Anthropometric measurements among four Asian countries in designing sitting and standing workstations

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Abstract. An anthropometric database for sitting and standing dimensions for Malaysian operators was developed based on the measurements from 146 male and 168 female participants (18–45 years old). The anthropometric data were subsequently compared to those from three selected Asian countries, focussing on the sitting and standing posture dimensions. Thirty-six anthropometric dimensions were selected for comparison based on common availability among the four countries. The results indicated that the Indonesians were the tallest (male: 172 cm, female: 159 cm) among the four countries, whereas the Filipinos were the shortest for both male and female (male: 167 cm, female: 153.9 cm). Filipinos and Malaysian data were almost similar and appear to have the smallest values for eye height (male: 155 cm, female: 143 cm) and elbow height (male: 104 cm, female: 96 cm). The knowledge of variations in the population is useful in designing sound workstations and facilities for the betterment of the industrial environment.

Keywords. Anthropometric; Asian; design; sitting; standing; workstation.

1. Introduction

Anthropometry is the science dealing with the physical measurements of the human individual, such as the person's size, form and functional capacities. Numerous efforts have been made to establish anthropometric database of various population groups, such as students, civilian, workers and military recruits [1–5]. These anthropometric data are utilised by the manufacturing community as a guideline in designing products for the global market [6–8]. Availability of country-specific anthropometric database allows the product to be designed ergonomically to fit the population of specific countries. Variability in human features relates to ethnicity, gender and age [9]. Ethnic diversity, which is more prominent among races rather than nations, is an important factor that influences anthropometric data. Furthermore, the same race coming from different nations may exhibit dissimilarity in body sizes due to variations in social and economic environments. It was suggested by Pheasant [10] that the variations in body dimensions of population groups can be highlighted in terms of the overall body size and bodily proportions. There are several distinctive anthropometric

dimensions that are noticeable when comparisons between ethnic and race groups are made, such as the mean stature and sitting height [11].

The Southeast Asian countries have strong relations and associations in terms of race, culture and history. In particular, the populations of Malaysia, Indonesia, Philippines and Thailand are geographically related based on their locations. Currently, no studies have been conducted to evaluate the differences in the anthropometric data of the countries in this region. Thus, this study aims to test a hypothesis that there are significant differences of body dimensions of Malaysian male and female. Secondly, this study aims to compare the differences in anthropometric dimensions of four Asian countries, namely Malaysia, Indonesia, Philippine and Thailand. This study will also highlight the variations in population dimensions required in the design of a sitting and a standing industrial workstation.

2. Methods

2.1 Malaysian anthropometric database

Ethical approval for the study was provided by the Medical Ethics Committee, University Malaya Medical Centre. In

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all, 146 male and 168 female healthy Malaysian subjects (aged 18–45 years) were selected to participate in this anthropometric study. The sample population was general, which consisted of students and workers of offices and factories. The sample size was estimated based on a study by Nurul Shahida *et al* [12] and Hu *et al* [13]. The number of subjects was estimated according to the equation given in Annex A of ISO 15535:2003 ‘General requirements for establishing anthropometric databases’ based on a 95% confidence interval and 5th and 95th percentiles:

$$n \geq (3.006 \times CV/\alpha)^2$$

where n is the sample size, CV is the coefficient of variation and α is the percentage of relative accuracy desired. The sample size was calculated based on the assumption that a relative accuracy of 10% is sufficient for the 5th and 95th percentiles and an empirical CV value of 25. It was discovered that the minimum sample size for this study is 112

(56 subjects for each gender). Thus the number of subjects for this study, with the total number of 314 subjects, is sufficient.

The participants provided their written consent to participate in this study. Anthropometric measurements were taken based on Pheasant’s [10] protocol using a standard professional anthropometry measuring set, a weighing scale, a measuring chair, a scientific Martin pelvimeter and a TTM bone caliper (TTM Martin’s human body measuring kit; Mentone Educational Centre, Australia). These instruments were used to measure body segment lengths, heights, breadths, depths, circumferences and body weights. Anthropometric dimensions calculated from the recorded data include stature, sitting height, hand length and head circumference. The recorded data are subsequently filtered for extreme outliers, which were probably due to erroneous measurements and recordings. A statistical package (SPSS for windows, Version 23.0) was used to analyse the results.

Table 1. Anthropometric data for Malaysian males (all dimensions in cm, body weight in kg).

No.	Anthropometric measurement	Mean	SD	1%tile	5%tile	50%tile	95%tile	99%tile
1	Weight	68.4	13.4	44.0	53.0	66.0	94.8	104.5
2	Stature	168.1	12.9	143.0	158.3	168.5	179.3	181.5
3	Standing eye height	155.5	14.1	116.3	146.9	156.1	167.9	171.6
4	Standing shoulder height	138.5	11.5	107.2	130.5	139.0	150.5	152.8
5	Standing elbow height	103.7	9.4	81.0	96.1	103.7	112.6	132.4
6	Waist height	99.1	9.7	68.2	91.6	99.8	109.1	111.0
7	Crotch height	78.8	6.7	60.9	70.1	79.0	88.1	93.3
8	Kneecap height	47.0	3.5	40.4	41.9	46.8	52.3	55.4
9	Coat height, standing	68.8	9.5	49.8	56.0	68.0	81.8	85.4
10	Span	169.9	15.5	117.4	158.4	170.5	184.2	189.8
11	Elbow span	85.9	9.3	66.7	75.6	86.5	96.3	105.9
12	Hip breadth, standing	37.2	38.1	25.8	28.8	32.5	37.5	150.8
13	Interscye breadth	30.8	3.3	24.2	25.8	30.5	36.1	38.1
14	Back waist length	46.6	4.7	36.6	38.2	46.5	54.7	59.3
15	Sleeve inseam	45.9	8.2	35.6	37.5	44.4	65.7	72.6
16	Shoulder breadth	40.0	5.0	29.5	31.4	41.0	47.1	49.5
17	Hip breadth, sitting	34.3	3.9	24.5	29.1	34.1	40.8	45.3
18	Forearm–hand length	39.5	9.5	23.1	24.0	44.4	49.0	50.6
19	Buttock–knee length	54.4	3.6	46.0	48.2	54.4	59.7	61.7
20	Buttock–popliteal length	43.0	3.8	34.0	36.5	43.3	49.1	50.3
21	Shoulder–elbow length	34.9	3.2	28.4	30.3	34.8	38.7	42.4
22	Thigh clearance	13.1	2.1	8.3	10.5	12.8	16.5	18.0
23	Arm reach forwards	80.9	8.5	68.7	70.4	81.0	93.4	104.7
24	Arm reach upwards	149.6	180.9	115.8	120.4	128.0	139.0	583.0
25	Sitting height	87.7	4.5	76.6	80.8	87.4	95.2	97.4
26	Sitting eye height	76.3	4.3	63.8	69.9	76.0	83.5	86.7
27	Sitting shoulder height	59.3	3.8	51.6	53.8	59.1	66.1	68.3
28	Sitting elbow height	23.1	3.7	15.5	17.4	23.1	29.9	30.4
29	Knee height	50.4	4.9	42.6	44.6	50.7	56.6	59.2
30	Popliteal height	42.4	4.4	34.9	37.9	42.8	46.8	49.7
31	Head length	19.1	3.9	15.9	16.3	18.1	25.7	33.2
32	Head breadth	15.2	1.0	12.7	13.8	15.4	16.8	17.1
33	Hand length	18.3	1.1	15.7	16.5	18.2	19.9	20.5
34	Hand breadth	8.1	0.8	6.6	7.0	8.1	9.6	10.4
35	Foot length	24.7	1.3	21.9	22.8	24.7	26.7	27.5
36	Foot breadth	9.6	0.7	7.9	8.4	9.6	10.6	11.3

Table 2. Anthropometric data for Malaysian females (all dimensions in cm, body weight in kg).

No.	Anthropometric measurement	Mean	SD	1%tile	5%tile	50%tile	95%tile	99%tile
1	Weight	58.7	14.1	40.0	42.7	55.8	81.0	103.1
2	Stature	155.7	6.2	143.9	146.4	155.1	165.5	170.4
3	Standing eye height	143.1	6.3	130.5	133.4	142.7	153.4	157.0
4	Standing shoulder height	127.6	6.5	112.8	118.2	127.2	137.8	140.1
5	Standing elbow height	96.2	4.6	86.4	89.4	96.3	103.8	106.5
6	Waist height	93.1	4.5	83.3	86.6	93.1	101.0	102.8
7	Crotch height	74.7	11.6	59.4	62.5	70.0	96.1	100.4
8	Kneecap height	42.7	3.3	33.3	37.6	42.3	47.6	49.3
9	Coat height, standing	64.1	18.8	56.0	56.2	60.7	68.4	135.8
10	Span	155.0	9.1	134.5	143.2	155.9	165.6	171.9
11	Elbow span	79.5	8.4	56.7	71.6	79.5	88.1	90.2
12	Hip breadth, standing	32.8	3.7	27.1	28.0	32.0	37.9	46.0
13	Interscye breadth	28.7	3.7	21.8	23.2	28.7	35.4	39.5
14	Back waist length	40.2	4.3	30.1	33.2	40.0	48.4	50.0
15	Sleeve inseam	43.4	4.9	34.0	36.1	43.3	51.6	53.4
16	Shoulder breadth	37.9	3.6	26.3	33.9	37.6	42.4	48.7
17	Hip breadth, sitting	35.3	4.1	28.1	30.0	34.6	42.0	49.9
18	Forearm–hand length	39.8	6.5	22.1	24.9	41.2	45.3	47.5
19	Buttock–knee length	52.5	4.7	33.2	47.0	53.0	58.5	60.3
20	Buttock–popliteal length	43.1	3.8	33.3	37.1	43.0	49.2	52.0
21	Shoulder–elbow length	32.2	3.1	26.1	28.5	32.1	35.1	42.6
22	Thigh clearance	13.4	2.5	8.9	10.2	13.0	18.9	19.4
23	Arm reach forwards	74.2	7.0	63.6	67.3	73.8	81.5	88.3
24	Arm reach upwards	117.9	8.0	101.8	105.1	118.8	128.6	129.8
25	Sitting height	81.5	4.5	73.0	75.9	81.5	87.5	89.9
26	Sitting eye height	70.9	5.1	63.4	64.6	70.7	77.9	80.7
27	Sitting shoulder height	54.5	4.7	42.4	49.0	54.4	60.5	64.8
28	Sitting elbow height	23.1	3.2	17.7	19.0	22.9	29.0	30.6
29	Knee height	47.5	3.7	36.1	41.8	48.0	52.7	55.5
30	Popliteal height	40.0	3.4	29.3	34.0	40.2	44.3	47.3
31	Head length	17.7	0.9	16.1	16.6	17.6	19.4	20.1
32	Head breadth	15.0	1.0	13.3	13.5	15.0	16.4	17.7
33	Hand length	17.0	0.8	15.2	15.9	17.0	18.2	19.0
34	Hand breadth	7.2	0.5	6.3	6.4	7.1	8.0	8.5
35	Foot length	22.7	1.2	20.4	20.9	22.5	25.0	25.5
36	Foot breadth	8.9	1.0	7.4	8.0	8.8	10.0	12.7

Thirty-six anthropometric dimensions (tables 1 and 2) were considered in the analysis. Comparison between male and female dimensions was analysed using *t*-test (table 3).

2.2 Comparison of mean values for selected Asian countries

The anthropometric databases for four Asian countries were chosen for comparison, which include previously published data for populations of Indonesia, Philippine and Thailand. The Indonesian anthropometric database was published by Chuan *et al* [14]. This database listed — 37 anthropometric dimensions obtained from 245 male and 132 female subjects from Indonesia within the age range of 18–45 years. The Filipinos anthropometric database includes

measurements for standing, sitting, hand and foot dimensions, breadth and circumference of various body parts obtained from 1805 workers, with a majority (77%) being below 30 years [15]. However, they are relatively shorter and smaller in stature compared with the general population of Filipinos. The anthropometric data for Thailand were adopted from the database published by a research working group involving 41 dimensions from 200 male and 200 female participants [16].

In this research, — 36 parameters are selected for comparison, chosen based on their common availability among the four population groups. Table 4 shows a comparison of the mean values for selected parameters of the population groups. It can be seen that there are differences in the mean values, indicating variations in the anthropometric dimensions between populations. This difference shows the

Table 3. Analysis of *t*-test for Malaysian male and female.

Anthropometric measurement	<i>t</i> -ratio	<i>p</i> -value
Weight	6.219	0.000*
Stature	0.453	0.651
Standing eye height	0.640	0.522
Standing shoulder height	7.809	0.000*
Standing elbow height	6.566	0.000*
Waist height	5.293	0.000*
Crotch height	2.415	0.017*
Kneecap height	8.347	0.000*
Coat height, standing	0.788	0.435
Span	9.793	0.000*
Elbow span	6.012	0.000*
Hip breadth, standing	1.144	0.254
Interscye breadth	4.884	0.000*
Back waist length	9.792	0.000*
Sleeve inseam	2.461	0.015*
Shoulder breadth	4.209	0.000*
Hip breadth, sitting	− 2.133	0.034*
Forearm–hand length	− 0.415	0.678
Buttock–knee length	3.920	0.000*
Buttock–popliteal length	− 0.163	0.871
Shoulder–elbow length	7.260	0.000*
Thigh clearance	− 0.889	0.375
Arm reach forwards	7.560	0.000*
Arm reach upwards	1.742	0.083
Sitting height	11.981	0.000*
Sitting eye height	10.018	0.000*
Sitting shoulder height	9.703	0.000*
Sitting elbow height	0.076	0.940
Knee height	5.980	0.000*
Popliteal height	5.265	0.000*
Head length	3.409	0.001*
Head breadth	1.905	0.059
Hand length	8.674	0.000*
Hand breadth	9.764	0.000*
Foot length	10.342	0.000*
Foot breadth	5.214	0.000*

*Significant at $p < 0.05$.

necessity for customised product design and workspaces, even for regional market and populations.

3. Anthropometric data for sitting and standing industrial workstations

The industrial workstation is a predominant component in the industrial workplace. Poorly designed workstations contribute to various complications such as visual problems, muscle aches and pains, repetitive trauma injuries such as carpal tunnel syndrome and job stresses [17]. Proper design of the workstation ensures comfort and suitability to the workers. Ergonomic principles and anthropometric database should be used in the design

process in order to fit the human to the machines and conditions [18].

Deros *et al* [17, 19] and Harry [20] described several major anthropometric dimensions critical in designing an industrial table top workstation for sitting and standing tasks. These dimensions are stature, eye height, elbow height, sitting height and sitting shoulder height. For this study, additional dimensions were also considered to highlight the differences in the anthropometric database among the population groups. In total, 10 dimensions were chosen to describe the standing and sitting postures. Figures 1 and 2 show segments proportions for 5th, 50th and 95th percentile of four countries male and female adults in standing posture. There are five selected body dimensions in the standing posture, which are stature, eye height, shoulder height, elbow height with flexed arm and knee height. Similarly, figures 3 and 4 show five body dimensions in the sitting posture, which are sitting height, sitting eye height, sitting elbow height, sitting knee height and sitting buttock to popliteal length.

4. Discussion

4.1 Standing and sitting anthropometry dimension implication to the Malaysian workstation design

Based on the *t*-test result, there were statistically significant differences in most of the mean dimensions between Malaysian male and female (table 3). There are some dimensions where there is no significant difference such as stature, standing eye height, standing coat height, standing hip breadth, forearm–hand length, buttock–popliteal length, thigh clearance, arm reach upwards, sitting elbow height and head breadth. The result from this study can be considered in designing a proper standing and a sitting workstation that suits the male and female workers. For example, for standing workstations, the table height should be adjustable in the range of 89.4 cm (5th percentile female standing elbow height) to 112.6 cm (95th percentile male standing elbow height) while the monitor height should be adjustable in the range of 133.4 cm (5th percentile female standing eye height) to 167.9 cm (95th percentile male standing eye height). Meanwhile the dimension of seat length can be the same for both female and male as there is no statistically significant difference in buttock–popliteal length between the male and female.

In the manufacturing line, workers usually remain seated for a long time. Long time spent sitting in bad posture puts an extreme physiological strain on the muscles, the ligaments and in particular on the discs and other health consequences such as cardiovascular disease mortality [21, 22]. A proper sitting workstation will help reduce the risks related to poor ergonomics design such as musculoskeletal stress disorders (MSDs), which result in eye, neck and back strain, fatigue, headache, wrist, hand, elbow and shoulder

Table 4. The mean anthropometric data for four Asian countries (all dimensions in cm, body weight in kg).

No.	Anthropometric measurement	Malaysian		Indonesian ^a		Filipinos ^b		Thai people ^c	
		Male	Female	Male	Female	Male	Female	Male	Female
1	Weight	68.4	58.7	NA	NA	NA	NA	65.4	51.4
2	Stature	168.1	155.7	172.0	159.0	167.0	153.9	168.6	157.5
3	Standing eye height	155.5	143.1	160.0	148.0	155.0	143.1	156.4	145.8
4	Standing shoulder height	138.5	127.6	143.0	132.0	137.5	127.2	139.6	131.1
5	Standing elbow height	103.7	96.2	107.0	100.0	104.1	96.3	107.0	98.3
6	Waist height	99.1	93.1	NA	NA	97.3	95.5	NA	NA
7	Crotch height	78.8	74.7	NA	NA	NA	NA	NA	NA
8	Kneecap height	47.0	42.7	NA	NA	49.7	45.9	NA	NA
9	Coat height, standing	68.8	64.1	NA	NA	NA	NA	NA	NA
10	Span	169.9	155.0	172.0	157.0	167.9	153.2	174.8	167.6
11	Elbow span	85.9	79.5	87.0	79.0	NA	NA	94.3	88.7
12	Hip breadth, standing	37.2	32.8	NA	NA	43.5	43.4	NA	NA
13	Interscye breadth	30.8	28.7	NA	NA	36.4	32.6	NA	NA
14	Back waist length	46.6	40.2	NA	NA	NA	NA	NA	NA
15	Sleeve inseam	45.9	43.4	NA	NA	NA	NA	NA	NA
16	Shoulder breadth	40.0	37.9	45.0	45.0	44.7	40.2	44.4	39.2
17	Hip breadth, sitting	34.3	35.3	36.0	36.0	48.5	47.7	33.7	35.0
18	Forearm–hand length	39.5	39.8	48.0	43.0	44.1	40.5	46.3	42.8
19	Buttock–knee length	54.4	52.5	56.0	53.0	54.8	52.7	56.1	54.9
20	Buttock–popliteal length	43.0	43.1	46.0	43.0	46.4	45.1	48.1	44.3
21	Shoulder–elbow length	34.9	32.2	NA	NA	33.1	31.4	37.1	32.7
22	Thigh clearance	13.1	13.4	16.0	15.0	13.5	12.8	16.4	15.1
23	Arm reach forwards	80.9	74.2	NA	NA	76.6	69.6	NA	NA
24	Arm reach upwards	149.6	117.9	NA	NA	127.9	116.9	NA	NA
25	Sitting height	87.7	81.5	88.0	83.0	84.8	79.9	88.9	84.7
26	Sitting eye height	76.3	70.9	76.0	73.0	73.4	68.4	76.2	73.9
27	Sitting shoulder height	59.3	54.5	59.0	57.0	NA	NA	59.1	55.8
28	Sitting elbow height	23.1	23.1	25.0	25.0	22.2	21.9	23.4	21.7
29	Knee height	50.4	47.5	54.0	51.0	50.0	47.0	47.5	45.4
30	Popliteal height	42.4	40.0	44.0	44.0	43.3	40.3	39.2	37.0
31	Head length	19.1	17.7	20.0	19.0	20.5	19.2	19.7	17.3
32	Head breadth	15.2	15.0	19.0	17.0	17.2	16.5	17.4	14.8
33	Hand length	18.3	17.0	19.0	18.0	19.8	18.0	18.4	17.3
34	Hand breadth	8.1	7.2	9.0	8.0	9.8	9.2	NA	7.8
35	Foot length	24.7	22.7	25.0	23.0	25.4	22.6	NA	22.6
36	Foot breadth	9.6	8.9	10.0	9.0	10.5	9.5	NA	9.4

^aFor mean value of Indonesian, the data of 245 male and 132 female were obtained from Chuan *et al* [14].

^bThe Filipinos anthropometric database of 1805 workers was obtained from Lu [15]. For Philippines, the 1805 subjects were manufacturing workers in the assembly line, and not the general Filipino population.

^cThe anthropometric data of 400 participants for Thai people were adopted from Yodpijit *et al* [16].

diseases and carpal tunnel syndrome [23, 24]. This study presents the recommended dimensions for the sitting workstation design. For sitting height, the seat should be adjustable in the range of 34.0 cm (5th percentile female popliteal height) to 46.8 cm (95th percentile male popliteal height). Meanwhile, for designing the sitting working table, the recommended table height should be adjustable in the range of 19.0 cm (5th percentile female sitting elbow height) to 29.9 cm (95th percentile male sitting elbow height) and for monitor height, the height should be

adjustable in the range of 64.6 cm (5th percentile female sitting eye height) to 83.5 cm (95th percentile male sitting eye height).

As a result of rapid increase of world population, the demand for better and more efficient products is growing. Ergonomic workstations are important not only for workers but also for the students and elderly people as the design would help increase comfort, work productivity and performance. Dawal *et al* [2] highlighted the importance of anthropometric database of high school and university

Figure 1. The illustration of segment proportions for Asian male adults in standing posture (all dimensions in cm).

Figure 2. The illustration of segment proportions for Asian female adults in standing posture (all dimensions in cm).

students from Malaysia. There were significant differences in anthropometric data between genders for both high school and university students. Musculoskeletal pain can

occur if these differences are not considered for workstation designs and selections. Meanwhile, Davari [25] presented a design of home office computer workstation set-up to

Figure 3. The illustration of segment proportions for Asian male adults in sitting posture (all dimensions in cm).

Figure 4. The illustration of segment proportions for Asian female adults in sitting posture (all dimensions in cm).

reduce perceived musculoskeletal discomfort. The necessities to be considered in anthropometric data of the design were highlighted to prevent strain injuries, which can lead to long-term disabilities. On the other hand, designing furniture for elderly is undoubtedly important for their survival to live independently in this challenging world [6]. Elderly anthropometric databases assist the designing process in creating a safe and healthy environment for the elderly. Due to economic status and also categories under developing countries, Southeast Asian countries undoubtedly are the centre of attractions for migration purposes. Therefore, the knowledge of variations in the population is useful in designing sound workstations and facilities for the

betterment of the environment, especially industrial environment.

4.2 Comparison of anthropometric data of selected Asian countries

Anthropometric data from populations of four countries were summarised and compared. In general, it can be seen that the Indonesians were the tallest (172 cm for male, 159 cm for female) among the four countries, whereas the Filipinos were the shortest for both male and female (167 cm for male, 153.9 cm for female). Indonesians were

also higher than other populations in several standing body heights, including eye height, shoulder height and elbow height. Filipinos and Malaysia data were almost similar and appear to have the smallest values for eye height (155 cm for male, 143 cm for female) and elbow height (104 cm for male, 96 cm for female).

The Thai people have the greatest sitting height and sitting eye height for both male and female while Filipinos have the lowest value (sitting height: 84.8 cm for male, 79.9 cm for female, sitting eye height: 73.4 cm for male, 68.4 cm for female). Accordingly, Malaysian females also appear to have similar low sitting height as Filipinos females. The smallest value for upper limb was for Filipinos male, which is 22.2 cm, and the Thai female, which is 21.7 cm. The Indonesians have the highest value for knee height (54 cm for male, 51 cm for female) and popliteal height (44 cm for both male and female). The Indonesian male knee height was the highest, while in contrast, Thai male and female have the smallest mean value for knee height (47.5 cm for male, 45.4 cm for female).

The selected dimensions illustrated in the figures 1, 2, 3 and 4 are the important reference dimensions for the workstation design that is safe and comfortable. The illustrations compare between male and female of each country. It can be seen that Indonesians and Filipinos have a large difference between the male and female mean stature dimension, which is 13 cm. Standing eye height is also difference between male and female by about 12 cm. Meanwhile, for sitting dimensions illustrated, it can be seen from the figure that there is a difference between Indonesian male and female sitting height, which is about 5 cm. Only small differences are found between the eye height of male and female from each country, such as 2.3 cm for Thai people and 5 cm for Malaysian. Based on these findings, it is important to design the standing and sitting workstation (table, chair, working entrance, machine interface, etc.) that fits both male and female body dimension to ensure workers' health and safety, while simultaneously improving their work performance and productivity [19].

4.3 Recommended chair and desk dimensions for Asian countries

With reference to the data in table 4, the mean values of the selected Asian countries were used to develop recommendations and suggestions for designing chair and desk. Figure 5 presents the recommended dimensions for the selected Asian countries. The calculations of the chair's back rest height, seat height, seat width, seat depth and desk height recommended dimensions were based on the equation by Gouvali and Boudolos [26]. The equations are as follows:

$$\text{backrest height (B): } 0.6S \leq B \leq 0.8S$$

$$\text{seat height (SH): } (P + 2)\cos 30^\circ \leq SH \leq (P + 2)\cos 5^\circ$$

Figure 5. Recommended chair and desk dimensions for Asian countries.

$$\text{seat width (SW): } 1.1H \leq SW \leq 1.30H$$

$$\text{seat depth (SD): } 0.80 PB \leq SD \leq 0.99 PB$$

$$\text{desk height (D): } E + [(P + 2)\cos 30^\circ] \leq D \leq [(P + 2)\cos 5^\circ] + (0.8517E) + (0.1483S)$$

where S is shoulder height, P is popliteal height, PB is popliteal–buttock length, H is hip breadth and E is elbow height.

The mean value of Malaysian female and male shoulder height was, respectively, the minimum and the maximum value among the four countries and was used in the calculation for the back rest height dimension. The height should be adjustable from 32.7 to 47.4 cm. The adjustable seat height of the chair should be from 33.8 to 45.8 cm. These data were taken from mean of Thai female citizen popliteal height and Indonesian male citizen popliteal height. This will allow the users to place their feet properly on the floor or on a footrest because hanging legs put extra loads on lower back muscles [17]. The seat width was designed to be adjustable from 37.1 to 63.1 cm from mean value of hip breadth of Thai male and Filipinos male. Meanwhile, seat depth was 34.4–47.6 cm from mean value of buttock–popliteal length of Malaysian and Thai male. The armrest of chairs was designed parallel to the floor and adjustable from 21.7 to 25.0 cm; these ranges were taken from the mean value of Thai female (minimum) and Indonesian male (maximum). On the other hand, the desk height is adjustable (55.5–75.9 cm) based on calculation of the minimum and maximum mean value related to sitting elbow and shoulder height and popliteal height among the four countries populations.

5. Conclusion

This study was motivated on the need to improve the ergonomics of the industrial environment, particularly in developing countries, where manual operators are

intensively used. In this study, the anthropometric dimensions for sitting and standing postures for the Malaysian population were identified and developed, and subsequently compared to three Asian counterparts. The results have highlighted several differences in body dimensions. The anthropometric database can be used to design sound industrial workstations and facilities ergonomically. Furthermore, knowing the variations in the anthropometric dimensions enables the designers to anticipate required modifications to their design to cater for other population groups.

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