

Inclusion of African-American Male Respirator Wearers in the NIOSH Bivariate Fit Test Panel and the Los Alamos National Laboratory Full-Facepiece and Half-Mask Panels

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ABSTRACT

There has been concern that the Los Alamos National Laboratories bivariate full facepiece and half-mask respirator fit test panels were not representative of the facial dimensions of current U.S. civilian respirator wearers and that respirator fit was not associated with those dimensions. As a result, in 2007 NIOSH introduced a new bivariate fit test panel, intended to include 95% of workers, based on the face length and face width of a large sample of subjects weighted to match the age and race distribution of the U.S. population. The purpose of this study was to determine how well that panel would incorporate the facial dimensions of 100 African-American male respirator wearers compared to the Los Alamos full facepiece and half-mask panels. Face length and face width of these subjects were plotted on the NIOSH and Los Alamos full facepiece test panels and face length and lip width was plotted on the Los Alamos half-mask panel, and total and cell incorporations were enumerated. Facial dimensions were also tested for their association with fit factors. It was found that 98% of the subjects' dimensions fell within the NIOSH panel while only 84% fell within the Los Alamos full facepiece panel and 83% fell within the half-mask panel. None of the dimensions were found to be associated with respirator fit.

Keywords: Respirator, Face Dimensions, Fit Test Panels, Fit Factor

INTRODUCTION

The 1973 Los Alamos National Laboratory (LANL) recommended bivariate fit test panels for full facepiece and half-mask respirators based on facial dimensions taken from 1967 and 1968 U.S. Air Force anthropometric surveys (Hack, *et al.*, 1973). The full facepiece panel was defined by face length and face width. The panel was divided into 16 cells, based on a 10-mm increment in face length and a 9-mm increment in face width. Six cells containing low percentages of the population were deleted, leaving the 10-cell panel shown in the shaded area of Figure 1. The test panel for half-mask respirators was defined by face length and lip width. The panel was divided into 12 cells based on a 10-mm increment in face length and a 9-mm increment in lip length. Two cells were deleted because they contained very low percentages of the population, resulting in the 10-cell test panel shown in Figure 2. Twenty-five subjects were selected as the sample size for both panels, as a practical limit of expense and time to perform tests.

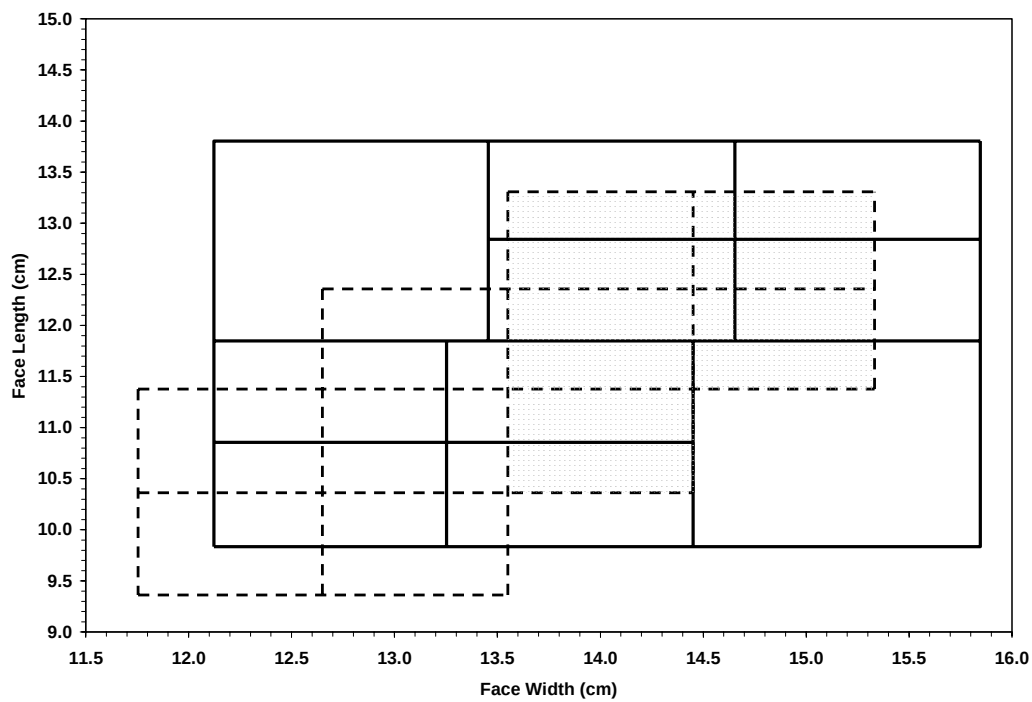


Figure 1. LANL full facepiece test panel (shaded area and dashed line) and NIOSH bivariate test panel (solid line).

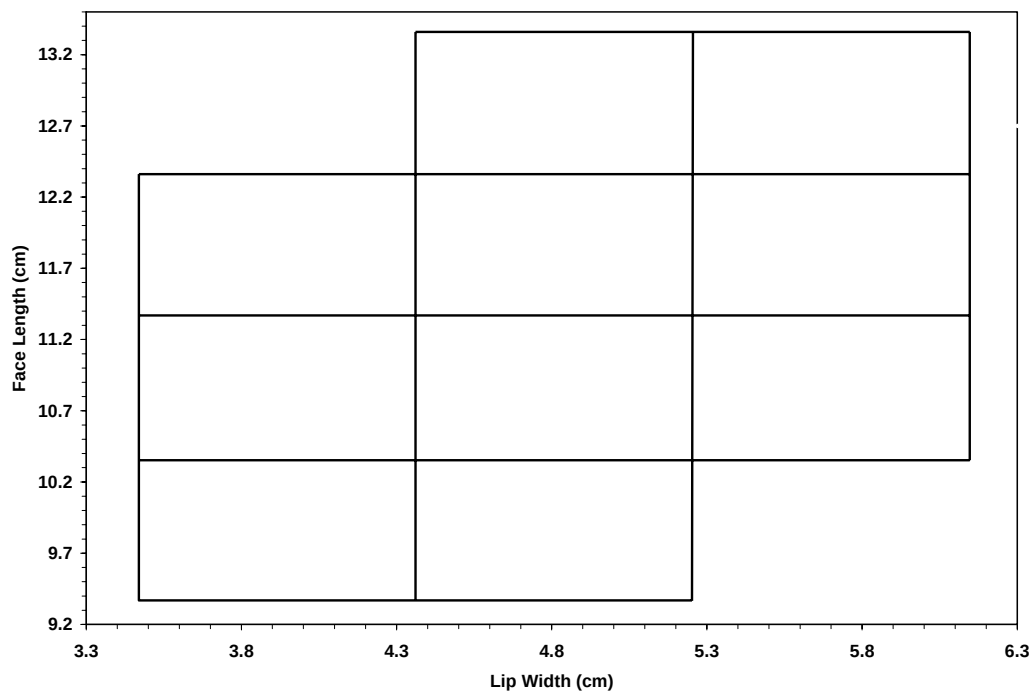


Figure 2. LANL Half-mask Test Panel.

Since the implementation of the LANL panel, concern has been raised about the applicability of test panels based on military data to civilian workers. Leigh (1975) measured 1467 civilian employees of a chemical manufacturer and found that 12.6% had measurements falling outside of the selection area established by the LANL panel for full facepiece respirators. Stein (1978) found that a bivariate ellipse based on the results of face length and face width measurements on 47 Caucasian male mine rescue workers was different from that based on the Air Force data used by the LANL to define the full facepiece panel. The author also suggested that a more extensive survey of civilian women and other racial groups who used personal protective equipment was needed. A recent NIOSH study (Zhuang, *et al*, 2004) using facial dimensions measured on 3998 civilian respirator wearers weighted to match the 2000 U.S. census gender and racial distributions found significant differences with the 1967 and 1968 U.S. Air Force data for face length, face width and lip width, and the LANL full face piece panel excluded 15.3% of the NIOSH survey subjects. Based on these results, it was concluded that the LANL panel was not representative of current U.S. respirator wearers.

There is conflicting scientific evidence that facial dimensions used to define the LANL half-mask test panel are associated with respirator fit. Three studies (Gross & Horstman, 1990; Oestenstad, *et al*, 1990; Brazile, *et al*, 1998) did not find a significant association between face length, face width or lip width and respirator fit. Liao, *et al*, (1982) found that lip width and face width were significantly associated with fit. Oestenstad & Perkins (1992) found face length to be significantly associated. Han & Choi (2003) found face width to be significantly associated with fit, and another study found face length and face width to be significantly associated with fit (Zhuang, *et al*, 2005).

Based on the evidence that the LANL panel was not representative of civilian workers and that facial dimensions used by the panel may not be predictive of respirator fit NIOSH developed new fit test panels representative of current U.S. civilian workers (Zhuang, *et al*, 2007). One was a bivariate panel (Figure 1) using the face length and face width dimensions of subjects weighted to match the age and race distribution of the U.S. population as determined from the 2000 census. Another panel was developed using the first two principal components obtained from a set of 10 facial dimensions (age and race adjusted). Respirators designed to fit these panels are expected to accommodate more than 95% of the current U.S. civilian workers.

Previous studies have found significant differences in facial dimensions of racial/ethnic groups (Brazile, *et al*, 1998; Han & Choi, 2003; and Zhuang, *et al*, 2004). However, the NIOSH bivariate fit test panel was intended to accommodate facial dimensions of diverse racial/ethnic groups because it was based on facial data weighted to match the age and race distribution of the U.S. population. The purpose of this study was to determine how well that panel incorporated the facial dimensions of a sample of African-American respirator wearers, and to measure the correlation of those dimensions to respirator fit.

MATERIALS AND METHODS

African-American males who were experienced respirator wearers at a large electrical utility company were recruited during company-sponsored meetings to participate in a study to measure facial dimensions and respirator fit. The 100 subjects who agreed to participate signed informed consent forms in accordance with the requirements of the University of Alabama at Birmingham Institutional Review Board. Face length (menton-sellion length), face width (bizygomatic breadth), and lip width were measured to the nearest 0.1 cm with sliding and spreading calipers before subjects were fit tested with their assigned half-mask respirators using a TSI Portacount[®] (TSI, Inc. Shoreview, MN, USA). Three fit tests according to the OSHA fit test protocol (OSHA, 1998) were conducted after subjects self-donned and doffed their assigned respirator. The average of the natural log (lnFF) of the three fit tests was used as the measure of respirator fit. The distribution of facial dimensions was plotted on the LANL half-mask and full facepiece panels and the NIOSH panel and inclusion in the panel cells enumerated. The

percentage of subjects within and outside the NIOSH and LANL test panels was compared by McNemar's Test (Norušis, 2004). Kendall's tau-b was used to compare the percentage of study subjects that fell within the cells of the LANL full facepiece panel to that observed by Zhuang, *et al*, (2004) in their evaluation of the LANL panels (Norušis, 2004). Where feasible, the difference among the InFFs of subjects within cells was tested by ANOVA, and differences between InFFs of subjects within and outside test panels was tested by two-sample t-tests (Norušis, 2004). In addition, the association between facial dimensions and InFFs was tested by correlation and stepwise linear and quadratic regression (Norušis, 2004). All tests of significance were at an alpha value of 0.05 ($\alpha=0.05$).

RESULTS

The subjects in this study ranged in age from 23 to 54 years. Descriptive statistics for their facial measurements are shown in Table I with those for African-American males from the NIOSH 2004 survey. (Zhuang, *et al*, 2004). As can be seen, the average values are almost identical, and the standard deviations are similar. The mean FF was 1292 with a minimum of 107 and a maximum of 34,434. The Geometric mean FF was 612 with a geometric standard deviation of 2.87.

Table I. Facial Dimension Descriptive Statistics (cm)

Facial Dimension	Mean (Std Dev)	
	Subjects	NIOSH ^a
Face Length	12.5 (0.71)	12.54 (0.73)
Face Width	14.0 (0.54)	14.47 (0.73)
Lip Width	5.4 (0.46)	5.43 (0.39)

^aBlack males from Zhuang, *et al* (2004)

Figure 3 shows subjects' face length and face width plotted on the NIOSH fit test panel while Figure 4 shows these dimensions plotted on the LANL full facepiece panel. Figure 5 shows face length and lip width plotted on the LANL half-mask panel. The number of subjects in each panel cell is shown in parentheses. It was found that the facial dimensions of 98% of the subjects placed them within the NIOSH panel, while only 84% fell within the LANL full facepiece panel, and 83% fell within the LANL half-mask panel. McNemar's Test found the differences between the NIOSH and both LANL panels to be significantly different ($p<0.001$). The percentage within the LANL full facepiece panel is the same as reported by Zhuang, *et al* (2004). In general, the distribution of subjects was shifted to the right and up relative to both LANL test panels. A significant Kendall's tau-b correlation coefficient of 0.814 ($p=0.001$) was obtained when the percent of subjects from this study in the cells of the LANL full facepiece panel was compared to the percent of males observed in those cells by Zhuang, *et al* (2004), and a Kendall's tau-b correlation coefficient of 0.659 ($p=0.010$) was obtained when comparing the percent in this study and those of Zhuang, *et al* (2004) on the LANL half-mask panel.

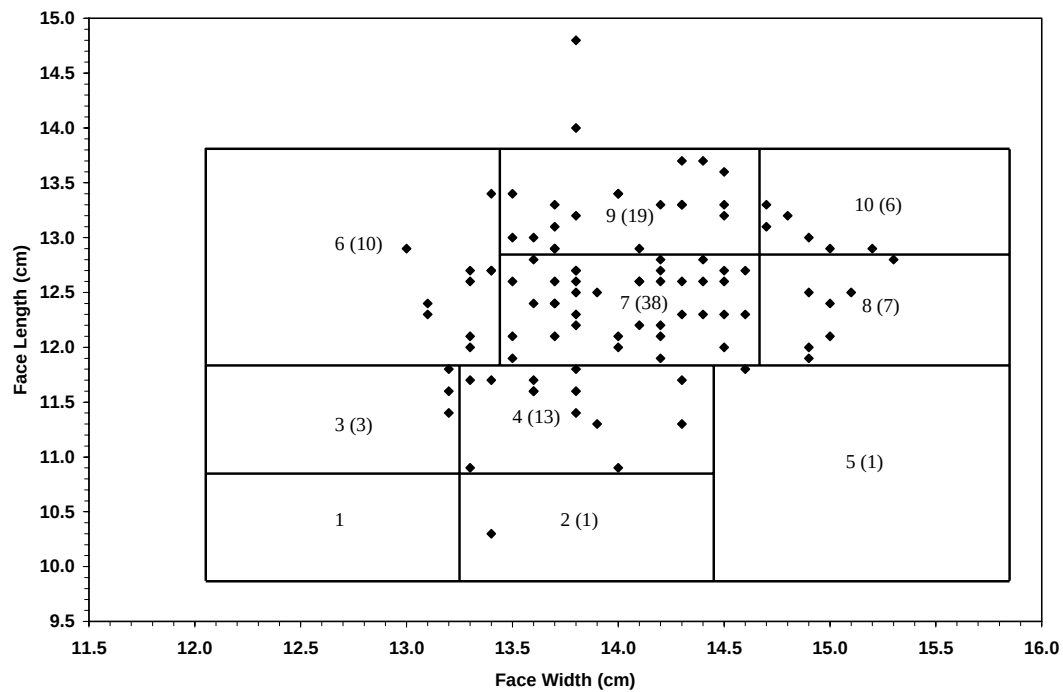


Figure 3. Subjects on the NIOSH Bivariate Panel.

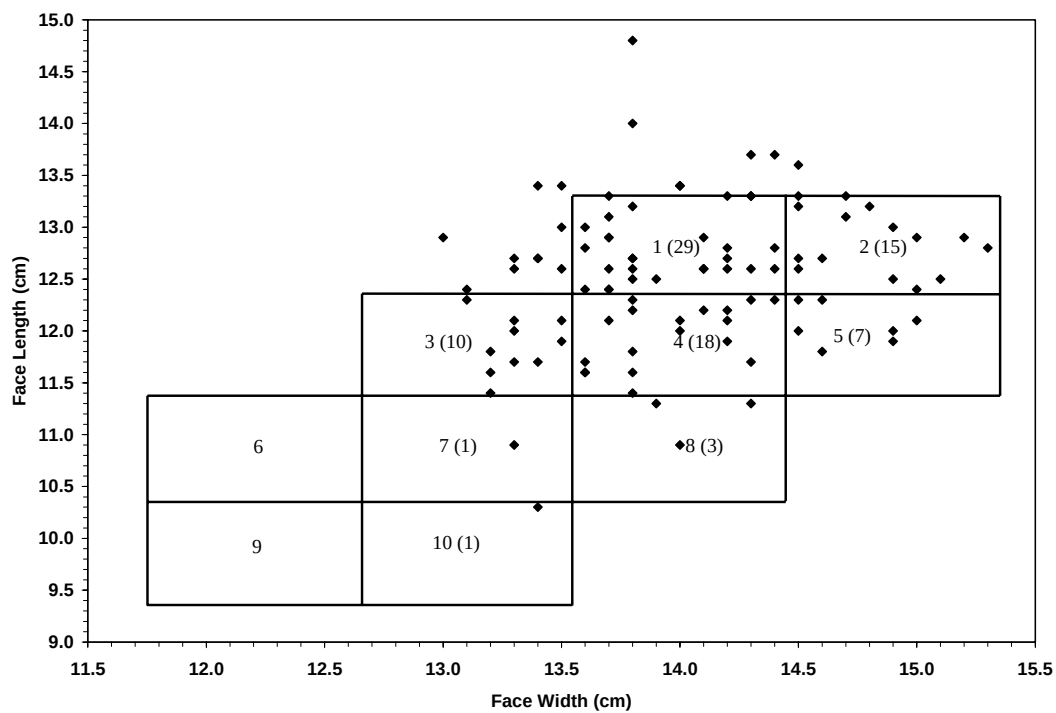


Figure 4 – Subjects on the LANL Full Facepiece Panel.

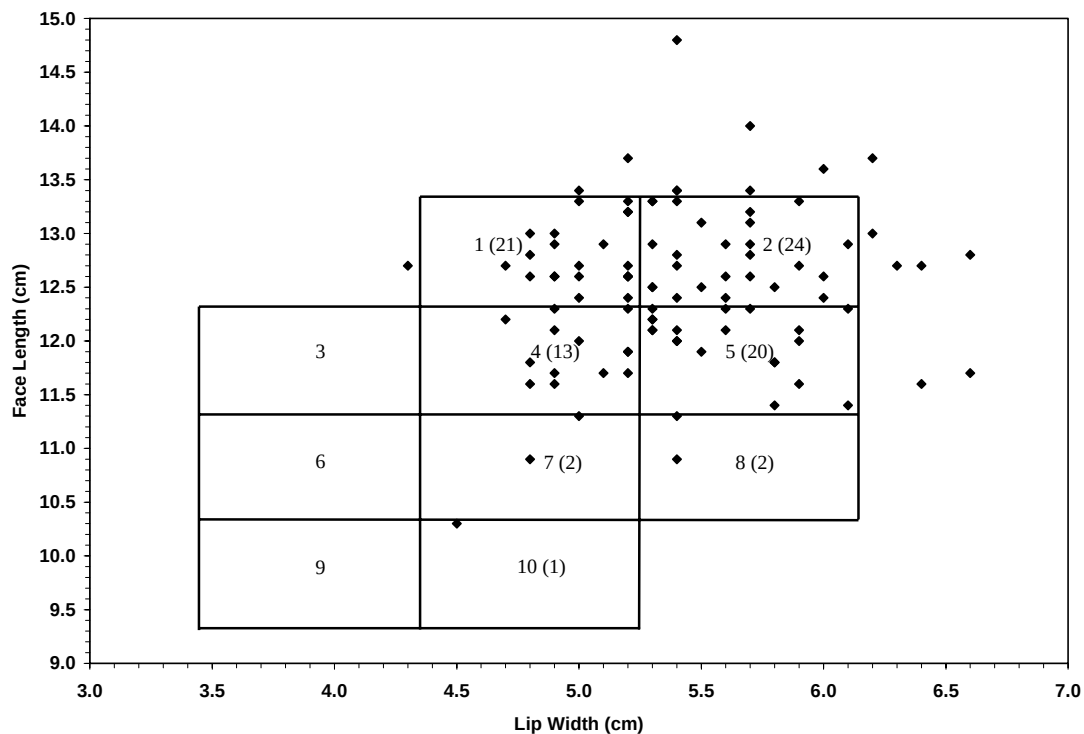


Figure 5 – Subjects on the LANL Half-mask Panel.

Subject FFs within the test panel cells are shown in Table II. Although the FFs for the two subjects who fell outside the NIOSH panel are much lower than those within the panel, a two-sample t-test found the difference between InFFs not to be significantly different. This test had almost no power due to the small number outside the panel. ANOVA found no significant difference among the InFFs within the cells of the NIOSH panel containing more than five subjects. A two-sample t-test found significant differences between InFFs outside and within the LANL half-mask ($p=0.009$) and full facepiece ($p=0.034$) panels. ANOVA found no significant differences among the InFFs within the cells of the LANL half-mask and full facepiece panels containing more than five subjects.

None of the measured facial dimensions were found to be significantly correlated with InFFs, and multiple linear and quadratic polynomial regression found that none of the measured facial dimensions were significantly associated with InFFs and resulted in non-significant R^2 values of less than 0.07. The lack of association found in this study is similar to the results of Gross & Horstman (1990), Oestenstad, *et al* (1990) and Brazile, *et al* (1998). However, caution should be exercised when comparing these studies because they used varying statistical methods.

CONCLUSIONS

The results of this study indicate that the NIOSH bivariate fit test panel is inclusive of facial dimensions of African-American male civilian respirator wearers. However, those dimensions were not associated with measured FFs. Because there are significant differences in facial dimensions between genders and among racial/ethnic groups, this evaluation should be repeated to determine if the NIOSH panel is also inclusive of other groups.

Table II. Subject Fit Factors within the Test Panel Cells

Cell	NIOSH Bivariate				LANL Full Face				LANL Half-mask			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
0*	2	346	165	526	16	520	107	1591	17	513	107	1976
1	0	-	-	-	29	1968	124	33434	21	2369	147	33434
2	1	703	-	-	15	1287	107	4730	24	1115	124	4731
3	3	1041	360	2347	10	753	131	2347	0	-	-	-
4	13	753	134	2871	18	1474	175	8047	13	1548	134	8035
5	1	2636	-	-	7	1107	284	2646	20	1057	131	3079
6	10	578	131	1298	0	-	-	-	0	-	-	-
7	38	1913	144	33434	1	418	-	-	2	477	418	536
8	7	1033	177	2766	3	516	431	581	2	506	431	581
9	19	1031	107	3848	0	-	-	-	0	-	-	-
10	6	1155	107	4731	1	703	-	-	1	703	-	-

*Facial dimensions were outside the test panel.

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