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Anthropometric measurement of Filipino manufacturing workers

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Abstract

This study conducted anthropometric measurements among 1805 Filipino workers in 31 manufacturing industries. Anthropometric data were measured for standing, sitting, hand and foot dimensions, breadth and circumference of the various body parts, and grip strength. The workplace assessment survey was also done among respondents coming from the subject population to look into the common work and health problems that may be associated with ergonomic hazards at work. The data gathered can be applied for the ergonomic design of workstations, personal protective equipment, tools, interface systems, and furniture that aid in providing a safer, more productive, and user-friendly workplace for the Filipino working population. This is the first ever comprehensive anthropometric measurement of Filipino manufacturing workers in the country which is seen as a significant contribution to the Filipino labor force who are increasingly employed by both domestic and foreign multinationals.

Keywords: Anthropometric measurements; Ergonomic design; Workplace assessment; Health and safety of workers

1. Introduction

Anthropometry is the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body. The uses of anthropometry in the workplace include: (1) to evaluate postures and distances to reach controls; (2) to specify clearances separating the body from hazards such as surrounding equipments; (3) to identify objects or elements that constrict movement; and (4) to assist in the biomechanical analysis of forces and torque.

The anthropometric measurements performed in this study can be used as a basis for the ergonomic design of PPEs and workstations that can make work environments safer and more user-friendly. Currently, there is increasing demand for this kind of information among those who develop measures to prevent occupational injuries. In the United States, the body size or body segment measurements of some occupational groups differ significantly compared to others. This implies that caution must be exercised in selecting databases for the design and evaluation of machinery, human–machine interfaces and PPEs (Hsieh et al., 2002).

This is the first ever comprehensive anthropometric measurement of Filipino workers in the country which is seen as a significant contribution to the Filipino labor force who are increasingly employed both in the local and international market, and by both domestic and foreign multinationals who put up their subsidiary plants in the Philippines. In fact, the top revenue export of the Philippines comes from electronics which is part of the study population.

The workplace assessment survey was also used to look into the common work and health problems that may be associated with ergonomic hazards at work. The data will assist regulatory bodies and manufacturers for an overview of health and work issues in the manufacturing sector which should be addressed to obtain both healthy work environment and productivity. The baseline study on anthropometry could be correlated with workplace assessment in future studies.

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2. Materials and methods

From the sampling plan provided by the export zones, 31 different kinds of manufacturing industries were randomly selected. Export zones host multinational companies that operate and hire Filipino laborers at lower wages, and better investment and trading benefits not readily available outside the zone. This is a strategy adopted by the government to attract multinational investment in the country. Export zones are special economic and social enclaves in developing countries. The benefits given to transnational corporations (TNCs) in export zones in the Philippines include: 100% ownership, no duties, no taxes nor license fees on imports to the zone, the privilege to borrow from Philippine banks, no taxes on exports, no minimum investment requirement, and unrestricted repatriation of capital and profits (Rowbotham and Mitter, 1994).

A proportionate random sampling was done from each industry based on the existing workforce involving only the assembly-line production workers. The sample population was 1805. Experimenters were all researchers from the occupational health and safety research division. Training of experimenters and observers were done rigorously for 2 months before the conduct of the study involving orientation on the objectives and methodology of the study, lecture series on the measurement protocol using body landmarks which are stable, series of pre-measurements among experimenters to establish accuracy of measurement, and correct body positioning. They were trained on how to conduct the measurement in reference to stable body landmarks used in biomechanics. Labeling landmarks before taking measurements improved precision, as was also shown in the study of Weinberg et al. in 2004. For instance, upper arm length was measured from the acromial process to the tip of the elbow. Measurement on one subject was done twice by the same person, and as such intrareliability measured was $r = 0.8$.

Body physique or anthropometric measurements were done using tape measure, a goniometer, calipers and anthropometers to measure body segment length, height, breadth, depth, and circumference. Examples of such measurements are hip breadth, crotch length, functional leg length, buttock–knee length, knee height, popliteal height and others.

After the anthropometric measurement, a workplace assessment survey was conducted among 520 respondents coming from the subject population to investigate the most common hazard exposures, ergonomic problems, and safety issues. The survey questionnaire also investigated pain, discomfort, limitation of motion, and affectation of activities of daily living. Data were encoded using word and SPSS 9.0. Statistical analyses were descriptive and inferential statistics.

3. Results

Among the 1805 individuals selected, 53.3% were females while 46.7% were males. Majority of them were single (60.4%) and below 30 years old (77%), indicating a relatively young working population. Forty-one percent of the workers were high-school graduates, followed by workers who finished vocational school (23.3%). Only 16% of the workers finished college education.

Majority (80.50%) of the subjects were between 150 and 174 cm in height (s.d. = 8), with the shortest at 54 in and the tallest at 71 in. Most of respondents (92.7%) weighed less than 80 kg, with measurements ranging from 40 to 170 kg.

Tables 1–9 show the anthropometric measurements of the workers. It shows that the mean standing height for males is higher than for females at 167.0 cm (s.d. = 8.03) and 153.9 (s.d. = 8.08) cm, respectively. Meanwhile, the mean sitting height is 84.8 cm for males (s.d. = 5.81) and 79.9(s.d. = 4.5) cm for females.

Many establishments and industries have yet to recognize the importance of ergonomics and anthropometry in the workplace. In the study conducted by Ijadunola et al. in 2003, they found that the design and layout of offices and workstations and access to equipment were suboptimal and promoted unnecessary physical efforts, decreasing the efficiency and productivity of workers. Two-thirds of these workers also complained of work-related backache.

In this study, similar problems were noted among the respondents. The top five hazards identified were poor posture leading to backache (72.2%), heat (66.6%), overwork (66.6%), poor ventilation (54.8%), and chemical exposure (50.8%). Among physical and psychomotor stresses, the top three were visual strain, overtime, and overwork. The most common illnesses related to ergonomic problems were backache (56%), fatigue and weakness (53.2%). Cuts (46.8%) topped the list of common injuries followed by slipping injury (23.2%).

Using logistic regression, cuts and bruises were significantly associated with slippery floors. Cuts and bruises were 1.8 times more likely to occur with both slippery floors and narrow storage rooms, and 0.49 times more likely among males. Falls were more likely to occur with slippery and uneven floors, while head trauma was more likely to occur in small and narrow storage rooms, more likely among males, and with work overload. (Table 10).

Table 11 shows the comparative frequencies of symptoms with respect to the different body areas investigated. Pain was the most commonly reported symptom across all body areas, followed by discomfort and limitation of motion. All were most commonly seen in the upper trunk and lower back (18.1%, 8.1%, and 7.9%, respectively).

4. Discussion

For the past few years, ergonomic initiatives have been growing in Asia due to increasing local needs. A number of studies in some developing countries in the region has contributed in improving the working conditions of locals in terms of materials handling, workstation design, work

Table 1
Anthropometric measurement for standing

Anthropometric measurement (cm) standing height	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Standing height	167.01	157.00	167.00	178.00	8.03	153.92	143.00	155.00	165.00	8.28
Eye height	155.01	145.00	155.00	166.00	6.92	143.05	134.00	143.00	153.00	6.15
Shoulder height	137.45	128.00	137.00	148.00	6.07	127.21	118.00	127.00	136.00	5.80
Shoulder width	44.67	39.00	44.00	49.40	7.33	40.24	34.00	40.00	46.00	8.29
Shoulder elbow length	33.05	28.00	33.00	37.00	3.97	31.39	27.00	31.00	35.00	10.28
Length of upper arm	25.99	20.00	26.00	31.00	4.54	24.92	20.00	25.00	29.00	8.38
Length of lower arm	25.83	21.10	25.00	30.00	4.41	24.16	20.00	24.00	30.70	4.18
Forearm hand length	44.06	40.00	44.00	48.00	4.12	40.47	36.00	41.00	45.00	5.39
Length of arm and hand	72.60	67.00	73.00	79.00	6.35	66.04	59.00	67.00	72.00	5.77
Elbow height	104.14	96.50	104.00	112.80	6.72	96.28	89.00	97.00	104.00	7.39
Knuckle height	72.51	66.00	73.00	79.00	5.80	67.77	62.00	68.00	74.00	6.33
Chest height	123.36	114.0	123.00	134.00	7.22	111.28	102.50	112.00	121.00	10.50
Chest breadth	36.35	29.00	35.50	47.00	6.17	32.63	25.00	31.00	47.43	7.22
Waist height	97.32	90.00	98.00	105.00	8.43	95.47	88.58	96.00	103.00	6.09
Waist hip length	10.11	5.00	9.00	15.00	6.44	10.19	6.00	9.00	14.00	6.32
Hip width	43.50	31.00	44.00	54.80	8.33	43.38	32.00	44.00	52.93	7.10
Hip height	87.66	81.00	89.00	96.00	8.57	85.34	79.00	86.00	94.00	9.01
Knee height	49.73	44.00	50.00	55.00	5.99	45.88	41.00	46.00	50.00	3.09
Popliteal height	46.35	41.50	47.00	51.00	2.99	42.05	37.00	42.00	47.00	4.02
Upper reach	193.40	175.00	190.00	208.00	10.8	190.19	177.00	191.00	204.00	10.28
Overhead fingertip reach	212.08	195.00	213.00	224.90	9.10	196.46	183.00	196.00	211.00	8.91
Arm span	167.92	154.20	169.00	181.00	9.15	153.18	141.00	153.00	165.00	8.53

Table 2
Anthropometric measurement for sitting

Anthropometric measurement (cm) sitting height	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Sitting height	84.84	78.00	85.00	92.00	5.81	79.92	73.00	80.00	87.00	4.50
Eye height	73.36	67.00	73.00	80.00	3.83	68.38	62.00	69.00	74.00	4.85
Elbow height	22.23	17.00	22.00	27.00	4.21	21.89	17.00	22.00	26.43	4.09
Waist height, sitting	19.44	15.00	19.00	24.00	6.15	22.41	18.00	22.00	27.00	3.21
Hip height	13.28	10.00	13.00	18.00	4.06	15.29	11.00	15.00	20.00	6.71
Hip breadth, sitting	35.60	31.00	35.00	41.00	4.19	36.39	31.00	36.00	42.43	4.83
Thigh clearance height	13.49	10.50	13.00	16.50	4.45	12.82	10.00	12.00	16.00	6.97
Buttock knee length	54.80	49.00	55.00	61.90	5.21	52.73	47.00	53.00	59.00	4.56
Buttock popliteal length	46.40	41.00	46.00	52.00	3.72	45.14	40.00	45.00	51.00	3.69
Knee height, sitting	50.03	45.00	50.00	55.90	3.99	46.98	42.15	47.00	52.00	4.43
Popliteal height	43.33	39.00	43.00	47.00	2.57	40.34	36.00	40.50	44.00	2.90
Buttock width	48.45	35.10	48.00	59.00	7.40	47.66	35.00	48.25	58.00	6.85
Length of upper leg	36.80	29.20	36.00	46.50	6.12	35.96	28.00	36.00	45.00	5.25
Length of lower leg and foot	45.27	38.00	46.00	52.00	4.53	42.14	35.00	42.50	48.00	4.31
Thumbtip reach	71.30	61.00	72.00	79.00	7.12	65.44	56.00	66.00	74.00	7.63
Overhead fingertip reach, sitting	127.92	117.00	128.00	138.00	7.81	116.87	108.00	117.00	128.00	9.77

organization and work environment through utilization of locally available resources. In these countries, varied sectors which include local government units, trade unions, industrial associations and the agricultural sector have participated actively in action-oriented ergonomic training programs (Chan and Jiao, 1996). This was also evident in Mexico where the growing manufacturing sector necessitated the need for an anthropometric database for the working population (Lavender et al., 2002). In HongKong, the increasing popularity of using computer-aided design (CAD) prompted investigators to look into the design of a suitable workplace for CAD operators by using

Table 3
Circumference anthropometric measurement

Anthropometric measurement (cm) circumference	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Head	55.28	53.00	55.50	58.00	3.086	53.88	51.00	54.00	56.43	2.63
Shoulder	106.67	96.00	106.00	120.00	9.243	94.52	85.00	95.00	107.85	10.86
Biceps	28.10	23.50	27.50	33.00	5.499	25.28	21.00	25.00	30.50	3.97
Lower arm	25.62	22.00	25.00	29.00	4.794	22.28	19.00	22.00	25.50	4.45
Buttock	92.69	83.00	93.00	105.00	9.035	92.53	83.00	92.00	104.85	7.52
Upper leg	46.14	37.00	46.00	54.40	6.401	45.46	38.00	45.00	54.00	5.21
Lower leg	35.68	30.00	35.00	42.00	5.292	33.83	29.00	33.00	39.00	4.59
Chest	86.66	76.10	87.00	100.80	9.344	84.42	74.00	84.00	98.43	9.31
Waist	79.42	66.00	79.00	94.00	8.566	72.74	60.00	71.00	90.00	9.05
Hips	88.34	79.00	88.00	100.00	7.934	86.64	75.00	86.00	101.00	9.44

Table 4
Grip strength measurement

Anthropometric measurement (cm) grip strength	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Standing (left)	38.53	23.00	39.00	53.00	8.56	20.72	11.00	20.85	29.00	7.00
Standing (right)	40.64	25.200	41.00	54.80	9.35	22.36	13.00	22.00	31.00	8.89
Sitting (left)	38.60	24.00	39.00	52.00	8.40	20.21	12.00	20.00	29.00	5.66
Sitting (right)	40.41	27.00	40.00	55.00	8.46	21.84	12.00	22.00	31.00	5.72

Table 5
Depth anthropometric measurement

Anthropometric measurement (cm) depths	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Forward reach, functional	76.58	78.00	78.00	86.00	7.61	69.64	59.08	70.00	79.00	6.83

Table 6
Breadth anthropometric measurement

Anthropometric measurement (cm) breadths	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Elbow to elbow breadth	30.57	32.00	31.00	48.00	2.07	28.85	30.00	29.00	46.00	1.68

anthropometric data to enhance performance and reduce musculoskeletal problems (Chan and Jiao, 1996). It is the objective of this study to come up with a database of anthropometric measurement of Filipino workers in the manufacturing sector to aid in tool and working equipment, personal protective equipment designs, and other applications. These measurements can be given to the regulatory body in the Philippines for adoption by industries, or directly accessed by manufacturers prior to plant design.

Table 7
Head dimension anthropometric measurement

Anthropometric measurement (cm) head dimension	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Head breadth	17.22	14.60	17.00	19.40	6.21	16.50	14.00	16.00	18.50	6.96
Head length	20.53	17.50	20.00	26.00	7.48	19.23	16.50	19.00	23.00	2.76
Interpupillary distance	7.74	6.50	7.50	8.00	4.63	7.37	6.00	7.00	8.00	5.18
Bitragion subnasale arc	28.62	25.00	29.00	31.00	3.03	27.09	25.00	27.00	29.00	1.43
Bitragion chin arc	30.57	27.00	31.00	33.40	2.07	28.85	26.00	29.00	31.00	1.68

Table 8
Hand anthropometric measurement

Anthropometric measurement (cm) hand dimension	Male ($n = 843$)					Female (962)				
	54.02	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Sleeve outseam	54.02	48.00	4.72	60.00	4.72	49.38	44.50	50.00	55.00	4.65
Hand length	19.75	17.00	7.82	21.50	7.82	17.95	15.50	18.00	20.00	3.44
Hand breadth	9.80	8.00	4.07	11.00	4.07	9.23	7.50	8.50	10.00	6.97
Hand circumference	20.78	19.00	1.64	23.00	1.64	18.39	16.00	18.00	20.00	7.44
Wrist center of grip length	9.20	7.50	3.93	11.00	3.93	8.69	7.00	8.50	10.00	4.10

Table 9
Foot anthropometric measurement

Anthropometric measurement (cm) foot dimension	Male ($n = 843$)					Female (962)				
	Mean	5th Percentile	Median	95th Percentile	Std. Dev	Mean	5th Percentile	Median	95th Percentile	Std. Dev
Foot length	25.42	23.00	25.50	28.00	1.67	22.63	20.00	23.00	25.00	1.64
Foot breadth, horizontal	10.52	8.50	10.00	11.50	6.37	9.50	8.00	9.00	11.00	4.41
Ankle circumference	24.18	21.00	24.00	27.00	2.23	21.93	19.00	22.00	25.00	2.80
Functional leg length	93.34	88.00	93.00	100.00	4.08	90.70	83.00	90.00	98.00	4.60
Step height	27.67	16.00	28.00	40.00	7.79	25.63	14.58	25.00	37.00	9.11

In the light of global industrialization, much attention is demanded to deal with occupational factors and their influence on health and safety of workers. Previous studies have correlated such factors with a wide variety of physical and psychophysiological disorders that impair human well-being and hamper one's ability to carry out responsibilities at work (DOLE, 1998; ILO, 1998). In particular, investigators have turned their attention to organizational variables and work hazards as possible sources of illness and distress among the working population. Both have been documented to be significant sources of occupational stress (van Vegchel et al., 2001; Mironov et al., 1994) and predictors of the occurrence of occupational injuries (Melamed et al., 1999).

This study has shown that significant associations exist between certain occupational factors and work-related injuries. These findings are similar to the work of Lee and Karusse (2002) where physical job demands and constant pressure led to work-related pain and disability. Torp et al. in 2001 also reported that social and organizational factors contributed to the development of musculoskeletal disorders among workers. Musculoskeletal disorders such as back pain, shoulder pain and carpal tunnel syndrome have been related to occupational factors, most of them ergonomic and psychosocial in nature. These include

Table 10
Odds ratio of factors associated with certain injuries in the workplace ($n = 500$)

Risk factors	Injuries		
	Cuts/Bruises	*Falls*	*Head trauma*
1. Sex	0.498 (0.025)[a]		0.220 (0.040)
2. Slippery floors	1.860 (0.009)	2.021 (0.018)	
3. Narrow, small storage room	1.898 (0.005)		0.156 (0.040)
4. No machine guards			
5. Uneven floors		1.872 (0.047)	
6. Work overload			12.204 (.001)

Level of significance originally set at 95% CI for all estimates.
[a]Number with parenthesis—odds ratio; ( ) in parenthesis—significance level.

Table 11
Descriptive statistics of symptoms per body area ($n = 520$)

	Frequency	Percentage
Pain		
Head and neck	69	13.3
Hands, wrists and shoulders	53	10.2
Upper trunk and lower back	94	18.1
Legs	63	12.1
Limitation of motion		
Head and neck	21	4.0
Hands, wrists and shoulders	11	2.1
Upper trunk and lower back	41	7.9
Legs	29	5.6
Affectation of daily living		
Head and neck	21	4.0
Hands, wrists and shoulders	12	2.3
Upper trunk and lower back	42	8.1
Legs	26	5.0
Discomfort		
Head and neck	23	4.4
Hands, wrists and shoulders	16	3.1
Upper trunk and lower back	42	8.1
Legs	35	6.7

repetition, force, static posture, dynamic movement (Schierhout et al., 1995), physically demanding job, poor workplace, social environment, inconsistency between job and education level, low job satisfaction, and low coworker support (Kerr et al., 2001).

Industrial ergonomics and anthropometry are now used to confront the above problems at work. As such, this study was conducted to come up with baseline data on both anthropometry and workplace ergonomic issues which may shed light on controlling occupational illnesses and injuries. Since mismatches in anthropometric dimensions has been postulated to be one of the main causes of work-related fatigue and occupational illness (Chan and Jiao, 1996), steps must be taken to gather anthropometric data that can aid in the formulation of ergonomic interventions in the workplace.

Previous studies show the application of anthropometry. McKay and Davies (2002) indicated the need for fitness testing of respirators based on anthropometry of the face. In addition, ergonomic interventions applied upon return of sicklisted workers suffering from chronic lower back pain have also been found to be effective (Mironov et al., 1994). Techniques such as occasionally changing posture, taking walks or sitting during breaks, use of proper shoes and footrests have been found to be effective in addressing this problem (Melamed et al., 1999).

The anthropometric data in this study can have many applications. It can be used as a reference for body mass index (BMI) and obesity index. This was done in the study of Eckhardt et al. in 2003 where they tried to look into the ability of BMI to predict body fat (BF) among youths in four Asian countries and to identify the degree to which additional anthropometric measures improved this prediction. On the other hand, Shiwaku et al. in 2005 suggested that BMI and waist circumference were useful for predicting multiple metabolic disorders in non-diabetic Mongolians and Japanese.

The anthropometric measurements gathered in this study can be applied in the improvement of manual materials handling, posture, interface and furniture design, workplace design and workstation layout, among many others. The use of anthropometry and ergonomics in design systems has reduced human error in system performance, minimized hazards to individuals in the work environment, reduced adverse health effects and improved system efficiency (Anema et al., 2004).

5. Conclusion

The gathering of anthropometric data as well as workplace health and safety assessment is a much needed and worthwhile pursuit in light of the increasing incidence of work-related illnesses and injuries. The gathered data from the 1805 workers in this study will hopefully be applied in the ergonomic design of workstations, tools, equipment, layout designs and interventions that are uniquely well-suited for Filipino workers. In addition, it is hoped that this information will be used in the improvement of local working conditions, targeting key problem areas in order to minimize ergonomic problems and related injuries and illnesses. Both implementing government agencies and corporate management must work together in the design and implementation of occupational health and ergonomic programs for the welfare of workers in the manufacturing sector.

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