Designing homes for the elderly based on the anthropometry of older Malaysians

ORIGINAL ARTICLE

SNSA Rashid[1] Ph.D, APPM, **MR Hussain**[1] B.Sc, **RM Yusuff**[2] Ph.D

[1] Institute of Gerontology, Universiti Putra Malaysia, Selangor, Malaysia
[2] Faculty of Engineering, Universiti Putra Malaysia, Selangor, Malaysia

ABSTRACT

Objective. To provide guidelines for ergonomically designed living environments for older Malaysians.

Method. The designs of 10 publicly funded welfare homes for the elderly were collected through observations, measurements and interviews. Anthropometric measurements of older Malaysians were taken; 24 body dimensions were applicable to designing an ergonomic living environment. Computer-aided engineering software was used to validate the extent to which the designs of the present fixtures and facilities match the anthropometric measurements of older Malaysians.

Results. The designs of all 10 homes did not take the anthropometric measurements of older Malaysians into account and may therefore cause discomfort.

Conclusion. Elderly people should be provided with specifically designed facilities to meet their physical and cognitive strengths, capabilities and limitations, and to match their body dimensions.

Key words: Aged; Anthropometry; Housing for the elderly; Human engineering; Malaysia

Correspondence to: Dr Sharifah Norazizan Syed Abd. Rashid, Gerontechnology Laboratory, Institute of Gerontology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia. E-mail: sharifah@putra.upm.edu.my

INTRODUCTION

In Malaysia, the older population (over 60 years of age) has doubled in the past two decades to almost 1.4 million in 2000. By 2020, this number is expected to grow to more than 3.4 million.[1] Special facilities must be provided to enable elderly people to live independently. Use of the ergonomics approach[2,3] and gerontechnology[4] enables ageing people to better adapt to their environment, and provides an integrated strategy for well being and satisfaction when ageing. Anthropometry is essential for designing safe products best suited to their users,[5,6] including designing products for older people, tooling aids, living facilities, ergonomically designed facilities such as storage shelves, kitchens, bedrooms, furniture and work stations.

This paper aims to provide guidelines for designing living places with ergonomically designed fixtures, facilities and spaces for older Malaysians in publicly funded welfare homes. This will assist designers to plan and design accessible living environments better suited to the elderly residents.

METHODOLOGY

Publicly funded welfare homes in Malaysia

This study was conducted in 10 publicly funded welfare homes (also known as rumah seri kenangan) in Malaysia, under the supervision of the Malaysian Social Welfare Department (**Table 1**). Data were collected through observations, measurements and interviews about the structures, fixtures, facilities and spaces of the homes. Observations were made to determine the design and suitability of interior (bathrooms, toilets and bedrooms) and exterior (corridors, ramps, handrails) facilities. Measurements of facilities were collected for comparison with the

Table 1
List of publicly funded welfare homes included in the study

No.	Publicly funded welfare homes	Locations	Year Established
1	Kompleks BAKTI Sungai Buloh	Sungai Buloh, Selangor	1998
2	Rumah Seri Kenangan Cheng	KM 12, Paya Rumput, Cheng, Melaka	1971
3	Rumah Seri Kenangan Seremban	Jalan Har Hui Foong, Seremban, N. Sembilan	1958
4	Rumah Seri Kenangan Johor Bahru	Kg. Ungku Mohsin, Johor Bahru, Johor	1969
5	Rumah Seri Kenangan Taiping	Jalan Stesen Ulu, Taiping, Perak	1950
6	Rumah Seri Kenangan Bedong	Jalan Sameling, Bedong, Kedah	1952
7	Rumah Seri Kenangan Arau	Kompleks Penyayang Dr. Siti Hasmah, Kg. Jejawi, Hutan Buloh, Arau, Perlis	1997
8	Rumah Seri Kenangan Kemumin	Taman Kemumin, Pengkalan Chepa, Kota Baharu, Kelantan	1951
9	Rumah Seri Kenangan Kuching	Batu 12, Jalan Kuching/ Serian, Kuching, Sarawak	1932
10	Rumah Warga Tua Sri Harapan	Sandakan, Sabah	1997

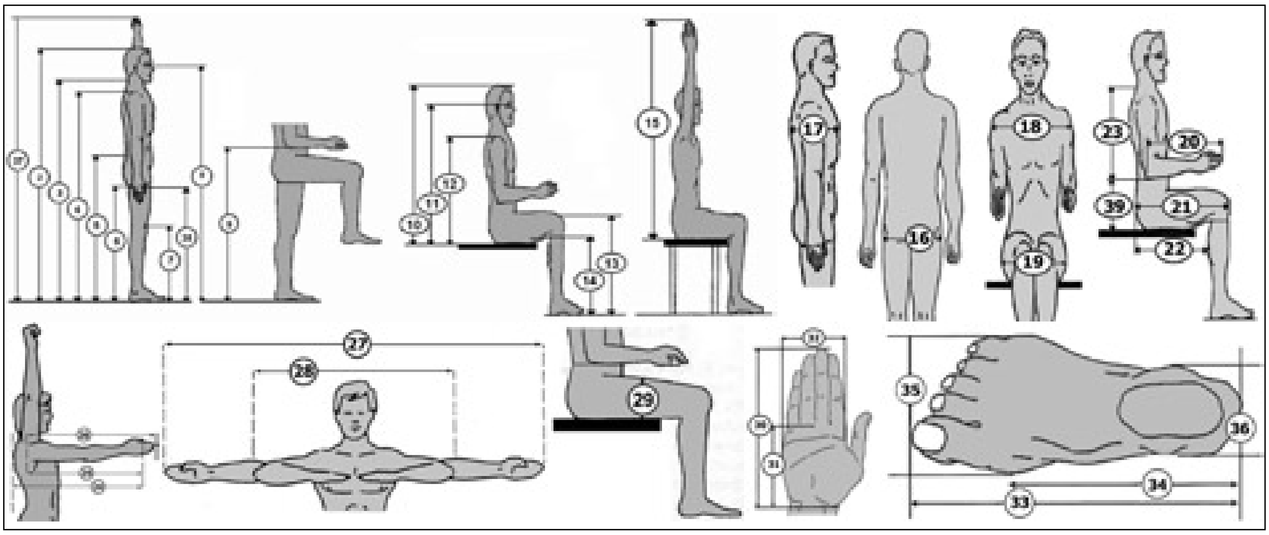

Figure 1. Anthropometric dimensions

anthropometric measurements of older Malaysians. Interviews were conducted with administrative and management staff for background information.

Anthropometry of older Malaysians

The anthropometric measurements of older Malaysians were drawn from a previous study done in 2003, in which 39 body dimensions (**Figure 1 and Table 2**) were measured on 230 respondents aged 60 years and older,[7] using the standard body measurement procedures.[8] Only 24 body dimensions were applicable to designing an ergonomic living environment for older persons.

To accommodate for the variation in the older population, the 5th or 95th percentile value for each anthropometric dimension was determined following the rules of anthropometric design. Clearance criteria took the larger value; for example the seat width of the 95th percentile female was used, whereas the'reach'was set by the 5th percentile female data. The list of the set values used for designing living environments for older Malaysian is tabulated in **Table 3**.

The design was carried out after the anthropometric data limits were set. Computer-aided engineering software (CATIA) parts and assembly designs were used for designing the fixtures. A simulated manikin was used in CATIA human and ergonomic analysis to validate the design environment. The designing

Table 2
List of anthropometric dimensions

Dimension no.	Measurements
1	Weight (kg)
2	Stature height*
3	Coat height, standing
4	Shoulder height, standing*
5	Waist height, standing
6	Crotch height, standing
7	Kneecap height, standing
8	Eye height, standing*
9	Elbow height, standing*
10	Sitting height*
11	Eye height, sitting*
12	Shoulder height, sitting
13	Knee height, sitting*
14	Popliteal height, sitting*
15	Arm reach upward, sitting*
16	Hip breath, standing*
17	Chest (bust) depth*
18	Shoulder breadth, sitting*
19	Hip breadth, sitting*
20	Forearm-hand length (elbow-finger tip length), sitting*
21	Buttock-knee length, sitting*
22	Buttock-popliteal length, sitting*
23	Shoulder-elbow length, sitting*
24	Arm reach forward, standing*
25	Shoulder grip length, standing*
26	Upper limb length
27	Span horizontal
28	Elbow span*
29	Thigh thickness*
30	Hand length
31	Palm length
32	Hand breadth*
33	Foot length
34	Instep length
35	Foot breadth
36	Heel breadth
37	Arm reach upward, standing*
-	Thumb strength (kg/N)
-	Grip strength (kg/N)
38	Knuckle height, standing
39	Elbow height, sitting

* Only 24 body dimensions are applicable for designing an ergonomic living environment for older persons

Table 3
Body dimension values used for design purposes

No.	Body dimensions	Male/female percentile	Value (cm)
1	Stature height	Male 95th	172.60
2	Shoulder height, standing	Female 5th	111.92
3	Eye height, standing	Female 50th	137.20
4	Elbow height, standing	Female 5th	81.60
5	Upward reach, standing	Female 5th	149.88
6	Shoulder grip length, standing	Female 5th	51.23
7	Elbow span, standing	Male 95th	97.45
8	Arm reach forward, standing	Female 5th	62.41
9	Hip breadth, standing	Female 95th	37.00
10	Chest depth, standing	Female 95th	31.68
11	Sitting height	Male 95th	88.75
12	Eye height, sitting	Female 50th	59.13
13	Shoulder height, sitting	Female 5th	43.05
14	Knee height, sitting	Male 95th	54.75
15	Popliteal height, sitting	Female 5th	33.92
16	Arm reach upward, sitting	Female 5th	84.61
17	Thigh thickness, sitting	Female 95th	16.80
18	Shoulder breadth, sitting	Male 95th	47.25
19	Hip breadth, sitting	Female 95th	39.77
20	Shoulder elbow length, sitting	Female 5th	30.42
21	Forearm hand length, sitting	Female 5th	38.30
22	Buttock-knee length, sitting	Male 95th	58.55
23	Buttock-popliteal length, sitting	Female 5th	37.67
24	Hand breadth	Male 95th	9.40
25	Knuckle height, standing	Male 95th	78.10
26	Elbow height, sitting	Female 5th	10.42

and simulation processes were done in two stages as indicated in **Figures 2 and 3**.

In the first stage, parts were drawn and assembled using CATIA to produce solid products. The second stage involved creating computer-simulated manikins by editing the anthropometric data in a human builder workspace. To create computer-simulated manikins resembling older Malaysian people, 20 anthropometric dimensions were edited in the human builder workspace (**Figure 4**). Two types of manikins, a 5th percentile female and a 95th percentile male, representing the smallest and largest sub-populations, were created for the simulation of each design environment.

The manikin's body segment was manipulated to

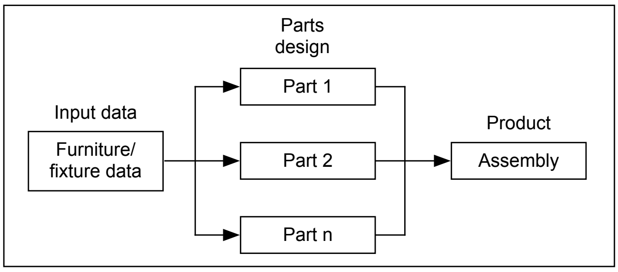

Figure 2. Flowchart showing the designing process

reach the product component. The rapid upper limb assessment (RULA) score, perfect reach, light of sight and reach envelope were analysed to check the interactions of the manikin with the environment.

RESULTS

Most of the basic facilities and fixtures at selected publicly funded welfare homes did not take the anthropometric measurements and needs of older Malaysians into account. This may cause discomfort and difficulties for the residents doing activities of daily living (**Table 4**).

Comparison of current situation using simulation

Human modelling is considered the fastest, cheapest and most reliable tool for evaluating the interactions between humans and designed areas. The CATIA human and ergonomics analysis software package developed by Dassault System simulates the virtual environment. Product design can be separately drawn and directly exported to the human activities analysis space for manikin simulation and posture analysis using RULA.

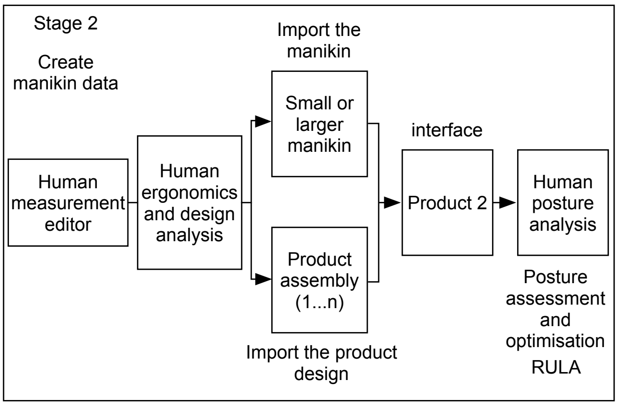

Figure 3. Flowchart showing the simulation process

For example, analysis using simulation showed that the current toilet seat heights (390 to 410 mm) and grab bar heights (700 to 1030 mm) in publicly funded welfare homes did not meet the elderly users' requirements (**Figures 5 and 6**). This may cause discomfort and increase the risk of falls and injuries.

Recommended guidelines for designing basic fixtures in publicly funded welfare homes

The door dimensions included the height, width (opening) and position of the peephole and the handle (**Figure 7**). The minimum door height should comply with the stature anthropometry of the 95th percentile male (72.60 cm). The door width should be the elbow span of the 95th percentile male (97.4 cm). A lever-type doorknob should be positioned at the elbow height of the 5th percentile female (81.60 cm). The peephole height should be at the standing eye height of the 50th percentile female (137.2 cm). The simulation and RULA results for door design are shown in **Figure 8**.

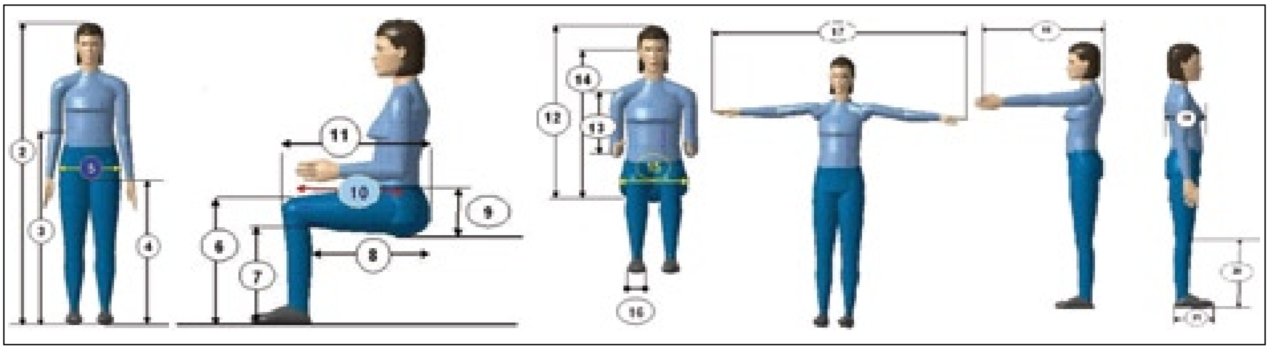

Figure 4. Anthropometric dimensions of a manikin

Table 4
Summary of findings based on observations

No.	Fixtures	Findings
1	Door	1. Different sizes, heights and widths (dorms, bedrooms, bathrooms and toilets) among publicly funded welfare homes 2. Lever-action and round knob (easy to open) 3. Knob heights (range, 920-1290 mm) 4. Ramp installed (for wheelchair user) 5. No auxiliary handrail
2	Window	1. Different heights among publicly funded welfare homes 2. Difficult to open (Jalousie type)
3	Switch	1. Both switches are close together (easy for elderly user) 2. Different heights (dorms, bedrooms, bathrooms and toilets) among publicly funded welfare homes 3. Some publicly funded welfare homes installed switches near the beds
4	Power outlet	1. Mostly located in living room (for TV, radio, etc) and bedrooms 2. 3-pin type power outlet 3. Located at different heights among publicly funded welfare homes
5	Sink (lavatory)	1. Different shapes, sizes and heights 2. Different water outlet design 3. Water outlet is difficult to open (basic type)
6	Toilet	1. Sitting and squatting types, posing difficulties for elderly users 2. Toilet seat heights (range, 390-410 mm) are of standard type but not specially designed for elderly users 3. Lever-action type (pump) 4. A few have handrails or grab bars of different heights (range, 30-40 mm) and diameters 5. Different sizes of toilets 6. Most doors open towards the inside (uncomfortable for users), posing problems if accidents occur inside 7. Different height of water outlet 8. No non-skid mat installed (to avoid slipping and falls)
7	Bathroom	1. Most have separate bathrooms and toilets 2. Fixed and adjustable shower head 3. Different sizes SK 4. A few installed handrails of different heights (range, 30-40 mm) and diameters 5. No seats installed 6. A few have tissue and soap holders 7. No temporary storage 8. A few have installed hooks 9. No non-skid mat installed (to avoid slipping and falls)
8	Handrail	1. Not standardised, different heights and diameters

The minimum windowsill height should be at the sitting eye height, measured from the floor, of the 5th percentile female (93 cm). The maximum height should be at the standing eye height of the 95th percentile male (159 cm); therefore a range of 93 to 159 cm is sufficient for window viewing. The window controller/handle should be positioned at the standing shoulder height of the 5th percentile female (111.9 cm). The window design and simulation are shown in **Figures 9 and 10**.

Switches and outlets should be positioned within the reach of shorter persons (**Figure 11**). The switch height should be at the standing shoulder height of the 5th percentile female (112 cm). Electrical outlets should be within reach of older persons while standing; excessive bending must be avoided. A suitable height should comply with the knuckle height anthropometry dimension of the 95th percentile male (78.10 cm). The simulation and RULA results for switch and outlet designs are shown in **Figures 12 and 13**.

The lavatory dimensions included hand basin, water faucet and mirror heights (**Figure 14**). The hand basin rim height should be 10 cm below the standing elbow height of the 5th percentile female (71.60 cm). A single-lever water faucet should be used, as it requires less force to operate. It should be located around 5 cm above the basin rim height (76.6 cm). The optimum water source height is the standing elbow height of the 5th percentile female (81.6 cm). The horizontal distance between the basin rim and water faucet should be around the forearm hand length of the 5th percentile female (38.30 cm). Use of a shorter horizontal distance prevents excessive

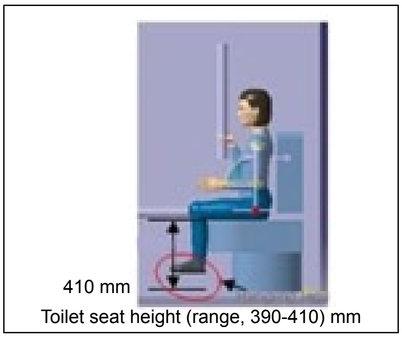

Figure 5. Simulation of the 5th percentile elderly female and the toilet seat height at publicly funded welfare homes

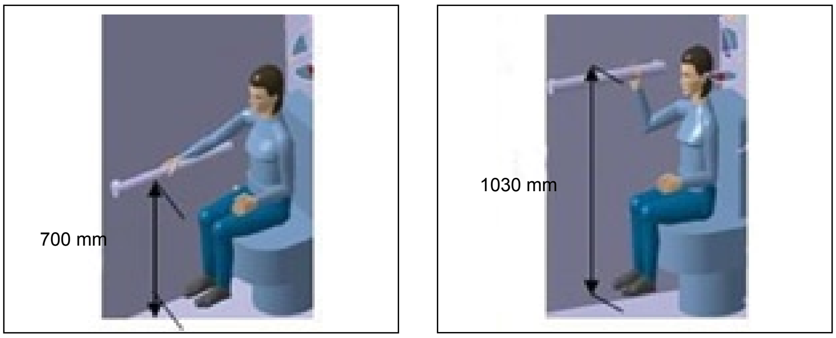

Figure 6. Simulation of the 5th percentile elderly female and the grab bar height at publicly funded welfare homes

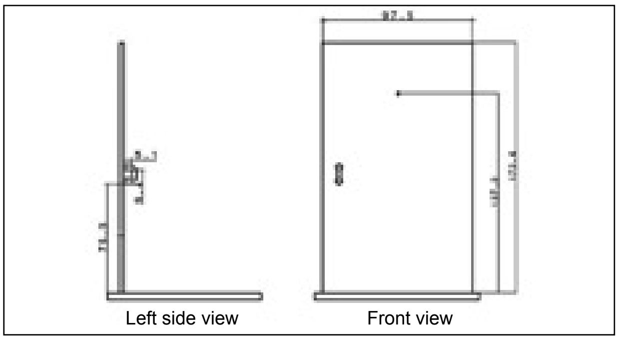

Figure 7. Guidelines for door design based on the anthropometry of older Malaysians (in cm)

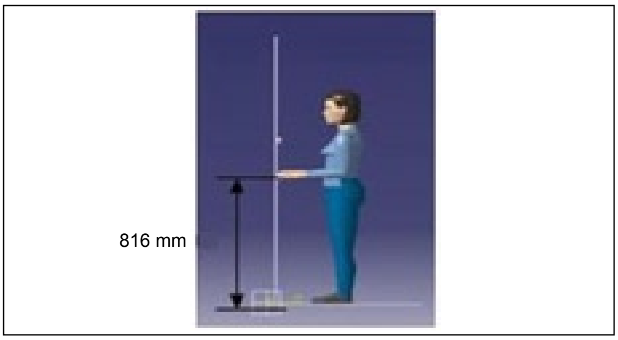

Figure 8. Simulation and rapid upper limb assessment of the 5th percentile elderly female with the door knob height based on anthropometry of older Malaysians

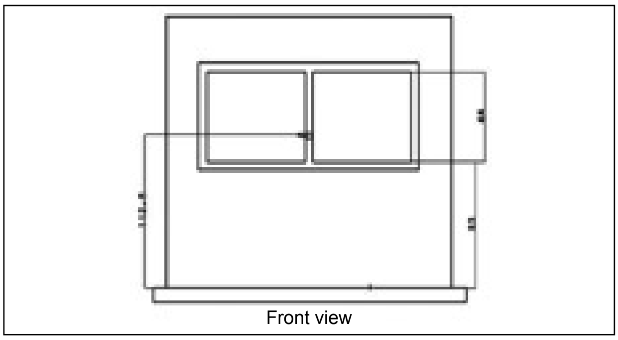

Figure 9. Guidelines for window design based on anthropometry of older Malaysians (in cm)

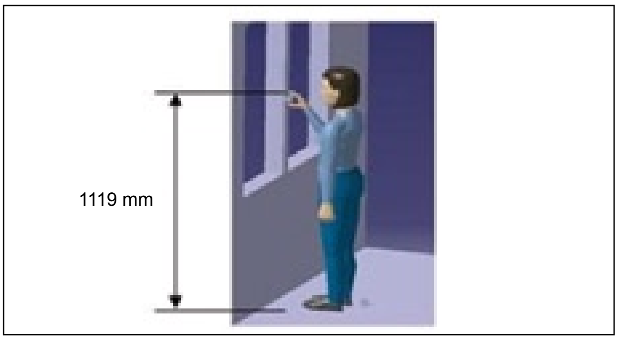

Figure 10. Simulation and rapid upper limb assessment of the 5th percentile elderly female with the window controller/ handle based on anthropometry of older Malaysians

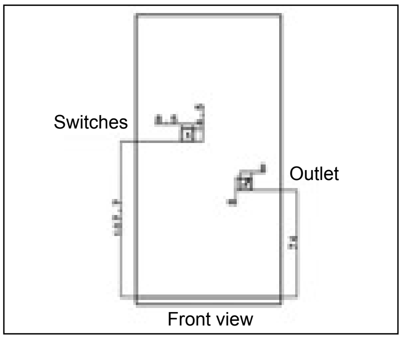

Figure 11. Guidelines for the switch and power outlet heights based on the anthropometry of older Malaysians (in cm)

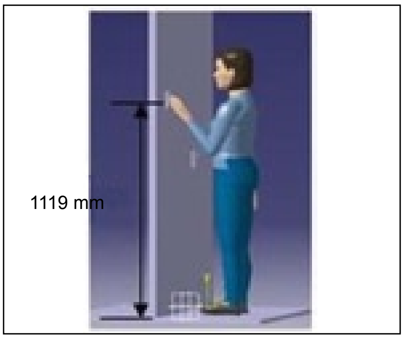

Figure 12. Simulation and rapid upper limb assessment of the 5th percentile elderly female with the switch height based on the anthropometry of older Malaysians

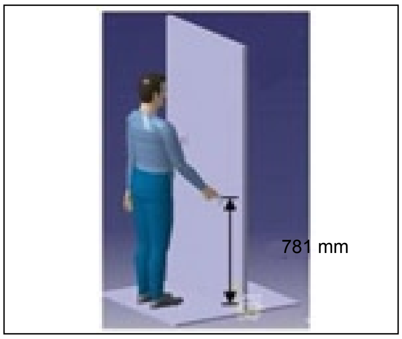

Figure 13. Simulation and rapid upper limb assessment of the 95th percentile elderly male with the power outlet height based on the anthropometry of older Malaysians

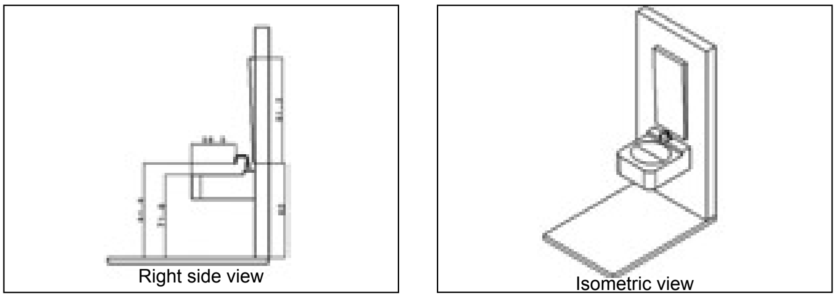

Figure 14. Guidelines for the sink design based on the anthropometry of older Malaysians (in cm)

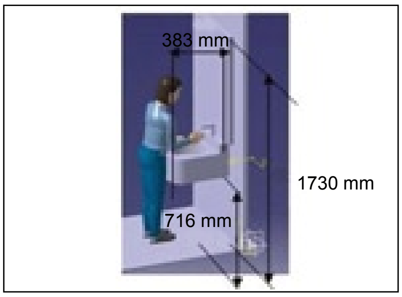

Figure 15. Simulation and rapid upper limb assessment of the 5th percentile elderly female with the sink design based on the anthropometry of older Malaysians

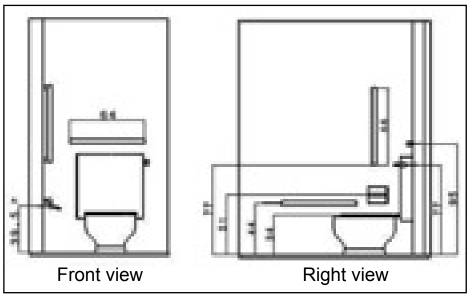

Figure 16. Guidelines for the toilet design based on the anthropometry of older Malaysians (in cm)

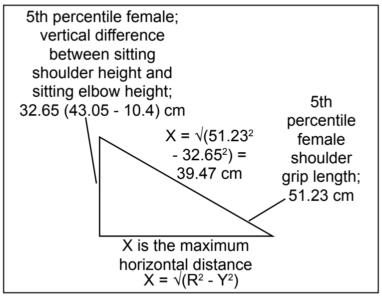

Figure 17. Using Pythagoras' theorem to calculate the horizontal distance

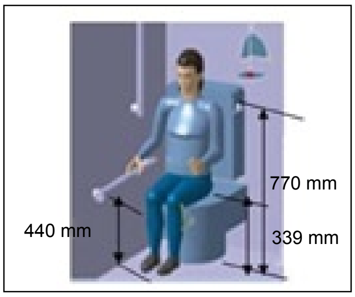

Figure 18. Simulation and rapid upper limb assessment of the 5th percentile elderly female with the toilet design based on the anthropometry older Malaysians

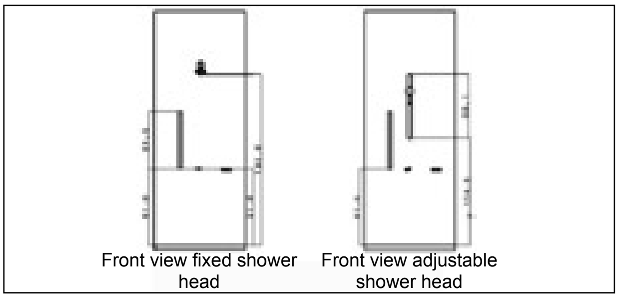

Figure 19. Guidelines for the showerhead, vertical handrail, water controller and soap dish height based on the anthropometry of older Malaysians (in cm)

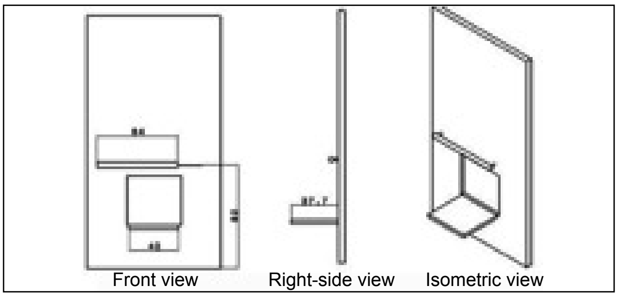

Figure 20. Guidelines for the seat and horizontal handrail height based on the anthropometry of older Malaysians (in cm)

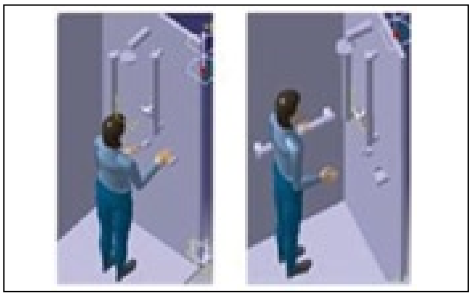

Figure 21. Simulation and rapid upper limb assessment of the 5th percentile elderly female with the bathroom design based on the anthropometry of older Malaysians

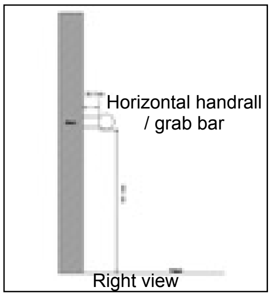

Figure 22. Guidelines for the horizontal handrail height based on the anthropometry of older Malaysians (in cm)

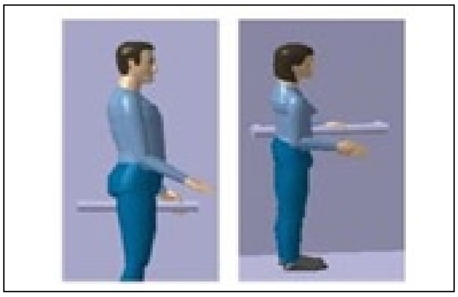

Figure 23. Simulation and rapid upper limb assessment of the 95th percentile elderly male and the 5th percentile elderly female with the handrail design based on the anthropometry of older Malaysians.

stretching. The mirror should be placed above the hand basin for viewing and its positioning should accommodate both shorter females and taller males (i.e. a range of 82 to 173 cm). The minimum clearance in front of the lavatory area should accommodate the stooping space of the 95th percentile male, which is equal to the sitting height (88.75 cm). The simulation and RULA results for the lavatory design are shown in **Figure 15**.

The toilet area included a toilet bowl, handrails and tissue holder (**Figure 16**). The toilet seat height should be the same height as the chair seat height, which is set at the sitting popliteal height of the 5th percentile female (34 cm). The flush control should be accessible during sitting and at the sitting shoulder height of the 5th percentile female. The water hose should be located on the right-hand side and the single-lever water control should be at the sitting elbow height of the 5th percentile female (44.42 cm, or 10.42 cm above the seat height). The maximum horizontal distance can be calculated using Pythagoras' theorem (**Figure 17**). The horizontal handrail in the toilet area is useful for support during sitting. Its height should be around the sitting elbow height of the 5th percentile female (44.42 cm). The diameter of the horizontal handrail and the gap between it and the vertical wall should be 3.81 cm.[9] The height of the tissue holder should be about the same height as the horizontal handrail (44.42 cm). The vertical handrail is useful for standing up after toilet use. Its height should be within the minimum sitting to maximum standing shoulder height (i.e. 77 to 143 cm). The diameter of the vertical handrail and the gap between it and the vertical wall should also be 3.81 cm.[9] The simulation and RULA results for the toilet design are shown in **Figure 18**.

Many accidents occur in the bathroom. Bathroom design based on the anthropometric measurement of older Malaysians is shown in **Figures 19 and 20**. The minimum width for the shower area should cover the elbowroom needed by the 95th percentile male (97.5 cm). The optimum height for the fixed showerhead should be high enough to accommodate the 95th percentile male stature height including clearance (173+10=183 cm). An adjustable showerhead should be within the range of both the sitting height of the 5th percentile female and the stature height with clearance of the 95th percentile male (i.e. 80.51 to 183 cm). A single water controller should be located in line with the showerhead and its height should be at the standing elbow height of the 5th percentile female (81.60 cm). The vertical handrail should be placed in the shower area for balancing while bathing, with the minimum height at the elbow height of the 5th percentile female and the maximum height at the shoulder height of the 95th percentile male (i.e. 82 to 143 cm). The horizontal handrail height should be at the knuckle height of the 95th percentile male (78.10 cm). The optional seat in the shower area should be the popliteal height of the 5th percentile female (34 cm), with a seat width of the 95th percentile female sitting hip breadth (40 cm), and a seat depth of the 95th percentile female buttock-popliteal length (38 cm). Temporary storage for toiletries should be located at the shoulder height of the 5th percentile female (112 cm). The soap dish should be within the reach of shorter persons, at the elbow height of the 5th percentile female (81.6 cm). The simulation and RULA results for the bathroom design are shown in **Figure 21**.

The handrails or grab bars are used for support during walking. They should be located inside and outside the building (e.g. corridor, pathway). Their height should be about the standing knuckle height of the 95th percentile male (78.10 cm, **Figure 22**). The diameter of the horizontal handrail and the gap between it and the vertical wall should be 3.81 cm.[9] The simulation and RULA results for the handrail design are shown in **Figure 23**.

CONCLUSION

Elderly people should be provided with living environments with specifically designed facilities appropriate for their physical and cognitive strengths, capabilities and limitations, and to match their body dimensions. A properly designed living environment increases the comfort, safety and health of the elderly.

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