Anthropometry and Agricultural Hand Tool Design for Javanese and Madurese Farmers in East Java, Indonesia

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Abstract

This study revealed that anthropometric measurements of Javanese farmers are mostly higher than that of Madurese farmers. The minimum, mean, and the maximum stature values are 146.3, 159.0, 174.6 cm for Javanese male farmers and 143.0, 156.3, 173.8 cm for Madurese male farmers, respectively. The minimum, mean, and the maximum stature of Javanese and Madures female farmers are 137.7, 152.5, 167.3 cm and 137.4, 150.1, 167.7 cm, respectively. The mean of Relative Sitting Height (RSH) of Javanese and Madurese, male is 0.49, 0.49, respectively, whereas the mean of RSH of Javanese and Madurese female is 0.52, 0.51, respectively. The mean values of body surface area (BSA) of Javanese, Madurese, male are 1.57, 1.54, and for female are 1.47, 1.44 m^2, respectively. Whereas, the body mass index (BMI) is 22.4, 22.88 for male and 22.38, 22.75 kg/m^2 for female Javanese and Madurese farmers, respectively. By using Principal Component Analysis (PCA) with varimax rotation, the first rank preference of farmers is safety for hand tools, and then followed by good fit in hand, easy to use, reliable and to no inflamed skin in the last. For agricultural hand tools, farmers prefer utilitarian performance than hedonic performance.

Keywords: Anthropometry, Agricultural Hand Tools, Javanese, Madurese, Farmer, Indonesia

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1. Introduction

Ergonomics is sometimes defined as the science of fitting the work to the user, instead of forcing the user to fit the work. A good match can be obtained if anthropometric data are used. Large scale anthropometric research was started in the 1940s in Western European countries and United States. Roberts [1], Damon and Stoudt [2] studied anthropometry related to works of human. Wang et al. [3] stated that anthropometry can provide solutions to resolve problems in operator to machine and equipments. Many researchers used anthropometric data to design tools/equipment or machines [4] and [5]. Researchers collect anthropometric data from different segments of the population step by step. The anthropometric data from developing countries is limited. Indonesia still generally lack data of anthropometric measurements. Some researchers collected data of anthropometry for Indonesian populations [6]-[9]. The anthropometric database of farmers in Indonesia is needed to update.

In Indonesia, it is estimated that about 41.20 million farmers are engaged in agricultural and allied activities. In the East Java, farm households constitute the largest number of national agricultural households (5.1 million), which is divided into three, namely a) the Agricultural Household work the land themselves, b) Farm Household work the land with the wage distribution of agricultural products, and c) the Agricultural Household work the land by people paid with money [10]. Agricultural equipments such as tractor, power tiller, animal drawn and agricultural hand tools with a variety of sizes and dimensions are widely used in Indonesia to cultivate, harvest and post harvest jobs. To bring comfort in the use of agricultural equipment and machinery, their design is required in accordance with the precise data on anthropometric farmers in Indonesia. To get better performance and higher safety for farmers when using tools or farm machineries or equipment, it is necessary to adjust the design of the machine with anthropometry of the target farmers [11] and [12]. To design agricultural equipments, its design or size should be rationalized to accommodate most size of workers. Gite [13] and Yadav [14] in their study stated that in the design of agricultural equipments, designers should take into account ethnic differences in body dimensions of the farmers.

The objective of this study was to provide data of body dimensions of Javanese and Madurese farmers who reside in East Java, Indonesia. The collected anthropometric data are expected to be used as a vital reference for designing or redesigning agricultural hand tools. Furthermore, this study ranks the agricultural hand tools according to the Indonesian farmer's preference.

2. Methodology

2.1. Anthropometry Measurement

The subjects who were taken as samples consisted of 80 males and 86 females of Java (Javanese) tribe, as well as 76 males and 80 females of Madura (Madurese) tribe. In this study the body dimensions measured of the farmers who were willing to participate. The measurements for standing and sitting posture were done using a Martin type anthropometer. Hand measurements were taken using digital calliper. Weight of subjects was measured with a digital weighting scale that have capacity of 180 kg and accurate to 0.1 kg. A plastic tape was used to measure vertical hand grip when standing. A squeeze dynamometer (Pneumatic Squeeze Bulb dynamometer-A2013601) was used to measure power of farmer hand.

2.2. Questionnaire for Agriculture Hand Tools

The study identified the rank of popularly used agricultural hand tools in the three districts Jember, Banyuwangi and Lumajang, of East Java, Indonesia. Out of the total 502 respondents, 132 and 138 were

Javanese male and female farmers, and 118 and 114 were Madurese male and female farmers, respectively. The data used in this study was primary data, which was collected by using instrument questionnaire, observation and interview.

3. Results and discussion

Anthropometric data collection of Javanese and Madurese famer males and females that living in East Java, Indonesia is presented in Tables 1 and Table 2. The age of male farmers was 16-67 years and farmer females ranged from 15-59 years. Javanese male farmers have stature, eye height, sitting height, chest (bust) depth, abdominal depth, span, hand breadth across thumb, and body weight higher than Madurese male farmers have. Javanese female farmers have stature, eye height, sitting height, hip breadth, abdominal depth, span, and body weight higher than Madurese female farmers.

The Minimum stature of Javanese and Madurese male farmer are 146.3 and 143.0 cm, respectively and the maximum stature of Javanese and Madurese male are 174.6 and 173.8 cm, respectively. Mean stature of Javanese and Madurese male farmers are 159.0 and 156.3 cm, respectively. These values are the lowest when compared with Indonesian citizen 172 cm [7], Indian Mizoram 160.9 cm [15], and Central Thai 168.56 cm [16], however the mean value of Javanese stature is higher than Indian Meghalaya 158.7 cm [11]. The minimum stature of Javanese and Madures female are 137.7 and 137.4 cm, respectively and the maximum stature of Javanese and Madurese are 167.3 and 167.7 cm, respectively. The mean stature of Javanese and Madurese female farmers are 152.5 and 150.1 cm, respectively. The mean stature of Javanese and Madurese female farmers are lower than Indonesian citizen 159 cm [7], Indian Mizoram 153.1 cm [15], and Central Thai 157.48 cm [16]. However, the mean value of Javanese female farmers' stature is higher than Indian Meghalaya 150.8 cm [11].

Table 1. Body dimensions of male farmers

Body Dimensions	Javanese (n = 80)				Madurese (n = 76)			
	Min	Mean	Max	SD	Min	Mean	Max	SD
Stature	146.3	159.0	174.6	5.0	143.0	156.3	173.8	7.8
Eye height	135.3	148.0	163.6	4.8	133.0	145.2	163.6	7.6
Sitting height	71.4	78.5	90.6	3.7	68.3	77.0	88.4	5.3
Hip breadth	28.7	33.1	43.2	1.9	31.2	34.5	38.2	1.5
Chest (bust) depth	17.3	20.4	28.5	1.5	17.2	19.8	23.7	1.5
Abdominal depth	16.7	19.7	23.4	1.5	16.4	19.5	23.8	1.8
Span	155.6	163.4	176.5	3.1	151.1	162.4	174.7	5.0
Palm length	9.0	10.3	17.9	1.3	9.3	10.0	11.3	0.6
Hand breadth across thumb	8.5	10.0	11.8	0.6	8.4	9.9	12.0	0.8
Grip diameter (inside)	2.4	4.2	5.1	0.4	2.7	4.2	5.3	0.6
Body weight (kg)	40.2	55.7	75.2	6.3	34.9	55.5	70.2	7.5
Age (years)	17.0	39.1	67.0	11.8	16.0	38.7	66.0	11.6
hand squeeze strength (psi)	9.5	15.3	18.3	2.4	7.5	14.7	18.3	2.6
Indices								
RSH	0.48	0.49	0.52	0.01	0.48	0.49	0.51	0.01
BSA (m^2)	1.38	1.57	1.78	0.08	1.19	1.54	1.78	0.13
BMI (kg/m^2)	13.83	22.44	29.49	3.22	16.09	22.88	30.39	3.17

(all body dimensions are in cm, unless specified)

From Tables 1 and Table 2, for the RSH, it appears that Javanese male farmers have minimum, mean and maximum RSH value of 0.48, 0.49, and of 0.52, respectively. Madurese male farmers have minimum, mean, and maximum value of 0.48, 0.49, and 0.51. Javanese female farmers have minimum, mean, and maximum RSH value of 0.49, 0.52, and 0.54. Madurese female farmers have minimum value of 0.49, 0.51, and 0.53.

According to Pheasan and Haslegrave [17] when the RSH value is less than 0.55, the sample is a short-legged, while if more than 0.55, the sample is considered long legged. The Javanese and Madurese farmers are therefore categorized the long legged.

Anthropometric data of stature obtained on Indonesia by Manuba and Nala [6] revealed BSA of 1.5 m^2. While this research provide the BSA mean value to Java, Madura, male and female as 1.57, 1.54, 1.47, and 1.44 m^2, respectively. The minimum value of BSA for male is 1.38, 1.19, and for female is 1.30 and 1.21 m^2, respectively for Javanese and Madurese. The maximum value of BSA for male is 1.78, 1.78, and for female is 1.64 and 1.65 m^2, respectively for Javanese and Madurese. The mean values of BSA and body weight of Javanese, Madurese were equal or greater than Tanzanians, English, Canadians, and Algerians. However, Javanese and Madurese have a smaller BSA and body weight than Sudanese, Algerians, Thai, Nigerians, Indians and Colombians [8].

Table 2. Body dimensions of female farmers

Dimension	Javanese				Madurese			
	Min	Mean	Max	SD	Min	Mean	Max	SD
Stature	137.7	152.5	167.3	5.5	137.4	150.1	167.7	7.1
Eye height	126.5	141.8	155.8	5.8	126.9	139.5	155.6	6.7
Sitting height	68.5	79.0	89.2	4.4	67.2	76.7	89.7	5.7
Hip breadth	30.9	33.6	38.9	1.4	30.1	33.4	38.5	1.5
Chest (bust) depth	19.8	22.8	26.4	1.4	18.5	22.8	27.2	1.8
Abdominal depth	17.5	20.7	22.8	1.1	1.4	20.4	26.2	2.8
Span	140.2	151.5	171.8	6.4	135.1	150.3	170.2	8.4
Palm length	8.5	9.5	11.6	0.6	8.0	9.5	10.2	0.5
hand breadth across thumb	8.1	9.1	10.8	0.6	8.1	9.2	11.0	0.6
Grip diameter (inside)	3.1	4.0	4.8	0.3	2.5	4.0	4.7	0.5
Body weight (kg)	41.3	51.9	64.3	5.7	38.4	51.1	66.9	6.8
Age (years)	18.0	37.0	57.0	9.7	15.0	35.3	59.0	9.8
hand squeeze strength (psi)	6.4	10.7	14.2	1.5	2.4	10.0	13.5	1.9
Indices								
RSH	0.49	0.52	0.54	0.01	0.49	0.51	0.53	0.01
BSA (m^2)	1.30	1.47	1.64	0.09	1.21	1.44	1.65	0.10
BMI (kg/m^2)	16.67	22.38	32.49	2.64	16.09	22.75	32.67	3.22

(all body dimensions are in cm, unless specified)

On the Anthropometric data related to BMI, it appears that the BMI mean values for male was 22.4, 22.88, and for female was 22.38, 22.75 kg/m^2, for the Javanese and Madurese, respectively. The BMI minimum value was 13.83, 16.05, 16.67, and 16.09 kg/m^2, for Javanese, Madurese, male and female farmers, respectively. The BMI maximum value was 29.49, 30.39, 32.43, and 32.67 kg/m^2, for Javanese, Madurese, male and female farmers, respectively. The BMI mean value indicates that Javanese, Madurese male and female farmers are in normal classification, not underweight or overweight [8].

Table 3 provides the ranking of the descriptors based on mean rank of the rating score of hand agricultural tools characteristics that farmers prefer. The farmers were asked using a questioner about their judgments imagining working with agricultural hand tools. Farmers were encouraged to think of farming tools that they want. They were allowed to their imagination, passion and experiences while using farm tools. The mean ranks from 5.92 for safe to 9.79 for no inflamed skin.

Table 3 describes that most farmers prefer safe hand tools, and then followed by good fit in hand, easy to use, reliable, and to no inflamed skin in the last. Preferences in this study were different than Kuijt-Evers et al. [18]. Kuijt-Evers et al. [18] stated that reliable, functional, and good fit in hand were ranked first, second and

third rank in their research. The difference in results of study is because of different population as sample target for hand tools.

Table 3 shows factor loading of description of Principal Component Analysis (PCA) with varimax rotation. The evaluation of comfort/discomfort is mostly based on cognitive judgments'. Mano and Oliver [19] stated that in product satisfaction theories it is assumed that cognitive judgment consists of two major dimensions: utilitarian performance and hedonic performance. Utilitarian performance such as functionally, whereby the product is seen as performing a useful function. Hedonic performances such as posture and muscles, pain in hand/fingers, handle surface, handle characteristics, and aesthetics, whereby products are valued for their intrinsically pleasing properties. The factor 1 contains descriptor as safe, good fit in hand, easy, handle feels comfortable in use are labelled in factor functionality. The factor 2 comprised pleasurable, no blister, light weight material, etc as labelled in hedonic performance [18]. By using the PCA with varimax rotation and 2 major factors, Table 3 shows that farmers prefer utilitarian performance than hedonic performance.

Table 3. Rank of agricultural hand tool descriptors based on mean ranks

	Descriptor	Mean rank	Factor 1	Factor 2
1	Safe	5.92	0.850	0.522
2	Good fit in hand	6.20	0.848	0.524
3	Easy to use	6.24	0.848	0.526
4	Reliable	6.49	0.821	0.564
5	Handle feels comfortable	7.23	0.797	0.597
6	Pleasurable	7.34	0.785	0.611
7	No blister	7.89	0.755	0.649
8	Lightweight material	8.15	0.711	0.690
9	Easy to take along	8.32	0.508	0.859
10	No pain	8.49	0.527	0.844
11	High quality	9.30	0.543	0.832
12	No numbness in fingers	9.43	0.590	0.803
13	No slippery handle	9.54	0.609	0.788
14	Handle shape	9.70	0.638	0.761
15	No inflamed skin	9.79	0.682	0.721

4. Conclusions

Anthropometric data of Javanese farmers are mostly higher than that of Madurese farmers. The results of the RSH showed that Javanese and Madurese male and female are classified to be long-legged. Furthermore, the mean values of body surface area (BSA) and body mass index (BMI) of Javanese farmers are slightly higher than Madurese farmer's values.

Majority farmers like safe hand tools, and then followed by good fit in hand, easy to use, reliable, and to no inflamed skin in the last. As functionality secures first choice by farmers; they prefer tool characteristics such as safe, good fit in hand, easy to use, reliable, and comfortable handle. Agricultural hand tools rank characteristics were analyzed by using PCA with varimax rotation, farmers prefer utilitarian performance than hedonic performance.

Acknowledgements

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