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This paper presents anthropometric data on elderly people in Australia. Data were collected in the metropolitan city of Sydney, NSW, Australia. In all 171 elderly people (males and females, aged 65 years and above) took part in the study. Mean values, standard deviations, medians, range, and coefficients of variation for the various body dimensions were estimated. Correlation coefficients were also calculated to determine the relationship between different body dimensions for the elderly population. The mean stature of elderly Australian males and females were compared with populations from other countries. The paper discusses design implications for elderly people and provides several examples of application of the anthropometric data.

anthropometry   elderly people   ergonomics design   ergonomics application

1. INTRODUCTION

Statistics from around the world show that the proportion of elderly people in the population has been steadily increasing over the last decades. For example, it is estimated that the elderly population (aged 65 years and above) in Australia will rise from the current level of 1.9 million (11.2%) to over 5 million (over 20%) in 2031, that is, there will be an increase of about 2.8% per decade (Economic Planning Advisory Council [EPAC], 1994). At the same time the numbers of those aged over 80 years are estimated to rise, at least three times (EPAC, 1994). Compared to this, the US population of the elderly will increase to about 20% by the year 2025 (Czaja, 1990). This trend in population change appears to be emerging in

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most economically developed countries. Tremendous improvements in medical technologies and health care delivery systems are believed to be the main reasons for this change in the elderly population. Diseases that were once thought to be fatal can now either be cured or at least life span can be increased by several years. People are living longer now than ever before.

On the other hand, several socioeconomic changes are taking place. Whereas only a decade or so ago, people were expected to retire from active employment at a certain age (normally 60 or 65 years), now it is not the case. Economic rationalism is compelling governments of the day to apply strict control on social security or other benefits available to elderly people. As a result, elderly people are trying to make themselves economically useful in the community as long as possible so as to be able to maintain their living standard. Moreover, due to lifestyle changes such as physical exercises, fitness programs, healthy diet, and so forth, a significant number of elderly people is remaining physically fit to continue in employment. Technology and legislation are extending a helping hand in this regard. Most developed countries now have equal opportunity and anti-age, anti-disability discrimination laws, which prohibit discrimination in employment on any basis. Further, computer and communication technologies have significantly advanced in the last few decades and are now playing a prominent role in modern manufacturing and service industries in making jobs physically and cognitively less demanding (i.e., jobs require low physical strength or force, or are supplemented with decision-making aids, etc.) for workers. This has enabled elderly workers to work nearly as productively as young workers. Thus, it is not difficult to find elderly (aged 65 years and above) workers in modern workplaces working alongside young workers. In fact there has been a gradual change in the composition of the working population in workplaces in favour of elderly workers.

There have also been other developments in the society. Young people, for example, are looking for entrepreneurial, business, management, and computer skills as they find these relatively more interesting, challenging, and important compared to traditional jobs. Thus a shortage of interested trained, skilled, or experienced people in many traditional workplaces such as public transport, banking, tourism, catering, medicine, police, armed forces, and so forth, is being felt. Due to difficulty in recruiting younger skilled workers with sufficient interest in traditional workplaces, elderly workers are being encouraged to remain in the workforce for as long as possible (Smith, 1990).

Further, most countries in the economically developed world have seen a rise in the number of elderly people living in old people's homes, nursing homes, and retirement villages. There is no doubt that living places for elderly people will have to be provided with specifically designed physical and living facilities to meet their needs. As elderly people are likely to form a significant proportion of the workforce in the future (whether by choice or circumstances), ergonomists cannot ignore the question of ergonomically designed workplaces, work stations, tools, and equipment for elderly people. Ergonomists will have to either introduce design modifications to existing workplaces, products, and so forth, or seriously consider new designs to suit elderly persons. Better still will be a new approach to design, that of universal design (Vanderheiden, 1997) suitable to almost whole population. Ergonomists will find it difficult to do so unless accurate and reliable data on anthropometry, physical and cognitive strengths, capabilities and limitations, and work performance of the elderly population can be collected and analysed.

Whereas there has been considerable work on the effect of ageing on functional capacities such as hearing, vision, physical strength in general, motor and sensory system, and so forth, physical body dimensions, that is, anthropometry, have remained relatively untouched. Apart from a few body dimensions such as height and body weight, there is practically no comprehensive anthropometric information on other body dimensions. According to Kelly and Kroemer (1990) there is no nationwide reliable anthropometric information available in the USA, especially on the dynamic anthropometry of elderly people. Some data on the elderly (e.g., Borkan, Hults, & Glynn, 1983; Damon & Stoudt, 1963; Juergens, 1984; Pheasant, 1986) are available in the literature but are limited in their applicability due either to their small sample size, selective population, or lack of wider demographic coverage. Some of this data (e.g., Damon & Stoudt, 1963) are now outdated, thus it cannot be used with confidence for industrial or other applications. A further complication in using published data is lack of information on the health status of the participants. In the case of the elderly population this information is more important than in a young population because of age-related body changes. Chumlea, Roche, and Roger (1984) collected anthropometric data in a sample of healthy adults (23 men and 21 women) aged between 54 and 85 years of age. They pointed out the difficulty in obtaining reliable data as they observed more frequent and larger interobserver errors for most body measurements with the elderly compared to groups of younger individuals. In the UK, the Institute of Consumer Ergonomics (ICE, 1983) has collected some data for the elderly British population. An anthropometric data set for the elderly Dutch population has been developed by Molenbroek (1987).

Fozard (1981) and Stoudt (1981) have pointed out that elderly people are anthropometrically very different with interindividual variance increasing with age. Hence anthropometric data available for young adults cannot be used even with allowances for the age-related changes for the elderly population. Another complicating factor is the ethnic mix, which could be very different in the elderly population compared to the young adult population.

In this study an attempt has been made to develop an anthropometric data set on the elderly population. At present there are no published data on the anthropometry of elderly people in Australia. This study was carried out in the geographical area of metropolitan Sydney, NSW, Australia. The main objective of the study was to collect data on a reasonable number of body dimensions, which can be useful for the design for the elderly. It is expected that this study will provide help to designers, who have been unable to design specifically suited products, equipment, and living facilities for the elderly population for lack of proper data.

2. METHODOLOGY

2.1. Participants

Participants for the study were randomly selected from the general public, senior citizens' clubs, old people's homes (retirement villages), and activity centres for the elderly located in the metropolitan Sydney area in New South Wales, Australia. All participants were of normal physical health and were active in life at the time of the measurements conducted for the study. Participants who were unable to stand unassisted for the duration of measurements were excluded from the study. Participants were explained before the start of data collection that the objective of the study was to develop a data set of anthropometric body dimensions for the purpose of improving or redesigning the workplace, living facilities, and products used by the elderly. The procedure of measurements was explained in detail to them and they were encouraged to ask any question they may have about the procedures. Participants were asked to sign a consent form only when they had fully understood the purpose of the study and the procedures to be used for measurements. It took about 20 min or so to complete all the measurements set out in the study. Participants were allowed rest in between measurements, if needed. Measurements were made with participants wearing light clothing and with bare feet.

2.2. Measuring Instruments

The measuring equipment for the collection of data consisted of a standard professional anthropometer (TTM Martin's Human Body Measuring Kit, Mentone Educational Centre, Carnegie, Vic., Australia), a weighing scale, and an adjustable chair. The measuring kit consisted of instruments for measurements of distances in straight lines, curves, circumferences, and thickness. The adjustable chair had a flat wooden seat with a high back rest. The seat and the backrest were aligned at right angles to each other and the seat acted as reference point for the measurements in the sitting position.

2.3. Selection of Body Dimensions

An adequate description of the human body may require over 300 measurements (Pheasant, 1986; Roebuck, Kroemer, & Thompson, 1975). The scope of this study was limited to measuring those body dimensions that were considered important and useful for the design of facilities and equipment used for daily living for the elderly and also for the design of the workplace environment (Steenbekkers & Beijsterveldt, 1998). In all 22 body dimensions were selected for measurements (Table 1, see Figures 1a, 1b, and 1c). The measurements were made according to the definitions of the selected body dimensions as given in Pheasant (1986). The selected body dimensions included most of the basic anthropometric measurements recommended by various sources (e.g., British Standards Institution, 1991; International Organization for Standardization [ISO], 1983; Molenbroek, 1987; Steenbekkers & Beijsterveldt, 1998). Each measurement was taken 3 times and the mean value was recorded in the data set. Measurements were made both in standing and sitting postures.

To eliminate interobserver variations, all measurements were made by the same person for all the participants. The measurer was given training in the use of the anthropometric instruments in the laboratory. Before the data collection was started, several trial runs were conducted in the laboratory to make sure that the measurer fully understood all procedures of measurement and followed them consistently over the period of data collection. The measurements made by the measurer in the trial runs was checked by another person to determine the accuracy and consistency of the measurements.

TABLE 1. List of Body Dimension Selected for Measurement

Dimension Number	Measure
1	Age
2	Weight
3	Stature
4	Eye height
5	Shoulder height
6	Elbow height
7	Sitting height
8	Sitting eye height
9	Sitting shoulder height
10	Sitting elbow height
11	Thigh thickness (thigh clearance)
12	Buttock-knee length
13	Buttock-popliteal length
14	Knee height
15	Popliteal height
16	Shoulder breadth (bideltoid)
17	Hip breadth
18	Chest (bust) depth
19	Elbow-fingertip length
20	Upper limb length
21	Shoulder grip length
22	Hand length
23	Hand breadth

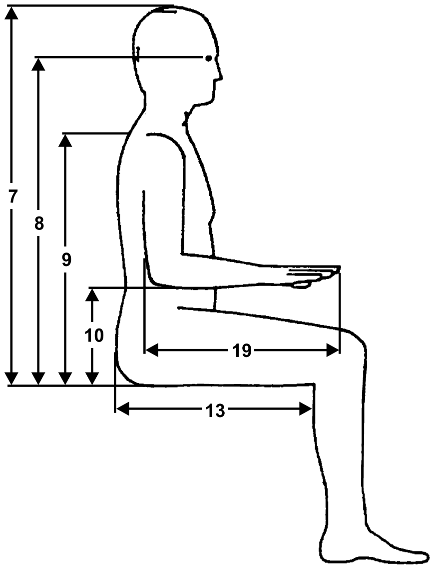

Figure 1a. Definitions of the dimensions measured on the elderly population sample. *Notes.* 7—sitting height, 8—sitting eye height, 9—sitting shoulder height, 10—sitting elbow height, 13—buttock-popliteal length, 19—elbow-fingertip length.

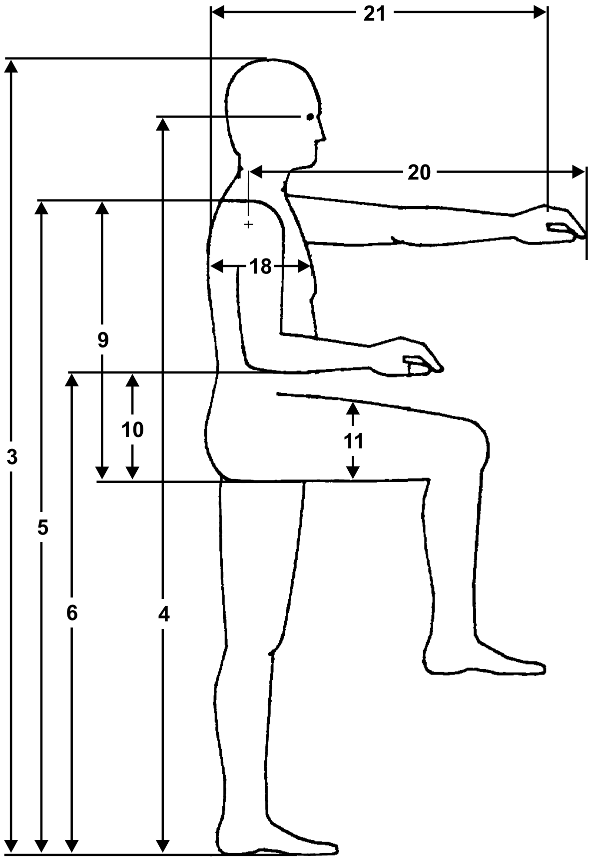

Figure 1b. Definitions of the dimensions measured on the elderly population sample. *Notes.* 3—stature, 4—eye height, 5—shoulder height, 6—elbow height, 9—sitting shoulder height, 10—sitting elbow height, 11—thigh thickness (thigh clearance), 18—chest (bust) depth, 20—upper limb length, 21—shoulder grip length.

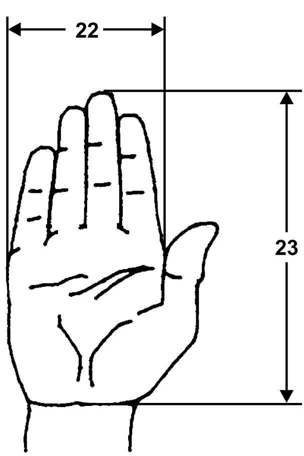

Figure 1c. Definitions of the dimensions measured on the elderly population sample. *Notes.* 22—hand length, 23—hand breadth.

2.4. Data Analysis

Data were analysed using SPSS/PC+ (Norušis, 1990). The program was used first to check accuracy of entries by checking on outliers and then for the statistical analysis. One participant (out of 172) was dropped as there were more than two extreme body dimensions associated with the participant.

3. RESULTS

A total of 171 participants, 33 males and 138 females, participated in the study. In the study sample, most of the participants (over 70%) were born in Australia, with about 9% British, 7% Asian, and the rest from various other countries. This mix, incidentally, roughly represents the current overall population distribution in Australia (Australian Bureau of Statistics [ABS], 1997).

Tables 2 and 3 present the descriptive statistics for male (n = 33) and female (n = 138) participants respectively. Tables show the mean (M), standard deviation (SD), median, range, and coefficient of variation (CV) of the measured body dimensions. Tables 4 and 5 present percentile values for the body dimensions of male and female participants.

TABLE 2. Descriptive Statistics of Elderly Australian Male Aged 65 Years and Above (*n* = 33)

Dimension		*M*	*SD*	Median	Range	*CV* (%)
1	Age (years)	76	7	73	65–92	9.6
2	Weight (kg)	72	11	72	46–99	15.9
3	Stature	1658	79	1650	1491–1824	4.8
4	Eye height	1532	70	1526	1368–1684	4.6
5	Shoulder height	1385	70	1378	1190–1547	5.1
6	Elbow height	1043	50	1036	936–1189	4.8
7	Sitting height	843	56	843	723–989	6.7
8	Sitting eye height	729	46	732	631–805	6.3
9	Sitting shoulder height	587	37	585	502–670	6.3
10	Sitting elbow height	232	35	235	168–297	15.2
11	Thigh thickness	103	23	100	65–158	22.3
12	Buttock-knee length	549	38	547	443–610	6.9
13	Buttock popliteal length	452	38	450	357–560	8.4
14	Knee height	515	31	513	462–580	6.0
15	Popliteal height	416	25	421	372–468	6.1
16	Shoulder breadth	394	30	395	336–463	7.7
17	Hip breadth	336	28	335	290–430	8.4
18	Chest depth	224	36	212	174–347	15.9
19	Elbow-fingertip length	422	30	418	365–487	7.2
20	Upper limb length	784	74	789	644–987	9.4
21	Shoulder-grip length	652	90	645	600–840	13.8
22	Hand length	184	10	184	164–200	5.3
23	Hand breadth	86	7	86	70–99	8.3

Notes. All linear dimensions are in mm; *CV*—coefficient of variation. Data presented in this table were published in Kothiyal and Tettey (2000).

TABLE 3. Descriptive Statistics of Elderly Australian Females Aged 65 Years and Above ($n = 138$)

	Dimension	*M*	*SD*	Median	Range	*CV* (%)
1	Age (years)	77	8	77.5	65–92	10.0
2	Weight (kg)	61	13	59	39–105	21.4
3	Stature	1521	70	1528	1300–1740	4.6
4	Eye height	1414	67	1416	1250–1565	4.7
5	Shoulder height	1271	64	1266	1120–1474	5.0
6	Elbow height	952	59	952	803–1132	6.2
7	Sitting height	784	40	788	677–904	5.0
8	Sitting eye height	676	42	679	570–782	6.3
9	Sitting shoulder height	531	35	533	456–632	6.7
10	Sitting elbow height	212	34	211	150–286	16.1
11	Thigh thickness	95	21	94	60–157	21.9
12	Buttock-knee length	530	35	530	446–620	6.7
13	Buttock-popliteal length	440	36	440	352–536	8.2
14	Knee height	475	28	474	400–570	5.9
15	Popliteal height	379	28	378	310–465	7.4
16	Shoulder breadth	356	32	357	267–450	9.0
17	Hip breadth	338	39	340	255–440	11.0
18	Chest depth	235	47	230	136–384	20.0
19	Elbow-fingertip length	385	36	380	322–623	9.0
20	Upper limb length	737	75	745	566–940	10.0
21	Shoulder-grip length	646	77	653	466–840	12.0
22	Hand length	170	10	169	146–195	6.0
23	Hand breadth	79	5	78	70–99	6.0

Notes. All linear dimensions are in mm; *CV*—coefficient of variation. Data presented in this table were published in Kothiyal and Tettey (2000).

TABLE 4. Percentile Values (P) of Anthropometric Measures of Elderly Australian Males Aged 65 Years and Above ($n = 33$)

	Dimension	P5	P25	P50	P75	P95
2	Weight (kg)	52	65	72	78	99
3	Stature	1518	1603	1650	1695	1816
4	Eye height	1406	1486	1526	1573	1670
5	Shoulder height	1241	1334	1378	1432	1514
6	Elbow height	965	1015	1036	1066	1173
7	Sitting height	749	802	843	882	943
8	Sitting eye height	632	693	732	766	799
9	Sitting shoulder height	522	561	585	608	667
10	Sitting elbow height	173	210	235	259	293
11	Thigh thickness	66	91	100	118	157
12	Buttock-knee length	453	531	547	581	601
13	Buttock-popliteal length	373	432	450	467	524
14	Knee height	470	486	513	539	570
15	Popliteal height	373	392	421	437	460
16	Shoulder breadth	342	367	395	415	453
17	Hip breadth	295	317	335	354	392
18	Chest depth	181	198	212	245	299
19	Elbow-fingertip length	369	398	418	443	477
20	Upper limb length	660	738	789	835	923
21	Shoulder-grip length	421	647	689	746	811
22	Hand length	165	178	184	191	200
23	Hand breadth	72	81	86	92	97

Notes. All linear dimensions are in mm. Data presented in this table were published in Kothiyal and Tettey (2000).

TABLE 5. Percentile Values (P) of Anthropometric Dimensions of Australian Females Aged 65 Years and Above (*n* = 138)

	Dimension	P5	P25	P50	P75	P95
2	Weight (kg)	45	51	58	70	85
3	Stature	1412	1470	153	1567	1627
4	Eye height	1297	1364	1415	1462	1520
5	Shoulder height	1171	1228	1266	1315	1384
6	Elbow height	855	916	952	990	104
7	Sitting height	720	756	788	808	848
8	Sitting eye height	600	646	679	706	749
9	Sitting shoulder height	471	502	535	557	587
10	Sitting elbow height	154	182	211	237	275
11	Thigh thickness	68	78	93	106	136
12	Buttock-knee length	475	504	529	558	589
13	Buttock-popliteal length	376	416	440	462	500
14	Knee height	432	452	474	491	521
15	Popliteal height	330	362	378	397	430
16	Shoulder breadth	307	333	357	377	417
17	Hip breadth	277	307	339	365	409
18	Chest depth	170	195	230	264	318
19	Elbow-fingertip length	337	362	380	400	442
20	Upper limb length	614	679	745	785	847
21	Shoulder-grip length	520	584	652	707	757
22	Hand length	153	163	168	176	188
23	Hand breadth	71	76	78	81	87

Notes. All linear dimensions are in mm. Data presented in this table were published in Kothiyal and Tettey (2000).

4. DISCUSSION

This study has attempted to collect and analyse anthropometric characteristics of the elderly population. The main objective was to fill in the gap in information on anthropometric measurements needed to design equipment and working and living facilities for elderly people in Australia. This study adds to a number of other studies (ICE, 1983; Molenbroek, 1987; Stoudt, 1981) on the anthropometry of elderly people done in the past in various countries. It is difficult to compare this study with others for a variety of reasons, such as, sample size, specific conditions of measurement, demographic coverage, ethnic mix, outdated data, health status of the participants, and so forth. However, the results of this study are similar to those of others as far as general trends are concerned.

The participation of elderly male participants in the study was relatively small (*n* = 33) compared to female participants (*n* = 138). There was a low level of interest in the male population for the anthropometric data collection. Many male participants who initially showed interest in the study, declined to participate at the last minute. It is difficult to know the exact reason for lack of interest in male participants as participation in the study was voluntary and it was not possible to follow up on these cases. Contrary to this, there was considerable enthusiasm in female participants to participate in the study. The lower participation of elderly male participants appears to be common in most anthropometric studies. For example, the Dutch study (Molenbroek, 1987) had only 197 male participants out of a total of 815, that is, approximately 24%. The British study (ICE, 1983) had only about 33% male participants (215 out of a total of 649).

Stature is one of the most important anthropometric characteristics affected by ageing. Table 6 compares male and female stature for different populations. Differences can be noticed in the stature of Australian males and females when compared with those of British population. On the other hand Australian males and Dutch males have nearly the same stature, but the data for females show considerable difference (about 20 mm). American males and females are taller than the rest of the populations. Data on British population are taken from ICE (1983), Dutch data from Molenbroek (1987), and American data from Stoudt (1981). It should be pointed out that the age composition of the samples is not exactly the same in all data sets. Table 6 shows the range, mean, and standard deviation of the age composition of the samples.

TABLE 6. Comparison of Age (in years) and Stature (in mm) of Different Elderly Populations

	Age *M* ± *SD* (range)		Stature *M* ± *SD*	
Population	**Male**	**Female**	**Male**	**Female**
Australian	76 ± 7 (65–92)	77 ± 8 (65–92)	1658 ± 79	1521 ± 70
British	65 and above	65 and above	1640 ± 77	1515 ± 70
Dutch	80.4 ± 7.8 (65–100)	81.5 ± 8.3 (65–100)	1656 ± 82	1543 ± 72
American	(65–74)	(65–74)	1699 ± 38	1562 ± 43

Tables 4 and 5 describe the percentile values of various body measurements. The percentiles are generally needed for determining design values for a specific application. For example, in designing for reach, it is usually recommended to use a lower percentile (5th percentile) in order to accommodate as many people of the population as possible. A higher percentile value (usually 95th percentile) is considered when designing for clearance, for example, door height, leg room, and so forth.

4.1. Design Implications of Anthropometric Data and Applications

The anthropometric data collected in the study can be used for a variety of product and facility design applications such as office chairs and tables, bedroom and dinning room furniture, kitchen tops and storage space, placement of electric switches, door handles, windows, and so forth, which would help elderly people to work and move about easily and comfortably. Some examples of the application of the data are given in the next sections.

4.2. Office Chairs and Tables for Elderly Employees

In Introduction it was mentioned that due to socioeconomic reasons elderly people are being encouraged to remain in the workforce for as long as possible. Workplace modifications are therefore needed to accommodate them. It is more likely that elderly people, due to diminishing with age physical strength, will be involved in sedentary office type of work. Office chairs and tables are the very basic items that almost every elderly employee will use. Critical measurements for an office chair are seat height, width, and depth. In addition arm rest height is also important for assisting elderly people in standing up from the chair. Table 7 describes the ergonomic criteria applied and recommended values. In the case of elderly people, an additional criterion should be applied on seat height. This criterion relates to the need of elderly people to be able to stand up and sit

TABLE 7. Recommendation for Office Chairs and Tables for Elderly Workers

Dimension	Criteria Applied	Recommended Values (mm)
Seat height	• Popliteal height, 5th percentile female • Make the seat a little higher to enable the elderly user to stand up and sit down easily and unassisted	400 (This includes 45 mm for shoe heel height)
Seat depth	Buttock-popliteal length, 5th percentile female	376
Seat width	Hip breadth, 95 percentile female	409
Back-rest height above the seat	Shoulder height, 95 percentile male	667
Arm-rest height above the seat	Sitting elbow height, 5th percentile female	154
Table height (for writing from floor)	Sitting elbow height from floor, 5th percentile female plus 50 mm plus 45 mm for shoe heel height	652

down from a chair unassisted. This can be achieved if the seat is made higher than recommended for young adult employees. As there are no published data on the preferred sitting height of the elderly, an arbitrary value of 20–50 mm has been used in making recommendation as shown in Table 7. A foot rest must be attached to the chair so that the elderly person can place feet flat to keep knee joint angle at approximately 90°.

A higher than usual seat would impact on the clearance between the thigh and the underside of the table required for the free movement of legs. Therefore table height for the elderly worker would need to be accordingly adjusted. The height of the work table depends on the nature of the activity. For example, observations on the general working population suggest that writing is better done at a table height a little higher than elbow height. Work involving a moderate amount of force requires the working height to be 50 to 100 mm below the elbow (Grandjean, 1988). There is lack of data on preferred working heights for the elderly population, however, observations on the young population can be considered as a guide. Table 7 shows some recommended values for office work tables and chairs for elderly people.

4.3. Placement of Storage Shelves

In general, the requirements of elderly users for clear visibility and easy reach should determine the placement of storage shelves in the home or at work. Also, elderly users have reduced muscular strength and joint mobility due to the ageing process. As far as possible most items should be stored between the knuckle and shoulder heights so that elderly users are not subjected to bending and overreaching demands. Table 8 shows some examples of storage options and their respective design values.

TABLE 8. Recommended Values for Some Storage Options at Work and Home Environment

Storage Option	Design Criteria	Recommended Design Values (mm)
Storage above shoulder height (for light, less frequently used items)	Shoulder height from floor, standing, accessible by 5th percentile female with a 20° (maximum) joint flexion	1350 (maximum)
Shelf height for items requiring visual inspection by the user	Standing eye height from floor, 5th percentile female	1330
Lower shelves (medium to heavy weight items)	Standing knuckle height from floor, 95th percentile male	630–650

4.4. Public Transport Bus Seat Dimensions for Elderly Commuters

Mobility for elderly people is most essential not only to maintain an independent life style but also to develop and expand their social relationships and recreational activities. With ageing, peoples' abilities to drive private cars and navigate through generally crowded roads decreases due to declining health. Moreover, the fear of an accident or getting injured refrains elderly persons from frequently using private cars. It is not therefore surprising that elderly people make extensive use of public transport, especially buses, to go to their workplaces and to visit activity centres (clubs), shopping centres, and friends and families. Current designs of buses make little consideration of the needs of elderly users. Important aspects of bus design that should be modified to accommodate elderly passengers include entry and exit doors, seat dimensions, space between seats, location of hand rails, and so forth. Table 9 shows the criteria that should be applied to seat design along with recommended values. According to Table 9, seat height should be about 330 mm plus shoe height. Considering 45 mm as a reasonable shoe heel height (Pheasant, 1986) bus seat height should not exceed 375 mm. Current Australian Design Rules (ADR, 1990) state that public transport bus seat height should not be less than 400 or more than 500 mm. Minimum seat depth recommended in ADR is 350 mm, which is less than the value recommended here. For the forward facing seats ADR recommends a seat clearance of 660 mm, which is comparatively less than the recommended value (701 mm) based on the anthropometric data collected in this study. This implies that there is need to modify current ADR to accommodate the elderly population on public buses.

TABLE 9. Recommended Values for Seats in Public Buses

Dimension	Criteria Applied	Recommended Values (mm)
Seat height	Popliteal height, 5th percentile female plus shoe heel height	330 + 45 = 375
Seat depth	Buttock to popliteal length, 5th percentile female	376
Clearance between seats	Buttock to knee length, 95th percentile male plus 10 cm for clearance	601 + 100 = 701

TABLE 10. Correlation Coefficients Between Body Parts of Australians Aged 65 Years and Above

	Dimension	1	2	3	4	5	6	7	8	9	10
1	Age (years)										
2	Weight (kg)	–.3210**									
3	Stature	–.2310*	.4588**								
4	Eye height	–.2789*	.4602**	.9395**							
5	Shoulder height	–.2555**	.4327**	.8962**	.9104**						
6	Elbow height	–.2474**	.4442**	.8136**	.8396**	.8331**					
7	Sitting height	–.3364**	.4275**	.8044**	.8236**	.7560**	.7181**				
8	Sitting eye height	–.3582**	.4450**	.7410**	.8025**	.7035**	.6845**	.9006**			
9	Sitting shoulder height	–.3309**	.4686**	.7826**	.8044**	.8050**	.7717**	.8612**	.8609**		
10	Sitting elbow height	–.2806**	.4161**	.4068**	.4308**	.4212**	.4783**	.6088**	.6582**	.7322**	
11	Thigh thickness	–.2341**	.5588**	.3436**	.3375**	.2620*	.2407**	.3577**	.3541**	.2446**	.2395**
12	Buttock-knee length	–.2497**	.5721**	.5962**	.6119**	.5302**	.4884**	.4570**	.4401*	.3981**	.2134
13	Buttock-popliteal length	–.2422**	.4152**	.4326**	.4675**	.4119**	.3507****	.3237**	.3266**	.2838**	.1466
14	Knee height	.0561	.4253**	.7992**	.7956**	.7826**	.7205**	.5591	.4965**	.5811**	.2584**
15	Popliteal height	.0027	.0540	.6897**	.6924**	.6716**	.6011**	.4632**	.3841**	.4659**	.12311
16	Shoulder breadth	–.2758**	.6980**	.5791**	.5743**	.4681**	.4341**	.5880**	.5827**	.5522**	.4066**
17	Hip breadth	–.2549**	.6626**	.2281*	.2682**	.2239*	.2155*	.2537**	.2781**	.2496**	.3170**
18	Chest depth	–.2694**	.6016**	.0720	.0720	–.0039	.0351	.1256	.1691	.0544	.1999*
19	Elbow-fingertip length	–.2272*	.2483**	.5802**	.5737**	.5184**	.4591****	.5045**	.4558**	.4049**	.2252*
20	Upper limb length	–.3230**	.3243**	.4501**	.4652**	.4463**	.3513**	.4723**	.4623**	.4190**	.2187*
21	Shoulder-grip length	–.2433**	.2143*	.3716**	.3774**	.3174**	.2516**	.4131**	.4029**	.3182**	.1681
22	Hand length	.1263	.3985**	.6939**	.7003**	.7111**	.6405**	.5927	.5594**	.6194**	.3507**
23	Hand breadth	–.0878	.4845**	.5517**	.5675**	.5505**	.5067**	.4834	.4097**	.1944**	.2809**

TABLE 10. (*continued*)

	11	12	13	14	15	16	17	18	19	20	21	22
12	.5237**											
13	.3564**	.7317**										
14	.6145**	.5397**	.4307**									
15	.0765	.4208**	.3725**	.7361**								
16	.5922**	.6010**	.3670**	.4715**	.2921**							
17	.5752**	.5655**	.4539**	.3100**	.0014	.5592**						
18	.5193**	.4352**	.3491**	.0375	−.1786*	.5081**	.5536**					
19	.3818**	.4438**	.2971	.4516**	.4763**	.4664**	.2724**	.2158*				
20	.3651**	.4386**	.4321	.3490**	.3796**	.4877**	.3182**	.2724**	.4842**			
21	.3164**	.3238**	.3178**	.2651**	.3010**	.4390**	.5536**	.2609**	.3683**	.7563**		
22	.2190*	.4599**	.3091**	.6439**	.5454**	.4408**	.2806**	.0035	.5021**	.4130**	.2780**	
23	.2857**	.4483**	.2500**	.5181**	.3813**	.4642**	.3055**	.1532	.4152**	.3005**	.1080	.5885**

Notes. One-tailed significance: *—.01; **—.001; 12 ... 23—cf. Table 1.

4.5. Correlation Coefficients Between Body Dimensions

Designers often use stature (body height) as an important reference value and try to relate it to other body dimensions to get approximate values for the purpose of designing items. This practice, however, is erroneous as stature may not be highly correlated with all other body dimensions. The relationship between different body parts can be determined by estimating Pearson's correlation coefficients (*r* values). Table 10 shows correlation coefficients for all body dimensions measured in the study. From Table 10 it becomes clear that age and weight are poorly correlated with all other dimensions. Stature, eye height, shoulder height, and elbow height, that is, measurements in the vertical direction, correlate highly with each other (*r* values ≥.7). National Aeronautics and Space Administration (NASA, 1978) obtained high correlation coefficients for stature, eye height, shoulder height, and elbow height for young air force personnel. In the absence of comparable data, it is difficult to say whether the relationships between different body dimensions obtained in the study will be applicable for other populations, for example, the elderly population.

4.6. Differences Between Elderly and Young Adult Dimensions

Anthropometric data on the elderly were compared with the available published data on young adults to determine the differences between the two population groups. Tables 11 and 12 present a comparison of the data between the young Australian population (Bullock & Steinberg, 1975) and the elderly Australian population (this study). The participants for the adult Australian survey were drawn from a stratified sample of 75 male and 35 female pilots. The age of the male pilots ranged between 18 and 62 years, with a mean age of 34.6 years. The female pilots had a mean age of 32.2 years and their ages ranged between 17 and 46 years. The data presented in Tables 11 and 12 show that both elderly males and females are significantly heavier ($\alpha = .05$) than the younger group, but elderly males and females were significantly shorter ($\alpha = .05$) than the younger group. Annis, Case, Clauser, and Bradtmiller (1991) have reviewed data from a number of sources to estimate the changes in mean weight and stature with age. The differences seen in the Australian population are consistent with the observations of Annis et al. (1991).

TABLE 11. Comparison of Anthropometric Dimensions of Elderly Australian Females (This Study) With Young Australian Female Pilots (Bullock & Steinberg, 1975)

Dimension		Young Australian Female $n = 35$		Elderly Australian Female $n = 138$	
		M	*SD*	*M*	*SD*
1	Weight (kg)	50	61	61	13
2	Stature	1657	66	1521	70
7	Sitting height	867	31	784	40
8	Sitting eye height	757	30	676	42
9	Sitting shoulder height	596	24	531	35
12	Buttock-knee length	583	26	530	35
14	Knee height	522	24	475	28
15	Popliteal height	401	22	379	28
18	Chest depth	185	14	235	47

Notes. All linear dimensions are in mm.

TABLE 12. Comparisons of Anthropometric Dimensions of Elderly Australian Males (This Study) With Young Australian Male Pilots (Bullock & Steinberg, 1975)

Dimension		Young Australian Male, $n = 75$		Elderly Australian Male, $n = 33$	
		M	*SD*	*M*	*SD*
1	Weight (kg)	66	102	72	11
2	Stature	1771	64	1658	79
7	Sitting height	916	32	843	56
8	Sitting eye height	799	31	729	46
9	Sitting shoulder height	609	31	587	37
12	Buttock-knee length	614	27	549	38
14	Knee height	565	24	515	31
15	Popliteal height	441	21	416	25
18	Chest depth	223	23	224	36

Notes. All linear measurements are in mm.

5. CONCLUSION

As the proportion of elderly people in the Australian population continues to increase, there are demands to keep them in the working force for as long as possible. This study was undertaken to provide anthropometric information on elderly Australians, aged 65 years and above, which could be used by designers for ergonomic design of the working and living environment.

The study has provided mean, standard deviation, and percentile values for 22 anthropometric dimensions of 171 elderly Australians. The study has also provided correlation coefficients between various body parts, which could help in estimating other body dimensions. The results of the study are consistent with other studies related to the anthropometry of elderly people conducted in other countries.

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