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ANTHROPOMETRIC SIZING STUDY FOR THE CANADIAN FORCES: MATCHED DATABASE VALIDATION

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13. ABSTRACT *(Maximum 200 words)*

A validation sample of 535 male Canadian Forces (CF) was measured. Unfortunately, the measuring sites chosen by the CF were atypical and led to a non-random sample. Prior to discovering this bias, the data were utilized to explore several alternative matching procedures. The most successful was a subject-to-subject individual matching procedure using age, height and weight. However, waist circumference continued to differ significantly between the CF validation subjects and their U.S. Army matches. This result could be indicative of a true anthropometric difference between the CF and the U.S. Army populations. Most probably, however, the large proportion of support personnel measured during the CF Validation Study has led to biased estimates. The tested matching procedures can be used to create a CF male database if representative height, weight and waist circumference data are collected.

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Preface

The Anthropometric Sizing Study was conducted to determine the usefulness of current anthropometric databases for the design and sizing of clothing and individual equipment for the Canadian Department of National Defense, Directorate of Ammunition, Clothing, Materiel, and Engineering. The project was conducted by the U.S. Army Soldier Systems Command, Natick Research, Development, and Engineering Center, with the assistance of GEO CENTERS, Inc. from January 1993 to April 1994. Six matching procedures were tested using the 1988 Anthropometric Survey of U.S. Army Personnel and the 1992 Canadian Forces Express Database.

Acknowledgements

The authors thank Ms. Ann Marie Sibbald, Directorate of Ammunition, Clothhing, Materiel, and Engineering Project Manager, for her extensive support throughout the project and her personal commitment during the difficult data collection phase of the study. Ms. Nancy Bell and Ms. Madeline Hinkes, of GEO-CENTERS, Inc., led the measuring team that collected the Canadian Forces field data used in this project.

This manuscript could not have been completed without the invaluable editorial and production assistance received from Mr. John Redgate and Mr. J. David Brantley of the U.S. Army Soldier Systems Command, Natick Research, Development, and Engineering Center.

Executive Summary

The Directorate of Ammunition, Clothing, Materiel and Engineering (DACME), Canadian Forces (CF), contracted the US Army Soldier Systems Command (SSCOM) Natick Research, Development and Engineering Center (NRDEC) to conduct a validation study that would determine if stratified random sampling can be used to create accurate anthropometric databases for the Canadian Forces population. During July and August of 1993, 535 male CF personnel, who met the age and element sampling criteria, were fully measured for 18 anthropometric dimensions at four locations. Because no differences were found between the rostered and substitute subjects, all 535 subjects were used to validate the matching procedures tested in the CF Validation study.

Unfortunately, the bases chosen by the CF as measuring sites were atypical, with an uncharacteristically high proportion of support personnel. The ratio of operational to support personnel measured for the study is ***not*** the same as the general CF male population. Because less physically fit CF personnel are preferentially placed in support roles, the large number of support personnel in the sample could impact the anthropometric distribution. Therefore, the sample is not random and may not be anthropometrically representative of the male CF population, preventing demographic only matching methods from being properly validated. In addition, statistically significant differences were observed between the anthropometric distributions of the CF Validation Study and the 1992 CF Express Database, even though both data sets purport to describe the same population.

Since the sample is not representative of male CF personnel, the Height and Weight data should not be used as input to an algorithm for constructing a matched database. It is recommended that additional anthropometric data (Height, Weight, and Waist Circumference) be collected on a representative sample of the CF male population. The representative data will be used to reassess demographic only matching procedures, and to corroborate the conclusions of this study. If demographic only methods continue to fail, the truly representative data can be used as input for a matching algorithm. It is recommended that the additional data be collected from a male sample during the proposed CF Female Validation Study.

Before the biases in the male CF Validation Study sample were discovered, the data were utilized to explore the validity and efficacy of several alternative matching procedures. These studies contributed considerably to our understanding of and confidence in the matching process itself. Among the matching techniques evaluated, the most successful was a subject to subject individual matching procedure using Age, Height, and Weight. However, a large proportion (38%) of the CF Validation Study subjects could not be matched simultaneously for all three criteria. A larger proportion of subjects (84%) could be successfully matched when flexible Age criteria were imposed; however

Waist Circumference continued to differ significantly between the CF Validation subjects and their US Army matches. This result could be indicative of a true anthropometric difference between the CF and the US Army populations, since the CF Validation Study subjects are significantly heavier than ANSUR subjects in the 25-29 and >35 year age categories. Most probable, however, is that the large proportion of support personnel measured during the CF Validation Study has led to biased estimates for a number of anthropometric dimensions, including Waist Circumference. By collecting additional Height, Weight and Waist Circumference data from a *representative* sample of CF male personnel, the tested matching procedures can be utilized to create and validate an anthropometrically representative database for the CF male population.

ANTHROPOMETRIC SIZING STUDY FOR THE CANADIAN FORCES: MATCHED DATABASE VALIDATION

Introduction

Recent research conducted by the Directorate of Ammunition, Clothing, Materiel and Engineering (DACME) of the Department of National Defence (DND) indicates that the anthropometric databases currently in use for the design and sizing of Clothing and Individual Equipment (CIE) may not accurately reflect the anthropometric distribution present in the contemporary Canadian Forces (CF). Recently, the CF population has undergone significant changes in both gender distribution and stature; factors that severely impact the fit and tariffing of standard clothing and equipment (5,6,7,8,9). In addition, the CF envisions the soldier of the 21st century being outfitted in integrated components and complex layering systems that may be more sensitive to individual anthropometric variation. Therefore, a comprehensive and accurate anthropometric database for the contemporary CF population must be available for the development, sizing and tariffing of CIE.

Traditionally, large-scale anthropometric surveys are conducted to provide the type of data required by DACME. Because these surveys can be prohibitively time-consuming and expensive, an alternative method, called statistical matching, can be used. The matching process selects a sample from an existing database that has the same anthropometric distribution found in the target population, in this case the CF. Earlier research has demonstrated that stratified random matching from the 1988 Anthropometric Survey of US Army Personnel (ANSUR) data can successfully represent the US Army pilot anthropometric distribution (10). However, statistical matching has never been validated for military populations outside of the United States (US). Therefore, the CF Validation Study was conducted by the US Army Natick Research, Development and Engineering Center (Natick) under contract to DACME to determine whether or not a matched database, selected from US Army data, is truly representative of the actual CF population anthropometric distribution.

To validate the matching process for the CF male population, anthropometric data were collected from a randomly selected sample of CF male personnel. A total of 18 anthropometric dimensions, carefully chosen to accurately describe all major segments of the body, were measured on a valid sample of 535 male CF personnel in July and August of 1993 following the test plan outlined in Appendix A. Because preliminary analyses of the 1992 CF Express Database indicated that significant differences for Height and Weight were present among members of the Land, Sea, and Air elements, the sampling strategy ensured that representative numbers of all three elements were

measured for the CF Validation Study (12). The measured sample was composed of 219 members of the Land element, 208 members of the Air element, and 108 members of the Sea element who were measured at CFB Kingston, CFB Trenton, CFB Halifax, and CFB Gagetown. The first three bases were chosen for inclusion in the study by DACME because of the large numbers of personnel who are affiliated with a specific element at each of these bases. The personnel stationed at CFB Kingston are predominately members of the Land element, those stationed at CFB Trenton belong to the Air element, and those at CFB Halifax are largely members of the Sea Element. CFB Gagetown was added as a final measuring site to meet the sampling goals for the Land element.

The anthropometric data collected for the CF Validation Study were carefully analyzed to ensure both the accuracy of the measurements and the impact of subject substitution. A discussion of issues related to sample acquisition begins on page 5. Observer error rates are discussed on page 28, and a discussion of population variation in the CF begins on page 33. The CF Validation Study data are compared to the 1992 CF Express Database and the ANSUR data in the section entitled "Comparison with 1992 CF Express Database and 1988 Anthropometric Survey of US Army Personnel". Beginning on page 73, the results of the six matching procedures that were tested are discussed, including the implications for developing a matched female database for the CF. A short review of the entire project is presented on page 159, followed by overall conclusions and recommendations. Appendix A contains the test plan and protocol used to collect anthropometric data from CF personnel. Appendix B presents the results of using statistical matching to create a specialized anthropometric database for the head and face.

Sample Acquisition

During July and August of 1993, a total of 18 anthropometric dimensions were measured on 557 CF male personnel. Of these subjects, 535 were of the correct element for the post where they measured. Because measuring took place during the summer, many of the rostered subjects were on annual leave and could not participate in the study. At CFB Halifax, many of the rostered subjects were unavailable because their ship was called to active duty. When rostered personnel were unavailable, substitute subjects were measured. The overall substitution rate for measured subjects was unexpectedly high at 34.2%. To ensure that the substitute subjects were not being preferentially selected from a specific portion of the CF population, characteristics of rostered and substitute subjects were compared and no statistically significant differences were found between the two groups.

When the results of the tested matching procedures were presented to the CF on 5 April 1994, it was noted that the three bases chosen by the CF as measuring sites have an unusually large proportion of support personnel (12). In addition, CF personnel may be transferred from operational to support MOC's due to a decrease in physical fitness level, regardless of age or rank. When the ratio of operational to support personnel measured in the study was compared to the actual ratio in the CF population by element, it was apparent that the operational MOC's in both the Land and Sea elements were dramatically under represented. In addition, the observed differences between means for operational and support personnel were larger than expected at the $p \leq .05$ level if the two samples were drawn from the same population. Thus, the data collected for the CF Validation Study ***cannot*** be considered representative of the CF male population. The implications of this are discussed in the conclusions of this section.

1. Comparison of Rostered and Substitute Subjects

Table 1 presents a summary of the subjects processed during data collection for the CF Validation Study. Overall, the substitution rate was 39.1% for all of the subjects who completed a biographical survey form. In some cases, the substitutes were not the correct element for the base where the team was measuring. For example, only members of the Land element were rostered at Kingston; however, some of the substitutes belonged to either the Air or the Sea element. Because posting at a different type of base may not be random, these subjects may be unusual for their element. Therefore, any substitute subject who was not of the correct element for the base was excluded from all analyses, decreasing the overall substitution rate to 36.0% for subjects who completed a biographical survey form.

Not all of the subjects who completed biographical survey forms were fully measured. A total of 557 subjects were fully measured. Height and Weight only were recorded for 59 subjects who could not be fully measured due to time constraints. Of those that were fully measured, 36.4% were substitutes. Substitutes that were not members of the element being measured were excluded from analyses, leaving a total of 535 subjects who were fully measured and of the correct element. Of these subjects, 34.2% were substitutes (see Table 1). The rate of substitution was very high overall, indicating that the sample may not be random. If the sample is not random, then it is not representative of the CF. In such a situation, a demographic only matching procedure, one that relies exclusively on age, race or other demographic characteristics, cannot be properly validated because some aspect of the database is not random and may have an unusual anthropometric dimension/demographic variable interaction. A procedure using Height and/or Weight as matching variables can be validated, since a random distribution of these variables is not necessary for validation. However, if the measured subjects are not a random sample, then the Height/Weight distribution may not reflect that of the CF population, and the data cannot be used to produce a final matched database with a high degree of reliability. If the characteristics of the substitute subjects are identical to those of the rostered subjects, then it is reasonable to assume that the substitute subjects measured for the CF Validation Study are also a random sample of CF personnel.

Although the substitution rate was high, the minimum sampling goals were met for all of the element and age category cells. Table 2 compares the original sampling goal with the subjects who were fully measured and of the correct element. In some cells, the minimum goal was exceeded and a total of 35 subjects were measured in addition to the minimum sampling goal.

Table 3 presents the number of rostered and substitute subjects for each element and age category, again using only those who were of the correct element and fully measured. The Sea element had a very high rate of substitution because one of the ships was called to active duty, and many of the rostered subjects were members of the crew. The number of substitutes in this element increases with age category, reaching a high of 68.4% in the oldest age category. The substitution rate for Land and Air were about the same, 29.7% and 28.8%, respectively. Interestingly, the highest substitution rates for these two elements occurs in the 20-24 year age category; not in the oldest category as would be expected in a military population where older individuals tend to be higher ranking and less likely to have the time to participate.

Table 4 presents the substitution rate by age category for each of the posts. Again, only those subjects who were fully measured and of the correct element are included. CFB Gagetown was added at the end of the survey to meet the minimum sampling goals for the Land element, so none of these

subjects can be considered rostered. At CFB Kingston, the substitution rate is highest at the lower age ranges and lowest in the oldest age category. CFB Trenton's highest substitution rate is in the 20-24 age category and lowest in the 30-34 category. The rate of substitution at CFB Halifax is very high and increases with age, with the highest substitution rate appearing in the oldest age category. Substitution rates, by age category, are clearly different between the bases.

Figure 1 shows the age distributions for rostered and substitute subjects. The distributions indicate that the rate of substitution for all elements combined is highest in the 20-24 age category and decreases with age. Student's *t*-tests were used to ascertain whether or not the differences between the age of rostered and substitute subjects was significant for the three elements. As shown in Table 5, no significant differences are present at the $p \leq .05$ level when a Bonferonni correction for multiple comparisons is used. However, differences may still be present within each of the five age categories that will be used for the matching procedure. Because the youngest age category (≤ 19) only has one subject for each of the three elements, it was not included in the analysis. The results, presented in Table 6, show that no significant differences are present in any of the age categories. Thus, the substitute subjects appear to be randomly selected in terms of age. In addition, no significant difference was found between the rostered and the substitute subjects based on overall rank (Enlisted vs. Officer, $t = 1.68$, $p = 0.94$).

Table 1. Summary of Subjects Processed

Total Subjects Processed	618	
Rostered		375 (60.9%)
Substitutes		241 (39.1%)
Unknown		2
Correct Element for Base	585	
Rostered		373 (64.0%)
Substitutes		210 (36.0%)
Unknown		2
Fully Measured	557	
Rostered		354 (63.6%)
Substitutes		203 (36.4%)
Fully Measured/Correct Element for Base	535	
Rostered		352 (65.8%)
Substitutes		183 (34.2%)

Table 2. Sampling Goals vs. Actually Measured

Age Category / Element	≤ 19	20-24	25-29	30-34	≥ 35	Totals
Land						
Goal	1 (0.16%)	32 (6.39%)	55 (11.09%)	55 (10.92%)	69 (13.90%)	212 (42.46%)
Actual	1 (0.19%)	32 (5.98%)	58 (10.84%)	56 (10.47%)	72 (13.46%)	219 (40.93%)
Sea						
Goal	1 (0.17%)	16 (3.10%)	21 (4.29%)	22 (4.38%)	31 (6.19%)	91 (18.14%)
Actual	1 (0.19%)	16 (2.99%)	28 (5.23%)	25 (4.67%)	38 (7.10%)	108 (20.19%)
Air						
Goal	1 (0.16%)	15 (2.99%)	36 (7.15%)	56 (11.15%)	89 (17.95%)	197 (39.40%)
Actual	1 (0.19%)	16 (2.99%)	39 (7.29%)	59 (11.03%)	93 (17.38%)	208 (38.88%)
Totals						
Goal	3 (0.40%)	63 (12.40%)	112 (22.53%)	133 (26.53%)	189 (38.13%)	500 (100.00%)
Actual	3 (0.56%)	64 (11.96%)	125 (23.36%)	140 (26.17%)	203 (37.94%)	535 (100.00%)

Table 3. Rostered Subjects vs. Substitute Subjects by Element and Age

Age Category / Element	≤ 19	20-24	25-29	30-34	≥ 35	Totals
Land	**1 (0.5%)**	**32 (14.6%)**	**58 (26.5%)**	**56 (25.6%)**	**72 (32.9%)**	**222 (100.0%)**
Rostered	0 (0.0%)	13 (40.6%)	45 (77.6%)	42 (75.0%)	54 (75.0%)	154 (70.3%)
Substitute	1 (100.0%)	19 (59.4%)	13 (22.4%)	14 (25.0%)	18 (25.0%)	65 (29.7%)
Sea	**1 (0.9%)**	**16 (14.8%)**	**28 (25.9%)**	**25 (23.1%)**	**38 (35.2%)**	**108 (100.0%)**
Rostered	1 (100.0%)	10 (62.5%)	15 (53.6%)	12 (48.0%)	12 (31.6%)	50 (46.3%)
Substitute	0 (0.0%)	6 (37.5%)	13 (46.4%)	13 (52.0%)	26 (68.4%)	58 (53.7%)
Air	**1 (0.5%)**	**16 (7.7%)**	**39 (18.8%)**	**59 (28.4%)**	**93 (44.7%)**	**208 (100.0%)**
Rostered	1 (100.0%)	9 (56.3%)	27 (69.2%)	46 (78.0%)	65 (69.9%)	148 (71.2%)
Substitute	0 (0.0%)	7 (43.7%)	12 (30.8%)	13 (22.0%)	28 (30.1%)	60 (28.8%)
Totals	**3 (0.6%)**	**64 (12.0%)**	**125 (23.4%)**	**140 (26.2%)**	**203 (37.9%)**	**535 (100.0%)**
Rostered	2 (66.7%)	32 (50.0%)	87 (69.6%)	100 (71.4%)	131 (64.5%)	352 (65.8%)
Substitute	1 (33.3%)	32 (50.0%)	38 (30.4%)	40 (28.6%)	72 (35.5 %)	183 (34.2%)

Table 4. Rostered Subjects vs. Substitute Subjects by Post and Age

Age Category / Post	≤ 19	20-24	25-29	30-34	≥ 35	Totals
Kingston	**2** (1.0%)	**22** (10.9%)	**57** (28.4%)	**55** (27.4%)	**65** (32.3%)	**201** (100.0%)
Rostered	1 (50.0%)	13 (59.1%)	45 (78.9%)	42 (76.4%)	54 (83.1%)	155 (77.1%)
Substitute	1 (50.0%)	9 (40.9%)	12 (21.1%)	13 (23.6%)	11 (16.9%)	46 (22.9%)
Trenton	**0** (0.0%)	**16** (7.7%)	**39** (18.8%)	**59** (28.5%)	**93** (44.9%)	**207** (100.0%)
Rostered	0 (0.0%)	9 (56.3%)	27 (69.2%)	46 (78.0%)	65 (69.9%)	147 (71.0%)
Substitute	0 (0.0%)	7 (43.8%)	12 (30.8%)	13 (22.0%)	28 (30.1%)	60 (29.0%)
Halifax	**1** (0.9%)	**16** (14.8%)	**28** (25.9%)	**25** (23.1%)	**38** (35.2%)	**108** (100.0%)
Rostered	1 (100.0%)	10 (62.5%)	15 (53.6%)	12 (48.0%)	12 (31.6%)	50 (46.3%)
Substitute	0 (0.0%)	6 (37.5%)	13 (46.4%)	13 (52.0%)	26 (68.4%)	58 (53.7%)
Gagetown	**0** (0.0%)	**10** (52.6%)	**1** (5.3%)	**1** (5.3%)	**7** (36.8%)	**19** (100.0%)
Rostered	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Substitute	0 (0.0%)	10 (100.0%)	1 (100.0%)	1 (100.0%)	7 (36.8%)	19 (100.0%)

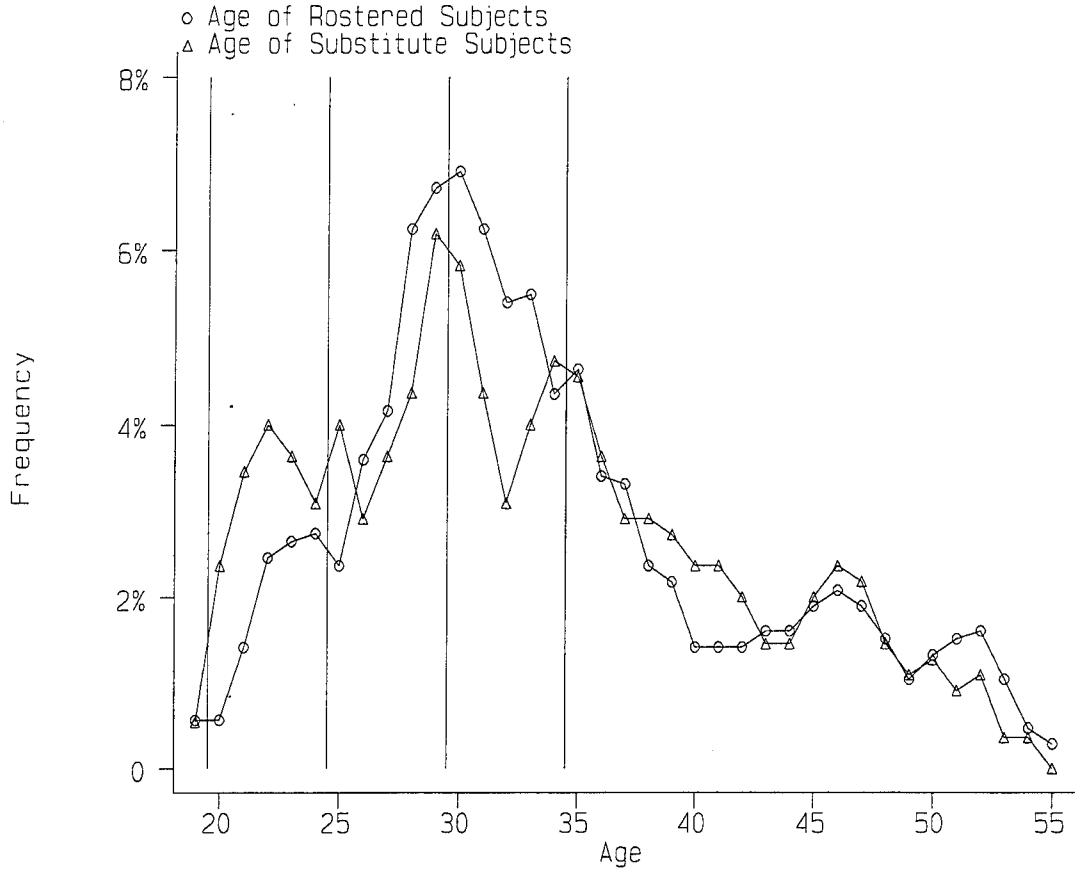

Figure 1. Age distribution of rostered and substitute subjects. (The vertical lines indicate the boundaries of the five age categories for matching.)

Table 5. Comparison of Mean Age Between Rostered and Substitute Subjects by Element

Element/Group		Mean Age	SD	*t*	*p*
Land				2.25	0.026
	Rostered	33.75[+]	8.09		
	Substitute	30.91	8.69		
Sea				-1.95	0.054
	Rostered	31.52	8.83		
	Substitute	34.83	8.78		
Air				0.89	0.374
	Rostered	34.78	7.81		
	Substitute	33.77	7.23		

[+] Age in years

* Significantly different at $p \leq .05$ using a Bonferroni correction (.05/3 = .0167)

Table 6. Comparison of Mean Age Between Rostered and Substitute Subjects by Element and Age Category

Element/Age	Mean Age	SD	*t*	*p*
Land				
20-24			1.74	0.093
Rostered	22.69[+]	1.03		
Substitute	21.95	1.39		
25-29			-0.55	0.592
Rostered	27.51	1.38		
Substitute	27.77	1.54		
30-34			0.37	0.713
Rostered	31.98	1.46		
Substitute	31.79	1.72		
≥ 35			0.26	0.800
Rostered	42.98	5.77		
Substitute	42.61	5.18		
Sea				
20-24			-0.61	0.554
Rostered	22.30	1.06		
Substitute	22.67	1.21		
25-29			0.67	0.507
Rostered	27.07	1.44		
Substitute	26.69	1.49		
30-34			2.26	0.034
Rostered	33.17	1.12		
Substitute	31.92	1.61		
≥ 35			0.46	0.654
Rostered	44.17	6.83		
Substitute	43.15	5.19		
Air				
20-24			-0.44	0.669
Rostered	22.33	1.00		
Substitute	22.57	1.13		
25-29			-0.34	0.733
Rostered	27.85	1.46		
Substitute	28.00	1.13		
30-34			-1.11	0.281
Rostered	31.52	1.31		
Substitute	32.08	1.66		
≥ 35			1.77	0.082
Rostered	41.92	5.72		
Substitute	39.82	5.04		

[+] Age in years

* Significantly different at $p \leq .05$ using a Bonferroni correction (.05/12 = .0042)

2. Rostered vs. Substitute Subjects for Race and Primary Language

As demonstrated in Table 7 and Figure 2, the distribution of race for both rostered and substitute subjects are very similar. However, the vast majority of subjects processed were White, so all other racial groups are presented separately as well. As seen in Figure 3, rostered or substitute status is not correlated to race. Table 8 presents the distribution of subjects by ethnic affiliation. For all categories, approximately one third of the subjects are substitutes.

Figure 4 and Table 9 show the frequency of rostered and substitute subjects who indicated English or French as a primary language. Again, no significant difference is apparent. When these data are analyzed using a Student's *t*-test, the $t = .76$ ($p = .450$) and is not statistically significant. Overall, substitution rates were not differentially affected by race, ethnicity, or primary language affiliation.

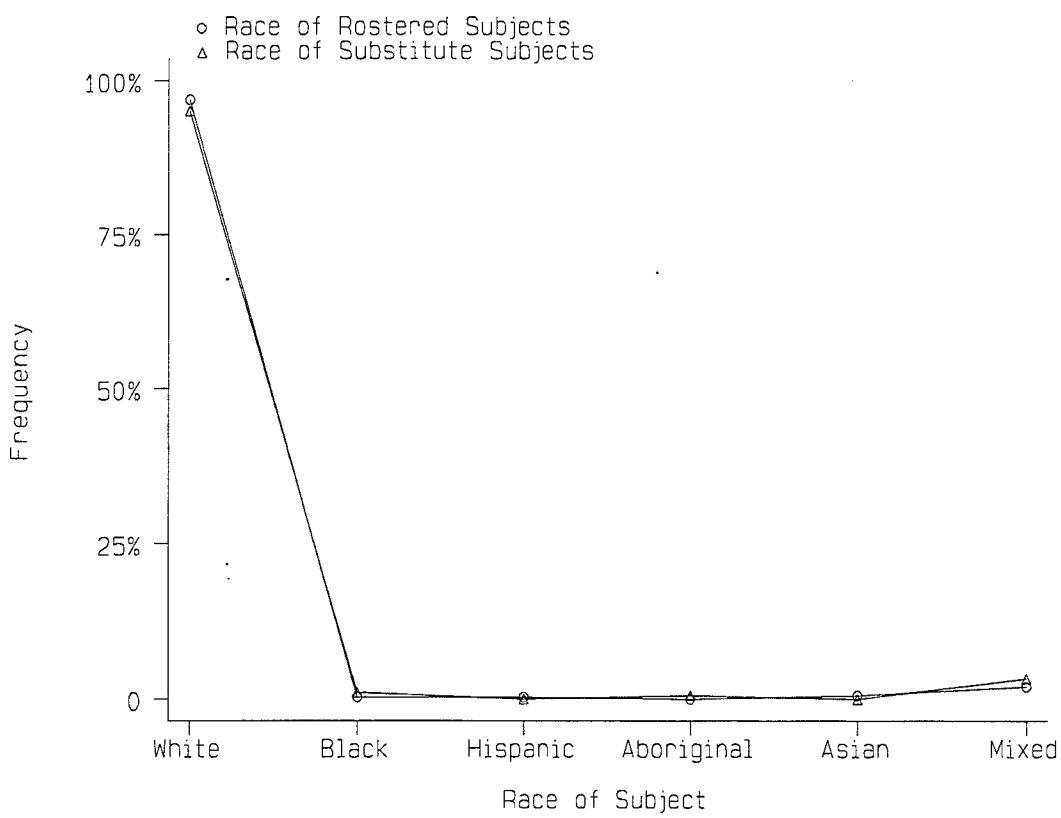

Figure 2. Race distribution of rostered and substitute subjects.

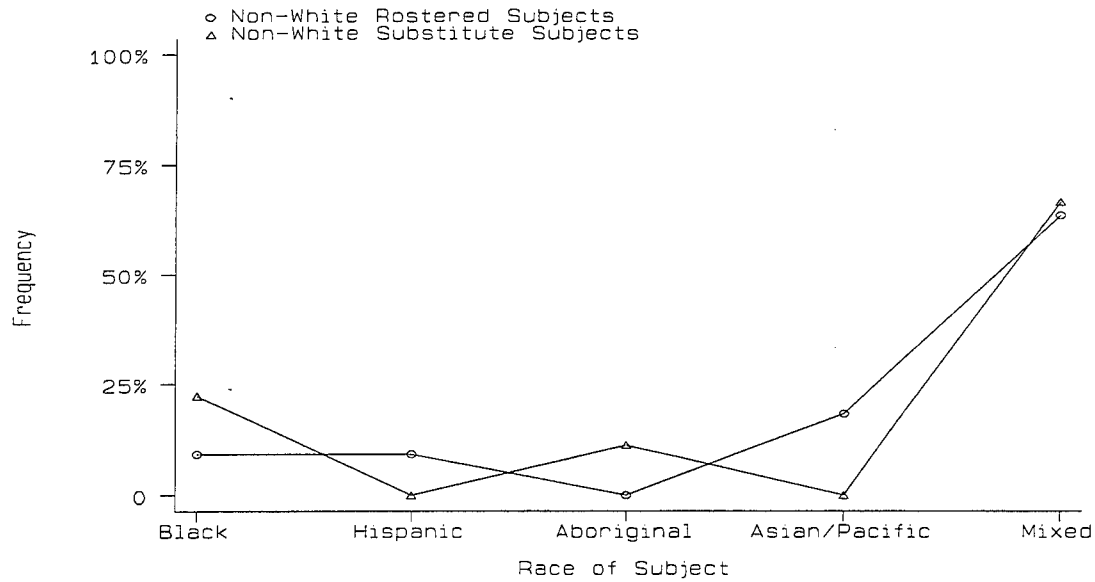

Figure 3. Race distribution of non-White rostered and substitute subjects.

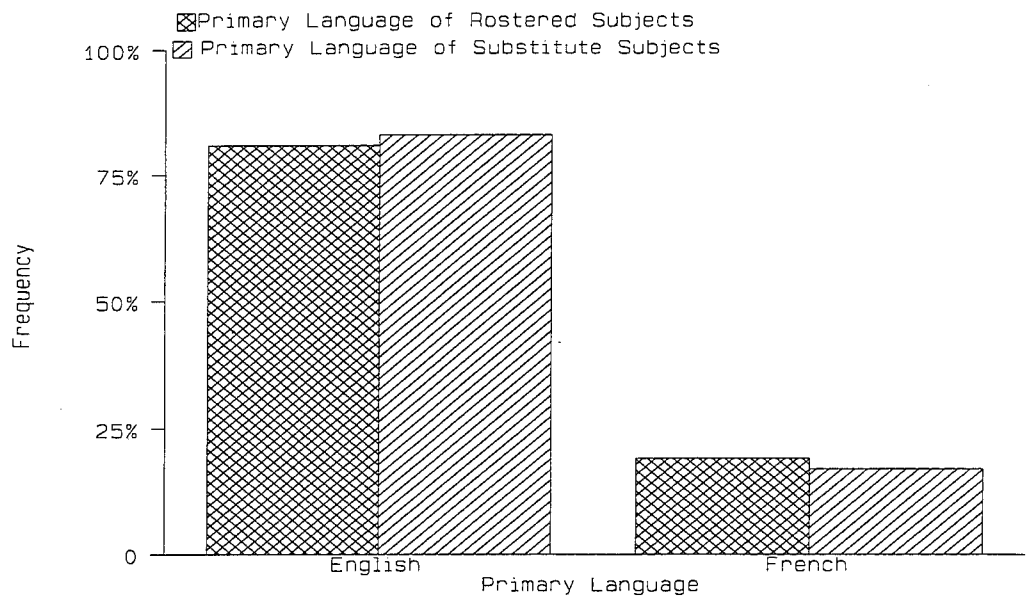

Figure 4. Primary language distribution of rostered and substitute subjects.

Table 7. Race of Subjects by Rostered Status

Race/ Status	Number of Subjects Sample	Number of Subjects Status	Frequency Sample	Frequency Status
White	515		96.26%	
Rostered		341		66.21%
Substitute		174		33.79%
Black	3		0.56%	
Rostered		1		33.33%
Substitute		2		66.67%
Hispanic	1		0.19%	
Rostered		1		100.0%
Substitute		0		0.0%
Aboriginal	1		0.19%	
Rostered		0		0.0%
Substitute		1		100.0%
Asian	2		0.34%	
Rostered		2		100.0%
Substitute		0		0.0%
Mixed/Other	13		2.43%	
Rostered		7		53.85%
Substitute		6		46.15%
Total	535		100.0%	
Rostered		352		65.79%
Substitute		183		34.21%

Table 8. Ethnicity of Subjects by Rostered Status

Ethnicity/ Status	Number of Subjects Sample	Number of Subjects Status	Frequency Sample	Frequency Status
English/British	159		29.72%	
Rostered		106		66.67%
Substitute		53		33.33%
French/French Canadian	122		22.80%	
Rostered		79		64.75%
Substitute		43		35.25%
Other	254		47.48%	
Rostered		167		65.75%
Substitute		87		34.25%
Total	535		100.0%	
Rostered		352		65.79%
Substitute		183		34.21%

Table 9. Primary Language of Subjects by Rostered Status				
Primary Language/ Status	**Number of Subjects**		**Frequency**	
	Sample	**Status**	**Sample**	**Status**
English	436		81.50%	
Rostered		284		65.14%
Substitute		152		34.86%
French	98		18.32%	
Rostered		67		68.37%
Substitute		31		31.63%
Other	1		0.19%	
Rostered		1		100.00%
Substitute		0		0.0%
Total	535		100.0%	
Rostered		352		65.79%
Substitute		183		34.21%

3. Rostered vs. Substitute Subjects for Height, Weight, and Body Mass Index (BMI)

Although the distributions for Height, Weight, and Body Mass Index [BMI=Weight(kg)/Stature(m)^2] are normal, the original variance for Weight was not. This was due to one very large subject who weighed 138 kg. Because this single individual had a severe impact on the standard deviation and variance, he was removed from this analysis. Without this subject, the variances are all homogeneous and *t*-tests indicate that no significant difference is present between subjects who were rostered and those who were substitutes for Height, Weight, and BMI (see Table 10 and Figures 5, 6 and 7).

Table 10. Comparison of Height, Weight, and BMI for Rostered and Substitute Subjects

Variable/Group	N	Mean	SD	*t*	*p*
Stature				0.91	0.362
Rostered	351	175.46	(6.38)		
Substitutes	180	174.91	(6.72)		
Weight				-0.33	0.740
Rostered	351	82.76	(12.26)		
Substitutes	180	82.94	(10.50)		
Body Mass Index				-1.12	0.265
Rostered	351	26.82	(3.39)		
Substitutes	180	27.16	(3.21)		

All values in mm, except Weight in kg

* Significantly different at $p \leq .05$ using a Bonferroni correction (.05/3 = .0167)

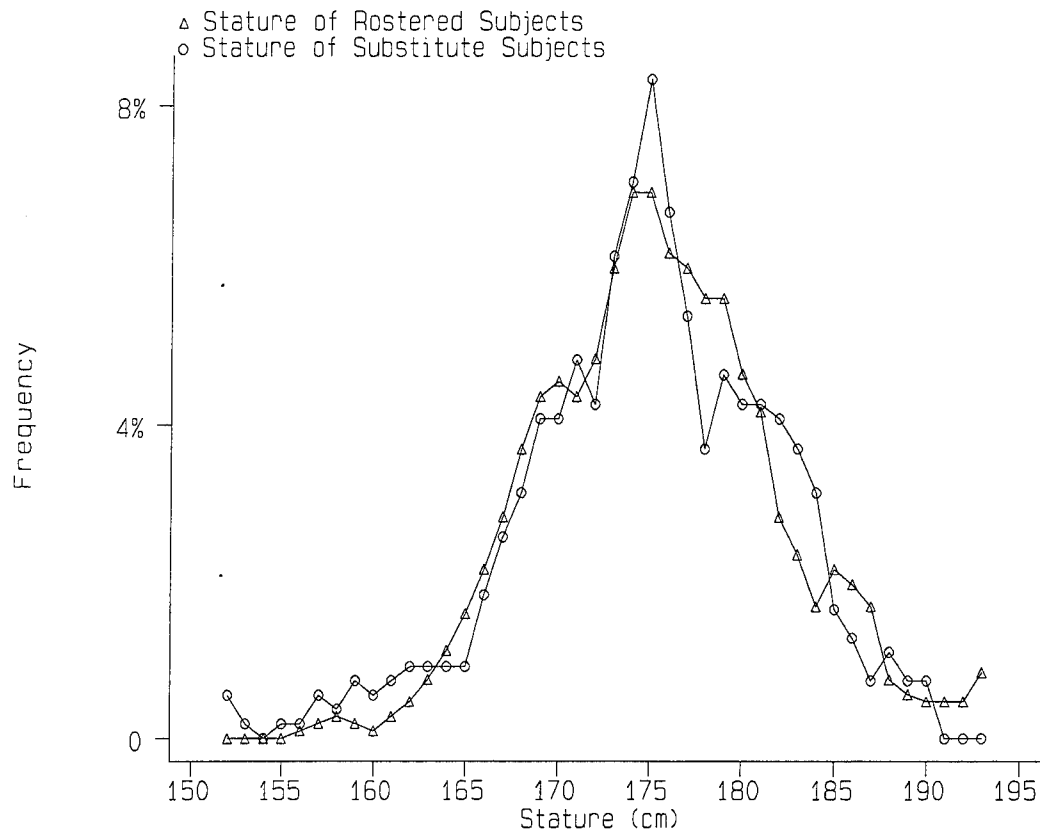

Figure 5. Stature distribution of rostered and substitute subjects.

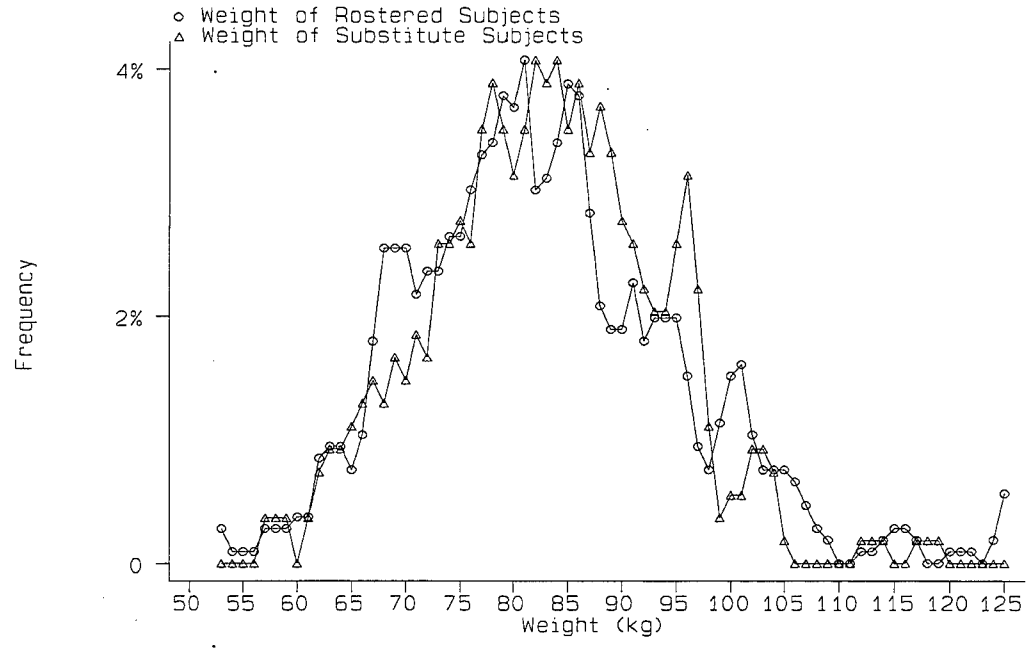

Figure 6. Weight distribution of rostered and substitute subjects

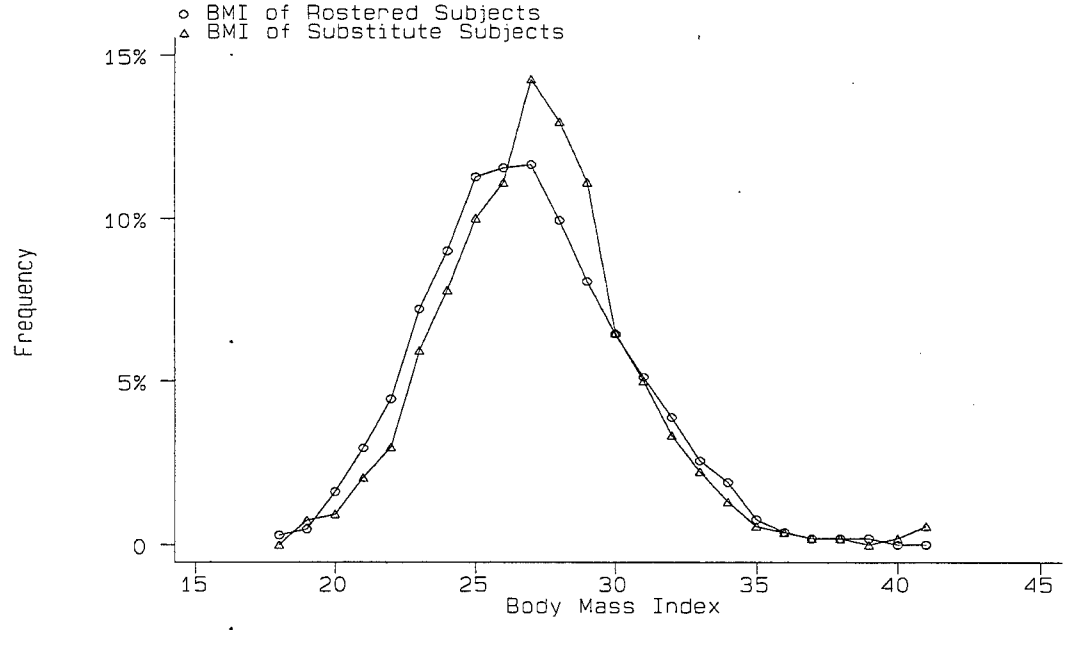

Figure 7. Body Mass Index distribution of rostered and substitute subjects.

4. Ratio of Operational to Support Personnel

On 5 April 1994 a meeting was held at DACME with representatives of the Canadian Forces (CF) and US Army Natick Research, Development and Engineering Center (Natick) to discuss the results and difficulties encountered while validating a matching process suitable for producing a CF Male Anthropometric Database using the 1988 Anthropometric Survey of US Army Personnel (ANSUR) data. The results of the analyses conducted to date were presented and during the ensuing discussion, Captain Harry Angel noted that the three bases chosen by the CF as measuring sites for the CF Validation Study (CFB Kingston, CFB Trenton and CFB Halifax) have an unusually large proportion of support personnel. In addition, Cpt. Angel noted that CF personnel may be transferred from operational to support Military Occupational Code (MOC) as their physical fitness level decreases, regardless of age or rank. Clearly, such trends would have an impact on anthropometry, and the anthropometric distributions of support and operational CF personnel could be quite different within any given age group. If such differences are expressed in the general population, any data used for validation must contain the correct proportion of support and operational personnel.

To determine if a representative proportion of operational and support MOC's were measured for the CF Validation Study during June and July of 1993, additional analyses were undertaken. CF data, indicating the MOC frequencies for the June 1993 male CF population, were used for comparison (13). The operational MOC's are as follows for each of the three elements: Land (21, 22, 23, 011, 021, 022, 031, 041, 042); Sea (71, 73, 74, 75, 76, 262); and Air (31, 32, 63, 65, 081, 091, 121, 131, 161, 171). As shown in Table 11, far too few operational personnel were measured for members of the Land and Sea Elements. In the case of the Air Element, the proportion of operational to support personnel measured is only 1.36% less than the actual proportion. Clearly, the proportion of operational and support personnel in the measured sample do not reflect that of the Land and Sea Elements.

If the anthropometric distributions for operational and support personnel in the Land and/or the Sea Elements are not the same for the male CF population, then the under-sampling of operational personnel in these two elements ensures that the measured sample used for the CF Validation Study is ***not*** representative of the male CF population and should not be used as such. Cpt. Angel suggested that the large Waist Circumference values in the CF Validation Study Database could be due to the high proportion of support personnel who may not be as physically fit as operational personnel. If this were true, one would expect support personnel, on average, to be heavier, to have larger circumference measurements, and to have a higher value for Body Mass Index (BMI).

Because such a small number of operational and support personnel were measured, a statistical method called bootstrapping was used to generate the actual probability of obtaining the observed, or a more extreme, difference between the means of the operational and the support populations, ***if*** the true population means are not significantly different (14). All three of the elements were combined since earlier analyses indicated that no significant differences are present among the Land, Sea, and Air Elements. The analyses were conducted separately for subjects in four of the five age categories used for sampling: 20-24 year olds; 25-29 year olds; 30-34 year olds; and $\geq$ 35 years. Subjects in the youngest age category, $\leq$ 19, were not analyzed because no operational personnel were measured in this age group. The results of the analyses are presented in Table 12.

For the two youngest age categories, 20-24 and 25-29, there is no significant difference between the two group means for any of the 18 dimensions tested. However, among the 30-34 year olds, the difference between the means of the two groups for Weight, Stature, Waist Height, Crotch Height, Sleeve Length, Buttock Circumference, and Sitting Height are significantly different at the $p \leq .05$ level. The mean values for the length measurements are all larger for the operational group, with a corresponding increase in Weight and Buttock Circumference. However, the mean values for BMI are not significantly different, suggesting that the operational personnel in this age category are, on average, taller than the support personnel with a corresponding, and proportional increase in Weight. In the oldest age group, only Head Circumference was significantly different between the two groups, with the operational personnel having a larger mean value. Although the direction of the observed differences is the opposite of what was expected, the results of this analysis do indicate that the anthropometric distribution of operational personnel measured for the CF Validation Study is different from that of support personnel. It is possible that operational personnel who are stationed at bases that primarily serve a support function (e.g., CFB Kingston and CFB Trenton) may be quite different from their counterparts who are stationed at more representative bases that have a higher proportion of operational personnel.

Regardless of which group has the largest mean value for a dimension, a statistically significant difference was found between the two groups. This finding, combined with the fact that the proportion of operational to support personnel measured for the Land and Sea Elements is very different from the actual proportion for these two elements, indicates that the measured sample should ***not*** be considered representative of the male CF population. The impact is that a demographic only matching method cannot be validated, *even if such a match accurately portrayed the true anthropometric distribution of the CF.* In addition, these data cannot be used as input to a matching algorithm that requires Height and Weight data to create a matched database. As discussed in the conclusion section, representative Height, Weight, and Waist Circumference

data for the male CF population could be collected during the proposed CF Female Validation Study. These data could then be used to re-asses demographic only matching procedures, and, if they fail, be used as input for an individual subject matching algorithm based on Height and Weight.

Table 11. Proportion of Operational and Support MOC's for Measured Sample and Actual June 1993 CF Male Personnel

Element	Measured Operation/Support	Actual Operation/Support	$\|\Delta\|$
Land	22/196 (11.22%)	11,851/19,368 (61.19%)	49.97%
Air	36/171 (21.05%)	5,877/26,225 (22.41%)	1.36%
Sea	9/ 98 (9.18%)	3,560/ 9,959 (35.75%)	26.57%

Table 12. Exact Probabilities of Observing the Operational and Support Mean Values by Age Category				
Age Category/ Variable	**Operational**	**Support**	**Δ**	**Exact *p***
20 - 24				
Weight	85.65 (n = 4)	79.33 (n = 60)	6.32	.144
Span	1853.75 (n = 4)	1807.10 (n = 60)	46.65	.099
Hand Length	194.00 (n = 4)	189.98 (n = 60)	4.02	.165
Hand Breadth	87.75 (n = 4)	87.68 (n = 60)	0.07	.452
Foot Length	265.50 (n = 4)	265.00 (n = 60)	0.50	.477
Foot Breadth	102.75 (n = 4)	101.42 (n = 60)	1.33	.325
Stature	1788.25 (n = 4)	1749.82 (n = 60)	38.43	.104
Waist Height	1082.50 (n = 4)	1048.25 (n = 60)	34.25	.077
Crotch Height	856.25 (n = 4)	836.80 (n = 60)	19.45	.165
Sleeve Length	597.25 (n = 4)	583.33 (n = 60)	13.92	.182
Chest Circ	1048.50 (n = 4)	1005.27 (n = 60)	43.23	.103
Waist Circ	910.25 (n = 4)	883.25 (n = 60)	27.00	.280
Buttock Circ	1031.75 (n = 4)	1002.55 (n = 60)	29.20	.171
Sitting Height	929.25 (n = 4)	924.10 (n = 60)	5.15	.363
Biacromial Breadth	420.75 (n = 4)	405.30 (n = 60)	15.45	.077
Menton-Sellion L	128.00 (n = 4)	122.75 (n = 60)	5.25	.077
Bizygomatic Breadth	141.75 (n = 4)	141.55 (n = 60)	0.20	.477
Head Circ	578.50 (n = 4)	575.38 (n = 60)	3.12	.374
BMI	26.74 (n = 4)	25.86 (n = 60)	0.88	.284

All values in mm, except Weight in kg

* Significantly different at $p \leq .05$

Table 12. (Cont.)

Age Category/ Variable	Operational	Support	Δ	Exact *p*
25 - 29				
Weight	81.68 (n = 10)	82.60 (n = 115)	-.92	.374
Span	1815.10 (n = 10)	1807.46 (n = 115)	7.64	.369
Hand Length	191.80 (n = 10)	190.23 (n = 115)	1.57	.281
Hand Breadth	90.30 (n = 10)	88.26 (n = 115)	2.04	.078
Foot Length	267.30 (n = 10)	264.86 (n = 115)	2.44	.272
Foot Breadth	104.30 (n = 10)	102.03 (n = 115)	2.27	.126
Stature	1766.70 (n = 10)	1754.22 (n = 115)	12.48	.257
Waist Height	1049.80 (n = 10)	1046.17 (n = 115)	3.63	.397
Crotch Height	833.30 (n = 10)	834.23 (n = 115)	-0.93	.480
Sleeve Length	585.20 (n = 10)	586.34 (n = 115)	-1.14	.442
Chest Circ	1019.20 (n = 10)	1027.27 (n = 115)	-8.07	.339
Waist Circ	901.90 (n = 10)	918.83 (n = 115)	-16.93	.283
Buttock Circ	1004.60 (n = 10)	1017.33 (n = 115)	-12.73	.301
Sitting Height	942.60 (n = 10)	927.76 (n = 115)	14.84	.072
Biacromial Breadth	402.20 (n = 10)	401.42 (n = 115)	0.78	.432
Menton-Sellion L	122.60 (n = 10)	123.64 (n = 115)	-1.04	.355
Bizygomatic Breadth	143.80 (n = 10)	143.64 (n = 115)	0.16	.471
Head Circ	576.60 (n = 10)	577.43 (n = 115)	-0.83	.429
BMI	26.08 (n = 10)	26.83 (n = 115)	-0.75	.317

All values in mm, except Weight in kg
* Significantly different at $p \leq .05$

Table 12. (Cont.)				
Age Category/ Variable	**Operational**	**Support**	**Δ**	**Exact *p***
30 - 34				
Weight	**88.68 (n = 17)**	**82.52 (n = 123)**	**6.16**	**.026***
Span	1845.71 (n = 17)	1812.35 (n = 122)	33.36	.055
Hand Length	192.24 (n = 17)	192.02 (n = 123)	0.22	.469
Hand Breadth	88.41 (n = 17)	88.27 (n = 123)	0.14	.447
Foot Length	270.65 (n = 17)	265.89 (n = 123)	4.76	.070
Foot Breadth	104.24 (n = 17)	101.93 (n = 123)	2.31	.051
Stature	**1802.71 (n = 17)**	**1754.23 (n = 123)**	**48.48**	**.003***
Waist Height	**1077.88 (n = 17)**	**1046.97 (n = 123)**	**30.91**	**.005***
Crotch Height	**861.24 (n = 17)**	**837.95 (n = 123)**	**23.29**	**.012***
Sleeve Length	**605.35 (n = 17)**	**590.11 (n = 123)**	**15.24**	**.023***
Chest Circ	1053.29 (n = 17)	1031.58 (n = 123)	21.71	.127
Waist Circ	954.88 (n = 17)	932.20 (n = 123)	22.68	.195
Buttock Circ	**1055.24 (n = 17)**	**1014.43 (n = 123)**	**40.81**	**.013***
Sitting Height	**946.24 (n = 17)**	**925.50 (n = 123)**	**20.74**	**.010***
Biacromial Breadth	406.65 (n = 17)	401.86 (n = 123)	4.80	.159
Menton-Sellion L	124.00 (n = 17)	123.77 (n = 123)	0.33	.442
Bizygomatic Breadth	142.29 (n = 17)	143.59 (n = 123)	-1.30	.182
Head Circ	577.24 (n = 17)	574.75 (n = 123)	2.49	.267
BMI	27.21 (n = 17)	26.79 (n = 123)	0.42	.394

All values in mm, except Weight in kg

* Significantly different at $p \leq .05$

Table 12. (Cont.)

Age Category/ Variable	Operational	Support	Δ	Exact *p*
≥ 35				
Weight	83.19 (n = 36)	83.73 (n = 164)	-.54	.389
Span	1793.06 (n = 35)	1794.78 (n = 164)	-1.72	.432
Hand Length	189.19 (n = 36)	190.49 (n = 164)	-1.30	.191
Hand Breadth	88.22 (n = 36)	88.09 (n = 164)	0.13	.449
Foot Length	261.72 (n = 36)	264.78 (n = 164)	-3.06	.116
Foot Breadth	101.33 (n = 36)	101.59 (n = 164)	-0.26	.418
Stature	1733.92 (n = 36)	1746.95 (n = 164)	-13.03	.145
Waist Height	1026.69 (n = 36)	1034.06 (n = 164)	-7.37	.231
Crotch Height	819.67 (n = 36)	830.21 (n = 164)	-10.54	.100
Sleeve Length	580.72 (n = 36)	584.84 (n = 164)	-4.12	.240
Chest Circ	1045.81 (n = 36)	1046.64 (n = 164)	-0.83	.473
Waist Circ	963.56 (n = 36)	968.87 (n = 164)	-5.31	.349
Buttock Circ	1013.92 (n = 36)	1020.28 (n = 164)	-6.36	.271
Sitting Height	918.36 (n = 36)	922.76 (n = 164)	-4.40	.219
Biacromial Breadth	398.56 (n = 36)	396.30 (n = 164)	2.26	.218
Menton-Sellion L	123.61 (n = 36)	123.21 (n = 164)	0.40	.389
Bizygomatic Breadth	145.22 (n = 36)	144.77 (n = 164)	0.45	.322
Head Circ	**579.47 (n = 36)**	**573.88 (n = 164)**	**5.59**	**.024***
BMI	27.65 (n = 36)	27.42 (n = 164)	0.23	.426

All values in mm, except Weight in kg

* Significantly different at $p \leq .05$

5. Ethnicity Data

In a total of 120 cases, there was some doubt as to the subject's, mother's or father's ethnicity. All ethnicities that were either missing or multiple were checked with the original data forms to ascertain if any data entry errors were responsible for the problem. Most cases where the subject's ethnicity was simply a combination of the mother's and father's ethnicity occurred during the first week of data collection and were no longer accepted as valid answers once the measuring team left CFB Kingston. Approximately half of the 120 cases had missing ethnicities for either the mother or father, and a few people answered that they were adopted when questioned about ethnicity.

In the vast majority of problem cases, ethnicity could not be absolutely identified. To prevent the loss of information, but to ensure that any questionable values were not used in this analysis, these values were coded with a 9, followed by the combination of ethnic codes listed in the order of the subject's response. For example, if a subject answered English/French, he was coded as 91012 (9 for caution, 10 for English, and 12 for French). All values created using this method were treated as missing; however the original information was retained. In addition, a code for the response of 'adopted' was added for use in the CF Validation Study.

6. Sample Acquisition Conclusions

As illustrated in the first three sections, no significant differences are present between the rostered and substitute subjects for age, military rank, race, primary language, Stature, Weight, or BMI. Thus, specific groups (i.e., younger or older personnel, lower or higher ranking personnel, French or English personnel, etc.) were not selected preferentially as substitutes and have the same distributions as the rostered sample. These data are not obviously skewed as a result of the high substitution rate. However, the proportion of operational to support MOC's is severely skewed for subjects of the Land and Sea elements. Because the proportion is not the same as the CF, and MOC may reflect the physical fitness level of a soldier, the Weight for Stature distribution of the validation sample must ***not*** be considered representative of the CF. The impact is that a demographic only matching method cannot be validated, *even if such a match accurately portrayed the true anthropometric distribution of the CF.* In addition, these data cannot be used as input to a matching algorithm that requires Height and Weight data to create a matched database.

Observer Error

Observer error data were collected daily during the CF Validation Study to ensure that the allowable errors were not being exceeded, and to quickly correct any measuring differences that may have developed between the two measurers/recorders. Because these data will be used to validate a statistical matching procedure that randomly selects subjects from the 1988 Anthropometric Survey of US Army Personnel (ANSUR) database, allowable error rates were set using the ANSUR observed error rates, thus ensuring that the observed error of the CF Validation Study is consistent with ANSUR. During each full day of measuring for the CF Validation Study, two subjects were chosen at random to be re-measured. One was chosen during the morning session and the other during the afternoon session. These subjects were measured a second time by the team member who had acted as recorder during the first measurement. These data were analyzed daily in the field. If the two sets of measurements exceeded the allowable error for a specific dimension, the team leader joined the measurer/recorders and the problem measurement was practiced until the required level of precision was reached.

Because no systematic differences were present between the two measurers, the mean absolute difference between the two measurements was used for the analysis. Most of the mean absolute differences for the morning sessions, afternoon sessions, and combined sessions did not exceed the allowable error. The mean absolute differences for observer error that exceeded the allowable error were never more than 0.40 mm larger than the allowable errors (see Table 13). The mean difference of the observer error was more than 1 mm between morning and afternoon sessions for Span, Sleeve Length, Chest Circumference, and Waist Circumference, indicating that observer error rates may be different between morning and afternoon sessions due to changing levels of fatigue. Analyses were performed to ascertain whether or not any significant differences exist between the error rates of the morning and afternoon sessions. Because the variances were not all homogenous for the observer error rates between the morning and afternoon sessions (see Table 14), a non-parametric analysis was required to ascertain if any significant differences were present. The results of the Mann-Whitney *U* analysis are shown in Table 15, and indicate that no significant differences exist between the observer error rates recorded for the morning and afternoon sessions at the $p \leq .05$ level using a Bonferroni correction for multiple comparisons (i.e., .05/18 = .0027).

In addition to daily differences, error rates may have fluctuated between the four posts where subjects were measured. Because the measuring team's accuracy may have improved over time, statistical analyses were used to determine if the error rates were significantly different between CFB Kingston, CFB Trenton and CFB Halifax. (The measuring team was at CFB Gagetown for

half a day and only one subject was re-measured, so it was excluded from the analysis.) Bartlett's-Box tests indicated that not all of the variances were homoscedastic, so a non-parametric test (Kruskal-Wallis) was used. Table 16 presents the analysis of variance and the Kruskal-Wallis results. Again, no significant differences were found in observer error rates between the posts.

Because no significant differences were found either by the time of day or by the post, the overall mean difference should be used as the final observed error for this study. These error rates should always be consulted when utilizing these data. The low observer error rate, consistent across posts and time of day, suggests that the measuring techniques did not drift or change during the data collection, thus increasing confidence in the quality of the data.

Table 13. Observer Error Rates for Morning, Afternoon, and Combined Measuring Sessions

Variable	AM Mean (SD)	PM Mean (SD)	AM and PM Mean (SD)	Allowable Error
Biacromial Br	1.85 (1.42)	2.57 (4.61)	2.22 (3.42)	4.00
Bizygomatic Br	0.65 (0.75)	0.76 (0.70)	0.71 (0.72)	1.00
Buttock Circ	2.20 (1.99)	3.14 (3.83)	2.68 (3.07)	5.00
Chest Circ	**7.40 (6.65)***	4.33 (3.23)	5.83 (5.35)	7.00
Crotch Height	2.70 (2.56)	2.67 (2.60)	2.68 (2.54)	6.00
Hand Breadth	0.55 (0.69)	0.19 (0.40)	0.37 (0.58)	1.00
Hand Length	1.20 (1.61)	0.48 (0.98)	0.83 (1.36)	2.00
Head Circ	0.90 (0.97)	**1.14 (1.28)***	**1.02 (1.13)***	1.00
Foot Breadth	0.90 (1.52)	0.81 (0.81)	0.85 (1.20)	1.00
Foot Length	0.60 (0.50)	0.62 (0.92)	0.61 (0.74)	1.00
Menton-Sellion	1.10 (0.85)	1.00 (0.89)	1.05 (0.87)	2.00
Sitting Height	**4.25 (4.44)***	3.48 (4.13)	3.85 (4.25)	4.00
Sleeve Length	2.90 (3.61)	1.62 (1.43)	2.24 (2.76)	4.00
Span	5.20 (4.01)	3.71 (3.50)	4.44 (3.78)	8.00
Stature	1.80 (1.06)	0.95 (0.74)	1.37 (0.99)	3.00
Waist Circ	4.55 (3.55)	2.76 (2.07)	3.63 (2.99)	5.00
Waist Height	1.85 (1.57)	1.86 (1.91)	1.85 (1.73)	3.00
Weight	0.12 (0.29)	0.09 (0.09)	0.10 (0.21)	0.20

All values in mm, except Weight in kg
*Values outside of allowable error tolerance level

Table 14. *F* Test Results for Homogeneity of Variances of Observer Error Rates (Mean Average Difference) for Morning and Afternoon Sessions

Variable	*F*	*p*	Type of Variance
Biacromial Breadth	10.48	0.000	**Heteroscedastic**
Bizygomatic Breadth	1.13	0.784	Homoscedastic
Buttock Circ	3.70	0.006	**Heteroscedastic**
Chest Circ	4.24	0.002	**Heteroscedastic**
Crotch Height	1.03	0.952	Homoscedastic
Foot Breadth	3.48	0.008	**Heteroscedastic**
Foot Length	3.36	0.011	**Heteroscedastic**
Hand Breadth	2.91	0.022	**Heteroscedastic**
Hand Length	2.69	0.033	**Heteroscedastic**
Head Circ	1.74	0.234	Homoscedastic
Menton-Sellion	1.10	0.836	Homoscedastic
Sitting Height	1.15	0.753	Homoscedastic
Sleeve Length	6.37	0.000	Homoscedastic
Span	1.32	0.548	Homoscedastic
Stature	2.04	0.123	Homoscedastic
Waist Circ	2.93	0.021	**Heteroscedastic**
Waist Height	1.48	0.397	Homoscedastic
Weight	11.16	0.000	**Heteroscedastic**

Table 15. Mann-Whitney *U* Results for Comparison of Observer Error Rates Between Morning and Afternoon Sessions

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Biacromial Breadth	171.5	458.5	0.2945
Bizygomatic Breadth	189.5	399.5	0.5600
Buttock Circ	209.5	419.5	0.9891
Chest Circ	143.5	486.5	0.0807
Crotch Height	207.0	423.0	0.9363
Foot Breadth	186.0	396.0	0.4923
Foot Length	190.0	440.0	0.5513
Hand Breadth	151.5	478.5	0.0608
Hand Length	149.0	481.0	0.0725
Head Circ	196.0	406.0	0.6993
Menton-Sellion	194.0	436.0	0.6424
Sitting Height	169.5	460.5	0.2851
Sleeve Length	156.0	474.0	0.1409
Span	159.5	470.5	0.1852
Stature	116.0	514.0	0.0100
Waist Circ	137.0	493.0	0.0539
Waist Height	200.0	430.0	0.7853
Weight	179.5	389.5	0.3864

* Significantly different at $p \leq .05$ using a Bonferroni correction ($p = .05/18 = .0027$)

Table 16. Analysis of Variance and Kruskal-Wallis Results for Comparison of Observer Error Rates Between Posts

Variable	*F*	*p*+	$\chi 2$	*p**
Biacromial Breadth	0.7353	0.4862	0.6974	0.7056
Bizygomatic Breadth	3.1768	0.0533	5.6249	0.0601
Buttock Circ	0.1109	0.8953	0.1704	0.9183
Chest Circ	0.7014	0.5023	1.1896	0.5517
Crotch Height	1.1253	0.3354	4.2794	0.1177
Foot Breadth	1.4242	0.2536	3.1453	0.2075
Foot Length	2.3099	0.1134	5.4436	0.0658
Hand Breadth	2.3473	0.1097	4.5345	0.1036
Hand Length	4.1968	0.0228	8.4044	0.0150
Head Circ	1.4190	0.2548	3.5631	0.1684
Menton-Sellion	3.1125	0.0563	5.6102	0.0605
Sitting Height	2.6675	0.0828	6.1342	0.0466
Sleeve Length	0.0537	0.9478	1.2214	0.5430
Span	0.7627	0.4736	1.6946	0.4286
Stature	1.1812	0.3182	2.4620	0.2920
Waist Circ	0.2503	0.7799	0.0332	0.9836
Waist Height	2.5957	0.0881	5.9054	0.0522
Weight	1.2902	0.2873	2.8799	0.2369

+ Analysis of Variance Results
* Kruskal-Wallis Results
** Significantly different at $p \leq .05$ using a Bonferroni correction ($p = .05/18 = .0027$)

Population Variation

Statistical matching procedures frequently utilize random stratified sampling to select subjects by race and/or age criteria to match the demographic distribution of the target population. The premise of such an approach is that demographic variables, such as age and race, explain much of the anthropometric variation present in a given population. If anthropometric distributions are being influenced by demographic variables not controlled by the matching procedure, then the anthropometric distribution of the matched database will not be representative of the target population. To ensure that common Canadian ethnic identities (i.e., English/British and French/French Canadian) do not need to be specifically controlled for a successful match, the anthropometric distributions of the two groups were compared.

1. Race Distribution of Subjects

Table 17 presents the race distribution of all the subjects that were processed, the appropriate element for the specific base, and fully measured. The vast majority of the processed subjects were White (96.4%), and most of the non-White subjects were of mixed race. The fully measured subjects were mostly White as well (96.3%). This finding supports the contention that the vast majority of CF personnel are White.

Table 17. Race Distribution of Subjects

Race	Total Processed	Correct Element for Base	Fully Measured/ Correct Element for Base
White	596 (96.4%)	563 (96.2%)	515 (96.3%)
Black	3 (0.5%)	3 (0.5%)	3 (0.6%)
Hispanic	1 (0.2%)	1 (0.2%)	1 (0.2%)
Aboriginal	1 (0.2%)	1 (0.2%)	1 (0.2%)
Asian	2 (0.3%)	2 (0.3%)	2 (0.4%)
White/Am Indian	7 (1.1%)	7 (1.2%)	6 (1.1%)
White/Asian	4 (0.6%)	4 (0.7%)	3 (0.6%)
White/East Indian	1 (0.2%)	1 (0.2%)	1 (0.2%)
Black/White	2 (0.3%)	2 (0.3%)	2 (0.4%)
Black/Am Indian	1 (0.2%)	1 (0.2%)	1 (0.2%)
Totals	618 (100.0%)	585 (100.0%)	535 (100.0%)

2. Ethnic Variation in Anthropometric Dimensions

If either the distribution or mean values of anthropometric dimensions are significantly different between Canadians of French/French Canadian and English/British descent, the reliability of a matched database that does not control for ethnicity could be compromised. In addition to ethnic comparisons, all 18 of the measured dimensions and BMI were tested for significant differences between subjects who indicated either English or French as their primary language. Because primary language is maintained in CF personnel records, it would be available for use in a matching process. Although ethnicity data per se are not available for the CF, statistical tests were first performed comparing those who indicated an English/British ethnicity or a French/French Canadian ethnicity on the biographical survey form.

A total of 157 subjects indicated either English or British as their ethnicity and 122 claimed to be ethnically French or French Canadian. When the 18 anthropometric dimensions were compared between these two ethnic groups, only Sitting Height was significantly different using a Bonferroni correction for multiple comparisons (see Table 18). Because the CF does not maintain ethnic identifiers in personnel records, such a variable could not be used in the matching procedure because it would be impossible to determine the ethnic distribution of CF personnel. Data on primary language is maintained in CF personnel records, thus the possibility that primary language could serve as a proxy for ethnicity was investigated. A total of 433 subjects indicated English as their primary language and 98 subjects primarily spoke French. Student's *t*-tests were used to determine if any statistically significant differences were present between means for any of the dimensions. The results, presented in Table 19, indicate that no significant differences are present between subjects who indicate English or French as their primary language using a Bonferroni correction for multiple comparisons. Because Sitting Height is not significantly different between these two groups, primary language cannot serve as a proxy variable for ethnicity in the matching procedure. The similarity between the two primary language groups is presented graphically, using the normal distributions, in Figures 8, 9, and 10.

Table 18. Student's *t*-Test and Mann-Whitney *U* Comparisons of Anthropometric Dimensions Between English/ British and French/French Canadian Ethnicities

Variable/ Ethnicity	N	Mean	SD	*t*	*p*	Mann-Whitney *U*	*p*
Weight				0.87	0.388	9128.0	0.502
Eng/British	157	82.39	12.14				
Fr/Fr Can	122	81.19	10.81				
Span				1.82	0.071	8264.0	0.050
Eng/British	157	1809.43	73.55				
Fr/Fr Can	122	1793.85	69.10				
Hand Length				1.48	0.139	8523.5	0.115
Eng/British	157	191.13	8.33				
Fr/Fr Can	122	189.58	8.91				
Hand Breadth				-0.19	0.846	9551.0	0.969
Eng/British	157	87.97	3.90				
Fr/Fr Can	122	88.06	3.72				
Foot Length				0.95	0.345	8899.5	0.311
Eng/British	157	264.63	12.09				
Fr/Fr Can	122	263.26	11.88				
Foot Breadth				0.77	0.445	9078.0	0.454
Eng/British	157	101.76	5.96				
Fr/Fr Can	122	101.25	5.03				
Stature				3.06	0.002	7688.5	0.005
Eng/British	157	1757.98	64.27				
Fr/Fr Can	122	1735.32	58.92				
Waist Height				2.22	0.027	8344.0	0.065
Eng/British	157	1046.99	47.79				
Fr/Fr Can	122	1034.33	46.71				
Crotch Height				2.11	0.035	8119.0	0.029
Eng/British	157	836.55	42.95				
Fr/Fr Can	122	826.30	37.81				
Sleeve Length				2.33	0.020	7946.0	0.115
Eng/British	157	589.29	29.58				
Fr/Fr Can	122	581.39	26.80				
Chest Circumference				-0.04	0.971	9555.5	0.974
Eng/British	157	1030.12	74.38				
Fr/Fr Can	122	1030.43	69.29				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/19 = .0026$)

Table 18. (Cont.)

Variable/ Ethnicity	N	Mean	SD	*t*	*p*	Mann-Whitney *U*	*p*
Waist Circumference				0.15	0.882	9303.5	0.683
Eng/British	157	931.62	97.23				
Fr/Fr Can	122	929.85	99.64				
Buttock Circumference				0.99	0.325	8931.5	0.334
Eng/British	157	1016.22	66.17				
Fr/Fr Can	122	1008.56	63.07				
Sitting Height				**3.23**	**0.001**	**7523.5**	**0.002***
Eng/British	157	927.85	31.04				
Fr/Fr Can	122	916.14	29.15				
Biacromial Breadth				1.03	0.303	8715.5	0.197
Eng/British	157	401.52	19.51				
Fr/Fr Can	122	399.17	18.26				
Menton-Sellion Length				0.79	0.431	9200.5	0.573
Eng/British	157	123.69	6.25				
Fr/Fr Can	122	123.02	7.61				
Bizygomatic Breadth				1.79	0.074	8467.5	0.096
Eng/British	157	144.16	6.09				
Fr/Fr Can	122	142.90	5.57				
Head Circumference				1.31	0.191	8784.0	0.235
Eng/British	157	574.82	15.91				
Fr/Fr Can	122	572.48	13.85				
BMI				-0.77	0.444	9242.0	0.616
Eng/British	157	26.63	3.43				
Fr/Fr Can	122	26.93	3.09				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/19 = .0026$)

Table 19. Student's *t*-Test and Mann-Whitney *U* Comparisons of Anthropometric Dimensions Between English and French Primary Languages

Variable/ Language	N	Mean	SD	*t*	*p*	Mann-Whitney *U*	*p*
Weight				1.44	0.153	18783.0	0.076
English	433	83.13	11.71				
French	98	81.29	11.44				
Span				1.01	0.313	19712.5	0.303
English	431	1806.88	75.72				
French	98	1799.18	66.11				
Hand Length				0.51	0.608	20434.0	0.568
English	433	190.85	9.00				
French	98	190.35	8.58				
Hand Breadth				-0.21	0.833	21178.0	0.977
English	433	88.16	3.84				
French	98	88.26	3.86				
Foot Length				1.36	0.177	19534.5	0.220
English	433	265.47	12.52				
French	98	263.68	11.59				
Foot Breadth				1.20	0.231	19846.5	0.317
English	433	102.00	5.68				
French	98	101.30	5.11				
Stature				2.82	0.005	17987.0	0.019
English	433	1755.55	66.48				
French	98	1737.53	54.79				
Waist Height				1.78	0.078	19178.0	0.137
English	433	1044.68	51.10				
French	98	1035.70	43.71				
Crotch Height				2.04	0.043	18534.0	0.050
English	433	835.77	43.72				
French	98	827.21	36.00				
Sleeve Length				1.53	0.129	19046.5	0.114
English	433	587.56	29.67				
French	98	583.01	25.92				
Chest Circumference				0.37	0.713	20106.5	0.418
English	433	1034.19	70.94				
French	98	1031.26	71.20				

All values in mm, except Weight in kg

* Significantly different at $p \leq .05$ using a Bonferroni correction ($p = .05/19 = .0026$)

Table 19. (Cont.)

Variable/ Language	N	Mean	SD	*t*	*p*	Mann-Whitney *U*	*p*
Waist Circumference				0.89	0.373	19175.5	0.137
English	433	938.80	95.42				
French	98	928.47	105.00				
Buttock Circumference				1.01	0.313	19179.0	0.137
English	433	1018.22	63.24				
French	98	1010.52	68.99				
Sitting Height				2.90	0.004	17913.0	0.016
English	433	927.25	32.91				
French	98	917.96	27.61				
Biacromial Breadth				0.00	0.996	20996.5	0.872
English	433	400.51	18.69				
French	98	400.50	18.60				
Menton-Sellion Length				0.09	0.932	20915.5	0.826
English	433	123.46	6.42				
French	98	123.40	7.05				
Bizygomatic Breadth				2.21	0.029	18114.5	0.024
English	433	144.02	5.60				
French	98	142.62	5.67				
Head Circumference				2.18	0.031	18278.0	0.032
English	433	576.24	15.15				
French	98	572.72	14.22				
BMI				0.19	0.846	19905.0	0.339
English	433	26.96	3.34				
French	98	26.88	3.26				

* Significantly different at $p \leq .05$ using a Bonferroni correction ($p = .05/19 = .0026$)

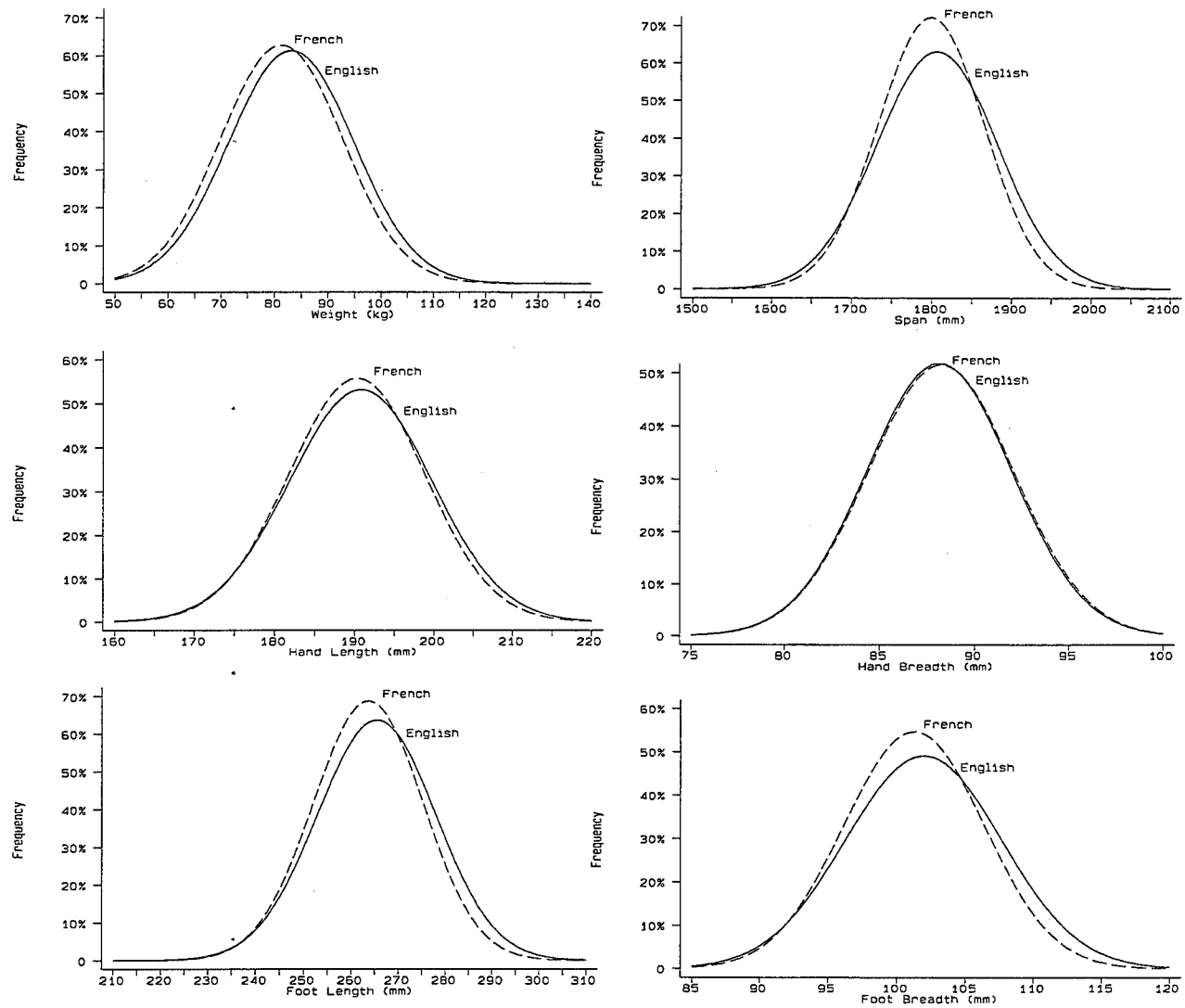

Figure 8. Normal distributions of Weight, Span, Hand Length, Hand Breadth, Foot Length and Foot Breadth for subjects who identified their primary language as English or French.

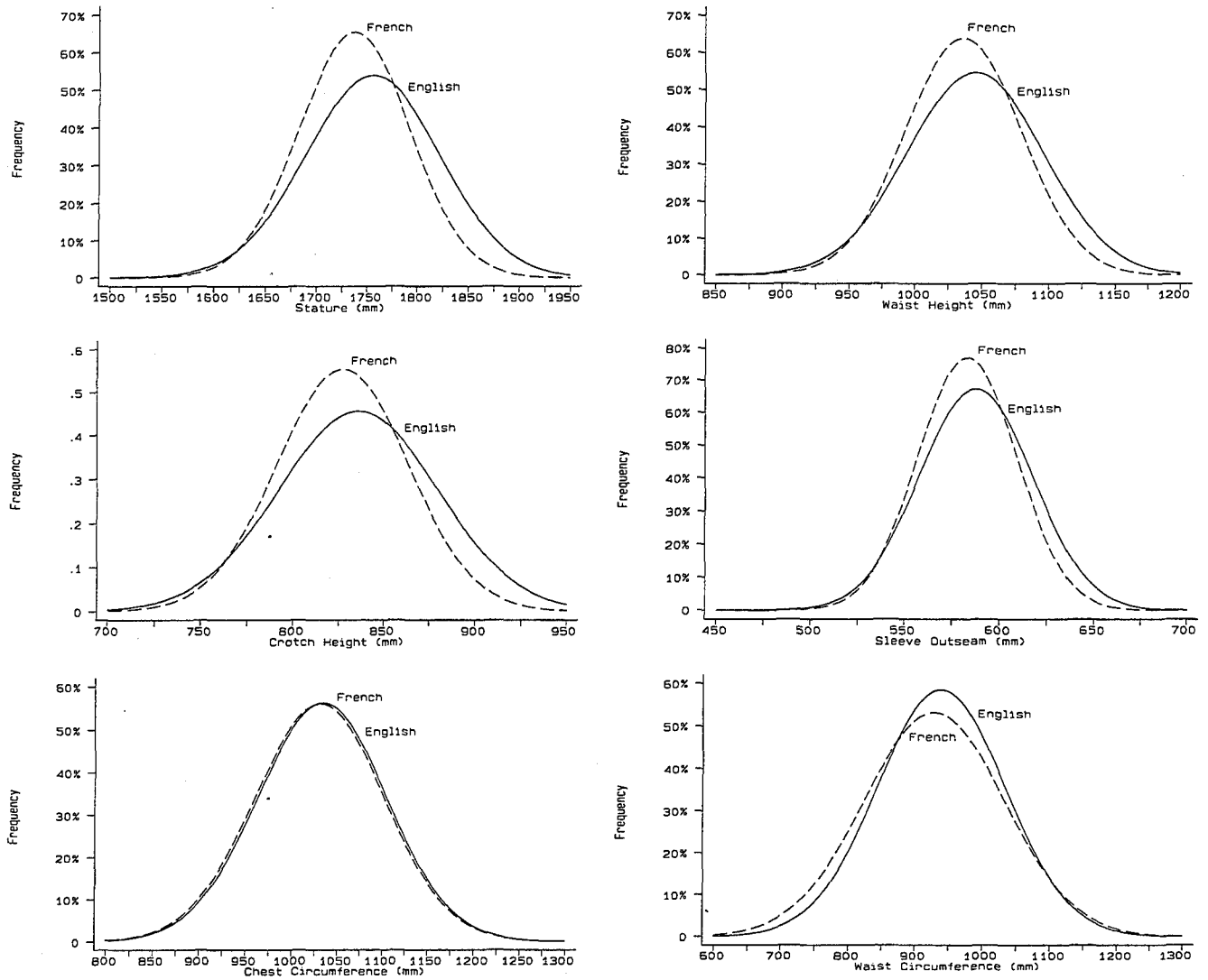

Figure 9. Normal distributions of Stature, Waist Height, Crotch Height, Sleeve Outseam, Chest Circumference and Waist Circumference for subjects who identified their primary language as English or French.

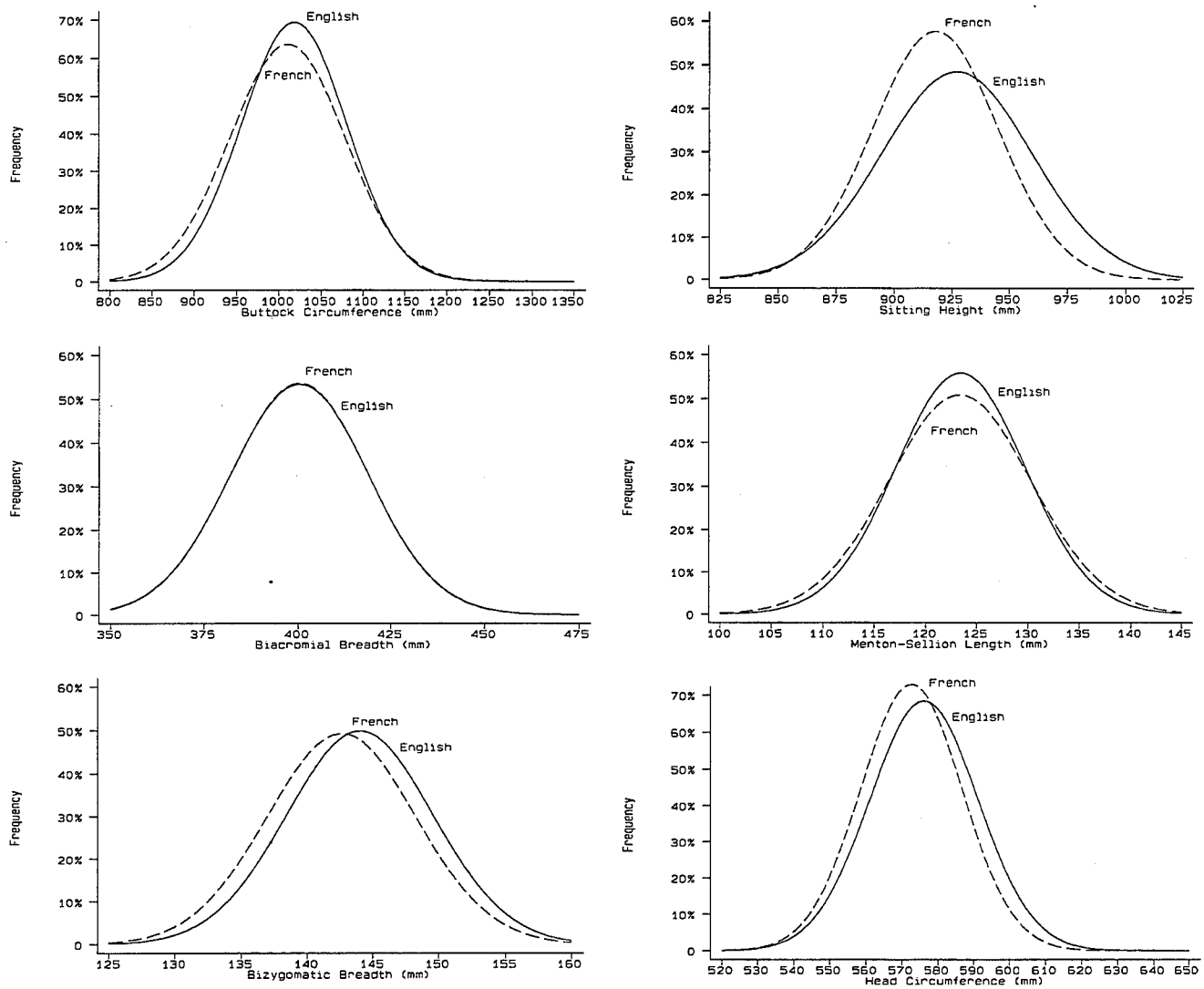

Figure 10. Normal distributions of Buttock Circumference, Sitting Height, Biacromial Breadth, Menton-Sellion Length, Bizygomatic Breadth and Head Circumference for subjects who identified their primary language as English or French.

Comparison with Canadian Forces Express and US Army Databases

The anthropometric data collected during July and August of 1993 for use in the CF Validation Study were compared to the 1992 CF Express Database. Both sets of data should describe the contemporary CF population, however statistically significant differences were found between the two for Height, Weight and Body Mass Index (BMI). These differences may be due to the non-representative proportion of operational to support personnel in the CF Validation Study and/or as a result of the way data were collected during Express Testing. The persistent differences between the two data sets strongly suggests a more reliable source for Height and Weight data is required for an anthropometrically matched database (see conclusions).

1. Comparison with 1992 CF Express Database

In 1992, the CF collected Height, Weight and BMI data from approximately 25,000 male and female subjects (1992 CF Express Database). Statistical analyses were used to determine if any significant differences were present between the 1992 CF Express Database and the CF Validation Study. Because the Express data were recorded to the nearest kilogram (kg) for Weight, and to the nearest decimeter (dm) for Height, the CF Validation Study data were rounded to the nearest kg and dm prior to comparison. Results of Student's *t*-tests and *F* statistics are presented in Table 20. Because the variances for the CF Validation Study and the 1992 CF Express Database are not homoscedastic, non-parametric statistics (Mann-Whitney *U* tests) were used to determine if any significant differences were present between the two sets of data (see Table 21). Because many anthropometric variables change with age, all comparisons were made within the five age categories that will be used for the matching procedure.

In the three older age categories (25-29, 30-34, and $\geq$ 35), significant differences between the two sets of data are present for Height and Weight. In addition, BMI is significantly different for all age groups except the youngest. To ensure that these results are not due to disproportional representation of elements in either of the databases, subsets of the 1992 CF Express Database and the CF Validation Study were selected using stratified random sampling to match the current age/element profile of the CF. These two subsets were then compared for any significant differences in Height, Weight, and BMI. Table 22 and 23 present the results of the parametric and non-parametric analyses that were performed. All three of the anthropometric variables are significantly different between the Validation and Express subsets of data, with the CF Validation Study subjects being heavier and taller.

Because significant differences persist for Height, Weight, and BMI when age and element variables are controlled, these two sets of data are ***not*** representative of the same population. This suggests that the CF Validation Study subjects, the 1992 CF Express Database subjects, or both groups may not have been drawn from a truly random sample. In such a case, a demographic only matching procedure cannot be validated using these data since the non-random nature of the sample affects the distribution of two important anthropometric dimensions: Height and Weight.

The unusually large proportion of support personnel measured at CFB Kingston and CFB Halifax strongly suggests that this sample is not random, impacting the distribution of the anthropometric dimensions that were measured. The Express database could have been influenced by the way in which the data were collected. Many observers, not trained in anthropometry, took and recorded the measurements, thus increasing observer error rates. Furthermore, Height was only recorded to the nearest decimeter. CF personnel also tend to diet and/or increase physical activity for several weeks prior to the Express Test, which may alter their anthropometry (Ms. Ann Marie Sibbald, pers. comm.). These factors alone, or in a combination, could explain why the two sets of data are not similar and strongly implies that neither data set should be used to create a database for the CF. Rather, truly representative Height and Weight data must be collected as input to the validated matching procedure to create a male database for the CF. As discussed in the conclusions, these data could be collected during the proposed Female CF Validation Study.

Table 20. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and 1992 CF Express Database

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Height						
≤ 19			1.47	0.984	-1.40	0.291
Validation	3	17.67 (0.58)				
Express	247	17.19 (0.70)				
20-24			1.16	0.465	-2.70	0.009
Validation	64	17.47 (0.69)				
Express	2620	17.23 (0.74)				
25-29			1.11	0.454	-5.78	**0.000***
Validation	125	17.62 (0.70)				
Express	4910	17.26 (0.74)				
30-34			1.08	0.484	-5.63	**0.000***
Validation	139	17.58 (0.76)				
Express	4761	17.21 (0.73)				
≥ 35			1.15	0.185	-5.56	**0.000***
Validation	200	17.45 (0.69)				
Express	7228	17.18 (0.74)				
Weight						
≤ 19			1.14	0.642	-0.60	0.606
Validation	3	77.67 (10.69)				
Express	246	73.92 (10.01)				
20-24			1.21	0.256	-2.07	0.043
Validation	64	79.84 (11.47)				
Express	2615	76.85 (10.44)				
25-29			1.03	0.874	-4.10	**0.000***
Validation	125	82.54 (10.41)				
Express	4897	78.67 (10.55)				
30-34			1.31	**0.017+**	-3.21	**0.002***
Validation	139	82.94 (11.97)				
Express	4753	79.64 (10.44)				
≥ 35			1.24	**0.025+**	-3.42	**0.001***
Validation	200	83.68 (11.62)				
Express	7214	80.83 (10.43)				

Height in dm and Weight in kg

+ Heteroscedastic variance

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/15 = .0033$)

Table 20. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
BMI						
≤ 19			8.85	0.214	-3.43	0.056
Validation	3	25.22 (0.93)				
Express	246	23.27 (2.78)				
20-24			1.25	0.188	-4.66	**0.000***
Validation	64	25.92 (3.10)				
Express	2613	24.09 (2.78)				
25-29			1.12	0.355	-8.28	**0.000***
Validation	125	26.77 (2.92)				
Express	4898	24.59 (2.76)				
30-34			1.60	**0.000+**	-5.94	**0.000***
Validation	139	26.76 (3.43)				
Express	4751	25.02 (2.71)				
≥ 35			1.59	**0.000+**	-8.02	**0.000***
Validation	200	27.46 (3.40)				
Express	7225	25.52 (2.70)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/15 = .0033$)

Table 21. Mann-Whitney *U* Results for Comparison of CF Validation Study and 1992 CF Express Database

Variable/ Age Category	Mann-Whitney *U*	Wilcoxon *W*	*p*
Height			
≤ 19	226.5	520.5	0.1967
20-24	69376.5	100383.5	0.0094
25-29	225207.5	396417.5	**0.0000***
30-34	251054.5	420454.5	**0.0000***
≥ 35	575799.5	889900.5	**0.0000***
Weight			
≤ 19	273.0	471.0	0.4385
20-24	72696.0	96744.0	0.0723
25-29	244220.5	375779.5	**0.0001***
30-34	277652.5	392744.5	**0.0013***
≥ 35	610099.0	852801.0	**0.0002***
BMI			
≤ 19	144.0	600.0	0.0677
20-24	55640.0	113672.0	**0.0000***
25-29	175563.5	444561.5	**0.0000***
30-34	231912.5	438206.5	**0.0000***
≥ 35	461707.0	1003399.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/15 = .0033$)

Table 22. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study Subset and 1992 CF Express Database Subset

Variable/ Age Category		Mann-Whitney *U*	Wilcoxon *W*		*p*
Height			1.01	0.906	- 8.28 **0.000***
	Validation 500	17.54 (0.72)			
	Express 1899	17.24 (0.72)			
Weight			1.27	**0.001+**	- 4.67 **0.000***
	Validation 500	82.75 (11.61)			
	Express 1900	80.09 (10.32)			
BMI			1.46	**0.000+**	-11.07 **0.000***
	Validation 500	26.92 (3.35)			
	Express 1897	25.12 (2.78)			

Height in dm and Weight in kg

+ Heteroscedastic variance

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/3 = .0167$)

Table 23. Mann-Whitney *U* Results for Comparison of CF Validation Study Subset and 1992 CF Express Database Subset

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Height	373727.0	701023.0	**0.0000***
Weight	412721.5	662528.5	**0.0000***
BMI	323705.0	750045.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/3 = .0167$)

2. Height and Weight Comparisons Among Elements

Initial analysis of the 1992 CF Express Database indicated that significant differences were present for Height and Weight among the elements (i.e., Land, Sea, and Air), and this finding was reported in the Anthropometric Sizing Study for the CF and Cadets Status Report of 1 June 1993 (11). These differences persisted even when age was controlled as a factor. To ensure that any differences between the elements were adequately represented in the CF Validation Study, the sampling strategy was devised to randomly select subjects for measurement by age and element designation (see Appendix A). Subjects were selected in the same proportion present in the CF population as of May 1993 (11). As a result, any Height and/or Weight differences between elements should be discernible in the CF Validation Study. If no differences are present, then it is possible that: too few subjects were sampled in the CF Validation Study to observe a statistically significant difference; the non-representative proportion of operational to support personnel in the CF Validation Study is having an impact; and/or some aspect of data collection may have been different between elements for the 1992 CF Express Database.

Because Bartlett's Box tests indicated that the variances for Height in the $\geq$ 35 year age category and Weight in the 30-34 year age category were heteroscedastic, Kruskal-Wallis tests were used to determine if any significant differences were present between the three elements. The results, presented in Table 24, show that no statistically significant differences are present for either Height or Weight among elements for any of the five age categories.

The difference in results between the CF Validation Study and the 1992 CF Express Database may be due to the nature of Express Testing; the Express data are collected for all CF personnel on an annual basis and have traditionally been used as a qualification for promotion. Because personnel are notified as to when the physical examination will occur and can choose to ***not*** be tested, it is likely that the 1992 CF Express Database is composed of more physically fit individuals. In addition, those that are tested usually prepare for it by increasing exercise and/or beginning dieting regimes. Furthermore, the Height data are only recorded to the nearest decimeter and are taken by many different observers, thus increasing the rate of observer error. The possibility exists that systematic differences are present between elements for 1) the collection of these data and/or 2) the response of the personnel to impending testing. If either, or both, of these explanations are correct, then the 1992 CF Express Database is probably not reflective of the CF population.

In terms of the CF Validation Study, three bases (CFB Kingston, CFB Trenton, and CFB Halifax) were chosen as measuring sites by the CF. They were ***not*** randomly chosen, as suggested by Natick personnel, but were chosen for their presence in a predominately English speaking province and accessibility

to DND headquarters in Ottawa. When the proportion of operational to support MOC's is examined, by element, the sample does ***not*** reflect the proportion present in the CF during the time of the study. Thus, the sample is not representative of the CF in terms of MOC distribution, and this factor could impact the anthropometric distribution of the measured sample.

A third possibility is that subjects measured at a single base do not accurately represent the overall CF population for a specific element. In the course of the CF Validation Study, subjects from a specific element were only selected from a single base. The possibility that measuring at a single location could introduce bias was tested using 1988 Anthropometric Survey of US Army Personnel (ANSUR) data and is discussed in Part 3 of this section.

The final possibility is that subjects present in the 1992 CF Express Database and/or the CF Validation Study were not randomly selected and the sample is skewed. In the case of the CF Validation Study, subjects were randomly chosen and no differences were found between rostered and substitute subjects. However, the bases were selected as measuring sites by the CF and not by Natick using statistical sampling methods. Further, the proportion of operational to support personnel indicated that the sample is not representative of the CF population. Because physical fitness levels may be correlated both with anthropometry (i.e., Weight for Height is impacted) and with MOC (i.e., heavier individuals are in support roles), the CF Validation Study data are not representative of the CF male population.

Table 24. Kruskal-Wallis Results for Comparison of Height and Weight Among Elements in CF Validation Study

Age/ Variable	Land Mean (SD)	Sea Mean (SD)	Air Mean (SD)	*p*
≤ 19				
Weight	80.00 (0.00)	86.50 (0.00)	66.20 (0.00)	0.3679
Height	1753.00 (0.00)	1844.00 (0.00)	1654.00 (0.00)	0.3679
20-24				
Weight	78.74 (11.06)	85.33 (13.24)	76.08 (8.70)	0.1307
Height	1744.28 (44.17)	1779.63 (57.78)	1740.69 (74.31)	0.1246
25-29				
Weight	83.21 (10.80)	83.30 (9.93)	80.95 (10.18)	0.5565
Height	1759.17 (58.92)	1762.86 (60.98)	1743.85 (74.25)	0.4998
30-34				
Weight	83.01 (11.24)	86.62 (18.06)	82.08 (11.40)	0.6271
Height	1756:64 (57.65)	1753.84 (77.84)	1766.07 (72.80)	0.6044
≥ 35				
Weight	82.87 (10.77)	86.53 (12.04)	83.01 (11.98)	0.1956
Height	1739.54 (71.09)	1750.92 (75.05)	1745.85 (53.92)	0.7734

Height in mm and Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/10 = .005$)

3. Samples Measured at a Single Base are Anthropometrically Representative of the US Army Population

Significant differences are present between the 1992 CF Express Database and the CF Validation Study Height/Weight distributions, even when age and element are controlled. In addition, anthropometric differences observed between elements in the Express data are not present in the CF Validation Study, perhaps due to the non-representative proportion of operational to support personnel in the Land and Sea elements (see Part 2 of this section). In addition, the demographic only matching procedure was unsuccessful in controlling the anthropometric variation for 7 of 18 anthropometric dimensions tested (see Parts 1 and 2 of Validation of Alternative Matching Procedures). While the explanation may be due entirely to the small numbers of operational personnel measured, the question of whether or not subjects measured from a single base could be truly representative of the overall population was raised. Because members of each element (Land, Sea, or Air) were measured at a single post, it is possible that they are not representative of the element overall (once the proportion of operational to support personnel is corrected) and that subjects from several geographically distinct locations must be measured to accurately portray the anthropometric variation found in military populations.

To test this hypothesis, White, male infantry data collected during the 1988 Anthropometric Survey of US Army Personnel (ANSUR) were used. This subset of the ANSUR database was chosen because 1) the data were collected by a single measuring team, 2) a large data set is available, 3) observer error rates are known, and 4) confounding factors such as race, age, and occupation could easily be controlled. Subjects measured at Ft. Bragg, North Carolina, and Ft. Ord, California, were chosen for comparison due to the large numbers of infantry that were measured at each site, and because the two posts are geographically distinct. In addition, the age distribution of each group was structured to be identical, using the five age categories for matching. Thus, any significant differences would indicate that a true, representative sample cannot be drawn from a single location, and the lack of differences would confirm that a single post can provide a representative sample.

Because the variance for Weight was heteroscedastic (see Table 25), Mann-Whitney *U* statistics were used to determine if any significant differences were present between the posts. Table 26 presents the results of the non-parametric tests and shows that no statistically significant differences are present between the two posts for Height and Weight. Each of the posts tested was also compared to the entire White, male infantry population that was structured to have the identical age distribution. Again, no significant differences were found for either Height or Weight (see Tables 27 and 28). The subjects measured at a single post in ANSUR are not significantly different for Height or Weight from the

overall US Army distribution when factors such as race, age and occupation are controlled. Thus, subjects measured at a single post in the CF Validation Study should be representative of the CF population in general. However, this will not necessarily hold true if the soldiers stationed at CFB Kingston, CFB Trenton, CFB Halifax, and CFB Gagetown were posted to these locations for ***any*** reason that may affect anthropometry.

Table 25. *F* Test and Student's *t*-Test Results for Comparison of Fort Bragg and Fort Ord Infantry (White Males)

Variable/ Post	N	Mean (SD)	*F*	*p*	*t*	*p*
Height			1.13	0.268	-0.84	0.403
Fort Bragg	309	1761.97 (59.43)				
Fort Ord	309	1766.10 (63.31)				
Weight			1.27	**0.037+**	-1.62	0.105
Fort Bragg	309	76.73 (9.29)				
Fort Ord	309	78.02 (10.46)				

Height in mm and Weight in kg
+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/2 = .0250$)

Table 26. Mann-Whitney *U* Results for Comparison of Fort Bragg and Fort Ord Infantry (White Males)

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Height	45793.0	93688.0	0.3802
Weight	44820.0	92715.0	0.1882

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/2 = .0250$)

Table 27. *F* Test and Student's *t*-Test Results for Comparison of Posts to Overall Infantry Population (White Males)

Variable/ Group	N	Mean (SD)	*F*	*p*	*t*	*p*
Height						
			1.21	**0.037+**	0.36	0.718
Fort Bragg	309	1761.97 (59.43)				
Infantry	1532	1763.33 (65.34)				
			1.07	0.488	- 0.70	0.486
Fort Ord	309	1766.10 (63.31)				
Infantry	1532	1763.33 (65.34)				
Weight						
			1.17	0.085	0.77	0.441
Fort Bragg	309	76.73 (9.29)				
Infantry	1532	77.18 (10.04)				
			1.09	0.340	-1.30	0.196
Fort Ord	309	78.02 (10.44)				
Infantry	1532	77.18 (10.04)				

Height in mm and Weight in kg.
+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/4 = .0125$)

Table 28. Mann-Whitney *U* Results for Comparison of Posts to Overall Infantry Population (White Males)

Variable/ Comparison	Mann-Whitney *U*	Wilcoxon *W*	*p*
Height			
Fort Bragg/Infantry	232853.5	280748.5	0.6523
Fort Ord/Infantry	231104.5	290178.5	0.5120
Weight			
Fort Bragg/Infantry	233939.0	281834.0	0.7465
Fort Ord/Infantry	225641.5	295641.5	0.1948

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/2 = .0250$)

4. Comparison of CF Validation Study and 1988 Anthropometric Survey of US Army Personnel

Table 29 presents the minimum values, maximum values, means and standard deviations of the 18 anthropometric variables that were collected in the CF Validation Study. These values are also presented for the ANSUR Male Working Database and for White males from the ANSUR Data Pool. For two of the anthropometric variables, Foot Length and Sleeve Length, the minimum values for the CF Validation Study were smaller than the minimum values from ANSUR. In addition, four variables (Waist Circumference, Buttock Circumference, Biacromial Breadth, and Head Circumference) were larger than the maximum ANSUR values. Because the ranges for these variables are different from the ANSUR database, further analyses were performed to determine whether or not the observed differences were significant (see Part 5 of this section).

Table 29. CF Validation Study vs. ANSUR Male Data

Variable	N	Min	Max	Mean	SD
Weight					
Male WDB[1]	1774	47.60	127.80	78.49	11.11
CF Validation	534	53.23	138.00	82.78	11.64
White Male DP[2]	1976	49.80	124.30	78.79	10.57
Span					
Male WDB	1774	1474.00	2159.00	1823.06	81.97
CF Validation	529	1528.00	2035.00	1805.49	73.99
White Male DP	1962	1474.00	2159.00	1816.76	75.62
Hand Length					
Male WDB	1774	160.00	233.00	193.78	9.78
CF Validation	531	163.00	218.00	190.73	8.94
White Male DP	2069	160.00	228.00	192.59	8.76
Hand Breadth					
Male WDB	1774	77.00	106.00	90.43	4.22
CF Validation	531	77.00	100.00	88.18	3.84
White Male DP	2069	77.00	104.00	90.34	3.98
Foot Length					
Male WDB	1774	228.00	310.00	269.68	13.10
CF Validation	531	**218.00***	304.00	265.15	12.36
White Male DP	1970	228.00	311.00	268.28	12.33
Foot Breadth					
Male WDB	1774	80.00	122.00	100.62	5.26
CF Validation	531	86.00	116.00	101.87	5.58
White Male DP	1970	80.00	122.00	100.31	5.07
Height					
Male WDB	1774	1497.00	2042.00	1755.81	66.81
CF Validation	534	1523.00	1932.00	1751.16	64.57
White Male DP	1975	1497.00	2042.00	1764.60	65.03

All values in mm, except Weight in kg

* Value does not fall within the range of ANSUR

[1]WDB - ANSUR Working Database

[2]WMDP - ANSUR White Male Data Pool

Table 29. (Cont.)

Variable	N	Min	Max	Mean	SD
Waist Height					
Male WDB	1774	860.00	1305.00	1058.81	50.93
CF Validation	531	893.00	1187.00	1043.06	49.86
White Male DP	1975	860.00	1277.00	1060.49	48.62
Crotch Height					
Male WDB	1774	675.00	1067.00	837.19	46.25
CF Validation	531	701.00	949.00	834.26	42.42
White Male DP	1975	675.00	1021.00	835.69	43.08
Sleeve Length					
Male WDB	1774	481.00	745.00	601.52	30.69
CF Validation	531	**478.00***	700.00	586.76	29.00
White Male DP	1976	481.00	736.00	599.68	29.27
Chest Circ					
Male WDB	1774	775.00	1281.00	991.37	69.06
CF Validation	531	837.00	1280.00	1033.78	70.79
White Male DP	1976	797.00	1281.00	997.99	67.26
Waist Circ					
Male WDB	1774	654.00	1185.00	862.42	86.40
CF Validation	531	693.00	**1298.00***	937.10	97.04
White Male DP	1976	684.00	1190.00	873.95	83.78
Buttock Circ					
Male WDB	1774	805.00	1239.00	983.67	62.18
CF Validation	531	858.00	**1325.00***	1016.82	64.33
White Male DP	1975	827.00	1239.00	986.10	58.67
Sitting Height					
Male WDB	1774	808.00	1032.00	913.93	35.58
CF Validation	531	831.00	1025.00	925.58	32.15
White Male DP	1976	823.00	1041.00	926.01	32.21
Biacromial Breadth					
Male WDB	1774	330.00	451.00	396.97	17.96
CF Validation	531	350.00	**471.00***	400.50	18.66
White Male DP	1976	330.00	449.00	397.31	18.09

* Value does not fall within the range of ANSUR

Table 29. (Cont.)

Variable	N	Min	Max	Mean	SD
Menton-Sellion Length					
Male WDB	1774	101.00	148.00	121.91	6.49
CF Validation	531	101.00	142.00	123.46	6.54
White Male DP	2069	101.00	145.00	121.56	6.35
Bizygomatic Breadth					
Male WDB	1774	118.00	161.00	140.47	5.60
CF Validation	531	129.00	159.00	143.77	5.63
White Male DP	2069	118.00	161.00	140.02	5.51
Head Circ					
Male WDB	1774	514.00	627.00	567.66	15.36
CF Validation	531	522.00	**649.00***	575.58	15.05
White Male DP	2069	518.00	633.00	568.26	15.01

* Value does not fall within the range of ANSUR

5. Comparison of CF Validation Study and 1988 Anthropometric Survey of US Army Personnel White Males by Age Categories

Because the CF Validation Study data and ANSUR data have different ranges for several anthropometric variables (see Part 4 of this section), statistical analyses were used to determine if any significant differences exist between the CF Validation Study data and the White males in the ANSUR Data Pool within the five age categories that will be used in the matching procedure. The results of Student's *t*-tests and *F* statistics are presented in Table 30 for the 18 anthropometric variables that were measured during the CF Validation Study and for BMI. Because the variances for Hand Breadth, Foot Breadth, Waist Circumference, Biacromial Breadth, Menton-Sellion Length, Bizygomatic Breadth, and BMI are heteroscedastic, non-parametric tests were used to determine if any significant differences are present between the two sets of data.

As shown in Table 31, no significant differences are found in any of the five age categories for 5 of the 19 anthropometric dimensions (Height, Weight, Crotch Height, Sitting Height, and Biacromial Breadth). The remaining 14 anthropometric dimensions are significantly different in at least one of the five age categories. Only Hand Breadth, Sleeve Length, Waist Circumference, Bizygomatic Breadth, and Head Circumference are significantly different in at least three of the five age categories. Because statistically significant differences are present between the two data sets, even when age and race are controlled as factors, a demographic only match may not successfully describe the CF population. It is very likely that the matching process will have to incorporate at least one anthropometric variable to be successful. (In fact, Parts 1 and 2 of the "Selection of Matching Procedure and the CF Male Anthropometric Database" section of this report describes the results of demographic only matching procedures that failed to accurately describe the anthropometric distribution in the CF.) Again, the observed differences between the measured CF sample and the ANSUR subjects may be due to the large proportion of support personnel that participated in the Validation Study.

Table 30. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and ANSUR Data Pool (White Males)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight						
≤ 19			1.46	0.470	-0.69	0.562
ANSUR	210	73.44 (8.58)				
Validation	3	77.57 (10.37)				
20-24			1.35	0.085	-1.52	0.132
ANSUR	613	77.45 (9.88)				
Validation	64	79.72 (11.48)				
25-29			1.04	0.795	-3.13	0.002
ANSUR	431	79.20 (10.61)				
Validation	125	82.52 (10.39)				
30-34			1.25	0.109	-2.34	0.020
ANSUR	328	80.12 (10.67)				
Validation	139	82.87 (11.94)				
≥ 35			1.11	0.380	-1.50	0.134
ANSUR	394	82.14 (11.01)				
Validation	200	83.63 (11.61)				
Span						
≤ 19			1.09	0.675	0.27	0.812
ANSUR	209	1801.12 (76.15)				
Validation	3	1788.67 (79.59)				
20-24			1.18	0.413	0.42	0.675
ANSUR	611	1813.93 (76.13)				
Validation	64	1810.02 (70.05)				
25-29			1.09	0.538	2.52	0.013
ANSUR	428	1826.92 (71.24)				
Validation	125	1808.07 (74.31)				
30-34			1.07	0.672	0.31	0.754
ANSUR	327	1818.05 (79.92)				
Validation	138	1815.56 (77.39)				
≥ 35			1.07	0.584	3.62	**0.000***
ANSUR	392	1817.35 (74.19)				
Validation	199	1794.48 (71.65)				

All values in mm, except Weight in kg

+ Heteroscedastic variance

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Length						
≤ 19			1.13	1.000	1.18	0.355
ANSUR	221	191.19 (8.51)				
Validation	3	185.67 (8.02)				
20-24			1.27	0.237	1.61	0.112
ANSUR	663	191.91 (8.84)				
Validation	64	190.23 (7.85)				
25-29			1.24	0.126	3.23	0.001
ANSUR	452	193.37 (8.49)				
Validation	125	190.35 (9.43)				
30-34			1.05	0.723	0.84	0.403
ANSUR	336	192.74 (9.08)				
Validation	139	191.96 (9.30)				
≥ 35			1.01	0.932	4.31	**0.000***
ANSUR	397	193.49 (8.62)				
Validation	200	190.26 (8.66)				
Hand Breadth						
≤ 19			1.44	0.999	1.11	0.380
ANSUR	221	89.94 (3.60)				
Validation	3	88.00 (3.00)				
20-24			1.51	**0.041+**	5.70	**0.000***
ANSUR	663	90.14 (3.96)				
Validation	64	87.69 (3.22)				
25-29			1.06	0.665	4.78	**0.000***
ANSUR	452	90.38 (3.96)				
Validation	125	88.42 (4.08)				
30-34			1.32	0.063	5.70	**0.000***
ANSUR	336	90.32 (3.96)				
Validation	139	88.24 (3.45)				
≥ 35			1.04	0.772	7.64	**0.000***
ANSUR	397	90.86 (4.20)				
Validation	200	88.11 (4.12)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Foot Length						
≤ 19			1.89	0.306	0.05	0.963
ANSUR	209	267.13 (11.31)				
Validation	3	266.67 (15.57)				
20-24			1.10	0.637	2.11	0.038
ANSUR	612	268.43 (12.79)				
Validation	64	265.03 (12.17)				
25-29			1.04	0.740	2.98	0.003
ANSUR	430	268.75 (11.98)				
Validation	125	265.06 (12.24)				
30-34			1.25	0.127	1.13	0.259
ANSUR	327	267.77 (13.23)				
Validation	139	266.37 (11.82)				
≥ 35			1.20	0.125	4.03	**0.000***
ANSUR	392	268.59 (11.70)				
Validation	200	264.23 (12.84)				
Foot Breadth						
≤ 19			1.14	0.642	-0.01	0.992
ANSUR	209	99.97 (4.95)				
Validation	3	100.00 (5.29)				
20-24			1.15	0.416	-1.48	0.142
ANSUR	612	100.48 (4.91)				
Validation	64	101.50 (5.27)				
25-29			1.34	**0.034+**	-3.24	0.001
ANSUR	430	100.37 (5.00)				
Validation	125	102.22 (5.79)				
30-34			1.07	0.670	-4.15	**0.000***
ANSUR	327	99.97 (5.29)				
Validation	139	102.14 (5.12)				
≥ 35			1.23	0.086	-2.25	0.025
ANSUR	392	100.43 (5.26)				
Validation	200	101.54 (5.84)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Height						
≤ 19			2.15	0.237	0.05	0.964
ANSUR	209	1753.10 (64.75)				
Validation	3	1750.33 (95.03)				
20-24			1.32	0.17	1.15	0.252
ANSUR	613	1761.08 (66.21)				
Validation	64	1752.22 (57.67)				
25-29			1.07	0.604	2.98	0.003
ANSUR	431	1774.61 (62.23)				
Validation	125	1755.22 (64.47)				
30-34			1.00	0.993	1.04	0.300
ANSUR	328	1766.17 (67.18)				
Validation	139	1759.12 (67.04)				
≥ 35			1.04	0.764	3.47	0.001
ANSUR	394	1763.92 (63.27)				
Validation	200	1744.61 (64.39)				
Waist Height						
≤ 19			2.35	0.196	0.01	0.989
ANSUR	209	1054.66 (49.92)				
Validation	3	1054.00 (76.51)				
20-24			1.09	0.682	1.73	0.088
ANSUR	613	1061.27 (49.76)				
Validation	64	1050.39 (47.64)				
25-29			1.08	0.568	4.52	**0.000***
ANSUR	431	1067.89 (45.24)				
Validation	125	1046.46 (47.04)				
30-34			1.04	0.799	2.08	0.039
ANSUR	328	1060.65 (49.89)				
Validation	139	1050.30 (48.91)				
≥ 35			1.16	0.215	4.92	**0.000***
ANSUR	394	1054.16 (47.64)				
Validation	200	1032.74 (51.34)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Crotch Height						
≤ 19			1.53	0.439	0.03	0.979
ANSUR	208	830.31 (45.09)				
Validation	3	829.33 (55.72)				
20-24			1.30	0.197	-0.33	0.742
ANSUR	614	836.32 (43.91)				
Validation	64	838.02 (38.55)				
25-29			1.02	0.904	2.10	0.037
ANSUR	431	842.59 (39.89)				
Validation	125	834.16 (39.47)				
30-34			1.03	0.859	-1.12	0.262
ANSUR	328	835.55 (44.32)				
Validation	139	840.55 (43.69)				
≥ 35			1.10	0.434	0.48	0.630
ANSUR	394	830.13 (42.04)				
Validation	200	828.32 (44.06)				
Sleeve Length						
≤ 19			1.44	0.479	0.65	0.583
ANSUR	210	594.82 (28.44)				
Validation	3	582.00 (34.12)				
20-24			1.16	0.482	3.96	**0.000***
ANSUR	613	598.73 (29.78)				
Validation	64	584.20 (27.71)				
25-29			1.04	0.787	5.88	**0.000***
ANSUR	431	603.14 (27.90)				
Validation	125	586.25 (28.39)				
30-34			1.14	0.379	2.84	0.005
ANSUR	328	600.22 (31.04)				
Validation	139	591.69 (29.08)				
≥ 35			1.07	0.582	6.09	**0.000***
ANSUR	394	599.52 (28.54)				
Validation	200	584.10 (29.49)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Chest Circumference						
≤ 19			1.48	0.981	-0.85	0.482
ANSUR	210	957.37 (56.35)				
Validation	3	980.33 (46.36)				
20-24			1.19	0.315	-2.49	0.015
ANSUR	613	986.03 (61.84)				
Validation	64	1007.97 (67.48)				
25-29			1.18	0.266	-4.43	**0.000***
ANSUR	431	999.58 (64.05)				
Validation	125	1026.62 (58.91)				
30-34			1.20	0.199	-3.32	0.001
ANSUR	328	1008.44 (66.97)				
Validation	139	1032.45 (73.26)				
≥ 35			1.11	0.396	-3.01	0.003
ANSUR	394	1027.81 (69.16)				
Validation	200	1046.49 (72.80)				
Waist Circumference						
≤ 19			1.03	0.720	-1.20	0.349
ANSUR	210	818.08 (65.23)				
Validation	3	864.33 (66.11)				
20-24			1.26	0.183	-2.96	0.004
ANSUR	613	851.84 (76.42)				
Validation	64	884.94 (85.84)				
25-29			1.27	0.081	-5.30	**0.000***
ANSUR	431	871.67 (77.22)				
Validation	125	917.48 (87.19)				
30-34			1.52	**0.003+**	-4.08	**0.000***
ANSUR	328	893.27 (82.64)				
Validation	139	933.06 (101.74)				
≥ 35			1.31	**0.024+**	-5.69	**0.000***
ANSUR	394	924.54 (79.95)				
Validation	200	967.91 (91.61)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Buttock Circumference						
≤ 19			1.04	0.710	-1.49	0.272
ANSUR	208	962.21 (50.70)				
Validation	3	1007.00 (51.73)				
20-24			1.30	0.129	-3.01	0.004
ANSUR	614	979.03 (56.76)				
Validation	64	1004.38 (64.79)				
25-29			1.03	0.835	-5.07	**0.000***
ANSUR	431	985.32 (59.58)				
Validation	125	1016.31 (60.36)				
30-34			1.28	0.075	-3.51	0.001
ANSUR	328	994.43 (58.53)				
Validation	139	1017.19 (66.29)				
≥ 35			1.12	0.351	-2.93	0.004
ANSUR	394	1003.64 (58.54)				
Validation	200	1019.14 (61.93)				
Sitting Height						
≤ 19			1.29	0.555	-0.18	0.873
ANSUR	209	920.65 (30.84)				
Validation	3	924.33 (35.02)				
20-24			1.15	0.506	-0.43	0.668
ANSUR	614	922.70 (32.30)				
Validation	64	924.42 (30.17)				
25-29			1.08	0.572	0.49	0.625
ANSUR	431	930.57 (31.71)				
Validation	125	928.94 (32.96)				
30-34			1.06	0.655	0.14	0.891
ANSUR	329	927.91 (32.49)				
Validation	139	927.45 (33.50)				
≥ 35			1.10	0.442	2.01	0.045
ANSUR	393	927.43 (32.30)				
Validation	200	921.97 (30.77)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Biacromial Breadth						
≤ 19			3.57	0.488	-1.30	0.314
ANSUR	209	392.38 (17.97)				
Validation	3	399.67 (9.50)				
20-24			1.46	**0.031**+	-3.38	0.001
ANSUR	614	396.87 (17.77)				
Validation	64	406.27 (21.45)				
25-29			1.21	0.163	-1.00	0.320
ANSUR	431	399.61 (17.15)				
Validation	125	401.48 (18.90)				
30-34			1.03	0.862	-2.45	0.015
ANSUR	329	397.70 (18.32)				
Validation	139	402.19 (18.07)				
≥ 35			1.22	0.117	0.69	0.490
ANSUR	393	397.78 (19.01)				
Validation	200	396.71 (17.23)				
Menton-Sellion Length						
≤ 19			1.13	1.000	-0.64	0.587
ANSUR	221	120.29 (5.84)				
Validation	3	122.33 (5.51)				
20-24			1.02	0.971	-1.99	0.050
ANSUR	663	121.36 (6.63)				
Validation	64	123.08 (6.57)				
25-29			1.35	**0.030**+	-2.09	0.038
ANSUR	452	122.10 (6.14)				
Validation	125	123.56 (7.13)				
30-34			1.16	0.302	-3.89	**0.000***
ANSUR	336	121.28 (6.61)				
Validation	139	123.74 (6.13)				
≥ 35			1.14	0.291	-1.92	0.055
ANSUR	397	122.23 (6.05)				
Validation	200	123.28 (6.44)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
Bizygomatic Breadth						
≤ 19			72.56	**0.027**[+]	-1.81	0.109
ANSUR	221	137.48 (4.92)				
Validation	3	138.33 (0.58)				
20-24			1.25	0.206	-3.10	0.003
ANSUR	663	139.13 (5.43)				
Validation	64	141.56 (6.06)				
25-29			1.17	0.265	-6.43	**0.000**[*]
ANSUR	452	140.06 (5.21)				
Validation	125	143.66 (5.62)				
30-34			1.25	0.113	-4.92	**0.000**[*]
ANSUR	336	140.57 (5.23)				
Validation	139	143.38 (5.85)				
≥ 35			1.19	0.175	-5.39	**0.000**[*]
ANSUR	397	142.39 (5.55)				
Validation	200	144.85 (5.10)				
Head Circumference						
≤ 19			3.24	0.530	-0.57	0.622
ANSUR	221	563.93 (14.67)				
Validation	3	566.67 (8.15)				
20-24			1.21	0.281	-4.14	**0.000**[*]
ANSUR	663	567.04 (14.45)				
Validation	64	575.58 (15.87)				
25-29			1.01	0.989	-5.18	**0.000**[*]
ANSUR	452	569.40 (15.27)				
Validation	125	577.37 (15.22)				
30-34			1.11	0.468	-4.66	**0.000**[*]
ANSUR	336	568.12 (15.26)				
Validation	139	575.02 (14.46)				
≥ 35			1.05	0.700	-2.57	0.010
ANSUR	397	571.52 (14.83)				
Validation	200	574.89 (15.18)				

[+] Heteroscedastic variance
[*] Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/95=.0005$)

Table 30. (Cont.)

Variable/ Age Category	N	Mean (SD)	*F*	*p*	*t*	*p*
BMI						
≤ 19			6.31	0.293	-2.38	0.120
ANSUR	209	23.88 (2.35)				
Validation	3	25.22 (0.93)				
20-24			1.30	0.128	-2.39	0.020
ANSUR	612	24.96 (2.72)				
Validation	64	25.92 (3.10)				
25-29			1.17	0.266	-5.72	**0.000***
ANSUR	431	25.10 (2.70)				
Validation	125	26.77 (2.92)				
30-34			1.43	**0.010+**	-3.33	0.001
ANSUR	328	25.66 (2.86)				
Validation	139	26.76 (3.43)				
≥ 35			1.38	**0.007+**	-3.92	**0.000***
ANSUR	394	26.36 (2.90)				
Validation	200	27.46 (3.40)				

+ Heteroscedastic variance
* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Table 31. Mann-Whitney *U* Results for Comparison of CF Validation Study and ANSUR Data Pool (White Males) by Age Category

Variable/ Age Category	Mann-Whitney *U*	Wilcoxon *W*	*p*
Height			
≤ 19	312.0	318.0	0.9887
20-24	18137.0	20217.0	0.3205
25-29	22811.0	30686.0	0.0091
30-34	20950.0	30680.0	0.1662
≥ 35	32832.0	52932.0	0.0009
Weight			
≤ 19	226.5	409.5	0.4037
20-24	17909.5	23402.5	0.2517
25-29	22121.5	39628.5	0.0023
30-34	19607.5	35714.5	0.0168
≥ 35	36219.0	62681.0	0.1076
BMI			
≤ 19	174.0	459.0	0.1861
20-24	16241.0	25007.0	0.0245
25-29	18147.0	43603.0	**0.0000***
30-34	18548.0	36774.0	0.0014
≥ 35	31713.0	67187.0	**0.0001***
Span			
≤ 19	293.0	299.0	0.8459
20-24	18827.0	20907.0	0.6252
25-29	22818.5	30693.5	0.0124
30-34	22396.5	31987.5	0.8999
≥ 35	32004.5	51904.5	**0.0004***
Hand Length			
≤ 19	205.5	211.5	0.2581
20-24	18558.5	20638.5	0.0974
25-29	23011.5	30886.5	0.0015
30-34	22111.0	31841.0	0.3616
≥ 35	31385.0	51485.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Table 31. (Cont.)

Variable/ Age Category	Mann-Whitney *U*	Wilcoxon *W*	*p*
Hand Breadth			
≤ 19	224.5	230.5	0.3351
20-24	13111.5	15191.5	**0.0000***
25-29	20632.5	28507.5	**0.0000***
30-34	16008.5	25738.5	**0.0000***
≥ 35	25713.0	45813.0	**0.0000***
Foot Length			
≤ 19	302.5	308.5	0.9169
20-24	16787.0	18867.0	0.0598
25-29	22058.0	29933.0	0.0023
30-34	21796.0	31526.0	0.4840
≥ 35	31228.0	51328.0	**0.0001***
Foot Breadth			
≤ 19	299.5	305.5	0.8942
20-24	16327.5	24920.5	0.0281
25-29	21896.5	39728.5	0.0016
30-34	17466.5	37716.5	**0.0001***
≥ 35	34840.5	63659.5	0.0265
Waist Height			
≤ 19	306.0	327.0	0.9433
20-24	17274.5	19354.5	0.1158
25-29	20179.5	28054.5	**0.0000***
30-34	20510.0	30240.0	0.0865
≥ 35	30177.5	50277.5	**0.0000***
Crotch Height			
≤ 19	310.5	319.5	0.9886
20-24	19127.5	22248.5	0.7270
25-29	23915.0	31790.0	0.0559
30-34	21142.0	34180.0	0.2148
≥ 35	38956.0	59056.0	0.8223

* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Table 31. (Cont.)

Variable/ Age Category	Mann-Whitney *U*	Wilcoxon *W*	*p*
Sleeve Length			
≤ 19	249.5	255.5	0.5366
20-24	14465.0	16545.0	**0.0005***
25-29	18281.0	26156.0	**0.0000***
30-34	19440.0	29170.0	0.0118
≥ 35	28228.5	48328.5	**0.0000***
Chest Circumference			
≤ 19	226.5	409.5	0.4037
20-24	16178.0	25134.0	0.0209
25-29	20275.5	41474.5	**0.0000***
30-34	18595.0	36727.0	0.0016
≥ 35	33337.5	65562.5	0.0022
Waist Circumference			
≤ 19	177.0	459.0	0.1929
20-24	15281.5	26030.5	0.0036
25-29	18589.0	43161.0	**0.0000***
30-34	17774.5	37547.5	**0.0002***
≥ 35	28049.0	70851.0	**0.0000***
Buttock Circumference			
≤ 19	159.5	470.5	0.1464
20-24	15118.0	26258.0	0.0024
25-29	19426.5	42323.5	**0.0000***
30-34	17790.0	37532.0	**0.0002***
≥ 35	33438.5	65461.5	0.0026
Sitting Height			
≤ 19	288.5	344.5	0.8127
20-24	18736.0	22640.0	0.5408
25-29	26252.0	34127.0	0.6646
30-34	22102.5	31832.5	0.5682
≥ 35	35839.0	55939.0	0.0793

* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Table 31. (Cont.)

Variable/ Age Category	Mann-Whitney *U*	Wilcoxon *W*	*p*
Biacromial Breadth			
≤ 19	224.0	409.0	0.3961
20-24	14827.5	26548.5	0.0012
25-29	25602.0	36148.0	0.3983
30-34	20415.0	35046.0	0.0668
≥ 35	37669.5	57769.5	0.4084
Menton-Sellion Length			
≤ 19	255.0	414.0	0.4917
20-24	18194.5	26317.5	0.0594
25-29	24792.0	39583.0	0.0359
30-34	18016.5	38417.5	**0.0001***
≥ 35	35180.5	64319.5	0.0229
Bizygomatic Breadth			
≤ 19	289.0	380.0	0.7024
20-24	16313.0	28199.0	0.0022
25-29	18354.5	46020.5	**0.0000***
30-34	16829.5	39604.5	**0.0000***
≥ 35	29625.5	69874.5	**0.0000***
Head Circumference			
≤ 19	283.5	385.5	0.6667
20-24	15153.5	29358.5	**0.0002***
25-29	20165.0	44210.0	**0.0000***
30-34	17806.0	38628.0	**0.0000***
≥ 35	34004.5	65495.5	0.0042

* Significantly different at $p \leq 0.05$ using a Bonferroni correction (p = .05/95=.0005)

Validation of Alternative Matching Procedures

Two demographic only statistical matching procedures were tested to determine if they could be used to create an anthropometric database that matches the CF Validation Study data using stratified random sampling to select subjects from the 1988 Anthropometric Survey of US Army Personnel (ANSUR) database. The first method consisted of using random stratified matching to select White males from the ANSUR data pool so that the resulting age distribution was identical to that of the CF Validation Study. The second procedure involved randomly selecting male ANSUR subjects to match the Age and Race distribution of the CF Validation Study. When both of these procedures failed to produce anthropometrically valid databases for the CF population, matching procedures that rely on Height and Weight were tested. Both Height/Weight Range matching and Individual Subject matching produced anthropometric distributions that were significantly different from that of the CF Validation Study for Hand Breadth, Waist Circumference, Bizygomatic Breadth, and Head Circumference. However, the observed differences for Waist Circumference could be due to the high proportion of less physically fit support personnel in the measured sample, and the magnitude of the remaining differences was too small to impact the development of CIE.

1. Age Only Match

To test whether or not a database can be matched from 1988 Anthropometric Survey of US Army Personnel (ANSUR) data to accurately represent the CF population using only demographic variables, four separate Age Only Matches were created to emulate the demographic profile of the CF Validation Study data. Although not all of the subjects measured were White, less than 4.0% were of other racial groups. Because the CF does not maintain records concerning the race of soldiers, the precise numbers of non-White CF personnel cannot be determined. Therefore, the most accurate way to match on race for the CF will be to select only White subjects from the ANSUR database, since the vast majority of CF personnel are White and over 95% of the Canadian general population is White (2). The age distribution of CF Validation Study subjects who were fully measured and the appropriate element for the base where they were measured, is presented in Table 32. This age distribution was used to determine the number of White, male ANSUR subjects to be randomly selected from each of the five age categories to create a matched database.

To minimize the possibility that one matched database was unusual, a total of four separate matches were completed. For each match, a unique seed for the SPSS sampling command was set using a random number table, ensuring that a different combination of subjects was randomly chosen for each

of the matches (15). After all four databases were compiled, Student's *t*-tests were used to determine if significant differences were present between the matched databases and the CF Validation Study data. Table 33 presents the results of the *t*-tests and the *F* statistics for the 18 anthropometric dimensions that were measured during the CF Validation Study. Because the variances for Waist Circumference were not homoscedastic, non-parametric tests were used to determine if significant differences were present between the CF Validation Study and the four matched databases (see Table 34). For all four of the matches, 12 of 18 anthropometric dimensions were significantly different (Weight, Hand Breadth, Foot Length, Foot Breadth, Waist Height, Sleeve Length, Chest Circumference, Waist Circumference, Buttock Circumference, Menton-Sellion Length, Bizygomatic Breadth and Head Circumference). In two of the matches, Hand Length was significantly different, while Stature was significantly different in only one.

The observer error rates for ANSUR and the CF Validation Study could, theoretically, cause some of these observed statistical differences. To determine if error rates were responsible, the sum of the ANSUR and CF Validation Study error rates (see Table 35) were either added to or subtracted from the CF Validation Study mean listed in Table 34. In two of the cases (Foot Breadth and Menton-Sellion Length), the means for all four of the matches converge with the CF Validation Study. The remaining 10 variables, however, continue to have different means. To test the significance of these differences, the total amount of observer error for these dimensions was either added to or subtracted from the CF values so that the mean value would be closer to those in the matched databases. Because the *F* statistic for Waist Circumference indicates a heteroscedastic variance, non-parametric tests were used to determine if any true differences are present (see Table 36). Table 37 presents the results of the Mann-Whitney *U* analysis and indicates that a total of eight dimensions (Weight, Hand Breadth, Waist Height, Sleeve Length, Waist Circumference, Buttock Circumference, Bizygomatic Breadth, and Head Circumference) are significantly different between at least two of the four matches and the CF Validation Study data when adjusted for the amount of known observer error.

The four matched databases were also compared to a 1992 CF Express Database subset that was randomly sampled to reflect the age/element distribution of the contemporary CF. Unlike the comparisons to the CF Validation Study data, the matches are not significantly different for Weight, but are different for Stature (see Tables 38 and 39).

Because of the significant difference between the matched databases and the actual validation data, an Age Only Match, that selects subjects from White male ANSUR subjects, may not be feasible for the CF. However, the proportion of operational to support personnel indicates that the sample was ***not*** random, thus a demographic only match cannot be validated, even if the procedure is

highly successful. To determine if these differences were being driven by the presence of non-White subjects in the CF Validation Study data, an Age and Race matching procedure was tested (see Part 2, Age/Race Match).

Table 32. Number of Subjects to be Selected for Matched Database

Age Category	% in CF Validation Study	Number of White Males in ANSUR	Number to Select	% Matched Database
≤ 19	0.6%	222	4	0.6%
20-24	12.1%	658	80	12.0%
25-29	23.5%	365	156	23.5%
30-34	26.2%	220	174	26.2%
≥ 35	37.7%	250	250	37.7%
Totals	100.1%*	1715	664	100.0%

* Different from 100.0% due to rounding

Table 33. Matched *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Age Only Matched Databases

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight						
Match 1			1.04	0.607	-3.64	**0.000***
Match	642	80.25 (11.19)				
Validation	531	82.67 (11.43)				
Match 2			1.04	0.655	-3.76	**0.000***
Match	646	80.17 (11.22)				
Validation	531	82.67 (11.43)				
Match 3			1.04	0.666	-3.33	**0.001***
Match	645	80.46 (11.23)				
Validation	531	82.67 (11.43)				
Match 4			1.05	0.525	-3.51	**0.000***
Match	642	80.34 (11.13)				
Validation	531	82.67 (11.43)				
Span						
Match 1			1.03	0.688	2.54	0.011
Match	639	1816.17 (75.17)				
Validation	529	1805.04 (73.92)				
Match 2			1.02	0.832	2.25	0.025
Match	642	1814.77 (73.28)				
Validation	529	1805.04 (73.92)				
Match 3			1.03	0.715	3.06	0.002
Match	641	1818.25 (72.81)				
Validation	529	1805.04 (73.92)				
Match 4			1.00	0.969	2.61	0.009
Match	637	1816.37 (73.81)				
Validation	529	1805.04 (73.92)				

All values in mm, except Weight in kg

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Length						
Match 1			1.05	0.548	4.06	**0.000***
Match	664	192.78 (8.72)				
Validation	531	190.70 (8.93)				
Match 2			1.05	0.533	2.66	0.008
Match	664	192.06 (8.71)				
Validation	531	190.70 (8.93)				
Match 3			1.08	0.327	3.67	**0.000***
Match	664	192.57 (8.58)				
Validation	531	190.70 (8.93)				
Match 4			1.02	0.780	3.14	0.002
Match	663	192.32 (8.83)				
Validation	531	190.70 (8.93)				
Hand Breadth						
Match 1			1.14	0.112	10.88	**0.000***
Match	664	90.67 (4.09)				
Validation	531	88.17 (3.83)				
Match 2			1.15	0.096	10.04	**0.000***
Match	664	90.48 (4.11)				
Validation	531	88.17 (3.83)				
Match 3			1.17	0.056	10.42	**0.000***
Match	664	90.58 (4.15)				
Validation	531	88.17 (3.83)				
Match 4			1.13	0.129	10.33	**0.000***
Match	663	90.54 (4.08)				
Validation	531	88.17 (3.83)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Foot Length						
Match 1			1.04	0.663	4.54	**0.000***
Match	640	268.41 (12.58)				
Validation	531	265.09 (12.35)				
Match 2			1.03	0.700	3.94	**0.000***
Match	643	267.93 (12.16)				
Validation	531	265.09 (12.35)				
Match 3			1.02	0.785	4.61	**0.000***
Match	641	268.42 (12.22)				
Validation	531	265.09 (12.35)				
Match 4			1.03	0.698	4.11	**0.000***
Match	638	268.05 (12.16)				
Validation	531	265.09 (12.35)				
Foot Breadth						
Match 1			1.08	0.345	-4.18	**0.000***
Match	640	100.50 (5.36)				
Validation	531	101.84 (5.57)				
Match 2			1.06	0.478	-5.53	**0.000***
Match	643	100.06 (5.41)				
Validation	531	101.84 (5.57)				
Match 3			1.09	0.304	-4.64	**0.000***
Match	641	100.35 (5.34)				
Validation	531	101.84 (5.57)				
Match 4			1.10	0.266	-4.76	**0.000***
Match	638	100.32 (5.32)				
Validation	531	101.84 (5.57)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Stature						
Match 1			1.03	0.683	2.98	0.003
Match	642	1763.24 (65.65)				
Validation	531	1751.85 (64.54)				
Match 2			1.01	0.897	2.75	0.006
Match	646	1762.24 (64.20)				
Validation	531	1751.85 (64.54)				
Match 3			1.00	0.959	3.55	**0.000***
Match	645	1765.30 (64.68)				
Validation	531	1751.85 (64.54)				
Match 4			1.03	0.730	3.11	0.002
Match	641	1763.54 (63.63)				
Validation	531	1751.85 (64.54)				
Waist Height						
Match 1			1.06	0.496	4.93	**0.000***
Match	642	1057.05 (48.48)				
Validation	531	1042.81 (49.86)				
Match 2			1.05	0.529	4.71	**0.000***
Match	646	1056.42 (48.58)				
Validation	531	1042.81 (49.86)				
Match 3			1.07	0.436	5.52	**0.000***
Match	645	1058.70 (48.28)				
Validation	531	1042.81 (49.86)				
Match 4			1.09	0.310	5.12	**0.000***
Match	641	1057.52 (47.81)				
Validation	531	1042.81 (49.86)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Crotch Height						
Match 1			1.01	0.891	-0.84	0.404
Match	643	831.98 (42.73)				
Validation	531	834.07 (42.48)				
Match 2			1.01	0.874	-0.92	0.359
Match	646	831.78 (42.77)				
Validation	531	834.07 (42.48)				
Match 3			1.01	0.945	-0.28	0.776
Match	645	833.36 (42.61)				
Validation	531	834.07 (42.48)				
Match 4			1.01	0.909	-0.62	0.533
Match	641	832.51 (42.69)				
Validation	531	834.07 (42.48)				
Sleeve Length						
Match 1			1.01	0.936	7.81	**0.000***
Match	642	599.90 (29.10)				
Validation	531	586.59 (29.00)				
Match 2			1.02	0.782	7.94	**0.000***
Match	646	600.01 (28.68)				
Validation	531	586.59 (29.00)				
Match 3			1.02	0.788	8.55	**0.000***
Match	645	601.05 (28.69)				
Validation	531	586.59 (29.00)				
Match 4			1.02	0.810	8.25	**0.000***
Match	642	600.56 (28.72)				
Validation	531	586.59 (29.00)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Chest Circumference						
Match 1			1.02	0.850	-5.45	**0.000***
Match	642	1010.62 (70.69)				
Validation	531	1033.12 (70.13)				
Match 2			1.05	0.561	-5.40	**0.000***
Match	646	1010.70 (71.85)				
Validation	531	1033.12 (70.13)				
Match 3			1.02	0.833	-5.12	**0.000***
Match	645	1011.99 (70.76)				
Validation	531	1033.12 (70.13)				
Match 4			1.01	0.952	-5.26	**0.000***
Match	642	1011.46 (70.31)				
Validation	531	1033.12 (70.13)				
Waist Circumference						
Match 1			1.22	**0.014+**	-7.69	**0.000***
Match	642	894.59 (87.28)				
Validation	531	936.33 (96.59)				
Match 2			1.23	**0.012+**	-7.46	**0.000***
Match	646	895.93 (87.03)				
Validation	531	936.33 (96.59)				
Match 3			1.22	**0.014+**	-7.25	**0.000***
Match	645	897.06 (87.29)				
Validation	531	936.33 (96.59)				
Match 4			1.26	**0.006+**	-7.61	**0.000***
Match	642	895.27 (86.18)				
Validation	531	936.33 (96.59)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)
\+ Heteroscedastic variance

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Buttock Circumference						
Match 1			1.09	0.274	-6.40	**0.000***
Match	643	992.93 (60.19)				
Validation	531	1016.11 (62.98)				
Match 2			1.06	0.480	-6.31	**0.000***
Match	646	993.15 (61.17)				
Validation	531	1016.11 (62.98)				
Match 3			1.07	0.432	-5.85	**0.000***
Match	645	994.84 (60.97)				
Validation	531	1016.11 (62.98)				
Match 4			1.07	0.395	-6.07	**0.000***
Match	641	994.01 (60.80)				
Validation	531	1016.11 (62.98)				
Sitting Height						
Match 1			1.03	0.741	-0.10	0.919
Match	643	925.16 (32.43)				
Validation	531	925.36 (31.99)				
Match 2			1.05	0.583	-0.37	0.708
Match	645	924.65 (32.73)				
Validation	531	925.36 (31.99)				
Match 3			1.05	0.597	0.26	0.794
Match	645	925.85 (32.70)				
Validation	531	925.36 (31.99)				
Match 4			1.01	0.908	-0.30	0.763
Match	641	924.79 (32.15)				
Validation	531	925.36 (31.99)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Biacromial Breadth						
Match 1			1.02	0.853	-2.64	0.008
Match	643	397.55 (18.73)				
Validation	531	400.44 (18.59)				
Match 2			1.02	0.773	-3.27	**0.001***
Match	645	396.89 (18.37)				
Validation	531	400.44 (18.59)				
Match 3			1.04	0.664	-2.77	0.006
Match	645	397.44 (18.26)				
Validation	531	400.44 (18.59)				
Match 4			1.02	0.806	-3.14	0.002
Match	641	397.03 (18.40)				
Validation	531	400.44 (18.59)				
Menton-Sellion Length						
Match 1			1.05	0.545	-4.34	**0.000***
Match	664	121.80 (6.37)				
Validation	531	123.44 (6.53)				
Match 2			1.05	0.580	-4.87	**0.000***
Match	664	121.61 (6.38)				
Validation	531	123.44 (6.53)				
Match 3			1.06	0.468	-4.95	**0.000***
Match	664	121.58 (6.33)				
Validation	531	123.44 (6.53)				
Match 4			1.09	0.278	-4.69	**0.000***
Match	663	121.69 (6.24)				
Validation	531	123.44 (6.53)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 33. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Bizygomatic Breadth						
Match 1			1.03	0.694	-9.10	**0.000***
Match	664	140.79 (5.54)				
Validation	531	143.75 (5.63)				
Match 2			1.07	0.432	-9.30	**0.000***
Match	664	140.75 (5.45)				
Validation	531	143.75 (5.63)				
Match 3			1.04	0.656	-9.14	**0.000***
Match	664	140.78 (5.53)				
Validation	531	143.75 (5.63)				
Match 4			1.00	0.988	-9.27	**0.000***
Match	663	140.71 (5.62)				
Validation	531	143.75 (5.63)				
Head Circumference						
Match 1			1.04	0.665	-6.96	**.000***
Match	664	569.39 (15.33)				
Validation	531	575.54 (15.06)				
Match 2			1.06	0.499	-7.14	**0.000***
Match	664	569.20 (15.49)				
Validation	531	575.54 (15.06)				
Match 3			1.10	0.247	-7.11	**0.000***
Match	664	569.17 (15.80)				
Validation	531	575.54 (15.06)				
Match 4			1.12	0.172	-7.11	**0.000***
Match	663	569.14 (15.94)				
Validation	531	575.54 (15.06)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .001$)

Table 34. Mann-Whitney *U* Results for Comparison of CF Validation Study and Age Only Matched Databases

Variable/ Match	Mann-Whitney *U*	Wilcoxon *W*	*p*
Stature			
Match 1	153224.0	294470.0	0.0029
Match 2	155271.0	296517.0	0.0051
Match 3	150837.0	292083.0	**0.0004***
Match 4	152312.5	293558.5	0.0019
Weight			
Match 1	148595.5	333552.5	**0.0002***
Match 2	149130.0	335142.0	**0.0001***
Match 3	151017.0	332724.0	**0.0005***
Match 4	149319.0	332829.0	**0.0003***
Span			
Match 1	154000.5	294185.5	0.0089
Match 2	156015.0	296200.0	0.0166
Match 3	151500.0	291685.0	0.0017
Match 4	152783.0	292968.0	0.0061
Hand Length			
Match 1	152116.5	293362.5	**0.0000***
Match 2	159887.0	301133.0	0.0056
Match 3	154660.5	295906.5	**0.0003***
Match 4	157128.5	298374.5	0.0014
Hand Breadth			
Match 1	116237.5	257483.5	**0.0000***
Match 2	120367.5	261613.5	**0.0000***
Match 3	119044.5	260290.5	**0.0000***
Match 4	118400.5	259646.5	**0.0000***
Foot Length			
Match 1	145409.0	286655.0	**0.0000***
Match 2	148839.5	290085.5	**0.0002***
Match 3	144833.5	286079.5	**0.0000***
Match 4	147319.5	288565.5	**0.0001***

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .0006$)

Table 34. (Cont.)

Variable/ Match	Mann-Whitney *U*	Wilcoxon *W*	*p*
Foot Breadth			
Match 1	146180.0	334906.0	**0.0000***
Match 2	138840.0	343839.0	**0.0000***
Match 3	143198.0	338419.0	**0.0000***
Match 4	142553.0	337471.0	**0.0000***
Waist Height			
Match 1	144133.5	285379.5	**0.0000***
Match 2	145871.5	287117.5	**0.0000***
Match 3	141220.5	282466.5	**0.0000***
Match 4	142079.0	283325.0	**0.0000***
Crotch Height			
Match 1	165560.5	317118.5	0.3725
Match 2	165724.0	318548.0	0.3185
Match 3	169379.0	314362.0	0.7472
Match 4	166459.5	315157.5	0.5183
Sleeve Length			
Match 1	128289.5	269535.5	**0.0000***
Match 2	128423.5	269669.5	**0.0000***
Match 3	124699.0	265945.0	**0.0000***
Match 4	125465.0	266711.0	**0.0000***
Chest Circumference			
Match 1	138841.0	343307.0	**0.0000***
Match 2	140285.0	343987.0	**0.0000***
Match 3	141766.5	341974.5	**0.0000***
Match 4	139953.5	342194.5	**0.0000***
Waist Circumference			
Match 1	127926.0	354222.0	**0.0000***
Match 2	130306.0	353966.0	**0.0000***
Match 3	131115.5	352625.5	**0.0000***
Match 4	128626.0	353522.0	**0.0000***

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .0006$)

Table 34. (Cont.)

Variable/ Match	Mann-Whitney *U*	Wilcoxon *W*	*p*
Buttock Circumference			
Match 1	133844.0	348835.0	**0.0000***
Match 2	135155.0	349117.0	**0.0000***
Match 3	137225.5	346515.5	**0.0000***
Match 4	135479.0	346138.0	**0.0000***
Sitting Height			
Match 1	170711.0	311957.0	0.9992
Match 2	169947.0	313794.0	0.8225
Match 3	169058.5	310304.5	0.7057
Match 4	169334.0	312283.0	0.8826
Biacromial Breadth			
Match 1	157991.5	324687.5	0.0277
Match 2	154874.5	328866.5	0.0047
Match 3	157598.0	326143.0	0.0185
Match 4	155136.0	326481.0	0.0091
Menton-Sellion Length			
Match 1	148778.0	345052.0	**0.0000***
Match 2	146292.0	347538.0	**0.0000***
Match 3	145379.0	348451.0	**0.0000***
Match 4	147324.5	345974.5	**0.0000***
Bizygomatic Breadth			
Match 1	124480.0	369350.0	**0.0000***
Match 2	122733.0	371097.0	**0.0000***
Match 3	123994.5	369835.5	**0.0000***
Match 4	122715.0	370584.0	**0.0000***
Head Circumference			
Match 1	136254.0	357576.0	**0.0000***
Match 2	135018.0	358812.0	**0.0000***
Match 3	136728.0	357102.0	**0.0000***
Match 4	134852.0	358447.0	**0.0000***

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/76 = .0006$)

Table 35. CF Validation Study vs. ANSUR Observer Error Rates

Variable	Validation Study Observer Error	ANSUR Observer Error	Combined Observer Error
Biacromial Br	2.22	3.62	5.84
Bizygomatic Br	0.71	0.58	1.29
Buttock Circ	2.68	4.15	6.83
Chest Circ	5.83	6.88	12.71
Crotch Height	2.68	6.02	8.70
Hand Br	0.37	0.32	0.69
Hand Length	0.83	1.17	2.00
Head Circ	1.02	0.82	1.84
Foot Br	0.85	0.56	1.41
Foot Length	0.61	0.53	1.14
Menton-Sellion	1.05	1.05	2.10
Sitting Height	3.85	3.14	6.99
Sleeve Length	2.24	3.91	6.15
Span	4.44	7.24	11.68
Stature	1.37	2.94	4.31
Waist Circ	3.63	4.33	7.96
Waist Height	1.85	2.74	4.59
Weight	0.10	0.12	0.22

All values in mm, except Weight in kg

Table 36. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Age Only Matched Databases Adjusted for Observer Error

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight						
Match 1			1.04	0.607	-3.31	**0.000***
Match	642	80.25 (11.19)				
Validation	531	82.45 (11.43)				
Match 2			1.04	0.655	-3.43	**0.001***
Match	646	80.17 (11.22)				
Validation	531	82.45 (11.43)				
Match 3			1.04	0.666	-3.00	0.003
Match	645	80.46 (11.23)				
Validation	531	82.45 (11.43)				
Match 4			1.05	0.525	-3.17	0.002
Match	642	80.34 (11.13)				
Validation	531	82.45 (11.43)				
Hand Breadth						
Match 1			1.14	0.112	7.88	**0.000***
Match	664	90.67 (4.09)				
Validation	531	88.86 (3.83)				
Match 2			1.15	0.096	7.04	**0.000***
Match	664	90.48 (4.11)				
Validation	531	88.86 (3.83)				
Match 3			1.17	0.056	7.43	**0.000***
Match	664	90.58 (4.15)				
Validation	531	88.86 (3.83)				
Match 4			1.13	0.129	7.32	**0.000***
Match	663	90.54 (4.08)				
Validation	531	88.86 (3.83)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/76 = .001$)

Table 36. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Foot Length						
Match 1			1.04	0.663	2.98	0.003
Match	640	268.41 (12.58)				
Validation	531	266.23 (12.35)				
Match 2			1.03	0.700	2.35	0.019
Match	643	267.93 (12.16)				
Validation	531	266.23 (12.35)				
Match 3			1.02	0.785	3.03	0.003
Match	641	268.42 (12.22)				
Validation	531	266.23 (12.35)				
Match 4			1.03	0.698	2.52	0.012
Match	638	268.05 (12.16)				
Validation	531	266.23 (12.35)				
Waist Height						
Match 1			1.06	0.496	3.34	**0.001***
Match	642	1057.05 (48.48)				
Validation	531	1047.40 (49.86)				
Match 2			1.05	0.529	3.12	0.002
Match	646	1056.42 (48.58)				
Validation	531	1047.40 (49.86)				
Match 3			1.07	0.436	3.92	**0.000***
Match	645	1058.70 (48.28)				
Validation	531	1047.40 (49.86)				
Match 4			1.09	0.310	3.52	**0.000***
Match	641	1057.52 (47.81)				
Validation	531	1047.40 (49.86)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/76 = .001$)

Table 36. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Sleeve Length						
Match 1			1.01	0.936	4.20	**0.000***
Match	642	599.90 (29.10)				
Validation	531	592.74 (29.00)				
Match 2			1.02	0.782	4.30	**0.000***
Match	646	600.01 (28.68)				
Validation	531	592.74 (29.00)				
Match 3			1.02	0.788	4.91	**0.000***
Match	645	601.05 (28.69)				
Validation	531	592.74 (29.00)				
Match 4			1.02	0.810	4.62	**0.000***
Match	642	600.56 (28.72)				
Validation	531	592.74 (29.00)				
Chest Circumference						
Match 1			1.02	0.850	-2.37	0.018
Match	642	1010.62 (70.69)				
Validation	531	1020.41 (70.13)				
Match 2			1.05	0.561	-2.34	0.020
Match	646	1010.70 (71.85)				
Validation	531	1020.41 (70.13)				
Match 3			1.02	0.833	-2.04	0.042
Match	645	1011.99 (70.76)				
Validation	531	1020.41 (70.13)				
Match 4			1.01	0.952	-2.17	0.030
Match	642	1011.46 (70.31)				
Validation	531	1020.41 (70.13)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/76 = .001$)

Table 36. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Waist Circumference						
Match 1			1.22	**0.014+**	-6.23	**0.000***
Match	642	894.59 (87.28)				
Validation	531	928.37 (96.59)				
Match 2			1.23	**0.012+**	-5.99	**0.000***
Match	646	895.93 (87.03)				
Validation	531	928.37 (96.59)				
Match 3			1.22	**0.014+**	-5.78	**0.000***
Match	645	897.06 (87.29)				
Validation	531	928.37 (96.59)				
Match 4			1.26	**0.006+**	-6.13	**0.000***
Match	642	895.27 (86.18)				
Validation	531	928.37 (96.59)				
Buttock Circumference						
Match 1			1.09	0.274	-4.52	**0.000***
Match	643	992.93 (60.19)				
Validation	531	1009.28 (62.98)				
Match 2			1.06	0.480	-4.43	**0.000***
Match	646	993.15 (61.17)				
Validation	531	1009.28 (62.98)				
Match 3			1.07	0.432	-3.97	**0.000***
Match	645	994.84 (60.97)				
Validation	531	1009.28 (62.98)				
Match 4			1.07	0.395	-4.20	**0.000***
Match	641	994.01 (60.80)				
Validation	531	1009.28 (62.98)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/76 = .001$)
\+ Heteroscedastic variance

Table 36. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Bizygomatic Breadth						
Match 1			1.03	0.694	-5.13	**0.000***
Match	664	140.79 (5.54)				
Validation	531	142.46 (5.63)				
Match 2			1.07	0.432	-5.30	**0.000***
Match	664	140.75 (5.45)				
Validation	531	142.46 (5.63)				
Match 3			1.04	0.656	-5.17	**0.000***
Match	664	140.78 (5.53)				
Validation	531	142.46 (5.63)				
Match 4			1.00	0.988	-5.34	**0.000***
Match	663	140.71 (5.62)				
Validation	531	142.46 (5.63)				
Head Circumference						
Match 1			1.04	0.665	-4.88	**0.000***
Match	664	569.39 (15.33)				
Validation	531	573.70 (15.06)				
Match 2			1.06	0.499	-5.07	**0.000***
Match	664	569.20 (15.49)				
Validation	531	573.70 (15.06)				
Match 3			1.10	0.247	-5.06	**0.000***
Match	664	569.17 (15.80)				
Validation	531	573.70 (15.06)				
Match 4			1.12	0.172	-5.07	**0.000***
Match	663	569.14 (15.94)				
Validation	531	573.70 (15.06)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/76 = .001$)

Table 37. Mann-Whitney *U* Results for Comparison of CF Validation Study and Age Only Matched Databases Adjusted for Observer Error

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight			
Match 1	150741.0	331407.0	**0.0006***
Match 2	151251.0	333021.0	**0.0005***
Match 3	153169.0	330572.0	0.0018
Match 4	151491.0	330657.0	**0.0010***
Hand Breadth			
Match 1	127528.0	268774.0	**0.0000***
Match 2	131805.0	273051.0	**0.0000***
Match 3	130437.0	271683.0	**0.0000***
Match 4	129854.0	271100.0	**0.0000***
Foot Length			
Match 1	156797.0	298043.0	0.0227
Match 2	160409.0	301655.0	0.0746
Match 3	156243.0	297489.0	0.0156
Match 4	158835.0	300081.0	0.0663
Waist Height			
Match 1	152819.0	294065.0	0.0023
Match 2	154611.0	295857.0	0.0036
Match 3	149862.0	291108.0	**0.0002***
Match 4	150674.0	291920.0	**0.0007***
Sleeve Length			
Match 1	149140.0	290386.0	**0.0002***
Match 2	149599.0	290845.0	**0.0002***
Match 3	145675.0	286921.0	**0.0000***
Match 4	146465.0	287711.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/40 = .0013$)

Table 37. (Cont.)

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Chest Circumference			
Match 1	155641.0	326507.0	0.0103
Match 2	156902.0	327370.0	0.0118
Match 3	158662.0	325079.0	0.0299
Match 4	156856.0	325292.0	0.0186
Waist Circumference			
Match 1	135338.0	346810.0	**0.0000***
Match 2	137731.0	346541.0	**0.0000***
Match 3	138589.0	345152.0	**0.0000***
Match 4	136057.0	346091.0	**0.0000***
Buttock Circumference			
Match 1	143671.0	339008.0	**0.0000***
Match 2	144998.0	339274.0	**0.0000***
Match 3	147186.0	336555.0	**0.0000***
Match 4	145339.0	336278.0	**0.0000***
Bizygomatic Breadth			
Match 1	149515.0	344315.0	**0.0000***
Match 2	147842.0	345988.0	**0.0000***
Match 3	149307.0	344523.0	**0.0000***
Match 4	147569.0	345730.0	**0.0000***
Head Circumference			
Match 1	146074.0	347756.0	**0.0000***
Match 2	144721.0	349109.0	**0.0000***
Match 3	146264.0	347566.0	**0.0000***
Match 4	144439.0	348860.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/40 = .0013$)

Table 38. *F* Test and Student's *t*-Test Results for Comparison of 1992 CF Express Database Subset and Age Only Matched Databases

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Stature						
Match 1			3.74	**0.000**+	11.00	**0.000***
Match	642	17.66 (0.73)				
Express	1903	17.18 (1.40)				
Match 2			3.89	**0.000**+	10.65	**0.000***
Match	646	17.64 (0.71)				
Express	1903	17.18 (1.40)				
Match 3			3.85	**0.000**+	11.15	**0.000***
Match	645	17.66 (0.71)				
Express	1903	17.18 (1.40)				
Match 4			3.97	**0.000**+	10.94	**0.000***
Match	641	17.65 (0.70)				
Express	1903	17.18 (1.40)				
Weight						
Match 1			1.06	0.396	0.70	0.482
Match	642	80.31 (11.20)				
Express	1903	79.95 (10.90)				
Match 2			1.06	0.360	0.54	0.588
Match	646	80.22 (11.22)				
Express	1903	79.95 (10.90)				
Match 3			1.06	0.344	1.09	0.277
Match	645	80.50 (11.23)				
Express	1903	79.95 (10.90)				
Match 4			1.04	.496	0.89	0.373
Match	642	80.40 (11.14)				
Express	1903	79.95 (10.90)				

Stature in dm and Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/8 = .0062$)

\+ Heteroscedastic variance

Table 39. Mann-Whitney *U* Results for Comparison of 1992 CF Express Database Subset and Age Only Matched Databases

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Stature			
Match 1	427755.5	1000373.5	**0.0000***
Match 2	437345.0	1000974.0	**0.0000***
Match 3	428700.5	1007069.5	**0.0000***
Match 4	429387.0	996197.0	**0.0000***
Weight			
Match 1	609945.0	816348.0	0.9545
Match 2	612769.0	821750.0	0.9064
Match 3	607268.0	828502.0	0.6895
Match 4	608132.0	819997.0	0.8652

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/8 = .0062$)

2. Age/Race Match

The Age Only Match, which selected White, male subjects to emulate the age structure of the CF Validation Study, was not successful (see Part 1, Age Only Match). Although 96% of the CF subjects were White, the possibility remains that the significant differences between the matched databases and the CF Validation Study were a result of not including non-White subjects. To test this possibility, one matched database was created that had the identical Age and Race distribution of the CF Validation Study (see Table 40). A single match should be sufficient to indicate if the same pattern of differences exist for Age Only Match and the Age/Race Match for the CF.

Table 41 presents the results of student's *t*-tests and the *F* statistics for the 18 variables that were collected in the CF Validation Study. Because not all of the variances are homoscedastic, Mann-Whitney *U* tests were used to determine if any significant differences are present between the match and the CF Validation Study. As shown in Table 42, 14 of the 18 variables are significantly different. These differences include all those variables identified for the Age Only Match (Weight, Hand Length, Hand Breadth, Foot Length, Foot Breadth, Waist Height, Sleeve Length, Chest Circumference, Waist Circumference, Buttock Circumference, Biacromial Breadth, Menton-Sellion Length, Bizygomatic Breadth, and Head Circumference). When observer error rates were controlled (see Tables 43 and 44), a total of 8 variables remain significantly different (Weight, Hand Breadth, Waist Height, Sleeve Length, Waist Circumference, Buttock Circumference, Bizygomatic Breadth, and Head Circumference). These dimensions are identical to those that could not be controlled in the Age Only Match described previously. Thus, the inclusion of non-White races for the matching procedure does not improve the match, and using demographic variables alone does not properly control anthropometric variation in this situation. Recall that the CF Validation Study data do not accurately portray the appropriate operational to support personnel ratio for the Land and Sea elements. Thus, it is not a random sample and cannot be used to validate a demographic only matching procedure. Still, it remains quite possible that a demographic only matching strategy would be the most accurate. To further explore the possibilities, a variety of matching procedures that involve anthropometric variables (Height and Weight) were tested as well (see Parts 3 to 6).

Table 40. Race and Age Distribution of CF Validation Study and Age/Race Match

Age/ Race	< 19	20-24	25-29	30-34	>35
White					
CF Study	3(0.6%)	63(11.8%)	122(22.8%)	131(24.5%)	196(36.6%)
Match	4(0.6%)	81(11.9%)	156(22.8%)	167(24.5%)	250(36.6%)
Black					
CF Study	0(0.0%)	0(0.0%)	0(0.0%)	2(0.4%)	1(0.2%)
Match	0(0.0%)	0(0.0%)	0(0.0%)	3(0.4%)	1(0.1%)
Hispanic					
CF Study	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(0.2%)
Match	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(0.1%)
Aboriginal					
CF Study	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(0.2%)
Match	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(0.1%)
Asian/Pacific					
CF Study	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	2(0.4%)
Match	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	3(0.4%)
Mixed/Other					
CF Study	0(0.0%)	1(0.2%)	3(0.6%)	5(0.9%)	4(0.7%)
Match	0(0.0%)	1(0.1%)	4(0.6%)	6(0.9%)	5(0.7%)
Totals					
CF Study	3(0.6%)	64(12.0%)	125(23.4%)	140(26.2%)	203(37.9%)
Match	4(0.6%)	82(12.0%)	160(23.4%)	179(26.2%)	258(37.8%)

Table 41. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Age/Race Match

Variable/ Match Group	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight			1.03	0.731	-3.93	**0.000***
Match	664	80.12 (11.50)				
Validation	532	82.77 (11.67)				
Stature			1.03	0.712	2.70	0.007
Match	664	1762.38 (65.79)				
Validation	532	1752.18 (64.79)				
Span			1.06	0.453	2.18	0.030
Match	660	1814.83 (76.41)				
Validation	530	1805.28 (74.07)				
Hand Length			1.01	0.945	3.38	**0.001***
Match	683	192.47 (8.92)				
Validation	532	190.72 (8.94)				
Hand Breadth			1.15	0.081	10.48	**0.000***
Match	683	90.58 (4.12)				
Validation	532	88.18 (3.84)				
Foot Length			1.06	0.509	4.39	**0.000***
Match	662	268.32 (12.71)				
Validation	532	265.12 (12.36)				
Foot Breadth			1.09	0.293	-4.83	**0.000***
Match	662	100.32 (5.35)				
Validation	532	101.86 (5.58)				
Waist Height			1.03	0.713	4.93	**0.000***
Match	664	1057.16 (49.15)				
Validation	532	1042.94 (49.90)				
Crotch Height			1.06	0.465	-0.84	0.400
Match	664	832.03 (43.78)				
Validation	532	834.14 (42.47)				

All values in mm, except Weight in kg

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/18 = .0027$)

Table 41. (Cont.)

Variable/ Match Group	N	Mean (SD)	*F*	*p*	*t*	*p*
Sleeve Length			1.05	0.545	7.89	**0.000***
Match	664	600.16 (29.77)				
Validation	532	586.67 (29.04)				
Chest Circumference			1.03	0.753	-5.59	**0.000***
Match	664	1010.41 (71.81)				
Validation	532	1033.52 (70.88)				
Waist Circumference			1.25	**0.007+**	-8.03	**0.000***
Match	664	893.46 (87.06)				
Validation	532	936.82 (97.16)				
Buttock Circumference			1.07	0.439	-6.54	**0.000***
Match	664	992.54 (62.32)				
Validation	532	1016.69 (64.33)				
Sitting Height			1.06	0.507	-0.39	0.700
Match	663	924.78 (33.05)				
Validation	532	925.51 (32.15)				
Biacromial Breadth			1.02	0.821	-3.77	**0.000***
Match	663	396.40 (18.82)				
Validation	532	400.50 (18.64)				
Menton-Sellion Length			1.14	0.119	-4.98	**0.000***
Match	683	121.62 (6.13)				
Validation	532	123.45 (6.53)				
Bizygomatic Breadth			1.03	0.736	-9.32	**0.000***
Match	683	140.76 (5.55)				
Validation	532	143.76 (5.63)				
Head Circumference			1.07	0.411	-7.74	**0.000***
Match	683	568.71 (15.56)				
Validation	532	575.55 (15.05)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/18 = .0027$)
+ Heteroscedastic variance

Table 42. Mann-Whitney *U* Results for Comparison of CF Validation Study and Age/Race Match

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight	152273.5	342752.5	**0.0000***
Stature	161076.5	302854.5	0.0088
Span	162665.0	303380.0	0.0378
Hand Length	161797.0	303575.0	**0.0010***
Hand Breadth	122071.5	263849.5	**0.0000***
Foot Length	151477.0	293255.0	**0.0000***
Foot Breadth	147690.0	346272.0	**0.0000***
Waist Height	150318.5	292096.5	**0.0000***
Crotch Height	169939.0	325087.0	0.2601
Sleeve Length	133979.5	275757.5	**0.0000***
Chest Circumference	143397.5	351628.5	**0.0000***
Waist Circumference	131215.5	363810.5	**0.0000***
Buttock Circumference	138453.5	356572.5	**0.0000***
Sitting Height	174927.5	319566.5	0.8093
Biacromial Breadth	156732.0	337762.0	**0.0009***
Menton-Sellion Length	150379.0	354755.0	**0.0000***
Bizygomatic Breadth	128356.0	376778.0	**0.0000***
Head Circumference	136999.0	368135.0	**0.0000***

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/18 = .0027$)

Table 43. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Age/Race Match Adjusted for Observer Error

Variable/ Group	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight			1.03	0.731	-3.60	**0.000***
Match	664	80.12 (11.50)				
Validation	532	82.55 (11.67)				
Hand Length			1.01	0.945	-0.49	0.624
Match	683	192.47 (8.92)				
Validation	532	192.72 (8.94)				
Hand Breadth			1.15	0.081	7.47	**0.000***
Match	683	90.58 (4.12)				
Validation	532	88.87 (3.84)				
Foot Length			1.06	0.509	2.82	0.005
Match	662	268.32 (12.71)				
Validation	532	266.26 (12.36)				
Foot Breadth			1.09	0.293	-0.40	0.686
Match	662	100.32 (5.35)				
Validation	532	100.45 (5.58)				
Waist Height			1.03	0.713	3.34	**0.001***
Match	664	1057.16 (49.15)				
Validation	532	1047.53 (49.90)				
Sleeve Length			1.05	0.545	4.29	**0.000***
Match	664	600.16 (29.77)				
Validation	532	592.82 (29.04)				
Chest Circumference			1.03	0.753	-2.52	0.012
Match	664	1010.41 (71.81)				
Validation	532	1020.87 (70.88)				

All values in mm, except Weight in kg

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/14 = .0036$)

\+ Heteroscedastic variance

Table 43. (Cont.)

Variable/ Group	N	Mean (SD)	*F*	*p*	*t*	*p*
Waist Circumference			1.25	**0.007+**	-6.56	**0.000***
Match	664	893.46 (87.06)				
Validation	532	928.86 (97.16)				
Buttock Circumference			1.07	0.439	-4.69	**0.000***
Match	664	992.54 (62.32)				
Validation	532	1009.86 (64.33)				
Biacromial Breadth			1.02	0.821	-2.58	0.010
Match	663	396.40 (18.82)				
Validation	532	399.21 (18.64)				
Menton-Sellion Length			1.14	0.119	0.73	0.466
Match	683	121.62 (6.13)				
Validation	532	121.35 (6.53)				
Bizygomatic Breadth			1.03	0.736	-5.30	**0.000***
Match	683	140.76 (5.55)				
Validation	532	142.47 (5.63)				
Head Circumference.			1.07	0.411	-5.66	**0.000***
Match	683	568.71 (15.56)				
Validation	532	573.71 (15.05)				

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/14 = .0036$)
\+ Heteroscedastic variance

Table 44. Mann-Whitney *U* Results for Comparison of CF Validation Study and Race/Age Range Matches Adjusted for Observer Error

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight	154456.0	320570.0	**0.0002***
Hand Length	178414.5	326719.5	0.5905
Hand Breadth	133860.0	275638.0	**0.0000***
Foot Length	163113.0	304891.0	0.0284
Foot Breadth	174578.0	319384.0	0.7981
Waist Height	159168.0	300946.0	**0.0033***
Sleeve Length	155377.0	297155.0	**0.0003***
Chest Circ	160606.0	334420.0	0.0070
Waist Circ	138934.0	356092.0	**0.0000***
Buttock Circ	148527.0	346499.0	**0.0000***
Biacromial Breadth	164674.0	329820.0	0.0488
Menton-Sellion Length	173077.0	314855.0	0.1562
Bizygomatic Breadth	153937.0	351197.0	**0.0000***
Head Circ	146752.0	358382.0	**0.0000***

* Significantly different at the $p \leq 0.05$ level using a Bonferroni correction ($p = .05/14 = .0036$)

3. Height/Weight Range Match

Because matching procedures based on demographic variables alone could not be validated (see Parts 1 and 2 of this section), four matched databases were created using Height and Weight ranges. As with the demographic only match, White, male subjects were selected from the ANSUR pool of subjects, using Height and Weight, to replicate the Height/Weight distribution of the CF Validation Study. The three matching ranges for Height and Weight were defined as the 1st to 33rd percentile, the 34th to 66th percentile, and the 67th to 100th percentile. The resulting matrix of Height vs. Weight was used to determine the number of subjects to be randomly selected in each of the nine cells, resulting in a CF Validation Study Height/Weight distribution (see Tables 45 and 46).

Table 47 presents a summary of those variables that are significantly different between the matched databases and the CF Validation Study. Because not all of the variances are homoscedastic, Mann-Whitney *U* tests were used to determine which dimensions were significantly different (see Table 48). As shown in Table 49, a total of 9 anthropometric dimensions are significantly different between the matched databases and the CF Validation Study. Tables 50 and 51 indicate that when observer error rates were controlled, only 4 of the 18 variables are significantly different (Hand Breadth, Waist Circumference, Bizygomatic Breath, and Head Circumference). Although these differences persist, the magnitude of the difference for all of the variables, except Waist Circumference, is very small and below the tolerance levels used for the manufacture of protective clothing and equipment. The large difference in the Waist Circumference values remains problematic, however, and could be the result of using Height and Weight ranges for matching instead of matching individual subjects for Height and Weight. This approach is examined in Part 4 of this section that discusses the use of an Individual Subject matching procedure. It is also possible that the large proportion of less physically fit support personnel in the measured sample is increasing the parameter estimate for Waist Circumference.

Table 45. Height and Weight Distribution of CF Validation Study for Matching

Weight/ Height	< 77.4	77.5-85.7	> 85.8	Totals
≤1726	92 (17.3%)	58 (10.9%)	25 (4.7%)	175 (32.9%)
1727-1777	52 (9.8%)	73 (13.7%)	54 (10.2%)	179 (33.6%)
≥ 1778	31 (5.8%)	50 (9.4%)	97 (18.2%)	178 (33.5%)
Totals	175 (32.9%)	181 (34.0%)	176 (33.1%)	532 (100.0%)

Height in mm and Weight in kg

Table 46. Height and Weight Distribution of White Male ANSUR Subjects Selected for Matching

Weight/ Height	< 77.4	77.5-85.7	> 85.8	Totals
≤1726	77 (17.2%)	49 (11.0%)	21 (4.7%)	147 (32.9%)
1727-1777	44 (9.8%)	61 (13.6%)	46 (10.3%)	151 (33.8%)
≥ 1778	26 (5.8%)	42 (9.4%)	81 (18.1%)	149 (33.3%)
Totals	147 (32.9%)	152 (34.0%)	148 (33.1%)	447 (100.0%)

Height in mm and Weight in kg

Table 47. Summary of Significantly Different Dimensions Between Height/Weight Range Matches and CF Validation Study Before and After Adjustment for Observer Error

Variable	Match 1		Match 2		Match 3		Match 4	
	Before	After	Before	After	Before	After	Before	After
Hand Breadth	•	•	•	•	•	•	•	•
Foot Length	•				•			
Foot Breadth	•							
Sleeve Length	•		•		•		•	
Chest Circ			•					
Waist Circ	•	•	•	•	•	•	•	•
Menton-Sellion	•		•		•		•	
Bizygomatic Br	•	•	•	•	•	•	•	
Head Circ	•	•	•	•	•	•	•	•

Table 48. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Height/Weight Range Matches

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight						
Match 1			1.21	**0.039+**	1.44	0.149
Match	447	81.74 (10.62)				
Validation	532	82.77 (11.67)				
Match 2			1.25	**0.016+**	1.59	0.112
Match	447	81.64 (10.45)				
Validation	532	82.77 (11.67)				
Match 3			1.11	0.269	1.41	0.160
Match	447	81.75 (11.09)				
Validation	532	82.77 (11.67)				
Match 4			1.11	0.234	1.70	0.089
Match	447	81.53 (11.05)				
Validation	532	82.77 (11.67)				
Span						
Match 1			10.69	**0.000+**	1.14	0.253
Match	447	1791.7 (242.2)				
Validation	530	1805.3 (74.1)				
Match 2			7.37	**0.000+**	0.58	0.559
Match	447	1799.4 (201.1)				
Validation	530	1805.3 (74.1)				
Match 3			7.43	**0.000+**	0.46	0.645
Match	447	1800.6 (201.9)				
Validation	530	1805.3 (74.1)				
Match 4			7.45	**0.000+**	0.91	0.363
Match	447	1796.1 (202.1)				
Validation	530	1805.3 (74.1)				

All values in mm, except Weight in kg

+ Heteroscedastic variance

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Length						
Match 1			1.04	0.636	-2.27	0.023
Match	447	192.0 (8.7)				
Validation	532	190.7 (8.9)				
Match 2			1.02	0.818	-1.71	0.087
Match	447	191.7 (8.8)				
Validation	532	190.7 (8.9)				
Match 3			1.14	0.151	-2.22	0.027
Match	447	192.0 (8.4)				
Validation	532	190.7 (8.9)				
Match 4			1.04	0.694	-2.08	0.038
Match	447	191.9 (8.8)				
Validation	532	190.7 (8.9)				
Hand Breadth						
Match 1			1.04	0.681	-9.51	**0.000***
Match	447	90.5 (3.9)				
Validation	532	88.2 (3.8)				
Match 2			1.14	0.160	-9.59	**0.000***
Match	447	90.6 (4.1)				
Validation	532	88.2 (3.8)				
Match 3			1.13	0.176	-10.89	**.000***
Match	447	91.0 (4.1)				
Validation	532	88.2 (3.8)				
Match 4			1.27	**0.008+**	-9.45	**0.000***
Match	447	90.7 (4.3)				
Validation	532	88.2 (3.8)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)
\+ Heteroscedastic variance

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Foot Length						
Match 1			1.01	0.952	-4.10	**0.000***
Match	445	268.4 (12.3)				
Validation	532	265.1 (12.4)				
Match 2			1.01	0.877	-3.62	**0.000***
Match	445	268.0 (12.3)				
Validation	532	265.1 (12.4)				
Match 3			1.00	0.974	-4.20	**0.000***
Match	446	268.5 (12.4)				
Validation	532	265.1 (12.4)				
Match 4			1.05	0.586	-3.47	**0.001***
Match	445	267.9 (12.7)				
Validation	532	265.1 (12.4)				
Foot Breadth						
Match 1			1.22	**0.027+**	3.67	**0.000***
Match	445	100.6 (5.0)				
Validation	532	101.9 (5.6)				
Match 2			1.21	**0.039+**	3.33	**0.001***
Match	445	100.7 (5.1)				
Validation	532	101.9 (5.6)				
Match 3			1.11	0.234	2.86	0.004
Match	446	100.9 (5.3)				
Validation	532	101.9 (5.6)				
Match 4			1.15	0.117	2.90	0.004
Match	445	100.9 (5.2)				
Validation	532	101.9 (5.6)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)
\+ Heteroscedastic variance

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Stature						
Match 1			1.01	0.893	-1.57	0.117
Match	447	1758.7 (65.2)				
Validation	532	1752.1 (64.8)				
Match 2			1.07	0.458	-1.51	0.132
Match	447	1758.3 (62.6)				
Validation	532	1752.1 (64.8)				
Match 3			1.06	0.510	-1.31	0.191
Match	447	1757.5 (62.9)				
Validation	532	1752.1 (64.8)				
Match 4			1.00	0.964	-1.26	0.208
Match	447	1757.4 (64.8)				
Validation	532	1752.1 (64.8)				
Waist Height						
Match 1			1.03	0.724	-3.66	**0.000***
Match	447	1054.6 (49.1)				
Validation	532	1042.9 (50.0)				
Match 2			1.12	0.197	-3.81	**0.000***
Match	447	1054.8 (47.0)				
Validation	532	1042.9 (50.0)				
Match 3			1.12	0.214	-3.59	**0.000***
Match	447	1054.1 (47.1)				
Validation	532	1042.9 (50.0)				
Match 4			1.08	0.385	-3.79	**0.000***
Match	447	1054.8 (48.0)				
Validation	532	1042.9 (50.0)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Crotch Height						
Match 1			1.08	0.418	1.54	0.125
Match	447	829.9 (44.1)				
Validation	532	834.1 (42.5)				
Match 2			1.01	0.909	1.88	0.060
Match	447	829.0 (42.7)				
Validation	532	834.1 (42.5)				
Match 3			1.02	0.796	1.68	0.092
Match	447	829.6 (42.0)				
Validation	532	834.1 (42.5)				
Match 4			1.02	0.803	1.77	0.078
Match	447	829.3 (43.0)				
Validation	532	834.1 (42.5)				
Sleeve Length						
Match 1			1.07	0.425	-5.98	**0.000***
Match	447	598.0 (30.1)				
Validation	532	586.7 (29.0)				
Match 2			1.08	0.395	-6.44	**0.000***
Match	447	598.4 (28.0)				
Validation	532	586.7 (29.0)				
Match 3			1.01	0.875	-6.52	**0.000***
Match	447	598.8 (28.8)				
Validation	532	586.7 (29.0)				
Match 4			1.02	0.859	-6.04	**0.000***
Match	447	597.9 (29.0)				
Validation	532	586.7 (29.0)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Chest Circumference						
Match 1			1.13	0.175	3.24	**0.001***
Match	447	1019.3 (70.9)				
Validation	532	1019.3 (66.6)				
Match 2			1.07	0.432	3.86	**0.000***
Match	447	1016.3 (68.4)				
Validation	532	1019.3 (66.6)				
Match 3			1.01	0.955	3.43	**0.001***
Match	447	1018.0 (70.7)				
Validation	532	1019.3 (66.6)				
Match 4			1.03	0.705	3.31	**0.001***
Match	447	1018.4 (72.1)				
Validation	532	1019.3 (66.6)				
Waist Circumference						
Match 1			1.26	**0.012+**	6.51	**0.000***
Match	447	898.6 (86.6)				
Validation	532	936.8 (97.2)				
Match 2			1.27	**0.009+**	6.35	**0.000***
Match	447	899.6 (86.2)				
Validation	532	936.8 (97.2)				
Match 3			1.17	0.080	5.92	**0.000***
Match	447	901.4 (89.7)				
Validation	532	936.8 (97.2)				
Match 4			1.20	**0.046+**	6.62	**0.000***
Match	447	897.5 (88.7)				
Validation	532	936.8 (97.2)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)
+ Heteroscedastic variance

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Buttock Circumference						
Match 1			1.18	0.074	3.25	**0.001***
Match	447	1003.8 (59.3)				
Validation	532	1016.7 (64.3)				
Match 2			1.20	0.050	3.07	0.002
Match	447	1004.6 (58.8)				
Validation	532	1016.7 (64.3)				
Match 3			1.10	0.318	3.08	0.002
Match	447	1004.3 (61.5)				
Validation	532	1016.7 (64.3)				
Match 4			1.06	0.521	3.16	0.002
Match	447	1003.8 (62.5)				
Validation	532	1016.7 (64.3)				
Sitting Height						
Match 1			1.01	0.935	1.15	0.251
Match	447	923.1 (32.0)				
Validation	532	925.5 (32.2)				
Match 2			1.11	0.270	1.67	0.096
Match	447	922.2 (30.6)				
Validation	532	925.5 (32.2)				
Match 3			1.00	1.000	1.56	0.119
Match	447	922.3 (32.2)				
Validation	532	925.5 (32.2)				
Match 4			1.00	0.976	1.67	0.094
Match	447	922.1 (32.2)				
Validation	532	925.5 (32.2)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Biacromial Breadth						
Match 1			1.02	0.837	2.43	0.015
Match	447	397.6 (18.5)				
Validation	532	400.5 (18.6)				
Match 2			1.20	**0.041**+	2.40	0.016
Match	447	397.8 (17.0)				
Validation	532	400.5 (18.6)				
Match 3			1.17	0.085	2.63	0.009
Match	447	397.5 (17.2)				
Validation	532	400.5 (18.6)				
Match 4			1.12	0.224	2.52	0.012
Match	447	397.6 (17.6)				
Validation	532	400.5 (18.6)				
Menton-Sellion Length						
Match 1			1.05	0.612	4.19	**0.000***
Match	447	121.7 (6.4)				
Validation	532	123.5 (6.5)				
Match 2			1.06	0.513	3.97	**0.000***
Match	447	121.8 (6.3)				
Validation	532	123.5 (6.5)				
Match 3			1.00	0.996	4.84	**0.000***
Match	447	121.4 (6.5)				
Validation	532	123.5 (6.5)				
Match 4			1.04	0.693	4.20	**0.000***
Match	447	121.7 (6.6)				
Validation	532	123.5 (6.5)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)
\+ Heteroscedastic variance

Table 48. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Bizygomatic Breadth						
Match 1			1.04	0.628	9.27	**0.000***
Match	447	140.4 (5.8)				
Validation	532	143.8 (5.6)				
Match 2			1.07	0.447	9.31	**0.000***
Match	447	140.5 (5.4)				
Validation	532	143.8 (5.6)				
Match 3			1.01	0.951	8.40	**0.000***
Match	447	140.7 (5.6)				
Validation	532	143.8 (5.6)				
Match 4			1.04	0.655	9.26	**0.000***
Match	447	140.4 (5.7)				
Validation	532	143.8 (5.6)				
Head Circumference						
Match 1			1.07	0.483	5.68	**0.000***
Match	447	569.5 (15.5)				
Validation	532	575.5 (15.0)				
Match 2			1.06	0.543	6.51	**0.000***
Match	447	569.4 (14.6)				
Validation	532	575.5 (15.0)				
Match 3			1.08	0.380	5.64	**0.000***
Match	447	570.0 (15.7)				
Validation	532	575.5 (15.0)				
Match 4			1.00	0.975	6.36	**0.000***
Match	447	569.4 (15.0)				
Validation	532	575.5 (15.0)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 49. Mann-Whitney *U* Results for Comparison of CF Validation Study and Height/Weight Range Matches

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight			
Match 1	114289.5	214417.5	0.2953
Match 2	114251.5	214379.5	0.2913
Match 3	114854.0	214982.0	0.3583
Match 4	113717.5	213845.5	0.2394
Span			
Match 1	114396.5	222641.5	0.3557
Match 2	112778.5	224259.5	0.1964
Match 3	112969.0	224069.0	0.2118
Match 4	116185.5	220852.5	0.6055
Hand Length			
Match 1	108794.5	229137.5	0.0217
Match 2	111690.5	226241.5	0.1015
Match 3	110251.0	227681.0	0.0495
Match 4	110500.5	227431.5	0.0564
Hand Breadth			
Match 1	78639.0	259293.0	**0.0000***
Match 2	79059.5	258872.5	**0.0000***
Match 3	74880.5	263051.5	**0.0000***
Match 4	80063.5	257868.5	**0.0000***
Foot Length			
Match 1	100899.0	235076.0	**0.0001***
Match 2	103617.5	232357.5	0.0008
Match 3	101623.0	235330.0	**0.0001***
Match 4	104258.0	231717.0	0.0013
Foot Breadth			
Match 1	102964.0	202199.0	**0.0004***
Match 2	103921.0	203156.0	0.0010
Match 3	106240.5	205921.5	0.0048
Match 4	105511.0	204746.0	0.0034

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 49. (Cont.)

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Stature			
Match 1	113515.5	224416.5	0.2216
Match 2	113809.5	224122.5	0.2478
Match 3	114384.0	223548.0	0.3053
Match 4	115092.0	222840.0	0.3873
Waist Height			
Match 1	104852.5	233079.5	0.0014
Match 2	104300.0	233632.0	0.0009
Match 3	105626.0	232306.0	0.0026
Match 4	104185.0	233747.0	0.0008
Crotch Height			
Match 1	110667.0	210795.0	0.0617
Match 2	109357.0	209485.0	0.0303
Match 3	109544.0	209672.0	0.0337
Match 4	109553.0	209681.0	0.0339
Sleeve Length			
Match 1	94358.5	243573.5	**0.0000***
Match 2	92985.0	244947.0	**0.0000***
Match 3	93692.0	244240.0	**0.0000***
Match 4	94568.5	243363.5	**0.0000***
Chest Circumference			
Match 1	105464.5	205592.5	0.0023
Match 2	103109.0	203237.0	**0.0003***
Match 3	105189.5	205317.5	0.0019
Match 4	104970.0	205098.0	0.0016
Waist Circumference			
Match 1	92265.5	192393.5	**0.0000***
Match 2	93358.5	193486.5	**0.0000***
Match 3	95055.5	195183.5	**0.0000***
Match 4	91667.0	191795.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 49. (Cont.)

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Buttock Circumference			
Match 1	105627.0	205755.0	0.0026
Match 2	106328.5	206456.5	0.0043
Match 3	107080.5	207208.5	0.0073
Match 4	106458.0	206586.0	0.0047
Sitting Height			
Match 1	113491.0	213619.0	0.2195
Match 2	111053.5	211181.5	0.0749
Match 3	112119.5	212247.5	0.1238
Match 4	110640.5	210768.5	0.0608
Biacromial Breadth			
Match 1	109678.0	209806.0	0.0363
Match 2	109961.0	210089.0	0.0424
Match 3	109522.0	209650.0	0.0333
Match 4	110852.0	210980.0	0.0677
Menton-Sellion Length			
Match 1	100126.0	200254.0	**0.0000***
Match 2	100637.5	200765.5	**0.0000***
Match 3	96651.0	196779.0	**0.0000***
Match 4	99502.0	199630.0	**0.0000***
Bizygomatic Breadth			
Match 1	80617.0	180745.0	**0.0000***
Match 2	80389.0	180517.0	**0.0000***
Match 3	84041.0	184169.0	**0.0000***
Match 4	79800.0	179928.0	**0.0000***
Head Circumference			
Match 1	94714.5	194842.5	**0.0000***
Match 2	92392.0	192520.0	**0.0000***
Match 3	94329.5	194457.5	**0.0000***
Match 4	91490.5	191618.5	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/72 = .0007$)

Table 50. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Height/Weight Range Matches Adjusted for Observer Error

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Breadth						
Match 1			1.04	0.681	-6.73	**0.000***
Match	447	90.54 (3.91)				
Validation	532	88.87 (3.84)				
Match 2			1.14	0.160	-6.88	**0 .000***
Match	447	90.62 (4.09)				
Validation	532	88.87 (3.84)				
Match 3			1.13	0.176	-8.18	**0.000***
Match	447	90.95 (4.08)				
Validation	532	88.87 (3.84)				
Match 4			1.27	0.008	-6.83	**0.000***
Foot Length						
Match 1			1.01	0.952	-2.67	0.008
Match	445	268.28 (12.33)				
Validation	532	266.26 (12.36)				
Match 2			1.01	0.877	-2.18	0.030
Match	445	267.99 (12.27)				
Validation	532	266.26 (12.36)				
Match 3			1.00	0.974	-2.77	0.006
Match	446	268.46 (12.38)				
Validation	532	266.26 (12.36)				
Match 4			1.05	0.586	-2.06	0.040
Match	445	267.92 (12.67)				
Validation	532	266.26 (12.36)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)

Table 50. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Foot Breadth						
Match 1			1.22	**0.027+**	-0.47	0.638
Match	445	100.61 (5.04)				
Validation	532	100.45 (5.58)				
Match 2			1.21	**0.039+**	-0.80	0.425
Match	445	100.72 (5.08)				
Validation	532	100.45 (5.58)				
Match 3			1.11	0.234	-1.19	0.234
Match	446	100.87 (5.29)				
Validation	532	100.45 (5.58)				
Match 4			1.15	0.117	-1.18	0.238
Match	445	100.86 (5.20)				
Validation	532	100.45 (5.58)				
Sleeve Length						
Match 1			1.07	0.425	-2.75	0.006
Match	447	598.04 (30.10)				
Validation	532	592.82 (29.04)				
Match 2			1.08	0.395	-3.07	0.002
Match	447	598.43 (27.93)				
Validation	532	592.82 (29.04)				
Match 3			1.01	0.875	-3.21	**0.001***
Match	447	598.78 (28.83)				
Validation	532	592.82 (29.04)				
Match 4			1.02	0.859	-2.73	0.007
Match	447	597.88 (28.80)				
Validation	532	592.82 (29.04)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)
\+ Heteroscedastic variance

Table 50. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Chest Circumference						
Match 1			1.13	0.175	0.35	0.726
Match	447	1019.33 (66.62)				
Validation	532	1020.87 (70.88)				
Match 2			1.07	0.432	1.01	0.314
Match	447	1016.38 (68.38)				
Validation	532	1020.87 (70.88)				
Match 3			1.01	0.955	0.63	0.529
Match	447	1018.02 (70.69)				
Validation	532	1020.87 (70.88)				
Match 4			1.03	0.705	0.54	0.587
Match	447	1018.38 (72.10)				
Validation	532	1020.87 (70.88)				
Waist Circumference						
Match 1			1.26	**0.012+**	5.16	**0.000***
Match	447	898.56 (86.63)				
Validation	532	928.86 (97.16)				
Match 2			1.27	**0.009+**	4.99	**0.000***
Match	447	899.58 (86.25)				
Validation	532	928.86 (97.16)				
Match 3			1.17	0.080	4.59	**0.000***
Match	447	901.44 (89.69)				
Validation	532	928.86 (97.16)				
Match 4			1.20	**0.046+**	5.28	**0.000***
Match	447	897.45 (88.70)				
Validation	532	928.86 (97.16)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)
\+ Heteroscedastic variance

Table 50. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Menton-Sellion Length						
Match 1			1.05	0.612	-0.89	0.375
Match	447	121.72 (6.38)				
Validation	532	121.35 (6.53)				
Match 2			1.06	0.513	-1.12	0.261
Match	447	121.82 (6.34)				
Validation	532	121.35 (6.53)				
Match 3			1.00	0.996	-0.17	0.863
Match	447	121.43 (6.53)				
Validation	532	121.35 (6.53)				
Match 4			1.04	0.693	-0.77	0.443
Match	447	121.68 (6.65)				
Validation	532	121.35 (6.53)				
Bizygomatic Breadth						
Match 1			1.04	0.628	5.74	**0.000***
Match	447	140.37 (5.75)				
Validation	532	142.47 (5.63)				
Match 2			1.07	0.447	5.67	**0.000***
Match	447	140.46 (5.45)				
Validation	532	142.47 (5.63)				
Match 3			1.01	0.951	4.82	**0.000***
Match	447	140.74 (5.61)				
Validation	532	142.47 (5.63)				
Match 4			1.04	0.655	5.73	**0.000***
Match	447	140.38 (5.74)				
Validation	532	142.47 (5.63)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)

Table 50. (Cont.)

Variable/ Match Number	N	Mean (SD)	*F*	*p*	*t*	*p*
Head Circumference						
Match 1			1.07	0.483	3.80	**0.000***
Match	447	569.97 (15.53)				
Validation	532	573.71 (15.05)				
Match 2			1.06	0.543	4.58	**0.000***
Match	447	569.36 (14.63)				
Validation	532	573.71 (15.05)				
Match 3			1.08	0.380	3.78	**0.000***
Match	447	569.98 (15.66)				
Validation	532	573.71 (15.05)				
Match 4			1.00	0.975	4.46	**0.000***
Match	447	569.41 (15.02)				
Validation	532	573.71 (15.05)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)

Table 51. Mann-Whitney *U* Results for Comparison of CF Validation Study and Height/Weight Range Matches Adjusted for Observer Error

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Hand Breadth			
Match 1	86418.0	251514.0	**0.0000***
Match 2	86705.0	251227.0	**0.0000***
Match 3	82428.0	255504.0	**0.0000***
Match 4	87556.0	250376.0	**0.0000***
Foot Length			
Match 1	108864.0	227111.0	0.0304
Match 2	111609.0	224366.0	0.1237
Match 3	109628.0	227325.0	0.0406
Match 4	112187.0	223788.0	0.1592
Foot Breadth			
Match 1	114918.0	221057.0	0.4317
Match 2	114451.0	221524.0	0.3721
Match 3	112915.0	224038.0	0.1933
Match 4	112667.0	223308.0	0.1940
Sleeve Length			
Match 1	108996.0	228936.0	0.0246
Match 2	108032.0	229900.0	0.0136
Match 3	108567.0	229365.0	0.0190
Match 4	109442.0	228490.0	0.0318
Chest Circumference			
Match 1	117840.0	217968.0	0.8096
Match 2	115164.0	215292.0	0.3963
Match 3	116968.0	217096.0	0.6608
Match 4	116851.0	216979.0	0.6416

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)

Table 51. (Cont.)

Variable/ Match Number	Mann-Whitney *U*	Wilcoxon *W*	*p*
Waist Circumference			
Match 1	97445.0	197573.0	**0.0000***
Match 2	98656.0	198784.0	**0.0000***
Match 3	100290.0	200418.0	**0.0000***
Match 4	96884.0	197012.0	**0.0000***
Menton-Sellion Length			
Match 1	111674.0	226258.0	0.1009
Match 2	111186.0	226746.0	0.0799
Match 3	115488.0	222444.0	0.4384
Match 4	113405.0	224527.0	0.2121
Bizygomatic Breadth			
Match 1	96913.0	197041.0	**0.0000***
Match 2	97328.0	197456.0	**0.0000***
Match 3	100451.0	200579.0	**0.0000***
Match 4	96148.0	196276.0	**0.0000***
Head Circumference			
Match 1	101074.0	201202.0	**0.0001***
Match 2	99090.0	199218.0	**0.0000***
Match 3	100659.0	200787.0	**0.0000***
Match 4	98058.0	198186.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/36 = .0014$)

4. Height/Weight Individual Subject Match

Each subject that was measured during the CF Validation Study was matched, with replacement, to a single subject from the ANSUR White, male data pool for Height (± 0.5 in or 12.7 mm) and Weight (± 2.5 lbs or 1.1 kg). As with previous matching efforts, Height was matched to ± 0.5 inches (±12.7 mm) and Weight was matched to ± 2.5 pounds (± 1.1 kg). A FORTRAN program was written to identify the closest match for each of the CF subjects. If an identical match was not available, then the program searched for the closest possible match by increasing the Height range by ± 1.0 mm and the Weight range by ± 0.1 kg simultaneously until a match was found, or until the previously assigned tolerances were reached and no suitable match was found.

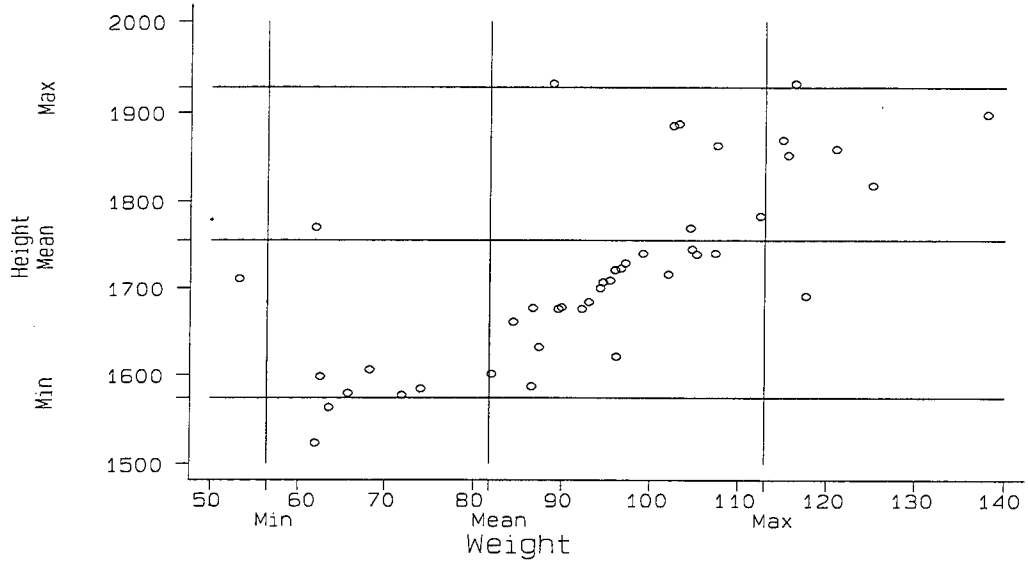

Figure 11. CF Validation Study subjects without an appropriate match from the ANSUR database. The vertical lines represent the minimum, mean and maximum values for Weight of the matched CF Validation Study subjects, while the horizontal lines represent the minimum, mean and maximum values for Height of the matched CF Validation Study subjects. Height in millimeters and Weight in kilograms.

Matches were identified for 489 (91.9%) of the CF Validation Study subjects. The subjects without an appropriate match did not cluster in one particular area for either Height or Weight. Rather, they fell across the entire range of Height and Weight values for those subjects with an appropriate match (see Figure 11). Only 11 of the unmatched subjects fell outside of the Height and Weight range, however these subjects do not cluster exclusively at a single end of the two ranges. Judging from the Height and Weight distribution in Figure

11, it is unlikely that a systematic bias for either of these variables was introduced by the 43 subjects who were not successfully matched. In terms of age, a larger proportion of the older CF Validation Study subjects could not be successfully matched for Height and Weight (see Figure 12). Overall, the subjects who were successfully matched have a very similar age/element distribution as the contemporary CF male population and the CF Validation Study (see Table 52).

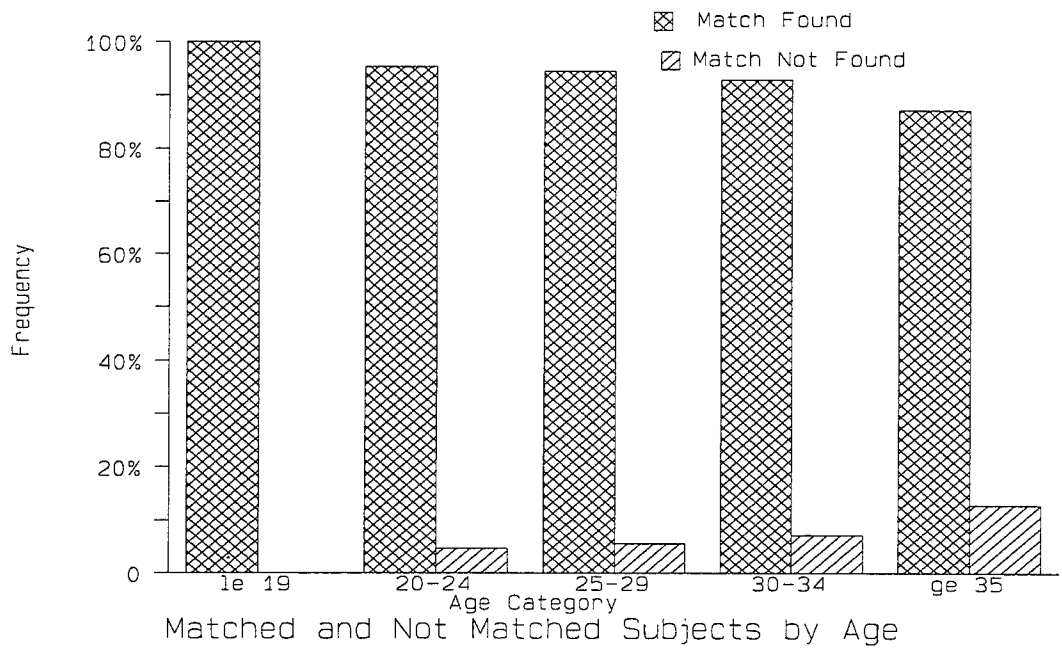

Figure 12. Frequency of CF Validation Study subjects for whom a Height/Weight match was either found or not found by age category.

In most cases, a single, best match was found (N=401); however, two or more potential matches were identified for the remaining 88 CF subjects. Two matches were identified for 68 of the subjects, 3 matches for 14 subjects and 4 matches for 5 subjects. In these instances, the closest possible match for both variables was selected. Occasionally, one match was randomly chosen from two possibilities that were equally valid. (Note: Although 535 subjects were measured in the CF Validation Study, Height and Weight variables were missing for 3 subjects, leaving a total of 532 subjects who could be matched using these criteria.)

The matched database, containing a total of 489 cases, was compared to the CF Validation Study data. Because the variances for 9 of the 18 anthropometric

dimensions do not have homoscedastic variances, Mann-Whitney *U* tests were used to determine if any significant differences were present (see Table 53). The results of the non-parametric analysis are presented in Table 54 and indicate that 9 of the 18 anthropometric dimensions are significantly different. When corrections were made for combined observer error, only four dimensions (Hand Breadth, Waist Circumference, Bizygomatic Breadth, and Head Circumference) remain significantly different between the CF Validation Study and the Individual Subject match (see Tables 55 and 56). These are the identical variables that are significantly different between the CF Validation Study and the Height/Weight Range matches (see Part 3). Again, the magnitude of the observed differences for Hand Breadth, Bizygomatic Breadth and Head Circumference are small and would not impact the development of CIE.

However, the 35mm difference between mean Waist Circumference values is comparable to that observed for the Height/Weight Range matches and could have a severe impact on the sizing and design of CIE, rendering this matching procedure unacceptable. As shown in Figures 13 and 14, the age distributions of the ANSUR subjects selected in the Height/Weight Range matches and the Height/Weight Individual Subject match are ***not*** similar to that of the CF Validation Study. Waist Circumference is the most age sensitive anthropometric dimension for men and increases with age, even when Height, Weight and other circumferential dimensions remain constant (Dr. C. Cronk, pers. comm.). Thus, the observed differences may be entirely the result of the different age distributions, or of the non-representative validation sample. To examine the possible impact of age, a fifth matching procedure was tested in which individual subjects were matched for Height, Weight and Age (see Parts 5 and 6 of this section).

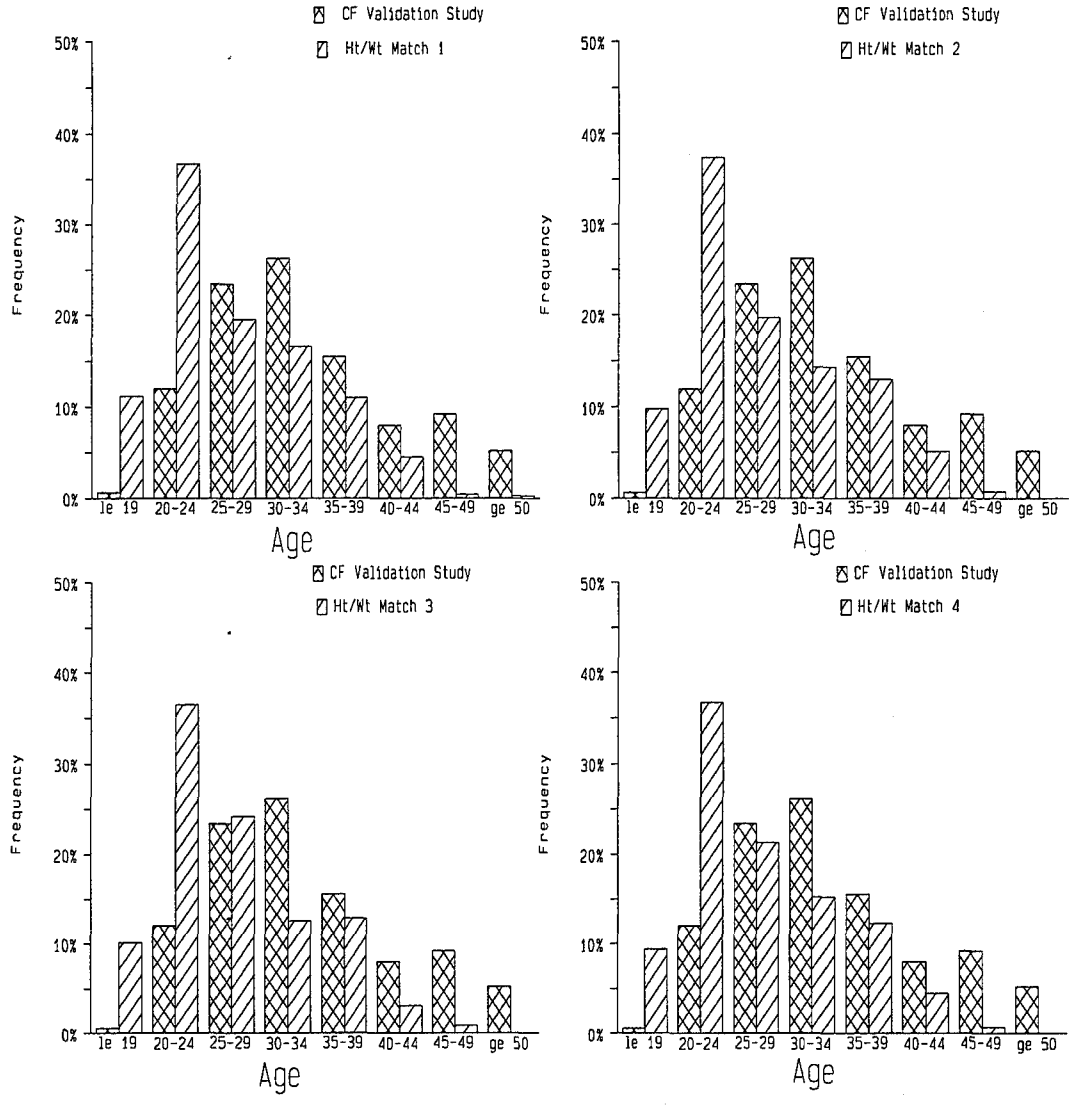

Figure 13. Age distribution of the CF Validation Study and the four Height/Weight Range matches.

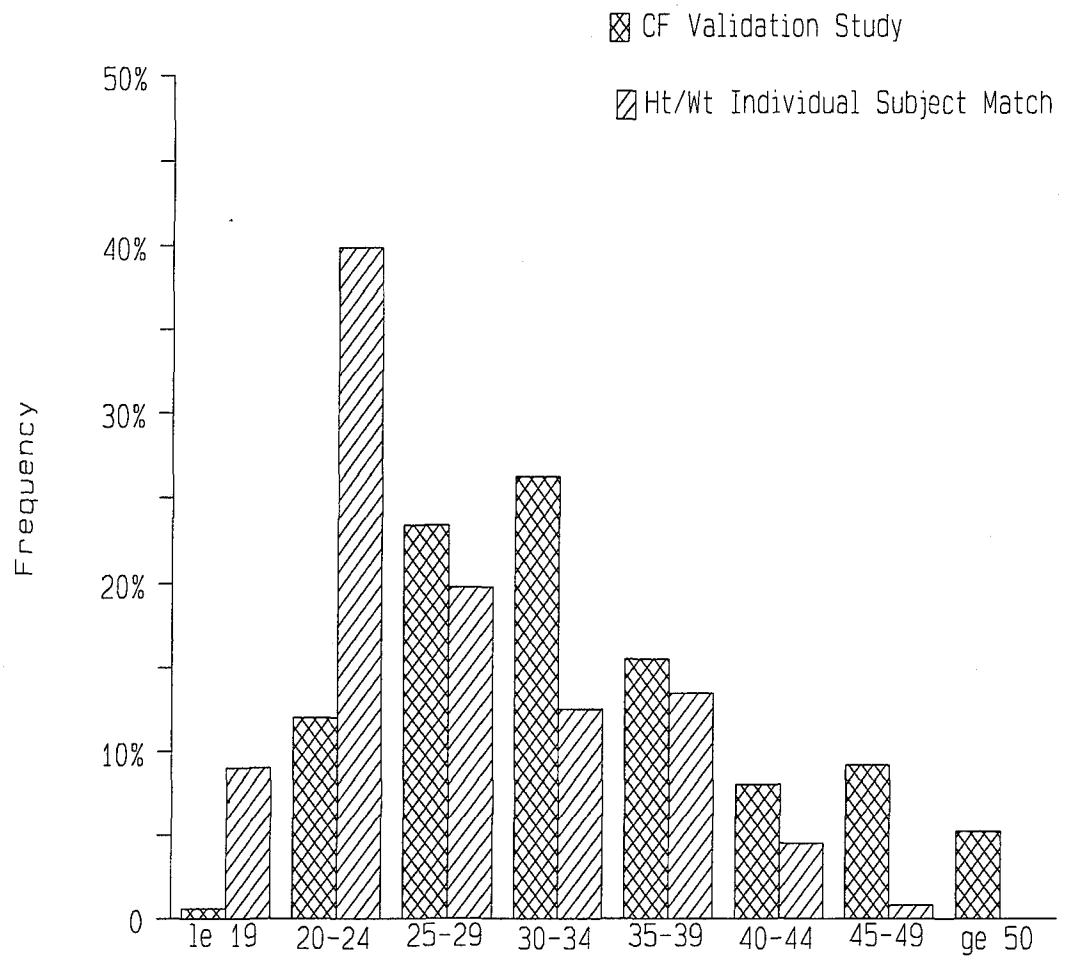

Figure 14. Age distribution of the CF Validation Study and the Height/Weight Individual Subject match.

Table 52. Age and Element Distribution of Contemporary CF Male Personnel, Matched Subjects, and CF Validation Study

Age Category	Land	Sea	Air	Total
≤ 19				
CF Males	110(0.2%)	120(0.2%)	113(0.2%)	343 (0.5%)
Matches	1(0.2%)	1(0.2%)	1(0.2%)	3 (0.6%)
CF Study	1(0.2%)	1(0.2%)	1(0.2%)	3 (0.6%)
20-24				
CF Males	4410(6.4%)	2140(3.1%)	2063(3.0%)	8613 (12.5%)
Matches	31(6.3%)	15(3.1%)	15(3.1%)	61 (12.5%)
CF Study	32(6.0%)	16(3.0%)	16(3.0%)	64 (12.0%)
25-29				
CF Males	7658(11.1%)	2964(4.3%)	4938(7.2%)	15560 (22.5%)
Matches	53(10.8%)	28(5.7%)	37(7.6%)	118 (24.1%)
CF Study	58(10.8%)	28(5.2%)	39(7.3%)	125 (23.4%)
30-34				
CF Males	7542(10.9%)	3028(4.4%)	7698(11.2%)	18268 (26.5%)
Matches	56(11.5%)	18(3.7%)	56(11.5%)	130 (26.6%)
CF Study	56(10.5%)	25(4.7%)	59(11.0%)	140 (26.2%)
≥ 35				
CF Males	9600(13.9%)	4273(6.2%)	12398(18.0%)	26271 (38.0%)
Matches	64(13.1%)	30(6.1%)	83(17.0%)	177 (36.2%)
CF Study	72(13.5%)	38(7.1%)	93(17.4%)	203 (37.9%)
Totals				
CF Males	29320(42.5%)	12525(18.1%)	27210(39.4%)	69055 (100.0%)
Matches	205(41.9%)	92(18.8%)	192(39.3%)	489(100.0%)
CF Study	219(40.9%)	108(20.2%)	208(38.9%)	535(100.0%)

Table 53. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Individual Subject Match

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight			1.30	0.003	1.43	0.154
Match	414	81.79 (10.23)				
Validation	532	82.77 (11.67)				
Span			9.65	**0.000+**	1.40	0.162
Match	489	1790.03 (230.08)				
Validation	530	1805.28 (74.07)				
Hand Length			1.19	0.054	-1.47	0.141
Match	489	191.51 (8.21)				
Validation	532	190.72 (8.94)				
Hand Breadth			1.09	0.318	-9.22	**0.000***
Match	489	90.44 (4.01)				
Validation	532	88.18 (3.84)				
Foot Length			1.15	0.109	-3.82	**0.000***
Match	486	267.98 (11.51)				
Validation	532	265.12 (12.36)				
Foot Breadth			1.21	**0.031+**	3.43	**0.001***
Match	486	100.72 (5.07)				
Validation	532	101.86 (5.58)				
Stature			1.20	**0.038+**	-0.71	0.478
Match	489	1754.88 (59.09)				
Validation	532	1752.13 (64.79)				
Waist Height			1.20	**0.042+**	-3.40	**0.001***
Match	489	1053.11 (45.58)				
Validation	532	1042.94 (49.90)				
Crotch Height			1.10	0.300	2.49	0.013
Match	489	827.66 (40.56)				
Validation	532	834.12 (42.47)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

\+ Heteroscedastic variance

Table 53. (Cont.)

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Sleeve Length			1.15	0.127	-5.45	**0.000***
Match	489	596.26 (27.13)				
Validation	532	586.67 (29.04)				
Chest Circumference			1.06	0.526	2.67	0.008
Match	489	1021.89 (68.91)				
Validation	532	1033.58 (70.88)				
Waist Circumference			1.40	**0.000+**	6.26	**0.000***
Match	489	901.68 (82.14)				
Validation	532	936.82 (97.16)				
Buttock Circumference			1.28	**0.005+**	3.34	**0.001***
Match	489	1004.03 (56.85)				
Validation	532	1016.69 (64.33)				
Sitting Height			1.21	**0.034+**	2.36	0.018
Match	489	920.97 (29.26)				
Validation	532	925.51 (32.15)				
Biacromial Breadth			1.23	**0.019+**	3.17	**0.002***
Match	489	396.98 (16.80)				
Validation	532	400.50 (18.64)				
Menton-Sellion Length			1.00	0.971	5.71	**0.000***
Match	489	121.12 (6.54)				
Validation	532	123.45 (6.53)				
Bizygomatic Breadth			1.00	0.978	8.25	**0.000***
Match	489	140.85 (5.64)				
Validation	532	143.76 (5.63)				
Head Circumference			1.18	0.063	5.82	**0.000***
Match	489	569.81 (16.34)				
Validation	532	575.55 (15.05)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)
\+ Heteroscedastic variance

Table 54. Mann-Whitney *U* Results for Comparison of CF Validation Study and Individual Subject Match

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight	125285.5	245090.5	0.3090
Span	127943.0	251032.0	0.7265
Hand Length	123403.5	256549.5	0.1562
Hand Breadth	90007.0	289946.0	**0.0000***
Foot Length	111959.0	264934.0	**0.0002***
Foot Breadth	113393.5	231724.5	**0.0007***
Stature	127235.0	252718.0	0.5464
Waist Height	115534.0	263319.0	**0.0020***
Crotch Height	117921.0	237726.0	0.0098
Sleeve Length	105938.0	274015.0	**0.0000***
Chest Circumference	118549.5	238354.5	0.0143
Waist Circumference	103685.0	223490.0	**0.0000***
Buttock Circumference	116513.0	236318.0	**0.0040***
Sitting Height	118455.5	238260.5	0.0136
Biacromial Breadth	116554.0	236359.0	**0.0041***
Menton Sellion Length	102741.5	222546.	**0.0000***
Bizygomatic Breadth	93512.0	213317.0	**0.0000***
Head Circumference	101634.0	221439.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

Table 55. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Individual Subject Match Adjusted for Observer Error

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Breadth			1.09	0.318	-6.42	**0.000***
Match	489	90.45 (4.01)				
Validation	532	88.87 (3.84)				
Foot Length			1.15	0.109	-2.30	0.022
Match	486	267.98 (11.51)				
Validation	532	266.26 (12.36)				
Foot Breadth			1.21	**0.031+**	-0.79	0.427
Match	486	100.72 (5.07)				
Validation	532	100.45 (5.58)				
Waist Height			1.20	**0.042+**	-1.87	0.062
Match	489	1053.11 (45.58)				
Validation	532	1047.53 (49.90)				
Sleeve Length			1.15	0.127	-1.96	0.051
Match	489	596.26 (27.13)				
Validation	532	592.82 (29.04)				
Waist Circumference			1.40	**0.000+**	4.84	**0.000***
Match	489	901.68 (82.14)				
Validation	532	928.86 (97.16)				
Menton Sellion			1.00	0.971	0.58	0.564
Match	489	121.12 (6.54)				
Validation	532	121.35 (6.53)				
Bizygomatic Breadth			1.00	**0.978+**	4.59	**0.000***
Match	489	140.85 (5.64)				
Validation	532	142.47 (5.63)				
Head Circumference			1.18	0.063	3.95	**0.000***
Match	489	569.81 (16.34)				
Validation	532	573.71 (15.05)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/9 = .0056$)

\+ Heteroscedastic variance

Table 56. Mann-Whitney *U* Results for Comparison of CF Validation Study and Individual Subject Match Adjusted for Observer Error

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Hand Breadth	98630.0	281323.0	**0.0000***
Foot Length	120904.0	255989.0	0.0740
Foot Breadth	124900.0	251993.0	0.3501
Waist Height	122325.0	257628.0	0.0997
Sleeve Length	122661.0	257292.0	0.1153
Waist Circumference	109595.0	229400.0	**0.0000***
Menton-Sellion Length	130012.0	249817.0	0.9895
Bizygomatic Breadth	111840.0	231645.0	**0.0001***
Head Circumference	108545.0	228350.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/9 = .0056$)

5. Height/Weight/Age Individual Subject Match

To determine if age was causing the observed differences in Waist Circumference for the Height/Weight matching procedures, a third type of match was tested in which each subject that was measured during the CF Validation Study was matched, with replacement, to a single subject from the ANSUR White, male data pool for Height (± 0.5 in or 12.7 mm), Weight (± 2.5 lbs or 1.1 kg) and Age (± 2.5 years). A FORTRAN program was written to identify the closest match for each of the CF subjects. If an identical match was not found, then the program searched for the closest possible match by increasing the Height range by ± 1.0 mm and the Weight range by ± 0.1 kg simultaneously. Once a Height and Weight match was found, the Age of the two subjects was compared. If the Age was not within ± 2.5 years, the match was rejected and the program continued searching for another Height/Weight match that also met the Age criterion. The search continued until a Height/Weight/Age match was found, or the previously assigned tolerances for Height and Weight were reached and no suitable match was found. (Note: Although 535 subjects were measured in the CF Validation Study, Height and Weight variables were missing for 3 subjects, leaving a total of 532 subjects who could potentially be matched using these criteria.)

Matches were successfully identified for 327 (61.5%) of the CF Validation Study subjects. A total of 162 (30.5%) of the subjects could not be matched because of the Age restriction, while only 43 (8.1%) failed to be matched due to Height and/or Weight criteria. Figure 15 presents a comparison of the subjects for whom a match was found with those for whom no match was found by age category. Clearly, most of the young subjects were successfully matched for Height, Weight, and Age, while far fewer successful matches were found for older subjects. Because the age distribution of the matched and non-matched subjects were radically different, the matched database was compared only to those subjects from the CF Validation Study for whom a match was found.

Student's *t*-tests and Mann-Whitney *U* tests were used to determine if any significant differences were present between the Height/Weight/Age matched database and the CF Validation Study subjects for whom a match was found. As shown in Tables 57 and 58, 8 of the 18 anthropometric dimensions were significantly different between the two sets of data. As shown in Tables 59 and 60, only Hand Breadth remains significantly different when adjusted for observer error. The magnitude of the difference between the means for Hand Breadth was only 2.2 mm with a combined observer error of 0.69 mm, clearly much too small of a difference to impact the sizing and development of CIE. Thus, the Height/Weight/Age matching ***procedure*** is successful and could be used to

provide an anthropometrically valid database for CF male personnel, provided that truly representative Height and Weight data were available as input for the algorithm and a match could be found for a large proportion of the subjects.

In addition, these results indicate that the Height/Weight Range matching procedure and Height/Weight Individual Subject matching procedure failed to provide an anthropometric distribution that matched the entire measured sample because the CF study subjects were heavier for their Height compared to ANSUR subjects in the older age ranges. While this may be a true difference between CF and US personnel, it may also be a result of the large proportion of support personnel that were measured for the Validation Study. Many of the CF subjects could be matched on Height and Weight alone, but the older CF subjects failed to be matched as frequently when all 3 variables were used as matching criteria (i.e., Height, Weight, Age). Because the White male ANSUR data pool is much younger than the target population, and Age has an impact on anthropometry independently of Height and Weight, Age must be specifically controlled in the matching procedure. Thus, a final procedure was tested in which age was allowed to vary beyond the ± 2.5 year interval for those over 25 years of age (see Part 6 of this section).

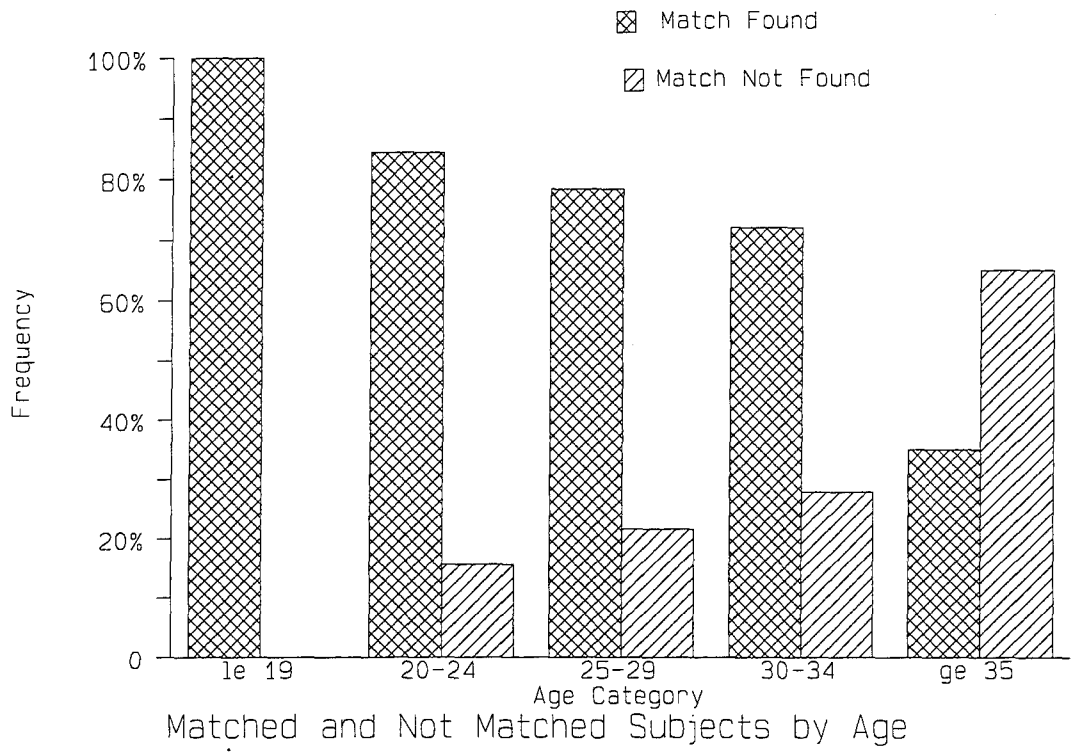

Figure 15. Frequency of matched and non-matched CF Validation Study subjects by age category.

Table 57. *F* Test and Student's *t*-test Results for Comparison of Match and Match Found

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight			1.02	0.884	0.06	0.948
Match	327	81.07 (9.37)				
Match Found	327	81.02 (9.29)				
Span			1.17	0.162	0.71	0.480
Match	326	1815.48 (65.54)				
Match Found	327	1811.98 (60.65)				
Hand Length			1.20	0.103	-0.44	0.659
Match	327	191.40 (8.59)				
Match Found	327	191.69 (7.85)				
Hand Breadth			1.07	0.545	-7.30	**0.000***
Match	327	88.23 (3.69)				
Match Found	327	90.38 (3.82)				
Foot Length			1.07	0.534	-2.34	0.020
Match	327	265.93 (11.57)				
Match Found	327	268.01 (11.18)				
Foot Breadth			1.27	**0.034+**	3.89	**0.000***
Match	327	101.91 (5.49)				
Match Found	327	100.33 (4.88)				
Stature			1.01	0.921	-0.04	0.971
Match	327	1758.90 (53.15)				
Match Found	327	1759.06 (53.44)				
Waist Height			1.07	0.532	-0.83	0.406
Match	327	1052.28 (41.19)				
Match Found	327	1054.92 (39.79)				
Crotch Height			1.04	0.751	3.84	**0.000***
Match	327	840.73 (36.07)				
Match Found	327	829.81 (36.71)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

\+ Heteroscedastic variance

Table 57. (Cont.)

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Sleeve Length			1.16	0.189	-4.30	**0.000***
Match	327	590.00 (25.65)				
Match Found	327	598.33 (23.84)				
Chest Circumference			1.11	0.349	0.85	0.397
Match	327	1019.38 (3.17)				
Match Found	327	1015.47 (60.38)				
Waist Circumference			1.19	0.112	2.30	0.022
Match	327	911.41 (79.54)				
Match Found	327	897.68 (72.82)				
Buttock Circumference			1.13	0.263	2.33	0.020
Match	327	1008.43 (54.14)				
Match Found	327	998.87 (50.89)				
Sitting Height			1.16	0.179	1.26	0.208
Match	327	926.80 (28.48)				
Match Found	327	923.88 (30.68)				
Biacromial Breadth			1.20	0.097	3.91	**0.000***
Match	327	401.87 (18.22)				
Match Found	327	396.54 (16.62)				
Menton-Sellion Length			1.04	0.721	4.67	**0.000***
Match	327	123.64 (6.37)				
Match Found	327	121.33 (6.24)				
Bizygomatic Breadth			1.10	0.382	4.43	**0.000***
Match	327	142.98 (5.37)				
Match Found	327	141.17 (5.11)				
Head Circumference			1.28	**0.028+**	3.43	**0.001***
Match	327	574.88 (14.06)				
Match Found	327	570.86 (15.88)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)
\+ Heteroscedastic variance

Table 58. Mann-Whitney *U* Results for Comparison of Match with No Match Found

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight	53312.0	107245.0	0.9497
Span	52153.0	107750.0	0.6339
Hand Length	51237.5	104865.6	0.3562
Hand Breadth	36543.5	90171.5	**0.0000***
Foot Length	48208.0	101836.0	0.0295
Foot Breadth	44167.5	116389.5	**0.0001***
Stature	53348.5	106976.5	0.9617
Waist Height	51325.5	104953.5	0.3759
Crotch Height	44776.0	115781.0	**0.0003***
Sleeve Length	43575.5	97203.5	**0.0000***
Chest Circumference	50894.0	109663.0	0.2873
Waist Circumference	47943.5	112613.5	0.0223
Buttock Circumference	47925.0	112632.0	0.0218
Sitting Height	50056.5	110500.5	0.1583
Biacromial Breadth	45195.0	115362.0	**0.0006***
Menton Sellion Length	42367.5	118189.5	**0.0000***
Bizygomatic Breadth	43572.0	116985.0	**0.0000***
Head Circumference	45437.5	115119.5	**0.0009***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

Table 59. *F* Test and Student's *t*-test Results for Comparison of Match and Match Found Adjusted for Observer Error

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Breadth			1.07	0.545	-4.95	**0.000***
Match	327	88.92 (3.69)				
Match Found	327	90.38 (3.82)				
Foot Breadth			1.27	**0.034+**	0.42	0.674
Match	327	100.50 (5.49)				
Match Found	327	100.33 (4.88)				
Crotch Height			1.04	0.751	0.78	0.435
Match	327	832.03 (36.07)				
Match Found	327	829.81 (36.71)				
Sleeve Length			1.16	0.189	-1.13	0.261
Match	327	596.15 (25.65)				
Match Found	327	598.33 (23.84)				
Biacromial Breadth			1.20	0.097	-0.38	0.707
Match	327	396.03 (18.22)				
Match Found	327	396.54 (16.62)				
Menton Sellion Length			1.04	0.721	0.41	0.681
Match	327	121.54 (6.37)				
Match Found	327	121.33 (6.24)				
Bizygomatic Breadth			1.10	0.382	1.28	0.199
Match	327	141.69 (5.37)				
Match Found	327	141.17 (5.11)				
Head Circumference			1.28	**0.028+**	1.86	0.063
Match	327	573.04 (14.06)				
Match Found	327	570.86 (15.88)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/8 = .0063$)

\+ Heteroscedastic variance

Table 60. Mann-Whitney *U* Results for Comparison of Match with No Match Found Adjusted for Observer Error

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Hand Breadth	40267.0	93895.0	**0.0000***
Foot Breadth	52748.0	107809.0	0.7667
Crotch Height	51703.0	108854.0	0.4659
Sleeve Length	51272.0	104900.0	0.3641
Biacromial Breadth	51838.0	105466.0	0.5008
Menton Sellion Length	53012.0	106640.0	0.8514
Bizygomatic Breadth	51565.0	108992.0	0.4315
Head Circumference	48453.0	112104.0	0.0380

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/8 = .0063$)

6. Height/Weight/Flexible Age Individual Subject Match

In an effort to match a greater proportion of subjects, Height and Weight criteria were kept at ± 0.5 inches (12.7 mm) and ± 2.5 pounds (1.1 kg), but the Age criteria were altered. Subjects less than 25 years old were matched within a 2 year age range (i.e., ± 2 years), and older individuals were matched within a 5 year age range (i.e., ± 5 years) with replacement. Among the older set of subjects, preference was given to the closest Age match. Subjects under 25 were an unacceptable match for those over 27 years old. Because men continue skeletal growth until 25, Age could have more of an effect on subjects who are less than 25, compared to older men (14). Thus, a tighter control of Age for this age range may be more important. In most cases, matches were found within a 5-year interval for those over 27 years of age and a total of 443 (84%) of the subjects were successfully matched.

When the matched database is compared to CF Validation Study subjects for whom a match was found, 8 of the 18 anthropometric dimensions were significantly different (see Tables 61 and 62). However, when adjusted for observer error, only Hand Breadth and Head Circumference are significantly different (see Tables 63 and 64). Although the observed difference of 2.36 millimeters for Hand Breadth and 4.82 millimeters for Head Circumference is statistically significant, these differences are too small to have an impact on the development of CIE. This matching method does replicate the anthropometric distribution of the subjects for whom a match was found and matches a significant proportion of the subjects (84%).

When compared to the entire sample measured for the CF Validation Study, 9 of the 18 dimensions are significantly different from the matched sample (see Tables 65 and 66). When adjusted for observer error, only 4 of the dimensions (Hand Breadth, Waist Circumference, Bizygomatic Breadth, and Head Circumference) remain significantly different (see Tables 67 and 68). Again, the observed difference is only 2.36 millimeters for Hand Breadth, 2.60 millimeters for Bizygomatic Breadth, and 5.37 millimeters for Head Circumference. These differences are negligible when manufacturing tolerances for CIE are considered. However, the observed difference for Waist Circumference remains unacceptably large at 33.66 millimeters. Because the CF Validation Study sample under-represents operational personnel for the Land and Sea elements, a group that may be more physically fit, it is possible that this large difference would not appear when a truly representative sample is used for matching.

Table 61. *F* Test and Student's *t*-test Results for Comparison of Match and Match Found Using Flexible Age

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight			1.01	0.906	0.04	0.967
Match	443	81.42 (9.63)				
Match Found	443	81.45 (9.68)				
Span			1.08	0.398	0.33	0.745
Match	443	1809.04 (65.62)				
Match Found	443	1810.50 (68.32)				
Hand Length			1.07	0.500	-0.51	0.610
Match	443	191.51 (8.30)				
Match Found	443	191.23 (8.57)				
Hand Breadth			1.16	0.113	-9.18	**0.000***
Match	443	90.54 (3.98)				
Match Found	443	88.18 (3.69)				
Foot Length			1.05	0.644	-2.86	0.004
Match	443	267.82 (11.55)				
Match Found	443	265.58 (11.81)				
Foot Breadth			1.06	0.551	4.03	**0.000***
Match	443	100.49 (5.20)				
Match Found	443	101.92 (5.35)				
Stature			1.00	0.984	-0.01	0.992
Match	443	1756.46 (57.25)				
Match Found	443	1756.42 (57.20)				
Waist Height			1.05	0.598	-1.56	0.119
Match	443	1052.51 (43.29)				
Match Found	443	1047.92 (44.39)				
Crotch Height			1.06	0.566	4.18	**0.000***
Match	443	827.14 (39.28)				
Match Found	443	838.03 (38.22)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

\+ Heteroscedastic variance

Table 61. (Cont.)

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Sleeve Length			1.09	0.364	-4.72	**0.000***
Match	443	596.54 (26.83)				
Match Found	443	596.88 (25.69)				
Chest Circumference			1.12	0.239	0.69	0.488
Match	443	1020.53 (63.68)				
Match Found	443	1023.42 (60.21)				
Waist Circumference			1.21	**0.047+**	3.44	**0.001***
Match	443	903.16 (75.82)				
Match Found	443	921.59 (83.33)				
Buttock Circumference			1.12	0.224	2.74	0.006
Match	443	1000.43 (52.27)				
Match Found	443	1010.35 (55.39)				
Sitting Height			1.08	0.421	1.57	0.116
Match	443	923.63 (30.72)				
Match Found	443	926.82 (29.56)				
Biacromial Breadth			1.12	0.218	3.23	**0.001***
Match	443	397.09 (16.98)				
Match Found	443	400.09 (16.98)				
Menton-Sellion Length			1.03	0.760	5.06	**0.000***
Match	443	121.34 (6.25)				
Match Found	443	123.48 (6.34)				
Bizygomatic Breadth			1.08	0.392	6.25	**0.000***
Match	443	141.16 (5.33)				
Match Found	443	143.45 (5.55)				
Head Circumference			1.14	0.180	4.70	**0.000***
Match	443	570.18 (15.72)				
Match Found	443	575.00 (14.75)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)
\+ Heteroscedastic variance

Table 62. Mann-Whitney *U* Results for Comparison of Match and Match Found Using Flexible Age

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight	97985.0	196610.0	0.9708
Span	97242.0	196467.0	0.8620
Hand Length	94387.5	192733.5	0.3261
Hand Breadth	65137.5	163483.5	**0.0000***
Foot Length	87444.5	185790.5	0.0050
Foot Breadth	83523.5	211071.5	**0.0001***
Stature	98097.5	196443.5	0.9943
Waist Height	92630.0	190976.0	0.1491
Crotch Height	82917.0	211678.0	**0.0001***
Sleeve Length	81103.5	179449.5	**0.0000***
Chest Circumference	94601.0	199994.0	0.3549
Waist Circumference	85720.5	208874.5	**0.0011***
Buttock Circumference	88203.5	206391.5	0.0092
Sitting Height	91881.5	202713.5	0.1012
Biacromial Breadth	86856.0	207739.0	0.0031
Menton Sellion Length	78877.0	215718.0	**0.0000***
Bizygomatic Breadth	75619.5	218975.5	**0.0000***
Head Circumference	80454.0	214141.0	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

Table 63. *F* Test and Student's *t*-test Results for Comparison of Match and Match Found Using Flexible Age Adjusted for Observer Error

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Breadth			1.16	0.113	-6.50	**0.000***
Match	443	90.54 (3.98)				
Match Found	443	88.87 (3.69)				
Foot Breadth			1.06	0.551	0.93	0.354
Match	443	100.49 (5.20)				
Match Found	443	100.82 (5.35)				
Crotch Height			1.06	0.566	0.84	0.400
Match	443	827.14 (39.28)				
Match Found	443	829.33 (38.22)				
Sleeve Length			1.09	0.364	-1.24	0.215
Match	443	596.88 (25.69)				
Match Found	443	594.69 (26.83)				
Waist Circumference			1.21	**0.047+**	1.96	0.051
Match	443	913.63 (83.33)				
Match Found	443	903.16 (75.82)				
Menton Sellion Length			1.03	0.760	0.09	0.925
Match	443	121.38 (6.34)				
Match Found	443	121.34 (6.25)				
Bizygomatic Breadth			1.08	0.392	2.72	0.007
Match	443	141.16 (5.33)				
Match Found	443	142.16 (5.55)				
Head Circumference			1.14	0.180	2.90	**0.004***
Match	443	570.18 (15.72)				
Match Found	443	573.16 (14.75)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/8 = .0063$)

\+ Heteroscedastic variance

Table 64. Mann-Whitney *U* Results for Comparison of Match with Match Found Using Flexible Age Adjusted for Observer Error

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Hand Breadth	71688.0	170034.0	**0.0000***
Foot Breadth	97247.0	195593.0	0.8177
Crotch Height	94838.0	199757.0	0.3882
Sleeve Length	94513.0	192859.0	0.3430
Waist Circumference	90674.0	203921.0	0.0504
Menton Sellion Length	95874.0	194220.0	0.5545
Bizygomatic Breadth	89834.0	204761.0	0.0294
Head Circumference	85829.0	208766.0	**0.0012***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/8 = .0063$)

Table 65. *F* Test and Student's *t*-test Results for Comparison of CF Validation Study and Match Found Using Flexible Age

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Weight			1.47	**0.000+**	1.98	0.048
Match	443	81.42 (9.63)				
CF Study	532	82.77 (11.67)				
Span			1.27	**0.008+**	-0.84	0.403
Match	443	1809.04 (65.62)				
CF Study	530	1805.28 (74.07)				
Hand Length			1.16	0.102	-1.44	0.151
Match	443	191.51 (8.30)				
CF Study	532	190.72 (8.94)				
Hand Breadth			1.07	0.432	-9.39	**0.000***
Match	443	90.54 (3.98)				
CF Study	532	88.18 (3.84)				
Foot Length			1.15	0.138	-3.52	**0.000***
Match	443	267.82 (11.55)				
CF Study	532	265.12 (12.36)				
Foot Breadth			1.15	0.122	3.95	**0.000***
Match	443	100.49 (5.20)				
CF Study	532	101.86 (5.58)				
Stature			1.28	**0.007+**	-1.11	0.268
Match	443	1756.46 (57.25)				
CF Study	532	1752.13 (64.79)				
Waist Height			1.33	**0.002+**	-3.21	**0.001***
Match	443	1052.51 (43.29)				
CF Study	532	1042.94 (49.90)				
Crotch Height			1.17	0.088	2.67	0.008
Match	443	827.14 (39.28)				
CF Study	532	834.14 (42.47)				

All values in mm, except Weight in kg

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

\+ Heteroscedastic variance

Table 65. (Cont.)

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Sleeve Length			1.28	**0.008+**	-5.82	**0.000***
Match	443	596.54 (26.83)				
CF Study	532	586.67 (29.04)				
Chest Circumference			1.24	**0.019+**	3.03	**0.003***
Match	443	1020.53 (63.68)				
CF Study	532	1033.58 (70.88)				
Waist Circumference			1.64	**0.000+**	6.07	**0.000***
Match	443	903.16 (75.82)				
CF Study	532	936.82 (97.16)				
Buttock Circumference			1.51	**0.000+**	4.36	**0.000***
Match	443	1000.43 (52.27)				
CF Study	532	1016.69 (64.33)				
Sitting Height			1.10	0.317	0.93	0.353
Match	443	923.63 (30.72)				
CF Study	532	925.51 (32.15)				
Biacromial Breadth			1.20	**0.042+**	2.99	**0.003***
Match	443	397.09 (16.98)				
CF Study	532	400.50 (18.64)				
Menton-Sellion Length			1.09	0.335	5.14	**0.000***
Match	443	121.34 (6.25)				
CF Study	532	123.45 (6.53)				
Bizygomatic Breadth			1.12	0.225	7.39	**0.000***
Match	443	141.16 (5.33)				
CF Study	532	143.76 (5.63)				
Head Circumference			1.09	0.331	5.41	**0.000***
Match	443	570.18 (15.72)				
CF Study	532	575.55 (15.05)				

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)
\+ Heteroscedastic variance

Table 66. Mann-Whitney *U* Results for Comparison of CF Validation Study and Match Found Using Flexible Age

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Weight	111491.0	209837.0	0.1471
Span	113435.5	219700.5	0.3644
Hand Length	109803.5	224218.5	0.0663
Hand Breadth	78784.0	255328.0	**0.0000***
Foot Length	102876.0	231146.0	**0.0006***
Foot Breadth	101544.5	199890.5	**0.0002***
Stature	113625.5	220396.5	0.3360
Waist Height	105514.5	228507.5	0.0049
Crotch Height	106105.0	204451.0	0.0074
Sleeve Length	94255.0	239767.0	**0.0000***
Chest Circumference	105449.0	203795.0	0.0047
Waist Circumference	94049.0	192395.0	**0.0000***
Buttock Circumference	100911.0	199257.0	**0.0001***
Sitting Height	112844.0	211190.0	0.2540
Biacromial Breadth	106228.5	204574.5	0.0080
Menton Sellion Length	95092.0	193438.0	**0.0000***
Bizygomatic Breadth	87672.0	186018.0	**0.0000***
Head Circumference	94544.5	192890.5	**0.0000***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/18 = .0027$)

Table 67. *F* Test and Student's *t*-test Results for Comparison of CF Validation Study and Match Found Using Flexible Age Adjusted for Observer Error

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Hand Breadth			1.07	0.432	-12.13	**0.000***
Match	443	90.54 (3.98)				
CF Study	532	87.49 (3.84)				
Foot Breadth			1.15	0.122	-0.13	0.900
Match	443	100.49 (5.20)				
CF Study	532	100.45 (5.58)				
Sleeve Length			1.28	**0.008+**	-2.31	0.021
Match	443	596.88 (25.69)				
CF Study	532	592.82 (29.04)				
Waist Circumference			1.64	**0.000+**	4.64	**0.000***
Match	443	913.63 (83.33)				
CF Study	532	928.86 (97.86)				
Menton Sellion Length			1.09	0.335	0.02	0.981
Match	443	121.38 (6.34)				
CF Study	532	121.35 (6.53)				
Bizygomatic Breadth			1.12	0.225	3.72	**0.000***
Match	443	141.16 (5.33)				
CF Study	532	142.47 (5.63)				
Head Circumference			1.09	0.331	3.56	**0.000***
Match	443	570.18 (15.72)				
CF Study	532	573.71 (15.04)				

All values in mm

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/7 = .0071$)

\+ Heteroscedastic variance

Table 68. Mann-Whitney *U* Results for Comparison of CF Validation Study and Match Found Using Flexible Age Adjusted for Observer Error

Variable	Mann-Whitney *U*	Wilcoxon *W*	*p*
Hand Breadth	71055.0	262967.0	**0.0000***
Foot Breadth	116087.0	217935.0	0.6891
Sleeve Length	109626.0	224396.0	0.0607
Waist Circumference	99539.0	197885.0	**0.0000***
Buttock Circumference	108383.0	206729.0	0.0308
Menton Sellion Length	115176.0	218846.0	0.5431
Bizygomatic Breadth	**104510.0**	**202856.0**	**0.0023***
Head Circumference	100854.0	199200.0	**0.0001***

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/7 = .0071$)

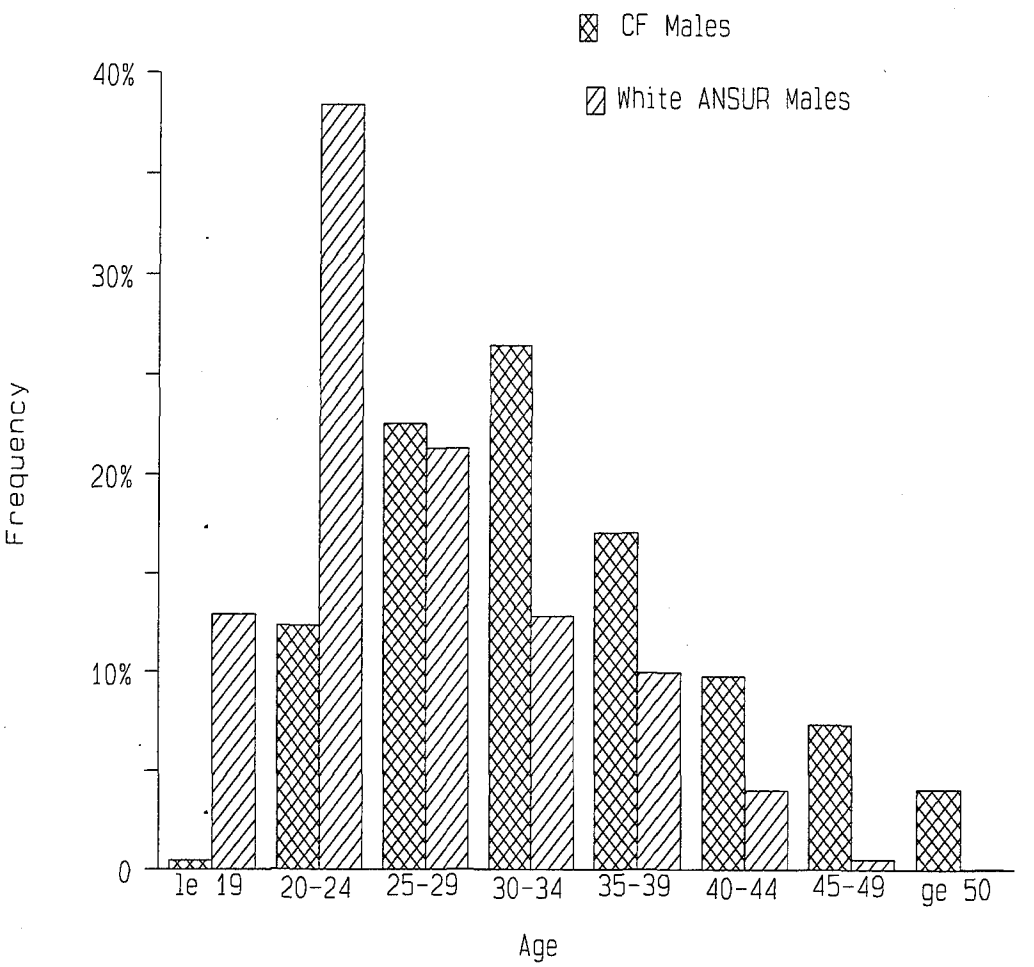

Figure 16. Age distribution of CF male personnel as reported in the March 1993 Persfacts and White male subjects from the ANSUR database (16)

7. Derivation of a CF Female Anthropometric Database

If possible, a female database was to be configured using the matching procedure that was chosen in the CF Validation Study. However, a female database ***cannot*** be configured at this time because reliable Height and Weight data are not available from a representative sample of CF females and their age distribution could present the same problems observed for their male counterparts. As discussed in Part 1 of the "Comparison with 1992 CF Express Database and 1988 Anthropometric Survey of US Army Personnel" section, the data collected during the CF Validation Study is ***not*** comparable to the 1992 CF Express Database for Height and Weight. Similar differences would be expected between the female Express data and data collected from a random sample of CF females in a controlled environment. In addition, Height was only recorded to the nearest decimeter, far too large a magnitude to ensure successful matching. To produce a reliable anthropometric database for CF females, accurate Height, Weight and Age data must be collected from a random sample of CF female personnel. These data could then be used to create an anthropometric database for females ***if*** subjects can be successfully matched on Height and Weight for the entire age range. As shown in Figure 17, the age distribution of the CF female population is older than that of the White ANSUR female subjects, however enough older female subjects should be successfully matched if the Weight for Height of CF females is similar to that of the ANSUR subjects.

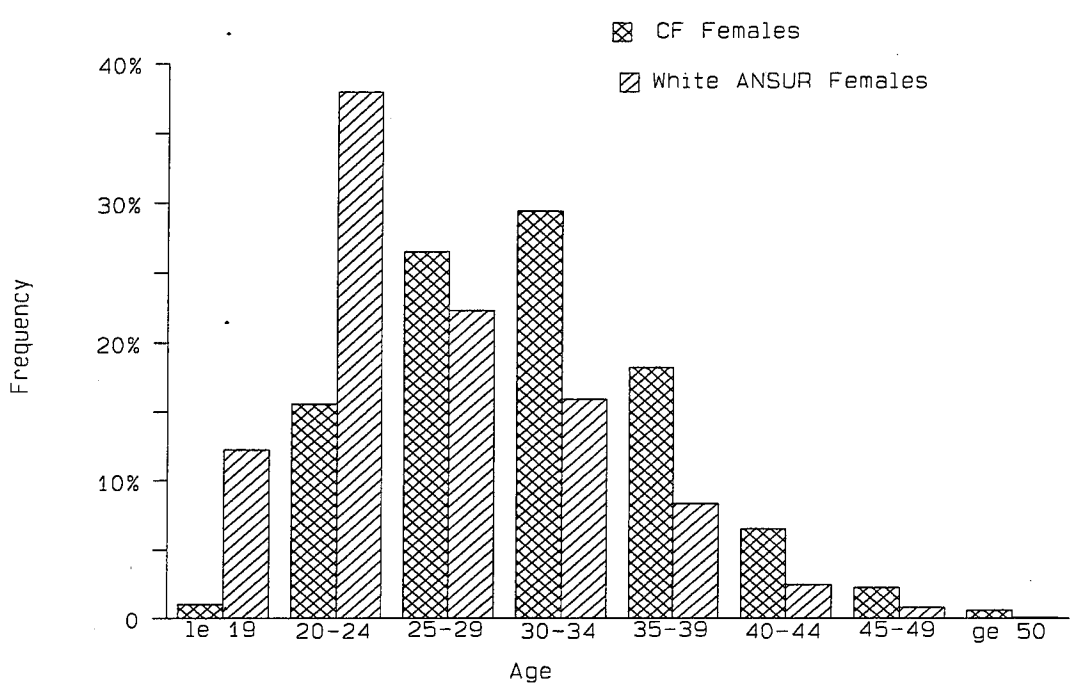

Figure 17. Age distribution of CF female personnel as reported in the March 1993 Persfacts and White female subjects from the ANSUR database (16).

Review

Introduction

Traditionally, large-scale anthropometric surveys have been conducted to provide body size data for the development, sizing and tariffing of personal protective clothing and individual equipment (CIE). Because these surveys can be prohibitively time-consuming and expensive, stratified random sampling techniques are sometimes employed to select a sample of subjects from an existing database to create an anthropometric database that can be used for a specific application or to describe a different population. To determine if such a procedure can be used to successfully create new anthropometric databases for the Canadian Forces (CF), the Directorate of Ammunition, Clothing, Materiel and Engineering (DACME) contracted the US Army Natick Research, Development and Engineering Center (Natick) to conduct the CF Validation Study.

Sample Acquisition

During July and August of 1993, a total of 557 male CF personnel were fully measured for 18 anthropometric dimensions at four locations: CFB Kingston (Land), CFB Gagetown (Land), CFB Trenton (Air), and CFB Halifax (Sea). Of the fully measured subjects, 535 met the age/element sampling criteria and were used to validate the matching procedures tested in this study.

Although most of the subjects measured during the study were selected using a statistically valid sampling technique, 34.2% of those measured were substitutes for individuals selected randomly within age/element groups. To determine if the substitute subjects were significantly different from those that were randomly selected, extensive comparisons were made between these groups. The results showed no significant differences between rostered and substitute subjects for mean age within the five age categories used in the sampling strategy. In addition, the distribution of other demographic characteristics (i.e., self-reported race and primary language) were not significantly different between the two groups. Finally, no significant differences were found between rostered and substitute subjects for either the mean or the distribution of Height, Weight, or Body Mass Index [BMI=Weight (kg)/Stature $(m)^2$]. Although the substitute subjects were not chosen by the same random process as the rostered subjects, they were not significantly different for any of the collected demographic or anthropometric data. Because no differences were found between groups, both rostered and substitute subjects were included in the validation analyses.

Although rostered and substitute subjects did not differ, the measured sample was unusual in terms of the ratio of operational to support Military Occupational Codes

(MOC's). The bases chosen by the CF as measuring sites are apparently atypical in that an uncharacteristically high proportion of soldiers stationed at these bases serve in support roles. Very few of the measured soldiers were assigned to operational MOC's. This could have a significant impact on anthropometric distributions, in particular those related to Weight, because less physically fit CF personnel are preferentially placed in support roles (12). Thus, even when age is controlled, anthropometric differences may be present between the two broad MOC categories. The ratio of operational to support personnel measured for the CF Validation Study was not the same as that of the June 1993 CF male population for both the Land and the Sea elements. Thus, the sample cannot be considered a random sample of the male CF population, and demographic only matching methods cannot be validated properly. In addition, the Height and Weight data collected for the study should not be used to construct a matched database, since it is not representative of male CF personnel. Additional Height, Weight, and Waist Circumference data must be collected on a truly representative sample of the CF male population to corroborate the conclusions of this study and, if necessary, to serve as input for a matching algorithm.

Comparison with CF Express Database

Prior to the CF Validation Study, Natick was provided with the 1992 CF Express Database that containing Height and Weight data on almost 25,000 CF personnel (1). Since both the Express and Validation data sets are intended to be representative of the CF population, the two Height and Weight distributions should have been very similar. However, statistically significant differences were found between the CF Validation Study data and the 1992 CF Express Database for Height, Weight and BMI. These differences persisted even after controlling for age and element variation in the analysis.

The CF Validation Study subjects were consistently taller and heavier than those in the 1992 CF Express Database. The observed Height differences may result from rounding errors, since Height was recorded to the nearest decimeter in the 1992 CF Express Database and to the nearest millimeter in the Validation Study. The observed Weight differences are more difficult to explain. However, anecdotal evidence provided by DACME suggests that many CF personnel respond to the impending Express Test with crash-dieting and increased exercise, potentially resulting in an underestimation of the true Weight distribution in the Express database. It is also possible that the over-representation of less physically fit support personnel in the CF Validation Study has led to an over-estimation of population parameters for Weight.

Alternatively, it is possible that the observed differences are the result of sampling error in the CF Validation Study, since each element was sampled at a single post to minimize travel and logistical costs. To test the assumption that a statistically valid sample from a single military post can accurately represent a larger group, White male

infantry subjects, measured at two geographically distinct posts (Fort Bragg and Fort Ord) during the 1988 US Army Anthropometric Survey (ANSUR), were compared to one another, and to the overall ANSUR White male infantry population. No statistically significant differences were found between posts for either Height or Weight. In addition, no significant differences were found between each post and the overall US Army infantry population for Height or Weight. Thus, a stratified random sample can be obtained from a single location and be representative of the general population for the US Army. By extension, it should also be possible to measure a properly stratified sample from a single CF location that is representative of its element.

Based on the available evidence, ***neither*** the CF Validation Study data nor the 1992 CF Express Database should be used to estimate population parameters for matching procedures that require Height and Weight data. Instead, matching procedures that rely on anthropometric information should utilize data collected under controlled conditions and obtained from a random sample of CF male personnel with the appropriate age, element, and MOC distribution. These data could be collected while measuring teams are collecting data for the proposed CF Female Validation Study.

Ethnic Variation in the Canadian Forces

In 1985, Anthropology Research Project, Inc. matched individual subjects from a US military database by face length and face breadth to a CF sample. The resulting database was used to create a sizing system and specify design values for the CF XC4 mask (2). Subsequent testing revealed that the respirator sizing system failed to provide adequate coverage for the CF population and that the fit of critical dimensions was compromised for a significant proportion of test subjects (3). This outcome may have arisen from sampling deficiencies in the CF sample and/or the misapplication of anthropometric design values in the mask design and manufacturing process. However, these results raise the possibility that the matching procedure may have failed to produce an anthropometrically representative database for the CF population because it did not control for ethnic differences between Canadian and US White populations.

To examine the possibility that English and French ethnicities might need to be explicitly controlled for in a matching procedure for the CF, the CF Validation Study data were analyzed to determine if these ethnic groups had significantly different means or distributions for anthropometric dimensions. Student's *t*-tests and Mann-Whitney *U* tests were used to determine if any significant differences were present between subjects who identified themselves as ethnically English/British or French/French Canadian. Of the 18 dimensions analyzed, only Sitting Height was significantly different between the two ethnic groups, with the mean Sitting Height of the English/British ethnic group being 11.7 mm greater than the mean Sitting Height of

those who declared themselves as French/French Canadian. This result suggests that controlling for English/French ethnicity may be desirable in a Canadian-US matching process, particularly if the data will be used for setting anthropometric design values in crewstations.

Unfortunately, ethnicity is not routinely identified in the official records of CF personnel, so the relative frequency of these groups in the CF is unknown. Primary language of CF personnel, however, is recorded. The tests described above were repeated using primary language to define the English and French groups. No statistically significant differences were found between English and French primary language groups for any of the 18 anthropometric dimensions. Thus primary language would ***not*** be helpful as a proxy variable for ethnicity in matching procedures applied to the CF population.

Validation of Alternative Matching Procedures

Initially, two demographic only matching methods were tested. The first used stratified random sampling to select White male subjects from the ANSUR data pool so that the resulting age distribution was identical to that of the CF Validation Study subjects. Means for 12 of the 18 anthropometric dimensions were significantly different between the CF Validation Study and the resulting database. However, since differences of small magnitude can be reliably detected in large samples, statistically significant differences were examined relative to the associated mean observer error (4). When the means were adjusted for the magnitudes of observer error, 8 of the 12 variables in the age matched database continued to be significantly different.

Because the first matching procedure tested assumed a White racial background, and 3.6% of the subjects measured during the CF Validation Study were non-White, a second demographic only matching procedure was tested in which stratified random matching was used to select male subjects from ANSUR to match both the age and race distribution of the CF Validation Study sample. However, the same 8 anthropometric dimensions continued to be significantly different between the CF Validation Study and the matched sample. Thus, demographic only matching methods did not produce a statistically valid database. These results could be due exclusively to the fact that the validation sample is not representative of the CF male population. The possibility remains that a demographic only matching procedure could produce a representative matched database. Additional methods that incorporate anthropometric criteria were also tested using the validation sample.

Frequently, body size differences that persist in demographic matching procedures can be controlled when Height and Weight distributions are explicitly used instead. Two Height/Weight matching procedures were tested: Range matching and Individual Subject matching. Both procedures resulted in databases that statistically represented

the anthropometric distribution of the male CF population for all but 4 of the dimensions studied: Hand Breadth (2.8 mm), Bizygomatic Breadth (3.4 mm), Head Circumference (6.2 mm), and Waist Circumference (38.9 mm).

Although statistically significant, Hand Breadth, Bizygomatic Breadth and Head Circumference differences were well within acceptable levels for the development of CIE. However, the large difference for Waist Circumference merited further study. The Waist Circumference means are very similar among all of the Height/Weight matched databases, and are within a reasonable range of published data for the male CF population (5,6). It is possible that CF males may actually have larger waists than US Army males when they are matched for Height and Weight due to a slightly older age distribution. Waist Circumference is known to increase significantly with age in men, even when Weight and other circumferences do not. Again, the very high proportion of support personnel in the Validation Study may artificially increase the parameter estimate for Waist Circumference.

A demographic/anthropometric match was then conducted (Age $\pm$ 2.5 years, Height $\pm$ 0.5 inches and Weight $\pm$ 2.5 pounds) to see if simultaneous control of age, Height, and Weight in White ANSUR males could reduce the observed differences at the waist. The resulting matched database also underestimated the mean Waist Circumference, but this time by only 13.7 mm; not large considering that the combined ANSUR and CF Validation Study observer error for this dimension is 8 mm. Unfortunately, only 61.5% of the subjects were successfully matched, perhaps due to the under-representation of operational personnel in the Validation Study.

In an effort to increase the proportion of subjects matched, while maintaining Age as a matching variable, a final demographic/anthropometric matching procedure was tested in which the Height and Weight criteria remained the same. However, a flexible Age criterion was invoked, based on skeletal growth. This was restricted at the younger ranges to Age $\pm$ 2 years, but allowed older subjects to be matched within $\pm$ 5 years for Age. In addition, subjects with the closest Age match were chosen preferentially over those with closer anthropometric matches. While this method resulted in the successful match of 84% of the subjects, the mean Waist Circumference value continued to be severely underestimated by 33.7 mm. Again, these results may be due to the very small proportion of operational personnel in the validation sample.

While these results validate the Age, Race, Height and Weight matching process for the CF male population, they do not necessarily indicate that a valid CF database can be constructed using the ANSUR data. Unfortunately, the inclusion of Age, Height, and Weight in the matching algorithm greatly reduces the proportion of the CF population that can be matched with the ANSUR database. Whereas most of the CF Validation Study subjects (91.9%) could be

matched simultaneously for Height and Weight, only 61.5% of the subjects could be matched for Height, Weight ***and*** Age. An intermediate proportion of subjects (84%) could be matched when the flexible Age criterion was utilized. The difficulty with matching individuals arises because the CF validation subjects have significantly larger BMI's than ANSUR subjects in the 25-29 and >35 year age categories. Thus, for the same Age and Height, the CF validation study subjects are significantly heavier than their ANSUR counterparts, and simultaneous matching of all three variables is very difficult. Again, this may be due, in whole or in part, to the large proportion of support personnel in the validation sample.

Theoretically, the inability to simultaneously match CF male Age, Height, and Weight distributions with the ANSUR database ***should*** have been predictable from our earlier analyses of the CF Express data. Unfortunately, the CF Express database significantly underestimates the actual CF Weight and BMI distributions observed in the measured CF sample. As noted earlier, crash-dieting and increased exercise regimens undertaken by many personnel prior to the Express Test and/or the lack of operational personnel in the Validation Study, may cause the observed disparity. In addition, Height is recorded only to the nearest decimeter in the Express database, making feasibility assessments tenuous at best. Thus, Height, Weight, and Waist Circumference data must be measured on a representative sample of CF males to allow reassessment of the demographic matching procedure. If this method continues to fail, the additional data can be used to create a CF database matched on Age, Race, Height, and Weight.

Implications for the Creation of a Female CF Database

Because a demographic only matching procedure could ***not*** be validated with this sample, demographic matching methods alone should not be relied upon to derive a CF Female Anthropometric Database. Furthermore, a database cannot be derived for females using one of the validated Height/Weight matching procedures with the existing 1992 CF Express Database because Height was recorded to the nearest decimeter and the Weight data are suspect. Rather, reliable Height and Weight data must be collected from a stratified random sample of CF female personnel. These data could then be used to create a CF Female Anthropometric Database using the Individual Subject matching procedure validated during this study.

As was the case with this sample of CF male personnel, it is possible that CF females are heavier than their US Army counterparts of similar Age and Height. If so, we may encounter the same limitations in using the ANSUR database as a reference source for the CF female population. Although we have already examined this possibility using the CF Express database, and multivariate concordance for the

females appears positive, the CF Express database may also underestimate the Weight distribution of CF females, making matching difficult. Unfortunately, a better reference source for CF female Age, Height, and Weight distributions does not exist, so a second preliminary check to ensure that ANSUR provides sufficiently broad BMI coverage in the older Age ranges cannot be conducted before proceeding with a CF Female Validation Study.

Conclusions and Recommendations

When Range Matching and Individual Subject Matching on Height (± 0.5 inches) and Weight (±2.5 pounds) were tested, most variables were reasonably controlled; however the differences between the observed CF values for Waist Circumference and the matched databases were unacceptably large. When Age (± 2.5 years) was also included as a matching variable, the matching procedure controlled the remaining 16 anthropometric dimensions very well for the subjects that were successfully matched, ***including*** Waist Circumference. However, an acceptable match was found for only 67% of the CF Validation Study subjects. A number of subjects failed to be matched because ANSUR subjects of the appropriate Height and Weight could not be found within the specified age range of ± 2.5 years. When subjects were matched on Height (± 0.5 inches), Weight (±2.5 pounds), and flexible Age (± 2.0 years for those 25 years old and younger, ± 5.0 years for all older subjects) most of the subjects (84%) were successfully matched. This matching procedure successfully controlled all 18 of the anthropometric dimensions when compared to those CF subjects for whom a match was found, while increasing the proportion of subjects successfully matched from 67% to 84%. When compared to the entire measured sample, Waist Circumference continues to be underestimated by 33.66 millimeters. Again, the large Waist Circumference values observed for the CF Validation Study subjects could be due to the large proportion of support personnel measured for the Land and Sea elements, and ***not*** to a failure of the matching procedure itself.

Because the measured CF sample is not representative of the CF population, due to the proportion of operational and support personnel measured for the Land and Sea elements, a matched database cannot be created for the male CF population at this time since representative Height and Weight data are not available as input to the matching algorithm. However, this does not mean that a matched database could not be created using a representative anthropometric database that includes Height, Weight, and Waist Circumference. In addition, the demographic only matching procedure was not validated during this study, however, this could be due to the validation sample not being random and/or not adequately representing the operational personnel of the Land and Sea elements. Thus, it is still possible that a matching procedure using Race and Age could successfully produce an anthropometrically representative, matched database for the CF male population. If demographic only matching continues to pose problems, the representative Height and Weight data could be used to create a CF Male Anthropometric Database that would be much more reliable than a match based on the currently available measured sample. Because it is quite possible that the anthropometric distributions may not be the

same for support and operational personnel, and the proportion sampled did not replicate the general CF population, it would not be wise to use the Height and Weight data collected for this study to create a matched database.

To address the problem of representative data, and determine if the anthropometric distributions are truly different between operational and support personnel, a random sample of male CF personnel could be rostered for measurement at each of the bases where female soldiers will be measured for the CF Female Validation Study. The sample would be randomly selected to ensure that the measured sample has the proper Element/Age/MOC distribution. Only three variables, Height, Weight and Waist Circumference, would need to be collected on approximately 550 male subjects. (Because of the difficulties encountered with matching a proper Waist Circumference distribution during the study, this dimension should be taken in addition to Height and Weight.) To collect these measurements, an extra day or two of measuring could simply be added to the measuring team's stay at each base chosen as a measuring site for the CF Female Validation Study. These data could then be used to check the validity of a demographic only matching procedure, and, if such a procedure still cannot produce valid results, then the data can be used to construct a Height/Weight/Age matched database.

This document reports research undertaken at the U.S. Army Soldier Systems Command, Natick Research, Development and Engineering Center and has been assigned No. NRDEC/TR-96/031 in the series of reports approved for publication.

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APPENDICES

Appendix A

Canadian Forces Validation Study Test Plan

BACKGROUND AND PURPOSE

The following test plan will be used to validate the statistical matching procedure that is proposed for creating anthropometric databases for the Canadian Forces. This is the first phase of a three part anthropometric study being conducted by the US Army under contract to The Directorate of Ammunition, Clothing, Materiel and Engineering (DACME), Department of National Defence, Ottawa, Canada. DACME designs clothing and equipment worn by the Canadian Forces. DACME's research has shown that the Canadian Forces population has undergone significant changes in gender distribution and stature in the last decade and these factors affect the fit of standard clothing and equipment. To accommodate the entire range of body sizes in the Canadian Forces most efficiently, designers need an anthropometric database that represents the user population. Previous studies commissioned by the Canadian Department of National Defence have addressed some aspects of the problem (1,8,9,11), but DACME has recognized the need for a comprehensive database that can provide reliable, contemporary anthropometric data applicable to the Canadian Forces population. These data can be used by researchers to develop, design, and evaluate current and future items of clothing and equipment.

Such a database can be derived in two different ways: (1) conduct a large-scale anthropometric survey of a representative sample of the Canadian Forces, or (2) draw a statistically matched sample from an existing database that provides the demographic profile and specific dimensions of interest to Canadian researchers. This study takes the second option, tapping into the 1988 Anthropometric Survey of US Army Personnel (ANSUR), which is a large (ca 9000 subjects), contemporary, meticulously collected anthropometric database (7). The matching procedure relies on the assumption that American and Canadian military populations with identical race/ethnicity, age, height and weight distributions will have similar distributions for other anthropometric dimensions.

To test the assumptions underlying the matching procedure, demographic and limited anthropometric data will be collected from 500 Canadian Forces males at three bases representing the Land, Sea, and Air elements. This measured sample will be compared to a statistically matched sample in terms of height, weight, and the other 16 anthropometric dimensions measured during the validation study. If no significant deviations are found between the matched and measured distributions, the statistical matching procedure will have been validated. The process will then be used to create male and female databases with 70 anthropometric variables that are necessary for the design, sizing, and tariffing of protective clothing, equipment, and load-carrying systems.

A comprehensive explanation of the matching process and its validation is contained in an internal progress report entitle Matching and Validation Procedures for the Canadian Forces (10). The following sections present details of the sampling strategy and data collection procedures that will be used for the validation study.

SAMPLING STRATEGY

A well planned sampling strategy is required for this validation study to ensure that subjects are representative of the target Canadian Forces population. If the validation study concludes that height and weight are necessary for the matching procedure, in addition to demographic variables, then a reliable source of Canadian Forces height and weight data must be available. The Express Database cannot be used because height was recorded to the nearest decimeter, a range far too broad for matching. Thus, the height and weight data collected during the validation study may be needed to create the matched databases, requiring that the distributions be entirely representative of the contemporary Canadian Forces.

AGE RELATED FACTORS AND ANTHROPOMETRIC DIMENSIONS

Previous research has indicated that demographic factors such as race, gender, and age contribute a great deal to anthropometric variability (2,7). For this validation study, the sample will be limited to males and race and age data will be collected. If the matching technique is validated on males, then a female sample can be similarly matched since the procedure itself is not gender dependent. Because the Canadian Forces is predominately white, making age the key demographic factor in this study (10). The age distribution quartiles of the Canadian Forces and the US Army are quite different, with the Canadian military being older overall as illustrated in Table A1 (3,7). Because a great deal of growth and body shape changes are still occurring during the late teens and early twenties, standard quartile divisions are too broad to capture and accurately represent body shape and size variation in the $\leq$ 25 year age category.

To demonstrate anthropometric change with age, statistical means for 15 age-influenced dimensions were plotted for males in the ANSUR database. As can be seen in Figures 1-15, the youngest age group (17-19 years of age) consistently experiences more rapid change than the other groups. From the age of 20 onward, weight and other circumferences tend to increase with age on a fairly predictable slope without abrupt changes. The change from the younger to the older ranges is significant, indicating that age is explaining much of the variation seen in these dimensions. It was determined that five-year ranges would best capture the changes with age. The final age categories for this study are $\leq$ 19, 20-24, 25-29, 30-34, and $\geq$ 35 years of age.

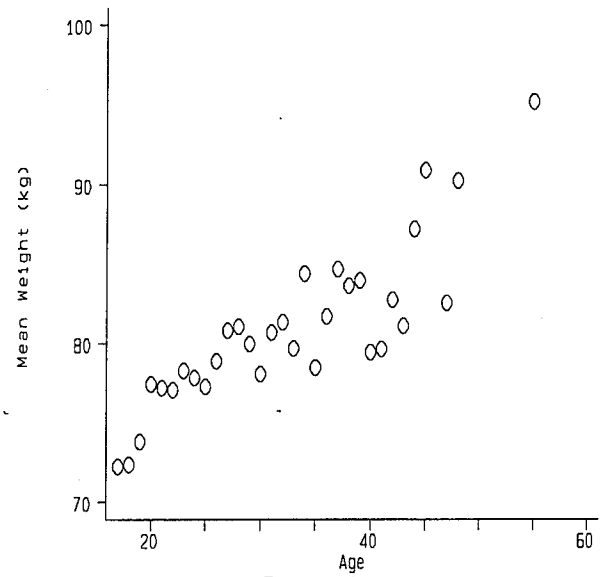
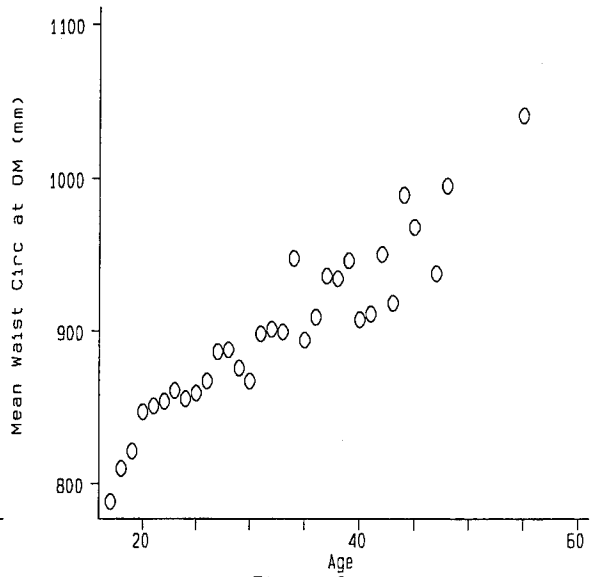


Figure 1



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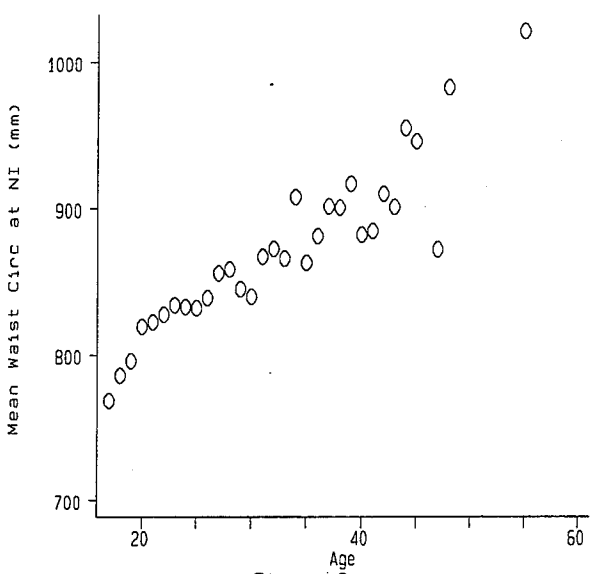

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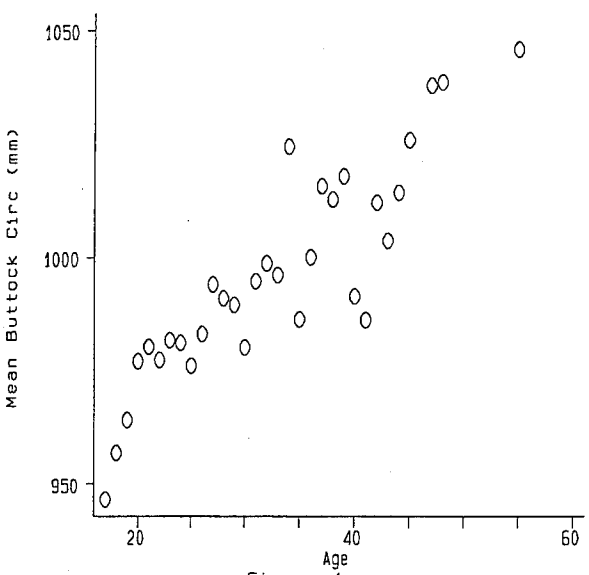

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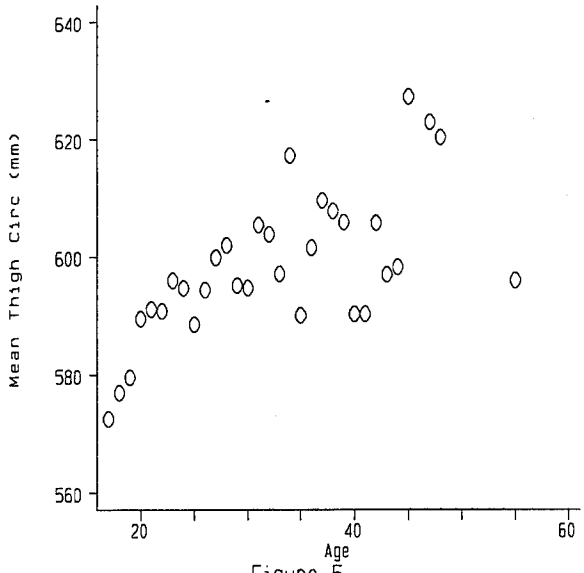

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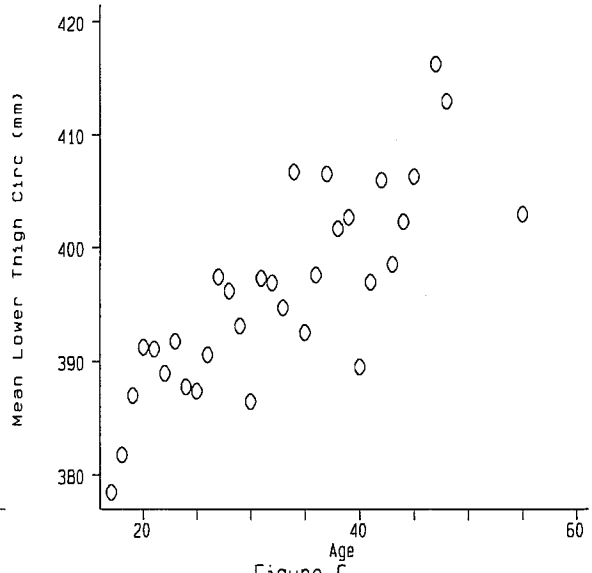

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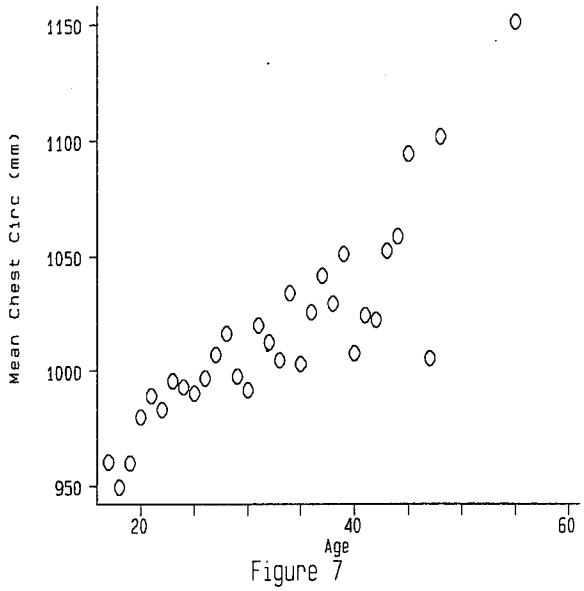

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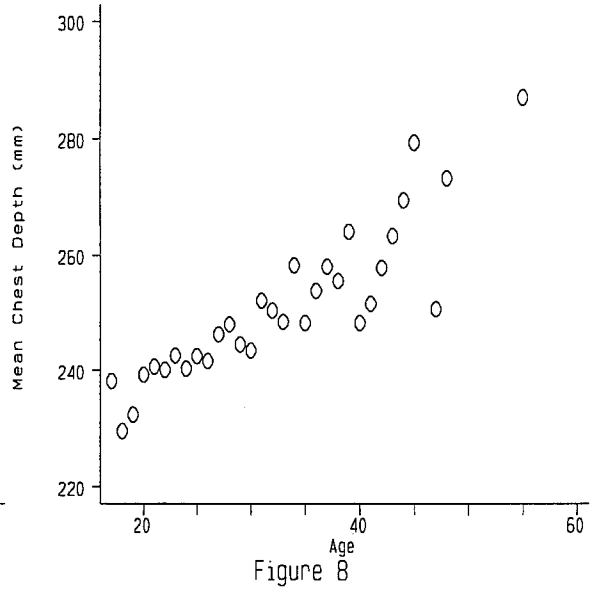

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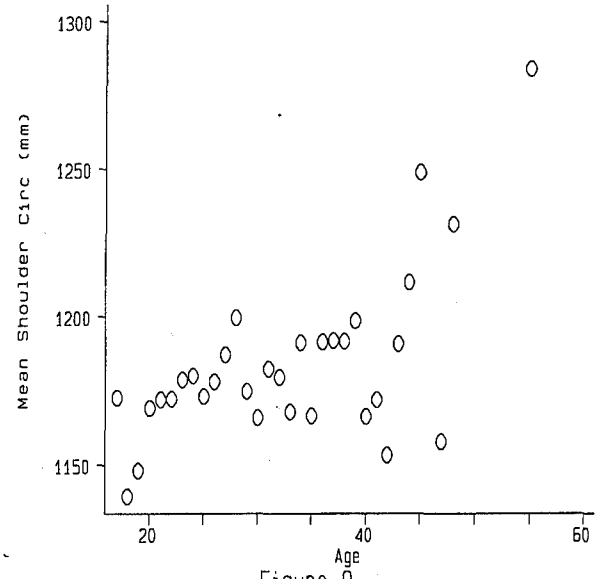

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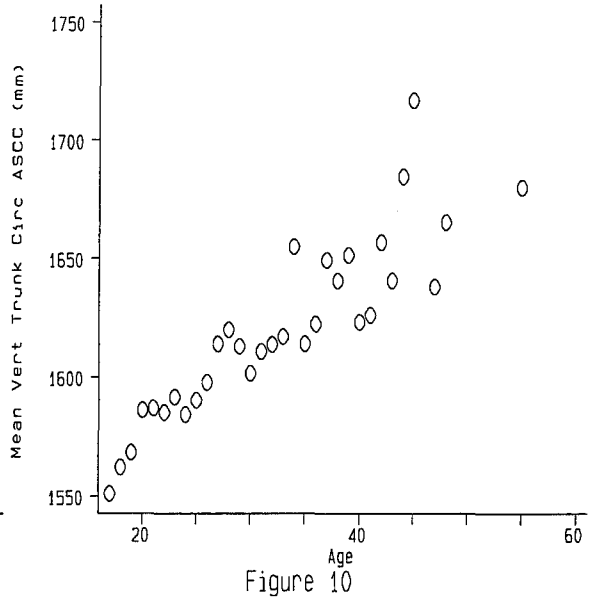

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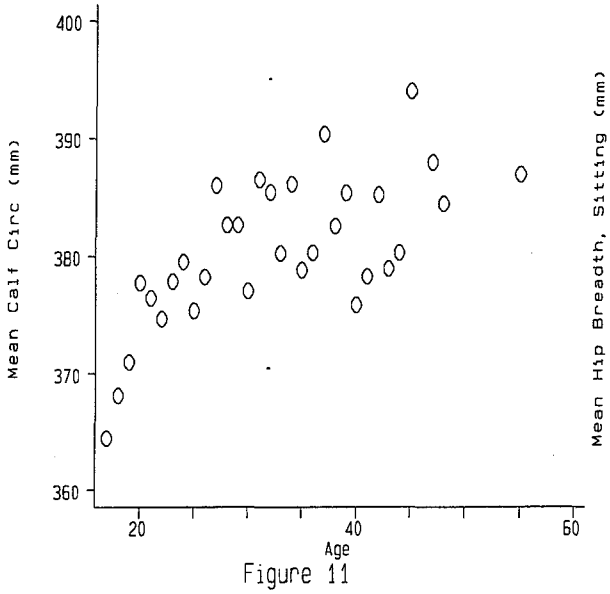

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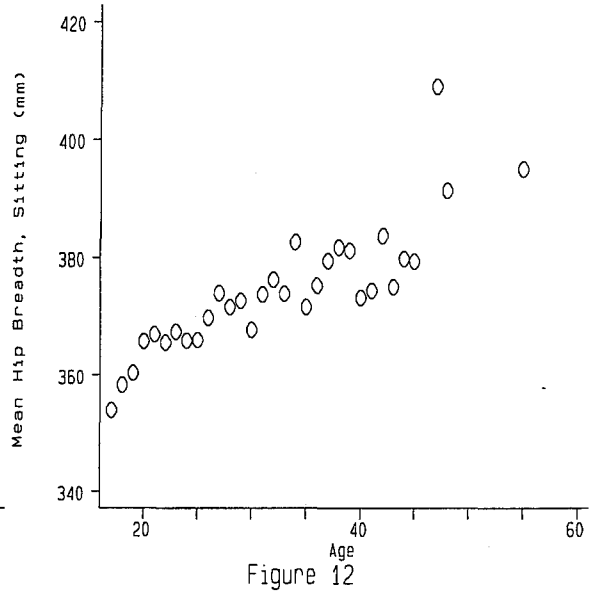

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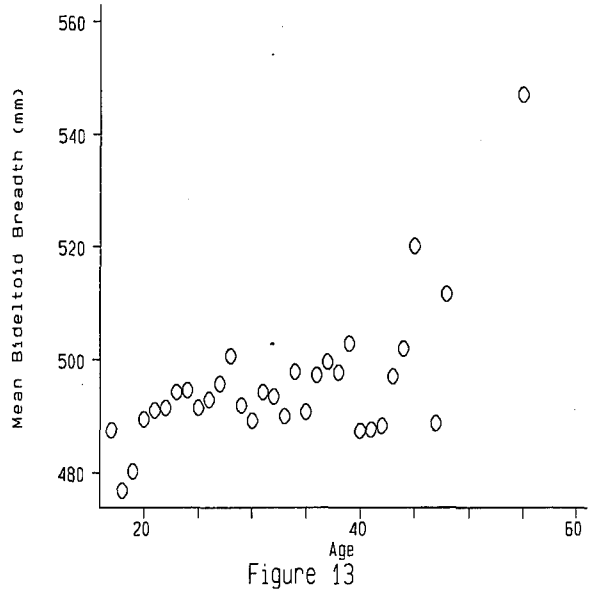

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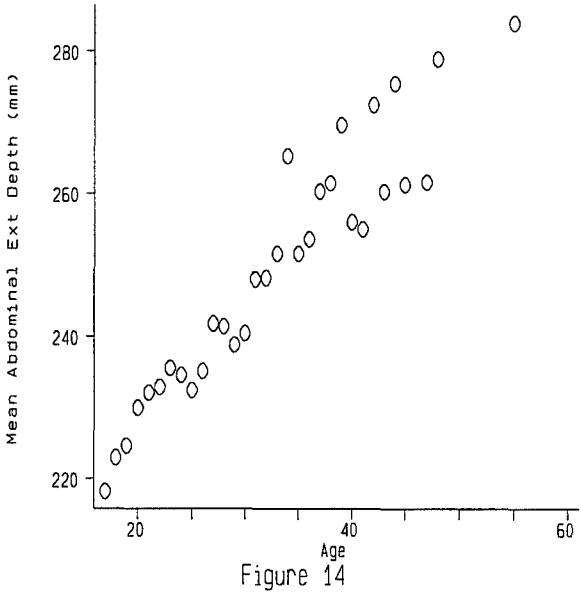

Figure 14

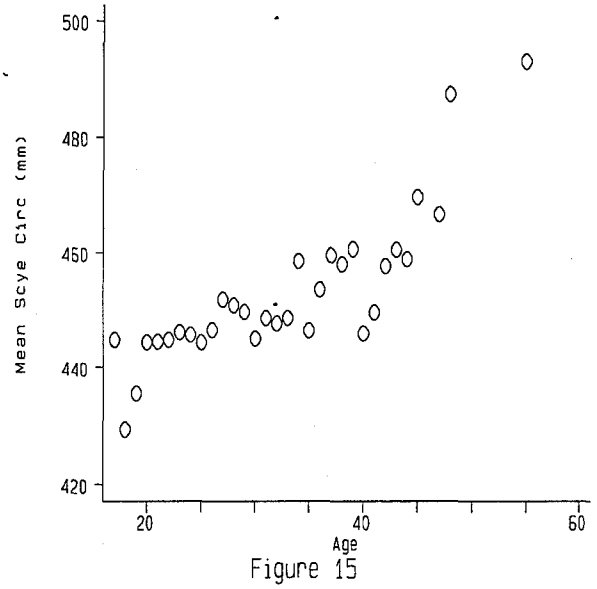

Figure 15

Table A1. Age Quartiles

	Canadian Forces	1988 US Army
Females		
	≤ 25	≤ 20
	26-28	21-24
	29-33	25-30
	≥ 34	≥ 31
Males		
	≤ 27	≤ 20
	28-31	21-24
	32-37	25-30
	≥ 38	≥ 31

Because these age categories will be used in the statistical matching procedure, the subjects measured in the validation study must represent all five of the categories in the same proportion that they are present in the Canadian Forces. This is a precaution in case a demographic-only match is not possible and valid Canadian Forces height and weight data are needed for the matching procedure. Subjects are to be measured at three bases: Trenton (Air), Kingston (Land), and Halifax (Sea). The age distribution at each base must be examined prior to scheduling subjects and if the distribution for the element being measured at a specific base is not statistically different from that of the element in the Canadian Forces overall, then a purely random selection of individuals should include the correct proportions for age categories in the given element. If, however, the age distribution is significantly different, then the subjects must be carefully selected for measurement based on their age. To ensure validity during the matching procedure, it is absolutely critical that the test subjects properly represent the older age categories because this is where the Canadian Forces and the US Army differ most.

HEIGHT AND WEIGHT VARIATION AMONG CANADIAN FORCES ELEMENTS

In addition to anthropometric variation due to age, height and weight differences are present among the Canadian Forces elements of Land, Sea, and Air. The height and weight information provided in the Express Database indicates that significant differences are present even when age is controlled as a factor. The use of non-parametric statistics (Kruskal-Wallis) in Table A2 shows that a significant difference exists among Land, Sea, and Air for height in four of the five age categories, while weight is only significantly different in the oldest age group. To ensure that this

variation is captured by the validation study, the sample must include subjects proportionately from each element in the contemporary Canadian Forces. Canadian personnel records indicate that 18.14% of all males are Sea, 42.46% are Land, and 39.40% are Air (12), and these percentages are taken into account during the rostering process.

Table A2. Land, Sea, and Air Anthropometric Variation: Male Express Data

Age and Variable	Land Mean	Sea Mean	Air Mean	p
≤ 19				
Height	17.18	17.23	17.41	.3734
Weight	74.17	72.45	76.23	.0406
20-24				
Height	17.19	17.27	17.32	**.0017***
Weight	76.77	75.95	77.46	.2354
25-29				
Height	17.22	17.38	17.31	**.0002***
Weight	78.89	78.80	78.85	.8774
30-34				
Height	17.14	17.31	17.29	**.0000***
Weight	79.50	81.47	79.81	.2549
≥ 35				
Height	17.13	17.33	17.24	**.0000***
Weight	80.75	82.78	81.26	**.0093***

*All differences significant at $p \leq .05$ using a Kruskal-Wallis test and a Bonferonni correction for multiple comparisons

SAMPLING STRATEGY FOR SURVEY OF 500 MALES

ELEMENT. The validation study sample must represent proportionately the elements of the Canadian Forces, due to height and weight differences among these three groups. Table A3 indicates the frequency of males in the three elements (12), and Tables A4 and A5 show the number of subjects who must be measured in each of these categories. Previous experience in such surveys suggests that an 80% to 90% rate of accession can be expected when subjects are rostered close to the time of measuring. Since the validation study is scheduled immediately after annual reassignments in the Canadian Forces, only a 70% accession rate of subjects will be assumed, and a total of 750 subjects will be rostered to ensure a measuring goal of 500.

AGE. In addition, test participants in the study will be selected to reflect the proportion of Canadian Forces males in the five age groupings chosen for the matching procedure. The number and frequency of males present in these categories as of 26 May 1993 are shown in Table A3 (12). Subjects will be selected from personnel lists provided by Canada for each base to be visited during the study. Because the Express Data do not include all of the personnel present at each base and major personnel changes occur in June prior to the onset of this study, the age distributions at each base must be re-analyzed before the rostering choices are finalized. This will guarantee that the age distributions are equivalent to the Canadian Forces at the time of the study and, if they are not, will enable corrections to be made during the rostering process to provide an appropriate age distribution of the subjects to be measured.

Table A3. Male Age Distribution in the Canadian Forces

Age Category	Land	Sea	Air	Total
≤ 19	110 (0.16%)	120 (0.17%)	113 (0.16%)	343 (0.50%)
20-24	4410 (6.39%)	2140 (3.10%)	2063 (2.99%)	8613 (12.47%)
25-29	7658 (11.09%)	2964 (4.29%)	4938 (7.15%)	15560 (22.53%)
30-34	7542 (10.92%)	3028 (4.38%)	7698 (11.15%)	18268 (26.45%)
≥ 35	9600 (13.90%)	4273 (6.19%)	12398 (17.95%)	26271 (38.04%)

SAMPLING GOALS. Table A4 presents the rostering goal of the study by age and element for Canadian Forces males, and Table A5 indicates realistic measurement goals. If the sampling goals are met, the demographic and anthropometric data collected will be more than adequate for use in validating the statistical matching procedure. In addition, the height and weight data can be used to structure the matching process if a demographic-only match is not feasible.

Table A4. Sampling Goals: Rostering

Age / Element	≤19	20-24	25-29	30-34	≥35	Totals
Land	1 (0.16%)	48 (6.39%)	83 (11.09%)	82 (10.92%)	104 (13.90%)	318 (42.46%)
Sea	1 (0.17%)	23 (3.10%)	32 (4.29%)	33 (4.38%)	47 (6.19%)	136 (18.14%)
Air	1 (0.16%)	22 (2.99%)	54 (7.15%)	84 (11.15%)	135 (17.95%)	296 (39.40%)
Totals	3 (0.40%)	93 (12.40%)	169 (22.53%)	199 (26.53%)	286 (38.13%)	750 (100.00%)

Table A5. Sampling Goals: Measuring

Age / Element	≤19	20-24	25-29	30-34	≥35	Totals
Land	1 (0.16%)	32 (6.39%)	55 (11.09%)	55 (10.92%)	69 (13.90%)	212 (42.46%)
Sea	1 (0.17%)	16 (3.10%)	21 (4.29%)	22 (4.38%)	31 (6.19%)	91 (18.14%)
Air	1 (0.16%)	15 (2.99%)	36 (7.15%)	56 (11.15%)	89 (17.95%)	197 (39.40%)
Totals	3 (0.40%)	63 (12.40%)	112 (22.53%)	133 (26.53%)	189 (38.13%)	500 (100.00%)

METHODS

TEST PARTICIPANTS

The test participants will be 500-750 Canadian Forces males, in the age and element distribution given in the sampling target (see Tables A4 and A5). Fifty subjects should be scheduled daily; 25 for the morning session and 25 for the afternoon session. If accession rates are higher than expected and time constraints prohibit their full measurement, excess subjects will be measured for height and weight only and released.

TEST PERSONNEL

Four individuals will have primary responsibility for the conduct of this study, with responsibilities as detailed below.

TEAM LEADER. A doctoral-level anthropologist will serve as principal investigator at each test site. This individual will be the primary point of contact for the Canadian Forces Base Liaison, coordinate the activities of other test personnel, ensure that the study is being conducted in the prescribed manner, brief test participants, review completed biographical surveys, elicit ethnicity information, and mark the hand, arm and face anatomical landmarks on each subject prior to measurement.

ANTHROPOMETRIC MEASURER/RECORDER TEAM. Two anthropologists will be trained to measure and record anthropometric data. One of the team members will be responsible for marking the shoulder, omphalion, and foot anatomical landmarks. At any given time, one will measure and the other will enter the results directly into a computer where an editing program will screen the data for unusual values. The measurer/recorder team will switch at will to alleviate fatigue; however, the role of marker will not be switched.

CANADIAN FORCES BASE LIAISON. A senior ranking officer at each base will assist in coordination and scheduling of test subjects and act as an English/French interpreter when necessary.

DATA ACQUISITION FORMS

Each test subject will be given a clipboard with an instruction sheet, two biographical data collection forms, and a diskette. Each subject will have the choice of receiving a test packet in either English or French. The test date and a subject number will already be entered at the top of each form and on the diskette. Descriptions of the forms follow.

INSTRUCTION SHEET (Attachment A) This sheet contains a summary of the purpose of the study and a brief description of the procedures involved.

BIOGRAPHICAL SURVEY (Attachment B) These forms document demographic information from the subject: name, age, rank, unit assignment, race, and ethnicity. It will be completed by the subject prior to measurement, except for the ethnicity questions. The team leader will question each subject individually on this topic.

MEASUREMENT RECORD (Attachment C) Body measurement data are entered directly into a computer by the recorder as they are called out by the measurer. A hard copy of the data will be printed immediately. Should a computer failure occur, this form will be used to record data. All entries are in millimeters, except for weight measured to the nearest 0.1 kilogram.

PHYSICAL LAYOUT OF TEST AREA

The test area should consist of either three rooms in close proximity to one another or one large room partitioned into three areas.

BRIEFING AREA. This area is used for the in and out-processing of test participants. It should be furnished with 10 chairs for subjects and a small Table for the briefer's computer. A 110 voltage outlet is required for the computer. Test subjects will be briefed on procedures and will fill out the biographical survey, which will be checked by the briefer while the subject changes clothes. Subjects will be landmarked in this room as well.

CHANGING AREA. This area will be used by the subjects to change from their uniforms into shorts and t-shirt. Facilities for garment storage should be provided (e.g., racks and hangers).

MEASURING AREA. This area will be used to place additional landmarks on the subject's shoulders, waist, and right foot and to measure the subjects. The area should be well lighted, and should contain two Tables for a computer and anthropometric instruments and two chairs. A 110 voltage outlet is required for the recorder's computer. There must be a right-angle corner with enough wall space to mount a 5 foot by 8 foot chart for measuring span.

EQUIPMENT

Anthropometric and related equipment will be provided by the US Army, to include anthropometers, and stands, steel tapes, a scale, sliding and spreading calipers, a span chart, a foot leveler, 2 levels, small ruler, 2 Compaq personal computers, 2 printers, printer paper, 750 (3.5") computer diskettes, a measuring platform with safety railing, nylon running shorts, foot boxes, a hand board, blocks, mirrors, marking pens, alcohol wipes, clipboards, and pencils.

PROCEDURES

PRE-TEST ACTIVITIES

ANTHROPOMETRIC STANDARDIZATION. The primary activity to take place prior to testing is the training of the measurer/recorder team and the marker (6). All three members of the validation study team must be familiar with the landmarks and the measurements to be taken. These are identical to those used in ANSUR and are described in Attachment D. The goal of the training practice is to achieve the extremely high level of precision and repeatability required to ensure that the body measurement data collected during the study are valid and reliable. The level of intra-observer and inter-observer repeatability to be achieved for each of the 18 anthropometric measurements is detailed in Table A6. These are the same levels of observer error which were documented in the ANSUR survey.

Table A6. Allowable and Observed Error for ANSUR Males

Variable	Observed Error	Allowable Error
Biacromial Breadth	3.62	4.00
Bizygomatic Breadth	.58	1.00
Buttock Circumference	4.15	5.00
Chest Circumference	6.88	7.00
Crotch Height	6.02	6.00
Foot Breadth, Horizontal	.56	1.00
Foot Length	.53	1.00
Hand Breadth	.32	1.00
Hand Length	1.17	2.00
Head Circumference	.82	1.00
Menton-Sellion Length	1.05	2.00
Sitting Height	3.14	4.00
Sleeve Outseam	3.91	4.00
Span	7.24	8.00
Stature	2.94	3.00
Waist Circumference (Omphalion)	4.33	5.00
Waist Height (Omphalion)	2.74	3.00
Weight	.12*	.20

*All values are in millimeters, except weight in kilograms

MISCELLANEOUS PRE-TEST ACTIVITIES. Data recording and editing software will be loaded and tested prior to the beginning of the study. All diskettes must be formatted and data form packets must be assembled. Data forms and diskettes must be pre-stamped with subject numbers. Supplies must be gathered and equipment calibrated.

TEST ACTIVITIES

PARTICIPANT SCHEDULING. The maximum time required to process each subject through all phases of the survey is 45 minutes, including briefing, filling out the biographical questionnaire, landmarking, and measurement. During an eight-hour workday, three subjects will be asked to report to the test site every half hour, according to a schedule coordinated with the liaison at each base.

PARTICIPANT PROCESSING. As each group of participants arrives at the test site, they will enter the briefing area, sign in at the log book, and be seated. Each subject will be given a clipboard and packet of test forms in their preferred language, either English or French. They will read the instruction sheet, and the team leader will brief them concerning the purpose of the study and answer any questions. The subjects will fill out the biographical survey form.

The team leader will review each biographical survey for completeness and accuracy as it is entered into the computer. She will complete any biographical information needed and question the subject for ethnicity information. The team leader will then mark five of the anatomical landmarks using a surgical marker. The landmarks are located on the face, arm, and hand. The subjects will be given shorts (and t-shirt, if needed) and sent to the changing area. Once changed, the subjects will wait just outside the measuring area until summoned one by one for measurement. If higher than expected attendance occurs and time constraints prevent full measurement of a subject, his height and weight only will be measured and recorded.

The chosen member of the measurer/recorder team will mark the remaining four landmarks (shoulders, omphalion, and foot). A total of 18 measurements will be taken from each subject and recorded. One diskette will be used to store the data recorded for each subject. The actual measuring process will take about 20 minutes. When measurement is complete, the subject can change back into his clothes and be dismissed. Twice each day (once in the morning and once in the afternoon), one subject will be chosen at random to be measured twice for the collection of observer error data.

TEST SUPPORT AND RECORD KEEPING. Great care will be taken throughout the testing period to ensure that the sampling goals are met. A sample tally sheet is contained in Attachment E. If it is found that subjects are not reporting to the test site from specific age categories as needed, then additional personnel must be rostered from these groups. After each of the first three weeks of the test, completed computer diskettes will be sent by overnight mail to the Anthropology Group at Natick, so that the

statistician can begin compiling the database and run additional checks for extreme values. In this way, the field team will receive rapid feedback on the success of the sampling strategy.

POST-TEST ACTIVITIES

After data collection is complete and encoded data are available on computer, a number of statistical analyses will be performed using these data to validate the process of statistically matching a database for the Canadian Forces. In brief, a minimum of five different databases will be matched to the demographic profile of the subjects measured in the validation study. Each theoretical matched database will be evaluated by determining the presence of statistically significant differences from the anthropometric data measured for the validation study. If differences are detected that are larger than the observer error for height, weight, or any of the other 16 dimensions measured, that match will be considered invalid. If necessary, the procedure will be repeated using both demographics and height and weight variables in the match to improve control over the other variables. If a suitable matching method is obtained, the matching process will be used to create male and female Canadian Forces anthropometric databases that will be summarized in Project 2. If no matching procedure is validated, the data collected in this study will be used to recommend a sampling strategy for use in a Canadian Forces anthropometric survey.

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11. Stewart, LE, 1985. 1985 Anthropometric Survey of Canadian Forces Aircrew. Technical Report No. 85-12-01, Human Elements Incorporated, Toronto, Ontario.

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Attachment A: Instruction Sheet

CANADIAN FORCES DATABASE VALIDATION STUDY

Military clothing and protective equipment must be designed and sized to fit their users--YOU. This mission is accomplished with an Anthropometric Database, a collection of body measurements of Canadian Forces personnel representing all the different body sizes and shapes present in the Canadian Forces. We need your help in updating and standardizing the Canadian Forces database. Although your participation will not directly benefit you today, you can be sure that it will result in better fitting clothing and equipment for you and other members of the Canadian Forces in the very near future.

We ask your support in two aspects of this study. First, you will be asked to provide some biographical information about you and your career in the Canadian Forces. Second, while wearing shorts and t-shirt, you will be measured for height, weight, and 15 other dimensions, including body circumferences and hand and foot lengths and breadths. The study has the full approval and support of your commanders.

All information and body measurements obtained from you today will be considered privileged information and will be held in confidence. You will not be identified individually in any presentation of the results. The measuring process involves no risks to your health or well-being. We need your full cooperation in order to get the best data for the Canadian Forces anthropometric database.

THANK YOU FOR HELPING TO UPDATE THE CANADIAN FORCES ANTHROPOMETRIC DATA BASE

Subject Number:_____

CANADIAN FORCES DATABASE VALIDATION

BIOGRAPHICAL DATA: MILITARY HISTORY

TODAY'S DATE: _____ TODAY'S POST: _____
Month Day Year

1. Name:_____

2. UIC and base name to which you are assigned:

_____

3. Military Component: _____ Land _____ Sea _____ Air

4. Military Personnel Class:

___ Enlisted
___ Warrant Officer (Specify Branch:_____)
___ Commissioned Officer (Specify Branch:_____)

5. Rank: _____ (e.g., LCOL)

6. Time in Service: _____Years, _____ Months (e.g., 2 years, 4 months)

7. MOC: _____

CANADIAN FORCES DATABASE VALIDATION

BIOGRAPHICAL DATA: PERSONAL HISTORY

8. Your Birthdate: _____
(Month) (Day) (Year)

9. Age: _____Years

10. Sex: _____ Male _____ Female

11. Race: _____White, not of Hispanic Origin
_____ Black, not of Hispanic Origin
_____ Hispanic
_____ Aboriginal (Specify:_____)
_____ Asian/Pacific Islander
_____ Mixed (Specify:_____)
_____ Other (Specify:_____)

12. Primary Language: _____ French _____ English _____ Other (Specify:_____)

13. How tall are you in bare feet? _____ (e.g., 5 ft 8 in) _____ (e.g., 157 cm)
Feet Inches Centimeters

14. How much do you weigh without clothes? _____ Kilograms

15. Your Birthplace:_____

16. Mother's Birthplace: _____

17. Father's Birthplace: _____

18. Mother's Race:. _____White, not of Hispanic Origin
_____ Black, not of Hispanic Origin
_____ Hispanic
_____ Aboriginal (Specify: _____)
_____ Asian/Pacific Islander
_____ Mixed (Specify: _____)
_____ Other (Specify: _____)

19. Father's Race: _____White, not of Hispanic Origin
_____ Black, not of Hispanic Origin
_____ Hispanic
_____ Aboriginal (Specify: _____)
_____ Asian/Pacific Islander
_____ Mixed (Specify: _____)
_____ Other (Specify: _____)

DO NOT WRITE BELOW THIS LINE:

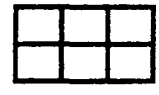
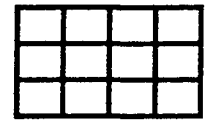
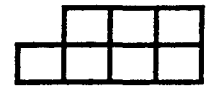
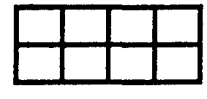
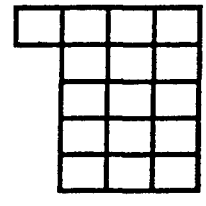
20. Your Ethnicity: _____

21. Mother's Ethnicity: _____

22. Father's Ethnicity: _____

Subject Number: _____

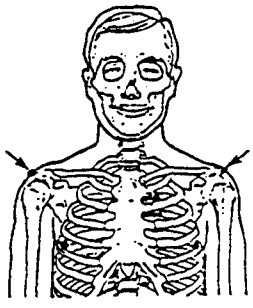
CANADIAN FORCES DATABASE VALIDATION: MEASUREMENT RECORD

Scale Wall Scale, Block	1. Weight 2. Span	
Pooch Caliper, 8mm Board	3. Hand Length 4. Hand Breadth	
Footbox, Footblock	5. Foot Length 6. Foot Breadth, Horizontal	 
Anthropometer	7. Stature 8. Waist Height 9. Crotch Height	
Tape	10. Sleeve Outseam Length 11. Chest Circumference 12. Waist Circumference (Omphalion) 13. Buttock Circumference	 
Anthropometer Pooch Caliper Spreading Caliper Tape	14. Sitting Height 15. Biacromial Breadth 16. Menton-Sellion Length 17. Bizygomatic Breadth 18. Head Circumference	

ANTHROPOMETRIC LANDMARKS

Acromion, right and left

The point of intersection of the lateral border of the acromial process and a line running down the middle of the shoulder from the neck to the tip of the shoulder.

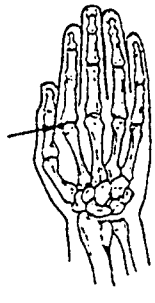


First Metatarsophalangeal Protrusion

The most medial protrusion of the right foot in the region of the first metatarso-phalangeal joint.

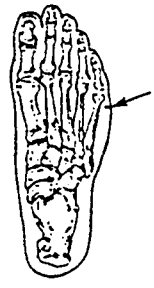
Metacarpale II

The lateral point of the right metacarpo-phalangeal joint II (at the base of the index finger).



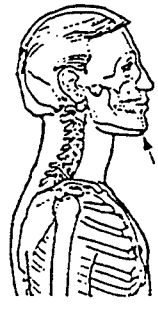
Fifth Metatarsophalangeal Protrusion

The most lateral protrusion of the right foot in the region of the fifth metatarso-phalangeal joint.



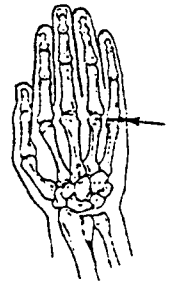
Menton

The inferior point of the mandible in the midsagittal plane (bottom of the chin).



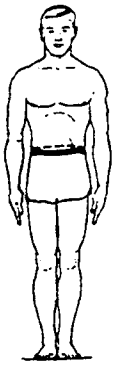
Metacarpale V

The medial point of the right metacarpo-phalangeal joint V (at the base of the little finger).



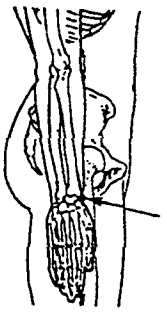
Omphalion

Center of the navel.



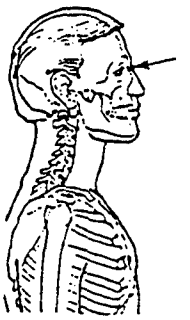
Stylion

The lowest point at the bottom of the radius.



Sellion

The point of the deepest depression of the nasal bones at the top of the nose.



MEASUREMENT DEFINITIONS

WEIGHT

Landmark: None

Instrument: Scale

Position of Subject: Subject stands on center of scale platform.

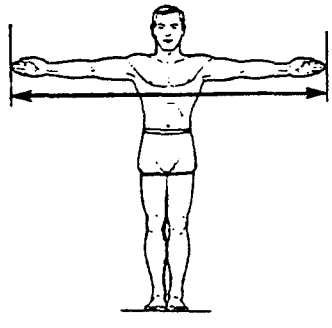
Procedure: Scale is read to the nearest 0.1 kilogram.

SPAN

Landmarks: Dactylion III, right; dactylion III, left

Instrument: Wall-mounted scale and block

Position of Subject: Subject stands with his back against a wall-mounted scale and his feet together. Both arms and hands are stretched horizontally against the back wall with the tip of the third finger of one hand just touching a side wall. Subject's arms are stretched laterally as much as possible.



Procedure: Stand near the subject's hand that is opposite the side wall. Use a block to establish, on the wall-mounted scale, the distance between the side wall and the tip of the middle finger. The subject's middle fingers are in light contact with the side wall on one side and the block on the other.

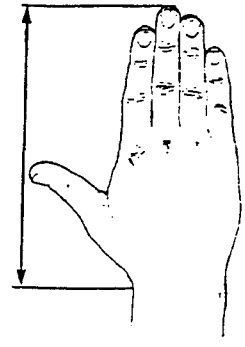
HAND LENGTH

Landmarks: Stylion; dactylion III, right

Instrument: Poech sliding caliper

Position of Subject: Subject sits with the right palm on a table and the fingers on a flat surface 8 mm higher. The fingers are together and the thumb is held away from the hand at about a 45-degree angle. The measurer presses the hand into firm contact with the table and instructs the subject to hold this position. The middle finger is parallel to the long axis of the forearm.

Procedure: Stand at the left of the subject and use the Poech sliding caliper to measure the length of the hand between the two landmarks. Place the fixed blade of the caliper on stylion. The beam of the caliper is parallel to the long axis of the arm.



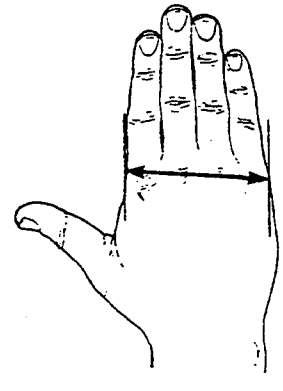
HAND BREADTH

Landmarks: Metacarpale II; metacarpale V

Instrument: Sliding caliper

Position of Subject: Subject sits with the right palm on a table and the fingers on a flat surface 8 mm higher. The fingers are together and the thumb is held away from the hand at about a 45-degree angle. The measurer presses the hand into firm contact with the table and instructs the subject to hold this position. The middle finger is parallel to the long axis of the forearm.

Procedure: Stand in front of the subject and use the sliding caliper to measure the breadth of the hand between the two landmarks.



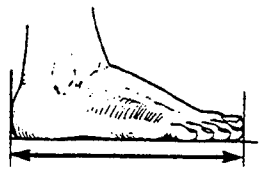
FOOT LENGTH

Landmarks: Acropodion; pternion; fifth metatarsophalangeal protrusion

Instrument: Footbox and block

Position of Subject: Subject stands on a table with each foot in a footbox.

Procedure: Stand behind the subject to position the right foot in the box with the back of the heel lightly touching the rear of the box and the fifth metatarsophalangeal protrusion lightly touching the side of the box. The medial side of the right foot is parallel to the long axis of the box. Move to the right side of the subject to take the measurement. Place a block against the tip of the longest toe to establish the length of the foot on the footbox scale.



FOOT BREADTH, HORIZONTAL

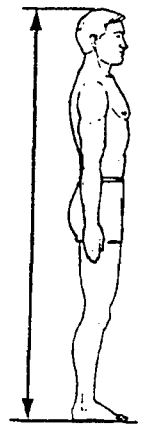
Landmarks: First metatarsophalangeal protrusion; fifth metatarsophalangeal protrusion

Instrument: Footbox and block

Position of Subject: Subject stands on a table with each foot in a footbox.

Procedure: Stand in front of the subject and position the right foot in the box with the back of the heel lightly touching the back of the box and the side of the foot at the drawn fifth metatarsophalangeal protrusion landmark lightly touching the side of the box. The medial side of the right foot is parallel to the long axis of the box. Place a block against the drawn landmark at the first metatarsophalangeal protrusion to establish the horizontal breadth of the foot on the footbox scale.

STATURE



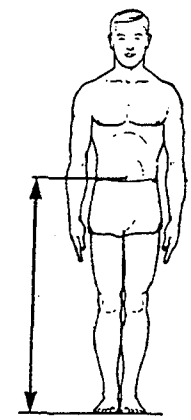
Landmark: None

Instrument: Anthropometer

Position of Subject: Subject stands erect, head in the Frankfort Plane, heels together, and weight distributed equally on both feet.

Procedure: With arm of anthropometer firmly touching the scalp, measure the vertical distance from the standing surface to the top of the head.

WAIST HEIGHT (OMPHALION)



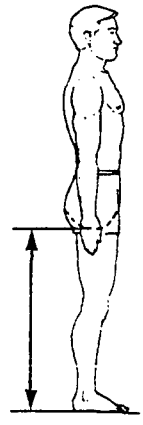
Landmark: Omphalion

Instrument: Anthropometer

Position of Subject: Subject stands erect looking straight ahead, heels together, and weight evenly distributed on both feet.

Procedure: Stand in front of the subject and use an anthropometer to measure the vertical distance between the standing surface and the center of the navel. The measurement is made at the maximum point of quite respiration.

CROTCH HEIGHT



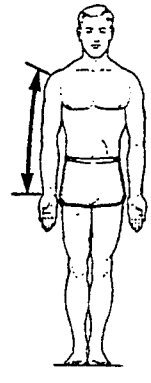
Landmark: None

Instrument: Anthropometer

Position of Subject: Subject stands erect, heels approximately 10 cm apart and weight distributed equally on both feet.

Procedure: Holding an anthropometer in front of the subject, request that he raise the arm of the anthropometer up into the crotch until light contact is made between the scrotum and right leg. The subject brings his heels together maintaining the contact of the anthropometer arm in the crotch. Record the vertical distance from the standing surface to that level.

SLEEVE OUTSEAM LENGTH



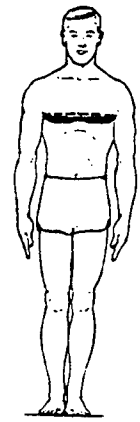
Landmarks: Acromion, right; stylion

Instrument: Tape

Position of Subject: Subject stands erect with both arms straight and the palms facing forward. The elbows lightly touch the sides of the body.

Procedure: Stand at the right of subject and use a tape to measure the straight-line distance between the acromion landmark and the stylion landmark. The tape will span body hollows. Be sure the zero point of the tape is on the acromion landmark.

CHEST CIRCUMFERENCE



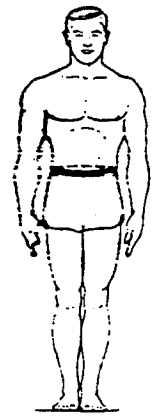
Landmark: Nipples

Instrument: Tape

Position of Subject: Subject stands erect looking straight ahead, heels together and weight distributed equally on both feet. The arms are abducted sufficiently to allow clearance of a tape between the arms and trunk and then relaxed.

Procedure: With the tape held in a horizontal plane, measure the circumference of the chest at the level of the nipples. The reading is made at the maximum point of quiet respiration.

WAIST CIRCUMFERENCE (OMPHALION)



Landmark: Omphalion

Instrument: Tape

Position of Subject: Subject stands erect looking straight ahead, heels together, and weight evenly distributed on both feet.

Procedure: With the tape held in a horizontal plane, measure the circumference of the trunk at the level of the waist landmark. The reading is made at the maximum point of quiet respiration. The subject must not pull in his stomach.

BUTTOCK CIRCUMFERENCE

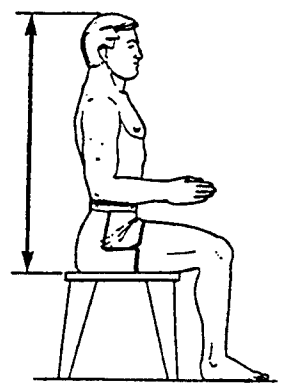
Landmark: None

Instrument: Tape

Position of Subject: Subject stands erect looking straight ahead, heels together, weight evenly distributed on both feet.

Procedure: The tape is passed around the hips in the horizontal plane at the level of the maximum posterior protrusion of the buttocks. Measure the maximum circumference of the hips at this level.

SITTING HEIGHT



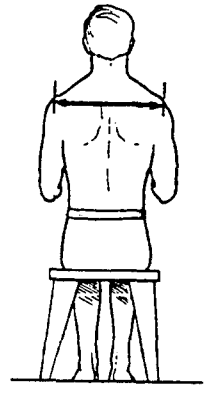
Landmarks: None

Instrument: Anthropometer

Position of Subject: Subject is in the anthropometric sitting position with the head in the Frankfort plane.

Procedure: Stand at right rear of subject and use anthropometer to measure the vertical distance between the sitting surface and the top of the head. Use sufficient pressure to compress the hair.

BIACROMIAL BREADTH



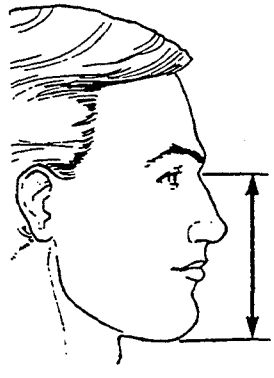
Landmark: Acromion, right; acromion, left

Instrument: Beam caliper

Position of Subject: Subject is in the anthropometric sitting position, with forearms at right angles to the body.

Procedure: Standing behind subject, measure the distance between the acromion landmarks. this measurement is taken at the maximum point of quiet inspiration.

MENTON-SELLION LENGTH



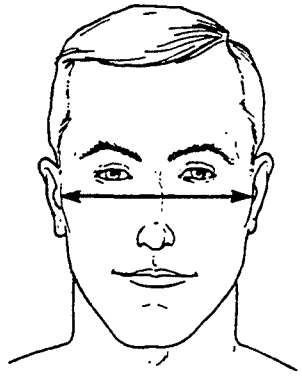
Landmarks: Menton; sellion

Instrument: Sliding caliper

Position of Subject: Subject sits. The teeth are together but not clenched.

Procedure: Stand toward the right of the subject and use a sliding caliper to measure in the midsagittal plane the distance between the landmarks. Place the fixed blade of the caliper on sellion.

BIZYGOMATIC BREADTH



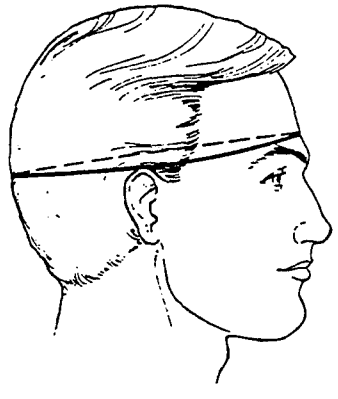
Landmarks: Lateral projection of zygomatic arches

Instrument: Spreading caliper

Position of Subject: Subject sits.

Procedure: Stand in front of the subject and use a spreading caliper to measure the maximum horizontal breadth of the face between the zygomatic arches.

HEAD CIRCUMFERENCE



Landmarks: None

Instrument: Tape

Position of Subject: Subject sits.

Procedure: Stand to the right of the subject and use the tape to measure the maximum circumference of the head above the attachment of the ears to the head. The bottom of the tape should pass just above the ridges of the eyebrows and around the back of the head.

Canadian Forces Database Validation: % Male No- Shows

Today's Date : _____

AGE	LAND	SEA	AIR	TOTAL
< 19 Years	Actual No-Shows:			
	% No-Shows			
20 - 24 Years	Actual No-Shows:			
	% No-Shows			
25 - 29 Years	Actual No-Shows:			
	% No-Shows			
30 - 34 Years	Actual No-Shows:			
	% No-Shows			
> 35 Years	Actual No-Shows:			
	% No-Shows			
TOTAL				

Canadian Forces Database Validation: Male Tally Sheet (Age By Element)

Today's Date : _____

AGE	LAND Kingston	SEA Halifax	AIR Trenton	TOTAL
< 19 Years	To Date:			
	Goal 1	1	1	3
20 - 24 Years	To Date:			
	Goal 32	16	15	63
25 - 29 Years	To Date:			
	Goal 55	21	36	112
30 - 34 Years	To Date:			
	Goal 55	22	56	133
> 35 Years	To Date:			
	Goal 69	31	89	189
TOTAL	212	91	197	500

Appendix B

Validation for Head/Face Matched Database

Specific types of research, such as the development of a respirator for a specialized subgroup of the military, may require the use of a unique database that contains appropriate head and face dimensions for that population. To avoid costly large-scale surveys, such a database can be created by selecting a subset of subjects from an existing database by matching on head and/or face variables. The CF Validation Study provides an opportunity to examine the efficacy of a head/face matched database. To determine which variable combinations would yield the best possible match, a correlation matrix of the three head and face variables measured during the CF Validation Study was produced. As shown in Table B1, Bizygomatic Breadth and Menton-Sellion Length are the least correlated and, together, should be able to control the most variation in the third variable. The second best variable combination is Menton-Sellion Length and Head Circumference. Two test matches were completed using each of these variable combinations.

Table B1. Correlation of Head and Face Variables in the CF Validation Study

	Bizygomatic Br	Menton-Sellion L	Head Circ
Bizygomatic Br	1.0000		
Menton-Sellion L	0.1550*	1.0000	
Head Circ	0.4862*	0.3556*	1.0000

* Significantly different at $p \leq 0.01$ using a 2-tailed test

For the Bizygomatic Breadth/Menton-Sellion Length match, the range of values for each variable was divided into thirds, based on percentile values, to produce the cells required for matching. Table B2 presents the number of CF Validation Study subjects and White, male ANSUR subjects randomly selected to create a matched database with the same anthropometric distribution. A total of 450 subjects were selected for inclusion in the matched database using random, stratified matching. As shown in Table B3, the matching ranges used for Bizygomatic Breadth and Menton-Sellion Length were adequate for controlling the distribution of these variables in the matched database, but Head Circumference was significantly different between the CF Validation Study and the matched database. When corrected for combined observer error, however, the difference is no longer significant. The use of Bizygomatic Breadth and

Menton-Sellion Length for matching a head/face database does control variation in the third dimension (Head Circumference) for the CF population. Compared to the Height/Weight matches (see Parts 4 and 5 of "Selection of Matching Procedure and CF Male Anthropometric Database"), this method provides a more reliable data set for the three head and face dimensions; however the magnitude of the improvement is not sufficient to have an obvious impact on the engineering, sizing, design or manufacture of CIE.

The Menton-Sellion Length/Head Circumference match was initially attempted by dividing each variable into thirds, but this process did not adequately control for Head Circumference. To control both of the key anthropometric dimensions, Menton-Sellion Length was divided into thirds and Head Circumference was divided into quartiles, based on percentile values. Table B4 shows the number of CF Validation Study subjects in each of the matching cells and the number of White, male ANSUR subjects that were randomly selected to produce the matched database. Table B5 presents the results of comparisons made between the CF Validation Study and the matched database. The matching procedure did not control for the variation present in the distribution of Bizygomatic Breadth, even when corrected for combined observer error. Although the difference is still quite small, and probably inconsequential in the design of CIE, the Menton-Sellion Length/Head Circumference variable combination should not be used for matching if it is possible to use Menton-Sellion Length and Bizygomatic Breadth instead.

Table B2. Distribution of Menton-Sellion Length and Bizygomatic Breadth for CF Validation Study and Matched Database

Menton-Sellion L	< 121	122-126	> 127	Totals
Bizygomatic Br				
≤ 141				
Validation	84 (15.8%)	62 (11.7%)	51 (9.6%)	197 (37.0%)
Match	71 (15.8%)	53 (11.8%)	43 (9.6%)	167 (37.1%)
142-147				
Validation	73 (13.7%)	50 (9.4%)	64 (12.0%)	187 (35.2%)
Match	62 (13.8%)	42 (9.3%)	54 (12.0%)	158 (35.1%)
≥ 148				
Validation	45 (8.5%)	39 (7.3%)	64 (12.0%)	148 (27.8%)
Match	38 (8.4%)	33 (7.3%)	54 (12.0%)	125 (27.8%)
Totals				
Validation	202 (38.0%)	151 (28.4%)	179 (33.6%)	532 (100.0%)
Match	171 (38.0%)	128 (28.4%)	151 (33.6%)	450 (100.0%)

All values in mm

Table B3. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Menton-Sellion Length/ Bizygomatic Breadth Match

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Menton-Sellion Length			1.01	0.918	0.06	0.953
Match	450	123.48 (6.56)				
Validation	532	123.45 (6.53)				
Bizygomatic Breadth			1.17	0.085	-1.63	0.104
Match	450	143.15 (6.08)				
Validation	532	143.76 (5.63)				
Head Circ			1.10	0.292	-2.37	**0.018***
Match	450	573.21 (15.78)				
Validation	532	575.55 (15.04)				
Adjusted for Observer Error						
Head Circ			1.10	0.292	-0.51	0.612
Match	450	573.21 (15.78)				
Validation	532	573.71 (15.04)				

All values in mm

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/3 = .0167$)

Table B4. Distribution of Menton-Sellion Length and Head Circ for CF Validation Study and Matched Database

Menton-Sellion L	< 121	122-126	> 127	Totals
Head Circ				
≤ 565				
Validation	84 (15.8%)	36 (6.8%)	25 (4.7%)	145 (27.3%)
Match	92 (15.8%)	40 (6.9%)	27 (4.6%)	159 (27.3%)
566-575				
Validation	57 (10.7%)	42 (7.9%)	40 (7.5%)	139 (26.1%)
Match	62 (10.6%)	46 (7.9%)	44 (7.5%)	152 (26.1%)
576-586				
Validation	33 (6.2%)	37 (7.0%)	50 (9.4%)	120 (22.6%)
Match	36 (6.2%)	41 (7.0%)	55 (9.4%)	132 (22.6%)
≥ 587				
Validation	28 (5.3%)	36 (6.8%)	64 (12.0%)	128 (24.1%)
Match	31 (5.3%)	39 (6.7%)	70 (12.0%)	140 (24.0%)
Totals				
Validation	202 (38.0%)	151 (28.4%)	179 (33.6%)	532 (100.0%)
Match	221 (37.9%)	166 (28.5%)	196 (33.6%)	583 (100.0%)

All values in mm

Table B5. *F* Test and Student's *t*-Test Results for Comparison of CF Validation Study and Menton-Sellion Length/ Head Circ Match

Variable	N	Mean (SD)	*F*	*p*	*t*	*p*
Menton-Sellion Length			1.02	0.798	-0.04	0.965
Match	583	123.44 (6.46)				
Validation	532	123.45 (6.53)				
Head Circ			1.11	0.214	-0.75	0.451
Match	583	574.85 (15.86)				
Validation	532	575.55 (15.04)				
Bizygomatic Breadth			1.01	0.941	-7.97	**0.000***
Match	583	141.07 (5.65)				
Validation	532	143.76 (5.63)				
Adjusted for Observer Error						
Bizygomatic Breadth			1.01	0.941	-4.16	**0.000***
Match	583	141.07 (5.65)				
Validation	532	142.47 (5.63)				

All values in mm

* Significantly different at $p \leq 0.05$ using a Bonferroni correction ($p = .05/3 = .0167$)