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RESEARCH ARTICLE

ANTHROPOMETRY OF INDONESIAN MALE AND ITS USE FOR THE DESIGN OF TRAIN PASSENGER SEATS

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ABSTRACT

An anthropometric study of male Indonesian who use economy class train in East Java was conducted. Fifty eight body dimensions, age, body weight, and hand squeeze strength for chair design importance were measured for 200 Indonesian males, comprising Javanese (100) and Madurese (100) tribes. The two tribes were compared to identity similarity and contrast existing in their respective body dimensions. Descriptive statistics provided mean, standard deviation, percentile value and coefficient of variance of each population. The survey also revealed that the mean values of Relative Sitting Height (RSH), body surface area (BSA), and hand squeeze strength of Javanese male farmers were higher than the Madurese have. However, their body mass index (BMI) of Javanese ware lower than Madurese BMI. For ergonomically design for train passenger seats are as follows seat height 37.9 cm, seat depth 40.2 cm, seat width per passenger 40.0 cm, height of back rest 86.2 cm, angle of tilt back rest is 105° to 115°, width of backrest is 43.3 cm, height of armrest is 18.2 cm, length arm of armrest is 26.7 cm, footrest width is 4.4 cm, legroom is 54.1 cm.

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INTRODUCTION

Anthropometry is a study of information on body dimensions and weight of the human body, further classified into groups usually based on gender, race, ethnicity and nationality. The anthropometric dimensions of agricultural importanace include stature, sitting height, and those of hand dimensions (Abeysekera and Shahnavas, 1989). The use of anthropometry in the design of machinery and tools improves safety, comfort and health of workers (Pheasant, 1997). Furthermore, studies reveal that consideration of anthropometric data could successfully improve worker performance and productivity (Klamklay *et al*., 2008). Similarly, it is expected that consideration of anthropometric information in design of agricultural tools could also help reducing drudgery in agricultural activities. Detailed surveys contribute to valuable data bank for practical use by designers and researchers. Several of such surveys have been conducted on anthropometry in the developed and developing countries, such as: Ray *et al*. (1995) conducted a survey of Indian school children aged 3-5 years; Jarosz (1999) studied anthropometry of elderly women in Poland; Liu *et al*. (1999) examined the anthropometry of female maquiladora workers; Kothiyal and Tettey (2000) compiled the anthropometric data of elderly people in Australia; Prado-Leon *et al*. (2001) studied Mexican primary school children; Bolstad *et al*. (2001) examined the anthropometry of Norwegian light industry and office workers; Victor *et al*. (2002) surveyed Indian farm workers; Mokdad (2002) examined the anthropometry of Algerian farmers; Wang *et al*. (2002) provided database of anthropometric children and young adults in Taiwan; Barroso *et al*. (2005) studied anthropometry of Portuguese workers; Dewangan *et al*. (2008) studied anthropometry of female farm workers in north-eastern India; Klamklay *et al*. (2008) obtained anthropometric data from Southern Thai population; Hanson *et al*. (2009) reported the Swedish anthropometric data for product and workplace design; Mokdad and Al-Ansari (2009) analyzed the anthropometric data of Bahraini school children; Chuan *et al*. (2010) reported anthropometry of the Singaporean and Indonesian population; and Dewangan *et al*. (2010) collected and analyzed anthropometric data of male agricultural workers in north-eastern India. Indonesian often use trains as one of the means of transport for them. Economy class trains are preferred by Indonesian because of their economical price. As one of the railway manufacturers in Indonesia, PT. INKA (Railway Industry) should have paid attention to ergonomic aspects in designing designs for railway, especially the design of passenger seats. The design of the existing economy-class train passenger seats still has not paid attention to the ergonomic aspect because there are still many complaints from the economy train passengers.

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The existing economic railway seats have a rigid shape that is less supportive of posture when sitting, lacking armrests and the distance between the passengers facing too narrow, only about 10 cm. When using a train for transportation, Indonesian will take a long time to sit in the economy class train so may have more fatigue. To reduce fatigue for Indonesia, ergonomic train passenger seats are required in accordance with the anthropometry of Indonesia in particular and Indonesians in general. In Indonesia, about 90% of agricultural machines, chairs, and equipments are developed and fabricated by local manufacturers itself, whereas, only 10% are imported from Thailand, China, Malaysia and others countries (Ministry of Industry, 2015). These equipment, not specifically designed with ergonomic consideration for Indonesia, may result fatigue, accident or injury. The researcher/designer of machinery refers to anthropometric data to design ergonomic tools to address specific needs of Indonesian. However, a lack of necessary data forces the designers to ignore the parameters associated with its intended operators. This, in turn, is likely to reduce efficiency of operation and cause problems of safety and discomfort of the operator (Gite and Singh, 1997). As a result, need is always there to collect anthropometric data for the target population based on gender, race, ethnic group and nationality in order to bring appropriate changes in equipment or agricultural tools design.

Java is one of the major islands of Indonesia, with the densest population in the country. This island is divided into six provinces, namely, Banten, DKI Jakarta, West Java, Central Java, DI Yogyakarta, and East Java. Javanese and Madurese tribes are represented by around 100 million and 20 million people respectively, in Indonesia. Population of Javanese and Madurese in East Java area is about 30 million and 11.2 million, respectively (Anonymous, 2010). Considering its sizeable population and ethnic diversity, Indonesia currently has limited anthropometric information. Published research on the anthropometry of Indonesian people (Manuba and Nala, 1969; Chuan *et al*., 2010) seems insufficient. Manuba and Nala (1969) provided anthropometric data of 5 farmers, while Chuan el al. (2010) examined university student (245 males and 132 females) in Indonesia by measuring 35 body dimension and body weight. Wibowo *et al*. (2012) studied anthropometry of Javanese and Madurese farmers in Indonesia. Since 1969 there appears lack of sufficient publication on anthropometry of indonesian people in Indonesia. Hence, to meet the design needs of ergonomic machines and tools, access to a comprehensive database was felt necessary.This study, therefore, aims to record anthropometric data of important body dimensions of Javanese and Madurese male who use train as transportation that spread in East Java, Indonesia. The anthropometric data from the research are expected to be used as a reference in design/redesign of train chair in accordance with anthropometry of male Indonesian in East Java.

METHODS

This study focused on Javanese and Madurase male who use train in economy class. Retrieval of data on the body dimensions took about 5 months in year 2017. Measurements followed the procedure that was used by Wibowo *et al*. (2013).

Subjects

A total of 200 male Indonesian participated in this study. The subjects were drawn from Javanese (100) and Madurese (100) ethnic groups who lived in Jember, Banyuwangi, Lumajang, Bondowoso, and Probolinggo East Java region. Population living in East Java ad ethnic representation mainly from Javanese (79%), Madurese (18%), Osing (1%), other (1%) (Anonymous, 2010).

Body dimensions

Information on 39 body dimensions, age, body weight, and hand squeeze strength were collected in this study. Subjects were approached during scholing or when they are at home. Measurements were made while male Indonesian wore T-shirt or naked chest and did not wear footwear. The study also included the calculation of various indices like relative anthropometric sitting height (RSH), body surface area (BSA), and body mass index (BMI). Measurements included in this study were as suggested by Pheasant and Haslegrave (2006).

Equipments Used

The measurements were performed by a team of university students who were thoroughly trained in laboratory, prior to field measurements. The measurements for standing and sitting posture were made using a Martin type anthropometer (Kroemer *et al*., 1986; Shao, 1985). Body weight of subjects was measured with a digital weighing scale. A spreading caliper and a digital caliper was used to measure hand and foot dimensions. A plastic tape was used to measure vertical hand grip when standing. A squeeze dynamometer was used to measure power of hand in squeezing action.

Procedure

The team of researchers was trained for a week on how to recognize the dimensions to be measured, to use measuring instruments and to record data into log sheet. Subjects were chosen randomly, having normal appearance and having no physical disabilities. Before the measurements are made, the subjects were given an explanation about the purpose of the study. Only subjects who gave their consent were considered further. During measurement of body dimensions, the subjects were requested to remove footwear and shirt while measuring their foot, chest and abdominal dimensions. Measurements were taken at the right and left side of the subjects. It took approximately 30-35 minutes per subject to complete the intended measurements.

RESULTS AND DISCUSSION

Anthropometric data of Javanese and Madurese males who use Economy Class Train

Descriptive statistics of anthropometric data of Javanese and Madurese males that lived in East Java is summarized in Tables 1 and 2, respectively. These tables include mean, standard error of mean (SEM), coefficient of variation (CV), standard deviation (SD), and 1^{st}, 5^{th}, 50^{th}, and 99^{th} percentile values of 58 body dimensions, age, body weight and hand squeeze strength. Relative sitting height (RSH), body surface area (BSA), and body mass index (BMI) are also included. The age of subjects was between 17-60 years. Measurements were taken in static position. He stated that all body dimensions should be reduced by about 0.3% of its value, while the elbow height to be increased by 0.5% for this conversion. The value of knee height remains unchanged.

Table 1. Anthropometric data of Javanese male (age 17-60 years, n = 100)

No.	Dimension	Mean	SEM	CV(%)	SD	Percentile				
						1st	5th	50th	95th	99th
1	Stature	159.0	0.51	3.38	4.78	150.0	151.1	159.0	165.0	170.9
2	Eye height	149.0	0.52	3.18	4.87	138.0	140.1	149.0	155.3	160.4
3	Elbow height	100.2	0.31	2.76	3.01	94.0	95.3	100.2	104.0	106.9
4	Fingertip height	56.0	0.35	5.87	3.04	49.1	50.1	55.9	60.8	64.0
5	Knuckle height	66.4	0.37	4.67	4.01	60.0	61.1	66.3	71.1	75.0
6	Wrist height	73.2	0.42	4.87	3.98	67.5	68.3	73.1	79.3	83.8
7	Hip height	82.0	0.51	5.43	3.88	72.3	74.2	81.8	86.4	94.4
8	Shoulder height	131.3	0.52	3.65	5.44	120.0	122.4	131.0	136.1	143.3
9	Vertical grip reach (standing)	192.3	0.72	3.45	6.92	176.3	180.4	192.2	199.9	207.1
10	Elbow span	83.4	0.20	2.65	3.02	77.3	80.2	83.1	85.4	90.2
11	Span	164.2	0.37	1.56	3.44	156.1	158.9	164.2	166.3	172.3
12	Forward grip reach	71.9	0.21	2.31	2.22	66.65	68.3	71.5	73.2	76.1
13	Shoulder-grip length	62.1	0.18	2.32	2.78	58.3	59.4	62.1	63.1	64.9
14	Upper limb length	71.3	0.17	2.08	2.37	67.0	68.0	71.2	72.1	74.8
15	Sitting height	79.3	0.37	4.85	4.66	71.9	73.1	79.2	84.1	87.7
16	Sitting eye height	68.5	0.44	5.37	3.50	61.5	62.0	68.5	73.0	76.0
17	Sitting shoulder height	50.0	0.42	7.43	3.87	43.0	44.4	49.9	55.2	60.0
18	Sitting elbow height	21.6	0.23	9.65	2.02	17.9	18.9	21.4	25.1	26.2
19	Shoulder-elbow length	31.2	0.28	6.23	2.19	25.8	27.1	31.1	33.0	35.0
20	Thigh Thickness	12.8	0.10	6.22	0.87	10.9	11.2	12.4	13.9	15.0
21	Popliteal height	42.1	0.16	2.69	1.28	38.1	39.1	42.0	42.1	42.4
22	Knee height	52.9	0.17	2.38	1.87	49.3	50.1	52.6	54.1	55.9
23	Elbow-fingertip length	41.0	0.22	4.82	2.01	37.1	38.2	40.8	43.3	45.0
24	Head length	20.2	0.09	3.76	0.67	17.0	17.4	20.2	19.7	21.0
25	Head breadth	18.1	0.11	4.37	0.90	14.9	15.1	18.0	18.1	19.0
26	Shoulder breadth (biacromial)	36.1	0.16	4.82	1.70	31.2	32.4	36.0	38.2	38.9
27	Shoulder breadth (bideltoid)	43.8	0.24	5.88	2.67	38.4	40.0	43.3	46.2	52.8
28	Hip breadth	38.2	0.20	5.84	1.68	33.5	35.8	38.3	39.6	40.9
29	Vertical grip reach (sitting)	114.3	0.58	4.69	5.45	102.3	104.1	114.0	122.0	126.9
30	Chest (bust) depth	21.2	0.16	7.33	1.75	17.0	18.3	21.1	22.0	23.9
31	Abdominal depth	20.0	0.16	7.32	1.35	16.4	17.0	19.6	22.3	23.0
32	Buttock-knee length	50.8	0.21	3.84	1.78	47.3	47.9	50.7	53.1	57.0
33	Buttock-popliteal length	45.1	0.19	4.85	1.89	41.1	42.1	44.9	47.4	50.3
34	Palm length	10.8	0.14	12.38	1.45	8.9	9.5	10.6	11.3	17.0
35	Foot length	23.8	0.25	9.67	2.11	18.2	21.8	23.7	26.1	28.1
36	Heel breadth	5.9	0.08	8.05	0.52	4.9	5.0	5.8	6.2	6.8
37	Foot breadth	10.6	0.09	5.44	0.46	9.3	9.2	10.5	11.1	12.0
38	Hand breadth	8.4	0.08	7.21	0.55	6.6	7.1	8.2	9.1	9.4
39	Hand length	18.0	0.07	4.87	0.69	16.1	16.5	18.1	18.9	19.9
40	Body weight (kg)	54.8	0.80	11.20	6.78	40.3	47.3	54.5	65.3	69.1
41	hand squeeze strength (psi)	15.5	0.27	15.23	2.04	9.9	10.1	15.4	17.9	19.3
	Indices									
	RSH	0.50	0.00	1.65	0.01	0.46	0.47	0.50	0.50	0.54
	BSA ($kg.m^2$)	1.58	0.01	5.04	0.08	1.36	1.42	1.57	1.68	1.78
	BMI (kg/m^2)	22.33	0.37	14.08	3.18	15.30	17.77	22.43	27.04	30.05

(all body dimensions are in cm, unless specified)

Forward reach is decreased by 30%, reach is increased around 20% if involving extensive shoulder and trunk. For Javanese subjects (Table 1), the value of CV % is highest for the hand squeeze strength (15.23%) and followed by palm length (12.38%) and body weight (11.20%). For Madurese subjects (Table 2) the value of CV% is also highest for the hand squeeze strength (17.23%) followed by the foot breadth (15.56%), and the body weight (13.89%). The value of CV% can be reduced by increasing the number of samples in the study. Pheasan (1997) considered a subject 'short-legged' if RSH is less or equal than 0.50, or 'long-legged' if more than 0.50. Results show that Javanese and Madurese have RSH value of 0.50 and 0.49 so they are categorized as the 'short-legged'. The BMI were 22.33 m^2 and 22.90 m^2 for the Javanese and Madurese farmers respectively, which indicate that they are neither underweight nor overweight. Frisancho, (1993) suggested that a subject having BMI in the range of 20.0-24.9 can be considered with a normal weight. Ethnic diversity significantly influenced on the differences in anthropometry of Javanese and Madurese populations. The difference between two populations can be fairly described as general access to better nutrition that results in a better body growth (Chuan *et al*., 2010).

Similarly, malnutrition plays a major role in inhibiting the human growth (Wall, 1993). Javanese showed higher hand squeeze strength (15.5 psi) than Madurese (14.9 psi). Mital and Kumar (2000) stated that several factors that affect human strength were age, gender, body dimensions, reach distance, arm, and wrist orientation. Javanese mostly have higher body dimensions than Madurese, that probably makes Javanese slightly stronger than Madurese in hand squeeze.

For ergonomic design of the ergonomic train seats as follows

- Seat Height. Height of chair = height of popliteal of data anthropometry. The data taken from the 5^{th} percentile anthropometric data of popliteal height, which is 39.1 cm for Javanese and 37.9 cm for Madurese. For the design of the chair used size 37.9 cm.
- Depth of seats. Seat depth = Buttock-popliteal length in 5^{th} percentile of anthropometric data i.e. 42.1 cm for Javanese and 40.2 cm for Madurese, excluding the

Table 2. Anthropometric data of Madurese male (age 18-58 years, n = 100)

SN	Dimension	Mean	SEM	CV(%)	SD	Percentile				
						1st	5th	50th	95th	99th
1	Stature	156.4	0.80	4.97	7.67	143.3	144.6	156.1	169.8	171.3
2	Eye height	144.3	0.90	5.13	6.89	133.5	134.1	144.2	158.2	161.2
3	Elbow height	98.3	0.45	4.21	4.26	90.0	92.8	98.2	105.2	105.8
4	Fingertip height	54.0	0.48	8.03	4,54	46.2	47.9	53.9	62.0	64.2
5	Knuckle height	64.0	0.48	6.32	4.34	56.0	58.0	63.6	72.2	73.0
6	Wrist height	71.8	0.60	7.08	5.65	63.4	64.9	71.2	82.2	83.1
7	Hip height	79.1	0.76	8.46	6.43	69.5	70.0	78.3	92.1	93.2
8	Shoulder height	126.5	0.80	5.27	6.98	115.0	117.4	126.4	140.0	143.0
9	Vertical grip reach (standing)	187.0	1.07	5.01	9.67	168.3	171.0	186.9	202.3	205.3
10	Elbow span	83.3	0.35	3.48	3.21	76.2	77.5	83.0	89.0	91.2
11	Span	162.3	0.57	3.02	4.87	150.5	152.3	162.2	170.5	173.5
12	Forward grip reach	71.3	0.30	3.27	2.46	64.9	66.1	71.1	74.2	76.2
13	Shoulder-grip length	61.3	0.28	3.63	2.36	55.5	56.1	61.2	64.2	65.0
14	Upper limb length	70.3	0.30	3.44	2.61	64.0	65.2	70.1	74.1	75.5
15	Sitting height	76.9	0.58	6.22	5.34	68.3	69.7	76.2	86.2	88.2
16	Sitting eye height	65.9	0.57	7.54	5.03	58.1	59.1	65.2	74.9	76.0
17	Sitting shoulder height	48.5	0.58	10.03	4.58	40.2	42.2	42.3	58.3	59.6
18	Sitting elbow height	21.2	0.25	11.63	2.33	15.4	18.2	21.1	24.8	25.7
19	Elbow-shoulder length	29.4	0.37	10.54	3,28	15.0	25.3	28.8	35.2	35.0
20	Thigh thickness	13.0	0.14	7.16	1.02	9.9	10.2	12.9	14.2	14.2
21	Popliteal height	40.4	0.18	4.03	1.65	37.5	37.9	40.2	43.3	44.8
22	Knee height	50.7	0.27	4.54	2,45	46.3	47.1	50.2	53.8	55.2
23	Elbow-fingertip length	40.1	0.33	7.43	3.22	34.6	35.3	39.9	45.1	47.0
24	Head length	19.4	0.08	4.34	0.76	17.0	17.5	19.3	20.1	21.1
25	Head breadth	17.6	0.08	4.05	0.72	15.0	16.0	17.4	18.1	18.7
26	Shoulder breadth (biacromial)	33.8	0.32	8.33	2.34	30.2	31.1	33.7	41.9	42.1
27	Shoulder breadth (bideltoid)	40.7	0.34	7.45	3.18	36.1	38.00	40.3	48.1	49.0
28	Hip breadth	36.8	0.17	4.98	1.45	33.2	35.6	36.8	39.0	40.5
29	Vertical grip reach (sitting)	111.5	0.82	6.72	7.24	98.1	101.2	111.2	122.5	124.9
30	Chest (bust) depth	19.9	0.18	7.34	1.32	17.0	17.3	19.5	22.1	24.1
31	Abdominal depth	19.4	0.22	9.04	1.54	16.1	16.3	19.5	22.0	24.0
32	Buttock knee length	50.3	0.31	5.61	2.98	46.0	46.1	50.0	55.5	57.8
33	Buttock-popliteal length	44.0	0.34	6.75	3.01	40.0	40.2	43.7	49.6	51.0
34	Palm length	10.0	0.09	5.34	0.54	9.1	9.3	9.8	11.0	12.7
35	Foot length	23.4	0.19	7.57	1.67	21.6	22.0	23.4	26.9	29.1
36	Heel breadth	5.6	0.07	10.78	0.88	3.7	4.8	5.6	6.4	6.5
37	Foot breadth	19.4	0.18	15.56	1.58	8.3	8.9	10.2	11.2	14.4
38	Hand breadth	8.4	0.07	8.23	0.67	6.9	7.3	8.2	9.4	10.0
39	Hand length	17.8	0.12	6.55	1.34	15.9	16.1	17.4	19.9	21.2
40	Body weight (kg)	55.8	0.86	13.89	6.88	34.7	40.2	55.6	65.1	68.2
41	hand squeeze strength (psi)	14.9	0.30	17.23	2.38	8.2	10.0	15.1	17.0	19.0
	Indices									
	RSH	0.49	0.00	1.78	0.01	0.45	0.45	0.49	0.49	0.53
	BSA ($kg.m^2$)	1.53	0.02	8.32	0.12	1.20	1.30	1.53	1.72	1.80
	BMI (kg/m^2)	22.90	0.34	13.39	3.08	16.54	17.23	22.85	28.20	30.32

(all body dimensions are in cm, unless specified)

addition of seat depth to support the back rest. For the design of the chair used size 40.2 cm.

- Length of Seats. Seat length = width of anthropometric data of hip of 95th percentile diminished 5 cm (2.5 cm right and 2.5 cm left, respectively). Data of anthropometric for hip width with 95th percentile that is 39.6 cm for Javanese and 39.0 for Madurese. For ergonomic design for seat length is minus 5 cm. So the seat length becomes 34.6 cm for Javanese and 34.0 cm for Madurese. In considering sufficient space to meet consumers' needs for the seating, the designer can round out the 34.6 cm and 34.0 cm long seat to 40.0 cm for the economy-class rail seat length. With design of a seat length of 40.0 cm, it can reach anthropometry of population from the 5th percentile to the 95th percentile.
- Backrest height of seat. The backrest height of seat size that used as the backrest of seat design parameters is the height data of the person at the sitting position in the 95th percentile, which is 84.1 cm for Javanese and 86.2 cm for Madurese. For the design of the chair used size 86.2 cm.
- Seat angle or tilt. A good seat should have good contact with a backrest. The design of a good backrest has a slope of = 105^{o} to 115^{o} in the direction of passengers in the reclining position.
- The width of the chair back. Design of the seat back is determined as the width of the backrest = Shoulder breadth (bideltoid) of anthropometry data at 50th percentile, which is 43.3 cm for Javanese and 40.3 cm for Madurese, respectively. For the design of the chair used size 43.3 cm.
- Armrests Height. Armrest height = elbow height in sitting position. The anthropometric data used is the 5th percentile i.e. 18.9 cm for Javanese and 18.2 cm for Madurese. For the design of the chair used size 18.2 cm.
- Armrest Length. Based on Scott and Erin (2006) armrest length is 26.7 cm (10.5 inches).
- Footrest width. Foothold width = 0.2 times of foot length. The anthropometry data of foot length in the 5th percentile that is 21.8 cm for Javanese and 22.0 cm for Madurese. From the calculation, obtained the width of the footrest is 4.4 cm for both.

- Legroom. According to Panero and Zelnik (1979), ideal lateral legroom measures approximately 45.0 cm in order for the legs of the average person to get enough space for movement. Vertical legroom is used according to the height of the 95th percentile of anthropometry data of knee, which are 54.1 cm for Javanese and 53.8 cm for Madurese. For the design of the chair used size 54.1 cm.

Conclusion

This research successfully collected anthropometric data of Javanese and Madurese males who use economy class train of East Java, Indonesia, through field study. Anthropometric data of Javanese males were mostly higher than the data of Madurese males. Furthermore, the mean values of body surface area (BSA), body mass index (BMI), and hand squeeze strength of Javanese maless are slightly higher than Madurese males; and for relative sitting height (RSH) they exhibit similar values. For ergonomically design for seat is seat height 37.9 cm, seat depth 40.2 cm, seat width per passenger 40.0 cm, height of back rest 86.2 cm, angle of tilt back rest is 105° to 115°, width of backrest is 43.3 cm, height of armrest is 18.2 cm, length arm of armrest is 26.7 cm, footrest width is 4.4 cm, legroom is 54.1 cm.

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