A HEAD-AND-FACE ANTHROPOMETRIC SURVEY OF U.S. RESPIRATOR USERS

Final Report

prepared for

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PREFACE

This work is the result of a collaborative scientific effort between Anthrotech, Inc. and the National Institute for Occupational Safety and Health (NIOSH), NPPTL/Pittsburgh Research Laboratory. The project's main goal was to create a data base of anthropometric information – both traditional and 3D – that could be used for respirator design in the decades to come.

A project of this magnitude could not be accommplished without the efforts of many persons. We are grateful to Dr. Ziqing Zhuang, NPPTL/PRL, for his leadership and the vision to see the long-term goal.

We visited 41 sites in 8 states. The cooperation of the liaison at each of those sites was critical to the success of the effort. Those individuals are too numerous to name here, but we are deeply in their debt. They have, of course, been thanked individually.

We are also indebted to the more than 4000 subjects who gave of their time to assist in this effort. They recognized the importance of the work we were doing, and played an important part.

Finally, the authors thank Belva Hodge, Shirley Kristensen and Ilse Tebbetts of Anthrotech, as well as several summer interns for their efforts in completing the project.

EXECUTIVE SUMMARY

In 1973, the National Institute for Occupational Safety and Health (NIOSH) sponsored a study that resulted in creation of a test panel of persons who were used to represent the head-and-face variability found in the U.S. population. Test panels based on these data, still used today for the design of protective respiratory products, are now more than 30 years old. Furthermore, the data were obtained from military subjects who do not necessarily represent the civilian working population of interest to NIOSH.

In 2001 NIOSH contracted with Anthrotech of Yellow Springs, OH, to develop an anthropometric data base representing the heads and faces of U.S. civilian respirator users. A secondary objective was to obtain a subset of three-dimensional head-and-face scans for the purpose of future research in the relationships between head-and-face shape and respirator sizing and design.

A total of 4026 subjects were recruited from among industrial and service workers using respirators in eight states across the country. Subjects were measured for 21 dimensions, using traditional anthropometric instruments (anthropometer, calipers, and tape). Of this total, 1045 were also scanned to produce three-dimensional images. The sampling plan called for roughly equal numbers of male and female subjects in four racial/ethnic groups (White, African American, Hispanic, and Other) divided into three age groups (18-29, 30-44, and over 45). Oversampling in some of these categories will allow modification of the data base as sex, age, and racial composition of the U.S. working force changes in future years.

A team that included trained measurers and an experienced scanner operator moved around the country during the first half of 2003 to collect the data. Anthrotech editing routines were used in the field to ensure optimum accuracy. Both the traditional measuring data and the 3-D scans were further edited and cleaned up before the final products were released. Traditional data were weighted to reflect the percentage of individuals in each sex, age, and race category found in the entire civilian population. As population demographics change, the sample can be re-weighted so it is continually correct. These data were analyzed for the purpose of producing new test panel matrices for the design and sizing of respirators.

This report includes revised test panels, and tables of anthropometric summary statistics for men and women separately. Head and face scans have been submitted to NIOSH electronically. While the main purpose of this study was to create a data base of respirator users, this document also describes a brief, exploratory examination of 3-D landmarks. Specific scanned subjects are identified by subject number as representing the range of face shapes in the U.S. population of civilian respirator users.

A HEAD-AND-FACE ANTHROPOMETRIC SURVEY OF U.S. RESPIRATOR USERS

INTRODUCTION

New materials and design techniques allow for the creation of ever more sophisticated head-and-face protective equipment that has the potential for providing significant improvement in protection levels. But in order to maximize the advantages offered by these new products, it is essential to have an understanding of the anthropometric variability of the population that must be protected. Existing anthropometric data on the heads and faces of U.S. workers is woefully inadequate and out of date.

In 1973, the National Institute for Occupational Safety and Health (NIOSH) sponsored a pioneering study on the development of a test panel of individuals who would, collectively, represent the facial variability seen in the U.S. (McConville et al., 1973; Hack et al., 1974). Current respiratory protection products are still tested on individuals chosen in accordance with those 30-year-old documents. Not only has the U.S. population changed in 30 years, but that earlier work was based on military anthropometry (the only data available at the time) that may not adequately represent the variability in the current *civilian* population. Furthermore, the data available at that time were limited to arcs and circumferences measured with a tape, and various point-to-point measures.

In 2001, the NIOSH National Personal Protective Technology Laboratory recognized the difficulties inherent in using these old data, and issued a contract to Anthrotech to develop an anthropometric data base of the heads and faces of civilian respirator users. The requirement was that the data base should be representative of the demographic variability in the U.S., and should include respirator users from all segments of the user population, including those in various types of industrial, health care, and emergency response jobs. This new data base would be used to update the NIOSH test panel.

A secondary objective was to collect three-dimensional (3-D) scans of a subset of the sample. While methods for using these data are not standardized, the data collection method is standard, and the resulting 3D data can be used in a variety of applications. Having the 3D data will enable NIOSH and other researchers to explore the relationship between facial shapes and contours and the shapes and contours of respirators.

A total of 4026 subjects were recruited from industries and public services in which workers routinely or occasionally use respirators. Although the sampling plan did not call for sampling specific geographic regions, subjects were obtained at 41 separate sites, located in 8 states from the east to west coasts of the U.S. Subjects were measured for 21 dimensions, and 1045 of the total were scanned with a 3D scanner.

THE SAMPLE

The original sampling plan called for approximately 4000 subjects, divided more or less evenly into three age categories, two gender strata, and four racial/ethnic groups: White, African American, Hispanic and “other” (Asian, Pacific Island, Native American, mixed race). The use of the term "race" throughout this report reflects common usage, but does not reflect current anthropological understanding of modern human diversity. Although the object was to produce a sample that reflected the distribution of these workers in the U.S. population, we deliberately oversampled racial minorities in order to ensure adequate variation in racial groups. The plan was to weight the race and age categories to accurately reflect the total workforce population. This approach allows re-weighting in the future, should racial proportions in the workforce change. The original sampling plan is shown in Table 1.

TABLE 1

Targeted Sample Size by Sampling Cell

RACE	MALE				FEMALE			
	AGE GROUP			TOTAL	AGE GROUP			TOTAL
	18-29	30-44	45-65		18-29	30-44	45-65	
White	166	166	166	498	166	166	166	498
African Am	166	166	166	498	166	166	166	498
Hispanic	166	166	166	498	166	166	166	498
Other	166	166	166	498	166	166	166	498
Total	664	664	664	1992	664	664	664	1992

Of the 4026 measured, those under 18 and over 66 were eliminated, leaving 3998 in the final sample. One subject did not provide age, so the total count in Table 2 is one subject short of the sample of 3998. The goals in some sampling cells were surpassed, and in others not quite met. It is important to note that by weighting the final sample, the summary anthropometric statistics provided later in the report are completely accurate for the population, even though the sampling goals were not met in a few of the cells.

TABLE 2

Final Sample by Sampling Cell

RACE	MALE				FEMALE			
	AGE GROUP			TOTAL	AGE GROUP			TOTAL
	18 – 29*	30 - 44	45 – 65		18 – 29*	30 - 44	45 – 65	
White	271	611	485	1367	151	194	174	519
African Am	101	255	278	634	51	213	325	589
Hispanic	155	182	75	412	53	36	37	126
Other	24	47	59	130	52	65	103	220
Total	551	1095	897	2543	307	508	639	1454

The subset of those subjects who were scanned is shown in Table 3, displayed in the same sampling cells. An anthropometrically representative 500 individuals were subsequently selected from this total.

TABLE 3

Scanned Sample by Sampling Cell

RACE	MALE				FEMALE			
	AGE GROUP			TOTAL	AGE GROUP			TOTAL
	17 - 29	30 - 44	≥ 45		17 - 29	30 - 44	≥ 45	
White	77	169	128	374	97	52	14	163
African Am	29	78	62	169	16	32	35	83
Hispanic	41	69	33	143	18	10	11	39
Other	6	21	11	38	12	4	14	30
Total	153	337	234	724	143	98	74	315

The distribution of subjects across geographic locations can be seen in Table 4. It was our intent to sample more or less evenly across the geographic regions. In practice, this was made difficult by widely varying levels of cooperation from survey sites. The result is that we have more subjects from the Midwest and Texas than we have from other geographic areas. Since there is no evidence that geographic location affects face size and shape (after race and age are taken into account), this apparent disparity is not a problem.

TABLE 4

Final Sample by Geographic Region

STATE	N	%
California	229	5.69
Illinois	1564	39.12
Kentucky	93	2.31
New York	120	2.98
Ohio	751	18.78
Pennsylvania	29	0.72
Texas	857	21.44
Virginia	355	8.82
Total	3998	100

The distribution of subjects among type of workplace is shown in Table 5. There was no requirement to sample equally across these workplace types. It was only important that we have representation from all types of workplaces where respirators are used. Table 5 shows that this goal was met.

TABLE 5

Final Sample by Type of Workplace

OCCUPATION	MALE		FEMALE		TOTAL	
	N	%	N	%	N	%
Construction	594	23.35	47	3.23	641	16.03
Fire Fighting	429	16.86	60	4.13	489	12.23
Health Care	776	30.50	75	5.16	851	21.29
Law Enforcement	381	14.98	1100	75.65	1481	37.04
Manufacturing	121	4.76	7	0.48	128	3.20
Others	243	9.55	165	11.35	408	10.21
Total	2544	100.00	1454	100.00	3998	100.00

In all, the sample can be seen to have captured the demographic, geographic, and occupational variability of the nation's respirator users. We were unable to locate a data source that would identify the distribution of all U.S. respirator users, specifically, across these demographic areas of interest. Thus, for purposes of calculating summary anthropometric statistics, this data set was weighted to reflect the U.S. workforce as a whole. If the appropriate demographic data for respirator users is available in the future, the data set can easily be re-weighted to reflect the new information.

THE DIMENSIONS

Dimensions were selected to maximize the information that could be obtained from each subject for respirator design and testing. Most dimensions are on the face, although the rest of the head is well represented. Stature and weight were taken because they form a set of useful basic body descriptors allowing this data set to be compared to others. Neck Circumference was added partway through data collection when it was learned that it plays a role in some national and international respirator standards. The final dimension list appears in Table 6.

TABLE 6

Final Dimension List

MEASURED DIMENSIONS
Bigonial Breadth
Bitragion Coronal Arc
Bitragion Frontal Arc
Bitragion Subnasale Arc
Bitragion Chin Arc
Bizygomatic Breadth
Head Breadth
Head Length
Head Circumference
Interpupillary Breadth
Lip Length
Maximum Frontal Breadth
Menton Sellion Length
Minimum Frontal Breadth
Nasal Root Breadth
Neck Circumference
Nose Breadth
Nose Protrusion
Stature
Subnasale Sellion Length
Weight

Prior to conducting the field study, a measurer's handbook was prepared (see Appendix A). Included in this guide were illustrated instructions for measuring the dimensions, and a table of values that represent allowable measurement error for technicians. The measurers practiced with each other until allowable levels of error were reached. An experienced scanner operator accompanied measurers to 11 sites.

EQUIPMENT

Anthropometric Instruments

The traditional anthropometric instruments consist of the anthropometer, a spreading caliper, a sliding caliper, and a steel measuring tape. The anthropometer and calipers are manufactured by GPM in Switzerland. These are illustrated in Figure 1. The tape is manufactured by Lufkin in the United States.

FIGURE 1

Anthropometric Instruments

The 3-D head scanner, Model 3030/RGB, is manufactured by Cyberware, Inc., of Monterey CA. It can be seen in Figure 2 to the right of a subject prepared for scanning. Figure 3 shows the computer screen with the scanned image of the same subject.

FIGURE 2

Subject Ready to be Scanned by Cyberware Scanner

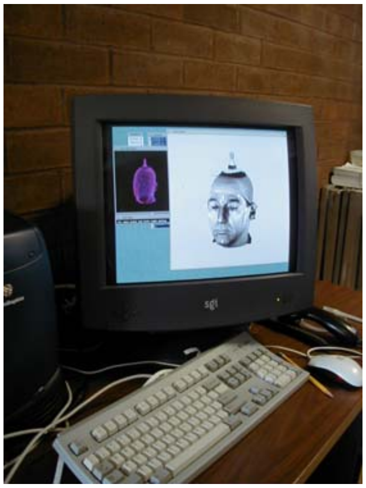

FIGURE 3

Typical Scan

Software

A number of software products are used to surface the scans, and to identify the marked landmarks on the scans. Software is also necessary to repair bad areas on the scan. The specific software products we use for image manipulation are:

> *INTEGRATE*, a Unix-based 3-D data visualization, analysis, and manipulation tool developed by the Air Force specifically for 3-D anthropometry (Burnsides et al, 1996).
>
> *MORPHEUS,* a public domain program that computes a Generalized Procrustes Analysis, and provides various outputs for further statistical analysis.

We use SPSS for statistical analysis of the traditional data.

METHODS

Preliminaries

We identified potential measuring sites in a number of ways. We used the public library, the Internet, and telephone directories to develop lists of potential sites. Then we began telephoning these sites to invite them to participate in the project. More often than not, the organization or company was interested in helping, but did not have the time or energy to participate. When an organization was willing and able to help, we sent a packet of information to explain, in detail, the purposes and protocol of the survey. With a partial list of sites, we began arranging them in a reasonable and efficient order, to minimize travel time and cost, and to minimize down-time between sites.

Since it was time-consuming and expensive to move the scanner, we sent the scanner to fewer sites than were used for the traditional measurements.

Upon arrival at a new site, we made contact with the local representative assigned to our project. This person was our point of access to the individual subjects. Sometimes, appointments were set up in advance. In other cases, subjects were recruited after we arrived and set up. In every case the local representative assisted with recruitment of subjects from that organization's workforce.

As subjects arrived at the room set aside for measuring (and/or scanning), our team explained the purposes of the study, and the specific protocol to be used. After the explanation, each subject signed a consent form (see Appendix B).

The subject then filled out the brief demographic questionnaire (top portion of data sheet, see Appendix C). The subject number recorded on the questionnaire was a critical element in allowing us to link the demographic and anthropometric data for a given subject. In cases where a person was scanned as well, the subject number became the file name for the scan, allowing us to link the scans with the traditionally measured data. After the paperwork was completed, the subject was ready to be marked and measured.

Landmarking

Landmarks are specific points on the body (in this case, on the head and face). They are generally, although not always, skeletal points, which are usually marked on the skin overlying the point. For this survey, a series of 26 landmarks was selected in advance. Most of the landmarks were used to define the measurements. The measurement descriptions in Appendix A indicate which landmarks served that purpose. Additionally, some landmarks were chosen for use in the 3D scans. These landmarks are helpful in aligning scans in the post-processing phase, and can be used subsequently to extract appropriate contours and curvatures.

Subjects were landmarked with a surgical marker or an eye-liner pencil prior to measurement or scanning. The scan-only landmarks were not drawn on subjects who were not scanned. Figure 4 shows the landmarks being applied.

FIGURE 4

Measurer Drawing Landmarks

Measuring

After landmarking, subjects were measured for each of the dimensions listed in Table 6. Although the measurements are listed alphabetically in the table, they were measured in an order that maximized measurer efficiency and minimized subject time. Figures 5 and 6 show measurements taken with the tape measure and spreading calipers, respectively.

FIGURE 5

Head Circumference Measured with the Steel Tape

FIGURE 6

Bizygomatic Breadth Measured with the Spreading Calipers

Data were recorded on data sheets (Appendix C), and simultaneously entered into laptop computers. The Anthrotech data entry and editing software evaluated each measurement as it was entered, and indicated to the recorder when a measurement value was out of the previously measured range, or was otherwise unexpected. In such cases, the measurer repeated the measurement. If the second measurement resolved the initial problem, it was recorded, and the initial measurement discarded. If the problem was not resolved, both values were recorded on the electronic data file. Both values were always recorded on the paper data sheet for use in data editing after data collection was complete.

Scanning

At selected sites, the next step was scanning. To minimize the effect of stray hair in the scan, a nylon wig cap was placed on the head. Loose hairs around the ears and neck were tucked under the cap. Then, the marked landmarks were covered with adhesive paper dots. These dots, ¼ inch in diameter, make it easier to identify the landmarks in the scanned image. Figure 7 shows a subject in the wig cap, and the measurer applying the paper dots.

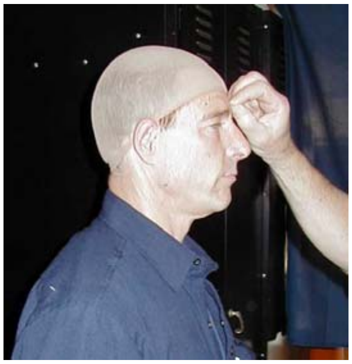

FIGURE 7

Subject in Wig Cap with Adhesive Paper Dots

After the subjects were finished, they were thanked for their time, and offered various swabs and lotions to remove the landmarks (see Figure 8).

FIGURE 8

Subject Removing Landmarks

If a subject was compensated for his/her time, that compensation was proffered at the end of the process. There were a variety of compensation/incentive plans used, depending on the type of work setting. In some cases, usually industrial sites, workers were paid directly with cash. In many fire or police departments the subjects were on duty and prohibited from accepting cash beyond their salary. In those cases, we made donations (based on the number of participants) to the appropriate Widows and Orphans Fund, or a similar charity selected by the local point of contact. Sometimes, we provided a pizza lunch for everyone who participated. In each case, we worked out the compensation/incentive plan in advance with the local contact person.

DATA ANALYSIS

Traditional Measurement Data

The first task in preparing traditional (i.e., measured with tape and calipers) anthropometric data is to make sure there are no errors. The first line of defense is the in-field data entry and editing system described in the previous section. Despite the efficiency of this system, however, erroneous values can sometimes creep into the data base. Therefore, the data were edited again using a combination of regression and outlier identification techniques. Demographic data were edited after entry by examining frequency distributions and identifying unusual values. These values were changed to "missing" if they could not be verified.

The second task in data preparation of the traditional data was the calculation of the data weights. Recall that our sampling strategy called for equal representation in each of the sampling cells. This was done to ensure that we had adequately captured the anthropometric variability in all segments of the population. People in the work force do not fall into those cells in equal proportion, however. Therefore, our sample needs to be proportionately weighted to be accurately representative of the U.S. workforce. As noted above, we do not have access to demographic statistics for the U.S. respirator-wearing population, so we weighted to the whole U.S. workforce instead.

Previous anthropometric surveys (e.g., Gordon et al., 1989) used another approach to correcting the sample demographics to match the total population. In those surveys, individuals in sampling cells where too many people had been measured were eliminated from the final data set. This approach allowed for an accurate demographic representation in the final data set, but had the disadvantage that some sampling cells (older American Indians, in the Army example) were represented by very, very few people. The weighting approach we use here does not eliminate any of the measured subjects. Instead, each measured subject is multiplied so that he/she represents many other persons with the same demographic characteristics as him/herself.

To calculate the weights, we used the 2000 U.S. census (www.census.gov), and broke it down into the same categories we had used in our sampling plan. Note our assumption that the workforce is the total U.S. population between the ages of 18 and 66. Clearly some people in this age range are not in the work force, but we have no reason to believe the workforce is anthropometrically distinct from the population as a whole.

The weights are calculated as the relative frequency of a given cell in the Census, divided by the relative frequency of the same cell in the present study. It can be expressed as:

$$[N_{1,1}/(N_{1,1} + N_{1,2} + \ldots + N_{i,,j})] \,/\, [n_{1,1}/(n_{1,1} + n_{1,2} + \ldots + n_{i,,j})]$$

where N is the count from the age/race cell in the Census,
n is the count from the age/race cell in the present study,

i is the subscript for the last age group, and
j is the subscript for the last racial group.

For example, the cells where we have fewer people in our sample as a percentage of their representation in the population (e.g. white females 18-29, Table 2), have a higher weight (same cell, Table 7). Then we created a new variable in our sample data base with those sample weights (see Table 7). *The sample weights should always be used when calculating any statistics from this data base. Statistics calculated without the use of the weights will be incorrect.*

TABLE 7

Weights by Sampling Cell

RACE	MALES			FEMALES		
	AGE GROUP			AGE GROUP		
	18 - 29	30 - 44	45 - 66	18 – 29	30 - 44	45 - 66
White	1.516531	1.070699	1.473671	1.502991	1.881647	2.407866
African Am	0.835324	0.424599	0.312164	1.000204	0.324416	0.181680
Hispanic	0.808564	0.691170	0.933218	1.124507	1.823606	1.150489
Other	2.332153	1.338566	0.741441	0.597626	0.566132	0.265141

Weights operate basically like a multiplier. For example, if we have measurements for a 22-year-old white male, his anthropometry in the data set would be repeated 1.517 times (Table 7). It is as if there are 1.517 persons exactly like him. Similarly, the anthropometric data for a 60-year-old African American female would be multiplied by 0.182 (Table 7). This multiplier effect can be used in the summary statistics as well.

For example, an unweighted mean can be expressed as:

$$\sum x_1 + x_2 + \ldots + x_n/n$$

where x is the value of a given measurement,
the subscripts refer to individual subjects, and
n is the number of subjects in the sample.

The same formula for the weighted mean can be expressed as:

$$\sum x_1y_1 + x_2y_2 + \ldots + x_ny_n/n$$

where x is the value of a given measurement,
y is the weight (from Table 7) for each subject,
the subscripts refer to individual subjects, and
n is the number of subjects in the sample.

Other statistics can be calculated in the same way. Of course it is not necessary to do these calculations by hand. Most statistical packages have a weighting feature, since this is a standard technique, and the user simply indicates which variable is the weighting variable, and the requested statistics are calculated using the weighted values.

Following the calculation of the weights, we calculated the basic summary statistics for each measured dimension. The summary statistics are shown in Table 8, for males and females, separately. In most cases, work force populations are not evenly split between the sexes. This is certainly true in the subpopulation that wears respirators. For example, users in the health professions tend to be mostly female. Those in construction tend to be mostly male. Fire and police are largely male, and so on. Therefore it would be inappropriate for a designer or tester of respirators to use combined sex data, since either the males or the females for a particular application would not be fit well. It is better to develop and test respirators for males and females separately. A given work group can order appropriate numbers of each size based on the specific population at that location.

In order to show a snapshot of the facial anthropometry of the total U.S. population aged 18 to 66, we have included Table 9. As noted above, *in most cases, the statistics in this table should not be used for respirator design, since most respirators are not used by men and women equally.*

It is interesting to see how these population data differ from military data. In the Army's 1987-1988 anthropometric survey, ANSUR, (Gordon et al., 1989), a number of these same dimensions were collected using the same measurement techniques. The mean and standard deviations for selected dimensions are shown in Table 10.
For this comparison, the Army data have been weighted to match the current U.S. civilian work force, using the same techniques described above.

TABLE 8

Anthropometric Summary Statistics by Sex: Respirator Sample Weighted to Represent U.S. Population Age 18-66
(weight in kg, all other values in mm)

MALES

DIMENSION	N	MEAN	STD DEV	SKEWNESS	KURTOSIS	MIN	MAX
Bigonial Breadth	2544	120.4	10.4	0.442	-0.012	90	160
Bitragion Chin Arc	2544	331.2	15.5	0.096	0.145	271	393
Bitragion Coronal Arc	2544	350.7	13.9	0.097	-0.054	310	405
Bitragion Frontal Arc	2544	304.1	13.0	0.091	0.128	263	349
Bitragion Subnasale Arc	2544	294.8	13.2	0.142	0.080	253	345
Bizygomatic Breadth	2542	143.5	6.9	0.145	0.014	120	170
Head Breadth	2544	153.0	6.0	0.151	0.320	135	179
Head Circ	2544	575.7	17.1	0.108	0.310	520	639
Head Length	2544	197.3	7.4	-0.048	0.040	174	225
Interpupillary Distance	2544	64.5	3.6	0.189	0.041	53	79
Lip Length	2544	51.1	4.2	0.125	-0.069	40	70
Maximum Frontal Br	2544	112.3	5.5	0.155	-0.019	95	131
Menton-Sellion Lth	2544	122.7	7.0	0.077	0.059	100	156
Minimum Frontal Br	2544	105.5	5.7	0.132	-0.044	90	127
Nasal Root Breadth	2544	16.6	2.3	0.196	0.225	10	29
Neck Circ	1024	406.7	32.6	0.543	0.908	312	570
Nose Breadth	2544	36.6	4.1	0.780	0.868	26	58
Nose Protrusion	2544	21.1	2.7	0.179	0.054	13	32
Stature	2544	1753.9	67.7	-0.019	-0.055	1488	2012
Subnasale-Sellion Lth	2544	52.0	4.1	0.092	-0.161	40	66
Weight	2541	90.4	17.5	0.692	0.691	42.9	167.8

TABLE 8 – CONTINUED

MALES

DIMENSIONS	PERCENTILES																
	1	2	5	10	20	25	30	40	50	60	70	75	80	90	95	98	99
Bigonial Breadth	101	102	105	108	111	113	115	116	120	122	125	127	130	135	140	145	147
Bitragion Chin Arc	297	300	306	311	318	320	323	326	330	335	340	340	345	350	355	364	370
Bitragion Coronal Arc	320	322	330	333	340	340	344	346	350	355	359	360	362	370	375	380	385
Bitragion Frontal Arc	275	280	282	290	295	295	297	300	305	307	310	312	315	320	326	333	335
Bitragion Subnasale Arc	265	269	275	279	285	285	288	290	295	298	301	305	305	312	315	322	328
Bizygomatic Breadth	130	130	132	135	137	139	140	142	143	145	147	148	150	152	155	158	160
Head Breadth	140	141	144	145	148	150	150	151	153	154	155	157	158	161	163	165	167
Head Circ	536	540	547	555	562	565	566	571	575	580	584	586	590	597	604	613	618
Head Length	180	181	185	187	191	192	194	195	197	200	201	202	203	206	210	212	215
Interpupillary Distance	57	58	59	60	62	62	63	64	65	66	67	67	68	69	71	73	74
Lip Length	42	43	44	46	47	48	49	50	51	52	53	54	55	56	58	60	61
Maximum Frontal Br	100	101	104	105	108	109	110	111	112	114	115	116	117	120	122	124	126
Menton-Sellion Lth	107	109	111	114	117	118	119	121	123	125	126	127	129	131	135	137	139
Minimum Frontal Br	92	94	95	99	100	101	102	104	105	107	109	110	110	113	115	118	120
Nasal Root Breadth	12	12	13	14	15	15	15	16	16	17	18	18	18	19	20	21	22
Neck Circ	340	345	355	370	380	385	390	396	403	410	420	425	432	450	465	485	502
Nose Breadth	29	30	31	32	33	34	34	35	36	37	38	39	40	42	45	47	48
Nose Protrusion	15	16	17	18	19	19	20	20	21	22	22	23	23	25	26	27	28
Stature	1597	1613	1642	1667	1697	1709	1719	1737	1754	1771	1790	1800	1809	1842	1866	1894	1911
Subnasale-Sellion Lth	43	44	45	47	48	49	50	51	52	53	54	55	55	57	59	60	62
Weight	57.9	61.1	65.7	69.7	75.8	78.3	80.3	84.4	88.4	92.5	97.8	100.1	103.4	113.9	122.7	134.8	140.3

TABLE 8 – Continued

FEMALES

DIMENSION	N	MEAN	STD DEV	SKEWNESS	KURTOSIS	MIN	MAX
Bigonial Breadth	1453	110.1	8.9	0.646	0.848	88	150
Bitragion Chin Arc	1453	303.9	14.9	0.179	0.498	248	375
Bitragion Coronal Arc	1453	339.3	15.0	0.026	0.269	290	425
Bitragion Frontal Arc	1453	287.4	11.9	0.082	0.156	250	330
Bitragion Subnasale Arc	1453	277.5	13.1	0.308	0.382	238	335
Bizygomatic Breadth	1453	135.1	6.5	0.174	0.183	115	157
Head Breadth	1453	146.8	5.6	-0.010	0.307	129	165
Head Circ	1453	554.9	17.8	0.230	1.013	475	654
Head Length	1453	187.5	7.2	-0.200	0.530	152	215
Interpupillary Distance	1451	61.9	3.5	0.281	0.394	52	78
Lip Length	1453	48.0	4.0	0.230	-0.116	35	63
Maximum Frontal Br	1453	108.6	5.3	0.094	-0.103	92	130
Menton-Sellion Lth	1453	113.4	6.1	0.130	-0.042	91	135
Minimum Frontal Br	1453	102.9	5.4	-0.004	-0.045	84	126
Nasal Root Breadth	1453	16.3	2.0	0.033	0.225	10	25
Neck Circ	793	339.5	30.9	0.902	1.993	260	505
Nose Breadth	1453	33.2	3.9	0.893	0.944	22	54
Nose Protrusion	1453	19.8	2.7	0.281	0.154	11	29
Stature	1453	1625.4	67.5	0.059	0.466	1310	1862
Subnasale-Sellion Lth	1453	48.2	3.8	0.209	-0.080	32	59
Weight,	1447	75.7	18.7	0.849	0.545	34.2	176.4

TABLE 8 – Continued

FEMALES

DIMENSION	PERCENTILES																
	1	2	5	10	20	25	30	40	50	60	70	75	80	90	95	98	99
Bigonial Breadth	93	95	98	100	102	104	105	107	110	111	114	115	117	122	125	131	136
Bitragion Chin Arc	270	275	280	285	290	295	295	300	305	307	311	313	315	322	328	338	342
Bitragion Coronal Arc	305	305	315	320	326	330	330	335	340	344	346	350	352	358	365	370	375
Bitragion Frontal Arc	260	265	270	271	277	280	280	285	287	290	295	295	298	302	305	312	320
Bitragion Subnasale Arc	249	252	258	260	267	269	270	275	277	280	284	285	288	295	300	305	313
Bizygomatic Breadth	121	122	124	127	130	131	132	133	135	136	138	140	140	144	146	149	152
Head Breadth	133	135	137	140	142	143	144	145	146	148	150	150	151	154	156	159	161
Head Circ	515	520	527	533	540	544	546	550	555	558	563	565	569	578	585	594	604
Head Length	170	172	175	178	182	183	184	186	187	190	191	192	194	196	199	202	205
Interpupillary Distance	55	55	56	58	59	60	60	61	62	63	64	64	65	67	68	69	71
Lip Length	40	40	42	43	44	45	46	47	48	49	50	51	51	53	55	57	58
Maximum Frontal Br	97	98	100	102	104	105	106	107	108	110	111	112	113	115	117	120	121
Menton-Sellion Lth	100	102	104	106	108	109	110	112	113	115	116	118	119	121	124	126	128
Minimum Frontal Br	90	91	94	96	99	100	100	101	103	105	106	106	107	110	111	114	115
Nasal Root Breadth	12	12	13	14	15	15	15	16	16	17	17	18	18	19	20	21	21
Neck Circ	285	290	295	305	313	320	321	330	335	343	352	357	365	380	395	415	425
Nose Breadth	26	27	28	29	30	31	31	32	33	33	34	35	36	39	41	43	45
Nose Protrusion	14	15	16	16	17	18	18	19	20	20	21	21	22	23	25	26	27
Stature	1479	1493	1513	1538	1570	1580	1590	1609	1627	1643	1660	1669	1680	1709	1731	1770	1794
Subnasale-Sellion Lth	40	41	42	44	45	46	46	47	48	49	50	51	51	53	55	57	58
Weight	44.5	48.4	51.8	54.5	59.7	61.6	63.6	67.6	72.1	76.9	82.8	86.8	91.5	102.5	112.1	123.0	126.7

TABLE 9

Anthropometric Summary Statistics: Respirator Sample Weighted to Represent U.S. Population Age 18-66
(weight in kg, all other values in mm)

DIMENISON	N	MEAN	STD DEV	SKEWNESS	KURTOSIS	MIN	MAX
Bigonial Breadth	3997	116.6	11.1	0.458	0.043	88	160
Bitragion Chin Arc	3997	321.3	20.1	-0.062	-0.284	248	393
Bitragion Coronal Arc	3997	346.6	15.3	-0.038	0.110	290	425
Bitragion Frontal Arc	3997	298.0	14.9	0.057	-0.099	250	349
Bitragion Subnasale Arc	3997	288.5	15.5	0.043	-0.146	238	345
Bizygomatic Breadth	3995	140.5	7.9	0.082	-0.117	115	170
Head Breadth	3997	150.7	6.6	0.072	0.206	129	179
Head Circ	3997	568.1	20.1	-0.014	0.169	475	654
Head Length	3997	193.7	8.7	-0.107	0.021	152	225
Interpupillary Distance	3995	63.6	3.8	0.185	0.064	52	79
Lip Length	3997	49.9	4.4	0.152	-0.143	35	70
Maximum Frontal Br	3997	110.9	5.7	0.141	-0.022	92	131
Menton-Sellion Lth	3997	119.3	8.1	0.113	-0.216	91	156
Minimum Frontal Br	3997	104.6	5.8	0.115	0.012	84	127
Nasal Root Breadth	3997	16.5	2.2	0.165	0.274	10	29
Neck Circ	1817	377.4	46.1	0.185	-0.358	260	570
Nose Breadth	3997	35.4	4.4	0.667	0.617	22	58
Nose Protrusion	3997	20.6	2.8	0.197	0.033	11	32
Stature	3997	1707.2	91.6	-0.167	-0.351	1310	2012
Subnasale-Sellion Lth	3997	50.6	4.4	0.137	-0.218	32	66
Weight	3988	85.1	19.3	0.518	0.293	34.2	176.4

TABLE 9 – CONTINUED

DIMENSIONS	PERCENTILES															
	1	2	5	10	20	25	30	40	50	60	70	75	80	90	95	98	99
Bigonial Breadth	95	98	100	103	107	109	110	113	115	118	122	124	125	132	137	143	145
Bitragion Chin Arc	275	281	288	295	305	307	310	315	321	326	333	335	340	347	354	360	365
Bitragion Coronal Arc	310	315	320	327	335	335	340	343	346	350	355	356	360	365	370	378	380
Bitragion Frontal Arc	265	270	275	280	285	288	290	295	299	301	305	309	310	317	323	330	334
Bitragion Subnasale Arc	255	258	264	269	275	278	280	285	290	293	296	300	301	310	315	320	324
Bizygomatic Breadth	123	124	128	131	134	135	136	138	140	143	145	145	147	151	154	157	160
Head Breadth	135	137	140	142	145	146	147	150	151	152	154	155	156	160	162	165	166
Head Circ	522	527	535	543	551	555	557	563	568	574	579	582	585	594	600	610	615
Head Length	174	175	180	183	186	188	190	192	194	196	198	200	201	205	208	211	213
Interpupillary Distance	55	56	58	59	61	61	62	63	64	65	66	66	67	69	70	72	73
Lip Length	41	41	43	44	46	47	47	49	50	51	52	53	54	55	57	59	61
Maximum Frontal Br	98	100	102	104	106	107	108	110	111	112	114	115	116	118	121	123	125
Menton-Sellion Lth	102	104	107	109	112	113	115	117	119	121	124	125	126	130	133	136	138
Minimum Frontal Br	91	93	95	97	100	100	101	103	105	106	107	108	110	112	114	117	118
Nasal Root Breadth	12	12	13	14	15	15	15	16	16	17	18	18	18	19	20	21	22
Neck Circ	290	295	305	315	332	340	349	365	380	392	402	410	415	435	451	476	498
Nose Breadth	27	28	29	30	32	32	33	34	35	36	37	38	39	41	44	46	47
Nose Protrusion	15	15	16	17	18	19	19	20	20	21	22	22	23	24	25	27	27
Stature	1498	1515	1551	1583	1627	1643	1657	1685	1712	1736	1761	1775	1789	1824	1854	1878	1899
Subnasale-Sellion Lth	41	42	44	45	47	47	48	49	51	52	53	54	54	56	58	60	61
Weight	49.0	51.8	56.5	61.4	68.2	71.1	73.8	79.0	83.6	88.5	93.9	96.8	100.2	110.3	119.4	130.1	138.1

TABLE 10

NIOSH Respirator Data (weighted) vs. U.S. Army Data (weighted) by Sex:
Means and Standard Deviations for Selected Dimensions
(weight in kg, all other values in mm)

MALES

DIMENSION	NIOSH RESPIRATOR SAMPLE (WEIGHTED) N	MEAN	STD DEV	MIN	MAX	U.S. ARMY SAMPLE (WEIGHTED) N	MEAN	STD DEV	MIN	MAX	STAT SIG
Bigonial Breadth	2544	120.4	10.4	90	160	1774	121.7	9.4	88	154	0.000
Bitragion Chin Arc	2544	331.2	15.5	271	393	1774	328.4	13.5	278	372	0.000
Bitragion Coronal Arc	2544	350.7	13.9	310	405	1774	353.1	12.6	299	395	0.000
Bitragion Frontal Arc	2544	304.1	13.0	263	349	1774	305.4	10.3	271	348	0.000
Bitragion Subnasale Arc	2544	294.8	13.2	253	345	1774	292.6	10.9	255	328	0.000
Bizygomatic Breadth	2542	143.5	6.9	120	170	1774	141.9	5.3	118	161	0.000
Head Breadth	2544	153.0	6.0	135	179	1774	153.6	5.3	128	173	0.001
Head Circ	2544	575.7	17.1	520	639	1774	570.9	15.5	514	627	0.000
Head Length	2544	197.3	7.4	174	225	1774	196.8	6.9	173	220	0.026
Interpupillary Distance	2544	64.5	3.6	53	79	1772	64.9	3.0	52.0	78.0	0.000
Lip Length	2544	51.1	4.2	40	70	1774	57.4	4.0	44	71	0.000
Maximum Frontal Br	2544	112.3	5.5	95	131	1774	112.9	4.5	95	134	0.000
Menton-Sellion Lth	2544	122.7	7.0	100	156	1774	122.2	6.5	101	148	0.025
Minimum Frontal Br	2544	105.5	5.7	90	127	1774	105.0	4.8	82	127	0.003
Neck Circ	1024	406.7	32.6	312	570	1774	385.2	26.8	316	470	0.000
Nose Breadth	2544	36.6	4.1	26	58	1774	36.4	3.7	26	53	0.132
Nose Protrusion	2544	21.1	2.7	13	32	1774	19.5	2.4	11	29	0.000
Stature	2544	1753.9	67.7	1488	2012	1774	1747.3	70.7	1497	2042	0.002
Subnasale-Sellion Lth	2544	52.0	4.1	40	66	1774	51.0	3.9	37	63	0.000
Weight	2541	90.4	17.5	43	168	1774	81.4	13.5	47.6	127.8	0.000

FEMALES

DIMENSION	NIOSH RESPIRATOR SAMPLE (WEIGHTED) N	MEAN	STD DEV	MIN	MAX	U.S. ARMY SAMPLE (WEIGHTED) N	MEAN	STD DEV	MIN	MAX	STAT SIG
Bigonial Breadth	1453	110.1	8.9	88	150	2208	109.4	7.3	87	144	0.013
Bitragion Chin Arc	1453	303.9	14.9	248	375	2208	302.1	12.2	261	350	0.000
Bitragion Coronal Arc	1453	339.3	15.0	290	425	2208	336.0	13.0	298	392	0.000
Bitragion Frontal Arc	1453	287.4	11.9	250	330	2208	287.2	9.6	250	320	0.522
Bitragion Subnasale Arc	1453	277.5	13.1	238	335	2208	274.4	9.9	242	315	0.000
Bizygomatic Breadth	1453	135.1	6.5	115	157	2208	132.3	5.4	117	150	0.000
Head Breadth	1453	146.8	5.6	129	165	2208	145.6	5.2	126	167	0.000
Head Circ	1453	554.9	17.8	475	654	2208	546.5	14.3	500	611	0.000
Head Length	1453	187.5	7.2	152	215	2208	186.7	5.8	158	211	0.000
Interpupillary Distance	1451	61.9	3.5	52	78	2204	61.7	3.3	52.0	76.0	0.037
Lip Length	1453	48.0	4.0	35	63	2208	55.1	3.9	41	69	0.000
Maximum Frontal Br	1453	108.6	5.3	92	130	2208	111.1	5.0	92	134	0.000
Menton-Sellion Lth	1453	113.4	6.1	91	135	2208	113.1	5.9	95	134	0.101
Minimum Frontal Br	1453	102.9	5.4	84	126	2208	103.5	4.5	86	121	0.002
Neck Circ	793	339.5	30.9	260	505	2208	314.7	13.9	272	372	0.000
Nose Breadth	1453	33.2	3.9	22	54	2208	33.4	3.9	23	50	0.145
Nose Protrusion	1453	19.8	2.7	11	29	2208	18.9	2.4	11	25	0.000
Stature	1453	1625.4	67.5	1310	1862	2208	1619.1	55.5	1428	1870	0.003
Subnasale-Sellion Lth	1453	48.2	3.8	32	59	2208	48.9	3.8	34	65	0.000
Weight	1447	75.7	18.7	34	176	2208	63.6	8.5	41.3	96.7	0.000

The significance levels in the table refer to univariate independent sample t-tests. As would be expected, our civilian sample with a full age range is different from the relatively young and fit military sample. The biggest differences are in weight, and the dimensions such as neck circumference that have some relationship to weight. It is interesting to note that the means for Menton-Sellion Length, which is important in respirator test panels, differ by less than 1 mm for both males and females. It should also be noted, however, that statistical significance is affected by large sample sizes, and that small differences, although of statistical significance, have no practical importance. The other dimensional difference that would appear to be of practical importance is lip length. In fact, this is a measurement artifact. In the ANSUR survey, lip length was measured using an automated headboard device which employed a digital touch probe. We believe there are differences between the way the probe touched the corner of the lip and the way the caliper touched the corner of the lip.

We also performed a multivariate analysis of variance, testing whether the two groups (ANSUR and the current sample) could be distinguished multivariately. On all statistical tests (Pillai, Wilks, etc.), the two groups are significantly different. This is not an unexpected result, given the large sample size in both groups. The results of the multivariate test are in Appendix D.

The comparison confirms our initial suspicions that using historic, military, data would be inadequate for describing the anthropometric variability of the current U.S. workforce.

We also compared groups within our respirator sample. Specifically, we looked at racial and age differences between our sampling cells. Table 11 shows the mean and standard deviations for the dimensions, grouped by sampling cell. Since individual cells are compared, and they do not represent the population, the values are unweighted. As would be expected, dimensions that are associated with weight tend to increase with age. There are differences between racial groups in all of the dimensions. We tested the univariate analysis of variance by age group and racial group. Those test results are seen in Appendix E.

Scan Data

The 3-D scans required more preparation than the traditional data. For each scan, we first cleaned the data of spikes and irregularities. Such spikes and irregularities can be caused by hair, clothing or even shiny objects in the scanning room. Further, we filled in blanks such as missing areas at the top of the head, and under the chin. Figure 9 shows a typical “before and after” scan.

Following data cleaning, the landmarks were identified on each scan. Recall that the landmarks are marked prior to scanning. An operator must identify each point, and then use software, in this case INTEGRATE, to create a data file that contains the X, Y, Z coordinates of the specific marked landmarks.

TABLE 11

NIOSH Respirator Data by Sex, Race and Age Group: Means and Standard Deviations (weight in kg, all other values in mm)

	MALES								FEMALES							
	AGE GROUP						TOTAL		AGE GROUP						TOTAL	
	18 - 29		30 - 44		45 - 66				18 - 29		30 - 44		45 - 66			
	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV
BIGONIAL BREADTH																
White	117.20	9.07	119.20	9.92	122.26	10.13	119.89	10.01	106.36	6.77	108.42	8.91	110.32	8.19	108.46	8.23
Black	118.19	11.17	121.29	11.40	121.22	11.29	120.76	11.35	112.47	7.06	114.04	10.00	113.78	9.23	113.76	9.35
Hispanic	122.91	11.78	123.69	11.59	124.47	11.76	123.54	11.68	111.89	9.47	113.31	11.29	116.46	11.45	113.63	10.70
Other	115.83	7.58	118.36	9.21	122.97	10.16	119.98	9.75	108.58	7.61	111.91	8.18	114.55	8.39	112.36	8.46
Total	118.93	10.52	120.39	10.67	122.17	10.66	120.70	10.70	108.71	7.89	111.57	9.79	113.12	9.14	111.64	9.27
BITRAGION CHIN ARC																
White	325.00	15.13	328.94	14.52	333.69	14.05	329.84	14.82	299.01	12.77	298.88	13.32	303.01	13.72	300.30	13.41
Black	333.47	15.08	339.3	14.81	341.39	15.94	339.29	15.57	315.29	10.97	318.92	14.53	318.15	15.45	318.18	14.79
Hispanic	329.61	15.81	335.11	14.96	337.92	14.11	333.55	15.45	306.94	15.90	308.86	12.54	311.92	13.27	308.95	14.29
Other	321.00	18.98	332.32	14.55	332.32	18.22	330.23	17.56	300.19	14.06	306.38	16.50	304.55	12.74	304.06	14.37
Total	327.67	15.86	332.52	15.28	336.34	15.36	332.82	15.76	303.29	14.58	308.95	16.81	311.47	16.07	308.86	16.32
BITRAGION CORONAL ARC																
White	350.32	12.87	350.37	14.65	350.51	13.76	350.41	13.99	341.08	13.70	336.28	14.85	337.58	14.28	338.11	14.44
Black	350.36	15.40	349.88	14.32	349.51	15.37	349.79	14.94	345.29	19.34	342.5	17.00	342.91	16.08	342.97	16.70
Hispanic	352.37	13.03	354.23	12.75	352.19	12.76	353.16	12.86	342.28	16.67	343.06	11.44	341.22	15.44	342.19	14.88
Other	351.42	15.79	350.89	12.29	351.32	14.55	351.18	13.91	340.23	15.57	340.71	12.73	344.13	14.90	342.20	14.51
Total	350.95	13.54	350.92	14.24	350.39	14.25	350.74	14.09	341.84	15.60	339.93	15.59	341.56	15.55	341.05	15.59
BITRAGION FRONTAL ARC																
White	301.71	13.23	303.11	13.01	305.80	13.32	303.79	13.25	289.44	11.17	285.28	12.43	286.24	11.20	286.81	11.77
Black	302.14	11.56	305.60	12.59	306.56	13.24	305.47	12.79	291.65	11.64	292.27	12.59	291.22	12.72	291.63	12.57
Hispanic	303.52	12.76	305.04	12.51	306.47	10.66	304.73	12.31	288.72	12.62	287.33	10.52	287.97	12.63	288.10	11.98
Other	300.71	11.22	306.68	11.53	305.63	11.09	305.10	11.39	286.42	10.94	286.98	12.60	286.99	10.79	286.85	11.34
Total	302.25	12.72	304.17	12.81	306.08	12.94	304.43	12.91	289.17	11.52	288.57	12.77	288.99	12.21	288.88	12.26
BITRAGION SUBNASALE ARC																
White	290.37	12.77	292.11	12.61	295.65	12.39	293.02	12.72	275.23	11.17	273.15	11.49	274.70	11.52	274.27	11.42
Black	297.83	13.34	302.25	12.70	303.51	13.42	302.10	13.24	289.10	12.18	291.43	13.06	289.99	13.49	290.43	13.23
Hispanic	296.17	13.40	299.65	12.41	299.67	11.27	298.35	12.68	282.09	12.51	280.69	11.51	284.89	14.41	282.52	12.83
Other	290.54	13.05	297.32	13.34	296.83	14.33	295.85	13.88	276.79	11.55	281.97	13.20	281.72	11.38	280.63	12.12
Total	293.38	13.43	295.95	13.37	298.50	13.22	296.29	13.46	278.98	12.68	282.48	14.83	284.20	14.27	282.50	14.28
BIZYGOMATIC BREADTH																
White	141.02	6.59	142.24	6.32	144.85	6.77	142.92	6.70	132.91	5.75	133.22	6.11	135.09	6.40	133.75	6.17
Black	142.18	7.70	144.39	6.58	145.75	6.32	144.63	6.77	137.31	5.98	138.10	6.48	137.21	6.11	137.54	6.24
Hispanic	145.26	7.47	145.82	6.82	146.48	5.68	145.73	6.88	137.51	6.25	137.56	6.67	138.05	6.73	137.68	6.47
Other	142.17	8.52	144.04	7.00	146.24	6.36	144.69	7.14	136.46	6.57	138.23	6.92	138.26	5.99	137.83	6.43
Total	142.48	7.35	143.41	6.64	145.35	6.54	143.89	6.86	135.04	6.35	136.21	6.82	136.85	6.30	136.24	6.53
HEAD BREADTH																
White	151.73	5.42	152.42	5.66	153.75	6.11	152.76	5.83	146.15	4.55	145.93	5.59	147.36	5.98	146.47	5.47
Black	151.64	6.35	153.01	6.06	154.25	5.84	153.34	6.07	146.43	5.67	146.23	5.71	147.04	5.66	146.69	5.68
Hispanic	152.75	6.33	153.77	5.72	154.72	5.67	153.56	5.98	146.60	4.90	146.64	5.93	147.11	5.95	146.76	5.49
Other	153.58	7.46	153.23	6.22	154.75	6.24	153.98	6.46	149.10	6.16	149.29	5.27	149.05	6.90	149.13	6.25
Total	152.08	5.97	152.82	5.81	154.05	6.00	153.10	5.96	146.77	5.19	146.53	5.71	147.45	6.01	146.99	5.75

TABLE 11 (continued)

	MALES								FEMALES							
	AGE GROUP						TOTAL		AGE GROUP						TOTAL	
	18 - 29		30 - 44		45 - 66				18 - 29		30 - 44		45 - 66			
	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV
HEAD CIRC																
White	573.64	16.33	577.16	17.00	577.49	16.32	576.58	16.68	554.86	16.45	552.03	16.33	552.82	15.34	553.12	16.05
Black	580.24	19.33	579.53	18.51	580.81	19.20	580.20	18.93	566.86	21.93	566.54	19.73	568.92	23.64	567.88	22.15
Hispanic	567.07	16.22	570.41	16.95	572.36	14.88	569.51	16.40	553.19	19.67	559.50	16.34	549.95	19.01	554.04	18.81
Other	569.33	18.57	572.26	16.11	571.86	15.36	571.54	16.16	553.27	19.28	553.25	18.62	546.70	15.87	550.20	17.78
Total	572.81	17.53	576.38	17.56	577.72	17.29	576.08	17.55	556.30	19.02	558.8	19.32	559.88	22.3	558.74	20.65
HEAD LENGTH																
White	197.90	7.04	198.50	7.19	197.83	7.01	198.14	7.10	189.76	6.73	187.72	6.59	187.53	6.89	188.25	6.79
Black	198.72	6.58	199.11	7.13	199.22	7.45	199.10	7.18	190.39	5.92	189.47	6.93	190.23	7.07	189.97	6.93
Hispanic	192.5	8.05	193.98	7.33	192.93	6.75	193.23	7.52	183.74	7.25	186.53	7.26	184.38	6.23	184.72	7.01
Other	191.71	8.46	195.55	6.03	193.12	8.06	193.74	7.55	182.17	7.94	181.06	7.26	180.63	7.09	181.12	7.34
Total	196.26	7.79	197.76	7.37	197.54	7.46	197.36	7.51	187.54	7.65	187.52	7.35	187.61	7.77	187.56	7.60
INTERPUPILLARY DISTANCE																
White	62.89	3.33	63.79	3.30	64.87	3.35	64.00	3.40	60.36	2.85	61.05	3.07	61.99	3.27	61.17	3.14
Black	66.19	3.30	67.86	3.71	68.11	3.56	67.70	3.64	65.53	3.89	65.38	3.82	65.60	3.73	65.51	3.77
Hispanic	63.90	3.41	65.01	3.01	65.41	3.56	64.66	3.32	61.56	3.25	61.85	3.16	63.36	2.67	62.17	3.14
Other	62.83	3.36	64.93	4.17	65.70	3.51	64.89	3.85	61.40	3.56	61.42	3.53	62.65	3.14	61.99	3.40
Total	63.78	3.56	64.99	3.77	65.97	3.73	65.07	3.80	61.60	3.70	62.97	4.03	64.02	3.83	63.14	3.98
LIP LENGTH																
White	49.06	3.74	50.34	3.77	51.97	4.00	50.66	3.99	45.67	2.97	47.16	3.48	48.16	3.63	47.06	3.53
Black	53.24	3.91	54.33	3.67	54.78	4.05	54.35	3.91	50.80	3.19	51.67	3.86	52.22	3.96	51.90	3.88
Hispanic	49.61	3.34	51.90	3.72	52.37	4.01	51.12	3.82	47.49	3.57	50.36	3.77	50.11	3.75	49.08	3.90
Other	47.75	4.52	50.40	3.69	51.83	4.57	50.56	4.48	44.73	3.45	46.54	3.75	47.99	4.41	46.79	4.20
Total	49.92	4.03	51.53	4.08	52.86	4.25	51.65	4.27	46.68	3.78	49.20	4.33	50.31	4.41	49.15	4.47
MAXIMUM FRONTAL BR																
White	111.05	5.50	111.46	5.19	112.89	5.43	111.89	5.39	107.99	4.97	107.57	5.14	108.37	5.01	107.96	5.05
Black	112.87	5.99	114.71	5.16	114.87	5.36	114.49	5.43	112.41	5.23	112.10	5.12	111.06	5.43	111.55	5.33
Hispanic	112.62	6.44	112.96	5.64	113.51	5.09	112.93	5.86	109.26	4.86	107.83	5.68	109.70	4.26	108.98	4.96
Other	111.04	6.02	112.17	5.65	112.58	5.28	112.15	5.54	106.69	5.94	108.2	5.17	108.68	5.06	108.07	5.35
Total	111.83	5.93	112.49	5.44	113.54	5.44	112.72	5.59	108.72	5.46	109.57	5.59	109.87	5.34	109.52	5.47
MENTON-SELLION LTH																
White	120.37	6.53	122.71	6.89	123.63	6.91	122.57	6.92	112.91	5.78	113.06	5.63	112.95	5.98	112.98	5.78
Black	123.37	6.81	124.68	7.13	126.80	7.47	125.40	7.34	115.31	5.90	116.10	6.34	117.02	6.43	116.54	6.37
Hispanic	120.70	6.34	123.04	6.65	125.48	7.24	122.60	6.85	113.55	6.31	115.31	6.06	115.05	6.63	114.49	6.34
Other	117.79	7.19	122.49	6.82	120.59	7.41	120.76	7.30	109.67	6.59	110.51	5.93	111.60	5.94	110.82	6.12
Total	120.90	6.67	123.21	6.95	124.57	7.35	123.19	7.16	112.87	6.24	114.17	6.30	114.92	6.63	114.23	6.47
MINIMUM FRONTAL BR																
White	104.20	5.63	104.96	5.54	106.88	5.52	105.49	5.65	103.19	4.83	102.32	5.41	103.26	5.42	102.89	5.26
Black	105.01	6.04	106.25	5.76	107.48	5.57	106.59	5.78	105.16	4.85	105.31	5.23	104.20	5.62	104.69	5.44
Hispanic	104.43	6.59	105.14	5.87	106.21	5.24	105.07	6.06	102.57	5.21	101.39	5.27	103.08	5.04	102.38	5.18
Other	103.46	5.69	104.70	5.48	105.39	5.95	104.78	5.74	99.38	5.93	100.75	5.51	101.41	5.17	100.74	5.49
Total	104.38	5.99	105.28	5.66	106.91	5.56	105.66	5.78	102.77	5.36	103.31	5.61	103.43	5.54	103.25	5.53

TABLE 11 (continued)

	MALE								FEMALE							
	AGE GROUP						TOTAL		AGE GROUP						FEMALE TOTAL	
	18 - 29		30 - 44		45 - 66				18 - 29		30 - 44		45 - 66			
	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV	MEAN	STD DEV
NECK CIRC																
White	398.56	27.92	405.1	31.48	418.16	31.5	408.81	31.79	324.05	20.68	340.87	35.03	344.48	32.82	334.3	30.09
Black	392.63	27.78	411.76	36.17	411.35	32.99	409.73	34.13	342.7	23.65	355.9	29.86	358.68	31.14	356.52	30.43
Hispanic	399.19	30.1	408.49	28.79	417.08	34.5	407.94	31.16	335.17	25.13	346.61	23.84	351	25.17	343.43	25.53
Other	364.17	21.2	393.58	29.38	391.61	24.45	387.85	27.59	306.05	17.34	325.92	29.56	334.39	30.62	325.97	29.97
Total	394.92	29.22	406.94	32.69	412.93	32.61	407.65	32.69	325.97	24.54	347.53	32.25	351.62	32.34	345.02	32.38
NOSE BREADTH																
White	34.24	2.94	34.83	2.91	36.5	3.27	35.31	3.18	30.91	2.22	31.09	2.36	32.64	2.83	31.56	2.6
Black	41.73	3.33	43.02	3.79	44.37	3.86	43.41	3.87	38.88	3.09	39.46	3.37	40.71	3.5	40.1	3.48
Hispanic	36.51	2.77	37.4	3.5	39.19	3.39	37.39	3.35	33.98	3.17	34.47	3.04	36.16	3.19	34.76	3.25
Other	37.42	3.66	37.13	3.67	39.54	4.38	38.28	4.14	32.92	2.62	34.42	3.39	36.39	3.44	34.99	3.53
Total	36.39	4.07	37.26	4.66	39.36	4.98	37.81	4.8	33.1	3.86	35.27	4.81	37.55	4.78	35.81	4.92
NASAL ROOT BREADTH																
White	16.62	2.27	16.45	2.09	16.45	2.26	16.49	2.19	16.25	1.82	16.01	2.02	16.07	2.09	16.1	1.99
Black	17.59	2.64	17.31	2.35	17.3	2.4	17.35	2.42	17.61	1.94	17.15	2.1	17.14	2.06	17.18	2.06
Hispanic	16.57	2.43	16.52	2.12	16.52	2.37	16.54	2.28	16.23	1.89	16.11	2.16	16.78	2.04	16.36	2.02
Other	15.38	1.95	16.02	2.12	16.49	2.34	16.12	2.22	16.56	1.82	16.71	1.66	16.38	1.72	16.52	1.72
Total	16.73	2.42	16.65	2.19	16.72	2.35	16.69	2.3	16.52	1.91	16.58	2.08	16.7	2.06	16.62	2.04
STATURE																
White	1763.39	61.45	1770.66	63.37	1759.12	64.6	1765.13	63.61	1646.11	62.76	1636.86	65.65	1628.52	65.09	1636.76	64.88
Black	1763.18	67.68	1764.32	67.25	1759.87	71.46	1762.19	69.12	1630.37	61.08	1629.42	65.86	1627.4	63.5	1628.39	64.06
Hispanic	1704.38	60.99	1712.14	62.32	1702	59.82	1707.38	61.38	1595.53	74.61	1596.5	56.22	1549.84	40.96	1582.39	64.25
Other	1710.21	76.32	1731.74	57.16	1705.93	81.03	1716.05	72.79	1590.54	59.21	1604.25	66.37	1548.95	60.31	1575.12	66.54
Total	1744.43	68.68	1757.79	67.43	1751.08	70.35	1752.53	68.91	1625.35	68.17	1626.7	66.33	1610.57	70.22	1619.33	68.85
SUBNASALE-SELLION LTH																
White	50.81	4.02	52.27	3.92	53.21	3.97	52.31	4.05	48.1	3.61	48.6	3.83	48.9	3.53	48.56	3.68
Black	49.55	3.62	50.11	4.14	51.84	4.07	50.78	4.13	47.08	3.81	46.64	3.37	47.9	3.79	47.37	3.69
Hispanic	51.35	3.75	52.73	3.69	53.28	4.51	52.31	3.94	47.34	3.92	48.53	3.81	48.95	4.45	48.15	4.09
Other	50.13	4.24	51.81	4.83	51.32	3.98	51.28	4.36	45.17	3.82	45.58	3.61	47.07	3.5	46.18	3.69
Total	50.7	3.92	51.82	4.09	52.67	4.11	51.88	4.12	47.3	3.86	47.39	3.78	48.1	3.77	47.68	3.81
WEIGHT																
White	86.09	17.52	91.65	17	93.72	15.63	91.28	16.84	68.59	14.53	76.58	18.45	78.28	18.74	74.81	17.93
Black	88.16	19.66	95.1	19.25	94.95	19.9	93.94	19.73	79.01	18.65	85.85	21.08	87.85	19.52	86.36	20.15
Hispanic	85.75	19.28	90.38	16.94	90.85	15.66	88.73	17.75	74.35	19.61	77.14	17.64	76.16	16.1	75.68	17.98
Other	76.42	16.59	84.3	15.02	81.61	17.84	81.63	16.74	56.78	12.51	63.33	15.08	62.61	10.73	61.45	12.78
Total	85.95	18.47	91.92	17.59	93.06	17.48	91.03	17.94	69.32	17.28	78.82	20.48	80.49	20.09	77.54	20.13

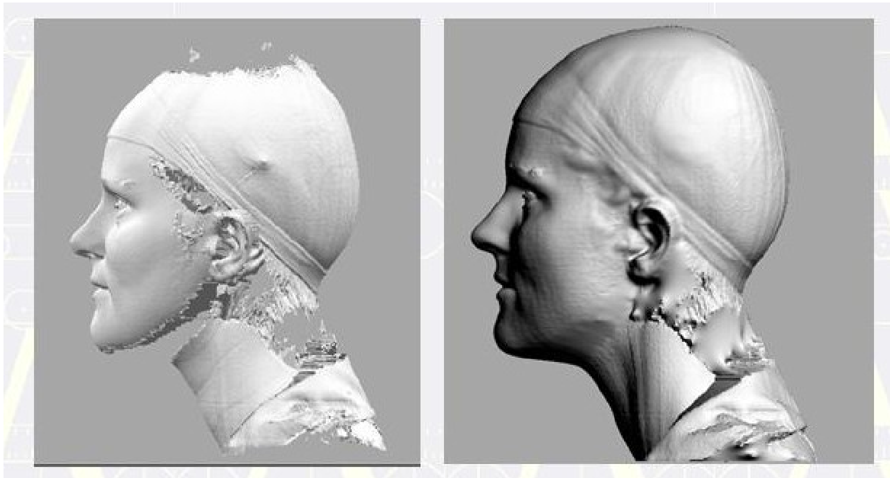

FIGURE 9

Typical Scan Before and After Data Cleaning

It is possible to calculate distances between pairs of landmarks. Such distances may, in some cases, be similar to dimensions that are measured by traditional techniques using calipers. Where the dimensions were similar, we compared the extracted and calculated value with the directly measured value. Table 12 presents the mean differences between the two measurement methods. The table is in two portions. The upper portion presents the mean of the *absolute* value of each difference, in which the effect of direction (which method had the larger value) is removed. The lower portion of the table presents the signed mean differences. In this statistic, a positive difference in effect cancels out a negative difference of the same magnitude. The mean absolute differences are useful for determining the level of difference between the two techniques. The signed differences are useful for identifying bias between the two techniques. We have included the minimum and maximum difference in each case. Some of these values are quite large. This may indicate an error in landmarking, or it may indicate an error in the traditional measurement. To try to identify the source of the error, we examined the scans of the individuals with the largest differences. There do not appear to be significant landmarking errors in the scan files, suggesting that the source of the difference may be in the traditional measurement.

TABLE 12

Mean Differences between Extracted Dimensions and Directly Measured Dimensions (values in mm)

	N	MIN	MAX	MEAN	STD DEV
ABSOLUTE VALUE OF DIFFERENCE					
Bigonial Breadth, Absolute	524	0.07	45.00	12.46	6.67
Bizygomatic Breadth, Absolute	490	0.45	50.39	12.16	5.98
Interpupillary Breadth, Absolute	543	0.00	21.70	3.29	2.43
Lip Length, Absolute	533	0.00	14.60	3.49	2.85
Maximum Frontal Breadth, Absolute	551	0.01	32.56	7.04	4.29
Menton-Sellion Length, Absolute	511	0.00	16.32	4.28	3.04
Minimum Frontal Breadth, Absolute	551	0.02	32.71	5.88	4.13
Nasal Root Breadth, Absolute	553	0.00	11.05	2.53	2.07
Nose Breadth, Absolute	562	0.02	12.22	2.43	1.66
Nose Protrusion, Absolute	560	0.00	14.87	2.01	1.73
Subnasale-Sellion Length, Absolute	558	0.00	11.94	2.82	2.15
SIGNED VALUE OF DIFFERENCE					
Bigonial Breadth, Signed	524	-45.00	10.06	-12.31	6.95
Bizygomatic Breadth, Signed	490	-50.39	3.04	-12.14	6.01
Interpupillary Breadth, Signed	543	-21.70	6.49	-2.75	3.03
Lip Length, Signed	533	-14.60	11.99	-1.49	4.26
Maximum Frontal Breadth, Signed	551	-32.56	7.50	-6.88	4.54
Menton-Sellion Length, Signed	511	-16.32	8.44	-3.56	3.86
Minimum Frontal Breadth, Signed	551	-32.71	7.78	-5.48	4.64
Nasal Root Breadth, Signed	562	-12.22	6.75	-2.17	1.99
Nose Breadth, Signed	560	-6.58	14.87	0.57	2.60
Nose Protrusion, Signed	553	-11.05	7.23	-1.87	2.68
Subnasale-Sellion Length, Signed	558	-11.94	5.99	-2.42	2.59

Given what we know about the nature of respirator fit, 3-D anthropometry may best capture the variability in human faces and may have a better association with respirator fit than the traditional dimensions. While the main purpose of this study was to build a data base of respirator users, we took this opportunity to conduct an exploratory examination of facial landmarks obtained for subjects in this study.

The 26 landmarks recorded for each subject are shown in Figure 10. These landmarks correspond to standard anthropometric points that are often used for traditional measurements, such as face length or width. While traditional point-to-point measures are often and successfully used in anthropometry, the analysis of 3-D landmark data is now recognized to have several advantages, the most relevant of which in this context are: (1) It allows for a better partition of size and shape variation and (2) it provides a more visual output by operating in the same 3D space as the object under study, in this case a human face.

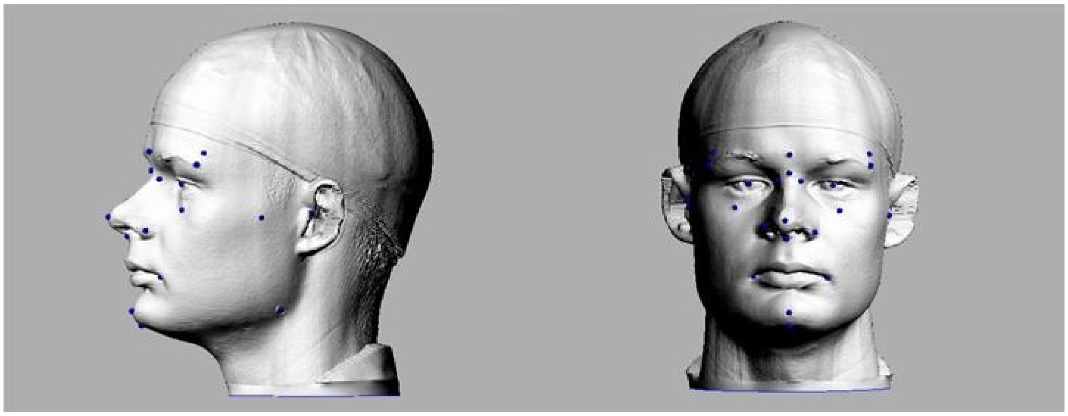

FIGURE 10

Facial Landmarks Recorded for Each Subject

Cartesian Coordinates are collected in raw space (scanner axis system) and then normalized for translation, rotation, and scale. This is referred to as Generalized Procrustes Analysis, or GPA (Rohlf, 2000).

GPA is a method for the statistical analysis of coordinate data. It is used specifically to partition the variation of a given sample of forms into components of size and shape. In order to achieve this partition and filter out any variation due to differences in position, orientation, or scale, the landmark configurations have to be normalized using Procrustes superimposition (Gower 1975, Rohlf & Slice 1990). Using a least squares-type of algorithm, this technique yields coordinate data that are optimally superimposed and rescaled to the same centroid size. Centroid size is the square root of the sum of the squared distances between pairs of homologous landmarks of each specimen and the mean of the total sample.

In the simplest case, Procrustes superimposition is performed with only two configurations, and it involves the following steps:

1. Each configuration's centroid (average of all xyz coordinates) is translated to the origin of the coordinate system.

2. Each configuration is rescaled by setting centroid size to 1.

3. Each configuration is rotated until the Procrustes distance for all homologous landmarks is minimized. The orthogonal rotation matrix, **H**, to rotate $\mathbf{X}_2$ to a least-squares orientation with respect to $\mathbf{X}_1$ is calculated as:

$$\mathbf{H} = \mathbf{V\Sigma U}^t$$

where **U** and **V** are obtained from the singular value decomposition of $\mathbf{X}_1^t\mathbf{X}_2 = \mathbf{UDV}^t$ and $\mathbf{\Sigma}$ is a diagonal matrix of 1s with the same sign as the corresponding elements of the diagonal matrix, **D**. This last substitution is to ensure a rigid rotation (Gower, 1975). For multiple specimens, the above outlined method is performed iteratively until the configurations converge (Rohlf & Slice 1990). The result of a GPA is a set of landmark configurations that are superimposed in a common orientation that is free of a fixed reference plane (such as the Frankfurt horizontal). Coordinate data that are superimposed in this manner have statistically desirable properties that make them directly suitable for uni- and multivariate analyses. Multiple configurations of specimens will cluster around the mean or consensus configuration, and differences between individual or mean configurations of groups can be visually represented as deviations from the consensus.

After the individual coordinate data have been aligned in this manner, they can be used as input variables for further statistical analysis, such as Principal Components Analysis (PCA) or regression analysis. Any resulting axis of interest can then be translated back into the three-dimensional space of the raw data and used to visually represent statistical results in the same geometry as the form studied.

In order to illustrate the approach and to assess the spatial variation of facial landmarks in the respirator user population, a principal components analysis (PCA) of the Procrustes-aligned subjects was computed. PCA reduces the raw input variables (in this case 28 landmarks *3 dimensions =84 shape variables) to a smaller number of explanatory factors, or components. The first component is computed in a way that maximizes the amount of variation it accounts for, and all subsequent components define the next highest direction of variation through the multidimensional space that is independent of (or orthogonal to) the first preceding component.

Overall, the amount of variation explained by the extracted components is relatively small, especially when compared to similar analyses based on traditional anthropometry. This is typically the case when a large portion of variation can be explained by absolute size differences, which have been filtered out in the course of the GPA. The remainder is mostly related to variation in proportions, or relative size (Bookstein, 1998).

As can be seen from the scatter plot of the individual scores along the first four components, sexual dimorphism can be used to explain a large part of the observed variance (Figure 11). The fact that both sexes scatter not only along the first but also the second principal component leads to overall similar shape changes associated with these components.

With respect to subsequent components, which only explain relatively small amounts of the total variance, there seems to be no obvious underlying factor to which the variation can be attributed. Population (or ethnic) background can be identified as a minor factor. However, the significant amount of scatter and overlap in the plot of PC3 vs. PC 4 (Figure 12) suggests that variation within ethnic groups dominates any between-group variation.

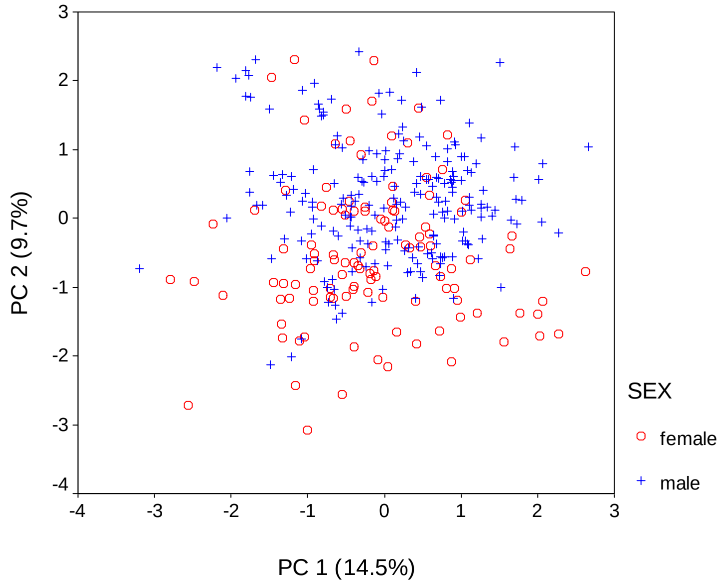

FIGURE 11

Scatter Plot of Individual PC Scores Along Principal Components 1-2
(Breakdown by Sex.)

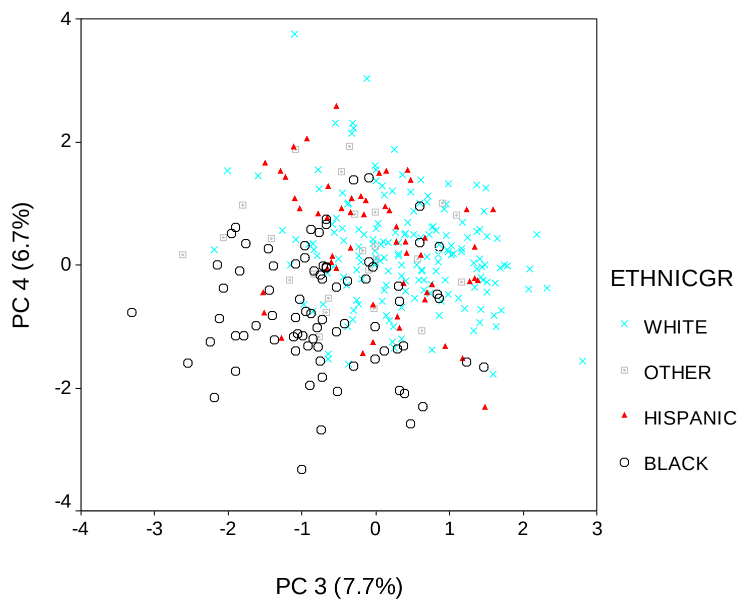

FIGURE 12

Scatter Plot of Individual PC Scores Along Principal Components 3-4
(Breakdown by Ethnic Group.)

Figures 13 and 14 are visual representations of PC 1 and PC 2, respectively. Each landmark configuration represents one direction of the shape variation in the sample, as assessed through a principal components analysis. In the present study, a total of 28 landmarks was used, which translates to 84 residuals (1 per landmark * 1 per dimension). A total of 10 principal components (accounting for 64.1 % of the variance) was extracted. The relatively low percentage of the first few components suggests that there is a significant amount of intra-individual variation, and that absolute size (filtered out in the GPA) accounts for much of the variance as well. For each PC, an observed point (subject) with negative and positive scores was taken as a representative of that shape component. An observation at the negative end of the axis is represented by diamonds, and at the positive end by (+) signs. Some of the key landmarks are connected through solid lines (for negative PC scores) and dashed lines (for positive scores). These lines are purely for visual purposes, and were not used in any computation. Although the variation along both principal components can be linked to sexual dimorphism (see Figure 11), the figures do not exactly represent differences between males and females. Such differences could be visualized in the same way, as the principal components are here, by using the discriminant scores of an ordinary discriminant function.

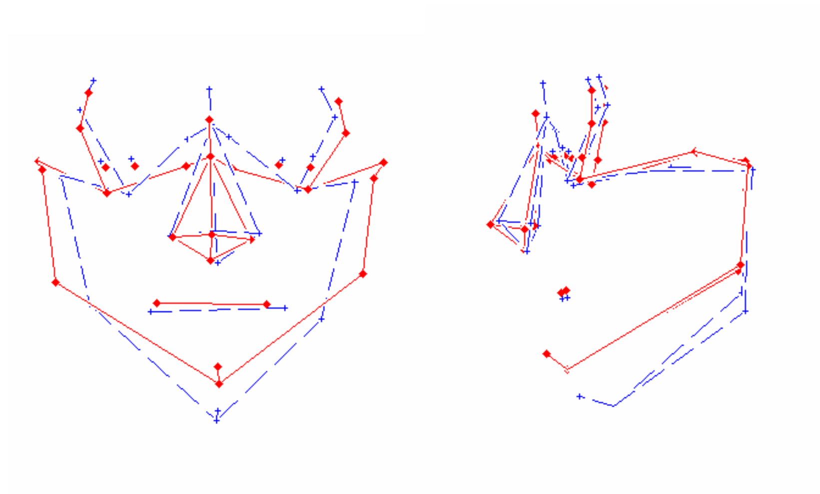

FIGURE 13

PC 1, Shape Differences Associated with
Negative (Diamonds) and Positive (+ Signs) Scores
(Frontal and Left Lateral View, Rotated into Frankfurt Horizontal.)

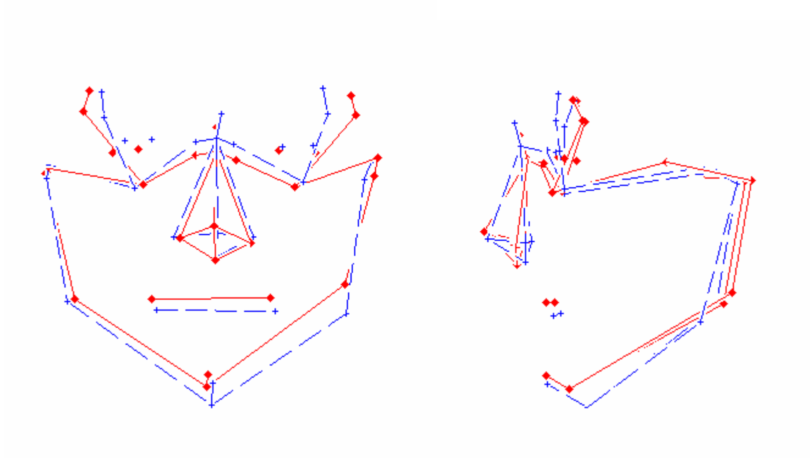

FIGURE 14

PC 2, Shape Differences Associated with
Negative (diamonds) and Positive (+ Signs) Scores
(Frontal And Left Lateral View, Rotated into Frankfurt Horizontal.)

Figure 13 suggests that the relative breadth across the zygomatic and lower jaw relative to the facial length account for the most pertinent differences. Another noticeable variation along PC 1 can be seen in the relative vertical position of the nasal root. The relative width of the upper face also shows important variation, especially along PC 2 (see Figure 14).

In order to make use of the data base in a CAD/CAM process without having to use every single individual data point, a small sample of representative individuals (20)has been identified. This process is based on the individual scores along the first 10 principal components, each of which represents a rigid rotation of the entire point cloud orthogonal (e.g. independent) to the previous component. Consequently, individuals with extreme values in either direction of each component represent precisely one direction of the total observed variance. Table 11 lists the subject numbers exhibiting extreme scores along PCs 1-10.   Screen shots of each of these 20 individuals' scans are presented in Appendix F.

TABLE 11

Data Reduction Using PCA: Explained Variance, Cumulative and by Component Representative

COMPONENT	INITIAL EIGENVALUES			
	TOTAL	% OF VARIANCE	CUMULATIVE %	SUBJECT NO's
1	0.001024402	14.522740	14.52274	729, 2856
2	0.000681898	9.667134	24.18987	2504, 418
3	0.000546616	7.749272	31.93915	2296, 2830
4	0.000471017	6.677512	38.61666	2947, 2328
5	0.000388777	5.511615	44.12827	2773, 4062
6	0.000337797	4.788875	48.91715	2368, 2315
7	0.000315138	4.467647	53.38479	4068, 2600
8	0.000306699	4.348018	57.73281	851, 2649
9	0.000255310	3.619480	61.35229	4071, 542
10	0.000194451	2.756695	64.10899	2587, 516

TEST PANEL REVISION

One of the important goals of this project is the revision of the Los Alamos test panel (Hack et al., 1974; McConville et al., 1973). Essentially a method for test design, this is an anthropometric matrix indicating how many of which facial sizes should be included in any test of a new respirator design. As noted in the Introduction, the method is sound, but the existing panel is based on outdated information.

We followed the general method used in the Hack and McConville publications, and used the same anthropometric dimensions. For method details, see Hack and coworkers (1974) and McConville and coworkers (1973). Our method differed only in that we did not restrict ourselves to a strictly rectangular arrangement of cells. By offsetting some test cells, coverage of the target population was increased.

It should be noted that a pilot laboratory study was underway at the NIOSH National Personal Protective Technology Laboratory at the time of writing this report. This work used quantitative fit tests as well as traditional anthropometry and 3D scans. It may suggest that other dimensions are more appropriate for test panel development than the ones used here. However, that study was not yet complete, so we used the dimensions from the earlier work, but based the new test panel numbers on the current population data. If the pilot study or a larger laboratory study should indicate that the set of dimensions needs to be revised, then it will be a simple matter to revise the test panel with the current population and the new dimensions.

Figure 15 shows the revised test panel for a full-face respirator. For the 25 individuals, males and females were distributed among the cells in approximate proportion to their anthropometric distribution with two exceptions: 1) males and females were represented approximately equally (13 males; 12 females); and 2) no cell was permitted to have only one inhabitant. Note that the revised test panel accommodates 96.2% of the current population. Figure 16 shows the revised test panel overlaid on the current population distribution. The older test panel is indicated for comparison. Figure 17 shows the population percentages in each of the test panel cells.

We repeated the procedures for a half-mask, and Figure 18 shows the resulting test panel. Figure 19 indicates the half-mask panel overlaid on the population distribution where it accommodates 97.2% of the population. The older test panel is illustrated for comparison. Finally, Figure 20 shows the percent of population that would fall in each cell for the half-mask panel.

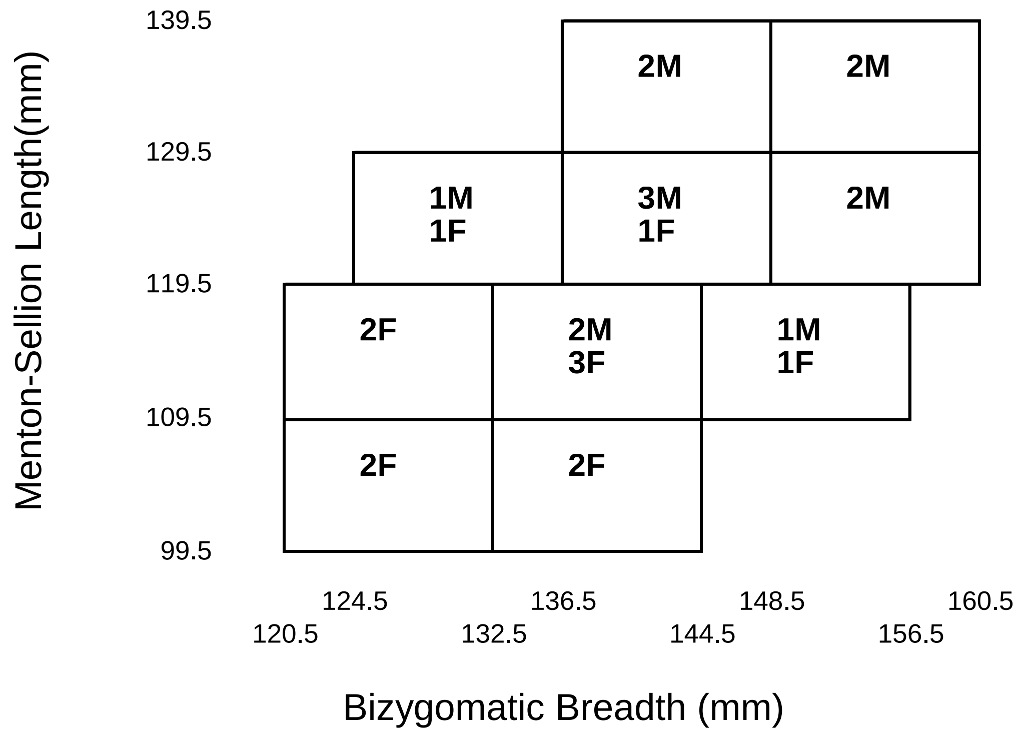

FIGURE 15

2004 Revised Male/Female 25-Person Panel – Full Facepiece Respirators

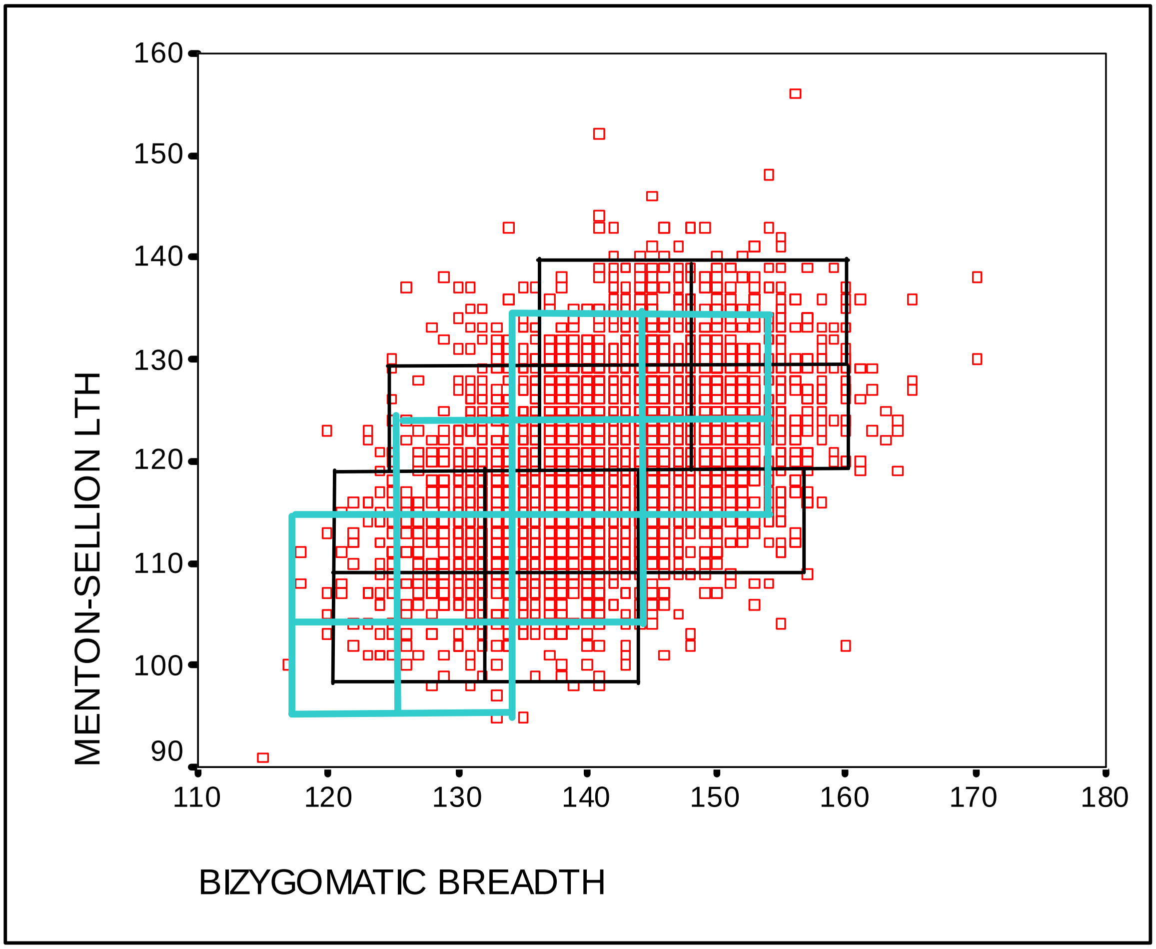

FIGURE 16

2004 Revised Panel Shown on Population Distribution – Full Facepiece Respirators
(Black boxes are 2004 Panel; Aqua boxes are Los Alomos Panel)

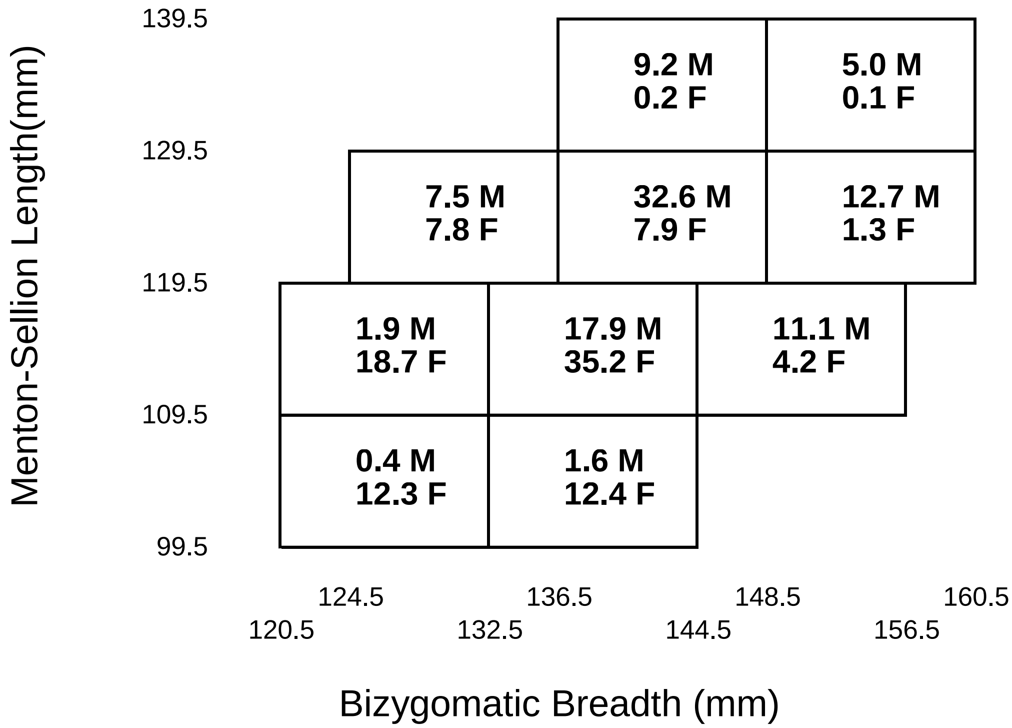

FIGURE 17

2004 Revised Male/Female Panel – Full Facepiece Respirators
(Expressed as the percentage of males and females in the population.)

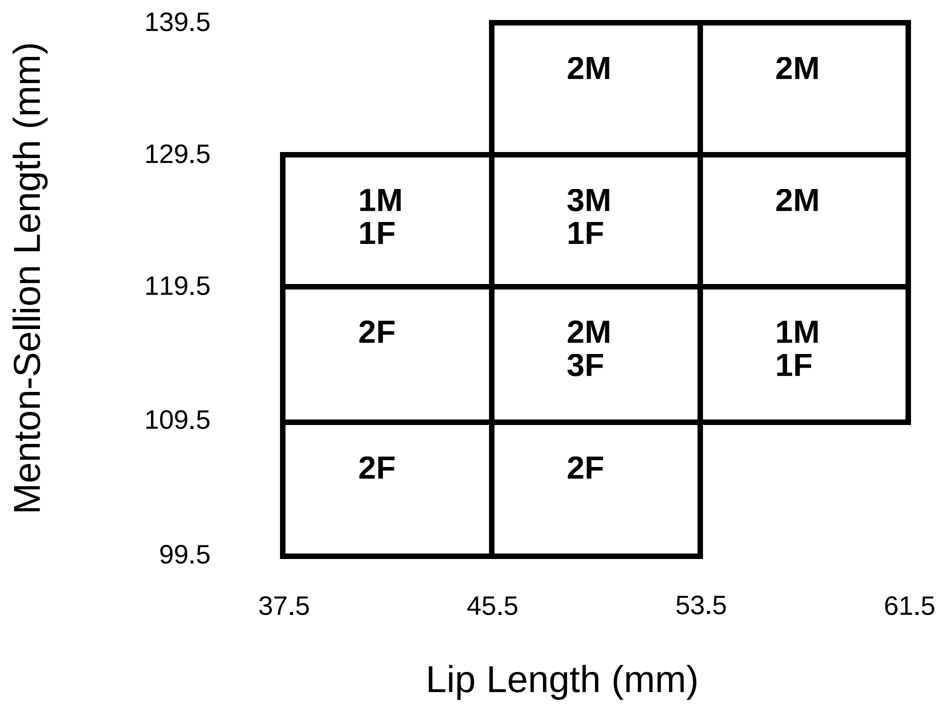

FIGURE 18

2004 Revised Male/Female 25-Person Panel – Half Facepiece Respirators

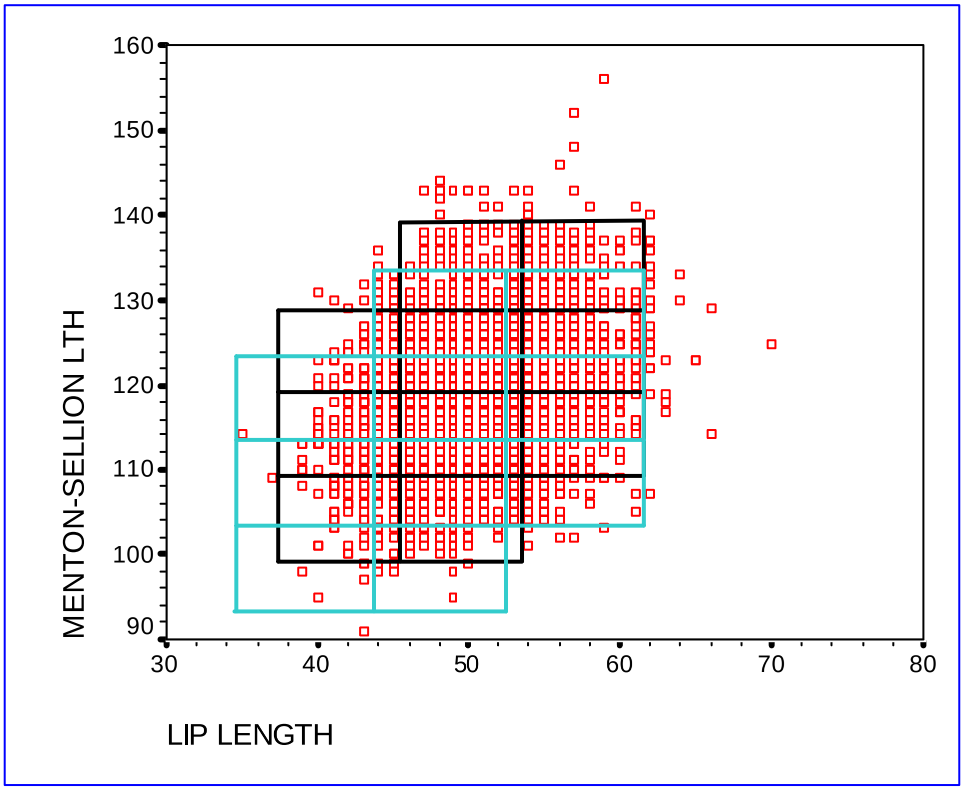

FIGURE 19

2004 Revised Panel Shown on Population Distribution – Half Facepiece Respirators
(Black boxes are 2004 Panel; Aqua boxes are Los Alomos Panel)

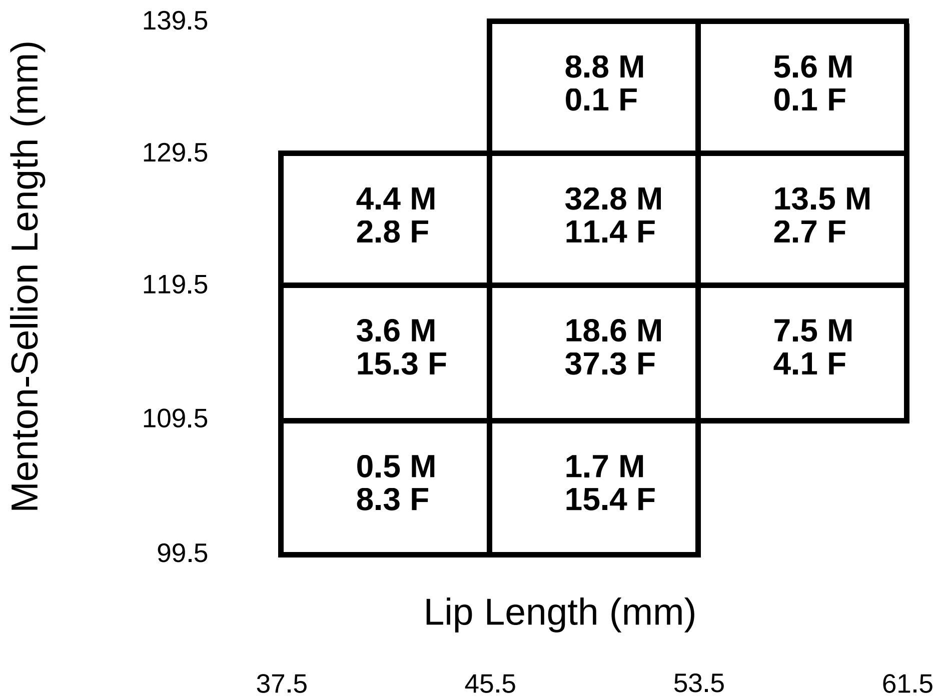

FIGURE 20

2004 Revised Male/Female Panel – Half Facepiece Respirators
(Expressed as the percentage of males and females in the population.)

CONCLUSIONS

It has been decades since the NIOSH respirator test panels have been created. They have never been previously updated. In the time since they were created, the nation's workforce has changed, and the original data – based on military subjects only – is not currently reflective of the anthropometric distribution of American faces.

This project responded to that need by creating the largest anthropometric data base on civilian heads and faces in U.S. history. More than 4000 people were measured. Dimensions were chosen to maximize their utility in the design and testing of new respiratory protection equipment. In addition, 3D scans were taken of more than 1000 persons. These 3D data sets can be used in the sizing of masks in the traditional way, but they open up the possibility of developing respirator architecture in a whole new way – following the curves and contours of the face as well as the anthropometry.

The test panel anthropometry has been updated, and new test panel charts are provided. We anticipate that these charts will be useful for years to come.

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APPENDIX A

Anthropometric Survey of Respirator Users

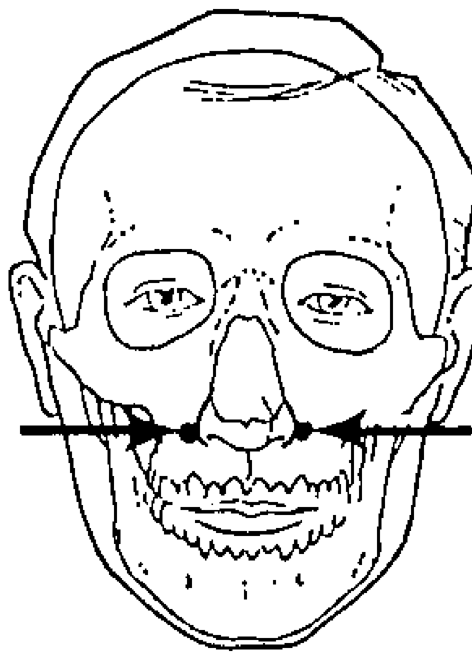
MEASURER'S HANDBOOK

9 January 2003

LANDMARK LIST

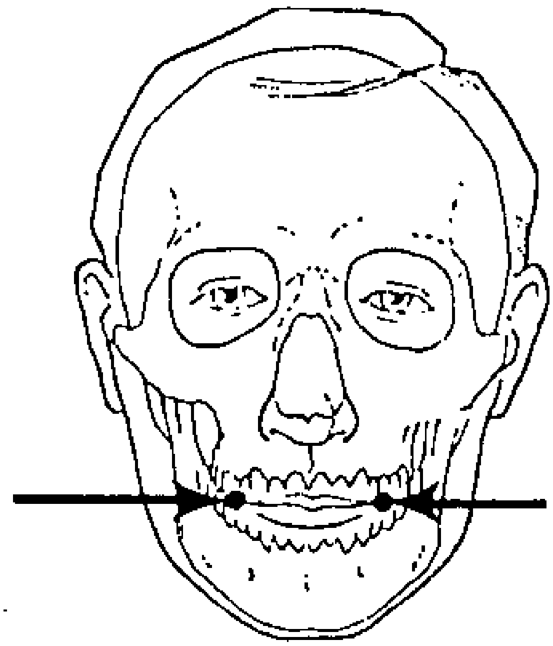
Alare, right and left: The lateral point on the flare or wing of the nose.

Method: It is located by visual inspection.



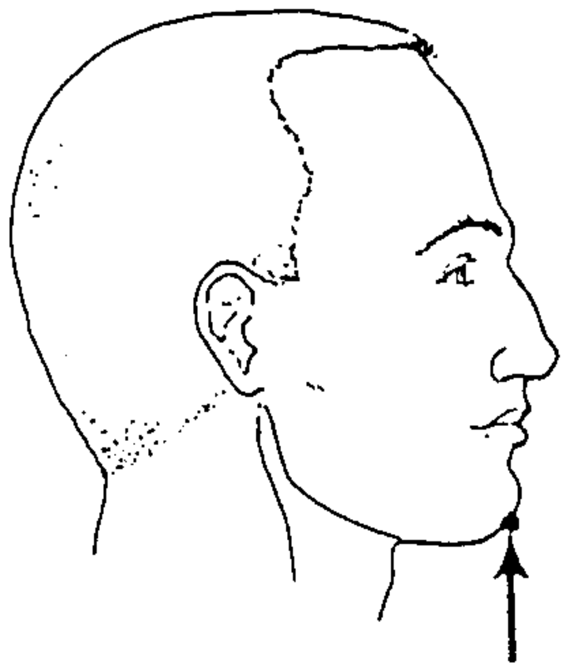
Cheilion, right and left: The lateral point of the juncture of the fleshy tissue of the lips with the facial skin at the corner of the mouth.

Method: It is located by visual inspection.



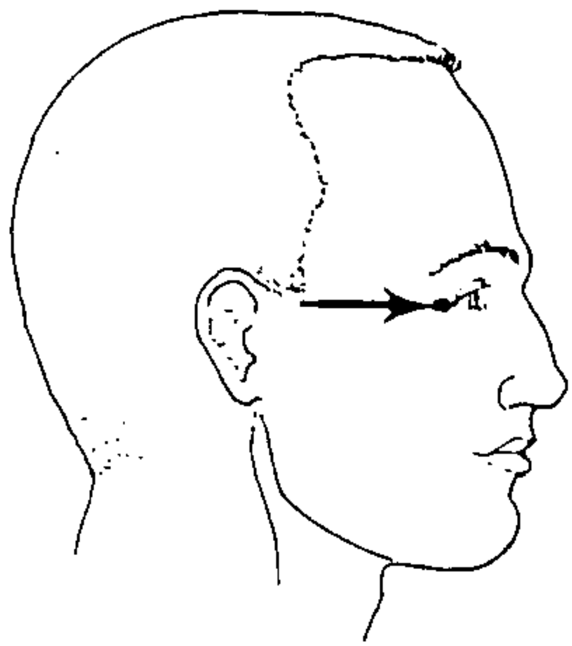
Chin: The most protruding point on the bottom edge of the chin, along the jawline.

Method: It is located by visual inspection.



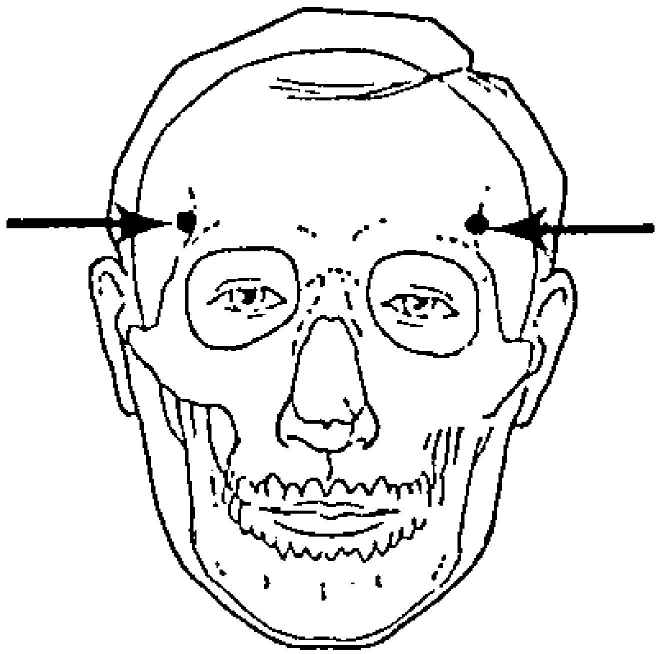
Ectocanthus (right and left): The outside corner of the eye formed by the meeting of the upper and lower eyelids. (unmarked)

Method: It is located by visual inspection.



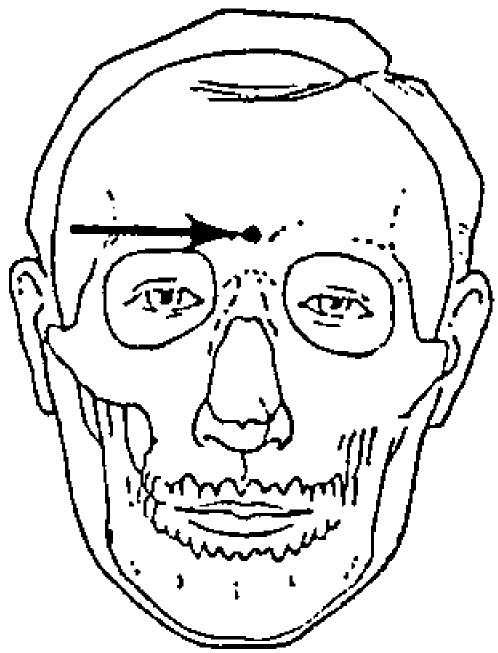
Frontotemporale, right and left: The point of deepest indentation of the temporal crest of the frontal bone above the browridges.

Method: It is located by palpation.



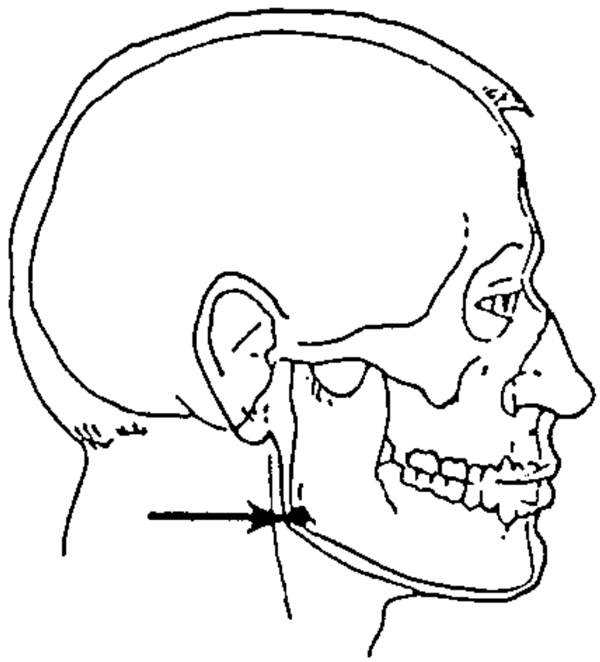
Glabella: The anterior point on the frontal bone midway between the bony browridges.

Method: It is located by visual inspection and palpation.



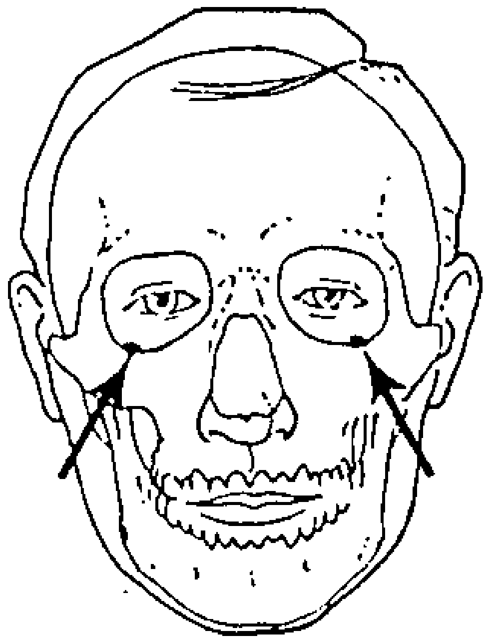
Gonion, right and left: The the most lateral, most inferior, and most posterior point on the angle of the mandible (jawbone).

Method: The subject stands with head in the Frankfort plane and with the teeth together (lightly occluded). Stand in front of the subject and locate the posterior angles of the mandible by palpation. The landmarks are the most lateral points of these angles.



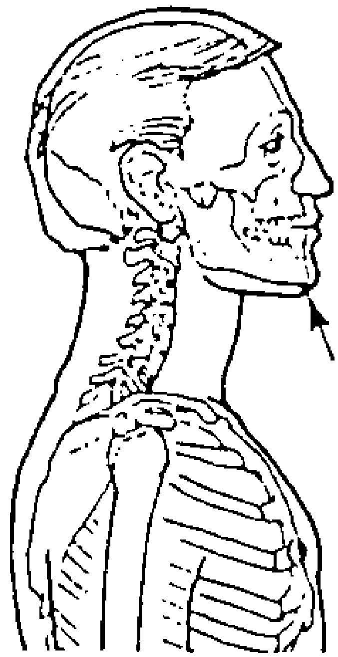
Infraorbitale, right and left: The lowest point on the anterior border of the bony eye socket.

Method: It is located by palpation.



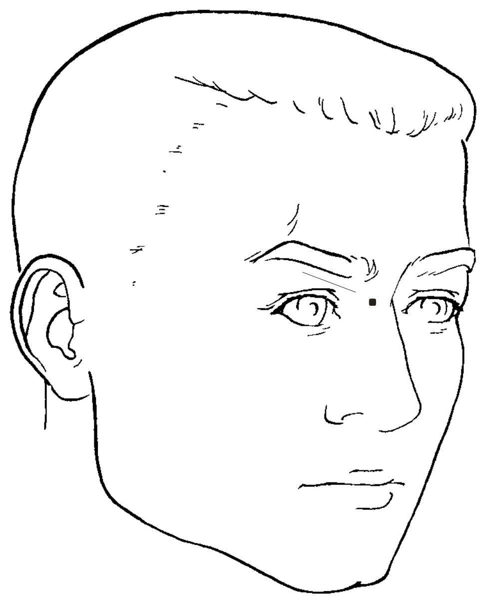
Menton: The inferior point of the mandible in the midsagittal plane (bottom of the chin).

Method: Subject stands with the head in the Frankfort Plane and the teeth together. Stand in front of the subject. Locate the landmark by palpation of the lower jawbone just under the chin, and place an adhesive dot on it.



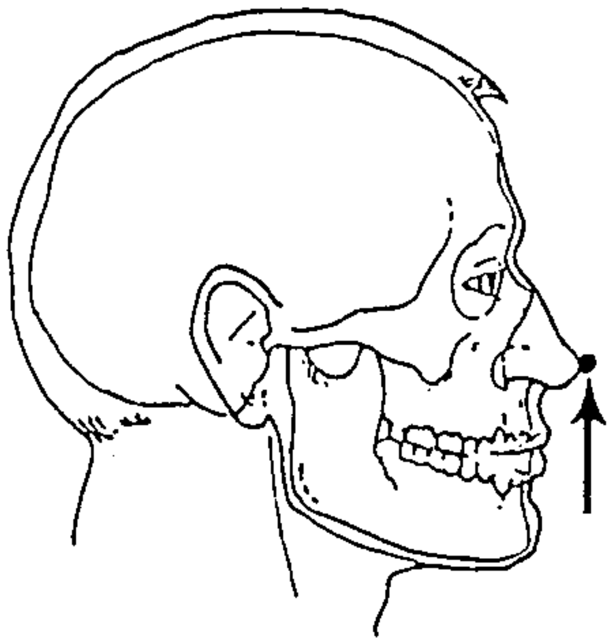
Nasal Root Point (right and left): The point on the side of the nasal root at a depth equal to one-half the distance from the bridge of the nose to the eyes.

Method: The subject stands looking straight ahead. Stand to the right side of the subject and locate the nasal root point by inspection.



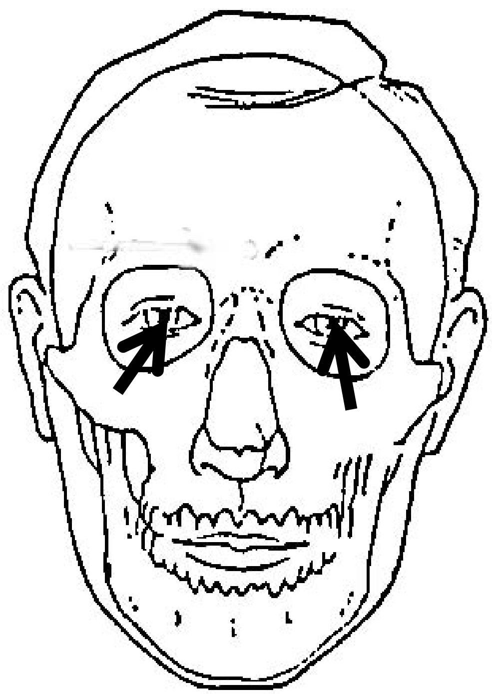
Pronasale: The point of the anterior projection of the tip of the nose.

Method: It is located by visual inspection.



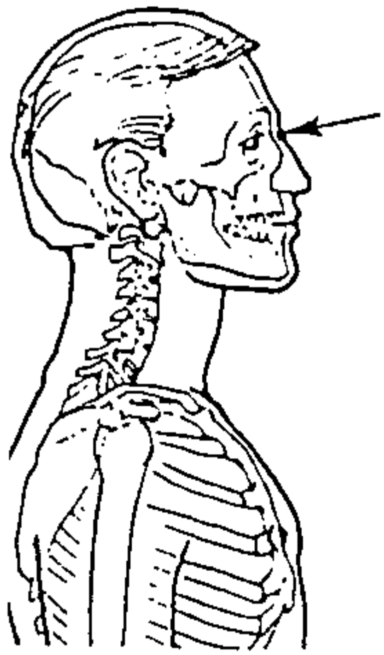
Pupil: The center of the pupil of a subject looking straight ahead.

Method: It is not marked on the subject, but is located by visual inspection on the scan.



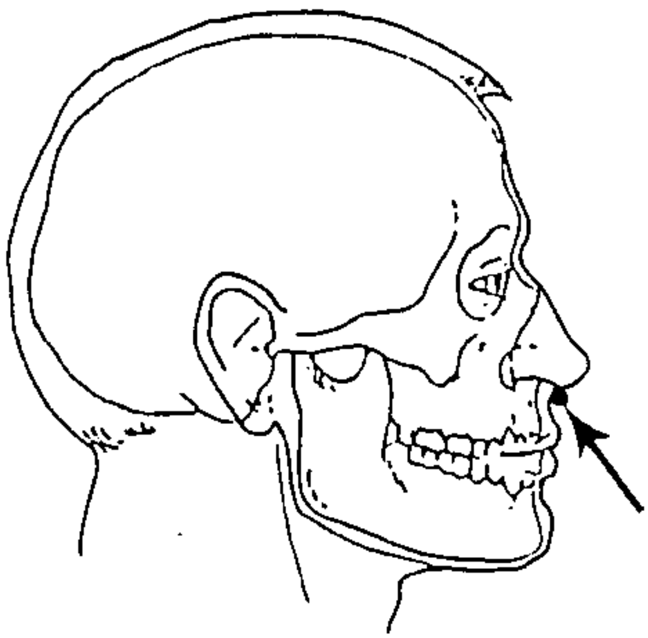
Sellion: The point of the deepest depression of the nasal bones at the top of the nose.

Method: The subject stands, looking straight ahead. Stand at the right of the subject and palpate the point of the deepest depression of the bridge of the nose in the midsagittal plane. On some subjects, however, there is no distinctly deepest point and judgment will have to be used to establish its location. Place an adhesive dot on the bridge of the nose at the landmark.



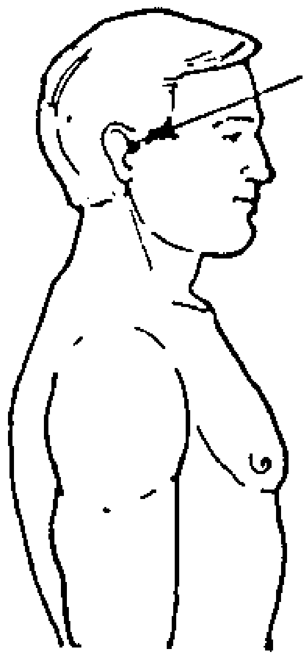
Subnasale: The point of intersection of the philtrum (groove of the upper lip) with the inferior surface of the nose, in the midsagittal plane.

Method: It is located by visual inspection.



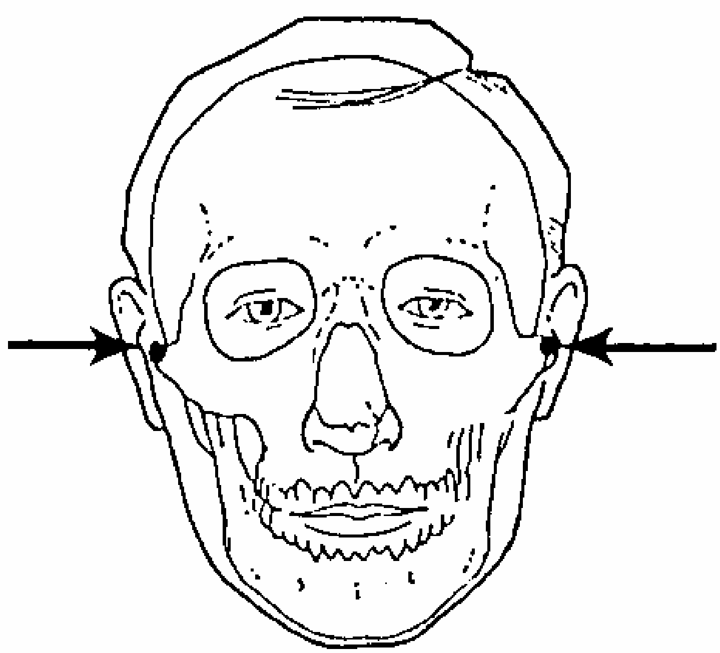
Tragion, right and left: The superior point on the juncture of the cartilaginous flap (tragus) of the ear with the head.

Method: Palpate the tragus to find the superior point of attachment to the head. Place an adhesive dot on each landmark.



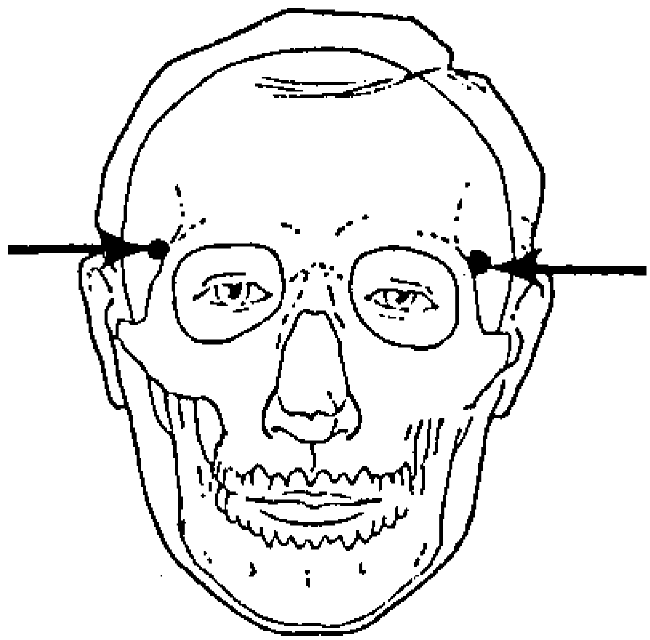
Zygion, right and left: The most lateral point on the zygomatic arch. (unmarked)

Method: The subject stands, looking straight ahead, with facial muscles relaxed. Stand in front of the subject and locate the most lateral point by palpation. (When unmarked, this is located by movement of the tips of the spreading caliper during measurement.)



Zygofrontale, right and left: The lateral point of the frontal bone on its zygomatic process.

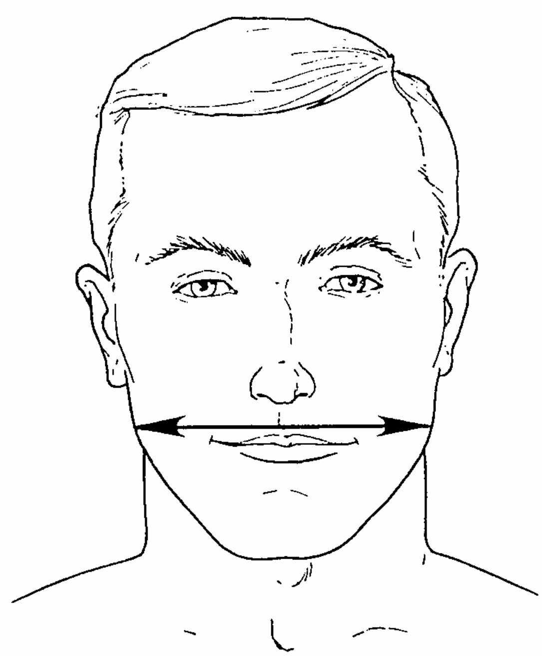
Method: It is located by palpation.



DIMENSION DESCRIPTIONS

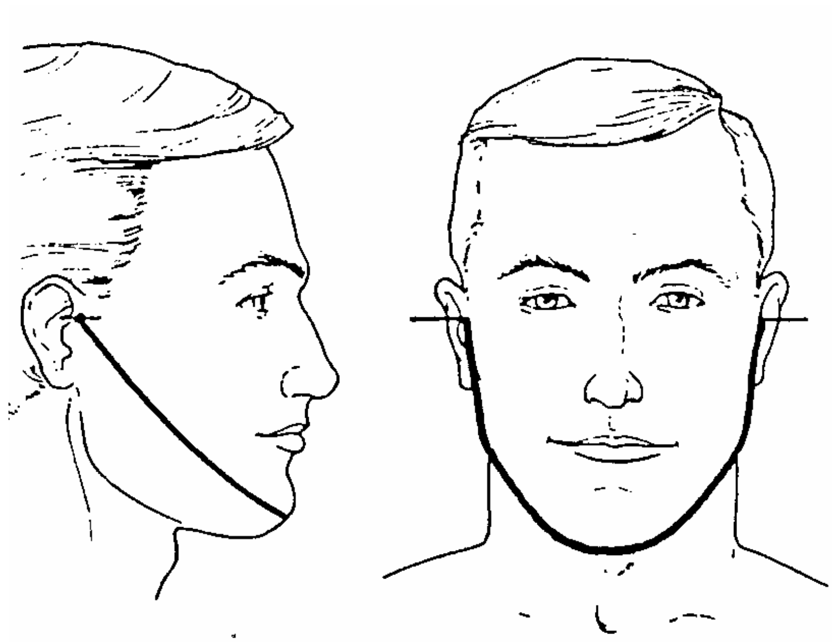
BIGONIAL BREADTH

The straight-line distance between the right and left Gonion landmarks on the corners of the jaw is measured with a spreading caliper. The subject sits looking straight ahead and with the teeth together (lightly occluded). Only enough pressure is exerted to ensure that the caliper tips are on the landmarks.



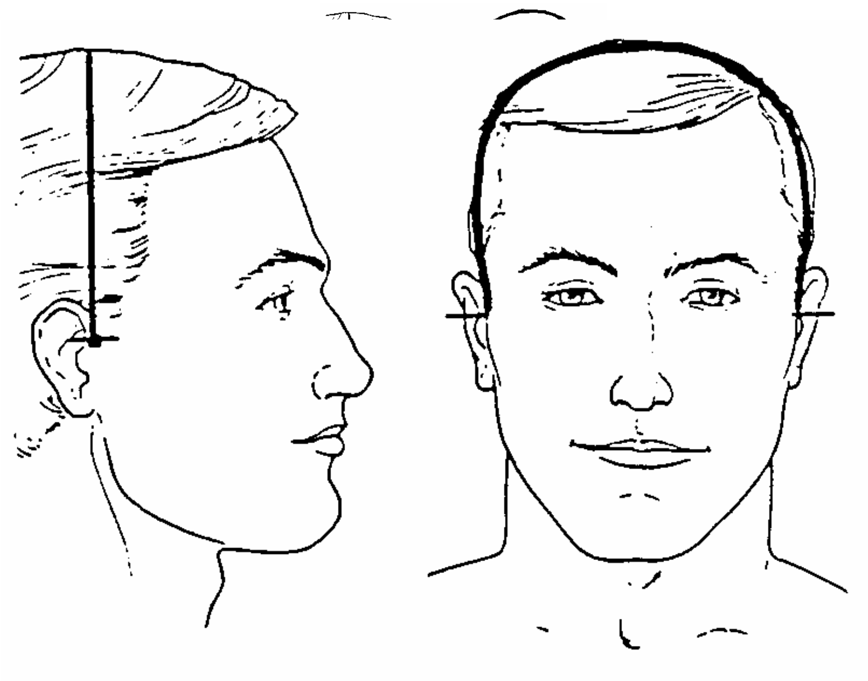
BITRAGION CHIN ARC

The surface distance between the right and left Tragion landmarks across the anterior point of the chin is measured with a tape. The subject sits looking straight ahead and with the teeth together (lightly occluded). Enough tension is exerted to maintain light contact between the tape and the skin. The chin will be slightly compressed.



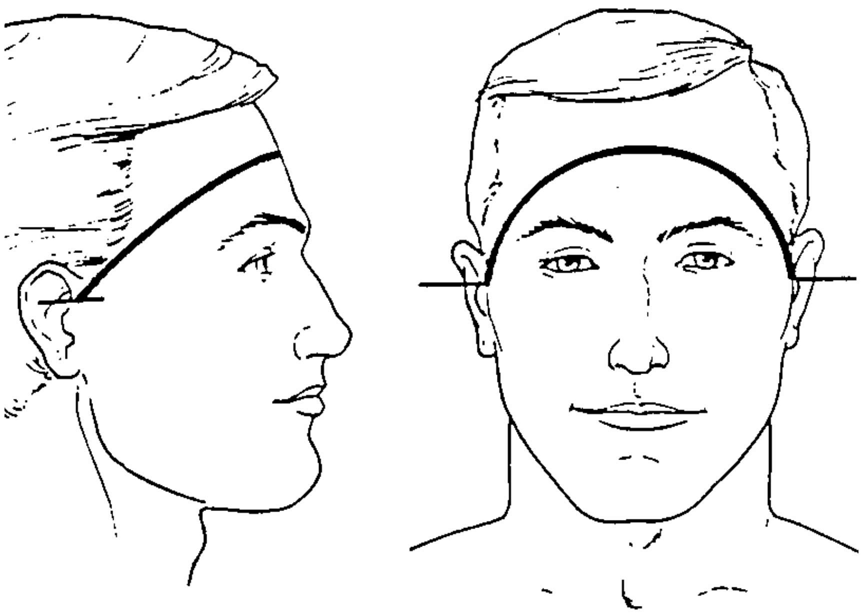
BITRAGION CORONAL ARC

The surface distance between the right and left Tragion landmarks across the top of the head in the coronal plane is measured with a tape. The subject sits with the head in the Frankfort plane. Enough tension is exerted to compress the hair.



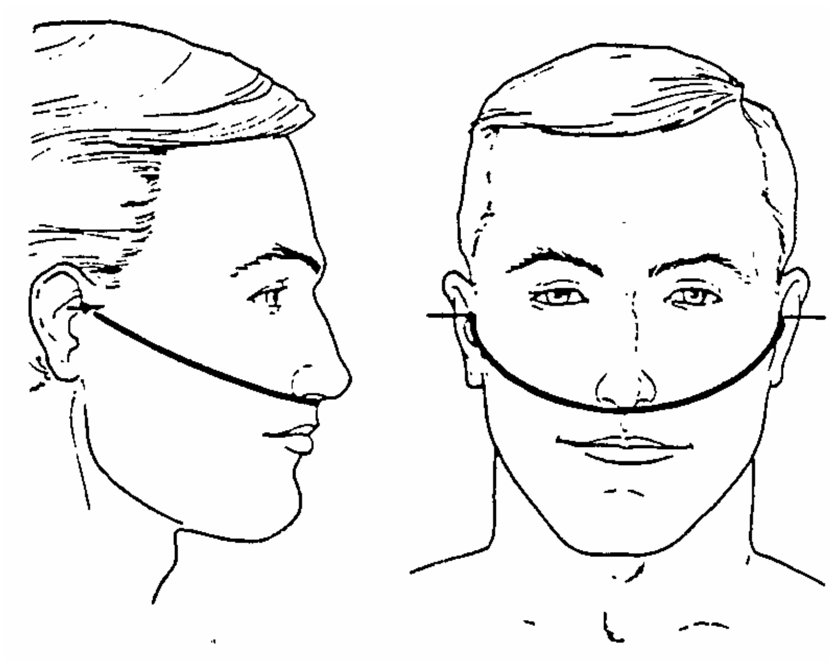
BITRAGION FRONTAL ARC

The surface distance between the right and left Tragion landmarks across the forehead just above the ridges of the eyebrows (supraorbital ridges) is measured with a tape. The subject sits looking straight ahead. Enough tension is exerted to maintain light contact between the tape and the skin.



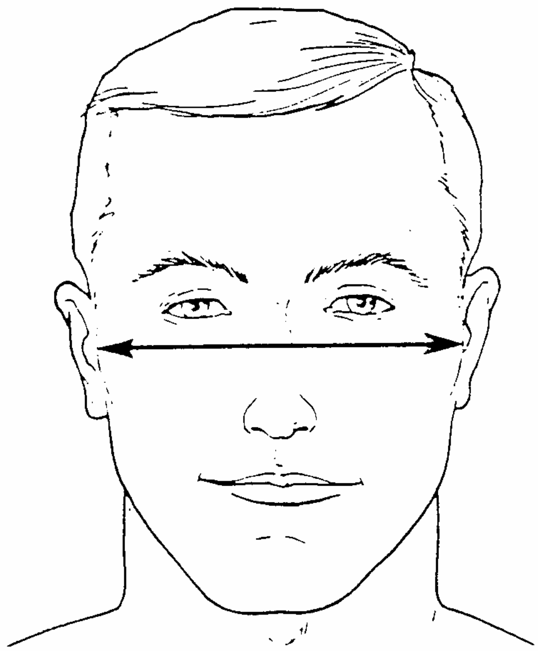
BITRAGION SUBNASALE ARC

The surface distance between the right and left Tragion landmarks across the Subnasale landmark at the bottom of the nose is measured with a tape. The subject sits looking straight ahead. Enough tension is exerted to maintain light contact between the tape and the skin, but not enough to compress the soft tissue under the nose.



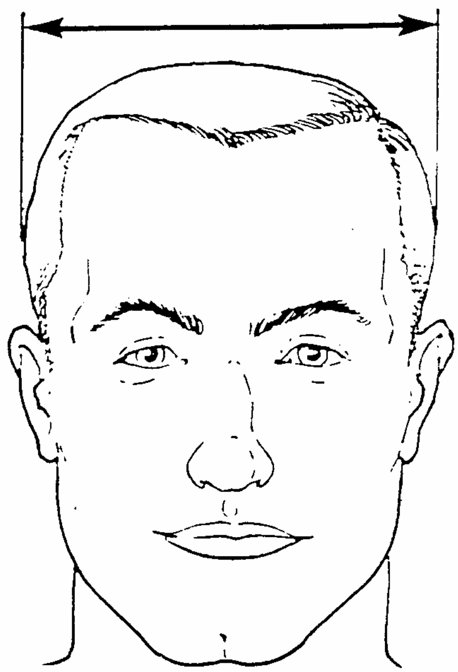
BIZYGOMATIC BREADTH

The maximum horizontal breadth of the face between the zygomatic arches is measured with a spreading caliper. The subject sits looking straight ahead and with the teeth together (lightly occluded). Only enough pressure to ensure that the caliper tips are on the zygomatic arches is exerted.



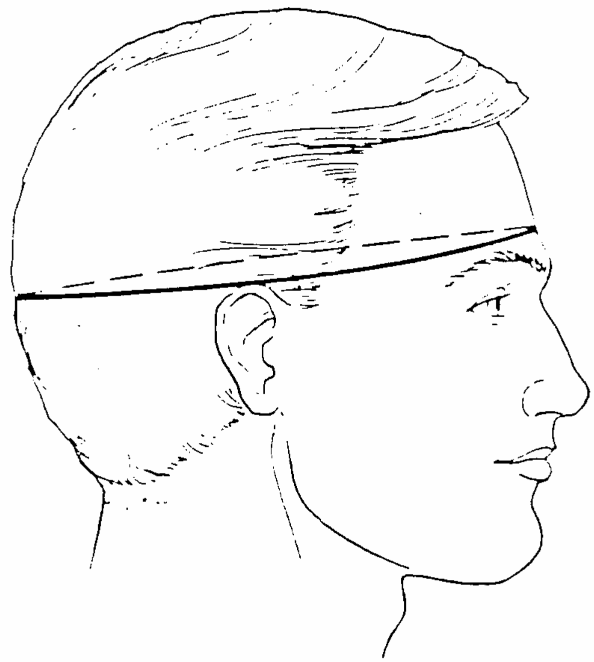
HEAD BREADTH

The maximum horizontal breadth of the head above the level of the ears is measured with a spreading caliper. The subject sits looking straight ahead. Enough pressure is exerted to obtain contact between the caliper and the skin.



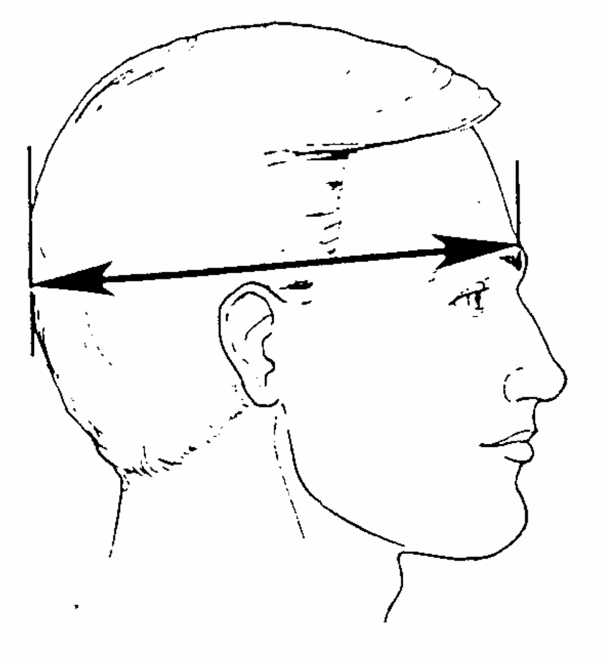
HEAD CIRCUMFERENCE

The maximum circumference of the head just above the ridges of the eyebrows (supraorbital ridges) and the attachment of the ears is measured with a tape. The subject sits looking straight ahead. The plane of the tape will be higher in the front than in the back and the sides should be parallel. Enough tension is exerted to compress the hair.



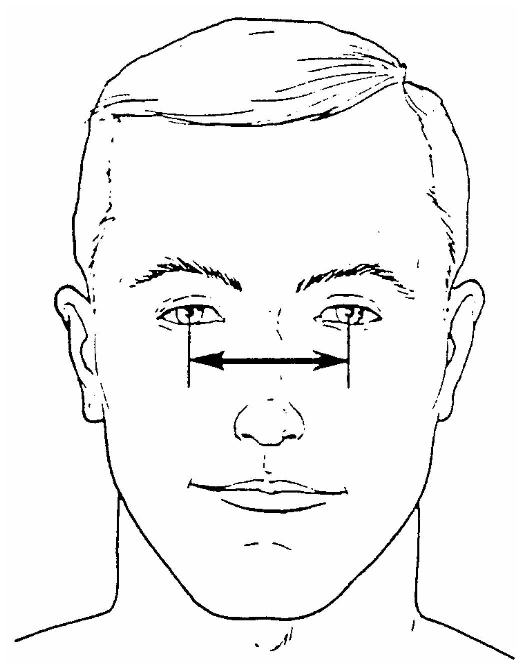
HEAD LENGTH

The maximum length of the head in the midsagittal plane is measured with a spreading caliper. The subject sits looking straight ahead. One tip of the caliper is placed on the Glabella landmark between the brow ridges and the other tip is moved up and down the back of the head until a maximum measurement is obtained. Light pressure is exerted on Glabella and enough pressure is exerted at the back of the head to compress the hair.



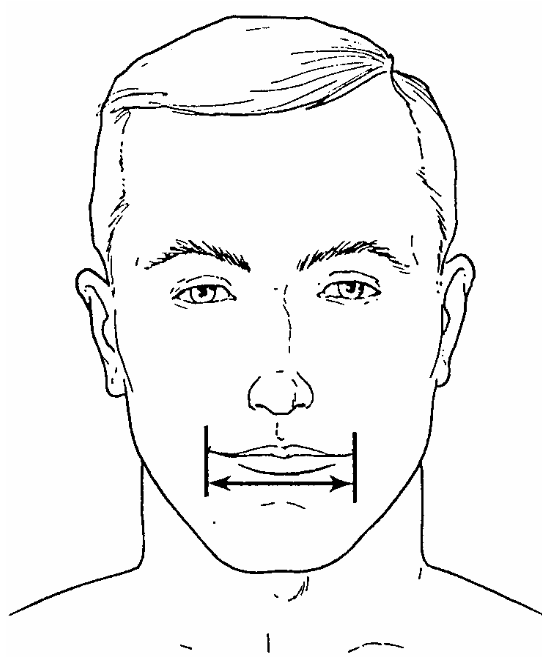
INTERPUPILLARY BREADTH

The horizontal distance between the center of the right and the center of the left pupil is measured with a pupillometer. Set the focal length of the pupillometer to infinity. Use the lever on top of the pupillometer to switch between eyes. Have the subject look at the light inside the pupillometer while holding it up against the eyes. Start with the lever on the left, and move the thumb slide on the bottom of the pupillometer until the cross hair is in the center of the pupil. Flip the lever to the right and repeat the process for the other eye. Read the total interpupillary breadth from the digital display.



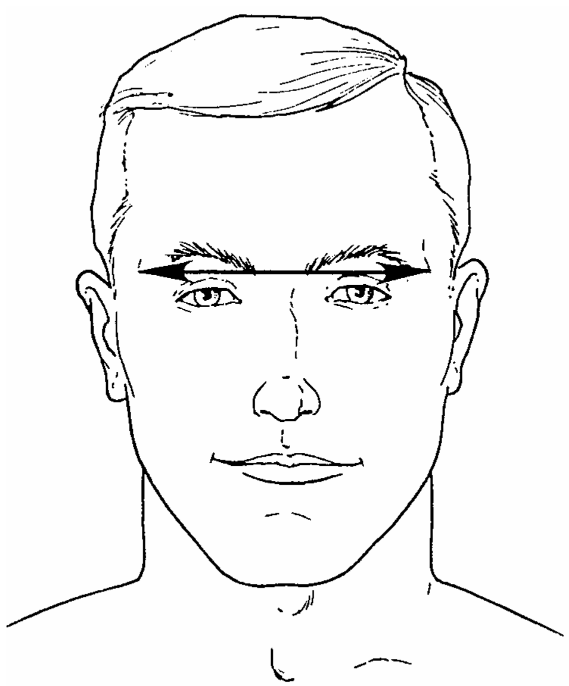
LIP LENGTH

The straight-line distance between the right and left Chelion landmarks at the corners of the closed mouth is measured with a sliding caliper. The subject sits looking straight ahead with the teeth together (lightly occluded). The facial muscles are relaxed, and the mouth is closed.



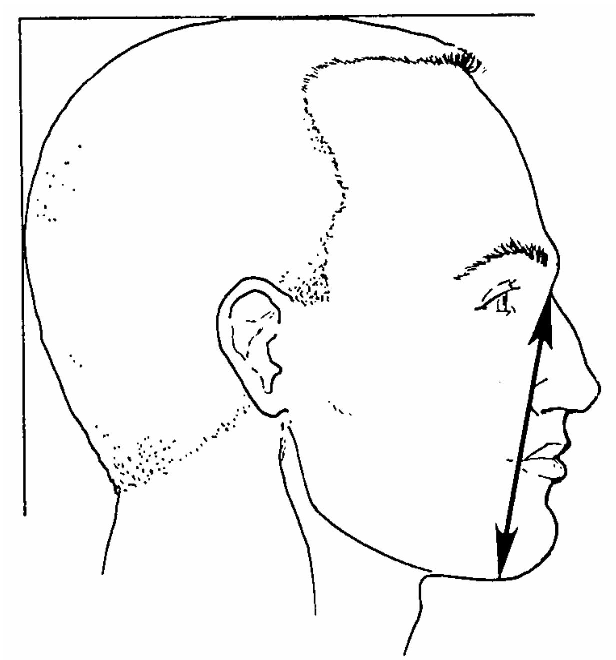
MAXIMUM FRONTAL BREADTH

The straight-line distance between the right and left Zygofrontale landmarks at the upper margin of each bony eye socket is measured with a spreading caliper. The subject sits looking straight ahead. Only enough pressure to ensure that the caliper tips are on the landmarks is exerted.



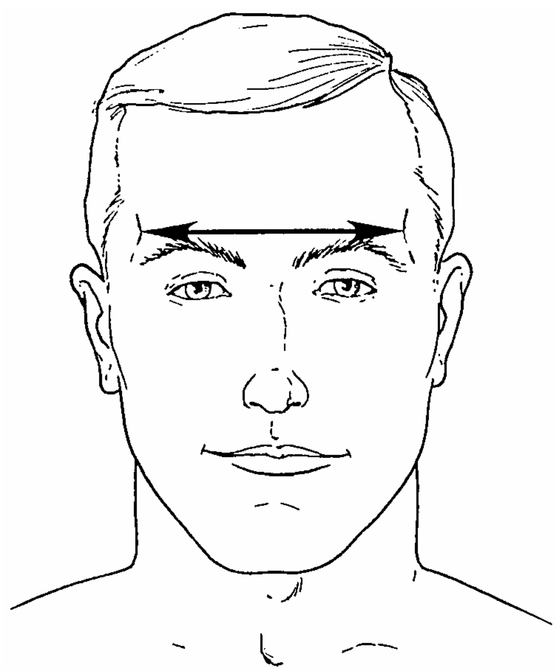
MENTON-SELLION LENGTH

The distance in the midsagittal plane between the Menton landmark at the bottom of the chin and the Sellion landmark at the deepest point of the nasal root depression is measured with a sliding caliper. The subject sits looking straight ahead and with the teeth together (lightly occluded). The fixed blade of the caliper is placed on Sellion. Only enough pressure to attain contact between the caliper and the skin is exerted.



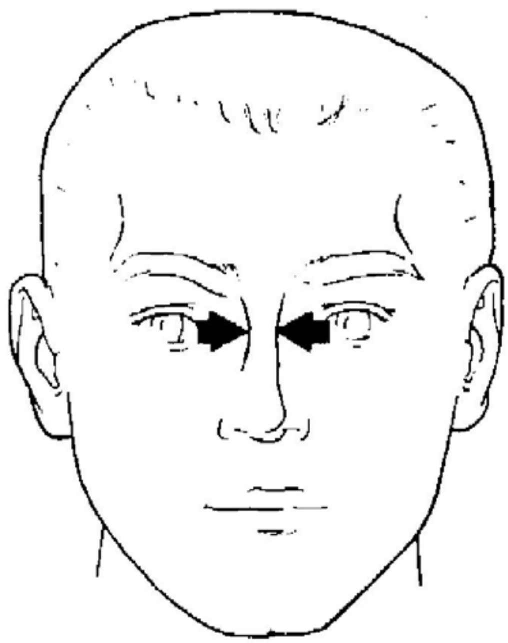
MINIMUM FRONTAL BREADTH

The straight-line distance between the right and left Frontotemporale landmarks on the temporal crest on each side of the forehead is measured with a spreading caliper. The subject sits looking straight ahead. Only enough pressure to ensure that the caliper tips are on the landmarks is exerted.



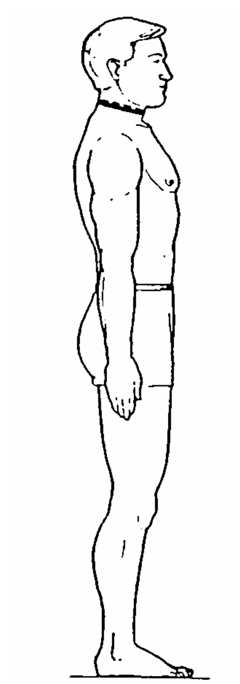
NASAL ROOT BREADTH

The horizontal breadth of the nose at the level of the deepest depression in the root (Sellion landmark) and at a depth equal to one-half the distance from the bridge of the nose to the eyes is measured with a sliding caliper. The subject sits looking straight ahead. The blunted points of the sliding caliper are used. Only enough pressure to attain contact between the caliper and the skin is exerted.



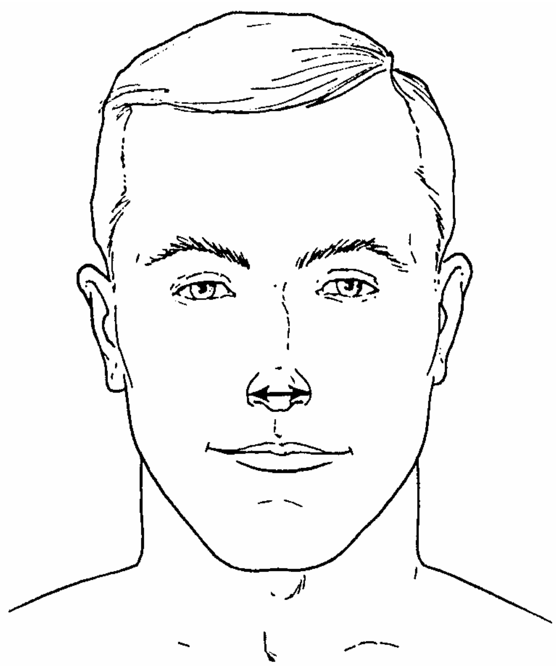
NECK CIRCUMFERENCE

The circumference of the neck at the level of the infrathyroid landmark (Adam's apple) is measured with a tape. The plane of the measurement is perpendicular to the long axis of the neck. The subject stands erect with the head in the Frankfort plane. The shoulders and upper extremities are relaxed.



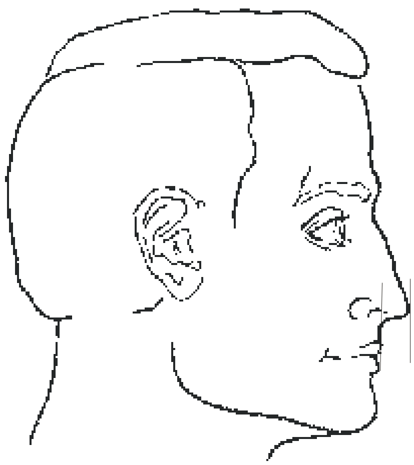
NOSE BREADTH

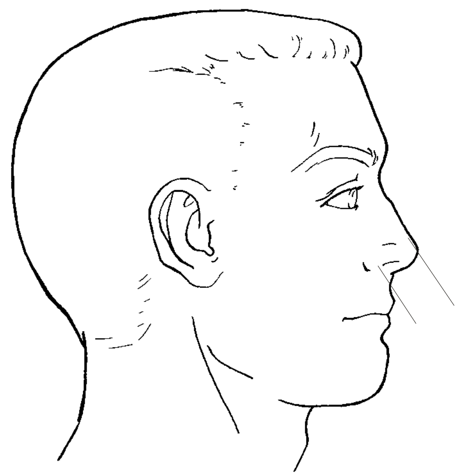
The straight-line distance between the right and left Alare landmarks on the sides of the nostrils is measured with a sliding caliper. The subject sits looking straight ahead. Only enough pressure to attain contact between the caliper and the skin is exerted.



NOSE PROTRUSION

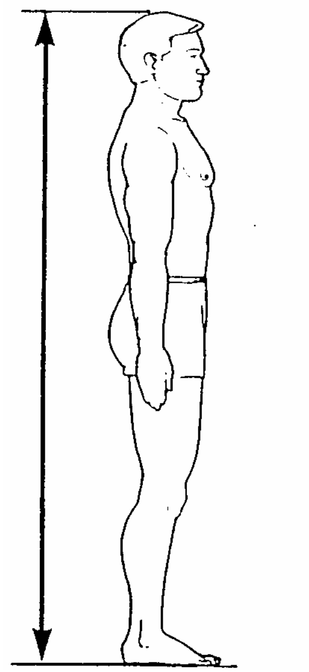
The straight-line distance between the Pronasale landmark at the tip of the nose and the Subnasale landmark under the nose is measured with a sliding caliper. The subject sits looking straight ahead. The sliding blade of the caliper is reversed and the base of the caliper is placed on the Subnasale landmark. The beam of the caliper is parallel to the line of the protrusion of the nose.





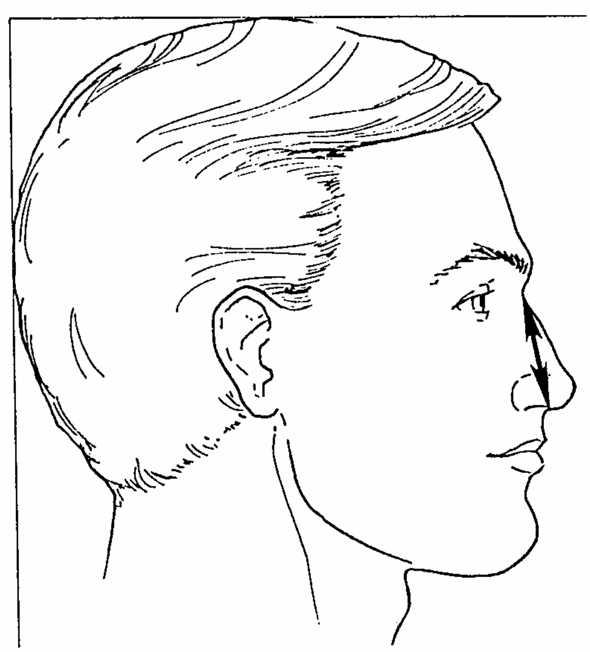
STATURE

The vertical distance between the standing surface and the top of the head is measured with an anthropometer. The subject stands erect with heels together and with the head in the Frankfort plane. The shoulders and arms are relaxed. Enough pressure is exerted to compress the hair. The measurement is taken at the maximum point of quiet respiration.



SUBNASALE-SELLION LENGTH

The straight-line distance between the Subnasale landmark under the nose and the Sellion landmark at the deepest point of the nasal root is measured with a sliding caliper. The subject sits looking straight ahead. Only enough pressure to attain contact between the caliper and the skin is exerted.



WEIGHT

The weight of the subject is taken to the nearest half kilogram. The subject stands on the center of the platform looking straight ahead. The heels are together and the weight evenly distributed on both feet.

APPENDIX B

SUBJECT CONSENT FORM

Scan

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)
CENTERS FOR DISEASE CONTROL AND PREVENTION
U.S. PUBLIC HEALTH SERVICE
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

> You have been asked to participate in a NIOSH research study. We explain here the nature of your participation, describe your rights, and specify how NIOSH will treat your records.

I. DESCRIPTION

a. Title: Anthropometric Survey of Respirator Users

b. Project Officer: Ziqing Zhuang, Ph.D.

c. Purpose and Benefits: The purpose of the present study is to develop information on head and face size and shape to develop fit-test panels for testing respirators, and to make better respirators. These fit-test panels are similar to the nation=s workers, just smaller in number. If the respirators fit the people on the panel, then they should fit almost all people who wear respirators.

The testing will be done at your normal work location.

You will not benefit directly from being in the study, but over time the information we discover will help:

i. You, because you will know that you helped make better respirators.

ii. You and other workers who are exposed to dangerous materials by making respirators work better and fit better.

iii. The companies that make respirators by providing them with information on how to improve the fit and design of respirators.

II. CONDITIONS OF THE STUDY

1. This study has three parts:

   (1). You will be asked to fill out a short questionnaire (five questions). It asks your age, race and sex, as well as some about the kind of work you do. This is important because we need to make sure that we get information from all sorts of Americans, so respirators will be able to fit most people. This part takes about 1 minute.

   (2). The researcher will feel your head and face for some bony points. These points will be marked with eye-liner pencil, which is easily removed when you are done. After marking, we will measure 18 dimensions using a tape measure and calipers. We will also measure your weight and height. The measurer is specially trained to do this. This part takes about 14 minutes.

   (3). The researcher will cover the marked points with small paper sticky dots. These allow the scanner to find the bony points. These dots are easily removed after scanning. For the 3-dimensional scanning, you will be asked to sit on a chair while the scanner moves around your head. You will need to hold your head still for about 20 seconds for the scan. You will be able to see a picture of yourself on the computer screen when the scan is finished. The scanner uses a low-level laser light, like a supermarket checkout scanner. When the scanning is finished, the dots and the eye-liner marks will be removed, and you will be compensated for your time, with our thanks. This part takes about 5 minutes.

2. The risk of injury is very low since you only need to sit or stand and be measured. Other possible risks include discomfort of having the tape measure and calipers on your face. It is possible that you will have an allergic reaction to the sticky dots. There is a slight risk that the caliper may slip into the eye, but the instrument is not sharp. Also, we measure in a certain way, so the risk of slipping into the eye is very small. If it does slip into the eye, you may feel some discomfort.

   If you have any reaction to the tests/procedures, you should contact Ziqing Zhuang, Ph.D., General Engineer, National Personal Protective Technology Laboratory, (304) 285-6167.

3. There are no alternative test procedures.

4. Injury from this project is unlikely. But if you are injured, we do not have medical care available, other than emergency treatment. If you are injured through negligence of a NIOSH employee, you may be able to obtain compensation under Federal Law. If you want to file a claim against the Federal government your contact point is: Public Health Service Claims Office (301) 443-1904. If you are injured through the negligence of a NIOSH contractor,

your claim would be against the contractor, not the federal government. If an injury should occur to you as the result of your participation, you should also contact: Ziqing Zhuang, Ph.D., General Engineer, National Personal Protective Technology Laboratory, (304) 285-6167, or Dr. Michael J. Colligan, Chairperson, NIOSH Human Subjects Review Board, (513) 533-8222.

5. If you have questions about this research contact, Ziqing Zhuang, Ph.D., General Engineer, National Personal Protective Technology Laboratory, (304) 285-6167. If you have any questions about your rights as a member of this study, contact Dr. Michael Colligan, Chair of the NIOSH Human Subjects Review Board at (513) 533-8222.

6. Your participation is voluntary and you may withdraw your consent and your participation in this study at any time without penalty or loss of benefits to which you are otherwise entitled.

   You will receive compensation of $10 for the testing which will take about 15 minutes of your own time.

7. The overall results of the study will be documented in a journal article or a National Personal Protective Technology Laboratory research report. Copies will be provided to you upon publication at your request. Please call Dr. Zhuang, the project officer, at the end of 2002 if you want the summary report.

III. USE OF INFORMATION

The National Institute for Occupational Safety and Health (NIOSH) of the Centers for Disease Control and Prevention (CDC), an agency of the Department of Health and Human Services, is authorized to collect this information, including your social security number (if applicable), under provisions of the Public Service Act, Section 301 (42 U.S.C. 241); Occupational Safety and Health Act, Section 20 (29 U.S.C. 669); and the Federal Mine Safety and Health Act of 1977, Section 501 (30 U.S.C. 95). The information you supply is voluntary and there is no penalty for not providing it. The data will be used to improve the representativeness of respirator test panels, and to provide face size and shape information for developing new respirators. Data will become part of CDC Privacy Act system 09-20-0159 "Records of Subjects in Certification, Testing, Studies of Personal Protective Devices, and Accident Investigations" and may be disclosed; to appropriate state or local health departments to report certain communicable diseases; to the State Cancer Registry to report cases of cancer where the state has a legal reporting program providing for the information's confidentiality; to private contractors assisting NIOSH; to collaborating researchers under certain limited circumstances to conduct further investigations; to one or more potential sources of vital statistics to make a determination of death; to the Department of Justice in the event of litigation, and to a congressional office assisting individuals in obtaining their records. An accounting of the disclosures that have been made by NIOSH will be made available to you upon request. Except for these and other permissible disclosures expressly authorized by the Privacy Act, or in limited circumstances when required by the Freedom of Information Act, no other disclosure may be made without your written consent.

IV. SIGNATURES

I have read this consent form and I agree to participate in this study.

PARTICIPANT ______________________________ AGE ________
(signature)

____ DATE _______
(and Guardian, if required)

I, the NIOSH representative, have accurately described this study to the participant.

REPRESENTATIVE ____________________________ DATE ______
(signature)

1 copy to participant
1 copy to project officer

Non-scan

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)
CENTERS FOR DISEASE CONTROL AND PREVENTION
U.S. PUBLIC HEALTH SERVICE
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

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   The testing will be done at your normal work location.

   You will not benefit directly from being in the study, but over time the information we discover will help:

   1. You, because you will know that you helped make better respirators.

   2. You and other workers who are exposed to dangerous materials by making respirators work better and fit better.

   3. The companies that make respirators by providing them with information on how to improve the fit and design of respirators.

II. CONDITIONS OF THE STUDY

1. This study has two parts:

   (1). You will be asked to fill out a short questionnaire (five questions). It asks your age, race and sex, as well as some about the kind of work you do. This is important because we need to make sure that we get information from all sorts of Americans, so respirators will be able to fit most people. This part takes about 1 minute.

   (2). The researcher will feel your head and face for some bony points. These points will be marked with eye-liner pencil, which is easily removed when you are done. After marking, we will measure 18 dimensions using a tape measure and calipers. We will also measure your weight and height. The measurer is specially trained to do this. When the measurement is finished, the eye-liner marks will be removed, and you will be compensated for your time, with our thanks. This part takes about 14 minutes.

2. The risk of injury is very low since you only need to sit or stand and be measured. Other possible risks include discomfort of having the tape measure and calipers on your face. There is a slight risk that the caliper may slip into the eye, but the instrument is not sharp. Also, we measure in a certain way, so the risk of slipping into the eye is very small. If it does slip into the eye, you may feel some discomfort.

   If you have any reaction to the tests/procedures, you should contact Ziqing Zhuang, Ph.D., General Engineer, National Personal Protective Technology Laboratory, (304) 285-6167.

3. There are no alternative test procedures.

4. Injury from this project is unlikely. But if you are injured, we do not have medical care available, other than emergency treatment. If you are injured through negligence of a NIOSH employee, you may be able to obtain compensation under Federal Law. If you want to file a claim against the Federal government your contact point is: Public Health Service Claims Office (301) 443-1904. If you are injured through the negligence of a NIOSH contractor, your claim would be against the contractor, not the federal government. If an injury should occur to you as the result of your participation, you should also contact: Ziqing Zhuang, Ph.D., General Engineer, National Personal Protective Technology Laboratory, (304) 285-6167, or Dr. Michael J. Colligan, Chairperson, NIOSH Human Subjects Review Board, (513) 533-8222.

5. If you have questions about this research contact, Ziqing Zhuang, Ph.D., General Engineer, National Personal Protective Technology Laboratory, (304) 285-6167. If you have any questions about your rights as a member of this study, contact Dr. Michael Colligan, Chair of the NIOSH Human Subjects Review Board at (513) 533-8222.

6. Your participation is voluntary and you may withdraw your consent and your participation in this study at any time without penalty or loss of benefits to which you are otherwise entitled.

   You will receive compensation of $10 for the testing which will take about 15 minutes of your own time.

7. The overall results of the study will be documented in a journal article or a National Personal Protective Technology Laboratory research report. Copies will be provided to you upon publication at your request. Please call Dr. Zhuang, the project officer, at the end of 2002 if you want the summary report.

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The National Institute for Occupational Safety and Health (NIOSH) of the Centers for Disease Control and Prevention (CDC), an agency of the Department of Health and Human Services, is authorized to collect this information, including your social security number (if applicable), under provisions of the Public Service Act, Section 301 (42 U.S.C. 241); Occupational Safety and Health Act, Section 20 (29 U.S.C. 669); and the Federal Mine Safety and Health Act of 1977, Section 501 (30 U.S.C. 95). The information you supply is voluntary and there is no penalty for not providing it. The data will be used to improve the representativeness of respirator test panels, and to provide face size and shape information for developing new respirators. Data will become part of CDC Privacy Act system 09-20-0159 "Records of Subjects in Certification, Testing, Studies of Personal Protective Devices, and Accident Investigations" and may be disclosed; to appropriate state or local health departments to report certain communicable diseases; to the State Cancer Registry to report cases of cancer where the state has a legal reporting program providing for the information's confidentiality; to private contractors assisting NIOSH; to collaborating researchers under certain limited circumstances to conduct further investigations; to one or more potential sources of vital statistics to make a determination of death; to the Department of Justice in the event of litigation, and to a congressional office assisting individuals in obtaining their records. An accounting of the disclosures that have been made by NIOSH will be made available to you upon request. Except for these and other permissible disclosures expressly authorized by the Privacy Act, or in limited circumstances when required by the Freedom of Information Act, no other disclosure may be made without your written consent.

IV. SIGNATURES

I have read this consent form and I agree to participate in this study.

PARTICIPANT ______________________________ AGE ________
(signature)

____ DATE _______
(and Guardian, if required)

I, the NIOSH representative, have accurately described this study to the participant.

REPRESENTATIVE ____________________________ DATE ______
(signature)

1 copy to participant
1 copy to project officer

APPENDIX C

DATA SHEET

NIOSH RESPIRATOR STUDY

Meas ___ Rec

Name ________________________________ **Date** ___________ **Sex** ______ **Age** _______

Latino or Hispanic: Yes __ No __

Race: Am.Indn/Alaskan __ Asian __
Black/Af. Am. __ Hawaiian/Pacific Isldr __
White __ More than 1 of those listed__

Occupations:

1 Construction
2 Manufacturing
3 Fire Fighting
4 Health Care
5 Law Enforcement
6 Others _________________

Respirator User:
Yes____ No____

Dimension (kg, mm)		**remeasure**
1. Weight		
2. Height (Stature)		
3. Head Circ		
4. Crown Arc (Bitragion Coronal Arc)		
5. Forehead Arc (Bitrgn Frontal Arc)		
6. Nose Arc (Bitrgn Subnasale Arc)		
7. Chin Arc (Bitragion Chin Arc)		
8. Neck Circumference (Infrathyroid)		
9. Head Width (Head Breadth)		
10. Head Length		
11. Min Forehead Width (Min Frontal Br)		
12. Max Forehead Width (Max Frontal Br)		
13. Face Width (Bizygomatic Breadth)		
14. Jaw Width (Bigonial Breadth)		
15. Nose Bridge Width (Nasal Root Breadth)		
16. Nose Width (Nose Breadth)		
17. Lip Length		
18. Nose Length (Subnasale-Sellion Length)		
19. Face Length (Menton-Sellion Length)		
20. Nose Protrusion		
21. Pupil distance (Interpupillary Distance)		

Scan No. ______________________ Scanner Initials _________ Comments:

APPENDIX D

MULTIVARIATE TESTS
BY MALES AND FEMALES

Multivariate Tests - MALES

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.999597	559498.9	19	4290	0.0000
	Wilks' Lambda	0.000403	559498.9	19	4290	0.0000
	Hotelling's Trace	2477.967	559498.9	19	4290	0.0000
	Roy's Largest Root	2477.967	559498.9	19	4290	0.0000
GROUP	Pillai's Trace	0.603024	342.9846	19	4290	0.0000
	Wilks' Lambda	0.396976	342.9846	19	4290	0.0000
	Hotelling's Trace	1.519046	342.9846	19	4290	0.0000
	Roy's Largest Root	1.519046	342.9846	19	4290	0.0000
a	Exact statistic					
b	Design: Intercept+GROUP					
c	Weighted Least Squares Regression - Weighted by Weighting Value					

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	WEIGHT, KG	84198.04	1	84198.04	329.9354	0.0000
	STATURE	44328.27	1	44328.27	9.324615	0.0023
	HEAD CIRC	23561.43	1	23561.43	87.0882	0.0000
	BITRAGION CORONAL ARC	5951.694	1	5951.694	33.1794	0.0000
	BITRAGION FRONTAL ARC	1706.459	1	1706.459	11.96021	0.0005
	BITRAGION SUBNASALE ARC	5010.336	1	5010.336	33.36111	0.0000
	BITRAGION CHIN ARC	8065.951	1	8065.951	37.60077	0.0000
	HEAD BREADTH	375.8731	1	375.8731	11.67186	0.0006
	HEAD LENGTH	245.9828	1	245.9828	4.735184	0.0296
	MINIMUM FRONTAL BR	244.4596	1	244.4596	8.51974	0.0035
	MAXIMUM FRONTAL BR	411.1532	1	411.1532	15.54398	0.0001
	BIZYGOMATIC BREADTH	2956.464	1	2956.464	74.98835	0.0000
	BIGONIAL BREADTH	1959.208	1	1959.208	19.61856	0.0000
	NOSE BREADTH	35.82963	1	35.82963	2.280358	0.1311
	LIP LENGTH	41751.78	1	41751.78	2499.942	0.0000
	SUBNASALE-SELLION LTH	1075.386	1	1075.386	65.61323	0.0000
	MENTON-SELLION LTH	214.3026	1	214.3026	4.625918	0.0315
	NOSE PROTRUSION	2937.098	1	2937.098	431.7492	0.0000
	INTERPUPILLARY DISTANCE	130.1128	1	130.1128	11.35432	0.0008
Intercept	WEIGHT, KG	30812837	1	30812837	120742.1	0.0000
	STATURE	1.28E+10	1	1.28E+10	2691232	0.0000
	HEAD CIRC	1.37E+09	1	1.37E+09	5071072	0.0000
	BITRAGION CORONAL ARC	5.17E+08	1	5.17E+08	2882559	0.0000
	BITRAGION FRONTAL ARC	3.88E+08	1	3.88E+08	2717421	0.0000
	BITRAGION SUBNASALE ARC	3.6E+08	1	3.6E+08	2397387	0.0000
	BITRAGION CHIN ARC	4.54E+08	1	4.54E+08	2116594	0.0000
	HEAD BREADTH	98074153	1	98074153	3045464	0.0000
	HEAD LENGTH	1.62E+08	1	1.62E+08	3119946	0.0000
	MINIMUM FRONTAL BR	46254941	1	46254941	1612046	0.0000
	MAXIMUM FRONTAL BR	52951864	1	52951864	2001888	0.0000
	BIZYGOMATIC BREADTH	85001256	1	85001256	2155989	0.0000
	BIGONIAL BREADTH	61167431	1	61167431	612500.9	0.0000
	NOSE BREADTH	5572635	1	5572635	354667.4	0.0000
	LIP LENGTH	12281496	1	12281496	735370.5	0.0000
	SUBNASALE-SELLION LTH	11085986	1	11085986	676396.2	0.0000
	MENTON-SELLION LTH	62587513	1	62587513	1351009	0.0000
	NOSE PROTRUSION	1721275	1	1721275	253024.9	0.0000
	INTERPUPILLARY DISTANCE	17465596	1	17465596	1524139	0.0000
GROUP	WEIGHT, KG	84198.04	1	84198.04	329.9354	0.0000
	STATURE	44328.27	1	44328.27	9.324615	0.0023
	HEAD CIRC	23561.43	1	23561.43	87.0882	0.0000
	BITRAGION CORONAL ARC	5951.694	1	5951.694	33.1794	0.0000
	BITRAGION FRONTAL ARC	1706.459	1	1706.459	11.96021	0.0005
	BITRAGION SUBNASALE ARC	5010.336	1	5010.336	33.36111	0.0000
	BITRAGION CHIN ARC	8065.951	1	8065.951	37.60077	0.0000
	HEAD BREADTH	375.8731	1	375.8731	11.67186	0.0006
	HEAD LENGTH	245.9828	1	245.9828	4.735184	0.0296
	MINIMUM FRONTAL BR	244.4596	1	244.4596	8.51974	0.0035
	MAXIMUM FRONTAL BR	411.1532	1	411.1532	15.54398	0.0001
	BIZYGOMATIC BREADTH	2956.464	1	2956.464	74.98835	0.0000
	BIGONIAL BREADTH	1959.208	1	1959.208	19.61856	0.0000
	NOSE BREADTH	35.82963	1	35.82963	2.280358	0.1311
	LIP LENGTH	41751.78	1	41751.78	2499.942	0.0000
	SUBNASALE-SELLION LTH	1075.386	1	1075.386	65.61323	0.0000
	MENTON-SELLION LTH	214.3026	1	214.3026	4.625918	0.0315
	NOSE PROTRUSION	2937.098	1	2937.098	431.7492	0.0000
	INTERPUPILLARY DISTANCE	130.1128	1	130.1128	11.35432	0.0008
Error	WEIGHT, KG	1099382	4308	255.1955		

	STATURE	20479790	4308	4753.897
	HEAD CIRC	1165515	4308	270.5468
	BITRAGION CORONAL ARC	772765.4	4308	179.3792
	BITRAGION FRONTAL ARC	614657.3	4308	142.6781
	BITRAGION SUBNASALE ARC	646996.8	4308	150.185
	BITRAGION CHIN ARC	924133.2	4308	214.5156
	HEAD BREADTH	138732	4308	32.20335
	HEAD LENGTH	223791.5	4308	51.9479
	MINIMUM FRONTAL BR	123610.8	4308	28.69332
	MAXIMUM FRONTAL BR	113950.7	4308	26.45096
	BIZYGOMATIC BREADTH	169845.7	4308	39.42564
	BIGONIAL BREADTH	430218.6	4308	99.86505
	NOSE BREADTH	67688.53	4308	15.71229
	LIP LENGTH	71948.33	4308	16.7011
	SUBNASALE-SELLION LTH	70607.17	4308	16.38978
	MENTON-SELLION LTH	199574.5	4308	46.3265
	NOSE PROTRUSION	29306.41	4308	6.802789
	INTERPUPILLARY DISTANCE	49366.75	4308	11.45932
Total	WEIGHT, KG	33599480	4310	
	STATURE	1.32E+10	4310	
	HEAD CIRC	1.42E+09	4310	
	BITRAGION CORONAL ARC	5.34E+08	4310	
	BITRAGION FRONTAL ARC	4.01E+08	4310	
	BITRAGION SUBNASALE ARC	3.73E+08	4310	
	BITRAGION CHIN ARC	4.71E+08	4310	
	HEAD BREADTH	1.01E+08	4310	
	HEAD LENGTH	1.68E+08	4310	
	MINIMUM FRONTAL BR	47931294	4310	
	MAXIMUM FRONTAL BR	54744505	4310	
	BIZYGOMATIC BREADTH	88139574	4310	
	BIGONIAL BREADTH	63473718	4310	
	NOSE BREADTH	5827884	4310	
	LIP LENGTH	12535137	4310	
	SUBNASALE-SELLION LTH	11560562	4310	
	MENTON-SELLION LTH	64877662	4310	
	NOSE PROTRUSION	1836072	4310	
	INTERPUPILLARY DISTANCE	18069022	4310	
Corrected Total	WEIGHT, KG	1183580	4309	
	STATURE	20524119	4309	
	HEAD CIRC	1189077	4309	
	BITRAGION CORONAL ARC	778717.1	4309	
	BITRAGION FRONTAL ARC	616363.7	4309	
	BITRAGION SUBNASALE ARC	652007.2	4309	
	BITRAGION CHIN ARC	932199.1	4309	
	HEAD BREADTH	139107.9	4309	
	HEAD LENGTH	224037.5	4309	
	MINIMUM FRONTAL BR	123855.3	4309	
	MAXIMUM FRONTAL BR	114361.9	4309	
	BIZYGOMATIC BREADTH	172802.1	4309	
	BIGONIAL BREADTH	432177.8	4309	
	NOSE BREADTH	67724.35	4309	
	LIP LENGTH	113700.1	4309	
	SUBNASALE-SELLION LTH	71682.56	4309	
	MENTON-SELLION LTH	199788.8	4309	
	NOSE PROTRUSION	32243.51	4309	
	INTERPUPILLARY DISTANCE	49496.86	4309	

Multivariate Tests - FEMALES						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.999508	388516.4	19	3632	0.0000
	Wilks' Lambda	0.000492	388516.4	19	3632	0.0000
	Hotelling's Trace	2032.437	388516.4	19	3632	0.0000
	Roy's Largest Root	2032.437	388516.4	19	3632	0.0000
GROUP	Pillai's Trace	0.700717	447.5618	19	3632	0.0000
	Wilks' Lambda	0.299283	447.5618	19	3632	0.0000
	Hotelling's Trace	2.34132	447.5618	19	3632	0.0000
	Roy's Largest Root	2.34132	447.5618	19	3632	0.0000
a	Exact statistic					
b	Design: Intercept+GROUP					
c	Weighted Least Squares Regression - Weighted by Weighting Value					

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	WEIGHT, KG	127821.2	1	127821.2	700.033	0.0000
	STATURE	31324.75	1	31324.75	8.577524	0.0034
	HEAD CIRC	61092.16	1	61092.16	246.0715	0.0000
	BITRAGION CORONAL ARC	9734.325	1	9734.325	50.82396	0.0000
	BITRAGION FRONTAL ARC	39.5554	1	39.5554	0.353434	0.5522
	BITRAGION SUBNASALE ARC	7742.212	1	7742.212	62.08872	0.0000
	BITRAGION CHIN ARC	2284.239	1	2284.239	13.03104	0.0003
	HEAD BREADTH	1220.174	1	1220.174	42.15715	0.0000
	HEAD LENGTH	533.702	1	533.702	13.05642	0.0003
	MINIMUM FRONTAL BR	252.3682	1	252.3682	10.61704	0.0011
	MAXIMUM FRONTAL BR	5623.781	1	5623.781	217.8058	0.0000
	BIZYGOMATIC BREADTH	6322.178	1	6322.178	187.3302	0.0000
	BIGONIAL BREADTH	327.0274	1	327.0274	5.196453	0.0227
	NOSE BREADTH	36.17033	1	36.17033	2.358327	0.1247
	LIP LENGTH	44911.26	1	44911.26	2957.384	0.0000
	SUBNASALE-SELLION LTH	448.1202	1	448.1202	30.85612	0.0000
	MENTON-SELLION LTH	73.04028	1	73.04028	2.073947	0.1499
	NOSE PROTRUSION	690.4113	1	690.4113	108.4999	0.0000
	INTERPUPILLARY DISTANCE	47.72755	1	47.72755	4.097134	0.0430
Intercept	WEIGHT, KG	16934417	1	16934417	92744.01	0.0000
	STATURE	9.18E+09	1	9.18E+09	2514598	0.0000
	HEAD CIRC	1.06E+09	1	1.06E+09	4262124	0.0000
	BITRAGION CORONAL ARC	3.98E+08	1	3.98E+08	2077488	0.0000
	BITRAGION FRONTAL ARC	2.88E+08	1	2.88E+08	2573295	0.0000
	BITRAGION SUBNASALE ARC	2.66E+08	1	2.66E+08	2130880	0.0000
	BITRAGION CHIN ARC	3.2E+08	1	3.2E+08	1826909	0.0000
	HEAD BREADTH	74541204	1	74541204	2575408	0.0000
	HEAD LENGTH	1.22E+08	1	1.22E+08	2989344	0.0000
	MINIMUM FRONTAL BR	37161434	1	37161434	1563368	0.0000
	MAXIMUM FRONTAL BR	42081261	1	42081261	1629783	0.0000
	BIZYGOMATIC BREADTH	62336207	1	62336207	1847062	0.0000
	BIGONIAL BREADTH	41997629	1	41997629	667340.7	0.0000
	NOSE BREADTH	3871669	1	3871669	252435.1	0.0000
	LIP LENGTH	9262814	1	9262814	609951.7	0.0000
	SUBNASALE-SELLION LTH	8237454	1	8237454	567204.7	0.0000
	MENTON-SELLION LTH	44737873	1	44737873	1270313	0.0000
	NOSE PROTRUSION	1302341	1	1302341	204666.2	0.0000
	INTERPUPILLARY DISTANCE	13330997	1	13330997	1144389	0.0000
GROUP	WEIGHT, KG	127821.2	1	127821.2	700.033	0.0000
	STATURE	31324.75	1	31324.75	8.577524	0.0034
	HEAD CIRC	61092.16	1	61092.16	246.0715	0.0000
	BITRAGION CORONAL ARC	9734.325	1	9734.325	50.82396	0.0000
	BITRAGION FRONTAL ARC	39.5554	1	39.5554	0.353434	0.5522
	BITRAGION SUBNASALE ARC	7742.212	1	7742.212	62.08872	0.0000
	BITRAGION CHIN ARC	2284.239	1	2284.239	13.03104	0.0003
	HEAD BREADTH	1220.174	1	1220.174	42.15715	0.0000
	HEAD LENGTH	533.702	1	533.702	13.05642	0.0003
	MINIMUM FRONTAL BR	252.3682	1	252.3682	10.61704	0.0011
	MAXIMUM FRONTAL BR	5623.781	1	5623.781	217.8058	0.0000
	BIZYGOMATIC BREADTH	6322.178	1	6322.178	187.3302	0.0000
	BIGONIAL BREADTH	327.0274	1	327.0274	5.196453	0.0227
	NOSE BREADTH	36.17033	1	36.17033	2.358327	0.1247
	LIP LENGTH	44911.26	1	44911.26	2957.384	0.0000
	SUBNASALE-SELLION LTH	448.1202	1	448.1202	30.85612	0.0000
	MENTON-SELLION LTH	73.04028	1	73.04028	2.073947	0.1499
	NOSE PROTRUSION	690.4113	1	690.4113	108.4999	0.0000
	INTERPUPILLARY DISTANCE	47.72755	1	47.72755	4.097134	0.0430
Error	WEIGHT, KG	666464.8	3650	182.5931		
	STATURE	13329643	3650	3651.957		

	HEAD CIRC	906185.3	3650	248.27
	BITRAGION CORONAL ARC	699085.3	3650	191.5302
	BITRAGION FRONTAL ARC	408497.9	3650	111.9172
	BITRAGION SUBNASALE ARC	455140.2	3650	124.696
	BITRAGION CHIN ARC	639816.1	3650	175.2921
	HEAD BREADTH	105643.6	3650	28.94346
	HEAD LENGTH	149199.6	3650	40.8766
	MINIMUM FRONTAL BR	86760.93	3650	23.77012
	MAXIMUM FRONTAL BR	94243.62	3650	25.82017
	BIZYGOMATIC BREADTH	123183.3	3650	33.74885
	BIGONIAL BREADTH	229704.8	3650	62.93281
	NOSE BREADTH	55981.08	3650	15.33728
	LIP LENGTH	55429.42	3650	15.18614
	SUBNASALE-SELLION LTH	53008.56	3650	14.52289
	MENTON-SELLION LTH	128545.7	3650	35.218
	NOSE PROTRUSION	23225.84	3650	6.363245
	INTERPUPILLARY DISTANCE	42518.89	3650	11.64901
Total	WEIGHT, KG	17861896	3652	
	STATURE	9.61E+09	3652	
	HEAD CIRC	1.1E+09	3652	
	BITRAGION CORONAL ARC	4.16E+08	3652	
	BITRAGION FRONTAL ARC	3.01E+08	3652	
	BITRAGION SUBNASALE ARC	2.78E+08	3652	
	BITRAGION CHIN ARC	3.35E+08	3652	
	HEAD BREADTH	77897946	3652	
	HEAD LENGTH	1.28E+08	3652	
	MINIMUM FRONTAL BR	38976265	3652	
	MAXIMUM FRONTAL BR	44302040	3652	
	BIZYGOMATIC BREADTH	65020148	3652	
	BIGONIAL BREADTH	44081636	3652	
	NOSE BREADTH	4108459	3652	
	LIP LENGTH	10066247	3652	
	SUBNASALE-SELLION LTH	8691039	3652	
	MENTON-SELLION LTH	46870896	3652	
	NOSE PROTRUSION	1372303	3652	
	INTERPUPILLARY DISTANCE	13967271	3652	
Corrected Total	WEIGHT, KG	794286	3651	
	STATURE	13360968	3651	
	HEAD CIRC	967277.5	3651	
	BITRAGION CORONAL ARC	708819.6	3651	
	BITRAGION FRONTAL ARC	408537.4	3651	
	BITRAGION SUBNASALE ARC	462882.5	3651	
	BITRAGION CHIN ARC	642100.4	3651	
	HEAD BREADTH	106863.8	3651	
	HEAD LENGTH	149733.3	3651	
	MINIMUM FRONTAL BR	87013.3	3651	
	MAXIMUM FRONTAL BR	99867.4	3651	
	BIZYGOMATIC BREADTH	129505.5	3651	
	BIGONIAL BREADTH	230031.8	3651	
	NOSE BREADTH	56017.25	3651	
	LIP LENGTH	100340.7	3651	
	SUBNASALE-SELLION LTH	53456.68	3651	
	MENTON-SELLION LTH	128618.8	3651	
	NOSE PROTRUSION	23916.25	3651	
	INTERPUPILLARY DISTANCE	42566.62	3651	

APPENDIX E

ANOVAS
BY MALES AND FEMALES

ANOVA for Age Group

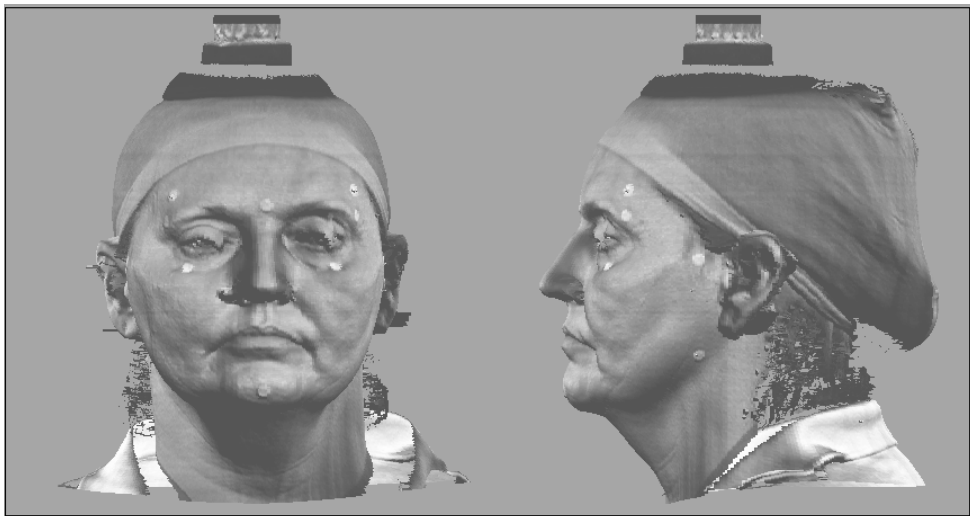
		Sum of Squares	df	Mean Square	F	Sig.
BIGONIAL BREADTH	Between Groups	5496.711	2	2748.356	22.57034	0.0000
	Within Groups	486465.1	3995	121.7685		
	Total	491961.8	3997			
BITRAGION CHIN ARC	Between Groups	29879.15	2	14939.58	39.26499	0.0000
	Within Groups	1520021	3995	380.4808		
	Total	1549900	3997			
BITRAGION CORONAL ARC	Between Groups	601.6412	2	300.8206	1.268633	0.2813
	Within Groups	947301.7	3995	237.1218		
	Total	947903.4	3997			
BITRAGION FRONTAL ARC	Between Groups	1650.597	2	825.2987	3.798418	0.0225
	Within Groups	868011	3995	217.2743		
	Total	869661.6	3997			
BITRAGION SUBNASALE ARC	Between Groups	10832.14	2	5416.072	23.42657	0.0000
	Within Groups	923618.5	3995	231.1936		
	Total	934450.6	3997			
BIZYGOMATIC BREADTH	Between Groups	2232.956	2	1116.478	19.08966	0.0000
	Within Groups	233534.7	3993	58.48603		
	Total	235767.7	3995			
HEAD BREADTH	Between Groups	717.3438	2	358.6719	8.314159	0.0002
	Within Groups	172343.8	3995	43.13989		
	Total	173061.2	3997			
HEAD CIRC	Between Groups	9265.207	2	4632.603	11.05951	0.0000
	Within Groups	1673005	3994	418.8797		
	Total	1682271	3996			
HEAD LENGTH	Between Groups	1417.664	2	708.8321	8.988352	0.0001
	Within Groups	315050.5	3995	78.86119		
	Total	316468.1	3997			
LIP LENGTH	Between Groups	5104.977	2	2552.489	134.1677	0.0000
	Within Groups	76003.32	3995	19.02461		
	Total	81108.3	3997			
INTERPUPILLARY DISTANCE	Between Groups	2575.729	2	1287.865	84.99295	0.0000
	Within Groups	60519.51	3994	15.15261		
	Total	63095.24	3996			
MAXIMUM FRONTAL BR	Between Groups	930.8554	2	465.4277	14.15297	0.0000
	Within Groups	131377.6	3995	32.88552		
	Total	132308.5	3997			
MENTON-SELLION LTH	Between Groups	4005.102	2	2002.551	30.56374	0.0000
	Within Groups	261754.3	3995	65.52048		
	Total	265759.4	3997			
MINIMUM FRONTAL BR	Between Groups	1576.121	2	788.0607	23.61629	0.0000
	Within Groups	133310.6	3995	33.36936		
	Total	134886.7	3997			
NASAL ROOT BREADTH	Between Groups	6.553846	2	3.276923	0.673664	0.5099
	Within Groups	19433	3995	4.86433		
	Total	19439.55	3997			
NECK CIRC	Between Groups	220596.5	2	110298.2	56.72659	0.0000
	Within Groups	4310698	2217	1944.383		
	Total	4531294	2219			
NOSE BREADTH	Between Groups	6928.139	2	3464.07	152.6047	0.0000
	Within Groups	90684.98	3995	22.69962		
	Total	97613.12	3997			
NOSE PROTRUSION	Between Groups	66.37219	2	33.1861	4.048497	0.0175
	Within Groups	32747.57	3995	8.19714		
	Total	32813.94	3997			
STATURE	Between Groups	440825.2	2	220412.6	25.20138	0.0000
	Within Groups	34940487	3995	8746.054		
	Total	35381312	3997			
SUBNASALE-SELLION LTH	Between Groups	917.923	2	458.9615	23.03789	0.0000
	Within Groups	79588.51	3995	19.92203		
	Total	80506.43	3997			
WEIGHT, KG	Between Groups	41298.53	2	20649.26	53.72623	0.0000
	Within Groups	1532757	3988	384.3423		
	Total	1574056	3990			

ANOVA for RACE

		Sum of Squares	df	Mean Square	F	Sig.
BIGONIAL BREADTH	Between Groups	10368.27	3	3456.09	28.65561	0.0000
	Within Groups	481586.8	3993	120.6078		
	Total	491955.1	3996			
BITRAGION CHIN ARC	Between Groups	86162.91	3	28720.97	78.41835	0.0000
	Within Groups	1462449	3993	366.2532		
	Total	1548612	3996			
BITRAGION CORONAL ARC	Between Groups	7802.679	3	2600.893	11.08644	0.0000
	Within Groups	936762.6	3993	234.6012		
	Total	944565.2	3996			
BITRAGION FRONTAL ARC	Between Groups	11761.83	3	3920.609	18.33345	0.0000
	Within Groups	853903	3993	213.85		
	Total	865664.8	3996			
BITRAGION SUBNASALE ARC	Between Groups	69919.5	3	23306.5	107.8136	0.0000
	Within Groups	863182.6	3993	216.174		
	Total	933102.1	3996			
BIZYGOMATIC BREADTH	Between Groups	5192.53	3	1730.843	29.99607	0.0000
	Within Groups	230290	3991	57.70233		
	Total	235482.5	3994			
HEAD BREADTH	Between Groups	1357.012	3	452.3375	10.53716	0.0000
	Within Groups	171410.9	3993	42.92786		
	Total	172767.9	3996			
HEAD CIRC	Between Groups	80251.39	3	26750.46	66.75118	0.0000
	Within Groups	1599790	3992	400.7489		
	Total	1680041	3995			
HEAD LENGTH	Between Groups	31820.26	3	10606.75	148.983	0.0000
	Within Groups	284279.2	3993	71.19438		
	Total	316099.4	3996			
LIP LENGTH	Between Groups	11655.23	3	3885.075	223.5304	0.0000
	Within Groups	69400.43	3993	17.38052		
	Total	81055.66	3996			
INTERPUPILLARY DISTANCE	Between Groups	9494.723	3	3164.908	235.8519	0.0000
	Within Groups	53568.83	3992	13.41905		
	Total	63063.55	3995			
MAXIMUM FRONTAL BR	Between Groups	5348.5	3	1782.833	56.11105	0.0000
	Within Groups	126870.8	3993	31.7733		
	Total	132219.3	3996			
MENTON-SELLION LTH	Between Groups	12354.15	3	4118.051	64.95583	0.0000
	Within Groups	253147.1	3993	63.39772		
	Total	265501.2	3996			
MINIMUM FRONTAL BR	Between Groups	3297.027	3	1099.009	33.393	0.0000
	Within Groups	131415	3993	32.91136		
	Total	134712.1	3996			
NASAL ROOT BREADTH	Between Groups	644.9111	3	214.9704	45.67566	0.0000
	Within Groups	18792.87	3993	4.706453		
	Total	19437.78	3996			
NECK CIRC	Between Groups	405609.1	3	135203	72.74002	0.0000
	Within Groups	4117056	2215	1858.716		
	Total	4522665	2218			
NOSE BREADTH	Between Groups	42576.82	3	14192.27	1030.852	0.0000
	Within Groups	54973.7	3993	13.76752		
	Total	97550.53	3996			
NOSE PROTRUSION	Between Groups	6321.819	3	2107.273	317.6318	0.0000
	Within Groups	26490.87	3993	6.634326		
	Total	32812.68	3996			
STATURE	Between Groups	3714080	3	1238027	156.1551	0.0000
	Within Groups	31657249	3993	7928.187		
	Total	35371329	3996			
SUBNASALE-SELLION LTH	Between Groups	5758.837	3	1919.612	102.5635	0.0000
	Within Groups	74734.29	3993	18.71633		
	Total	80493.12	3996			
WEIGHT, KG	Between Groups	125344.1	3	41781.37	115.0668	0.0000
	Within Groups	1447338	3986	363.1053		
	Total	1572682	3989			

APPENDIX F

20 REPRESENTATIVE HEADS - SCREEN SHOTS



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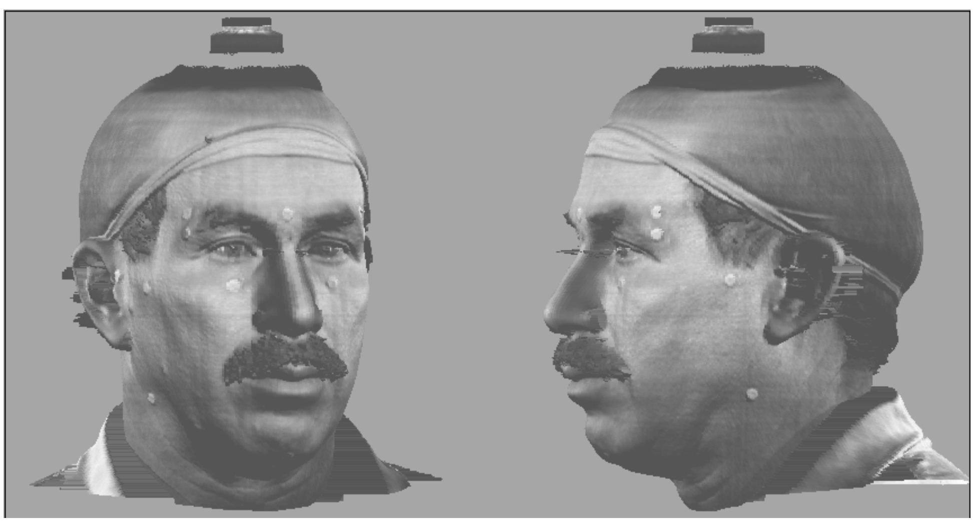

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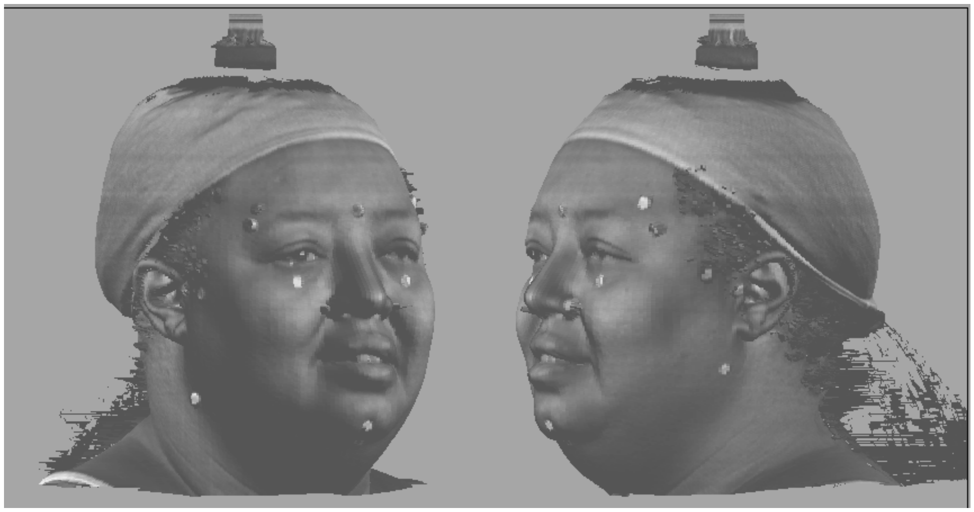

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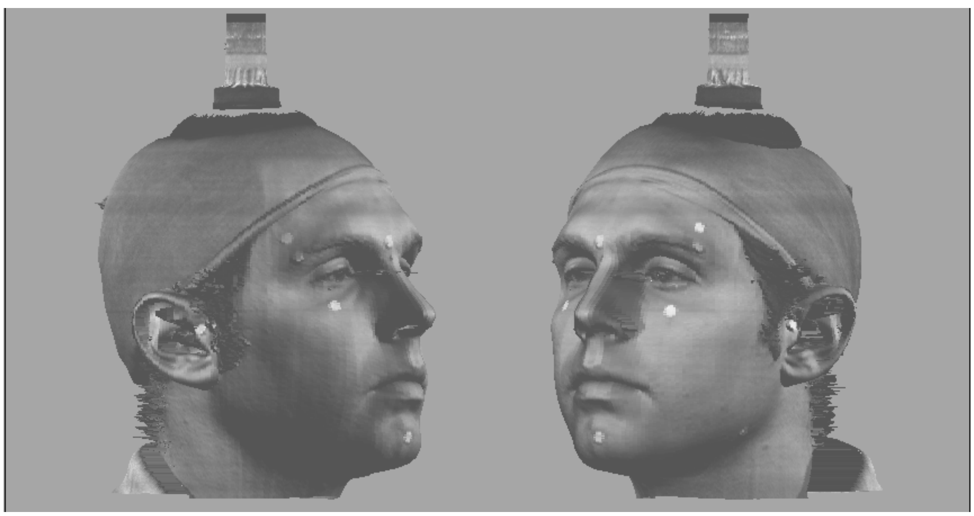

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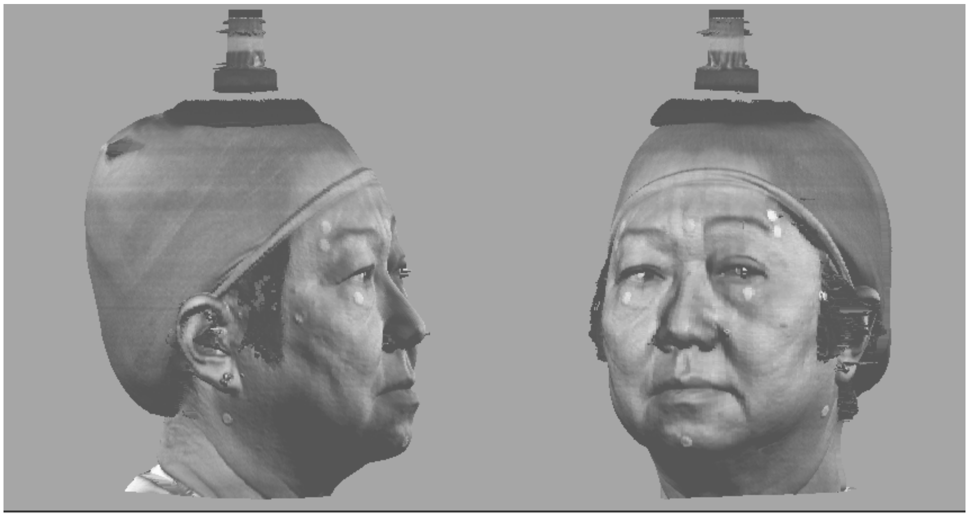

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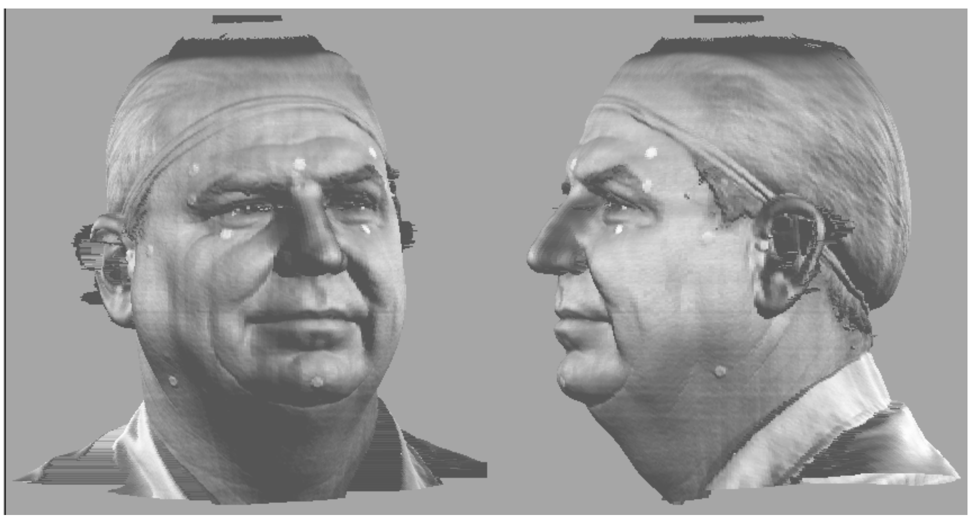

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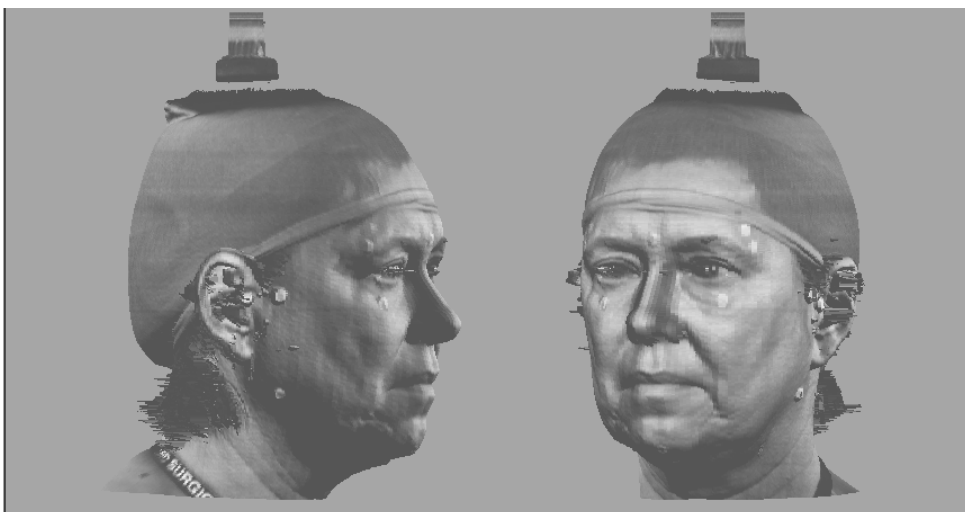

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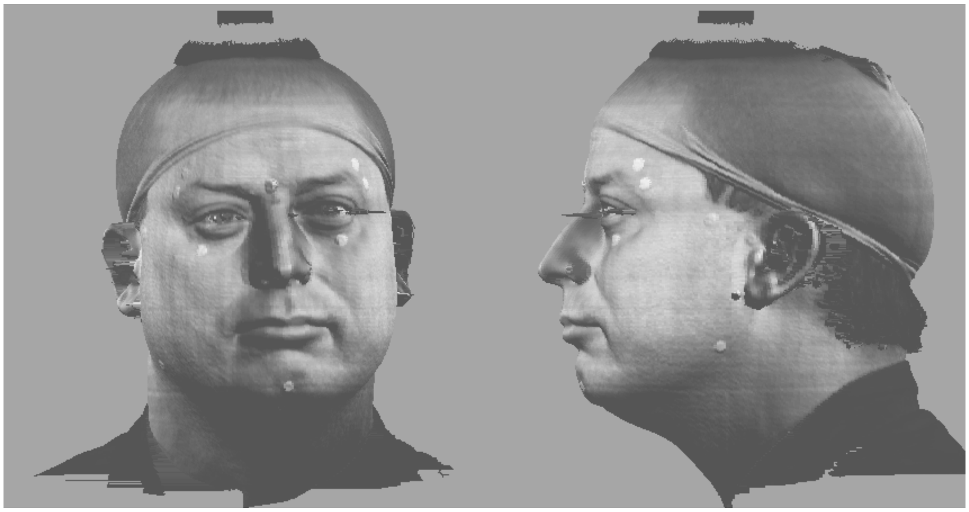

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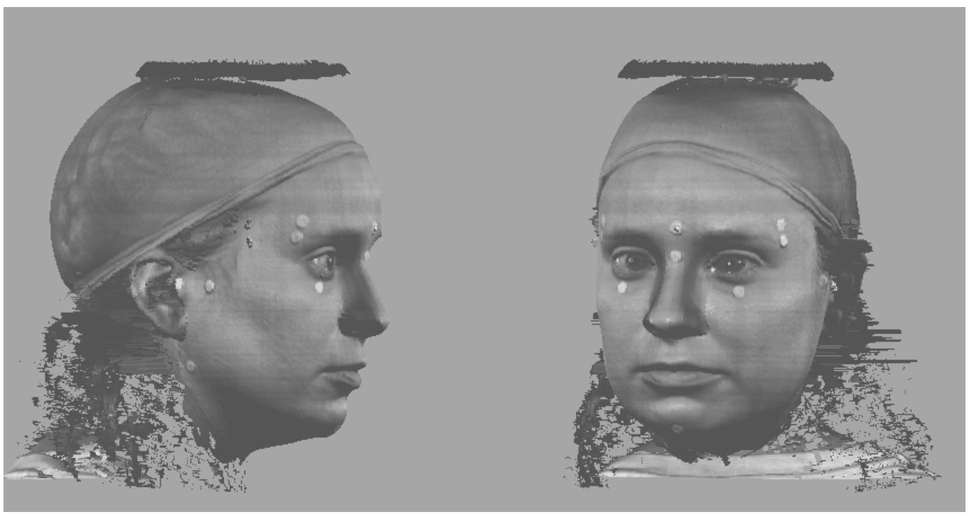

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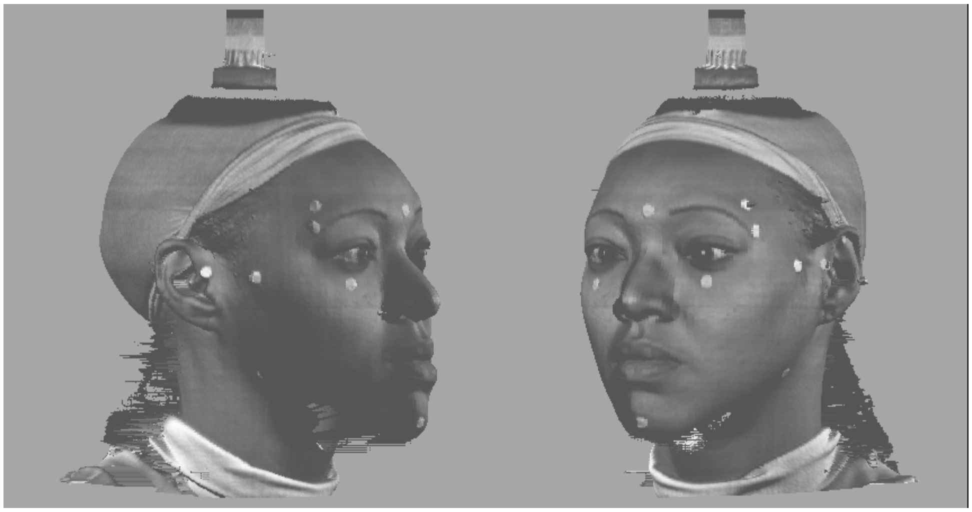

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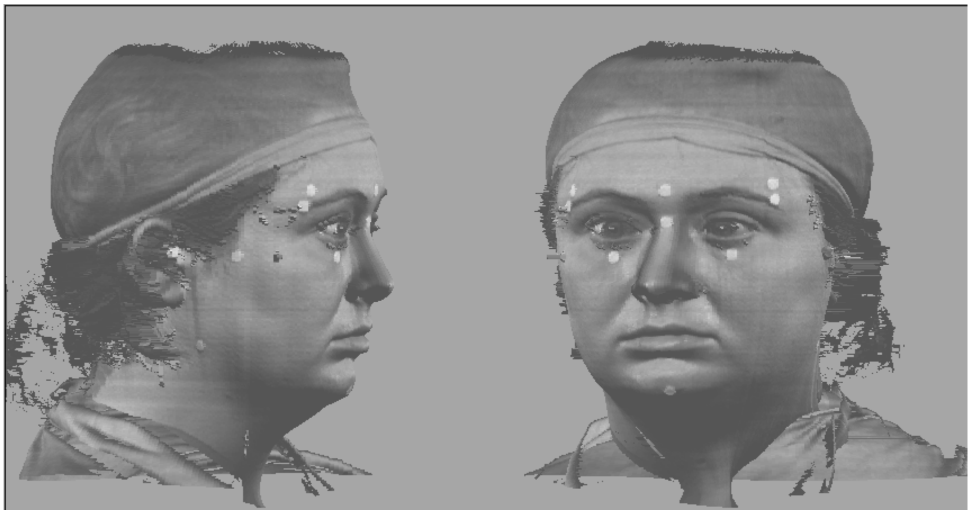

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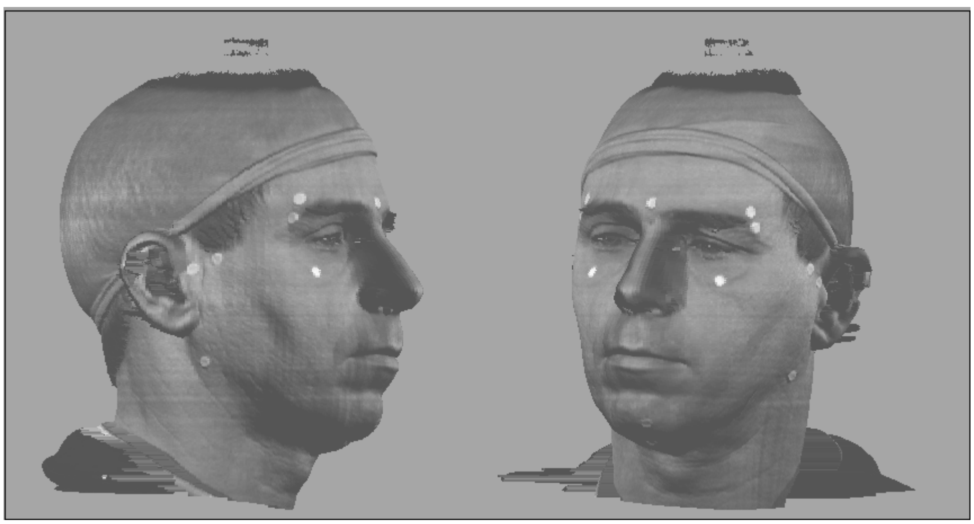

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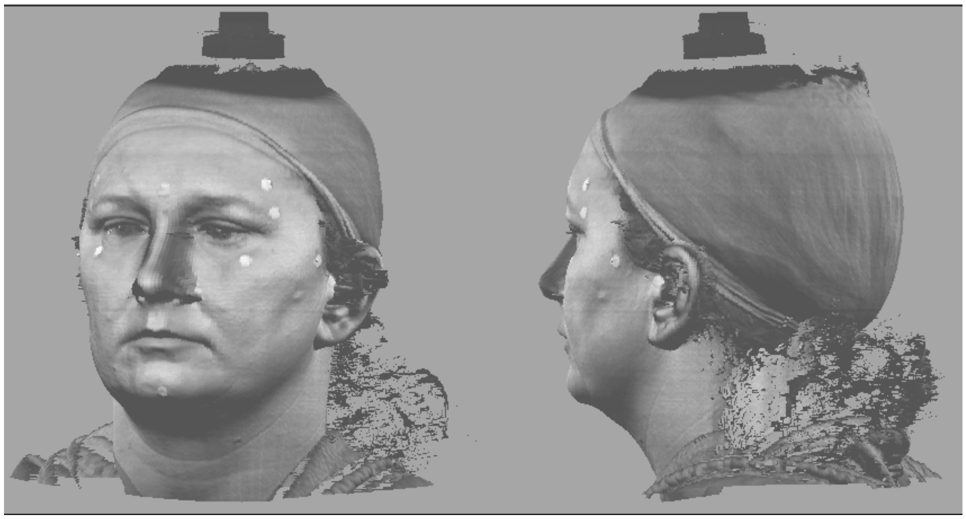

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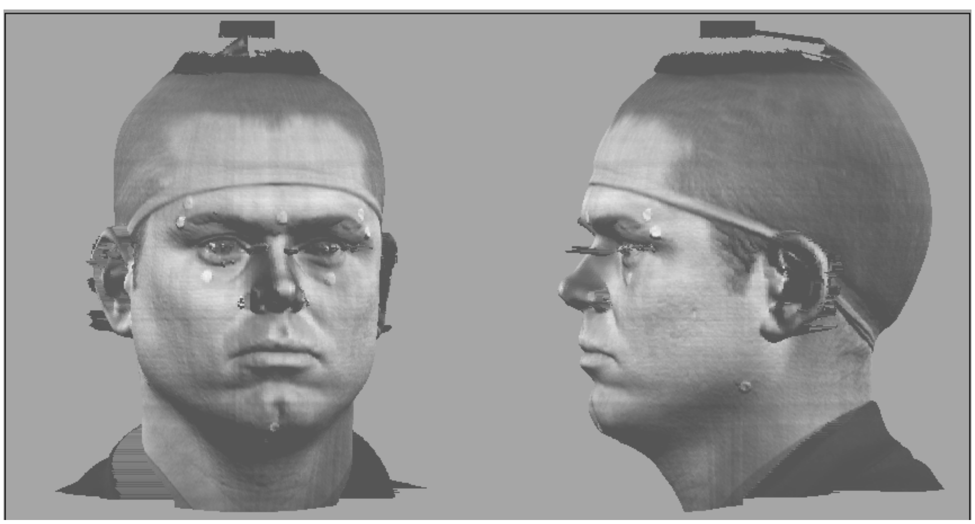

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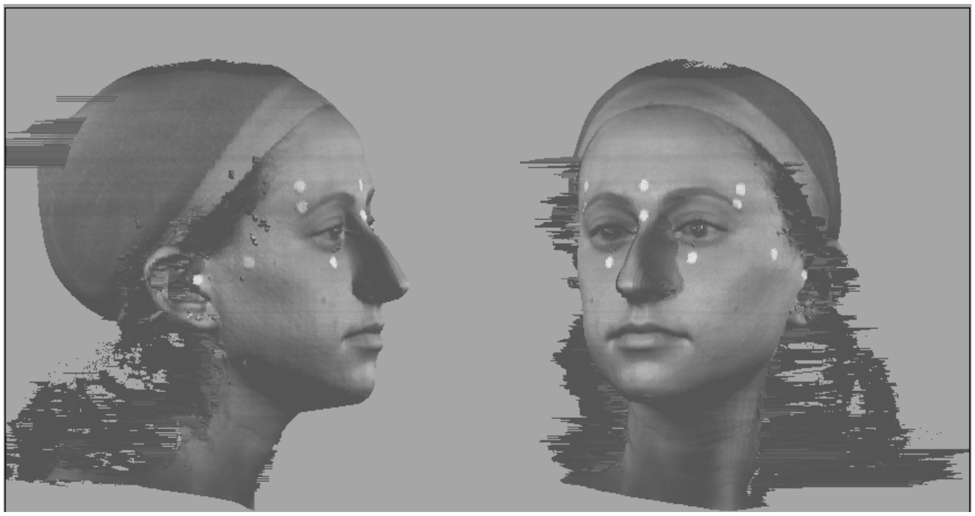

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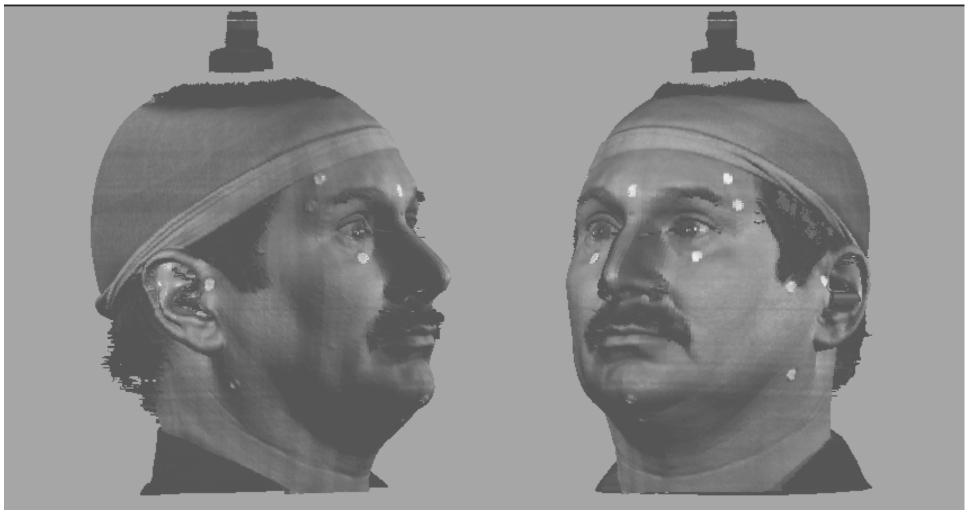
542



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