

Research article

Preliminary comparison of Anthropometric datasets for the Australian Defence Force

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Abstract

Background: A valid Australian Defence Force (ADF) anthropometric dataset is essential to optimise the design of personal equipment and vehicles. Until recently there was no up-to-date anthropometric data available for the ADF population, and hence international military data have often been used in Defence procurement specifications. However, the representativeness of these datasets is not known. The University of South Australia were contracted to conduct a pilot survey of Army personnel. This provided anthropometric data and allowed a comparison with international anthropometric datasets for the first time. **Aims:** This research aims to: (1) compare the pilot anthropometric data to that of the wider Army population; (2) compare the anthropometric data to that of the United States (US) and United Kingdom (UK) data; and (3) address appropriate usage of the current pilot anthropometric dataset. **Methods:** The pilot data was collected using a combination of manual techniques and 3D laser scanning technology. Height and weight data for the entire Army population was collected via health records and compared to the pilot data as a means to check for validity of the sample. Secondly, measurements were identified from UK and US standards, so that a comparison could be conducted with international military datasets. **Results:** The pilot sample male data were similar to the wider Army on several key dimensions, particularly at the 95th percentile. The pilot survey data differed markedly from the other international standards. **Conclusion:** The results of the pilot study are sufficient for use as an interim solution, subject to several caveats; however, it is recommended that a larger survey of ADF anthropometric measurements take place.

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Background

An understanding of the size and shape of the population is vital for the accurate design of everything from clothing to car interiors. Valid anthropometric data is especially important in the military environment. Modern day male and female military personnel must wear a range of clothing and protective equipment, including helmets, respirators and body armour. Protective equipment, like

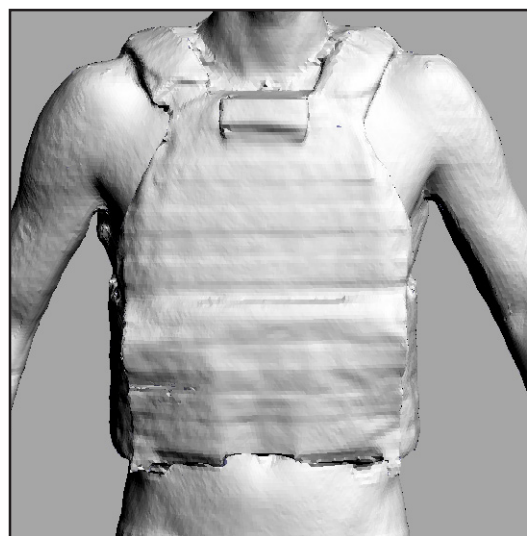


Figure 1. An example of personal protective equipment requiring accurate anthropometric data

body armour, such as in Figure 1, must conform closely to body, while minimising any restriction of movement and at the same time providing adequate protection of the vital organs. Furthermore, a sufficient number of sizes for each item of clothing and protective equipment are required to accommodate both males and females. Personnel may also be required to travel in or operate a range of land, sea and air vehicles, such as submarines, armoured personnel carriers, and fighter aircraft. Clearly, data on the size of the current population is required to ensure the vehicle is designed to maximise the percentage of personnel who can operate or travel in the vehicle. If the vehicle is an existing design and purchased “off the shelf”, body size data on the Australian Defence Force (ADF) population is required to determine the percentage of personnel accommodated in the vehicle.

Military Anthropometric Surveys

The last comprehensive anthropometric survey of ADF personnel took place in 1977 [1]. The main goal of the survey was to inform the design of workstations. Initially, a number of job occupations were identified that were associated with types of equipment and work environments, including aircrew, transportation, catering, and air traffic controllers (18 in total across the Army, Navy and Air Force). Approximately 200 subjects were measured in each of these categories to ensure the 5th and 95th percentile values were within the range of the expected measurement errors. The subjects measured were all male and were employed full time

and had ranks up to Lieutenant Colonel or equivalent. Data were gathered in each mainland state, except South Australia, Western Australia and the Northern Territory. This survey took 32 measurements on 2,945 male personnel, including stature, sitting height, bideltoid breadth, chest circumference, and hand length.

Both the United States (US) and United Kingdom (UK) Defence forces have completed large scale anthropometric surveys of their Army personnel. The US released their 1988 survey as Mil Std 1472F (ANSUR88) [8] and completed a follow-up pilot survey in 2006 (A2P) [9]. The UK released their 2006-07 survey as Defence Standard 00-25 (the UK study) [10].

Secular Trends

Over the last 150 years humans have, in general, been growing taller. This intergenerational change in body size is referred to as a secular trend, although some researchers prefer to use the term secular change [1][2] as the size of humans can, and has, decreased over the generations. In Australia, a secular trend in the height of adults has been estimated to be around one centimetre per decade [3], which is similar to many western European countries [2]. Although, for some populations, secular trends of up to three centimetres per decade have been observed during recent years, the Japanese being one example [4].

The most striking example of the inter-generational increase in stature overseas is the Dutch, who are now the tallest of the measured nations in the world. Based on conscript data, in the mid 1800s, the average young Dutchman was 165 cm tall [2]. In 1955, the average young Dutchman had grown to 176 cm (5' 9") tall and the average young Dutchwoman was 163 cm (5' 4") tall. The most recent survey (published in the year 2000) of the Dutch found that the average 21 year old Dutchman is now 184 cm (6' 1/2") tall and the average 21 year old Dutchwoman is now 171 cm (5' 7 1/2") [5].

Along with an increase in stature, the weight of adults and children in many countries has also been increasing. The secular trend in weight of Australian adults has been estimated to be about one kilogram per decade [3]. One commonly used measure of a person's "fatness" is the body mass index (BMI), defined as weight (in kilograms) divided by stature squared (in metres). In the National Nutrition Survey conducted in 1995, 29% of women and 45% of men were overweight based on their BMI ($25 \leq \text{BMI} < 30$), and a further 18% of men and women were found to be obese ($\text{BMI} \geq 30$) [6]. A recent survey of South Australian adults reported that 19.6% of the population had a body mass index greater than 30 (classifying them as obese) based on self-reported height and weight [7]. For a person who is 180 cm tall to have a BMI of 30 they would have to weigh 97.2 kg. Furthermore, researchers estimated that by 2013 27.8% of the adult South Australian population would be obese.

Clearly, given the increasing size of the population, and potential differences between surveyed populations, updated anthropometric data on the ADF population is urgently required. The Defence Materiel Organisation recognised this issue and tasked the Defence Science and Technology Organisation to co-ordinate a preliminary survey of a sample of the ADF population (Australian Army Anthropometric

Pilot Study; AAAPS). The AAAPS was completed in order to inform the design and procurement of a protective vest. The vest was intended for use primarily by infantry (part of Army), who are characterised by a younger age and leaner body mass. It is acknowledged that there are therefore limitations to using the AAAPS dataset; however it is not known to what degree this data represents the wider Army population and if it is more appropriate to use than relying on international anthropometric datasets at this time. Additionally this preliminary dataset can be used to make a case for and guide a future large scale survey, possibly including Navy and Air Force personnel, with more appropriate sampling methods. This paper therefore has three aims, to: (1) compare the AAAPS data to that of the wider Army population; (2) compare the AAAPS data to US and UK data; and (3) to address appropriate usage of the AAAPS dataset.

Methods

AAAPS data

The anthropometric study was designed in conjunction with the University of South Australia (UniSA), with UniSA contracted to handle data collection and management. Variables were chosen to allow for direct comparison with ANSUR88 and A2P. A convenience sample of 417 personnel (371 male and 46 female) had a total of 76 digital and manual measurements collected over a period of two weeks at Robertson Barracks (Palmerston, NT). Because of the low number of female personnel, it was decided to exclude their data from any analysis. Procedures need to be put in place in future surveys to ensure that females are adequately represented. Personnel who volunteered in this study were covered under the Australian Defence Health Research Ethics Committee approval number 499/07. Detailed anthropometric data collection methods have been reported separately [16].

Comparison datasets

Height and weight data is collected from personnel when they attend medicals. This data for the last 10 years was obtained from ADF records, in addition to age and gender. This data was used as an indication of the distribution of these key measurements of the wider Army.

Three international military datasets were obtained to enable comparison to the AAAPS dataset, namely; ANSUR88, A2P (summary statistics only) and the UK study. The ANSUR88 and A2P datasets were Army specific, whereas the UK dataset was tri-service.

Each dataset was imported into SPSS (v18), relabelled to be consistent with the AAAPS dataset and merged into a larger dataset. Forty measurements were common to AAAPS, across the ANSUR88, A2P and the UK study. UK measurements were predominantly extracted from scanned images rather than manual techniques. For the purposes of this paper, nine key measurements indicative of overall body size and proportions were compared. These measurements are defined in Table 1. All UK measurements except weight and stature were measured differently to the other datasets, which may affect comparability. However, no common measurement framework currently exists to ensure that measurements are standardised across datasets.

Table 1. Comparison of methods between studies

Measurement	ANSUR88/A2P [8/9]	AAAPS	Wider Army	UK Study [10]
Weight	The weight of the subject is taken to the nearest tenth of a kilogram. The subject stands on the platform of a scale	Manual as per ANSUR88 protocol	Unknown	Manual as per ANSUR88 protocol
Stature	The vertical distance from a standing surface to the top of the head is measured with an anthropometer. The subject stands erect with the head in the Frankfort plane. The heels are together with the weight distributed equally on both feet. The shoulders and upper extremities are relaxed.	Manual as per ANSUR88 protocol	Unknown	Manual as per ANSUR88 protocol
Waist circumference (omphalion)	The horizontal circumference of the waist at the level of the centre of the navel (omphalion) is measured with a tape. The subject stands erect looking straight ahead. The heels are together with the weight distributed equally on both feet.	Manual as per ANSUR88 protocol	Unknown	Scan. Taken at natural waistline
Hip breadth	The distance between the lateral points of the hips or thighs (whichever are broader) are measured with a beam caliper. The subject sits erect with the feet and knees together.	Manual as per ANSUR88 protocol	Not measured	Scan
Chest circumference	The maximum horizontal circumference of the chest at the fullest part of the breast is measured with a tape. The subject stands erect looking straight ahead. The shoulders and upper extremities are relaxed.	Manual as per ANSUR88 protocol	Not measured	Scan. Taken at the height of the axilla
Bideloid breadth	The maximum horizontal distance between the lateral margins of the upper arms on the deltooid muscles is measured with a beam caliper. The subject sits erect looking straight ahead. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other.	Manual as per ANSUR88 protocol	Not measured	Scan. Standing posture varied. 5.8% greater than manual as arms slightly abducted.
Sitting height	The vertical distance between a sitting surface and the top of the head is measured with an anthropometer. The subject sits erect with the head in the Frankfort plane. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90° with the feet in line with the thighs.	Manual as per ANSUR88 protocol	Not measured	Scan
Knee height	The vertical distance between a footrest surface and the Suprapatella landmark at the top of the right knee is measured with an anthropometer. The subject sits with the thighs parallel, the knees flexed 90°, and the feet in line with the thighs	Manual as per ANSUR88 protocol	Not measured	Scan. Mid knee level in standing
Buttock-knee length	The horizontal distance between a buttock plate placed at the most posterior point on either buttock and anterior point of the right knee is measured with an anthropometer. The subject sits erect. The thighs are parallel and the knees flexed 90° with the feet in line with the thighs.	Manual as per ANSUR88 protocol	Not measured	Scan. Buttocks to front of patella

Independent sample t-tests were used to find a statistical difference for each mean, 5th and 95th percentiles (%ile) measurement between AAAPS and ANSUR88 and the UK study. Absolute difference in means, 5th and 95th %iles and 95% confidence intervals in reference to the pilot study are reported for each study. Effect sizes were derived using the difference in means divided by the AAAPS SD [17], and interpreted using <0.19 as trivial effects, 0.20-0.59 as small, 0.60-1.19 as moderate and >1.2 as large [18].

Results

Table 2 details the age distribution of the AAAPS and wider Army datasets. It is obvious from this table that the younger personnel were over-represented, and except for four personnel, those aged 50 years and older were not represented in the AAAPS. As one of the aims was to compare the AAAPS data to that of the wider Army population and address appropriate usage, only data for those personnel aged less than 35 years from the wider Army dataset was used for comparisons (Tables 3 to 5). This limitation is noted and recommendations to provide a more age representative sampling strategy in future surveys will be provided to the ADF.

Table 2. Frequency of personnel by study and age

Age group	AAAPS study		Wider Army	
	n	%	n	%
16-24	213	57.4%	8,636	31.3%
25-29	93	25.1%	5,710	20.7%
30-34	33	8.9%	4,141	15.0%
35-39	8	2.1%	3,551	12.9%
40-44	11	3.0%	2,520	9.1%
45-49	9	2.4%	1,643	6.0%
50-54	4	1.1%	870	3.2%
55-59			414	1.5%
60+			87	0.3%
Total	371	100.0%	27572	100.0%

Table 3 lists the mean data for each variable and study for Army males. Differences between datasets range from -25.6 to 60.0mm. Standard deviations are similar between the studies, except for waist and chest circumference. The only significant difference between the AAAPS and wider Army data was for height. Significant differences were evident in

the majority of variables, with the UK dataset showing more variables with differences than ANSUR88. Table 3 also highlights the standardised effect sizes between studies for each variable. Mostly effects are trivial and small; however there are a number of moderate effects. These are all for the UK study (as compared to AAAPS); bideltoid breadth, sitting height and knee height.

The 5th%ile data is listed in Table 4. Differences ranged from -21.4 to 57.7mm. Moderate standardised effect sizes were

seen in sitting height for ANSUR88 and A2P (as compared to AAAPS). Large effect sizes were seen in sitting height and bideltoid breadth for the UK study. Table 5 lists the 95%ile data. Differences ranged from -61.0 to 77.0mm. Moderate effect sizes were seen in weight and waist circumference for ANSUR88, chest circumference for A2P and sitting height for the UK study. Large effect sizes were seen for bideltoid breadth for the UK study.

Table 3. Mean comparison between studies

	AAAPS mean ± SD (n=371)	Wider Army ± SD (n=3287-18487; <35years old only)	ANSUR88 mean ± SD (n=1774)	A2P mean ± SD (n=2811)	UK mean ± SD (n=636-1005)	AAAPS / wider Army absolute difference in means ±95% CI	AAAPS / ANSUR88 absolute difference in means ±95% CI	AAAPS / A2P absolute difference in means ±95% CI	AAAPS /UK absolute difference in means ±95% CI	AAAPS / wider Army Standardised effect size	AAAPS / ANSUR88 Standardised effect size	AAAPS / A2P Standardised effect size	AAAPS /UK Standardised effect size
Weight (kg)	83.3 ±12.9	83.0 ±11.9	78.5 ±11.1	85.2 ±14.0	82.4 ±13.0	0.3 ±1.3	4.8 ±1.4	-1.9 ±1.4	0.9 ±1.6	0.02 Trivial	0.37 Small	-0.15 Small	0.07 Trivial
Stature (mm)	1785.3 ±68.5	1800.9 ±67.2	1755.8 ±66.8	1755.5 ±69.9	1773.5 ±63.1	-15.6 ±7.0	29.5 ±3.4	29.8 ±2.9	11.8 ±4.5	-0.23 Small	0.43 Small	0.44 Small	0.17 Trivial
Waist circumference – omphalion (mm)	901.2 ±101.2	896.3 ±93.0	862.4 ±86.4	940.2 ±111.0	841.2 ±199.3	4.9 ±10.8	38.8 ±4.2	-39.0 ±4.3	60.0 ±13.7	0.05 Trivial	0.38 Small	-0.39 Small	0.59 Small
Hip breadth (mm)	371.6 ±31.1	-	366.8 ±25.2	372.9 ±30.5	375.7 ±23.5	-	4.8 ±1.8	-1.2 ±1.7	-4.1 ±2.2	-	0.16 Small	-0.04 Trivial	-0.13 Trivial
Chest circumference (mm)	1008.6 ±78.3	-	991.4 ±69.1	1048.0 ±92.7	1034.3 ±91.0	-	17.2 ±3.5	-39.4 ±3.7	-25.6 ±6.4	-	0.22 Small	-0.50 Small	-0.33 Small
Bideltoid breadth (mm)	493.5 ±29.4	-	491.8 ±25.9	501.8 ±32.6	515.3 ±33.2	-	1.7 ±1.8	-8.3 ±1.8	-21.6 ±6.4	-	0.06 Trivial	-0.28 Small	-0.74 Moderate
Sitting height (mm)	931.8 ±33.9	-	913.9 ±35.6	918.6 ±36.6	905.1 ±39.0	-	17.9 ±2.1	13.2 ±1.9	26.7 ±3.3	-	0.53 Small	0.39 Small	0.79 Moderate
Knee height (mm)	553.4 ±29.2	-	558.8 ±27.9	555.9 ±28.3	534.4 ±26.7	-	-5.4 ±1.8	-2.5 ±1.7	19.0 ±2.4	-	-0.18 Trivial	-0.09 Trivial	0.65 Moderate
Buttock-knee length (mm)	616.6 ±29.1	-	616.4 ±29.9	616.8 ±31.1	609.0 ±29.9	-	0.2 ±1.9	-0.2 ±1.7	7.6 ±2.7	-	0.01 Trivial	-0.01 Trivial	0.26 Small

Numbers in bold denote significant differences (p<.05)

Table 4. 5th Percentile comparison between studies

	AAAPS mean (n=371)	Wider Army (n=3287-18487; <35years old only)	ANSUR88 mean (n=1774)	A2P mean (n=2811)	UK mean (n=636-1005)	AAAPS / wider Army absolute difference in means ±95% CI	AAAPS / ANSUR88 absolute difference in means ±95% CI	AAAPS / A2P absolute difference in means ±95% CI	AAAPS /UK absolute difference in means ±95% CI	AAAPS / wider Army Standardised effect size	AAAPS / ANSUR88 Standardised effect size	AAAPS / A2P Standardised effect size	AAAPS /UK Standardised effect size
Weight (kg)	63.9	65.0	61.8	63.9	63.4	-1.1 ±1.3	2.1 ±1.4	0.0 ±1.4	0.5 ±1.6	0.00 Trivial	0.16 Trivial	0.00 Trivial	0.04 Trivial
Stature (mm)	1674.8	1690.0	1649.0	1643.0	1675.0	-15.2 ±7.0	25.8 ±3.4	31.8 ±2.9	-0.2 ±4.5	-0.22 Small	0.38 Small	0.46 Small	0.00 Trivial
Waist circumference – omphalion (mm)	764.0	760.0	735.0	765.0	706.3	4.0 ±10.8	29.0 ±4.2	-1.0 ±4.3	57.7 ±13.7	0.04 Trivial	0.29 Small	-0.01 Trivial	0.57 Small
Hip breadth (mm)	326.0	-	329.0	326.0	337.0	-	-3.0 ±1.8	0.0 ±1.7	-11.0 ±2.2	-	-0.10 Trivial	0.00 Trivial	-0.35 Small
Chest circumference (mm)	881.6	-	886.0	903.0	897.0	-	-4.4 ±3.5	-21.4 ±3.7	-15.4 ±6.4	-	-0.06 Trivial	-0.27 Small	-0.20 Trivial
Bideltoid breadth (mm)	448.0	-	450.0	451.0	463.0	-	-2.0 ±1.8	-3.0 ±1.8	46.0 ±2.6	-	-0.07 Trivial	-0.10 Trivial	1.56 Large
Sitting height (mm)	879.0	-	855.0	858.0	833.0	-	24.0 ±2.1	21.0 ±1.9	46.0 ±3.3	-	0.71 Moderate	0.62 Moderate	1.36 Large
Knee height (mm)	505.0	-	514.0	510.0	494.0	-	-9.0 ±1.8	-5.0 ±1.7	11.0 ±2.4	-	-0.31 Small	-0.17 Trivial	0.38 Small
Buttock-knee length (mm)	569.2	-	568.0	566.0	560.0	-	1.2 ±1.9	3.2 ±1.7	9.2 ±2.7	-	0.04 Trivial	0.11 Trivial	0.32 Small

Table 5. 95th Percentile comparison between studies

	AAAPS mean (n=371)	Wider Army (n=3287-18487; <35years old only)	ANSUR88 mean (n=1774)	A2P mean (n=2811)	UK mean (n=636-1005)	AAAPS / wider Army absolute difference in means $\pm 95\%$ CI	AAAPS / ANSUR88 absolute difference in means $\pm 95\%$ CI	AAAPS / A2P absolute difference in means $\pm 95\%$ CI	AAAPS / UK absolute difference in means $\pm 95\%$ CI	AAAPS / wider Army Standardised effect size	AAAPS / ANSUR88 Standardised effect size	AAAPS / A2P Standardised effect size	AAAPS / UK Standardised effect size
Weight (kg)	108.4	104.0	98.8	110.7	106.6	4.4 ± 1.3	9.6 ± 1.4	-2.3 ± 1.4	1.8 ± 1.6	0.34 Small	0.74 Moderate	-0.18 Trivial	0.14 Trivial
Stature (mm)	1898.2	1910.0	1868.0	1872.0	1885.0	-11.8 ± 7.0	30.2 ± 3.4	26.2 ± 2.9	13.2 ± 4.5	-0.17 Trivial	0.44 Small	0.38 Small	0.19 Trivial
Waist circumference – omphalion (mm)	1092.0	1060.0	1015.0	1126.0	1054.3	32.0 ± 10.8	77.0 ± 4.2	-34.0 ± 4.3	37.7 ± 13.7	0.32 Small	0.76 Moderate	-0.34 Small	0.37 Small
Hip breadth (mm)	429.0	-	412.0	427.0	414.0	-	17.0 ± 1.8	2.0 ± 1.7	15.0 ± 2.2	-	0.55 Small	0.06 Trivial	0.48 Small
Chest circumference (mm)	1151.0	-	1115.0	1212.0	1194.0	-	36.0 ± 3.5	-61.0 ± 3.7	-43.0 ± 6.4	-	0.46 Small	-0.78 Moderate	-0.55 Small
Bideltoid breadth (mm)	541.4	-	535.0	557.0	577.6	-	6.4 ± 1.8	-15.6 ± 1.8	-36.2 ± 2.6	-	0.22 Small	-0.53 Small	-1.23 Large
Sitting height (mm)	985.4	-	972.0	980.0	966.0	-	13.4 ± 2.1	5.4 ± 1.9	20.4 ± 3.3	-	0.40 Small	0.16 Trivial	0.60 Moderate
Knee height (mm)	599.0	-	605.0	604.0	587.0	-	-6.0 ± 1.8	-5.0 ± 1.7	12.0 ± 2.4	-	-0.21 Small	-0.17 Trivial	0.41 Small
Buttock-knee length (mm)	664.4	-	668.0	668.0	659.0	-	-3.6 ± 1.9	-3.6 ± 1.7	6.4 ± 2.7	-	-0.12 Trivial	-0.12 Trivial	0.22 Small

Discussion

The main objective of this study was to build a case for the further study of anthropometric measures of the Australian Army by comparing the AAAPS to that of basic wider Army measures and several international datasets. A further objective was to ascertain whether the AAAPS dataset could be used as an interim solution for design and procurement decisions, instead of relying on datasets based on other populations. Apart from the clear discrepancies in age stratification, the AAAPS data was similar to the limited wider Army data available at the mean, 5th and 95th %iles. The AAAPS group was approximately 16mm shorter than the wider Army, which may have been for a number of reasons. No attempt was made to weight the sample of groups and occupations (e.g. riflemen versus carpenters) to that of the wider Army. Because of this, there may have been a greater proportion of one group or occupation who were sampled who were similarly built soldiers. The difference in height may also be due to the way that stature was measured. The methods for determining stature were not easily available, as wider Army testing occurs by various individuals at various locations around the country. It is possible that differences in measuring stature have contributed to the differences in height between surveys.

When comparing between international datasets, the largest difference was between the AAAPS and the 1988 ANSUR88 study, which is to be expected given the US survey was conducted 22 years before the AAAPS survey. If, as is often the case, the ANSUR88 data is used as a substitute for more up to date data, errors may be made in equipment design and procurement decisions. Even when comparing the AAAPS to the 2006 A2P dataset, differences in chest and waist circumference and stature still remained, suggesting that differences are likely to exist in ethnic composition and adiposity.

Differences between the AAAPS and the UK study are at times substantial and not easily attributed to either ethnic composition differences or the methods of determining variables, which differed markedly between the two studies. The differences are likely to be due to a mixture of the two. The largest effect sizes were seen between AAAPS and the UK study, particularly for sitting height and bideltoid breadth. The large differences in bideltoid breadth was accounted for in the report, however sitting height (mean difference 30mm) has no such explanations (most likely this difference is due to the difficulty accurately determining the location of the vertex in the scan). Using the UK data for sitting height in, for example, the design of a vehicle cab may result in Australian soldiers being more uncomfortable or prone to injury.

Limitations

Only Army personnel were included in this voluntary survey and only one military base was included in this survey; therefore the data is skewed towards the attributes found in this group. Personnel tended to be younger and fit for operational duty. No attempt was made to balance this sample according to the wider ethnic or age makeup of the Army, nor the group or occupation profile. Although the percentage of females initially captured in this study was similar to that of the wider Army, an overall small sample size restricted the practical use of this group in any comparisons.

Conclusion

The AAAPS dataset is representative of the younger, fitter male members of the Australian Army. Large differences are apparent between the AAAPS dataset and that of the international datasets. It is recommended that the AAAPS dataset be used in place of international data for procurement and design decisions, while considering the limitations of the data.

Acknowledgements

The authors wish to thank Alistair Furnell, Renee Attwells, Major Graeme Tilley, the University of South Australia and 1 Brigade for making this survey possible.

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