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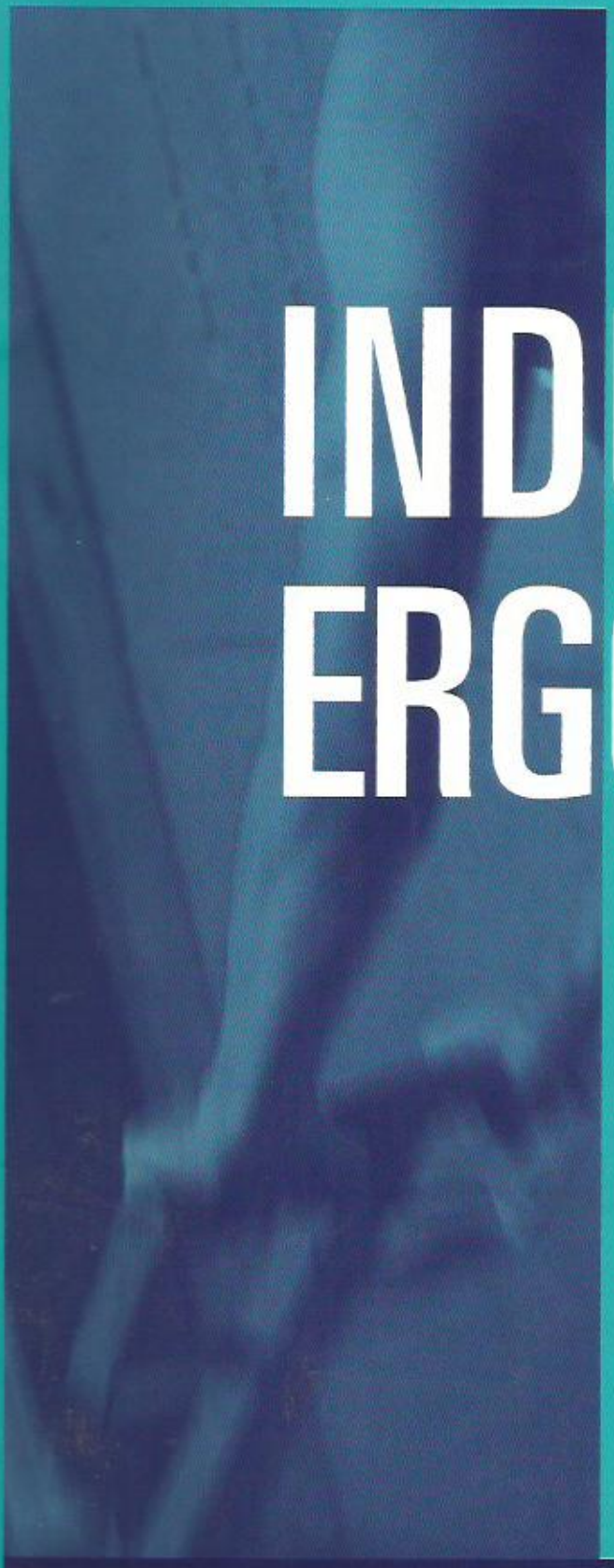

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Anthropometry of the Singaporean and Indonesian populations

Tan Kay Chuan*, Markus Hartono, Naresh Kumar

Department of Industrial and Systems Engineering, National University of Singapore, Singapore

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ABSTRACT

This research collected anthropometric data of the Singaporean and Indonesian populations. The data were mainly from university students. In total, 245 male and 132 female subjects from Indonesia and 206 male and 109 female subjects from Singapore were measured. The Singapore data were divided into three sub-groups, comprising Singapore overall, Singapore citizens, and the Chinese ethnic sub-group. The Indonesians data were divided into two sub-groups, comprising Indonesia citizens and Indonesia Chinese. This study used 36 measurement dimensions. The authors made a comparison with previous anthropometric data collected in 1990 of over a thousand Singaporeans.

The main contributions of this study are: i) an updated anthropometric database of Singaporeans and Indonesians, ii) a comparison of the two samples obtained, and iii) a projection of dimensional changes over time from comparing past to more recent anthropometric data. Statistical analyses show that Singaporeans (both male and female) tend to have larger dimensions than Indonesians in general. In addition, the data reveal the current sample to be significantly larger on more than 50 percent of the dimensions measured, for both males and females.

In providing instances of possible application, the Body Mass Index (BMI) of all sub-groups was calculated. The results show both samples to have normal indexes with BMIs in the range of 18.5–25.0. This paper presents also an empirical estimation of unknown anthropometric characteristics using the Ratio Scaling Method. The purpose is to estimate uncollected anthropometric data based on a given scaling dimension. Overall, the reported anthropometric data and analyses can be used as relevant consideration in product and systems design.

Relevance to industry: The findings of this study indicate differences between Singaporean and Indonesian anthropometry in the citizen and Chinese sub-groups. The utilization of an updated anthropometric database that incorporates geographical origin and ethnic group is useful. Product designers would be able to cater to a wider range of target users.

1. Introduction

Products can be deemed successful only when people are able to use them well. This is in accordance with the fundamental principle of ergonomics which is to fit the task to the human (Kroemer and Grandjean, 1997). In doing so, a high level of safety and worker efficiency can be achieved. This means of user-centered design involves the product, the user, and the task. However, variation in body dimension among people, between the sexes, and among different races, can make product design problematic. While it is impossible to design systems to suit all body types and sizes, it is prudent to deal at least with the important dimensions. Thus, anthropometry should be taken into account. Anthropometric data are useful in achieving effective design for high performance and productivity (Klamklay et al., 2008). Nowadays, the collection of anthropometric had been conducted through a sophisticated technology (i.e. three-dimensional measurement) which even proposing an error detection procedure (Park et al., 2009). A lack of anthropometric consideration in equipment design may lead to work-related injuries such as musculoskeletal disorder.

There exists anthropometry data of several Asia Pacific populations. Examples include the hand anthropometry of Jordanian (Mandahawi et al., 2008), static anthropometry of Tehran University students (Mououdi, 1997), anthropometry of the elderly in Australia (Kothiyal and Tettey, 2000), anthropometry of Taiwanese women (Huang and You, 1994), anthropometry of Portuguese workers (Barroso et al., 2005), anthropometry of Turkish woman (Gonen et al., 1991), anthropometry of the Turkish population (İşeri and Arslan, 2009), anthropometry of the Thai population (Klamklay et al., 2008), anthropometry of

* Corresponding author. Tel.: +65 6516 3128; fax: +65 777 1434.
E-mail address: isetankc@nus.edu.sg (T.K. Chuan).

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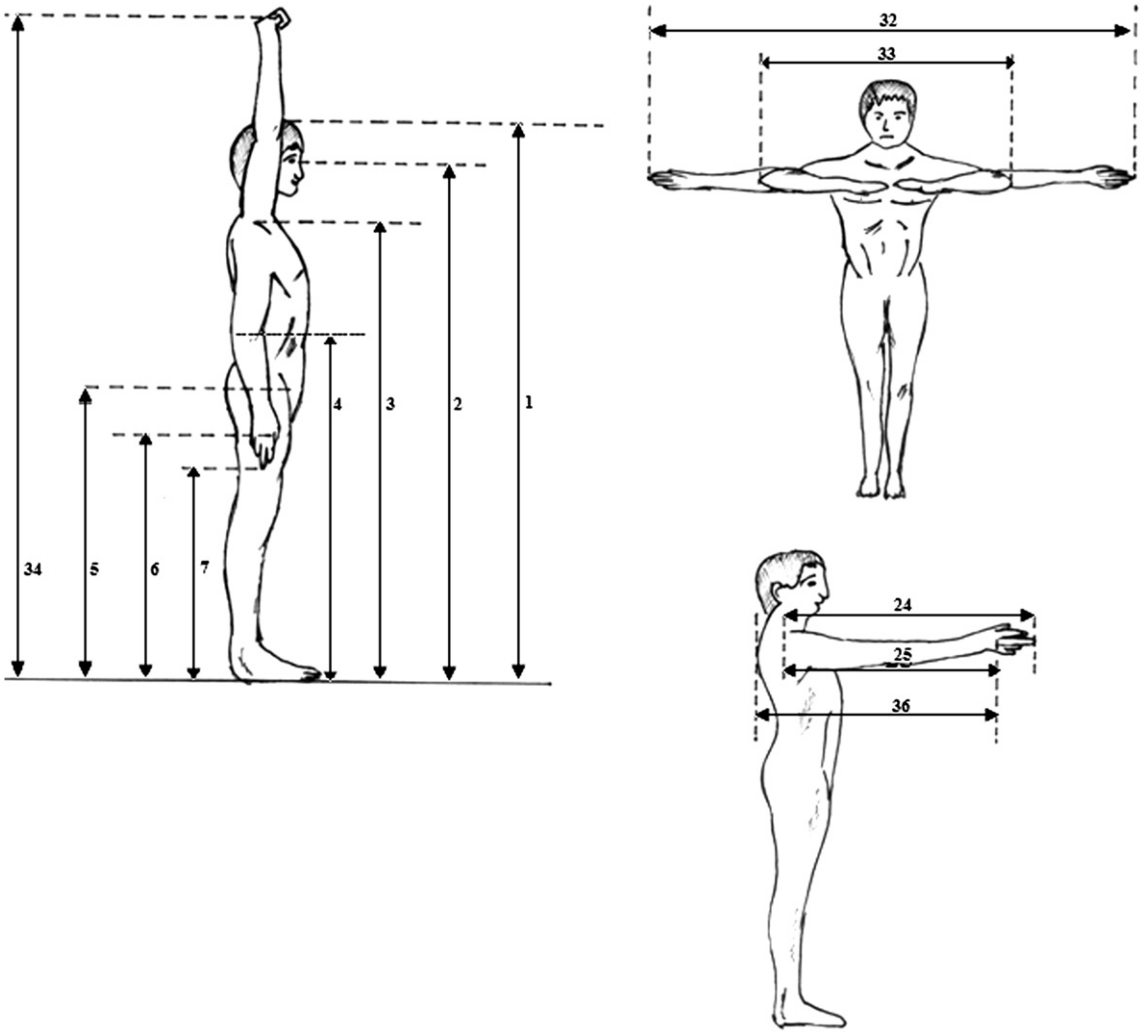

Fig. 1. Body measurement in standing position.

Bahraini school children (Al-Ansari and Mokdad, 2009), anthropometry of north eastern Indian female farm workers (Dewangan et al., 2008), and anthropometry of Sri Lankan university students (Thariq et al., 2010). Since 1990, however, there has been no publication of anthropometric data of the Singaporean population. This research updates the anthropometric data of Singaporeans. We analyze differences in data collected in 1990 and today. Inspired by Lin et al. (2004), we compared the anthropometric characteristics of two groups of people in South-east Asia. This study analyzed significant differences in body dimensions found between the Singaporean and Indonesian samples. Several sub-groups were covered, including population overall, citizens only, and an ethnic sub-group.

This research had four objectives. The first objective was to examine and compare the physical measurements of the Singaporean and Indonesian samples for all three sub-groups. The second objective was to analyze differences between the old and the new anthropometric data of the Singaporean samples. The third objective was to shed light on an important application of anthropometric data. The Body Mass Index (BMI) is taken as an illustrative application that can describe the health of Singaporeans and Indonesians. The final objective was to conduct an empirical estimation of unknown anthropometric characteristics using the Ratio Scaling Method as pioneered by Pheasant (1982).

2. Method

This research is a combination of two anthropometric data gathering exercises as mentioned earlier. The study and data gathering were carried out over a period of 36 months.

2.1. Subjects

Male and female students from a university in Singapore and a university in Indonesia voluntarily participated in this study. In total, 245 male and 132 female subjects from Indonesia (total of 377 subjects) and 206 male and 109 female subjects from Singapore (total of 315 subjects) with ages ranged from 18 to 45 years, were measured (grand total is 692 subjects).

In Indonesia, there were 245 males and 132 females in citizen sub-group and 88 males and 54 females in Chinese sub-group; whereas in Singapore, there were 206 males and 109 females in overall sub-group, 138 males and 57 females in citizen sub-group, and 104 males and 47 females in Chinese sub-group. For Indonesian population, the percentage of Chinese within the citizen sub-group was 37.67%. This was also the same percentage of Chinese within the whole group since there were only 2 sub-groups for Indonesian subjects, i.e. citizen and Chinese. But for Singaporean population, the percentages of Chinese within the citizen sub-group and the

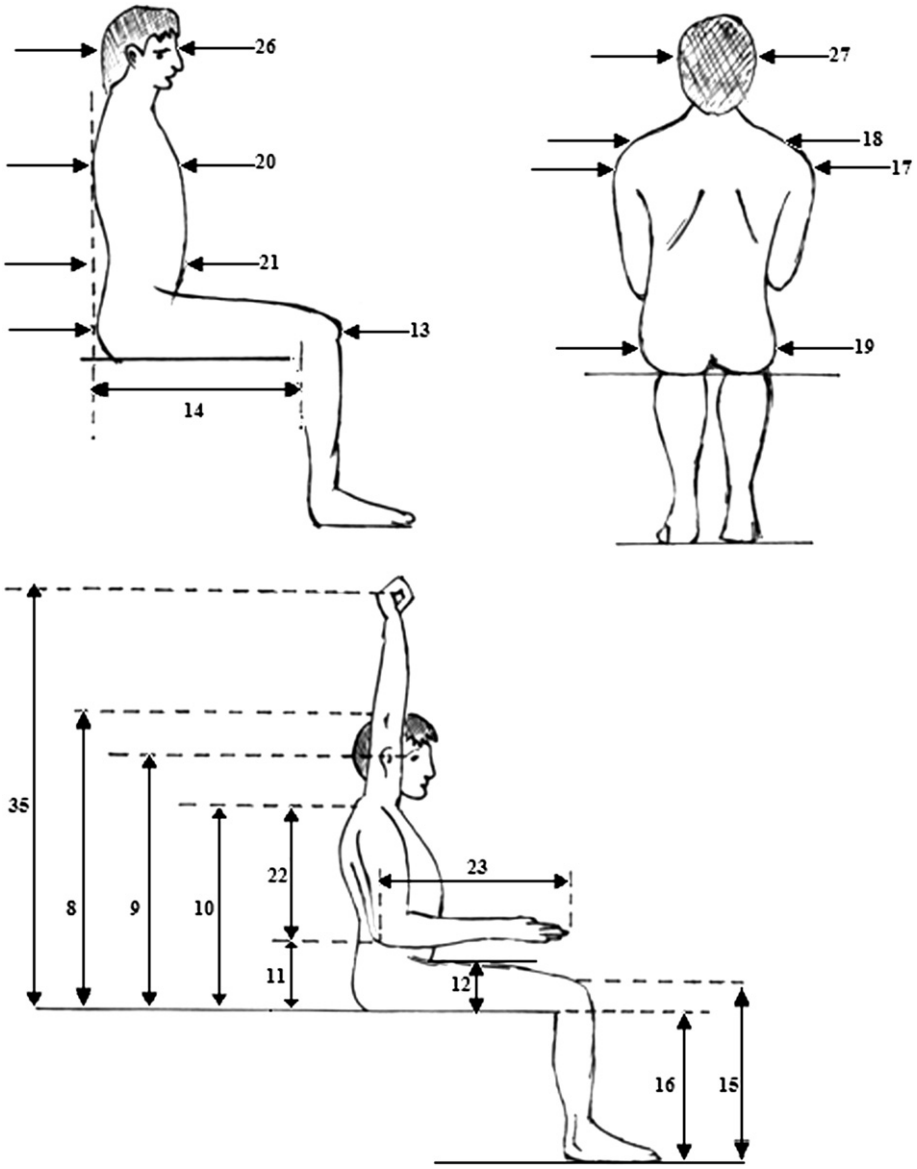

Fig. 2. Body measurement in sitting position.

whole group were 77.44% and 47.94% respectively. Most have taken a course in ergonomics/human factors engineering. Each received a token of appreciation for their time. It is assumed that university students are representative of a population's anthropometry.

The taking of anthropometric data is a sensitive issue to some people who may refuse to be measured. Due to this, we used convenience sampling as opposed to random sampling. Convenience sampling selects subjects arbitrarily and in an unstructured manner from the sample frame (Lohr, 1999).

2.2. Body dimensions

All measurements were taken in the afternoon. Subjects were barefooted, wearing t-shirts or shirts, and shorts or pants while the measurements were taken. For the anthropometric data of Indonesians, the body weight and 35 body dimensions were measured. For the anthropometry of Singaporeans, the body weight and 36 body dimensions were taken. The landmarks of body dimensions are shown in Figs. 1–3. The body dimensions and measurement as specified by Pheasant and Haslegrave (2006) were used.

2.3. Equipment

Traditional anthropometric tools were used rather than a more sophisticated and high-tech equipment such as a three-dimensional scanner. They are simple, portable, inexpensive, and as

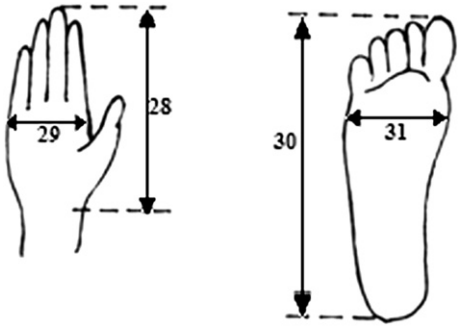

Fig. 3. Body measurement in standing/sitting position.

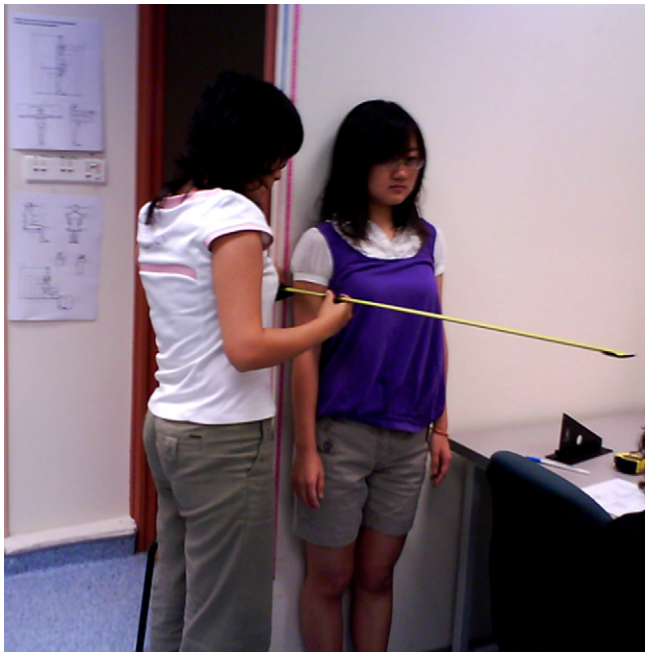

Fig. 4. A female experimenter measures a female subject.

reliable and accurate as those obtained by high-tech anthropometric tools (Al-Ansari and Mokdad, 2009). For the data collection in Singapore, three sets of the Rosscraft Anthropometer Centurion Kit were used. Each set consists of 1 Campbell caliper 20, 1 Campbell caliper 10, 1 segmometer, 1 headboard, and 1 anthropometric measuring tape. A weighing scale, meter scales, and small stools were used also. For the data collection in Indonesia, a similar portable manual anthropometer, meter scales, a weighing scale, and small tools were used. All the equipments used were calibrated against standards/rules.

2.4. Procedure

In managing the data collection in Indonesia, four female and four male experimenters received prior training to become familiar with the equipment, body landmarks, and measurement techniques. In addition, some pilot tests were conducted. Inherently, the experimenters had an experience to be a subject of the same measurement in the previous anthropometry experiment. At the start of each data collection session, the subjects were informed of the purpose of the study, equipment, measurement procedure, and possible application of the data to be collected. The male experimenters measured the male subjects; whereas the female experimenters measured the female subjects (see Fig. 4).

In Singapore, one female and three male experimenters collected the data. The same procedure as used in Indonesia was applied in Singapore. Accuracy and repeatability in taking the

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

Dimension	Overall				Citizens				Chinese only			
	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD
1. Stature	165	174	183	5.75	166	174	182	5.17	165	173	181	5.45
2. Eye height	153	163	172	6.67	153	163	169	5.03	153	162	169	5.25
3. Shoulder height	136	145	153	5.36	136	144	151	4.78	136	143	151	4.88
4. Elbow height	103	110	116	4.05	104	110	114	3.55	103	109	114	3.54
5. Hip height	86	97	106	5.42	85	97	104	5.32	85	96	104	5.57
6. Knuckel height	69	75	81	3.47	70	75	81	3.24	70	75	81	3.37
7. Fingertip height	61	65	71	3	61	65	68	2.69	61	65	68	2.82
8. Sitting height	84	90	96	4.38	84	90	96	3.43	85	90	97	3.37
9. Sitting eye height	73	78	83	4.9	73	77	83	4.24	73	78	83	4.53
10. Sitting shoulder height	55	61	67	4.49	55	61	66	3.34	55	61	67	3.42
11. Sitting elbow height	18	24	30	5.43	17	24	30	6.12	17	25	30	6.82
12. Thigh thickness	12	15	19	2.54	12	15	19	1.79	12	15	18	1.8
13. Buttock-knee length	53	57	63	3.34	53	57	63	2.85	53	57	61	2.52
14. Buttock-popliteal length	41	46	51	3.36	41	46	51	3.29	40	46	51	3.54
15. Knee height	49	54	58	2.89	50	54	58	2.93	50	54	57	3.05
16. Popliteal height	39	43	46	2.94	39	43	46	3.18	39	43	46	3
17. Shoulder breadth (bideltoid)	41	45	48	2.54	41	45	48	1.97	41	44	48	2.1
18. Shoulder breadth (biacromial)	31	37	43	3.59	31	37	42	3.5	31	37	41	3.26
19. Hip breadth	32	35	39	2.33	32	35	38	2	32	35	38	1.89
20. Chest (bust) depth	18	21	25	2.46	18	21	25	2.19	18	20	25	2.21
21. Abdominal depth	19	22	27	2.76	19	22	27	2.65	19	22	27	2.78
22. Shoulder-elbow length	33	37	43	5.99	33	37	43	7	32	37	43	7.85
23. Elbow-fingertip length	43	47	51	3.22	43	47	51	2.41	43	47	50	2.34
24. Upper limb length	70	76	82	3.55	71	76	81	3.17	71	76	80	3.01
25. Shoulder-grip length	60	66	72	3.37	61	66	71	3.01	61	66	71	2.95
26. Head length	18	19	21	1.08	18	19	21	1.03	18	19	21	1.08
27. Head breadth	15	17	19	1.03	15	17	18	0.99	15	17	18	1.02
28. Hand length	16	19	24	2.88	15	19	26	3.34	17	19	24	2.73
29. Hand breadth	8	9	10	0.67	8	9	10	0.58	8	9	10	0.57
30. Foot length	23	26	28	1.39	23	26	28	1.4	22	26	28	1.51
31. Foot breadth	9	10	11	0.55	9	10	11	0.53	9	10	11	0.57
32. Span	162	175	186	7.43	165	175	185	6.6	164	174	183	6.36
33. Elbow span	82	91	98	5.91	82	91	98	6.29	82	91	98	6.81
34. Vertical grip reach (standing)	194	208	224	15.28	196	208	223	15.1	195	207	221	16.46
35. Vertical grip reach (sitting)	117	124	132	5.39	117	124	131	4.39	117	123	131	4.5
36. Forward grip reach	70	75	80	3.25	70	75	80	3.16	70	74	79	3.21
37. Body weight (kg)	55.00	68.50	80.32	7.77	55.00	68.00	79.00	6.89	55.00	67.60	79.00	7.34

measurements were achieved somewhat with practice prior to data collection. Initially, it took about 30 min to completely measure each subject. Very quickly, this plateaued to about 15–20 min.

3. Results

3.1. Anthropometric data of the Singaporean and Indonesian samples

A summary of the anthropometry data collected in Singapore is shown in Table 1 (for male) and Table 2 (for female). Table 3 presents the same for the Indonesia data. Information on the sub-groups and average weight are shown.

3.2. Comparison of selected median values for the Singaporean and Indonesian samples

The Mann–Whitney *U* test is used to assess whether the two independent samples (i.e., anthropometric data of Singaporean and Indonesian samples) are different. It assumes distribution-free data which is a reasonable assumption to be made of the anthropometry data collected in this study.

Table 4 presents a comparison of the 36 dimensions measured, including weight. In general, both male and female Singaporeans tend to have larger dimensions than their Indonesians counterparts. Statistical analysis shows that up to 50 percent of the dimensions have significant differences in median values. For the sub-group of citizens, 23 out of 36 for male and 21 out of 36 for female, were significantly different. For the sub-group of Chinese, 10 out of 36 for male and 15 out of 36 for female, were significantly different.

Comparing Singaporean to Indonesian male and female in the citizen sub-group and ethnic Chinese sub-group, there were significant differences in the dimensions of, stature, eye height, elbow height, fingertip height, head length, and elbow span.

3.3. Comparison of current and past anthropometric data of Singaporeans

The current Singaporean anthropometric data were compared with older similar data obtained in 1990. From the current data, only information from the citizen sub-group was used. The past data are from Lim et al. (1990). The sample size included in the study by Lim et al. (1990) was 587 male and 464 female Singaporean workers. The ages of the samples ranged from 18 to 45 years. The two data sets do not correspond completely. Twenty-four body dimensions were selected for comparison. Using the Student's *t*-test for independent mean difference, the result showed that more than 50 percent of the dimensions were significantly different, including weight, stature, eye height, knuckle height, sitting height, sitting eye height, sitting shoulder height, and others (see Table 5).

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

Dimension	Overall				Citizens				Chinese			
	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD
1. Stature	154	162	168	4.23	154	162	166	3.66	155	162	166	3.69
2. Eye height	143	150	156	5.41	143	150	155	3.66	143	150	155	3.61
3. Shoulder height	127	134	139	3.83	128	134	139	3.35	127	133	139	3.47
4. Elbow height	98	102	108	3.5	98	103	106	3.55	98	102	107	3.77
5. Hip height	85	89	95	3.26	86	89	94	2.38	86	89	94	2.39
6. Knuckel height	67	71	76	2.49	67	71	73	1.88	67	71	73	1.92
7. Fingertip height	58	62	67	2.57	59	62	65	2.11	58	62	65	2.14
8. Sitting height	81	85	91	3.41	81	85	89	3.25	81	85	89	3.47
9. Sitting eye height	70	74	80	3.5	70	74	78	3.42	71	74	79	3.67
10. Sitting shoulder height	53	58	62	2.5	55	58	61	2.02	55	57	61	2.12
11. Sitting elbow height	19	25	31	3.17	22	25	29	2.31	21	25	29	2.44
12. Thigh thickness	12	14	16	1.33	13	14	16	1.15	13	14	16	1.23
13. Buttock-knee length	51	54	58	2.72	51	54	58	1.87	51	54	58	1.91
14. Buttock-popliteal length	42	45	49	2.19	43	45	48	1.84	43	45	49	1.94
15. Knee height	46	49	51	2.18	46	49	51	1.81	46	49	51	1.91
16. Popliteal height	38	40	42	1.32	38	40	42	1.28	38	40	42	1.35
17. Shoulder breadth (bideltoid)	37	40	43	2.1	38	40	43	1.85	38	40	43	1.97
18. Shoulder breadth (biacromial)	31	34	38	2.58	31	34	36	1.95	31	34	36	2.03
19. Hip breadth	32	35	39	2.32	32	35	37	2.42	32	35	38	2.59
20. Chest (bust) depth	20	23	27	2.84	20	23	25	1.94	20	23	25	2.07
21. Abdominal depth	17	20	23	2.88	17	20	22	1.77	16	20	22	1.77
22. Shoulder-elbow length	30	33	36	2.39	30	33	35	1.69	30	33	35	1.75
23. Elbow-fingertip length	40	43	45	1.52	40	43	44	1.11	41	42	44	1.13
24. Upper limb length	66	70	73	2.35	66	69	72	1.75	67	69	72	1.76
25. Shoulder-grip length	57	60	65	3	57	60	62	1.76	57	60	62	1.74
26. Head length	17	18	19	0.74	17	18	19	0.46	17	18	19	0.45
27. Head breadth	15	16	17	0.66	15	16	17	0.5	15	16	17	0.52
28. Hand length	16	17	18	0.68	16	17	18	0.55	16	17	18	0.57
29. Hand breadth	7	7	8	0.62	7	7	8	0.62	7	7	8	0.67
30. Foot length	22	23	25	0.89	22	23	24	0.8	22	23	25	0.85
31. Foot breadth	8	9	10	0.52	8	9	9	0.37	8	9	9	0.39
32. Span	149	158	169	10.02	149	157	166	5.43	151	157	166	5.28
33. Elbow span	79	84	91	7.87	78	84	91	3.89	78	84	90	3.76
34. Vertical grip reach (standing)	179	189	202	14.07	179	188	197	8	179	187	197	8.39
35. Vertical grip reach (sitting)	109	116	126	5.45	110	115	121	4.04	110	115	121	4.2
36. Forward grip reach	63	68	73	2.88	64	67	70	1.98	64	67	70	2.02
37. Body weight (kg)	46.40	53	62	5.42	46.20	55	69.70	6.73	47.60	52.90	61.79	4.94

Table 3
Anthropometric data for Indonesian males and females (all dimensions in cm, body weight in kg).

Dimension	Male citizens				Male Chinese				Female citizens				Female Chinese			
	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD	5th	50th	95th	SD
1. Stature	162	172	183	6.23	165	171	180	4.81	150	159	169	5.76	151	159	166	5.06
2. Eye height	151	160	172	6.3	153	160	169	5.08	139	148	158	6.12	137	146	158	6.73
3. Shoulder height	134	143	155	6.41	134	143	151	5.05	123	132	141	5.91	123	132	139	5.43
4. Elbow height	99	107	114	5.12	99	106	112	4.29	91	99	108	6.4	92	98	107	5.35
5. Hip height	83	95	105	6.76	81	94	103	6.48	78	88	97	5.91	79	90	96	5.68
6. Knuckel height	68	75	82	4.75	69	74	80	5.13	63	70	78	4.37	64	69	77	3.89
7. Fingertip height	58	64	71	4.82	59	64	70	5.13	54	60	65	3.67	53	60	68	3.99
8. Sitting height	80	89	96	5.24	85	90	96	6.55	78	83	90	4.7	79	84	88	2.97
9. Sitting eye height	69	76	84	4.58	72	78	85	6.54	67	73	80	5.83	68	72	79	3.64
10. Sitting shoulder height	52	59	67	6.27	55	61	72	7.15	51	56	63	4.94	52	57	64	3.67
11. Sitting elbow height	19	24	30	4.74	19	25	31	7.13	19	25	32	5.19	21	24	30	3.24
12. Thigh thickness	12	16	22	3.59	13	16	20	2.76	11	15	19	3.22	12	15	19	2.81
13. Buttock-knee length	48	56	64	4.89	49	57	64	4.83	45	53	60	4.81	48	53	60	4.06
14. Buttock-popliteal length	40	46	54	4.82	38	47	56	5.36	37	43	51	4.21	39	44	52	3.97
15. Knee height	46	54	62	5.21	44	53	61	5.65	43	50	60	5.27	42	49	60	5.38
16. Popliteal height	38	44	49	3.78	36	44	50	5.36	38	44	50	3.92	36	43	47	3.85
17. Shoulder breadth (bideltoid)	36	45	52	4.66	38	45	50	4.6	37	43	53	5.43	40	44	53	4.97
18. Shoulder breadth (biacromial)	31	37	43	3.61	33	38	44	3.83	33	38	44	3.56	34	38	44	3.18
19. Hip breadth	28	35	43	4.41	30	35	44	4.09	29	35	45	7.22	30	34	42	4.21
20. Chest (bust) depth	16	21	27	3.5	17	22	27	4.02	17	21	28	3.38	19	23	28	3.61
21. Abdominal depth	15	21	29	4.46	15	21	30	5.19	14	18	25	3.44	15	20	26	3.93
22. Shoulder-elbow length	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23. Elbow-fingertip length	42	47	56	4.55	41	46	53	4.27	37	43	50	4.27	37	42	47	3.72
24. Upper limb length	68	76	84	6.39	68	75	85	5.06	62	70	77	4.69	64	68	74	3.92
25. Shoulder-grip length	56	65	73	6.29	59	66	74	5.13	54	60	68	4.3	54	60	68	4.64
26. Head length	17	20	24	2.21	17	20	24	2.58	15	18	22	3.95	15	19	22	2.13
27. Head breadth	15	18	22	2.06	15	18	21	1.89	14	17	21	2.48	14	18	21	2.11
28. Hand length	17	19	22	1.64	15	19	22	2.42	16	18	20	1.72	17	18	20	2.16
29. Hand breadth	7	9	11	1.09	8	9	11	0.89	6	8	10	4.85	6	8	9	0.73
30. Foot length	22	25	29	2.58	11	25	28	4.43	21	23	26	2.63	21	23	26	2.3
31. Foot breadth	8	10	12	3.96	8	10	12	1.16	7	9	11	2.2	7	9	10	1.08
32. Span	158	172	186	8.5	155	171	182	8.73	146	156	170	7.61	150	159	168	6.52
33. Elbow span	78	86	96	5.97	79	87	94	4.36	73	79	89	5.38	73	81	88	4.53
34. Vertical grip reach (standing)	192	206	221	10.54	197	206	222	7.74	174	186	204	9.1	176	189	202	8.07
35. Vertical grip reach (sitting)	112	122	136	7.9	116	123	130	5.18	101	113	124	7.2	106	115	128	10.25
36. Forward grip reach	64	73	81	5.89	66	74	81	4.7	61	67	76	4.39	60	67	74	4.76
37. Body weight (kg)	50	63	89.25	13.19	53.05	63	93.45	13.35	39.80	53	80	11.68	41.90	55	70.40	9.49

3.4. Body Mass Index (BMI) as a utilization of anthropometric data

BMI is a comparison of a person's weight against stature. It is defined as weight in kg divided by the square of stature in m (kg/m^2). Essentially, BMI can be a health indicator. The BMI values for all sub-groups in this research are shown in Table 6. All values are within the normal range of 18.5–25.0, as specified by WHO (2008). The presented BMI in this study is only valid to explain the health condition of the Singaporean and Indonesian populations in their productive age since the samples were taken from people in the age range of 18–45 years.

3.5. Empirical estimation of unknown anthropometric characteristics using the Ratio Scaling Method

Pheasant and Haslegrave (2006) proposed that if given that two populations A and B which are similar in terms of age range, gender, and ethnicity, and if the parameters of variables x and y are known in population A (i.e., the reference population), but only the parameters of x are known in population B (i.e., the target population), then:

$$m_y/m_x(\text{inreferencepopulationA}) \approx m_y/m_x(\text{intargetpopulationB}) \quad (1)$$

$$s_y/s_x\ (\text{in reference population A}) \approx s_y/s_x\ (\text{in target population B}) \quad (2)$$

The variable x, which is known in both populations, is called as the "scaling dimension." Stature or body height is commonly chosen as the scaling dimension and will be used here. Pheasant and Haslegrave proposed the simplest technique of coefficients calculation as follows:

$$E_1 = (\text{mean of required dimension})/(\text{mean stature}) \quad (3)$$

$$E_2 = (\text{standard deviation of required dimension})/(\text{standard deviation of stature}) \quad (4)$$

The E_1 and E_2 coefficients calculated from the Singaporean and Indonesian anthropometric data for two sub-groups (i.e., citizen sub-group, ethnic Chinese sub-group) are presented in Tables 7 and 8.

The objective of this exercise is to show that it is possible to estimate various anthropometric dimensions of a sample (e.g., mean, SD, percentiles) based only on the dimension of stature. However as mentioned, one requirement is that the ethnicity, age, and gender group must be the same. In further method development, Wang and Chao (2010) have developed an improvement of this Ratio Scaling Method. They called it the Constant Body Ratio benchmarks (CBR benchmarks) which is least affected by age and gender factors. Pheasant (1982) argued that when properly qualified in use, the error estimate of this technique can be considered acceptable.

A comparison of the E_1 coefficient between the current and previous studies of Singaporean citizen anthropometry is presented (see Table 9). The ratio E_1 difference (shown in "%diff")

Table 4
Comparison of median values for Singaporean and Indonesian samples (all dimensions in cm, body weight in kg).

Dimension	Male citizens			Male Chinese			Female citizens			Female Chinese		
	A	B	*p*-value	A	B	*p*-value	A	B	*p*-value	A	B	*p*-value
1. Stature	172	174	0.0005*	171	173	0.0089*	159	162	0.0026*	159	162	0.0051*
2. Eye height	160	163	0*	160	162	0.0013*	148	150	0.0082*	146	150	0.0056*
3. Shoulder height	143	144	0.0371*	143	143	0.2343	132	134	0.0156*	132	133	0.0481*
4. Elbow height	107	110	0*	106	109	0*	99	103	0*	98	102	0.0005*
5. Hip height	95	97	0.0015*	94	96	0.0571	88	89	0.0016*	90	89	0.3176
6. Knuckel height	75	75	0.5019	74	75	0.1891	70	71	0.1613	69	71	0.0879
7. Fingertip height	64	65	0.0243*	64	65	0.019*	60	62	0*	60	62	0.0005*
8. Sitting height	89	90	0.0002*	90	90	0.3991	83	85	0.0003*	84	85	0.0198*
9. Sitting eye height	76	77	0*	78	78	0.3829	73	74	0.0017*	72	74	0.0125*
10. Sitting shoulder height	59	61	0*	62	61	0.6355	56	58	0.0052*	57	57	0.3485
11. Sitting elbow height	24	24	0.9111	25	25	0.7932	25	25	0.2003	24	25	0.0868
12. Thigh thickness	16	15	0.0007*	16	15	0.0075*	15	14	0.2182	15	14	0.6055
13. Buttock-knee length	56	57	0.0272*	57	57	0.87	53	54	0.001*	53	54	0.1889
14. Buttock-popliteal length	46	46	0.4569	47	46	0.1332	43	45	0*	44	45	0.0404*
15. Knee height	54	54	0.2232	53	54	0.1741	50	49	0.002*	49	49	0.1475
16. Popliteal height	44	43	0.0127*	44	43	0.0296*	44	40	0*	43	40	0.0002*
17. Shoulder breadth (bideltoid)	45	45	0.933	45	44	0.9665	43	40	0*	44	40	0*
18. Shoulder breadth (biacromial)	37	37	0.7922	38	37	0.0496*	38	34	0*	38	34	0*
19. Hip breadth	35	35	0.1687	35	35	0.1774	35	35	0.3078	34	35	0.9284
20. Chest (bust) depth	21	21	0.254	22	21	0.1353	21	23	0.0019*	23	23	0.9687
21. Abdominal depth	21	22	0*	21	22	0.4464	18	20	0.0005*	20	20	0.9821
22. Shoulder-elbow length	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23. Elbow-fingertip length	47	47	0.6452	46	47	0.6657	43	43	0.7043	42	42	0.6493
24. Upper limb length	76	76	0.7576	75	76	0.9131	70	69	0.476	68	69	0.6902
25. Shoulder-grip length	65	66	0.08	66	66	0.5971	60	60	0.8928	60	60	0.9731
26. Head length	20	19	0.0221*	20	19	0.2596	18	18	0.1938	19	18	0.5251
27. Head breadth	18	17	0*	18	17	0*	17	16	0.0003*	18	16	0.0004*
28. Hand length	19	19	0.9333	19	19	0.4641	18	17	0.0014*	18	17	0*
29. Hand breadth	9	9	0.1064	9	9	0.2885	8	7	0.0522	8	7	0.462
30. Foot length	25	26	0.0013*	25	26	0.0023*	23	23	0.0842	23	23	0.0588
31. Foot breadth	10	10	0.0097*	10	10	0.1544	9	9	0.1574	9	9	0.0234*
32. Span	172	175	0.0009*	171	174	0.0726	156	157	0.4114	159	157	0.5898
33. Elbow span	86	91	0*	87	91	0.0002*	79	84	0*	81	84	0.0079*
34. Vertical grip reach (standing)	206	208	0.0058*	205	207	0.2913	186	188	0.3456	189	187	0.9373
35. Vertical grip reach (sitting)	122	124	0.0042*	122	123	0.2159	113	115	0.0024*	115	115	0.4967
36. Forward grip reach	73	75	0.0001*	74	75	0.312	67	67	0.44	67	67	0.6778
37. Body weight (kg)	63	68	0.0001*	63	67.6	0.0618	53	55	0.2398	55	52.9	0.7873

*Significant at $p < 0.05$; A = Indonesian; B = Singaporean.

Table 5
Comparison of 50th percentile values for previous (old) and current studies (new) of Singaporeans (all dimensions in cm, body weight in kg).

Dimension	Male citizens					Female citizens				
	50th Old	SD Old	50th New	SD New	*p*-value	50th Old	SD Old	50th New	SD New	*p*-value
1. Stature	169	6.21	174	5.17	0*	155	5.8	162	3.66	0*
2. Eye height	158	6.3	163	5.03	0*	144	5.57	150	3.66	0*
3. Knuckel height	78	5.23	75	3.24	0*	74	5.45	71	1.88	0*
4. Sitting height	87	4.14	90	3.43	0*	80	4.51	85	3.25	0*
5. Sitting eye height	75	4.36	77	4.24	0*	70	4.5	74	3.42	0*
6. Sitting shoulder height	58	4.74	61	3.34	0*	55	3.92	58	2.02	0*
7. Sitting elbow height	23	3.64	24	6.12	0.028*	23	3.31	25	2.31	0*
8. Thigh thickness	14	2.58	15	1.79	0*	14	3.9	14	1.15	0.012*
9. Buttock-knee length	56	3.44	57	2.85	0*	54	3.85	54	1.87	0.514
10. Buttock-popliteal length	45	3.6	46	3.29	0.001*	44	3.93	45	1.84	0*
11. Knee height	54	3.28	54	2.93	0.482	49	4.35	49	1.81	1
12. Popliteal height	43	3.36	43	3.18	0.512	40	4.23	40	1.28	0.441
13. Shoulder breadth (bideltoid)	43	2.75	45	1.97	0*	38	2.78	40	1.85	0*
14. Hip breadth	34	3.86	35	2	0*	35	3.64	35	2.42	0.582
15. Chest (bust) depth	21	3.02	21	2.19	0.076	22	2.87	23	1.94	0.001*
16. Abdominal depth	20	3.03	22	2.65	0*	20	4.05	20	1.77	1
17. Elbow-fingertip length	45	2.65	47	2.41	0*	41	2.97	43	1.11	0*
18. Head length	20	1.47	19	1.03	0*	19	1.59	18	0.46	0*
19. Head breadth	16	1.35	17	0.99	0*	16	1.78	16	0.5	0.005*
20. Hand length	19	1.02	19	3.34	0.084	17	1	17	0.55	1
21. Hand breadth	8	0.68	9	0.58	0*	7	0.61	7	0.62	0.001*
22. Foot length	25	1.33	26	1.4	0*	23	1.25	23	0.8	0*
23. Foot breadth	10	0.66	10	0.53	0*	9	0.67	9	0.37	0.088
24. Weight (kg)	60	7.83	68	6.89	0*	50	9.15	55	6.73	0*

*Significant at $p < 0.05$.

Table 6
Body Mass Index of Singaporean and Indonesian samples.

Subject		Body Mass Index (BMI) in kg/m^2	
		Male	Female
Singaporean	Overall	22.58	20.65
	Citizens	22.62	21.43
	Chinese	22.5	20.71
	Citizen (for old data)	21.01	20.81
Indonesian	Citizens	22.21	21.76
	Chinese	22.7	21.89

indicates that the errors are relatively small in all body dimensions except for knuckle height and head length. The average difference is 2.28 percent for males and 3.14 percent for females.

4. Discussion and conclusion

Anthropometric data from Singaporean and Indonesian adults were collected and summarized. Based on statistical analysis and depending on the sub-group sample, up to half of the dimensions were significantly different. The Singaporean sample was relatively taller than the Indonesian sample for both male and female. Singaporeans were also significantly larger than Indonesians in several body dimensions including eye height, elbow height, fingertip height, and elbow span. However, Singaporean adults appear to have a relatively smaller head length than Indonesian adults.

The above indicates that geographical origin does have an effect on variation of anthropometry. This confirms with reports by other researchers. For example, Sirajuddin et al. (1994) found that geographic factors have an overwhelming effect on the genetic differentiation of ethnic groups in the southern part of Indian. İşeri and Arslan (2009) found geographical region to have a significant effect on stature and weight of the Turkish population. Another variable is the various ethnic sub-groups.

Singapore is a highly diverse and cosmopolitan country with the Chinese people forming the largest ethnic majority. Other sub-groups include Malays, Indians, Eurasians, and Arabs. It is interesting to note that in Indonesia alone, there are over 300 distinct native ethnicities. On the issue of ethnicity affecting anthropometry, it is not a question of whether it does, but how much it does.

Better nutrition and higher social status may be an explanation for differences found between the two samples. Compared to Indonesia, Singapore has a higher status since its GDP (nominal) per capita (i.e., USD38,972) was ranked 22nd, whereas Indonesia (i.e., USD2239) was ranked 116th in year 2008 (International Monetary Fund, 2008). Higher socioeconomic status implies higher income and is associated with better education, resulting in better nutrition, better child care, and better medical and social services. İşeri and Arslan (2009) argue that over time, this leads to an increase in overall stature. Malnutrition which is prevalent in underdeveloped countries plays a major role in inhibiting the human growth process including height and weight (Wall, 1993). As empirical proof, in Europe during the last 100 years, people have become taller, the onset of puberty has commenced at a younger

Table 7
E_1 and E_2 coefficients calculated from Singaporean anthropometric data as reference populations.

Body dimension	Male citizen				Female citizen				Male Chinese				Female Chinese			
	Mean	SD	E_1	E_2	Mean	SD	E_1	E_2	Mean	SD	E_1	E_2	Mean	SD	E_1	E_2
1. Stature	174	5.17	1	1	162	3.7	1	1	174	5.45	1	1	161	3.69	1	1
2. Eye height	163	5.03	0.94	0.97	150	3.7	0.9	1	162	5.25	0.94	0.96	150	3.61	0.93	0.98
3. Shoulder height	144	4.78	0.83	0.93	133	3.4	0.8	0.9	144	4.88	0.83	0.9	133	3.47	0.83	0.94
4. Elbow height	110	3.55	0.63	0.69	103	3.6	0.6	1	109	3.54	0.63	0.65	103	3.77	0.64	1.02
5. Hip height	97	5.32	0.56	1.03	90	2.4	0.6	0.7	96	5.57	0.55	1.02	90	2.39	0.56	0.65
6. Knuckel height	75	3.24	0.43	0.63	71	1.9	0.4	0.5	75	3.37	0.43	0.62	71	1.92	0.44	0.52
7. Fingertip height	65	2.69	0.37	0.52	62	2.1	0.4	0.6	65	2.82	0.37	0.52	62	2.14	0.39	0.58
8. Sitting height	90	3.43	0.52	0.66	85	3.3	0.5	0.9	90	3.37	0.52	0.62	85	3.47	0.53	0.94
9. Sitting eye height	77	4.24	0.45	0.82	74	3.4	0.5	0.9	77	4.53	0.45	0.83	74	3.67	0.46	0.99
10. Sitting shoulder height	61	3.34	0.35	0.65	58	2	0.4	0.6	61	3.42	0.35	0.63	58	2.12	0.36	0.57
11. Sitting elbow height	25	6.12	0.14	1.18	25	2.3	0.2	0.6	25	6.82	0.15	1.25	25	2.44	0.16	0.66
12. Thigh thickness	15	1.79	0.09	0.35	14	1.2	0.1	0.3	15	1.8	0.09	0.33	14	1.23	0.09	0.33
13. Buttock-knee length	57	2.85	0.33	0.55	54	1.9	0.3	0.5	57	2.52	0.33	0.46	54	1.91	0.34	0.52
14. Buttock-popliteal length	46	3.29	0.27	0.64	45	1.8	0.3	0.5	46	3.54	0.27	0.65	46	1.94	0.28	0.53
15. Knee height	54	2.93	0.31	0.57	49	1.8	0.3	0.5	54	3.05	0.31	0.56	49	1.91	0.3	0.52
16. Popliteal height	43	3.18	0.25	0.62	40	1.3	0.2	0.3	43	3	0.25	0.55	40	1.35	0.25	0.37
17. Shoulder breadth (bideltoid)	44	1.97	0.26	0.38	40	1.9	0.3	0.5	44	2.1	0.25	0.39	40	1.97	0.25	0.53
18. Shoulder breadth (biacromial)	37	3.5	0.21	0.68	34	2	0.2	0.5	37	3.26	0.21	0.6	34	2.03	0.21	0.55
19. Hip breadth	35	2	0.2	0.39	35	2.4	0.2	0.7	35	1.89	0.2	0.35	35	2.59	0.22	0.7
20. Chest (bust) depth	21	2.19	0.12	0.42	23	1.9	0.1	0.5	21	2.21	0.12	0.41	23	2.07	0.14	0.56
21. Abdominal depth	22	2.65	0.13	0.51	20	1.8	0.1	0.5	22	2.78	0.13	0.51	20	1.77	0.12	0.48
22. Shoulder-elbow length	38	7	0.22	1.35	33	1.7	0.2	0.5	38	7.85	0.22	1.44	33	1.75	0.2	0.47
23. Elbow-fingertip length	47	2.41	0.27	0.47	42	1.1	0.3	0.3	47	2.34	0.27	0.43	42	1.13	0.26	0.31
24. Upper limb length	76	3.17	0.44	0.61	69	1.8	0.4	0.5	75	3.01	0.44	0.55	69	1.76	0.43	0.48
25. Shoulder-grip length	66	3.01	0.38	0.58	60	1.8	0.4	0.5	66	2.95	0.38	0.54	60	1.74	0.37	0.47
26. Head length	19	1.03	0.11	0.2	18	0.5	0.1	0.1	19	1.08	0.11	0.2	18	0.45	0.11	0.12
27. Head breadth	17	0.99	0.1	0.19	16	0.5	0.1	0.1	17	1.02	0.1	0.19	16	0.52	0.1	0.14
28. Hand length	19	3.34	0.11	0.65	17	0.6	0.1	0.1	19	2.73	0.11	0.5	17	0.57	0.11	0.15
29. Hand breadth	9	0.58	0.05	0.11	7	0.6	0	0.2	9	0.57	0.05	0.1	7	0.67	0.05	0.18
30. Foot length	26	1.4	0.15	0.27	23	0.8	0.1	0.2	26	1.51	0.15	0.28	23	0.85	0.14	0.23
31. Foot breadth	10	0.53	0.06	0.1	9	0.4	0.1	0.1	10	0.57	0.06	0.11	9	0.39	0.06	0.11
32. Span	175	6.6	1.01	1.28	158	5.4	1	1.5	174	6.36	1	1.17	158	5.28	0.98	1.43
33. Elbow span	91	6.29	0.52	1.22	84	3.9	0.5	1.1	91	6.81	0.52	1.25	84	3.76	0.52	1.02
34. Vertical grip reach (standing)	208	15.1	1.19	2.92	188	8	1.2	2.2	206	16.5	1.19	3.02	187	8.39	1.16	2.27
35. Vertical grip reach (sitting)	124	4.39	0.71	0.85	116	4	0.7	1.1	124	4.5	0.71	0.83	116	4.2	0.72	1.14
36. Forward grip reach	75	3.16	0.43	0.61	67	2	0.4	0.5	75	3.21	0.43	0.59	67	2.02	0.42	0.55

Table 8
E_1 and E_2 coefficients calculated from Indonesian anthropometric data as reference populations.

Body dimension	Male citizen				Female citizen				Male Chinese				Female Chinese			
	Mean	SD	E_1	E_2	Mean	SD	E_1	E_2	Mean	SD	E_1	E_2	Mean	SD	E_1	E_2
1. Stature	172	6.23	1	1	159	5.8	1	1	171	4.81	1	1	159	5.06	1	1
2. Eye height	160	6.3	0.93	1.01	148	6.1	0.9	1.1	160	5.08	0.93	1.06	147	6.73	0.93	1.33
3. Shoulder height	143	6.41	0.83	1.03	132	5.9	0.8	1	143	5.05	0.83	1.05	132	5.43	0.83	1.08
4. Elbow height	107	5.12	0.62	0.82	100	6.4	0.6	1.1	106	4.29	0.62	0.89	99	5.35	0.62	1.06
5. Hip height	95	6.76	0.55	1.08	87	5.9	0.5	1	94	6.48	0.55	1.35	88	5.68	0.56	1.12
6. Knuckel height	75	4.75	0.44	0.76	70	4.4	0.4	0.8	74	5.13	0.43	1.07	70	3.89	0.44	0.77
7. Fingertip height	64	4.82	0.37	0.77	60	3.7	0.4	0.6	64	5.13	0.37	1.07	60	3.99	0.38	0.79
8. Sitting height	88	5.24	0.51	0.84	83	4.7	0.5	0.8	91	6.55	0.53	1.36	84	2.97	0.53	0.59
9. Sitting eye height	76	4.58	0.44	0.74	73	5.8	0.5	1	79	6.54	0.46	1.36	73	3.64	0.46	0.72
10. Sitting shoulder height	59	6.27	0.35	1.01	57	4.9	0.4	0.9	62	7.15	0.37	1.49	57	3.67	0.36	0.73
11. Sitting elbow height	25	4.74	0.14	0.76	25	5.2	0.2	0.9	26	7.13	0.15	1.48	24	3.24	0.15	0.64
12. Thigh thickness	16	3.59	0.1	0.58	15	3.2	0.1	0.6	17	2.76	0.1	0.57	15	2.81	0.1	0.56
13. Buttock-knee length	56	4.89	0.33	0.78	53	4.8	0.3	0.8	57	4.83	0.33	1	54	4.06	0.34	0.8
14. Buttock-popliteal length	46	4.82	0.27	0.77	43	4.2	0.3	0.7	47	5.36	0.28	1.11	45	3.97	0.28	0.79
15. Knee height	54	5.21	0.31	0.84	51	5.3	0.3	0.9	53	5.65	0.31	1.17	50	5.38	0.32	1.06
16. Popliteal height	44	3.78	0.26	0.61	44	3.9	0.3	0.7	44	5.36	0.26	1.11	43	3.85	0.27	0.76
17. Shoulder breadth (bideltoid)	45	4.66	0.26	0.75	45	5.4	0.3	0.9	44	4.6	0.26	0.96	45	4.97	0.28	0.98
18. Shoulder breadth (biacromial)	37	3.61	0.21	0.58	38	3.6	0.2	0.6	38	3.83	0.22	0.8	39	3.18	0.24	0.63
19. Hip breadth	36	4.41	0.21	0.71	36	7.2	0.2	1.3	36	4.09	0.21	0.85	36	4.21	0.22	0.83
20. Chest (bust) depth	21	3.5	0.12	0.56	21	3.4	0.1	0.6	22	4.02	0.13	0.84	23	3.61	0.14	0.71
21. Abdominal depth	21	4.46	0.12	0.72	19	3.4	0.1	0.6	22	5.19	0.13	1.08	20	3.93	0.13	0.78
22. Shoulder-elbow length	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23. Elbow-fingertip length	48	4.55	0.28	0.73	43	4.3	0.3	0.7	47	4.27	0.27	0.89	42	3.72	0.26	0.74
24. Upper limb length	75	6.39	0.44	1.03	70	4.7	0.4	0.8	76	5.06	0.44	1.05	69	3.92	0.44	0.77
25. Shoulder-grip length	65	6.29	0.38	1.01	60	4.3	0.4	0.7	66	5.13	0.38	1.07	60	4.64	0.38	0.92
26. Head length	20	2.21	0.12	0.35	19	4	0.1	0.7	20	2.58	0.12	0.54	18	2.13	0.11	0.42
27. Head breadth	19	2.06	0.11	0.33	17	2.5	0.1	0.4	18	1.89	0.11	0.39	17	2.11	0.11	0.42
28. Hand length	19	1.64	0.11	0.26	18	1.7	0.1	0.3	19	2.42	0.11	0.5	18	2.16	0.11	0.43
29. Hand breadth	9	1.09	0.05	0.18	8	4.9	0.1	0.8	9	0.89	0.05	0.19	7	0.73	0.05	0.15
30. Foot length	25	2.58	0.15	0.41	23	2.6	0.1	0.5	24	4.43	0.14	0.92	23	2.3	0.15	0.46
31. Foot breadth	10	3.96	0.06	0.64	9	2.2	0.1	0.4	10	1.16	0.06	0.24	8	1.08	0.05	0.21
32. Span	172	8.5	1	1.36	157	7.6	1	1.3	172	8.73	1	1.81	158	6.52	1	1.29
33. Elbow span	87	5.97	0.5	0.96	79	5.4	0.5	0.9	87	4.36	0.51	0.91	81	4.53	0.51	0.9
34. Vertical grip reach (standing)	206	10.5	1.2	1.69	187	9.1	1.2	1.6	207	7.74	1.21	1.61	188	8.07	1.19	1.6
35. Vertical grip reach (sitting)	123	7.9	0.71	1.27	113	7.2	0.7	1.3	123	5.18	0.72	1.08	116	10.3	0.73	2.03
36. Forward grip reach	73	5.89	0.42	0.94	67	4.4	0.4	0.8	74	4.7	0.43	0.98	67	4.76	0.43	0.94

Table 9
Comparison of E_1 and E_2 coefficients between previous (old) and current (new) studies of Singapore citizen anthropometry.

Body dimension	Old data for male				New data for male		Diff* (%)	Old data for female				New data for female		Diff** (%)
	Mean	SD	E_1	E_2	E_1	E_2		Mean	SD	E_1	E_2	E_1	E_2	
1. Stature	169	6.2	1	1	1	1	–	155	5.8	1	1	1	1	–
2. Eye height	158	6.3	0.9	1	0.936	0.973	0.08	144	5.6	0.9	1	0.926	1	0.38
3. Knuckel height	78	5.2	0.5	0.8	0.432	0.626	**6.48**	74	5.5	0.5	0.9	0.438	0.514	**8.24**
4. Sitting height	87	4.1	0.5	0.7	0.517	0.663	0.94	80	4.5	0.5	0.8	0.527	0.889	1.6
5. Sitting eye height	75	4.4	0.4	0.7	0.445	0.819	0.77	70	4.5	0.5	0.8	0.457	0.935	1.24
6. Sitting shoulder height	58	4.7	0.3	0.8	0.349	0.646	1.12	55	3.9	0.4	0.7	0.357	0.553	1.39
7. Sitting elbow height	23	3.6	0.1	0.6	0.139	1.184	2.19	23	3.3	0.1	0.6	0.154	0.632	**5.47**
8. Thigh thickness	14	2.6	0.1	0.4	0.087	0.347	**5.45**	14	3.9	0.1	0.7	0.088	0.315	0.01
9. Buttock-knee length	56	3.4	0.3	0.6	0.328	0.551	0.96	54	3.9	0.3	0.7	0.335	0.512	3.88
10. Buttock-popliteal length	45	3.6	0.3	0.6	0.265	0.636	0.5	44	3.9	0.3	0.7	0.279	0.502	1.62
11. Knee height	54	3.3	0.3	0.5	0.31	0.567	2.51	49	4.4	0.3	0.8	0.3	0.494	4.23
12. Popliteal height	43	3.4	0.3	0.5	0.248	0.616	2.42	40	4.2	0.3	0.7	0.248	0.349	3.75
13. Shoulder breadth (bideltoid)	43	2.8	0.3	0.4	0.256	0.382	0.63	38	2.8	0.2	0.5	0.248	0.506	2.66
14. Hip breadth	34	3.9	0.2	0.6	0.2	0.387	0.6	35	3.6	0.2	0.6	0.215	0.661	4.78
15. Chest (bust) depth	21	3	0.1	0.5	0.118	0.424	4.72	22	2.9	0.1	0.5	0.139	0.531	0.22
16. Abdominal depth	20	3	0.1	0.5	0.126	0.513	**6.31**	20	4.1	0.1	0.7	0.124	0.485	4.23
17. Elbow-fingertip length	45	2.7	0.3	0.4	0.268	0.467	0.69	41	3	0.3	0.5	0.263	0.303	0.73
18. Head length	20	1.5	0.1	0.2	0.11	0.199	**6.76**	19	1.6	0.1	0.3	0.111	0.126	**10.72**
19. Head breadth	16	1.4	0.1	0.2	0.095	0.192	0.14	16	1.8	0.1	0.3	0.099	0.137	2.4
20. Hand length	19	1	0.1	0.2	0.109	0.645	0.25	17	1	0.1	0.2	0.105	0.149	4.23
21. Hand breadth	8	0.7	0	0.1	0.049	0.112	3.2	7	0.6	0	0.1	0.046	0.169	0.19
22. Foot length	25	1.3	0.1	0.2	0.149	0.271	1.22	23	1.3	0.1	0.2	0.14	0.22	1.7
23. Foot breadth	10	0.7	0.1	0.1	0.058	0.102	2.19	9	0.7	0.1	0.1	0.055	0.1	**5.3**
Diff average							2.28							3.14

*E_1 difference $= \{|(E_1 \text{ old} - E_1 \text{ new})/E_1 \text{ old}|\} \times 100\%$ for male; **E_1 difference $= \{|(E_1 \text{ old} - E_1 \text{ new})/E_1 \text{ old}|\} \times 100\%$ for female.

age, and the full-grown state has been reached at an earlier age (Wall, 1993).

In comparing the past and current anthropometric data of Singaporean adults, it is not surprising to find many dimensions significantly different (refer to Table 5). The results indicate that current Singapore citizens (both male and female) are larger than those in the 1990s. Some significant dimensions include stature, eye height, knuckle height, sitting height, and weight. The average stature has increased by 50 mm for male and 68.5 mm for female in Singapore over the last 19 years. More than 50 percent of the dimensions are significantly different (20 out of 24 for male; 17 out of 24 for female). Again, the factors of nutrition, disease, socio-economic status, urbanization, physical activity, climate, and psychosocial deprivation, all contribute to the growth of body dimensions (Wall, 1993).

Based on the results of the BMI calculation, both Singaporeans and Indonesians for all sub-groups, have healthy body weights. Compared to the previous study of Singaporean anthropometric data, the current study indicate that the Singaporean sample (both male and female) has gained more weight, as evidenced by their higher BMI and stature.

The comparison of ratio E_1 between the existing and current Singapore citizen anthropometric data (both male and female) showed that there is relatively no difference. It is indicated by the small difference in the averages (i.e., 2.28 percent for males, 3.14 percent for females). Essentially, this finding may be utilized as a reference population to compare against another population (e.g., compare Singapore Chinese to Malays, Indians, etc). The utilization of this method was shown by İşeri and Arslan (2009) who estimated Turkish adult anthropometric data. They had to assume that the body ratios of the Turkish people have not changed for the past 45 years.

In conclusion, the Singaporean sample is significantly different from the Indonesian sample in various body dimensions. In general, Singaporeans have larger dimensions than Indonesians. The current Singaporean sample is also significantly larger than past Singaporeans. Geographical origin, nutrition, social status, and ethnic composition of populations are some general factors influencing the distribution of anthropometric characteristics. Hence, a regular updating of anthropometric data is required. These could be used as relevant consideration in system design when there is a need to deal with human anthropometric variability.

Since there are significant increases in certain body dimensions with time due to changes in dietary habits, nutrition, and socio-economic status etc as mentioned by Wall (1993), it implies that the human body dimensions (e.g. stature and body weight) can be predicted in the near future by proposing a mathematical modeling (e.g. a linear regression model of certain human body dimension which taking 'time' as an independent variable). In addition to that, it is essential to provide adjustable equipment/facilities in order to achieve comfort and proper posture. Some examples concerned with adjustability are: (i) Building a prototype of an adjustable table and chair for schools (Jung, 2005), (ii) An adjustable vice mount (Boussena and Davies, 1989), (iii) Redesigning a hospital meal cart by incorporating ergonomic principles and data (Das et al., 2002). Besides, in the future, the apparel industry can be considered as a very dramatic phenomenon due to changes in the size of the human body dimensions. For example, the current small (S), medium (M), and large (L) sizes could not be applied as a benchmark for mass production in the future; these will certainly evolve.

However, this study is far from complete. The time and resource constraints were limiting factors. Further research and the collection of more data are necessary.

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