	0	0%	0	0%
Back Vest Length	Too Long	0	0%	0	0%	1	8.3%	1	4.8%
	OK	3	100%	27	100%	11	91.7%	20	95.2%
	Too Short	0	0%	0	0%	0	0%	0	0%
Overall Fit	Acceptable	3	100%	27	100%	12	100%	20	87%
	Not Acceptable	0	0%	0	0%	0	0%	3	13%

Table 15b. Fit Ratings by Predicted Size (32 – 52)

		Predicted Size							
		32		**41**		**42**		**52**	
		N	%	N	%	N	%	N	%
Neck	Too Big	0	0%	0	0%	0	0%	0	0%
	OK	20	100%	10	100%	13	100%	3	100%
	Too Small	0	0%	0	0%	0	0%	0	0%
Chest	Too Big	0	0%	0	0%	2	15.4%	1	33.3%
	OK	19	95%	10	100%	11	84.6%	2	66.7%
	Too Small	1	5%	0	0%	0	0%	0	0%
Waist	Too Big	2	10%	0	0%	1	7.7%	1	33.3%
	OK	18	90%	10	100%	12	92.3%	2	66.7%
	Too Small	0	0%	0	0%	0	0%	0	0%
Shoulder Strap Length	Too Long	0	0%	0	0%	0	0%	0	0%
	OK	20	100%	10	100%	12	100%	3	100%
	Too Short	0	0%	0	0%	0	0%	0	0%
Shoulder Strap Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	18	90%	10	100%	11	91.7%	3	100%
	Too Narrow	2	10%	0	0%	1	8.3%	0	0%
Arm Scye	Too Big	14	**70%**	4	**40%**	8	**66.7%**	1	33.3%
	OK	6	30%	6	60%	4	33.3%	2	66.7%
	Too Small	0	0%	0	0%	0	0%	0	0%
Front Vest Length	Too Long	1	5%	0	0%	2	15.4%	0	0%
	OK	19	95%	9	90%	11	84.6%	3	100%
	Too Short	0	0%	1	10%	0	0%	0	0%
Back Vest Length	Too Long	2	10%	0	0%	3	23.1%	0	0%
	OK	18	90%	9	90%	10	76.9%	3	100%
	Too Short	0	0%	1	10%	0	0%	0	0%
Overall Fit	Acceptable	19	95%	10	100%	11	84.6%	3	100%
	Not Acceptable	1	5%	0	0%	2	15.4%	0	0%

Table 16a. Plate Size and Location Ratings by Predicted Size (11 – 31)

		Predicted Size							
		11		**21**		**22**		**31**	
		Count	%	Count	%	Count	%	Count	%
Front Plate Length	Too Long	0	0%	0	0%	3	25%	0	0%
	OK	3	100%	25	92.6%	9	75%	21	100%
	Too Short	0	0%	2	7.4%	0	0%	0	0%
Front Plate Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	2	66.7%	25	92.6%	9	75%	12	57.1%
	Too Narrow	1	33.3%	2	7.4%	3	25%	9	**42.9%**
Front Plate Location	Too High	0	0%	0	0%	0	0%	0	0%
	OK	0	0%	3	11.1%	1	8.3%	1	4.8%
	Too Low	3	**100%**	24	**88.9%**	11	**91.7%**	20	**95.2%**
Back Plate Length	Too Long	0	0%	0	0%	2	16.7%	0	0%
	OK	3	100%	27	100%	10	83.3%	21	100%
	Too Short	0	0%	0	0%	0	0%	0	0%
Back Plate Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	3	100%	24	92.3%	7	58.3%	15	71.4%
	Too Narrow	0	0%	2	7.7%	5	**41.7%**	6	**28.6%**
Back Plate Location	Too High	0	0%	0	0%	0	0%	0	0%
	OK	0	0%	4	14.8%	3	25%	3	14.3%
	Too Low	3	**100%**	23	**85.2%**	9	**75%**	18	**85.7%**
Side Plate Length	Too Long	0	0%	1	3.7%	1	8.3%	3	14.3%
	OK	0	0%	11	40.7%	10	83.3%	18	85.7%
	Too Short	3	**100%**	15	**55.6%**	1	8.3%	0	0%
Side Plate Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	3	100%	27	100%	12	100%	21	100%
	Too Narrow	0	0%	0	0%	0	0%	0	0%
Side Plate Location (V)	Too High	0	0%	0	0%	1	8.3%	1	4.8%
	OK	3	100%	27	100%	11	91.7%	20	95.2%
	Too Low	0	0%	0	0%	0	0%	0	0%
Side Plate Location (H)	Forward	0	0%	0	0%	1	8.3%	2	9.5%
	OK	3	100%	27	100%	11	91.7%	19	90.5%
	Back	0	0%	0	0%	0	0%	0	0%

Table 16b. Plate Size and Location Ratings by Predicted Size (32 – 52)

		Predicted Size							
		32		**41**		**42**		**52**	
		Count	%	Count	%	Count	%	Count	%
Front Plate Length	Too Long	1	5%	0	0%	1	7.7%	0	0%
	OK	19	95%	8	80%	11	84.6%	3	100%
	Too Short	0	0%	2	20%	1	7.7%	0	0%
Front Plate Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	20	100%	9	90%	13	100%	3	100%
	Too Narrow	0	0%	1	10%	0	0%	0	0%
Front Plate Location	Too High	0	0%	0	0%	0	0%	0	0%
	OK	2	10%	1	10%	0	0%	3	100%
	Too Low	18	**90%**	9	**90%**	13	**100%**	0	0%
Back Plate Length	Too Long	0	0%	0	0%	2	15.4%	0	0%
	OK	20	100%	8	80%	11	84.6%	3	100%
	Too Short	0	0%	2	20%	0	0%	0	0%
Back Plate Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	18	90%	9	90%	12	92.3%	3	100%
	Too Narrow	2	10%	1	10%	1	7.7%	0	0%
Back Plate Location	Too High	0	0%	0	0%	0	0%	0	0%
	OK	12	60%	0	0%	4	30.8%	2	66.7%
	Too Low	8	**40%**	10	**100%**	9	**69.2%**	1	33.3%
Side Plate Length	Too Long	0	0%	2	20%	1	7.7%	0	0%
	OK	18	90%	8	80%	12	92.3%	3	100%
	Too Short	2	10%	0	0%	0	0%	0	0%
Side Plate Width	Too Wide	0	0%	0	0%	0	0%	0	0%
	OK	20	100%	10	100%	13	100%	3	100%
	Too Narrow	0	0%	0	0%	0	0%	0	0%
Side Plate Location (V)	Too High	0	0%	0	0%	0	0%	0	0%
	OK	20	100%	10	100%	13	100%	3	100%
	Too Low	0	0%	0	0%	0	0%	0	0%
Side Plate Location (H)	Forward	2	10%	0	0%	0	0%	0	0%
	OK	18	90%	10	100%	13	100%	3	100%
	Back	0	0%	0	0%	0	0%	0	0%

The only problem area of the soft armor vest was the arm scye. It was rated as 'Too Big' for a majority of those fit in sizes 11, 21, 31, 32, and 42. This was observed as too much of the front and / or back area of the shoulder being exposed, or not covered by ballistic protective material (Figure 4).

Figure 4. Arm scye area is too big.

For the plates, the primary problem was the position of the front and back plates being 'Too Low' on the body. This occurred in all sizes except 52. In size 31, the front plate was rated 'Too Narrow' for 42% of those predicted into that size and the back plate was 'Too Narrow' for 28%. The back plate was also rated 'Too Narrow' for 42% of those predicted into size 22. The side plates were rated 'Too Short' for sizes 11 and 21. Additional data from a separate plate size assessment, done without the vest on a subsample of 25 test participants, is presented in Appendix B.

4. Discussion and Recommendations

A. Sample

As of September 2011, there were approximately 176,000 females in the U.S. Army, making up 15.6% of the total Army (Ref. F). With a small sample of 121 females, the primary concern is to try to get the range of variation in anthropometry to approximate that found in the total population. Figure 5 illustrates that this was achieved. For the primary sizing dimensions of Chest Circumference and Torso Length the evaluation sample went beyond the 5th and 95th percentile values. Although the overall range of anthropometry was very good, there were two sizes, 11 and 52, that were evaluated as the predicted size for only 3 females each. That number is too low for a valid assessment of those sizes except for very obvious issues.

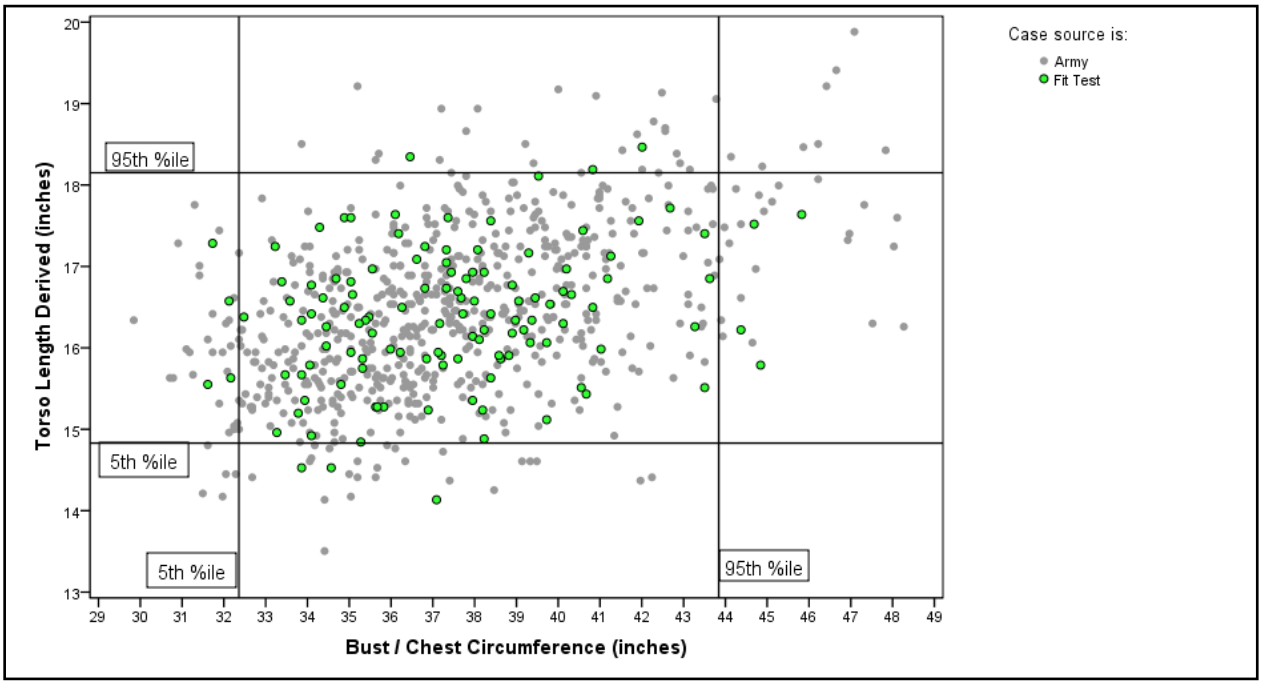

Figure 5. Fit evaluation sample anthropometry compared to Army females (Ref. D.)

B. Sizing and Tariffs

The eight sizes made for this evaluation were based on an analysis of Army female anthropometric data. They are optimized to accommodate the most individuals in the fewest sizes, given a three inch sizing interval for Chest Circumference and a two inch sizing interval for Torso Length. With the predicted size being the best fit size for 83% and providing at least an 'Acceptable' fit for 95% of those who predicted into one of the eight sizes, it seems that the sizing works well, especially for a first prototype design. Also, over 99% of test participants had an acceptable fit in one of the eight sizes available. This indicates that additional sizes are probably not required to provide an acceptable fit for nearly all female Soldiers. The objective of providing an acceptable fit to 90% of female Soldiers has been met. Improving the percentage of predicted size also being the best fitting size to at least 85% can be achieved by implementing design changes based on the fit evaluation results.

A tariff estimate for the eight sizes of body armor was calculated using the data reported in Reference D. It assumes that the predicted size provides at least an acceptable fit and that any females predicting outside of these sizes will find an acceptable fit with one of the eight sizes. The tariff should be updated with new Army anthropometric data that is expected to be available in FY 2013.

Table 17. Tariff Estimate

Size	Count
11	83
21	210
22	65
31	167
32	167
41	70
42	139
52	99
	1000

C. Design

Since the sizing used in this evaluation works well, further improvements in fit can best be made by modifying the design and patterns for each size based on the fit evaluation ratings. A comparison of the anthropometry of those predicted into a size with those best fit in a size can be used to quantify any changes. That comparative data is presented in Appendix C. The only relevant, large differences occur for the waist circumference in sizes 41 and 42, but the fit evaluation ratings do not indicate any problems with the fit of the waist for those sizes. Table 18 presents the recommended changes for each size based on the fit evaluation ratings. In all sizes, the front and back plate pockets should be moved up and additional material should be added around the arm scye area. A new plate size, 13 inches tall by 8 inches wide, should be developed for vest sizes 22 and 32. Other vest sizes will utilize existing front and back plate sizes. The 6 inch by 6 inch sides plate is recommended for the shorter sizes (11, 21, 31, 41) and the 8 inch by 6 inch side plate is recommended for the longer sizes (22, 32, 42, 52). These recommendations have already been provided to NSRDEC clothing designers and they have begun modifying the patterns. One these changes have been implemented, improvements in fit should be validated with additional testing.

D. Further Development and Testing

The NSRDEC Anthropology Team and Design, Pattern, & Prototype Team recommend that PM SPE continue development of the eight sizes of female specific body armor evaluated in this fit test. A group of female Soldiers has been identified as a potential field testing unit, and they have been measured for sizing. When pattern changes are completed, a small lot of vests should be manufactured and issued to the unit for a preliminary user evaluation.

Table 18. Prototype Female Body Armor Recommended Changes

All Sizes

- Move front plate location up
- Move back plate location up
- Increase coverage in arm scye area

Size 11

- No other changes

Size 21

- No other changes

Size 22

- Change front/back plate to 13” x 8”
- Adjust front/back plate pocket for new plate dimensions

Size 31

- Change front/back plate to current size Small (11.75” x 8.75”)
- Adjust front/back plate pockets for new plate dimensions
- Change side plate to 6” x 6”
- Adjust side plate pockets for new plate dimensions

Size 32

- Change front/back plate to 13” x 8”
- Adjust front/back plate pockets for new plate dimensions

Size 41

- Change front/back plate to current size Small (11.75” x 8.75”)
- Adjust front/back plate pockets for new plate dimensions
- Change side plate to 6” x 6”
- Adjust side plate pockets for new plate dimensions

Size 42

- Change front/back plate to current size Medium (12.5” x 9.5”)
- Adjust front/back plate pockets for new plate dimensions

Size 52

- Change front/back plate to current size Medium (12.5” x 9.5”)
- Adjust front/back plate pockets for new plate dimensions

5. References

A. *Anthropometric Size and Fit Evaluation of the Improved Outer Tactical Vest (IOTV) with Females, Fort Campbell, Kentucky, June 2009.* Ergonomics Team, Natick Solider Research, Development, & Engineering Center (NSRDEC), Natick, MA, August 2009.

B. *Anthropometric Size and Fit Evaluation of the Improved Outer Tactical Vest (IOTV) with Females, Grafenwoehr, Bamburgh, Mannheim, & Kaiserslautern, Germany, May 2009*. Ergonomics Team, Natick Solider Research, Development, & Engineering Center (NSRDEC), Natick, MA, August 2009.

C. *Anthropometric Size and Fit and Human Factors Evaluation of the Improved Outer Tactical Vest (IOTV): Generation II with Females, Fort Campbell, Kentucky, April 2010*. Anthropometry & Human Factors Teams, Natick, Soldier Research, Development, and Engineering Center (NSRDEC), Natick, MA, June 2010.

D. *Anthropometric Survey (ANSUR) II Pilot Study: Methods and Summary Statistics*. Steve Paquette, et al, Technical Report, NATICK/TR-09/014, April 2009.

E. *Measurer's Handbook: U.S. Army Anthropometric Survey 1987 – 1988.* Charles Clauser, et al, Technical Report, NATICK/TR-88/043, May 1988.

F. *Army Demographics FY11 Army Profile*. Headquarters, Department of the Army, Deputy Chief of Staff of Personnel, G-1, Office of Army Demographics.

Appendix A.

Data Forms

Female Body Armor

Please print in ink. To be filled out by Soldier

Component: ___Active(1) ___Reserve(2) ___National Guard(3)

___Other(4) _____

Unit: _____

Today's Date: Month:_____ Day:_____ Year:_____

Grade / Rank: _____ (example: E5 / Sergeant)

Primary MOS: _____
(Example: 88M - Motor Trans. Operator.)

Time in Service: _____ years _____ months

Age: _____

Gender: _X_Female(1)

Race / Ethnicity:
Select all that apply.

___White, not Hispanic(1)
___Black, not Hispanic(2)
___Hispanic(3)
___Asian / Pacific Islander(4)
___American Indian / Native Alaskan(5)

___Mixed(6): Please pecify_____

___Other(7): Please pecify_____

Bra Size: _____ (example: 34 B)

Bra Type: Sports Bra(1) Underwire(2) Non-Underwire(3) None(4)
Circle One

Other(5)_____

STOP! Please do not write below this line.

Female Body Armor

Please do not write on this form. For evaluator use only.

*Chest/ Bust Circ._____mm

Neck Circ., Base _____ mm

Waist Circ. O. _____mm

Stature _____mm

Cervicale Ht. _____mm

Waist Height O. _____mm

#Torso Length, D (Cervicale Ht – Waist Ht O) _____mm

X-F-IOTV	*Chest Circ. (Bust)						
#Torso Length, D		762-838	839-914	915-990	991-1066	1067-1143	
>470	03	13	23	33	43	53	63
420 - 470	02	12	**22**	**32**	**42**	**52**	62
368 - 419	01	**11**	**21**	**31**	**41**	51	61
<368	00	10	20	30	40	50	60

Comments:

_____

_____

Female Body Armor

Please do not write on this form. For evaluator use only.

Predicted Size: (see sizing data form)			
Neck	Too Big (1)	OK (2)	Too Small (3)
Chest	Too Big (1)	OK (2)	Too Small (3)
Waist	Too Big (1)	OK (2)	Too Small (3)
Shoulder Strap	Too Long (1)	OK (2)	Too Short (3)
	Too Wide (1)	OK (2)	Too Narrow (3)
Arm Scye	Too Big (1)	OK (2)	Too Small (3)
Front Vest Length	Too Long (1)	OK (2)	Too Short (3)
Front Plate Length	Too Long (1)	OK (2)	Too Short (3)
Front Plate Width	Too Wide (1)	OK (2)	Too Narrow (3)
Front Plate Location	Too High (1)	OK (2)	Too Low (3)
Back Vest Length	Too Long (1)	OK (2)	Too Short (3)
Back Plate Length	Too Long (1)	OK (2)	Too Short (3)
Back Plate Width	Too Wide (1)	OK (2)	Too Narrow (3)
Back Plate Location	Too High (1)	OK (2)	Too Low (3)
Side Plate Length	Too Long (1)	OK (2)	Too Short (3)
Side Plate Width	Too Wide (1)	OK (2)	Too Narrow (3)
Side Plate Location (a)	Too High (1)	OK (2)	Too Low (3)
(b)	Forward (1)	OK (2)	Back (3)
Overall Fit	Acceptable(1)	Not Acceptable(2)	
Comments:			

Female Body Armor

Please do not write on this form. For evaluator use only.

Alternate Size:			
Neck	Too Big (1)	OK (2)	Too Small (3)
Chest	Too Big (1)	OK (2)	Too Small (3)
Waist	Too Big (1)	OK (2)	Too Small (3)
Shoulder Strap	Too Long (1)	OK (2)	Too Short (3)
	Too Wide (1)	OK (2)	Too Narrow (3)
Arm Scye	Too Big (1)	OK (2)	Too Small (3)
Front Vest Length	Too Long (1)	OK (2)	Too Short (3)
Front Plate Length	Too Long (1)	OK (2)	Too Short (3)
Front Plate Width	Too Wide (1)	OK (2)	Too Narrow (3)
Front Plate Location	Too High (1)	OK (2)	Too Low (3)
Back Vest Length	Too Long (1)	OK (2)	Too Short (3)
Back Plate Length	Too Long (1)	OK (2)	Too Short (3)
Back Plate Width	Too Wide (1)	OK (2)	Too Narrow (3)
Back Plate Location	Too High (1)	OK (2)	Too Low (3)
Side Plate Length	Too Long (1)	OK (2)	Too Short (3)
Side Plate Width	Too Wide (1)	OK (2)	Too Narrow (3)
Side Plate Location (a)	Too High (1)	OK (2)	Too Low (3)
(b)	Forward (1)	OK (2)	Back (3)
Overall Fit	Acceptable(1)	Not Acceptable(2)	
Comments:			

Best Fit Size _____

Appendix B.

Plate Only Sizing Assessment

Table B1. Fit Test Plate Size Ratings by Predicted Size

		Predicted Size						
		21	**22**	**31**	**32**	**41**	**42**	**52**
XS Plate Length (11.5 x 7.25)	Too Long							
	OK			1				
	Too Short	4	4	1	5	1	4	2
XS Plate Width (11.5 x 7.25)	Too Wide							
	OK	2	3					
	Too Narrow	2	1	2	5	1	3	2
Plate 22 Length (13 x 7)	Too Long							
	OK	4	3	1	4	1		
	Too Short							1
Plate 22 Width (13 x 7)	Too Wide							
	OK							
	Too Narrow	4	3	1	4	1		1
Plate 32 Length (13 x 7.5)	Too Long							
	OK	4	3	1	5	1		1
	Too Short							
Plate 32 Width (13 x 7.5)	Too Wide							
	OK	4	3		2			
	Too Narrow			1	3	1		1
Plate 41 Length (11.5 x 8)	Too Long							
	OK							
	Too Short	4		1	4	1		
Plate 41 Width (11.5 x 8)	Too Wide							
	OK	4			4	1		
	Too Narrow			1				

Table B1 (cont.). Fit Test Plate Size Ratings by Predicted Size

		Predicted Size						
		21	**22**	**31**	**32**	**41**	**42**	**52**
Plate 42 Length (13 x 8)	Too Long							
	OK	4		1	4	1	2	2
	Too Short						1	
Plate 42 Width (13 x 8)	Too Wide							
	OK	4			4	1		1
	Too Narrow			1			3	1
Plate 52 Length (xxx)	Too Long							
	OK						4	2
	Too Short							
Plate 52 Width (xxx)	Too Wide							
	OK						4	1
	Too Narrow							1

Shaded cells indicate vest size that corresponds to plate size.

Table B2. Current IOTV Plate Size Ratings by Predicted Size

		Predicted Size						
		21	**22**	**31**	**32**	**41**	**42**	**52**
XS Plate Length (11.5 x 7.25)	Too Long							
	OK			1				
	Too Short	4	4	1	5	1	4	2
XS Plate Width (11.5 x 7.25)	Too Wide							
	OK	2	3					
	Too Narrow	2	1	2	5	1	3	2
Small Plate Length (11.75 x 8.75)	Too Long							
	OK	1		1				
	Too Short	3	4	1	5	1	4	2
Small Plate Width (11.75 x 8.75)	Too Wide	2	4		2			
	OK	2		2	3	1	3	1
	Too Narrow						1	1
Medium Plate Length (12.5 x 9.5)	Too Long			1				
	OK	4	2	1	2		2	
	Too Short				3	1	2	2
Medium Plate Width (12.5 x 9.5)	Too Wide	4	2	2	5	1	2	1
	OK						2	1
	Too Narrow							
Large Plate Length (13.25 x 10.25)	Too Long							
	OK	3		1	5	1	3	1
	Too Short							
Large Plate Width (13.25 x 10.25)	Too Wide	4	1	1	5	1	3	1
	OK							
	Too Narrow							

Shaded cells show most frequent rating.

Appendix C.

Predicted Size Compared to Best Fit Size Anthropometry

Table C1. Predicted Size Compared to Best Fit Size Anthropometry (11 – 31)

			Predicted Size		Best Fit Size		
Size	Dimension		N	Median (mm)	Median (mm)	N	Δ (mm)
11	Chest Circ		3	817	817	3	0
	Neck Circ		3	350	350	3	0
	Waist Circ		3	725	725	3	0
	Stature		3	1565	1565	3	0
	Torso Length Derived		3	397	397	3	0
21	Chest Circ		27	884	886	27	-2
	Neck Circ		27	361	359	27	2
	Waist Circ		27	756	748	27	8
	Stature		27	1638	1637	27	1
	Torso Length Derived		27	400	398	27	2
22	Chest Circ		12	877	878	14	-1
	Neck Circ		12	363	365	14	-2
	Waist Circ		12	761	767	14	-6
	Stature		12	1650	1664	14	-14
	Torso Length Derived		12	428	425	14	3
31	Chest Circ		23	964	964	21	0
	Neck Circ		23	367	366	21	1
	Waist Circ		23	822	822	21	0
	Stature		23	1632	1626	21	6
	Torso Length Derived		23	404	404	21	0

Includes only those who predicted into one of the eight prototype sizes.

Table C2. Predicted Size Compared to Best Fit Size Anthropometry (32 – 52)

			Predicted Size		Best Fit Size		
Size	Dimension		N	Median (mm)	Median (mm)	N	Δ (mm)
32	Chest Circ		20	950	951	19	-1
	Neck Circ		20	371	372	19	-1
	Waist Circ		20	845	847	19	-3
	Stature		20	1673	1680	19	-8
	Torso Length Derived		20	432	434	19	-3
41	Chest Circ		10	1014	1009	15	5
	Neck Circ		10	375	378	15	-4
	Waist Circ		10	865	908	15	-44
	Stature		10	1605	1605	15	-1
	Torso Length Derived		10	408	414	15	-6
42	Chest Circ		13	1021	1031	11	-10
	Neck Circ		13	380	378	11	2
	Waist Circ		13	955	971	11	-16
	Stature		13	1666	1676	11	-10
	Torso Length Derived		13	431	435	11	-4
52	Chest Circ		5	1105	1110	2	-5
	Neck Circ		5	377	394	2	-17
	Waist Circ		5	971	984	2	-13
	Stature		5	1650	1667	2	-17
	Torso Length Derived		5	445	448	2	-3

Includes only those who predicted into one of the eight prototype sizes.