Determination of the significant anthropometry dimensions for user-friendly designs of domestic furniture and appliances – Experience from a study in Malaysia

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ABSTRACT

Future design for the elderly is undoubtedly important for their survival to live independently in this challenging world. Therefore to realize the mentioned design, an anthropometric database for Malaysian elderly population need to be developed. A total of 107 participants took part in the study which involved 61 females and 46 males with ages ranging between 55 and 70 years. An earlier anthropometric database for Malaysian elderly population has been developed. Sixty body dimensions were measured in the study. It is hoped that from this study, the database can be used as a guideline in designing household facilities for the Malaysian elderly and elderly of other countries. The design of the household facilities should be influenced by sound ergonomics dimensions in order to create a safe and healthy environment for the elderly.

1. Introduction

At present, life span for people all over the world are longer compared to previous decades due to improvement in the medical technologies and efficient health care system [1]. The definition of 'elderly' or 'senior citizen' according to the United Nations World Assembly on Ageing used '60 years and over' as the cut-off in deliberating ageing trends which has been adopted by Malaysian policy makers in planning for senior citizens. In Malaysia, the statistics of the elderly citizens in 2009 is about 2.03 million, which represent 7.1% of the total population and the percentage is predicted to rise to 9.8% in 2020 [2,3]. Additionally, according to the Ageing Workforce™ 2006 Report [4], Asia Pacific will be home to most of the world's elderly people with 998 million people aged 60 and above by 2050 especially in Asia's most develop countries. For example, the proportion of the population over age 50 in Singapore is set to increase from 23% to 50% over the next 25 years.

This trend is similar to the US population where the percentages of the elderly citizens depute 13% of the entire population in 2010 and is believed to increase to almost 23% by June 2050 as reported by Intergenerational Report, 2010. The same trend of higher growth in most developing world is a result of successful efforts to lower fertility levels and increase longevity [3]. This phenomenon is also influenced by the transformation in socioeconomics. In order to maintain a high standard of living, elderly people are being made to be economically useful. In addition, the practices of healthy lifestyle among the elderly today, for instance, balanced diet, exercise regularly, fitness programs and so on contribute in making them to remain

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physically fit to continue in services which require less physical strength.

The increasing number of older people in the population points to the need for concerted research efforts within the area of human factor design and aging. The elderly needs an environment and facilities to support their needs within their limitations and abilities to be independently performing their regular everyday life chores comfortably and safely [5–12]. Thus due to the above reasons, it is important to develop a significant anthropometric database to realize the future facilities design for the elderly. This study was conducted among the Malaysian population. However, the data collected and the findings can are also useful for other countries.

2. Material and methods

2.1. Participants

One-hundred-and-seven participants took part in the study which involved 61 female and 46 male. All participants were in good health and have no problem with normal mobility.

2.2. Measuring apparatus

Standard professional anthropometer, sliding caliper, spreading caliper and a measuring tape were used in the data collection sessions.

2.3. Selection of body dimensions

The selection of the anthropometry body dimensions was considered according to their significance and usefulness for the development of designing the elderly housing facilities and safety. It includes 61 body dimensions and the dimensions were made according to Pheasant [13]. To facilitate the measurements, participants were requested to wear light clothing. Table 1 presents the list of body dimensions taken and Fig. 1 illustrates the body diagrams.

2.4. Statistical analysis

The 5th percentile, 95th percentile, mean (M), standard deviation (SD) and coefficient of variation (CV) of the elderly anthropometric dimensions were calculated. According to Pheasant [13] the 5th percentile is essential in determining the reachability and limitation for household facilities. The 95th percentile is used to ensure adequate clearance to avoid unwanted contact or trapping. The coefficient of variance (CV) measures the precision of the participants' anthropometry dimensions taken during the measurement.

3. Results and discussion

Table 2 presents the anthropometric dimensions for male and female elderly aged above 55 years. In this study, it is noted that there are several measurements that cannot be measured accurately due to physical weakness and disability to perform in certain required postures. Consequently, there are few standard deviations for the anthropometry dimensions which are considerably large e.g. the arm reach upward for male which is 34.11 and for female which is 22.57 cm.

3.1. Facilities design

In order to design the household facilities for the elderly the 5th and 95th percentile value of the anthropometry dimensions were selected. The continuous growth of the number of the aged people has created a big market of health care and living products [14]. Due to that, anthropometry dimensions obtained in this research study are important in order to provide the older Malaysian people to live independently. One of the most important aspects of design is that they have one or more illnesses and have movement or function difficulties [15]. Many household facilities can be designed to ease the elder people in their daily activities such as the washing machine facility, toilet and shower tools, stove, cooking utensils and facility and also storage placement [16] which could create comfort and satisfaction to the living environment [17].

Most of the daily activities require a standing posture and a study stature is one of the most important anthropo-

Table 1
Significant anthropometric body dimensions of Malaysian elderly.

Anthropometric dimension				
1. Weight	14. Back waist length	27. Sitting shoulder height	40. Waist circumference	53. Face breadth
2. Stature	15. Sleeve inseam	28. Sitting elbow height	41. Hip circumference	54. Hand length
3. Standing eye height	16. Shoulder breadth	29. Knee height	42. Crotch thigh circumference	55. Palm length
4. Standing shoulder height	17. Hip breadth, sitting	30. Popliteal height	43. Lower thigh circumference	56. Hand breadth
5. Standing elbow height	18. Forearm-hand length	31. Head circumference	44. Calf circumference	57. Foot length
6. Waist height	19. Buttock-knee length	32. Neck circumference	45. Ankle circumference	58. Instep length
7. Crotch height	20. Buttock-popliteal length	33. Shoulder circumference	46. Ball Foot circumference	59. Foot breadth
8. Kneecap height	21. Shoulder-elbow length	34. Upper arm circumference	47. Heel-ankle circumference	60. Heel breadth
9. Coat height, standing	22. Thigh clearance	35. Wrist circumference	48. Head length	61. Foot height
10. Span	23. Arm reach forward	36. Thumb circumference	49. Head breadth	
11. Elbow span	24. Arm reach upward	37. Index finger circumference	50. Head height	
12. Hip breadth, standing	25. Sitting height	38. Middle finger circumference	51. Face length	
13. Interscye breadth	26. Sitting eye height	39. Chest circumference	52. Interpupillary distance	

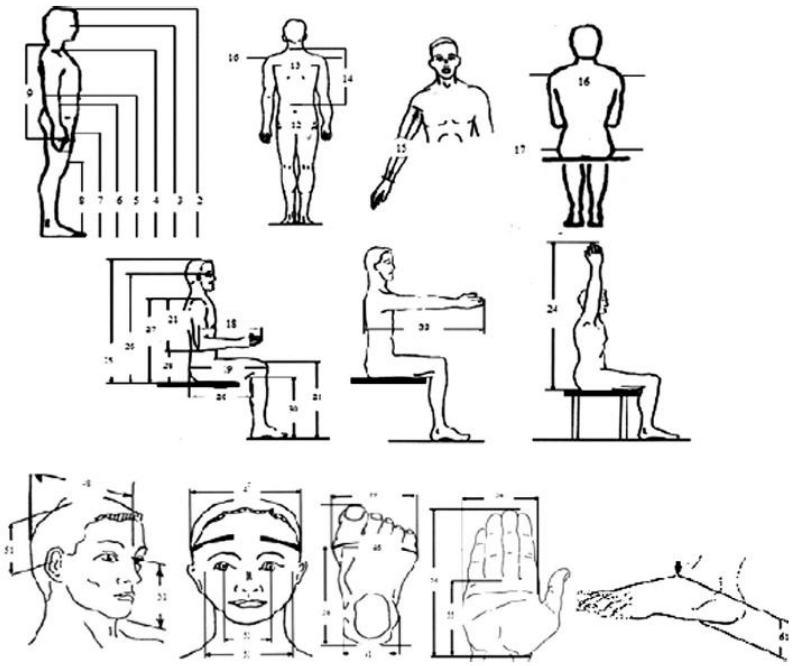

Fig. 1. Anthropometric dimensions *Source:* Pheasant [13].

metric characteristics affected by ageing [1]. According to Ranzijn [18] the extent of personal accommodation to the environment determines the quality of life of the older people. In line with that most of the items should be stored between the knuckle and shoulder height so that elderly users are not subjected to bending and over-reaching demands [19,20].

Due to that, with the aid of new technology safe household facilities such as storage shelf, door, lavatory dimensions including hand basin and water faucet should be designed. In the kitchen or in the toilet, shower facility and switch can be designed to meet the safe and comfortable home environment for the elderly. Table 3 shows the list of the set values used for designing household facilities for the elderly. The dimension values stated in Table 3 are based on the appropriate percentiles. These chosen values will produce household features which are inclusive of the smallest to the largest dimensions of the studied population. While for standing arm reach upward, the dimension value is taken from Rashid et al. [4]. Table 4 shows the implication of standing anthropometry dimensions with the design.

The recommended dimension is the reference optimum dimension for the elderly household design to provide a safe and independent environment. Besides, it helps to promote a good posture to avoid musculoskeletal disorder among the elderly. In addition, the elderly use a minimum ability in muscular strength and joint mobility due to the ageing process. In line with that the elderly may have problems in reaching such as for shelf storage. Table 5 presents the recommended anthropometry dimensions for shelf design implicating reachability.

3.2. Sitting anthropometry dimension implication to the elderly household

Older people usually remain seated for a large amount of time in their accommodation every day. Static posture and prolonged sitting in a forward bending position, as elderly often acquire, puts an extreme physiological strain on the muscles, the ligaments and in particular on the discs [14]. Table 6 presents the recommended dimensions for the sitting anthropometry dimension implication.

The sitting anthropometry dimensions could also be used in designing a computer workstation for the elderly. The development provides a proper working in home environment for the elderly. All considerations will concern with the reduction or elimination of physical disorders associated with poor ergonomics design known as Musculoskeletal Stress Disorders (MSD's), which result in eye, neck and back strain, fatigue, headache, wrist, hand, elbow and shoulder diseases and Carpal Tunnel Syndrome [20]. A good posture in computer workstation helps overcome the musculoskeletal disorder problem especially for the elderly. Table 7 presents the recommended dimensions for the computer workstation for elderly.

Table 2
Anthropometric dimensions of Malaysian elderly age 55 years and above.

Dimension		Male (N = 46)					Female (N = 61)				
		M	SD	CV (%)	5th	95th	M	SD	CV (%)	5th	95th
1	Weight	75.05	15.13	20.16	52.50	99.50	62.10	14.71	23.69	32.71	85.20
2	Stature	157.8	8.60	5.45	144.6	169.95	145.4	18.91	13.00	134.97	160.39
3	Standing eye height	146.2	8.75	5.98	131.4	158.27	135.6	7.82	5.77	122.98	147.22
4	Standing shoulder height	131.8	7.76	5.88	117.1	142.15	119.5	15.40	12.89	109.62	130.37
5	Standing elbow height	100.2	5.91	5.90	90.28	108.36	94.27	13.86	14.70	83.00	104.15
6	Waist height	92.37	4.74	5.13	84.16	98.26	87.79	6.79	7.73	78.00	97.80
7	Crotch height	71.29	4.94	6.93	62.48	78.37	68.12	6.15	9.03	57.50	78.01
8	Kneecap height	43.59	3.19	7.32	39.02	49.86	43.49	6.41	14.74	35.29	53.43
9	Coat height, standing	67.12	7.56	11.26	57.98	81.11	61.01	5.38	8.82	51.99	71.61
10	Span	159.6	18.16	11.38	142.5	177.73	147.3	13.61	9.24	129.63	163.58
11	Elbow span	83.24	6.67	8.01	74.81	91.60	77.10	13.91	18.04	62.26	89.51
12	Hip breadth, standing	32.78	2.59	7.90	29.18	37.44	32.63	3.55	10.88	27.41	38.22
13	Interscye breadth	31.34	3.38	10.78	27.40	36.31	28.64	2.73	9.53	23.97	32.24
14	Back waist length	46.22	4.42	9.56	38.38	53.88	40.33	3.90	9.67	34.49	47.35
15	Sleeve inseam	50.25	4.52	9.00	40.84	55.89	46.29	4.43	9.57	38.35	52.41
16	Shoulder breadth	42.29	4.45	10.52	35.18	49.14	39.76	4.08	10.26	31.98	45.01
17	Hip breadth, sitting	37.15	6.35	17.09	29.06	51.93	36.59	5.24	14.32	29.70	47.00
18	Forearm-hand length	44.70	2.82	6.31	40.35	49.02	41.95	2.70	6.44	36.50	45.13
19	Buttock-knee length	53.01	3.30	6.23	47.17	57.47	50.68	5.24	10.34	40.40	56.03
20	Buttock-popliteal length	43.24	3.40	7.86	37.06	49.00	41.90	4.03	9.62	36.60	48.13
21	Shoulder-elbow length	34.66	2.44	7.04	30.59	37.49	32.21	3.14	9.75	28.60	36.21
22	Thigh clearance	12.05	2.25	18.67	9.19	16.61	12.07	3.89	32.23	8.00	17.4
23	Arm reach forward	78.59	8.30	10.56	71.15	85.69	73.44	11.48	15.63	66.00	80.00
24	Arm reach upward	111.9	34.11	30.48	39.48	131.75	105.1	22.57	21.46	39.10	121.03
25	Sitting height	88.79	12.15	13.68	77.59	117.91	79.20	10.05	12.69	68.80	105.43
26	Sitting eye height	72.05	8.07	11.20	60.16	81.10	66.62	6.01	9.02	58.00	79.04
27	Sitting shoulder height	62.29	14.44	23.18	52.08	78.85	56.67	13.33	23.52	45.48	94.23
28	Sitting elbow height	32.25	15.10	46.82	19.50	63.02	32.62	17.14	52.54	19.20	69.54
29	Knee height	46.83	10.52	22.46	21.71	54.39	46.68	7.74	16.58	25.30	52.34
30	Popliteal height	44.27	3.89	8.79	40.00	52.82	42.18	3.64	8.63	38.20	48.80
31	Head circumference	55.09	1.44	2.61	53.05	57.00	55.16	2.57	4.66	51.00	59.36
32	Neck circumference	40.19	5.09	12.66	33.10	47.9	37.31	5.19	13.91	30.03	46.9
33	Shoulder circumference	107.9	8.85	8.20	96.03	120.00	99.03	8.53	8.61	84.10	114.28
34	Upper arm circumference	30.51	4.60	15.08	24.00	38.80	30.45	5.79	19.01	22.03	39.95
35	Wrist circumference	16.83	1.49	8.85	15.00	19.27	15.75	1.56	9.90	13.51	18.00
36	Thumb circumference	6.51	4.92	75.58	5.50	7.50	6.20	0.51	8.23	5.50	7.00
37	Index finger circumference	5.85	0.69	11.79	5.00	6.80	5.53	0.68	12.30	4.50	6.79
38	Middle finger circumference	5.91	0.61	10.32	5.00	6.70	5.49	0.63	11.48	4.50	6.50
39	Chest Circumference	92.05	16.07	17.46	79.25	111.18	93.20	15.9	17.06	43.99	111.90
40	Waist circumference	93.66	13.34	14.24	72.65	115.62	92.16	12.84	13.93	67.62	106.99
41	Hip circumference	100.8	12.2	12.10	83.10	123.58	100.8	11.89	11.79	72.81	126.09
42	Crotch thigh circumference	52.49	7.92	15.09	41.03	64.00	50.84	7.69	15.13	40.02	61.95
43	Lower thigh circumference	40.95	6.63	16.19	31.82	53.60	41.38	6.85	16.55	33.00	52.00
44	Calf circumference	33.84	4.39	12.97	27.50	40.00	32.77	4.87	14.86	26.03	40.71
45	Ankle circumference	28.23	31.13	110.2	19.10	27.95	22.05	2.59	11.75	18.72	26.00
46	Ball foot circumference	24.4	2.01	8.24	21.55	27.00	22.51	2.44	10.84	17.61	27.68
47	Heel-ankle circumference	31.24	3.10	9.92	26.55	35.95	29.25	2.46	8.41	25.52	33.00
48	Head length	17.34	0.77	4.44	16.20	18.50	17.04	0.84	4.93	15.81	18.30
49	Head breadth	15.07	0.84	5.57	13.58	16.28	16.28	12.77	78.44	13.60	15.60
50	Head height	14.38	1.30	9.04	12.40	16.20	13.47	1.32	9.80	10.84	15.29
51	Face length	11.72	1.26	10.75	9.78	13.48	12.00	10.8	90.00	8.31	13.00
52	Interpupillary distance	6.71	2.15	32.04	5.00	10.65	6.24	0.70	11.22	5.01	7.49
53	Face breadth	12.79	1.50	11.73	10.70	14.58	11.85	1.43	12.07	9.71	13.60
54	Hand length	17.02	2.21	12.98	12.85	19.35	16.30	1.17	7.18	15.11	17.70
55	Palm length	10.19	2.28	22.37	8.93	11.18	9.16	0.60	6.55	8.11	10.00
56	Hand breadth	7.99	0.73	9.14	7.03	8.75	7.28	0.48	6.59	6.70	7.80
57	Foot length	23.74	1.29	5.43	21.70	25.80	21.66	2.85	13.16	19.52	24.10
58	Instep length	16.89	2.21	13.08	13.48	19.90	16.29	1.47	9.02	13.33	18.80
59	Foot breadth	9.48	0.86	9.07	8.05	10.95	10.10	10.17	100.69	7.70	10.30
60	Heel breadth	6.13	0.55	8.97	5.18	7.00	5.81	1.47	25.30	4.50	6.99
61	Foot height	6.92	1.57	22.69	5.04	9.96	6.62	1.98	29.91	4.80	9.98

Note: All dimensions are in cm.

Table 3
Body dimension values used for household design purposes.

Body dimensions	Male/female percentile	Dimension (cm)
Stature	Minimum, female 5th	134.97
	Maximum, Male 95th	169.95
Eye height, standing	Female 5th	122.98
Shoulder height, standing	Female 50th	119.51
Elbow height, standing	Female 5th	83.00
Waist height, standing	Female 5th	78.00
Span	Male 95th	177.73
Arm reach upward, standing	Female 5th	149.88
Arm reach forward, standing	Female 5th	6.60
Sitting height	Male 95th	117.91
Shoulder height, sitting	Female 50th	56.67
Shoulder elbow length sitting	Female 50th	32.21
Elbow height, sitting	Female 5th	19.20
Popliteal height sitting	Female 5th	38.20
Hip breadth, sitting	Female 95th	47.00
Arm reach upward sitting	Female 5th	39.10
Arm reach forward, sitting	Female 5th	6.60
Shoulder breadth	Male 95th	49.14
Elbow span	Male 95th	91.60
Forearm hand length	Female 5th	36.50
Buttock-popliteal length	Male 95th	49.00

Table 4
Standing anthropometry dimension implication for elderly household.

Type of household	Design criteria	Recommended dimension (cm)
Storage shelf	Shoulder height from floor, 5th percentile female with a 20° (maximum) joint flexion	117.19
Storage shelf (visual required)	Standing eye height from floor, 5th percentile female	131.48
Door height	Stature, 95th percentile male (minimum)	160.39
Door knob height	Standing elbow height, 5th percentile female	90.28
Peephole height	Standing eye height, 50th percentile female	146.26
Hand basin height	10 cm below standing elbow height, 5th percentile female	80.28
Water faucet	5 cm below standing elbow height, 5th percentile female	85.28
Shower head	Standing stature, 95th male, 10 cm clearance	170.39
Shower knob	In line with shower head, standing elbow, height 5th percentile female	90.28
Switches	Standing shoulder height of 5th percentile female	117.19
Vertical handrail (standing aid)	Elbow height (minimum), 5th percentile male Shoulder height (maximum), 95th percentile male	Minimum = 90.28 maximum = 130.37

Table 5
Standing anthropometry dimension implication for the elderly household.

Type of household	Design criteria	Recommended dimension (cm)
Optimal height surface of shelf	Standing Upward reach, 50th percentile	111.9

Table 6
Sitting anthropometry dimension implication for the elderly household.

Type of household	Design criteria	Recommended dimension (cm)
Chair, Toilet bowl chair	Sitting popliteal height, 5th percentile male	40
Toilet flush placement	Sitting shoulder, 5th percentile female	52.08
Table	Sitting elbow height, 95th percentile female	49.5
Bed	Sitting height, 5th percentile female	77.59
Horizontal handrails (walking aid)	Sitting elbow height, 5th percentile female	19.5

Table 7
Anthropometry dimension implication in computer workstation.

Type of household	Design criteria	Recommended dimension (cm)
Table height	Sitting elbow height, 95th percentile female	49.5
Chair height	Popliteal height, 5th percentile female (seat slightly higher to allow elderly to stand up and sit down unassisted)	40
Seat depth	Buttock-popliteal length, 5th percentile female	37.06
Seat width	Hip breadth, 95th percentile female	37.44
Back-rest height above the seat	Shoulder height, 95th percentile female	78.85
Arm-rest height above the seat	Sitting elbow height, 5th percentile female	19.5
Keyboard height	Sitting elbow height, 5th percentile female	19.5
Monitor height	Sitting eye height, 50th percentile female	72.05

3.3. Recommended guidelines for designing basic fixtures in the households of older Malaysian

The need to design home that fits for the elderly based on the anthropometry is important. This fact relies on several reasons, for instance, the designed home enables ageing people to better adapt to their environment, and provides an integrated strategy for well-being and satisfaction when ageing [15]. Another significant reason is to enable them to live independently in their own homes. Apart from cognitive aspect, the physical independence is also crucial, so they need to consistently concern about their health. However, unintentional injuries are the uncontrollable events. Among older people, falls are the most common accidental injuries which occur at home. Several studies have concluded that the most common sites for falls to occur are at the bathrooms, lavatories, and kitchens [2,8]. These findings are concurrent to the studies by other researchers [1,4,10,15] which showed that older people spent most of their times at these particular areas for their activity of daily lives (ADL). With regard to the mentioned problem, this study proposed the guidelines

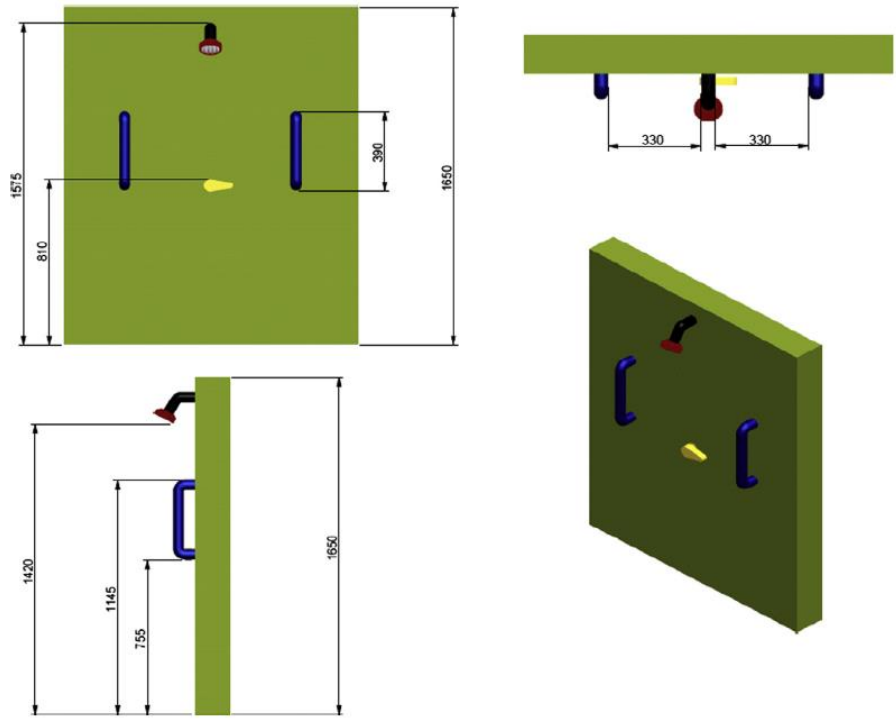

Fig. 2. 5th percentiles female (all in mm).

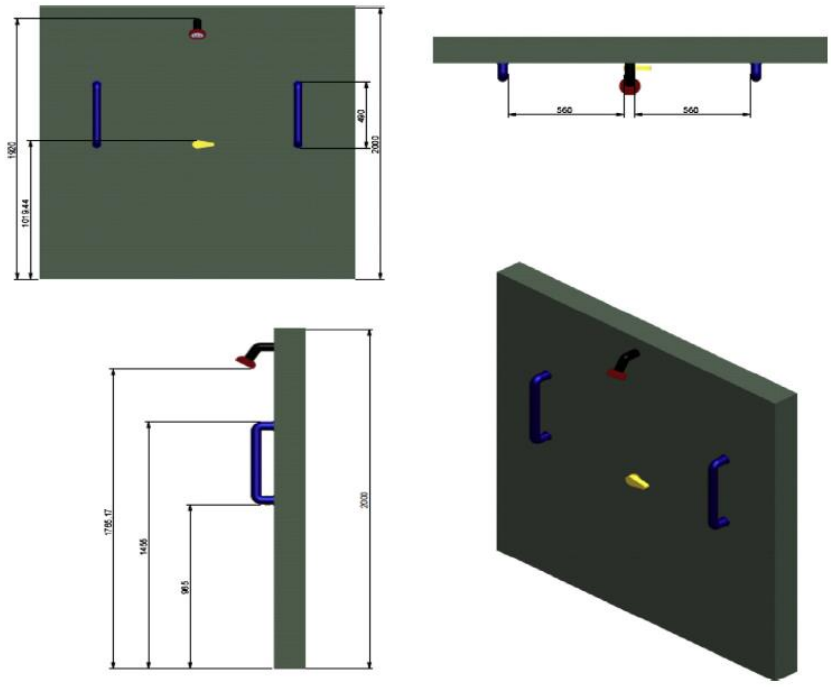

Fig. 3. 95th percale male (all in mm).

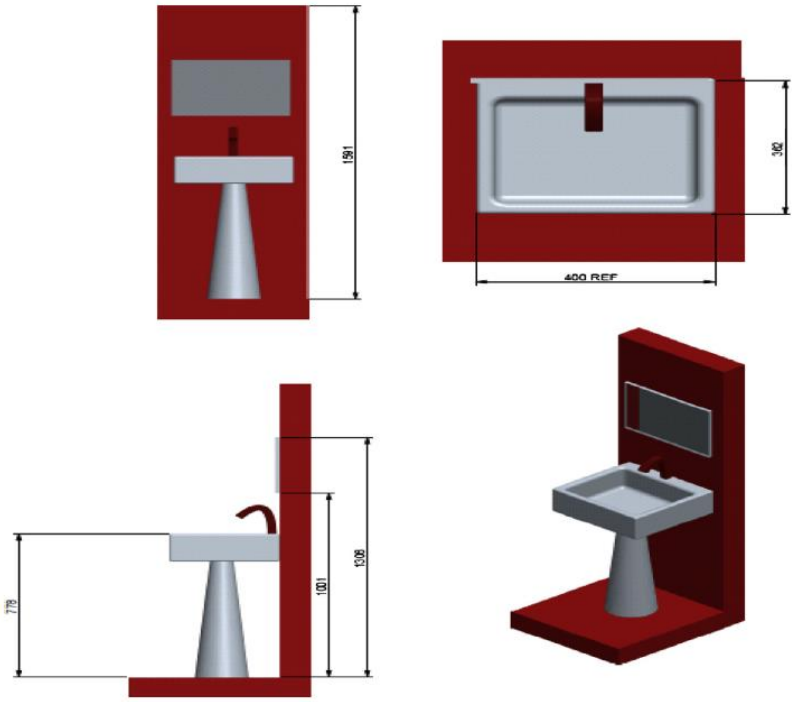

Fig. 4. 5th percentiles female (all in mm).

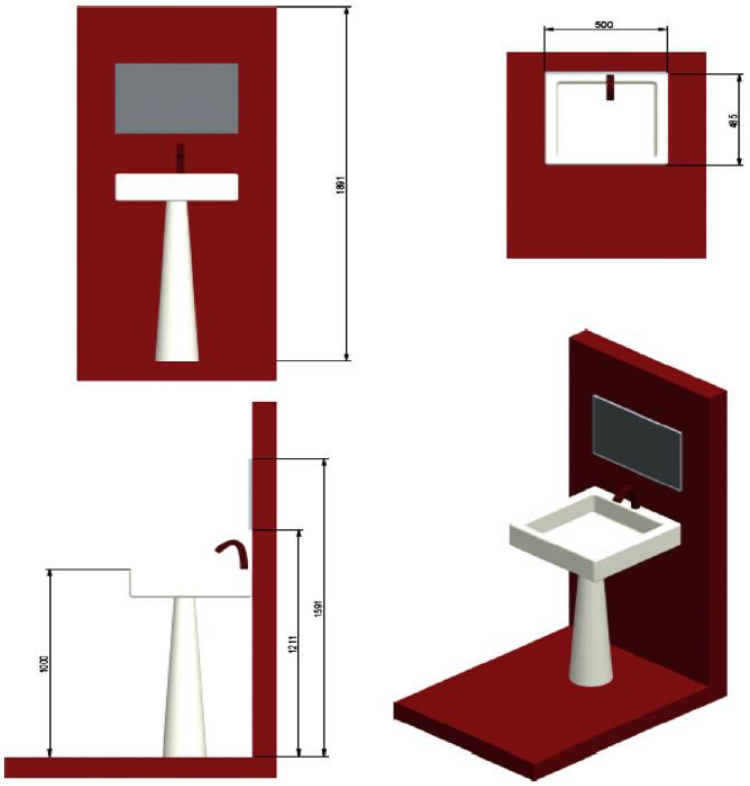

Fig. 5. 95th percentile male (all in mm).

for designing bathrooms, lavatories, and kitchens based on the anthropometry of Malaysian elderly.

3.4. Recommended guidelines for designing basic bathrooms of the older Malaysian

The recommended guidelines for the bathroom areas included shower, toilet and hand basin area. The essential features for this area are wider doors; grab bars in shower and toilet, curbless shower, lever-style door handles and faucets, toilet with no-slam lids, wall-mounted sinks and wheelchair clearance for the disabled elderly. The bathroom design is shown in Figs. 3 and 4. The dimensions of the bathroom area are 8 ft 6 in. × 8 ft. This is to allow wheelchair clearance for the disabled elderly. The width for the shower area needs to cover the elbowroom including clearance which is 95th percentile male (92 cm + 20 cm = 112 cm) and 5th female (62.60 cm + 20 cm = 82.60 cm). The optimum height for the fixed showerhead should be sufficient to accommodate stature height including clearance. For 95th percentile male should cover 180 cm (170 + 10 = 180 cm) and 5th percentile female 145 cm (135 cm + 10 cm. A single water controller is located in line with the showerhead and its height is at the standing waist height. For 95th percentile male 96.5 cm and 5th percentile female is 75.5 cm. The vertical handrail is placed in the shower area for balancing while bathing with the minimum waist height for 95th female is 96.5 cm from the floor and 5th percentile female 75.5 cm from the floor. The design for hand basin, shower and toilet are shown in figure. The lavatories area included a toilet seat, handrails and tissue holder. The toilet seat height is similar to the chair seat height should cover popliteal height, which is discussed in Section 2 (B), 5th percentile female is 38.0 cm and 95th percentile male is 52.8 cm. The water hose is located on the right-hand side and the single-lever water control is at the sitting elbow height for both percentiles. The maximum horizontal distance is calculated using the method proposed by [21] which is using Pythagoras' theorem. The designs for bathroom, toilet and hand basin are shown in Figs. 2–7 below.

3.5. Recommended guidelines for designing basic kitchen for the older Malaysian

To design of cabinet kitchen for the elderly should consider the kitchen space, the features at the cabinet and the height and size of the cabinet drawer. These considerations are needed to make sure the elderly's activities in kitchen are made easier. The essential features for this area include

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