Hand Dimensions of Hispanic and Other Ethnic Group Meat Processing Workers

James Spahr, M.P.H.[1], Bruce Bradtmiller, Ph.D.[2], Jinhua Guan, Ph.D[1]
[1]National Institute for Occupational Safety and Health (NIOSH)
Morgantown, West Virginia, USA
[2]Anthrotech, Yellow Springs, Ohio, USA

This paper reports a pilot study of hand dimensions of 147 male and 103 female meat processing workers measured at a pork processing plant in the United States, with an emphasis on the Hispanic subsample in the study population. Thirteen hand dimensions out of the 26 anthropometric dimensions measured in this study are presented besides weight and stature. Comparisons are made between the Hispanic meat processing worker data and the U.S. Hispanic military data as well as between different racial/ethnic groups in the meat processing sample. The Hispanic meat processing workers are different from the Hispanic personnel in the military survey in hand dimensions, with some dimensions bigger and other dimensions smaller. A comparison of the male Hispanic and African American/Sudanese subsamples in the meat processor sample show that the two subgroups are similar in weight and stature, but the male Hispanic subgroup is smaller in most hand dimensions than the male African American/Sudanese subsample. The female Hispanic subsample is smaller in weight, stature, finger length and most hand size dimensions than the female African American/Sudanese subsample, except the finger circumference dimensions. The Hispanic subsample and the White subsample are significantly different in weight and stature but not in any hand dimensions. Compared to their Asian counterparts, the Hispanics are taller and heavier and their fingers are thicker but not longer. These results may have implications for the design of gloves and other personal protective equipment in the meat processing industry. It is cautioned that due to the limited sample size, the study results must be considered preliminary in nature; an expanded study is recommended to address the sizing issue of cut-resistance gloves for the meat processing worker population.

INTRODUCTION

An estimated 527,000 workers are employed in the animal slaughtering and processing industry in the U.S. Workers in this industry suffer from injuries at a higher rate than the national manufacturing average [GAO Report 05-96, (2005)]. In their daily work practice, meat processing workers handle knives, saws, and other tools that expose them to high rates of traumatic injuries. The use of protective equipment (e.g., metal mesh or cut resistant woven gloves) is important in reducing the number of injuries in this industry.

The efficacy of protective equipment depends on how well it accommodates the user population for whom it is designed. Current sizing schemes for cut resistant safety equipment were rooted in military anthropometric data which are different from the civilian data. In addition, workers in meat processing plants were historically white males, many of whom were middle-aged and older. The current meat processing workforce is shifting toward younger Hispanic workers, and it is estimated that this trend will continue. This new demographic change requires updating of the anthropometric data used for designing safety equipment for this user population.

In 2008, the National Institute for Occupational Safety and Health (NIOSH) initiated a pilot study to begin addressing the sizing issues of cut-resistance gloves in meat processing industry. This paper describes two issues: (1) Is the Hispanic subsample in military anthropometric surveys a reliable source for the design of safety equipment for Hispanic meat processing workers? (2) Are Hispanic meat processing workers different from meat processing workers of other racial/ethnic backgrounds?

METHODS

Participants of this pilot study were drawn from a pork processing workforce. Two hundred fifty full-time meat processing workers, consisting of 57% Hispanic, 21% African American/Sudanese, 13% White, and 9% Asian, were used in this study. The male-female mix was 1.4 to 1. This was a convenience sample and was not designed to be representative of the meat processing workforce in general.

In addition to weight, a total of 26 anthropometric measurements essential for the design of safety equipment for the meat processing industry were taken. This study reports only 13 hand dimensions because of its focus on hand and finger sizes. Other measurements will be reported elsewhere. Measurements were taken of clothed participants. Participants were asked to take off their shoes, hats, and outerwear, and to remove all objects from their pockets before being measured. Anthropometric measurements were collected using standard anthropometry tools including a digital weight scale, Lufkin tape measure, and GPM sliding caliper.

A team of four experienced measuring technicians collected the measurements. Before the data collection started, the technicians were trained for this project. Training was considered complete when technicians achieved preset values for allowable inter- and intra-observer errors (Gordon et al, 1989). In addition, the data collection team employed data entry and editing software specifically designed for anthropometric surveys. The software signals the measurer when an unexpected value is entered. The value can then be verified on site by re-measuring the participant.

Since the convenience sample was not designed to be representative of the nation's meat processing workforce in its raw form, statistical weighting was employed to render the

sample more representative of the population of interest (Gordon, 2000; Harrison and Robinette, 2002, ISO TR 7250-2, 2008; ISO 11228-2, 2007).

In addition to the data from the current survey, the 1988 Anthropometric Survey of U.S. Army Personnel (ANSUR, Gordon et al, 1989) was involved in the present data analysis. The ANSUR survey has a sample of 1774 men and 2208 women that matched the proportions of age and racial/ethnic groups found in the active duty Army of June 1988. The Hispanics subsample of this survey is used in this analysis. ANSUR has a large set of hand measurements, which can potentially be used in the design of safety equipment for meat processing workers.

For statistical analysis, t-test for two independent samples is employed to examine possible differences in weight and stature between the NIOSH Hispanic meat processing workers and ANSUR Hispanic military personnel. In addition, the Bonferroni *t* procedure is used to compare hand size (hand length, hand breadth, and hand circumference), finger length (I through V) and finger circumference (I though V), respectively, between the Hispanic subsamples of the NIOSH and ANSUR survey as well as between the Hispanic group and other racial/ethnic groups in the NIOSH survey. Since each of the three hand dimensions (hand size, finger length and finger circumference) is evaluated by a Bonferroni *t* procedure, the familywise (FW) error rate for each procedure is set at $\alpha = 0.05$. Then, for hand size, the per comparison error rate with Bonferroni adjustment is limited to $\alpha = 0.05/3 = 0.0167$. For finger length measurements, the per comparison error rate with Bonferroni adjustment is limited to $\alpha = 0.05/5 = 0.01$. For finger circumference measurements, the per comparison error rate with Bonferroni adjustment is also limited to $\alpha = 0.05/5 = 0.01$.

RESULTS

Table 1 shows weighted means and standard deviations for the measurement of hand dimensions, stature and weight for 147 male and 103 female meat processing workers.

Table 1
Weighted means and standard deviations of hand size measurements, stature, and weight for meat processing workers (values in mm except when noted otherwise)

Dimension	Men (n = 147)		Women (n = 103)	
	M	S.D.	M	S.D.
Finger I circ	72	4.3	62	3.3
Finger II circ	69	4.0	60	3.2
Finger III circ	71	4.5	61	3.4
Finger IV circ	67	4.6	58	3.1
Finger V circ	59	3.9	51	3.1
Finger length I	63	5.0	57	4.5
Finger length II	74	5.0	67	4.6
Finger length III	81	4.8	74	4.8
Finger length IV	76	4.6	69	4.9
Finger length V	61	4.5	54	3.8
Hand Breadth	90	4.9	79	4.1
Hand Circ	220	10.7	191	9.3
Hand Length	190	10.0	174	9.3
Stature	1720	73.4	1600	74.8
Weight, kg	87.9	21.4	75.6	17.7

To answer the first research question, whether the Hispanic subsample in military surveys is a reliable source for the design of safety equipment for Hispanic meat processing workers, we compared hand measurements in the Hispanic subsample of the current NIOSH survey with a Hispanic subsample in ANSUR. Table 2 shows the comparisons of hand measurements between the Hispanic subsample in ANSUR and that in the current NIOSH meat processing worker survey.

For male Hispanics, the finger length of meat processing workers is about 2 to 7 mm shorter than in ANSUR. The Bonferroni *t* shows that these differences are all statistically significant. Likewise, the hand length of the meat processing workers is significantly shorter than in ANSUR, $t = -3.05$, $p < 0.0167$. However, the hand circumference of the meat processing workers is significantly bigger than in ANSUR, $t = 6.20$, $p < 0.0167$. The hand breadth and finger circumference measurements are similar to those found in ANSUR, except for fingers IV and V circumference.

Table 2
T-Test on the means of hand dimensions between NIOSH and ANSUR Hispanic Subsamples (values in mm)

Dimensions	Mean Diff.	df	*t*	Signif. (2-tailed)
MEN				
Finger length I	-6.9	828	-11.88	< **0.01**
Finger length II	-2.1	832	-4.06	< **0.01**
Finger length III	-2.9	832	-5.21	< **0.01**
Finger length IV	-4.2	832	-7.89	< **0.01**
Finger length V	-4.6	831	-9.63	< **0.01**
Hand breadth	-0.3	937	-0.66	> 0.0167
Hand circ	6.3	937	6.20	< **0.0167**
Hand length	-3.0	937	-3.05	< **0.0167**
Finger circ I	-0.4	937	-1.06	> 0.01
Finger circ II	0.0	832	0	> 0.01
Finger circ III	0.3	832	0.79	> 0.01
Finger circ IV	0.7	832	2.84	< **0.01**
Finger circ V	0.6	832	2.62	< **0.01**
WOMEN				
Finger length I	-4.6	369	-7.27	< **0.01**
Finger length II	-0.9	369	-1.40	> 0.01
Finger length III	-1.7	369	-2.39	> 0.01
Finger length IV	-2.0	369	-2.95	< **0.01**
Finger length V	-2.8	369	-4.73	< **0.01**
Hand breadth	-0.2	363	-0.39	> 0.0167
Hand circ	5.8	363	5.11	< **0.0167**
Hand length	-3.7	363	-3.00	< **0.0167**
Finger circ I	-0.4	363	-1.06	> 0.01
Finger circ II	-1.6	369	-4.88	< **0.01**
Finger circ III	-0.7	369	-2.19	> 0.01
Finger circ IV	-0.3	369	-0.02	> 0.01
Finger circ V	-0.2	369	-0.71	> 0.01

For female Hispanics, three finger length measurements (I, IV and V) of meat processing workers are significantly shorter than in ANSUR while the remaining two (Fingers II and III) are not different. Like the male Hispanics, the female Hispanics show no difference in hand breadth. The hand length of the meat processing workers is significantly shorter than in ANSUR, $t = -3.00$, $p < 0.0167$, but the hand circumference of the meat processing workers is significantly greater than in ANSUR, $t = 5.11$, $p < 0.0167$.

To answer the second research question, whether the Hispanic meat processing workers are different from meat processing workers of other racial/ethnic groups, we compared the Hispanic subsample with the White, African American/Sudanese, and Asian subsamples, respectively. Table 3 presents results of these comparisons between the Hispanics and the African Americans/Sudanese.

The Hispanic men are not different in weight (t = -0.02, p > 0.05) or in stature (t = -0.03, p > 0.05) from African American/Sudanese men. However, all measurements of hand size (hand length, breadth, and circumference) of the Hispanic men are significantly smaller than those of the African American/Sudanese men. Their finger length measurements (Finger I though V) are found to be smaller than those of the African American/Sudanese men. In addition, three of five finger circumference measurements (Fingers II, III, and V) are smaller than those of the African American/Sudanese men.

The Hispanic women are generally smaller in weight and stature than their African American/Sudanese counterparts (weight, t = -2.46, p < 0.05; stature, t = -4.61, p < 0.05). Two of the three hand size indices (hand length and circumference) are smaller than those of the African American/Sudanese women. Four out of five finger length measurements (Finger I through IV) are found to be smaller than those of the African American/Sudanese women.

Table 3
Comparing the means of hand dimensions between Hispanic subsample and the African American/Sudanese subsample in the NIOSH meat processing worker survey (values in mm or kg)

Dimensions	Mean Diff.	df	t	Signif. (2-tailed)
MEN				
Weight, kg	-2.2	119	-0.02	> 0.05
Stature	91.1	119	-0.03	> 0.05
Finger length I	-5.8	119	-6.95	< **0.01**
Finger length II	-5.6	119	-5.85	< **0.01**
Finger length III	-6.3	119	-6.59	< **0.01**
Finger length IV	-5.0	119	-5.71	< **0.01**
Finger length V	-3.2	118	-3.75	< **0.01**
Hand breadth	-2.6	119	-3.10	< **0.0167**
Hand circ	-6.1	119	-3.36	< **0.0167**
Hand length	-13.0	119	-7.25	< **0.0167**
Finger circ I	-3.0	119	-0.10	> 0.01
Finger circ II	-2.4	119	-3.45	< **0.01**
Finger circ III	-2.4	119	-2.96	< **0.01**
Finger circ IV	-1.9	118	-2.38	> 0.01
Finger circ V	-2.8	119	-3.86	< **0.01**
WOMEN				
Weight, kg	-10.6	71	-2.46	< **0.05**
Stature	82.4	71	-4.61	< **0.05**
Finger length I	-4.1	71	-3.62	< **0.01**
Finger length II	-3.8	71	-2.92	< **0.01**
Finger length III	-4.5	71	-3.44	< **0.01**
Finger length IV	-4.5	71	-3.42	< **0.01**
Finger length V	-2.7	71	-2.46	> 0.01
Hand breadth	-2.2	71	-1.98	> 0.0167
Hand circ	-6.9	71	-2.62	< **0.0167**
Hand length	-10.8	71	-4.11	< **0.0167**
Finger circ I	-2.8	71	-2.68	< **0.01**
Finger circ II	-2.1	71	-2.14	> 0.01
Finger circ III	-1.9	71	-1.92	> 0.01
Finger circ IV	-2.5	71	-2.55	> 0.01
Finger circ V	-1.3	71	-1.45	> 0.01

Table 4 presents the results of t-test procedures between the Hispanics and the Whites. For both men and women, the Hispanics are smaller in weight and stature than the Whites. However, there were not statistical differences in hand dimensions to those of their White counterparts.

Table 4
Comparing the means of hand dimensions between Hispanic subsample and the White subsample in the NIOSH meat processing worker survey (values in mm or kg)

Dimensions	Mean Diff.	df	t	Signif. (2-tailed)
MEN				
Weight, kg	-15.1	103	-3.49	< **0.05**
Stature	-97.4	103	-6.86	< **0.05**
Finger length I	-4.9	103	1.02	> 0.01
Finger length II	-5.5	103	1.09	> 0.01
Finger length III	-4.6	103	1.07	> 0.01
Finger length IV	-4.2	103	1.09	> 0.01
Finger length V	-5.1	103	0.93	> 0.01
Hand breadth	-3.9	103	1.10	> 0.0167
Hand circ	-8.7	103	2.33	> 0.0167
Hand length	-7.3	103	2.09	> 0.0167
Finger circ I	-2.3	103	0.95	> 0.01
Finger circ II	-2.9	103	0.87	> 0.01
Finger circ III	-3.7	103	1.00	> 0.01
Finger circ IV	-3.6	103	1.00	> 0.01
Finger circ V	-2.7	103	0.84	> 0.01
WOMEN				
Weight, kg	-10.6	68	-3.13	< **0.05**
Stature	82.4	68	-3.37	< **0.05**
Finger length I	-4.1	68	-1.09	> 0.01
Finger length II	-3.8	68	-0.93	> 0.01
Finger length III	-4.5	68	-0.78	> 0.01
Finger length IV	-4.5	68	0.29	> 0.01
Finger length V	-2.7	68	0.25	> 0.01
Hand breadth	-2.5	68	-2.06	> 0.0167
Hand circ	-6.4	68	-2.28	> 0.0167
Hand length	-3.1	68	-1.08	> 0.0167
Finger circ I	-2.8	68	-0.84	> 0.01
Finger circ II	-2.1	68	-1.31	> 0.01
Finger circ III	-1.9	68	-1.76	> 0.01
Finger circ IV	-2.5	68	-2.07	> 0.01
Finger circ V	-1.3	68	-1.65	> 0.01

Table 5 presents the results of t-test procedures between the Hispanics and the Asians. For both men and women, the Hispanics are significantly larger in weight and stature than their Asian counterparts (for men, weight, t = 2.42, p < 0.05; stature, t = 2.27, p < 0.05; for women, weight, t = 3.49, p < 0.05; stature, t = 3.19, p < 0.05). Their fingers are significantly thicker, but not longer than their Asian counterparts. Their hand size seems very similar to that of the Asians except for hand circumference measurement in men. In this case, the Hispanics men are found to be significantly greater than their Asian counterparts, t = 2.42, p < 0.01. However, since the number of Asian men is very limited (6 cases), the results should be validated with a larger sample.

DISCUSSION

In general, the Hispanic subsample of this survey is smaller in finger length measurements than the Hispanic subsample in ANSUR, but not in finger circumference measurements. But there are some subtle differences between the two samples in

finger dimensions. Specifically, the male Hispanic meat processing workers are smaller in all finger length

Table 5
Comparing the means of hand dimensions between Hispanic subsample and the Asian subsample in the NIOSH meat processing worker survey (values in mm or kg)

Dimensions	Mean Diff.	df	*t*	Critical Value (FW α = 0.05)
MEN				
Weight, kg	15.6	89	2.42	< **0.05**
Stature	56.3	89	2.27	< **0.05**
Finger length I	3.1	89	1.82	> 0.01
Finger length II	1.3	89	0.66	> 0.01
Finger length III	1.9	89	0.99	> 0.01
Finger length IV	2.9	89	1.52	> 0.01
Finger length V	1.1	89	0.71	> 0.01
Hand breadth	2.8	89	1.57	> 0.0167
Hand circ	9.3	89	2.42	< **0.0167**
Hand length	5.8	89	1.68	> 0.0167
Finger circ I	5.6	89	3.58	< **0.01**
Finger circ II	4.8	89	3.40	< **0.01**
Finger circ III	5.8	89	3.50	< **0.01**
Finger circ IV	6.2	89	3.75	< **0.01**
Finger circ V	5.5	89	4.01	< **0.01**
WOMEN				
Weight, kg	12.4	72	3.49	< **0.05**
Stature	54.9	72	3.19	< **0.05**
Finger length I	-0.6	72	-0.61	> 0.01
Finger length II	-0.2	72	-0.15	> 0.01
Finger length III	-0.8	72	0.61	> 0.01
Finger length IV	0.7	72	0.60	> 0.01
Finger length V	0.5	72	0.43	> 0.01
Hand breadth	0.4	72	0.35	> 0.0167
Hand circ	2.6	72	1.00	> 0.0167
Hand length	1.5	72	0.45	> 0.0167
Finger circ I	2.8	72	2.94	< **0.01**
Finger circ II	2.4	72	2.60	< **0.01**
Finger circ III	2.3	72	2.49	> 0.01
Finger circ IV	3.0	72	3.27	< **0.01**
Finger circ V	3.5	72	4.17	< **0.01**

measurements than the male Hispanic personnel in ANSUR. But the female Hispanic meat processing workers are smaller in three out of five finger length measurements. Furthermore, the male Hispanic subgroups in both surveys are similar in three out of five finger circumference measurements, while the female subgroups are similar in four out of five circumference measurements. The finger dimensions in ANSUR were derived from photometric boxes instead of traditional measurements. Although the photometric box was validated against traditional measurements, it is still possible that there are subtle differences in the way the measurements were extracted that make them not precisely equivalent to the directly measured ones. It is no longer possible to definitively answer this question, as the photometric equipment has been disassembled

The results on hand size are more consistent for men and women alike. The meat processing workers are greater than the military personnel in hand circumference, smaller in hand length, but not different in hand breadth. It is worth noting that hand length in both samples may have been measured in different ways between the two surveys. In the meat processing worker survey, hand length was measured from the tip of middle finger to the crease of the wrist, while the same dimension is measured from the tip of middle finger to the stylion landmark in ANSUR. Conceptually, the measurements in the meat processing worker survey should be smaller on the average than that in ANSUR. Our data show this is indeed the case. Due to the differences in hand and finger dimensions between the two samples and the situation surrounding the ANSUR photometric box, it is not advisable to apply the military data for the design of personal protective equipment for the meat processing workers.

One of the most noticeable findings is made when we compare the NIOSH Hispanic subsample and each of the other racial/ethnic groups. Namely, the differences in weight and stature between different racial/ethnic groups are not consistent with the differences in hand dimensions. While the male Hispanics in the sample are not different from the male African American/Sudanese in weight or stature, they are significantly smaller in all hand dimensions examined in this study. Conversely, while the male and female Hispanics are significantly smaller than the male and female Whites in both weight and stature, they are not different from the Whites in any hand dimension. While the Hispanics are greater in stature and weight than their Asian counterparts, their finger length and most of their hand size measurements are not different from those of the Asians.

CONCLUSIONS

This study reports preliminary data on hand dimensions among the meat processing workers at a pork processing facility located in the U.S. Due to differences in hand dimensions between the Hispanic subsample of this survey and a military survey, it is not advisable to apply military data to the civilian meat processing workers. Furthermore, the Hispanics meat processing workers are found to be significantly different in hand dimensions from the African American/Sudanese and Asian meat processing workers, but not different from the White meat processing workers in this survey. A survey with a larger sample size is recommended to confirm these results.

ACKNOWLEDGEMENT

The authors are grateful to Nancy Stout, Ed.D. and Les Boord, Ph.D., for their assistance in supporting the funding of this research; Mathew Hause for data collection support; Darlene Weaver, M.Sc., for manufacturing ergonomics literature search support; and to Hongwei Hsiao, Ph. D. and Alfred A. Amendola, Ph.D. for a constructive review of this report.

DISCLAIMER

The findings and conclusions in the report are those of the authors and do not necessarily represent the views of NIOSH.

Mention of any product in this report does not constitute an endorsement of the product by NIOSH or the authors.

REFERENCES

CDC (2004) National health and nutrition examination survey (NHANES), 2003-2004. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Health Statistics.

General Accounting Office (2005) Workplace safety and health – safety in the meat and poultry industry, while improving, could be further strengthened. GAO-Report 05-96. Washington, DC.

Gordon, C.C. (2000) Case studies in statistical weighting of anthropometric databases to match target audience distributions. XIVth Triennial Congress of the International Ergonomics Association and the 44th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, CA.

Gordon, C.C., Churchill, T., Clauser, C.E., Bradtmiller, B., McConville, J.T., Tebbetts, I., & Walker RA (1989) 1988 Anthropometric survey of US Army personnel: Methods and summary statistics. Technical Report (Natick/TR-89-044).US Army Natick Research, Development, and Engineering Center, Natick MA.

Harrison, C.R. and Robinette, K.M. (2002) Civilian American and European surface anthropometry resource (CAESAR): Summary statistics for the adult population (ages 18-65) of the United States of America. Human Effectiveness Directorate, Crew Systems Interface Division, Wright-Patterson Air Force Base, OH.

ISO TR 7250-2 (2008) Basic human body measurements for technological design – Part 2: Statistical summaries of body measurements from individual ISO populations. Technical Report, International Standards Organization, Geneva.

ISO 11228-2 (2007) Ergonomics – Manual handling – Part 2: Pushing and pulling. International Standards Organization, Geneva.