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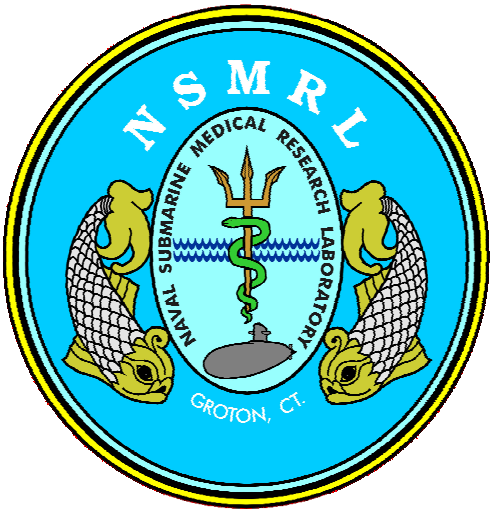

A REVIEW AND COMPARISON OF ANTHROPOMETRIC INDICES APPLICABLE TO THE US NAVY SUBMARINER POPULATION

by

Linda M. Hughes, MS and Wayne G. Horn, MD

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D.G. SOUTHERLAND, CAPT, MC, USN
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No anthropometric survey dedicated uniquely to submariners has been conducted since the 1970's. Indices that reflect the physical dimensions of today's sailors are needed to design and construct equipment, tools, and devices to be used by submarine personnel. Reference tables of outlying percentiles for upper body, lower body, and heights and weights for female and male Navy personnel were developed to reflect the physical dimensions of today's sailors. The average height of submariners has remained unchanged in the last 30 years. Today's submariners are taller than the Army, overall Navy, and the US populations. Military populations weigh less and are taller than their US population counterparts. Indices provided in this report may be useful in designing equipment such as stretchers and submarine escape suits to be used onboard submarines. When designing military equipment, anthropometric measures sampled from diverse male and female military populations should be used as opposed to the general US population.

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Authors: Linda M. Hughes, MS and Wayne G. Horn, MD

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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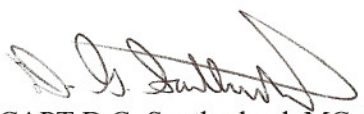

CAPT D.G. Southerland, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory
Submarine Base New London Box 900
Groton, CT 06349-5900

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The views expressed in this report are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the United States Government. This Technical Report has been designated as NSMRL/TR--2006-1249.

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ABSTRACT

BACKGROUND: Anthropometric surveys and data are highly important in the design and construction of equipment, tools, and devices that interface in part or whole with the human frame. Surveys of male and female US adults across different ethnic and age groups have shown continuing changes in anthropometric indices over the past recent decades[1,2]. Despite these changes no anthropometric survey dedicated uniquely to submariners has been conducted since the 1970's[3]. As a result, indices that more accurately reflect the physical dimensions of today's sailors are needed.

METHODS: From a sample of 1262 enlisted and officer Navy males, outlying percentiles of 25 anthropometric measures were obtained from the Navy Clothing and Textile Research Facility's (NCTRF) most recent men's anthropometric survey[4]. From a sample of enlisted and officer Navy women, outlying percentiles were calculated from summary statistics of 7 anthropometric measures obtained from the Navy's latest uniform sizing report for women[5]. Graphical comparisons of percentiles for heights and weights from other population studies were performed. Using summary statistics, one-way analysis of variance (ANOVA) tests were used to compare the heights and weights from the NCTRF survey and sizing reports to other military and nonmilitary samples. English and SI scales of measurement were used.

RESULTS: Tables of calculated or collected reference values of outlying percentiles for upper body, lower body, and heights and weights for female and male Navy personnel were developed to accurately reflect the physical dimensions of today's sailors. For males, one-way ANOVA tests found no difference in the heights (cm) of submariners in the last 30 years ($P < .84$). Contemporary submariners were found to be taller than the Army, the 1996 Navy, and the US population sample ($P < .001$) by at least 1 cm. Submariners in the 1970's were also found to be taller than the Army and US population samples ($P < .001$) by at least 1 cm. The US population sample was significantly heavier than the military populations sampled ($P < .001$) by at least 5 kg, while the Army weighed less than both Navy samples ($P < .001$) by at least 2 kg. For women, a one-way ANOVA showed the US population sample to be at least 0.84 cm shorter than all military samples ($P < .01$), but no differences in height (cm) among the military samples were found. The US population's female sample was also significantly heavier than all of the military female samples ($P < .001$) by at least 12 kg. The 1977 female Army sample was significantly lighter than all of the other female samples ($P < .001$) by at least 2 kg.

CONCLUSIONS: The upper and lower limit indices provided in this report may be useful in the current design and construction of equipment, tools, and devices used by submarine personnel. These tables provide useful parameters for designing equipment such as stretchers and submarine escape suits to be used onboard submarines. For men, recent Navy data show the lower height limits of the 1st and 5th percentiles are 158.05 cm (62.22 inches) and 164.30 cm (64.69 inches) with the upper height limits of the 95th and 99th percentiles at 189.56 cm (74.63 inches) and 193.92 cm (76.35 inches). For women, the lower height limits of the 1st and 5th percentiles are 148.71 cm (58.55 inches) and 153.07 cm (60.26 inches) with the upper height limits of the 95th and 99th percentiles at 174.13 cm (68.56 inches) and 185.50 cm (73.03 inches). While the average height of a submariner has not changed in 30 years, recent measures of submariners show they are taller than the overall Navy population. When designing military equipment, anthropometric measures sampled from diverse male and female military populations should be used as opposed to the general population.

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INTRODUCTION

Anthropometric surveys and data are highly important in the design and construction of equipment, tools, and devices that interface in part or whole with the human frame. This is particularly true for military applications and work in extreme environments. Therefore, it is vital that the anthropometric measurements used in the design and construction of equipment applies to the population for which it will be used.

In recent decades, national government surveys of male and female adults across different ethnic and age groups have shown continuing changes in anthropometric indices[1, 2]. Many of these changes are believed to be due to lifestyle changes and the increased diversification of the population. Similarly, today's US Navy is a diverse ethnic/racial population. Furthermore, the number of females in the Navy is also increasing.

Development and design of new equipment for use onboard submarines requires anthropometric indices that accurately reflect the physical dimensions of today's submariners. But despite the Navy's demographic changes, no anthropometric survey dedicated uniquely to submariners has been conducted since the 1970's[3]. Due to the time and cost involved in conducting an anthropometric study unique to submariners, estimates based on a broader Navy population need to be used. Fortunately, recent anthropometric measurements were collected on a sample of US Navy male personnel that included submariners[4] and, in a separate study, on a sample that included US Navy female personnel[5]. Although the US Navy does not currently assign women to submarines, it is a future possibility. Therefore, women's anthropometric measures are also considered.

In contrast to uniforms that are constructed in many sizes to fit each individual closely and comfortably, equipment such as stretchers and submarine escape suits are constructed in one size that must fit all individuals. Hence, applying anthropometric measures to the development, design, and sizing of such equipment requires the use of only upper and lower limit estimates. With regard to ordinary design conditions the latest Department of Defense (DOD) standard (formerly titled Military Standard[6]) of human engineering design criteria states it is acceptable to exclude 5% of the (male or female) population due to physical factors[7]. However, it also states under special conditions:

> Where failure to accommodate the size or performance of personnel could result in a hazardous condition leading to personnel injury or equipment damage, the total percentage of men excluded by the design for all physical factors (size, weight, reach, strength, and endurance) shall not exceed 1 percent, and the total percentage of women excluded by the design for all physical factors (size, weight, reach, strength, and endurance) shall not exceed 1 percent[7].

Therefore, if percentiles of the population are known, stretchers and escape suits should be designed at the 0.5^{th} and 99.5^{th} percentiles, thereby only excluding 1% of the population. In addition, the military standard also gives allowance to special populations. Thus, if equipment is only to be used by a unique population (e.g., Navy divers, submariners) percentiles based on the respective population may be used. (It should also be noted that the DOD standard[7] does not address nonmilitary personnel [e.g., civilian submarine riders] who, under special circumstances, may find themselves in a military environment for a short period of time.)

Although submariners could be considered a special population, they are also a diverse ethnic/racial population. And, as such, equipment and gear intended only for submarine use, especially when used to save lives, should be designed with the broadest population considered.

The goals of this report are to summarize the upper and lower limits of select anthropometric measures obtained from the Navy Clothing and Textile Research Facility's (NCTRF) most recent men's anthropometric survey[4]. These measures will be useful in the development, design, and sizing of stretchers, submarine escape suits, and other equipment for use onboard a submarine. Additionally, the NCTRF male height and weight measures will also be compared to heights and weights reported in the 1970's submariner study[3], a 1988 US Army study[8] (provided in the military handbook of anthropometry as the latest measures of male personnel[9]), and the US Department of Health and Human Services' US population reference survey[10]. Comparisons for height will also include recent measurements on US Navy submariners[11]. Because of the future possibility of women being assigned to submarines, select measures derived from the NCTRF women's sizing report[5] will also be summarized here. The heights and weights from the NCTRF report[5] will be compared to three other women's studies; a 1977 US Army study[12], a 1988 US Army study[8] (provided in the military handbook of anthropometry as the latest measures of female personnel[9]), and the US Department of Health and Human Services' US population reference survey[10].

METHODS

Men

To obtain upper and lower limits, outlying percentiles of 25 selected anthropometric measures were obtained from the Navy Clothing and Textile Research Facility's (NCTRF) most recent men's anthropometric survey[4]. Their sample consisted of 715 enlisted men and 547 officers representative of the Navy's racial/ethnic and age mix[4] with a median age of 28 years. (Further statistics on age, such as mean, SD, and the exact range, were not provided in the NCTRF report[4]; however, a detailed frequency distribution was given [see appended report].) These sailors, some of which were submariners, were selected from 6 sites within the Navy from 1996-1997[4].

The NCTRF percentiles that were calculated separately for enlisted men and officers combined all ages and racial/ethnic groups. Therefore, these percentiles represent either the enlisted men or officer group (officer group included E-7 through E-10), but not the two groups combined. To estimate the upper and lower limits, only percentiles clustered at the top and bottom of the distributions are reported. Measures are reported in English and metric units (International System of Units [SI]).

Percentiles for both height and weight from the NCTRF study were compared graphically to a 1970's[3] submariner study, a 1988 US Army study[8], and the US Department of Health and Human Services' US population reference survey[10]. Comparisons for height also included recent measurements on US Navy submariners[11]. The US population survey did not provide 1st and 99th percentiles, and because the distribution for weights was skewed, reasonable approximations of these measures could not be done. The height distribution, however, was normal; therefore the 1st and 99th percentiles were calculated from the summary statistics provided in the survey report as $P = \text{mean} \pm (z \times SD)$[13]. Data represented in graphical comparisons are expressed in SI. Percentiles expressed include all race/ethnicity groups for which data were collected on. The ages included for the military studies are similar, however, the US population sample excluded males younger than 20 and included men well beyond military retirement age (i.e., beyond 80 years old).

Women

Anthropometric measures from a sample of 888 women representative of the racial/ethnic and officer/enlisted mix of the Navy's female population from 8 Atlantic coast naval facilities were

obtained from the Navy's latest uniform sizing report for women[5]. The sample included enlisted women (88.5%) and officers (11.5%). Ages ranged from 19-49 years with the mean age of 26.5 years (SD = 5.1). A more detailed breakdown of age groups can be found in the appended NCTRF sizing report[5].

The only summary statistics provided in the NCTRF report were means, standard deviations, minimums, and maximums. Therefore, based on these limited statistics, percentiles needed to be calculated for the anthropometric measures obtained from the sizing evaluation report[5]. Only 7 measurements identified as useful in equipment sizing and design are included. The minimum and maximum values used represent the overall lowest and highest values that were reported from all racial groups when combined. Although all groups' means and standard deviations were similar (with the exception of the SD for the Asian women, whose large standard deviations would have resulted in unusually low or high limits), because white women had the largest group (n = 662), and therefore most likely to be normally distributed, the means and standard deviations from this group were used to calculate the percentiles. Normal distributions were assumed, and percentiles were again calculated as $P = \text{mean} \pm (z \times SD)$[13].

Head circumference was not reported in NCTRF sizing report[5]. Therefore, head circumference percentiles were obtained and used from the 1988 US Army study[8].

Similar to what was done for the male data, percentiles calculated for both height and weight from the NCTRF women's sizing report were compared graphically to 3 other women's studies; a 1977 US Army study[12], a 1988 US Army study[8], and the US Department of Health and Human Services' US population reference survey[10]. The US population survey did not provide 1st and 99th percentiles, and because the distribution for weights was skewed, reasonable approximations of these measures could not be done. The height distribution was normal; therefore, using the aforementioned percentile formula, the 1st and 99th percentiles were calculated from the summary statistics provided in the US survey report. Data represented in graphical comparisons are expressed in SI. Percentiles from the Army and US population studies include all race/ethnicity groups for which data were collected on. The Navy (NCTRF) percentiles for height and weight include only white women. The ages included for the military studies were similar, however, as with the male US population sample, the US female sample included women from 20 to beyond 80 years of age.

Men and Women

For the male and female samples, the summary data obtained or derived from the aforementioned studies were used to conduct one-way ANOVA tests to determine if the average height or weight among the male or female samples differed. Tests for homogeneity of variances could not be performed because the data were already aggregated. Therefore, unequal variances were assumed, and the alternative Brown-Forsythe F-tests were done. All post hoc comparisons were performed using the Tamhane T2 test.

All statistical analyses were done using SPSS 13.0 for Windows. Statistical tests and graphical comparisons were done in SI units. Type I error probability acceptance was set at .05 and all significance tests were nondirectional.

RESULTS

Men

Using the NCTRF data collected from 1996-1997, Tables 1-3 show the smallest values reported at the 1st, 2nd, 3rd and 5th percentiles and the largest 95th, 97th, 98th, and 99th percentiles, as well as the overall minimum and maximum sizes obtained for all personnel for height and weight, upper body, and lower body, respectively.

Table 1. Height and Weight: Upper and Lower Limits for US Navy Men

		Percentiles									
		Lower Limits					Upper Limits				
Measure		Min	1st	2nd	3rd	5th	95th	97th	98th	99th	Max
Height	cm	151.30	158.05	160.60	162.19	164.30	189.56	191.41	192.22	193.92	200.10
	inches	59.57	62.22	63.23	63.86	64.69	74.63	75.36	75.68	76.35	78.78
Weight	kg	43.50	51.08	55.16	57.00	60.50	103.10	107.78	110.00	115.34	130.00
	lbs	95.90	112.61	121.61	125.66	133.38	227.30	237.61	242.51	254.28	286.60

Table 2. Upper Body: Upper and Lower Limits for US Navy Men

		Percentiles									
		Lower Limits					Upper Limits				
Measure		Min	1st	2nd	3rd	5th	95th	97th	98th	99th	Max
Head circumference	cm	51.60	53.02	53.63	53.85	54.10	59.56	60.21	60.61	61.15	64.17
	inches	20.31	20.87	21.11	21.20	21.30	23.45	23.71	23.86	24.08	25.26
Neck circum-ference, base	cm	35.70	36.43	37.10	37.40	38.08	45.70	46.30	47.00	47.90	51.00
	inches	14.06	14.34	14.61	14.72	14.99	17.99	18.23	18.50	18.86	20.08
Chest circumference	cm	79.50	83.26	86.40	86.80	88.40	116.74	119.60	121.00	122.58	134.40
	inches	31.30	32.78	34.02	34.17	34.80	45.96	47.09	47.64	48.26	52.91
Interscye II	cm	35.70	36.73	37.93	38.60	39.10	48.30	48.96	49.22	50.52	51.90
	inches	14.06	14.46	14.93	15.20	15.39	19.02	19.28	19.38	19.89	20.43
Shoulder circumference	cm	97.00	103.30	105.00	105.95	107.38	132.04	133.45	135.00	137.66	143.10
	inches	38.19	40.67	41.34	41.71	42.28	51.98	52.54	53.15	54.20	56.34
Shoulder length	cm	10.50	11.50	12.00	12.10	12.34	16.40	16.70	16.90	17.10	18.20
	inches	4.13	4.53	4.72	4.76	4.86	6.46	6.57	6.65	6.73	7.17
Sleeve length: Spine-wrist	cm	74.00	78.00	79.86	80.30	81.30	95.70	96.61	97.00	99.10	101.50
	inches	29.13	30.71	31.44	31.61	32.01	37.68	38.04	38.19	39.02	39.96
Sleeve outseam	cm	45.72	49.91	50.70	51.19	51.87	61.31	61.99	62.49	63.27	68.58
	inches	18.00	19.65	19.96	20.15	20.42	24.14	24.41	24.60	24.91	27.00
Hand breadth	cm	7.30	7.70	7.80	7.90	8.00	9.56	9.66	9.70	9.80	10.20
	inches	2.87	3.03	3.07	3.11	3.15	3.76	3.80	3.82	3.86	4.02
Hand circumference	cm	17.90	18.30	18.70	18.90	19.14	22.80	23.00	23.00	23.28	24.90
	inches	7.05	7.20	7.36	7.44	7.54	8.98	9.06	9.06	9.17	9.80
Hand length	cm	16.90	17.50	17.80	17.94	18.10	21.60	22.00	22.20	22.67	23.30
	inches	6.65	6.89	7.01	7.06	7.13	8.50	8.66	8.74	8.92	9.17
Digit III length	cm	6.80	7.10	7.20	7.25	7.40	9.10	9.20	9.40	9.50	10.00
	inches	2.68	2.80	2.83	2.85	2.91	3.58	3.62	3.70	3.74	3.94

Table 3. Lower Body: Upper and Lower Limits for US Navy Men

Measure		Percentiles									
		Lower Limits					Upper Limits				
		Min	1st	2nd	3rd	5th	95th	97th	98th	99th	Max
Waist back length, referred	cm	39.50	40.72	41.36	41.85	42.66	54.00	55.00	55.41	56.20	58.50
	inches	15.55	16.03	16.29	16.48	16.80	21.26	21.65	21.81	22.13	23.03
Waist circumference (natural indentation)	cm	65.90	68.38	70.33	71.10	73.28	101.84	103.40	105.41	107.56	116.50
	inches	25.94	26.92	27.69	27.99	28.85	40.09	40.71	41.50	42.35	45.87
Waist circum-ference, omphalion	cm	66.00	69.03	70.83	72.64	74.90	106.14	108.64	110.64	112.94	118.00
	inches	25.98	27.18	27.89	28.60	29.49	41.79	42.77	43.56	44.46	46.46
Waist circum-ference, preferred	cm	66.30	70.10	71.62	72.80	75.00	104.68	107.28	108.82	110.76	115.50
	inches	26.10	27.60	28.20	28.66	29.53	41.21	42.24	42.84	43.60	45.47
Waist front length, preferred	cm	33.90	37.32	37.83	38.74	39.60	52.10	53.45	54.47	55.50	58.00
	inches	13.35	14.69	14.89	15.25	15.59	20.51	21.04	21.44	21.85	22.83
Buttock circumference	cm	78.60	83.50	85.00	86.40	88.48	111.84	114.00	115.00	117.42	126.70
	inches	30.94	32.87	33.46	34.01	34.83	44.03	44.88	45.28	46.23	49.88
Buttock height	cm	75.40	78.86	79.96	80.50	82.04	99.94	101.55	102.54	103.68	112.00
	inches	26.69	31.05	31.48	31.69	32.30	39.35	39.98	40.37	40.82	44.09
Crotch height	cm	69.00	71.34	73.30	73.75	74.70	92.00	93.50	94.70	95.78	101.10
	inches	27.17	28.09	28.86	29.03	29.41	36.22	36.81	37.28	37.71	39.80
Crotch length, preferred	cm	47.20	49.33	50.36	51.00	51.98	71.16	73.06	74.01	76.80	80.30
	inches	18.58	19.42	19.83	20.08	20.46	28.02	28.76	29.14	30.23	31.61
Thigh circumference	cm	43.40	47.02	48.73	49.25	50.50	68.62	70.40	71.47	72.19	78.50
	inches	17.09	18.51	19.19	19.39	19.88	27.02	27.72	28.14	28.42	30.91
Foot length	cm	22.60	23.60	24.03	24.35	24.68	29.50	29.95	30.20	30.58	31.10
	inches	8.90	9.29	9.46	9.59	9.72	11.61	11.79	11.89	12.04	12.24

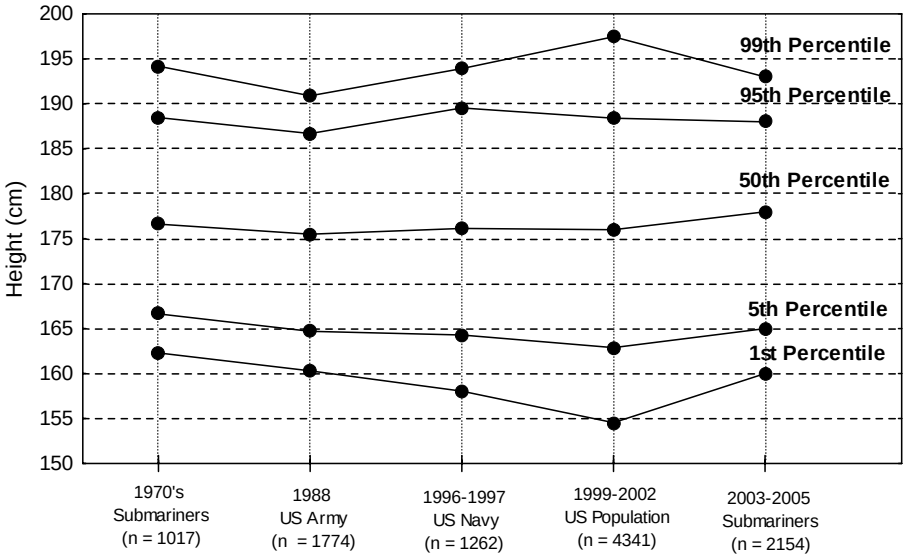

Figure 1. Comparison of male height percentiles by sample. Percentiles were extracted from survey reports. 1996 - 1997 Navy median is the midpoint of the officer and enlisted medians. US population 1st and 99th percentiles were calculated from summary statistics.

Figures 1 and 2 compare the NCTRF (1996 – 1997 Navy) percentiles to percentiles of 3 other military samples for heights, and 2 other military samples for weights, both to a sample of the general US population. The heterogeneous US population sample shows the largest range in measures for both height and weight. For heights, the 2 submariner groups, sampled about 30 years apart, are similar while the US Navy NCTRF sample shows a slightly broader range in heights. For weights, the US population's 95th percentile exceeds all military samples' 99th percentiles with the US Army showing the smallest range. Figure 1 shows the height medians to be similar, and Figure 2 shows the weight medians to be similar.

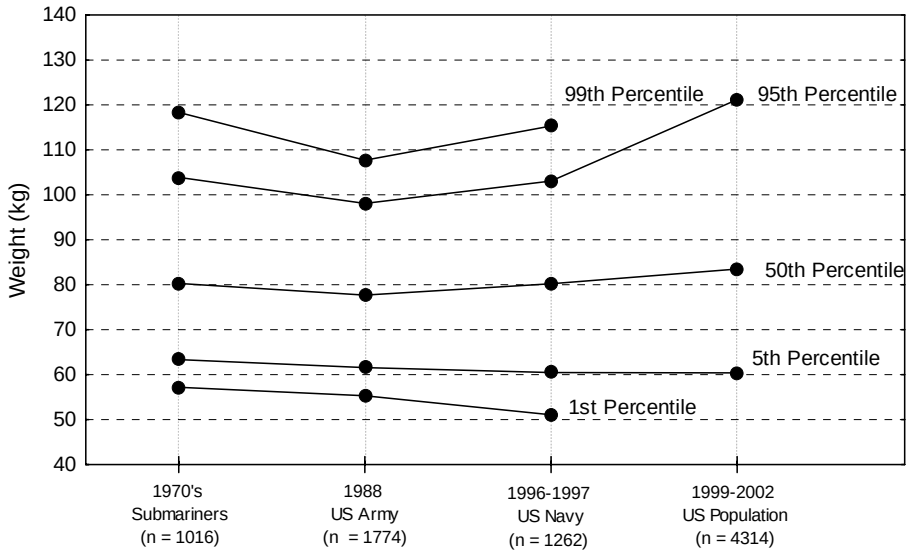

Figure 2. Comparison of male weight percentiles by sample. Percentiles were extracted from survey reports. 1996 - 1997 Navy median is the midpoint of the officer and enlisted medians. US population 1st and 99th percentiles could not be calculated from summary statistics due to the skewness of the distribution.

Using the summary data provided in the aforementioned reports, a one-way ANOVA showed a significant main effect for height (cm) (Brown-Forsythe $F_{4,8593} = 20.81$, $P < .001$). The Tamhane T2 showed the recent submariner sample to be significantly taller than all other samples ($P < .001$) except for the 1970's submariners ($P < .84$). The 1970's submariners were also found to be significantly taller than the Army ($P < .001$), the US population ($P < .001$), and the NCTRF Navy ($P = .05$) samples. No other post hoc differences were found. See Figure 3 for mean group comparisons.

The summary data used in the one-way ANOVA for weights (kg) also showed a significant main effect (Brown-Forsythe $F_{3, 7812} = 127.54$, $P < .001$). As shown with the Tamhane T2, the US population sample was significantly heavier than all of the military samples ($P < .001$). The only other significant differences among the groups were for the Army, which was found to weigh significantly less than both Navy groups sampled ($P < .001$). No difference was found between the NCTRF Navy and 1970's submariner samples ($P = .79$). Figure 4 compares these group means.

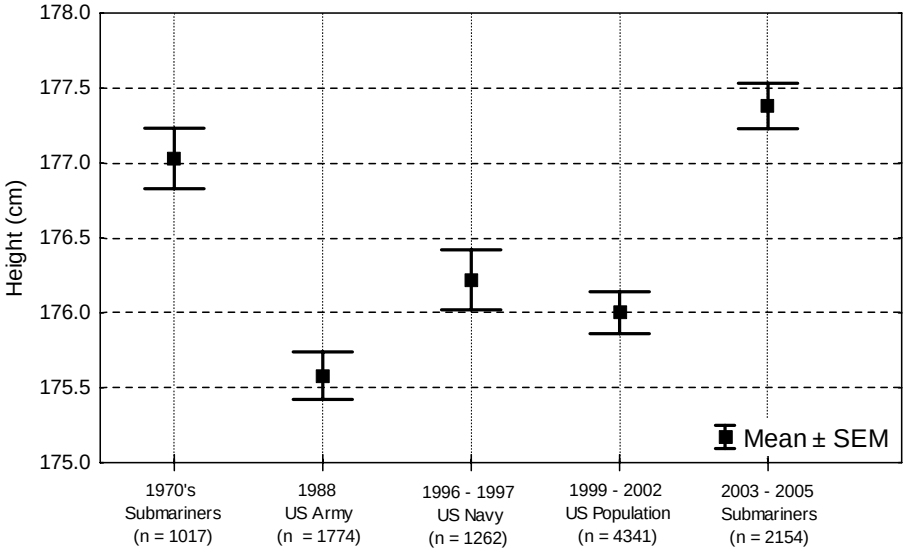

Figure 3. Comparison of mean male height ± standard error of the mean by sample. Values were taken from survey reports. Comparisons illustrate the differences among the groups.

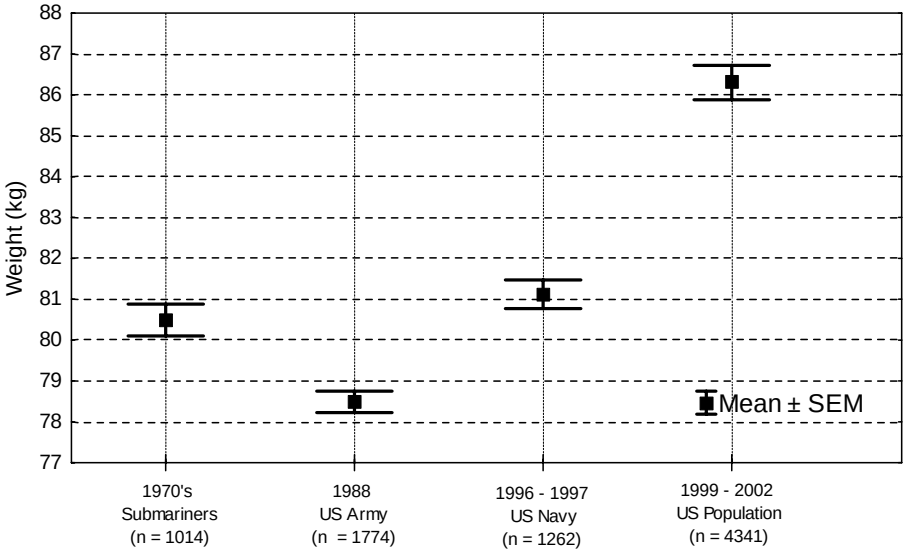

Figure 4. Comparison of mean male weight ± standard error of the mean by sample. Values were taken from survey reports. Comparisons illustrate the differences among the groups.

Women

All percentiles, except those for head circumference, found in Table 4 were calculated from the summary statistics for white women in the NCTRF report[5]. Women's head circumference values are from the 1988 US Army report[8]. Table 5 shows the number of women in each racial/ethnic group from which the NCTRF minimum and maximum values were taken. White women were generally found to have the broadest size range. In addition, they had the largest maximum measures except for sleeve outseam and length. White women also had the smallest measures except neck circumference. All values are displayed in English and metric units.

Table 4. Upper and Lower Anthropometric Limits for US Navy Women

		Percentiles									
		Lower Limits					Upper Limits				
Measure		Min	1st	2nd	3rd	5th	95th	97th	98th	99th	Max
Weight	kg	39.46	41.32	43.75	45.28	47.38	76.63	78.73	80.26	82.69	95.25
	lbs	87.00	91.10	96.45	99.84	104.46	168.94	173.56	176.95	182.30	210.00
Height	cm	146.99	148.71	150.46	151.56	153.07	174.13	175.64	176.75	178.49	185.50
	inches	57.87	58.55	59.23	59.67	60.26	68.56	69.15	69.59	70.27	73.03
Waist height	cm	87.00	90.89	92.24	93.10	94.27	110.56	111.73	112.58	113.93	121.01
	inches	34.25	35.78	36.32	36.65	37.11	43.53	43.99	44.32	44.86	47.64
Crotch Height	cm	62.99	65.10	66.25	66.97	67.96	81.75	82.74	83.46	84.60	89.99
	inches	24.80	25.63	26.08	26.37	26.76	32.18	32.57	32.86	33.31	35.43
Head	cm	50.00	51.34	51.69	51.92	52.25	57.05	57.48	57.82	58.40	61.10
circumference*	inches	19.69	20.21	20.35	20.44	20.57	22.46	22.63	22.76	22.99	24.06
Neck	cm	27.94	29.39	29.87	30.18	30.59	36.41	36.83	37.13	37.62	40.64
circumference	inches	11.00	11.57	11.76	11.88	12.05	14.33	14.50	14.62	14.81	16.00
Sleeve length	cm	69.85	72.26	73.28	73.93	74.82	87.18	88.07	88.72	89.75	95.25
	inches	27.50	28.45	28.85	29.11	29.46	34.32	34.67	34.93	35.33	37.50
Sleeve outseam	cm	45.72	49.91	50.70	51.19	51.87	61.31	61.99	62.49	63.27	68.58
	inches	18.00	19.65	19.96	20.15	20.42	24.14	24.41	24.60	24.91	27.00

*Head circumference was not included in the NCTRF sizing report[5]. The values listed in this table are from the US Army sample[8].

Table 5. Number of US Navy Women by Race/Ethnicity

Race	%	n
White	74%	662
Black	21%	183
Hispanic	1%	9
Asian	4%	34
Total	100%	888

Figures 5 and 6 graphically compare selected height and weight percentiles, respectively, of military females compared to a US population sample. As expected, the more heterogeneous US population sample's 1st and 99th percentile range for heights exceeds that of all the military populations sampled. The medians for heights are similar for all samples. For weight, the US population sample's 95th percentile exceeds all 99th percentiles for the military samples. The US population's median weight is nearly 10 kg heavier than all the military population's median weights.

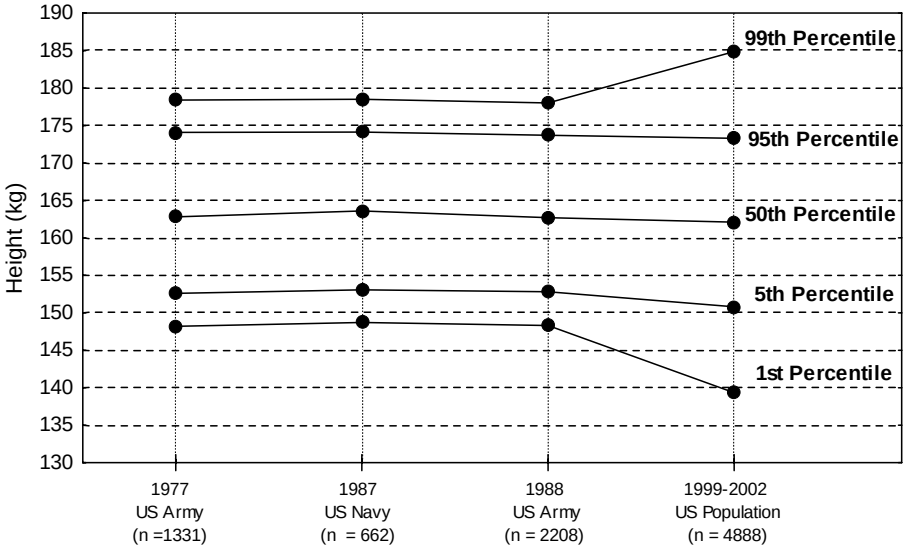

Figure 5. Comparison of female height percentiles by sample. Percentiles were extracted from survey reports. Because Navy percentiles were derived from parametric summary statistics, the median is actually the mean. US population 1st and 99th percentiles were calculated from summary statistics.

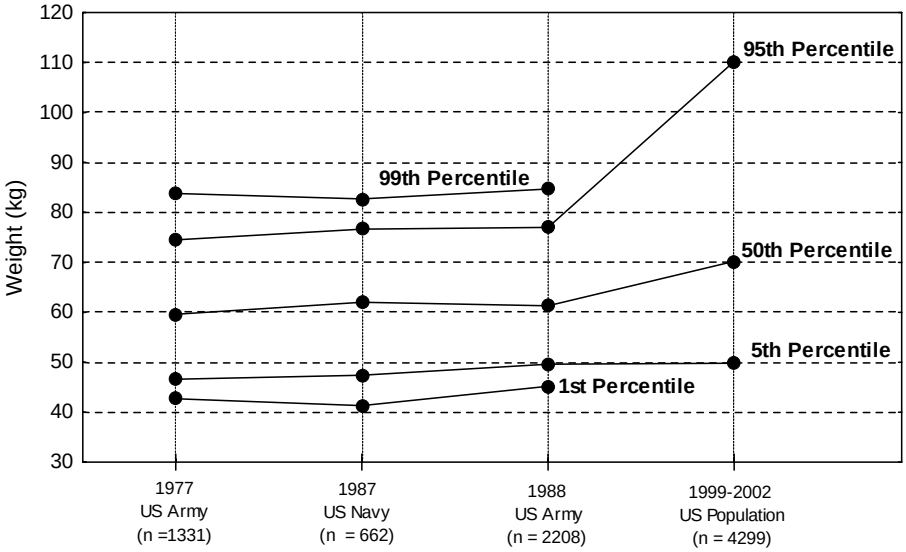

Figure 6. Comparison of female weight percentiles by sample. Percentiles were extracted from survey reports. Because Navy percentiles were derived from summary statistics, the median is actually the mean. US population 1st and 99th percentiles could not be calculated from summary statistics due to the skewness of the distribution.

Using the summary data provided in the aforementioned women's studies, a one-way ANOVA showed a significant main effect for height (cm) (Brown-Forsythe $F_{3, 5566} = 12.61$, $P < .001$). Tamhane T2 post hoc comparisons found the US population sample to be significantly shorter

than all military samples ($P < .01$), but no differences in height (cm) among the military samples were found. See Figure 7 for mean group comparisons.

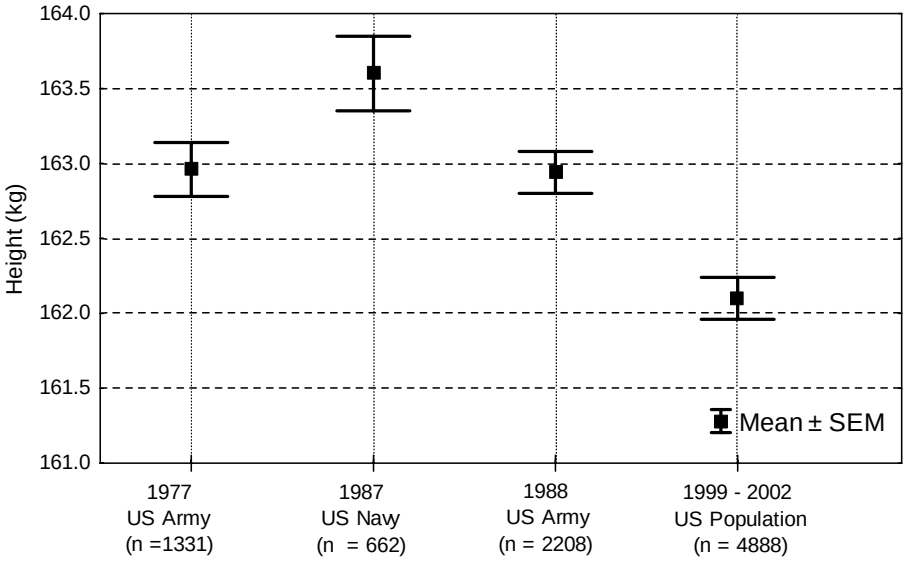

Figure 7. Comparison of mean female height ± standard error of the mean by sample. Values were taken from survey reports. Comparisons illustrate the differences among the groups.

The summary data used in the one-way ANOVA for weights (kg) also showed a significant main effect (Brown-Forsythe $F_{3, 6857} = 546.395$, $P < .001$). The US population sample was significantly heavier than all of the military samples (Tamhane T2, $P < .001$) by at least 12 kg. In contrast, the 1977 Army sample was significantly lighter than all of the other samples (Tamhane T2, $P < .001$) by at least 2 kg. Figure 8 compares these group means.

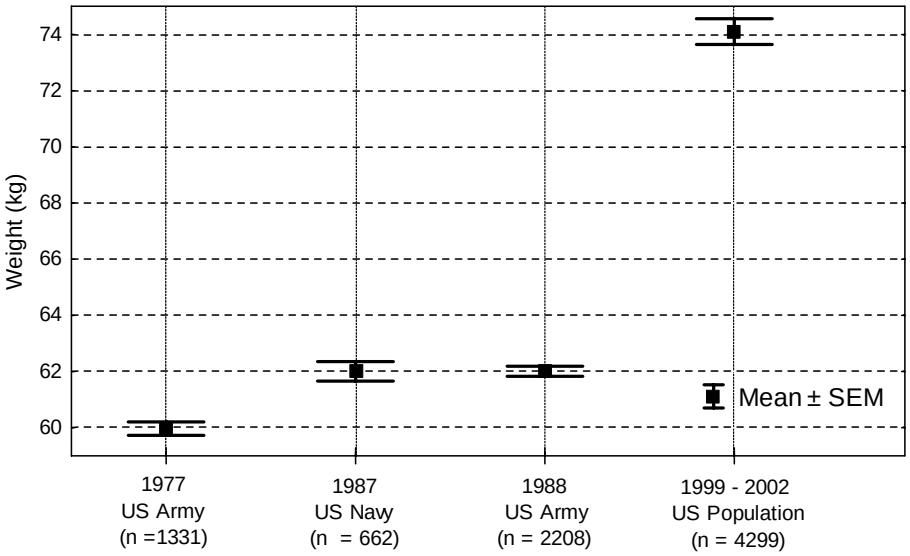

Figure 8. Comparison of mean female weight ± standard error of the mean by sample. Values were taken from survey reports. Comparisons illustrate the differences among the groups.

COMMENTS

Selected anthropometric measures included in the male NCTRF survey[4] and the female NCTRF sizing report[5] (both electronically appended) considered useful in the development, design, and sizing of stretchers, submarine escape suits, and other equipment requiring updated anthropometric measurements of contemporary submariners are included in this report. Unfortunately, many of the measurements obtained from the men's NCTRF report were not duplicated in the women's sizing report. Because head circumference is a key measure in the design of submarine escape suits, and it was not included in the women's sizing report, these values were obtained from the 1988 women's Army report[8]. It should be noted that a recent NIOSH report[14] found the mean head circumference of the Army's female sample to be significantly smaller than their US population sample. Therefore, if broader ranges are desired, the NIOSH report could be used for this measure. Also, while the men's data were collected from 1996-1997, the women's NCTRF data are nearly 20 years old. The Navy is currently re-evaluating it (B. A. Avellini [BAvellini@NCTRF.Natick.Army.Mil], e-mail, July 13, 2006).

Because the goal of this report is to provide measurements to be used in a "one size fits all" sizing scheme, only estimates of the upper and lower limits of these measures were used. While it is well known that people from different races or ethnicities do vary across anthropometric measures, the actual breakdown of the varying race/ethnicities was not a concern as long as no race/ethnicity groups were excluded.

The graphical comparison of male heights suggests that while the US Navy population has become more diverse in its size, its subset, the submariner population, may not be, or is becoming more diverse at a much slower rate. Further, it is surprising that the heights of the submariner population have not changed significantly in 30 years. No racial breakdown was provided in the 1970's submariner report[3]; however, 70% of the sample NCTRF male report sample was white[4]. This is 11% less than the recent submariner survey that found 81% of its sample reporting they were white[11]. This suggests that a submariner community subgroup could have different anthropometric dimension limits. However, even if the submariner population is disproportionate in its race/ethnicity breakdown as compared to other naval communities, equipment should be designed with the broader population in mind.

With regard to the women, it is interesting to note that while means did differ among the women's military samples, the plots of percentiles show little difference in medians or upper and lower percentiles for their heights and weights. This suggests that although the mean differences were statistically significant these differences may have little practical importance in the design of escape suits and stretchers.

While adult heights are known to be normally distributed, the distribution of adult weights is typically non-normal. Therefore, it is unfortunate that the raw data were unavailable. Had they been available, data transformations could have been done on weight to normalize the distributions for more accurate comparisons. Despite these limitations, the differences found in weights between the military and the US population samples for both men and women is profound.

Finally, the differences seen between the military samples and the US population samples demonstrate the continued need of anthropometric sampling from unique military populations and the importance of avoiding the use of measures derived from the general US population. When applying the upper and lower limits of anthropometric measures to the design of equipment, it is crucial that the data applied accurately reflect the dimensions of the target population for which

the equipment will be used for. Along with these restricted dimensions is the caveat that the occasional nonmilitary member who finds himself in a military environment (e.g., civilian submarine riders) may be unable to use such specialized equipment.

The data tables in this report provide guidelines for designing equipment such as stretchers and submarine escape suits to be used onboard submarines.

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APPENDIX

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