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Vehicle Anthropometric Specification

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ABSTRACT

The Australian Defence Force (ADF) will be acquiring a number of vehicles in the near future. When acquiring a new vehicle, numerous factors must be considered when determining the most suitable option for the ADF. One very important consideration concerns the anthropometric accommodation aspect of the workstation. Ideally, the vehicle should safely accommodate a wide range of male and female body sizes, maximising the pool of potential users. This report provides an athropometric specification that can be used to support vehicle acquisitions and upgrades when no suitable data on the relevant ADF population is available.

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Executive Summary

In the near future, a number of new vehicles will be acquired by the Australian Defence Force (ADF). When acquiring a new vehicle, numerous factors must be considered when determining the most suitable option. One very important consideration concerns the anthropometric accommodation aspect of the workstation human machine interface. Ideally, the vehicle should safely accommodate a wide range of male and female body sizes.

While a number of ADF groups have been surveyed over the last decade, the last comprehensive tri-service anthropometric survey of the ADF population was conducted in 1977. Given the increasing size of the military population, 36 year old body size data realistically no longer accurately reflects the size and shape of the ADF population. Furthermore, no females were measured in the 1977 survey. Given this situation, it was decided to use a subset of the Civilian American and European Surface Anthropometry Resource (CAESAR) anthropometric dataset to represent the dimensions of these groups (18-50 year old white North Americans with a body mass index less than 30) to create an anthropometric specification to represent ADF groups for which there is no current anthropometric data. This specification can be used when no suitable ADF data is available to inform the anthropometric fit aspects of new vehicles acquisitions and any upgrades of existing vehicles.

It is recommended that a comprehensive anthropometric survey of all ADF occupations be conducted to ensure future acquisitions accommodate an optimum number of personnel.

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Contents

Glossary

ADF	Australian Defence Force
BMI	Body Mass Index
CAESAR	Civilian American and European Surface Anthropometry Resource
MAM	Multivariate Accommodation Model
NATO	North Atlantic Treaty Organisation
PC	Principal Component
PCA	Principal Component Analysis
USAF	United States Air Force

1. Introduction

The Australian Defence Force (ADF) will be acquiring a number of new vehicles in the near future. For example, a replacement for the Collins-class submarine, a new rotary-wing training aircraft, along with new troop transport vehicles. When acquiring a new vehicle, numerous factors must be considered when determining the most suitable option for the ADF. One very important consideration concerns the anthropometric accommodation aspects of the vehicle human machine interface. Ideally, the vehicle should safely accommodate a large proportion of the male and female ADF population.

Historically, when designing a seated work environment it has been assumed that the difficult to accommodate subjects are the uniformly very small and the very large. When specifying the proportion of the population to be accommodated a percentile method has been traditionally used (a percentile gives the relative ranking of a measurement). For example, if 90% of males were to be accommodated in a cockpit, it was assumed that by specifying the 5th to 95th percentile male size values for key cockpit dimensions (such as buttock-knee length and sitting height) when designing an aircraft, then approximately 90% of the male population would be accommodated. Unfortunately, due to the multivariate nature of human anthropometric dimensions (for example, a person may have long limbs and a short torso), a much smaller percentage of people are actually accommodated than the uniform model predicts (Robinette and McConville 1982). Furthermore, as the number of anthropometric restrictions increases, the proportion of the intended population accommodated decreases.

To illustrate the potential problems that can occur due to using a percentile specification, an example from the United States Air Force (USAF) is presented here. The T-1 Jayhawk is a twin engine jet aircraft that is used by USAF to train pilots who will go on to fly tanker and transport aircraft. The initial percentile anthropometric specification required the aircraft to accommodate (ensuring the pilot has the required field of view, has the appropriate clearance with the cockpit structures, and can reach all the controls) 98% of the pilot population (Zehner and Hudson 2002). However, an "in cockpit" assessment of the anthropometric accommodation of this aircraft found that it did not accommodate 30% of Caucasian pilots, 80% of African American pilots and 90% of female pilots for whom it was designed (Robinette, Nemeth et al. 1998). The pilots who were eliminated typically had a short seated eye height and long legs, or a short seated height and a large thigh circumference. The pilots with a short seated height were required to have the seat at or near its highest position, which then made it difficult to achieve full control yoke range of motion.

Following the identification of the problems inherent in the percentile method, a specification technique based principal component analysis (PCA) was developed. PCA is a data reduction technique that minimises the number of dimensions needed to describe anthropometric variability by combining related measurements into a set of factors based on their correlation (Zehner, Meindl et al. 1993). Typically, in cockpit accommodation studies, the first two factors are retained for the analysis, with these components accounting for approximately 90% of the original variation. About eight to ten test cases (virtual people) are then identified that represent the extreme cases from the population of interest. These cases represent the very tall and very short subjects, along with subjects of near average height who have contrasting proportions (for example, a long torso and short limbs). It should be noted that while these test cases describe the extremes of the population for workstation accommodation they do not necessarily describe extremes of the population for other applications, for example, the design of a helmet. In this case, a separate analysis would have to be conducted using the key dimensions that define helmet fit. The PCA technique has been applied to a wide range of workstation and protective equipment design problems, including aircraft cockpits (Zehner, Meindl et al. 1993), office workstations (Gordon 2002), tractor cabs (Hsiao, Whitestone et al. 2005), fall protection harnesses (Hsiao, Bradtmiller et al. 2003), and body armour (Gordon, Corner et al. 1997).

While a number of ADF groups, such as aircrew (Singh and Smith 2008), have been surveyed over the last ten years, the last comprehensive tri-service survey of the ADF population was conducted in 1977 (Hendy 1979). Given the increasing size of the military populations (Soar 1999; Tomkinson, Clark et al. 2010; Fulton 2011), data 36 years old no longer accurately reflects the ADF population. Given this, it was decided to use an anthropometric dataset from a similar overseas population (18-50 year old white North Americans with a body mass index less than 30) to create an anthropometric specification to represent ADF groups for which there is no current anthropometric data. This specification (see Tables 8, 9 and 10) using the CAESAR subset can be used to inform the anthropometric fit aspects of new vehicles acquisitions and any upgrades of existing vehicles.

2. Method

2.1 Anthropometric Data

The Civilian American and European Surface Anthropometry Resource (CAESAR) project surveyed three countries that are members of the North Atlantic Treaty Organisation (NATO), the Netherlands, Italy and the United States of America (Robinette, Blackwell et al. 2002). The United States was chosen because it has the largest and most diverse population of the NATO countries, the Netherlands was selected because it has the tallest population, and Italy because it is one of the shortest NATO populations. Data was collected at 12 locations in North America (one site was in Canada), while only one location was used for each European country. In total, over 4000 adults (18-65 years old) were measured. This was the first major anthropometric survey to use three-dimensional scanners to capture a "digital statue" of the volunteers. Each of the volunteers was laser scanned in three postures, standing, a comfortable seated working posture and a seated coverage posture. The final posture was included to capture parts of the body missed by the seated working posture scan, such as under the chin and between the thighs and underneath the arms. A number of one dimensional measurements were extracted from these scans, including standing acromial height, biacromial breadth and acromion-radiale length. In addition to the measurements extracted from the laser scans, 40 manual measurements were taken, including buttock-knee length; knee height, sitting; eye height, sitting; and hand length. To approximate the ADF population, white North American CAESAR subjects between the ages of 18 and 50 with a body mass index less (BMI) than 30 were used for this analysis.

2.2 Measurement Selection

The critical dimensions which determine cockpit accommodation and that must be considered simultaneously are: sitting height; eye height, sitting; thumb tip reach; acromion height, sitting; buttock-knee length; and knee height, sitting (Zehner, Meindl et al. 1993). Using the PCA technique, extreme boundary cases can be created that represent the hard to accommodate cases using the body dimensions that must be considered simultaneously. Other anthropometric dimensions that are also important for cockpit accommodation are simply clearance dimensions and can be considered separately (Zehner, Meindl et al. 1993). These clearance dimensions are bideltoid breadth; hip breath, sitting; buttock-popliteal length; popliteal height; thigh circumference and foot length. All but two of these measurements were taken on the CAESAR survey subjects (buttock-popliteal length and popliteal height). A measurement very similar to popliteal height (knee height, standing) was taken on the CAESAR subjects and was substituted for popliteal height for this analysis. Buttock-popliteal length was estimated using a regression equation using data from the US Army 1988 survey[1] (Gordon, Churchill et al. 1989). Summary statistics for the 12 measurements critical for cockpit accommodation are shown in Table 2 and Table 3.

Table 1 Critical measurements for cockpit accommodation.

Measurement	Measured in CAESAR Survey
Sitting height	Yes
Eye height, sitting	Yes
Thumb-tip reach	Yes
Acromion height, sitting	Yes
Buttock-knee length	Yes
Knee height, sitting	Yes
Buttock-popliteal length	No[2]
Popliteal height	No[3]
Bideltoid breadth	Yes
Hip breadth, sitting	Yes
Thigh circumference	Yes
Foot length	Yes

[1] Using subjects 18-50 years old who were classified as white.
[2] This measurement can be estimated using buttock-knee length.
[3] A closely related measurement (knee height, standing) was measured.

Table 2 Summary statistics for key cockpit dimensions for males. All units are millimetres.

Measurement	Mean	5th Percentile	95th Percentile
Sitting height	935	876	999
Eye height, sitting	817	760	880
Thumb-tip reach	813	753	879
Acromion height, sitting	609	562	660
Buttock-knee length	615	569	669
Knee height, sitting	564	518	612
Buttock-popliteal length	499	459	545
Knee height, standing	500	457	550
Bideltoid breadth	488	443	531
Hip breadth, sitting	373	333	412
Thigh circumference	594	529	662
Foot length	268	246	292

Table 3 Summary statistics for key cockpit dimensions for females. All units are millimetres.

Measurement	Mean	5th Percentile	95th Percentile
Sitting height	874	821	935
Eye height, sitting	764	713	819
Thumb-tip reach	737	682	799
Acromion height, sitting	572	529	616
Buttock-knee length	582	537	632
Knee height, sitting	511	472	556
Buttock-popliteal length	475	437	518
Knee height, standing	450	411	492
Bideltoid breadth	421	385	460
Hip breadth, sitting	396	349	449
Thigh circumference	585	512	665
Foot length	238	220	256

2.3 Statistical Analysis

Following the process described in Zehner (2000)[4], the multivariate accommodation model[5] (MAM) version 3 and the CAESAR subset (white North Americans 18-50 years old with a BMI < 30) were used to create eight male and eight female boundary cases that encompassed 95% of the male and female populations, respectively. These boundary cases were then compared to produce a final set of cases representing the extremes of the male and female populations.

[4] This methodology was also used to create the anthropometric specification for the Joint Strike Fighter.
[5] The MAM software was kindly supplied by Dr Greg Zehner (Senior Research Physical Anthropologist, Air Force Research Laboratory, Wright-Patterson Air Force Base, USA)

3. Results

3.1 Males

Following Zehner (2000), the first two principal components were retained for this analysis. The first component describes the overall size of the subjects, while the second component describes the contrasting height of the torso and the length of the limbs. A plot of the values of each of the male subjects for the first two principal components is shown in Figure 1. Also plotted on this figure is an ellipse that encloses 95% of the male cases. Following Zehner (2000), eight points (A – D, W – Z)[6] are selected on the ellipse at the intersection of the ellipse and the axes and at the mid-points between the axes to represent the extreme cases of the population for this particular application (setting the accommodation level at 95%). The anthropometric dimensions of these eight cases are listed in Table 4. The horizontal axis shown in Figure 1 represents the overall body size of the subjects, whilst the vertical axis represents the contrasting proportions of the subjects. Case W represents the overall largest subject, while case Y represents the overall smallest subject. Cases X and Z represent subjects of approximately average height who have contrasting proportions. Case Z has a long torso (large sitting height) and relatively short arms and legs. In contrast, case X has a small sitting height and relatively long arms and legs. Cases B (long limbs, short torso) and D (long torso, short limbs) are below average height, although not as short as case Y, and like cases X and Z have contrasting proportions. Finally, cases A (long limbs, short torso) and C (long torso, short limbs) represent subjects that are tall, but not quite as tall as case W, who have contrasting proportions.

[6] Each case can be thought of as a virtual person of a particular size and proportion.

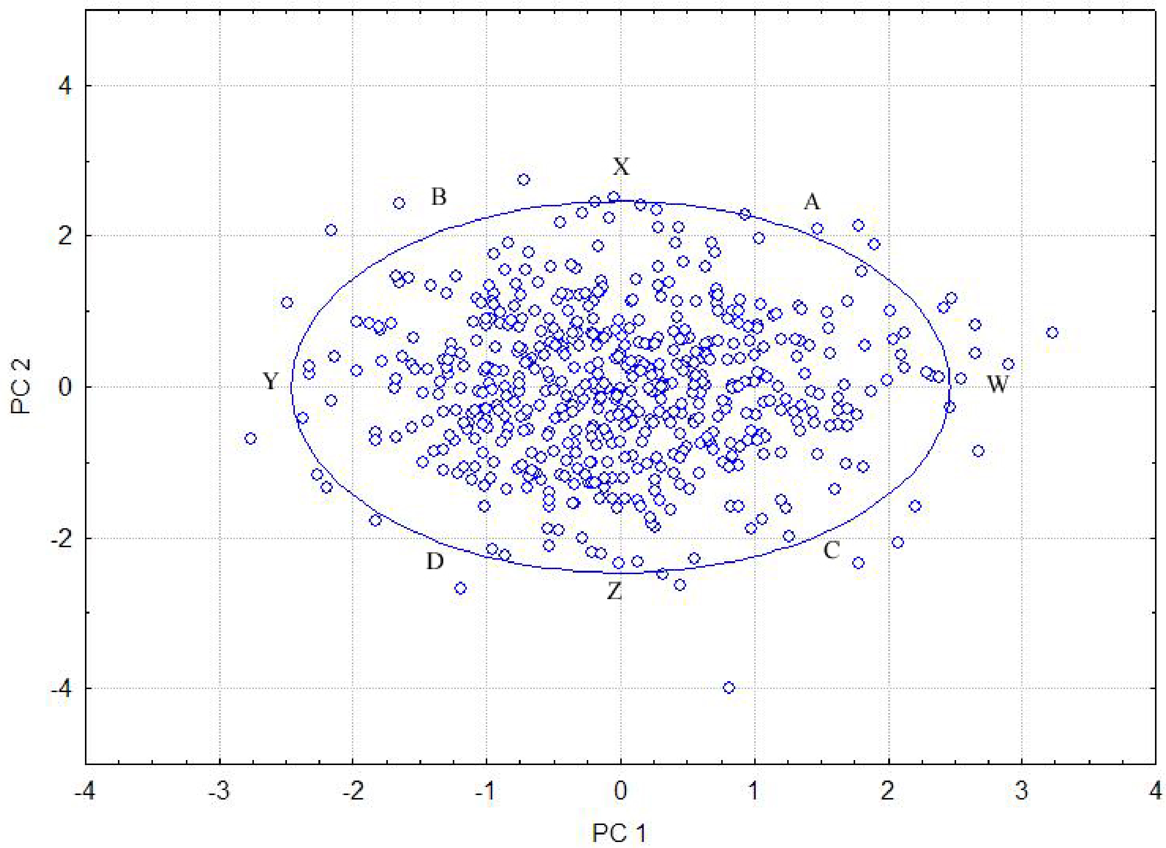

Figure 1 Scatterplot of the male cases for the first two principal components. Also plotted is an ellipse enclosing 95% of cases, along with eight boundary cases (A-D, W-Z).

3.1.1 Boundary Cases

Table 4 Eight boundary cases for the male dataset. All units are millimetres.

Measurement	Case A	Case B	Case C	Case D	Case W	Case X	Case Y	Case Z
Buttock-knee length	682	595	636	548	677	649	554	582
Thumb-tip reach	900	785	842	727	895	854	732	772
Eye height, sitting	849	735	899	785	897	781	736	852
Knee height, sitting	629	536	592	499	629	590	498	538
Acromion height, sitting	635	542	676	584	675	580	544	639
Sitting height	968	851	1019	902	1018	899	852	971

3.2 Females

Following Zehner (2000), the first two principal components were retained for this analysis. The first component describes the overall size of the subjects, while the second component describes the contrasting height of the torso and the length of the limbs. A plot of the values of the first two principal components for the female cases is shown in Figure 2. Also plotted on this figure is an ellipse that encloses 95% of the cases. Following Zehner (2000), eight points (A – D, W – Z) are selected on the ellipse at the intersection of the ellipse and the axes and at the mid-points between the axes to represent the extreme cases of the population for this application (which sets the accommodation level at 95%). The anthropometric dimensions for these eight cases are listed in Table 5. Case W represents the overall largest subject, while case Y represents the overall smallest subject. Cases X and Z represent subjects of average height who have strongly contrasting proportions. Case Z has a long torso (large sitting height) and relatively short arms and legs. In contrast, case X is of approximately average height but has a short torso and relatively long arms and legs. Cases B and D are below average height and like cases X and Z have contrasting proportions, with case B having long limbs and a short torso and case D having a long torso and short limbs. Finally, cases A and C represent subjects that are tall, but not as tall as case W, but who have contrasting proportions.

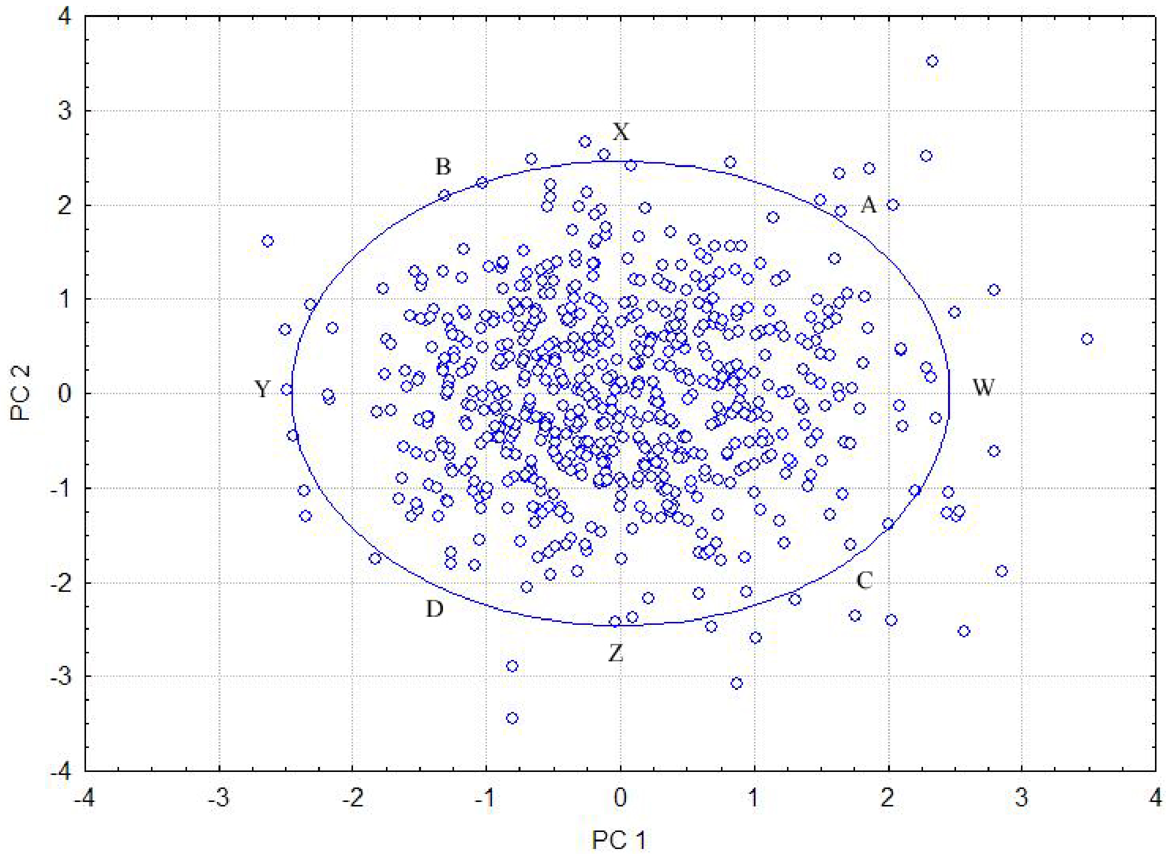

Figure 2 Scatterplot of the female cases for the first two principal components. Also plotted is an ellipse enclosing 95% of cases, along with eight boundary cases (A-D, W-Z).

3.2.1 Boundary Cases

Table 5 Eight boundary cases for the female dataset. All units are millimetres.

Measurement	Case A	Case B	Case C	Case D	Case W	Case X	Case Y	Case Z
Buttock-knee length	648	569	595	516	637	619	526	544
Thumb-tip reach	817	713	761	657	811	777	663	697
Eye height, sitting	792	691	837	735	836	733	692	795
Knee height, sitting	570	490	532	452	568	538	454	484
Acromion height, sitting	589	509	635	555	628	539	515	604
Sitting height	906	796	953	842	952	841	796	907

3.3 Combined Male and Female Boundary Cases

Following Zehner (2000), the eight male and female cases are compared in this section (see Table 6 and Table 7) so that the most extreme case for each pair of cases can be determined. These extreme cases describe boundary cases which should ensure accommodation at the 95% level for males and females (see Table 8). To assist with the comparison of the cases below, Figure 3 shows 95% ellipses for buttock-knee length versus sitting height for males and females. Also plotted are the eight boundary cases for males and females.

3.3.1 Case A – Longest limbs

Case A represents the subject with the longest limbs of the eight boundary cases. The male case A has longer arms (larger by 83 mm) and legs (buttock-knee length larger by 34 mm, knee height, sitting larger by 59 mm) than the female case.

3.3.2 Case B – Shortest torso

Case B has the shortest torso of the eight cases. In this case, the female has a sitting height 55 mm smaller and an acromion height, sitting 33 mm smaller than the male case.

3.3.3 Case C – Longest torso

Case C represents the subject with the largest torso (sitting height). The male case has a sitting height 66 mm larger and an acromion height, sitting 41 mm larger than the female case.

3.3.4 Case D – Shortest limbs

Case D represents the boundary case with the shortest arms and legs. In this case, the female subject has shorter limbs than the male case. The female's arms are 70 mm shorter than the males. Furthermore, the female subject's buttock-knee length and knee height, sitting are smaller by 32 mm and 47 mm, respectively.

3.3.5 Case W - Overall largest

Case W is the tallest of the eight cases. The male case is considerably larger than the female case for all six dimensions. For example, the male case has a sitting height 66 mm larger and a buttock-knee length 40 mm larger than the female case.

3.3.6 Case X – Extreme contrast (long limbs/short torso)

Case X represents a subject of near average size who shows the most extreme contrast in proportions of the eight subjects, with this case having long limbs relative to their torso. In this case, both the male and female cases represent extreme contrasts in body proportions. Furthermore, it is difficult to determine which of the two cases is more extreme. Following Zehner (2000), both of these cases are retained for the final set of boundary cases.

3.3.7 Case Y – Overall smallest

Case Y is the shortest of the eight cases. Clearly in this case the female case is considerably smaller than the male case for all six dimensions. For example, the sitting height of the female case is 56 mm shorter than the male case and the female's arms are 69 mm smaller.

3.3.8 Case Z – Extreme contrast (short limbs/long torso)

As for case X, both the male and female cases represent extreme contrasts in body proportions (in this case a long torso and short limbs). The male case has a sitting height of 971 mm and a buttock-knee length of only 582 mm. The female is similarly proportioned, with a sitting height of 907 mm and a buttock-knee length of 544 mm. Following Zehner (2000), both of these cases are retained for the final set of combined cases.

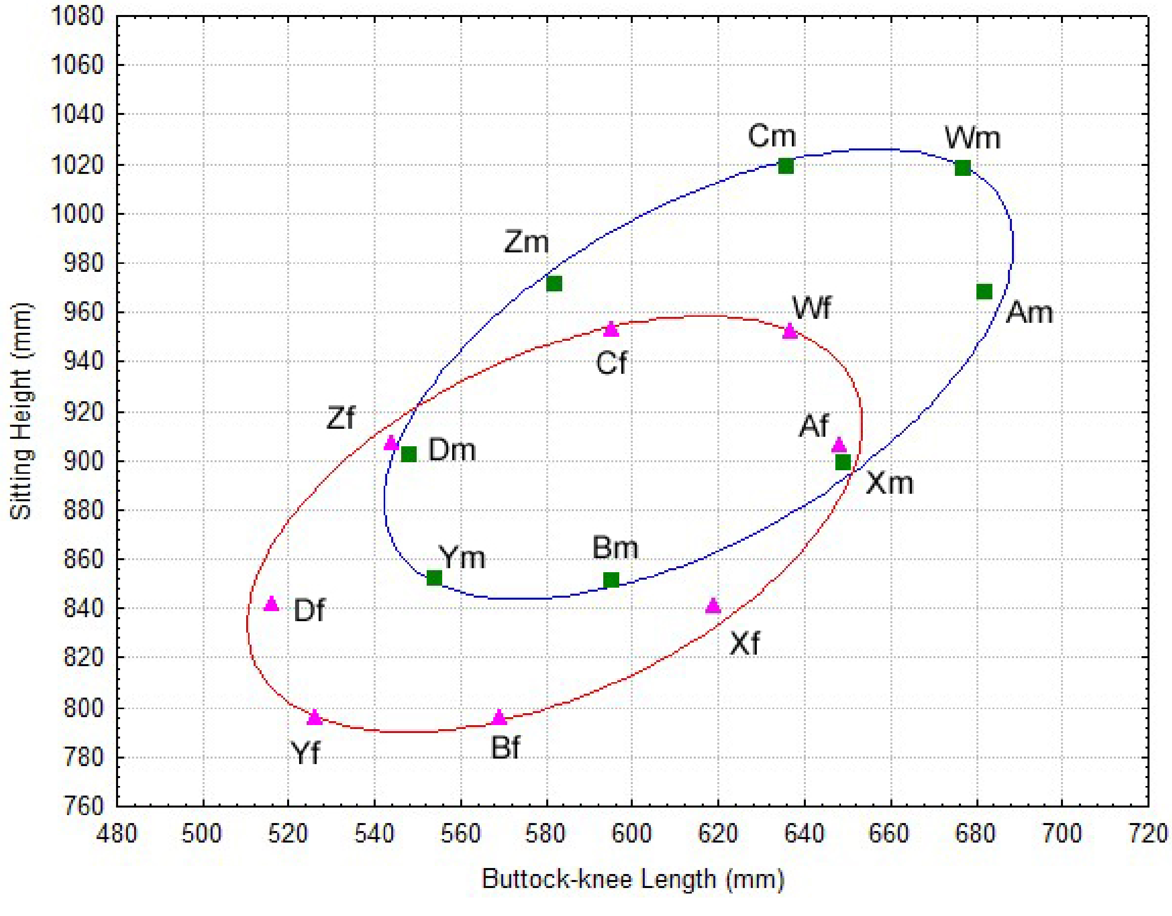

Figure 3 Plot of buttock-knee length versus sitting height. Ellipses enclose 95% of male (blue ellipse) and female (red ellipse) cases. The male (green square) and female (pink triangle) boundary cases A-D and W-Z (f – female, m- male) are also plotted.

Table 6 Comparison of male and female boundary cases (cases A – D, m – male, f - female). All units are millimetres.

Measurement	Case A f	Case A m	Case B f	Case B m	Case C f	Case C m	Case D f	Case D m
Buttock-knee length	648	682	569	595	595	636	516	548
Thumb-tip reach	817	900	713	785	761	842	657	727
Eye height, sitting	792	849	691	735	837	899	735	785
Knee height, sitting	570	629	490	536	532	592	452	499
Acromion height, sitting	589	635	509	542	635	676	555	584
Sitting height	906	968	796	851	953	1019	842	902

Table 7 Comparison of male and female boundary cases (cases W – Z, m- male, f - female). All units are millimetres.

Measurement	Case W f	Case W m	Case X f	Case X m	Case Y f	Case Y m	Case Z f	Case Z m
Buttock-knee length	637	677	619	649	526	554	544	582
Thumb-tip reach	811	895	777	854	663	732	697	772
Eye height, sitting	836	897	733	781	692	736	795	852
Knee height, sitting	568	629	538	590	454	498	484	538
Acromion height, sitting	628	675	539	580	515	544	604	639
Sitting height	952	1018	841	899	796	852	907	971

Table 8 Combined male and female boundary cases (m – male, f – female) representing accommodation at the 95% level. All units are millimetres.

Measurement	Case A	Case B	Case C	Case D	Case W	Case X f	Case X m	Case Y	Case Z f	Case Z m
Buttock-knee length	682	569	636	516	677	619	649	526	544	582
Thumb-tip reach	900	713	842	657	895	777	854	663	697	772
Eye height, sitting	849	691	899	735	897	733	781	692	795	852
Knee height, sitting	629	490	592	452	629	538	590	454	484	538
Acromion height, sitting	635	509	676	555	675	539	580	515	604	639
Sitting height	968	796	1019	842	1018	841	899	796	907	971

3.4 Clearance Dimensions

Some anthropometric dimensions that are important for vehicle accommodation are simply clearance dimensions and can be considered in isolation (Zehner 2000). For example, anthropometric dimensions like hip breadth, sitting; buttock-popliteal length; and popliteal height are important when assessing if the dimensions of the seat are appropriate. Also, extreme values of shoulder width must be considered when assessing the clearance of the pilot with the cockpit structures. Summary statistics for the key anthropometric clearance dimensions bideltoid breadth; buttock-popliteal length; knee height, standing; hip breadth, sitting; thigh circumference and foot length are presented in Table 9 (males) and Table 10 (females).

Table 9 Male clearance dimensions for vehicle accommodation. All units are millimetres.

Dimension	5th Percentile	95th Percentile
Buttock-popliteal length	459	545
Knee height, standing	457	550
Bideltoid breath	443	531
Hip breadth, sitting	333	412
Thigh circumference	529	662
Foot length	246	292

Table 10 Female clearance dimensions for vehicle accommodation. All units are millimetres.

Dimension	5th Percentile	95th Percentile
Buttock-popliteal length	437	518
Knee height, standing	411	492
Bideltoid breath	385	460
Hip breadth, sitting	349	449
Thigh circumference	512	665
Foot length	220	256

4. Discussion

The ADF will be acquiring a number of new vehicle types in the near future. An important consideration in the acquisition of a new vehicle or the upgrading of existing vehicle is the vehicle human machine interface. The vehicle should be designed to ensure a wide range of subjects can position the seat so that they have an appropriate internal and external field of view, can reach all the controls (by hand and foot), and maintain a safe clearance of the vehicle structures. Following an appreciation of the problems inherent in using the percentile technique for cockpit specifications, a method was developed using a statistical technique called principal component analysis which appropriately describes the hard to fit members of the population. The PCA technique has been used to create specifications to support the design of many vehicles and items of protective equipment such as aircraft (including the Joint Strike Fighter), body armour, tractor cabs, and fall protection harnesses.

Using the CAESAR subset, the anthropometric accommodation methodology developed by Zehner et al. (1993) was used to create eight male and eight female boundary cases that encompassed 95% of the male and female populations, respectively. These boundary cases ranged from the very small subject (female case Y), who has a buttock-knee length of 526 mm and a sitting height of 796 mm to the very big (male case W) who has a sitting height 1018 mm and a buttock-knee length of 677 mm. The remaining six cases represent subjects who have heights between cases Y and W but who have contrasting proportions. Cases D, Z and C represent subjects who have a long torso and short limbs, while cases B, X and A represent subjects who have long limbs and a short torso. Again, following Zehner (2000), each of the eight male and female cases were compared to determine which of each pair of male and female cases was the most extreme case. For three of the paired comparisons, the most extreme case was female (cases B, D and Y). These cases represent the shortest of the eight cases. For a further three of the paired comparisons, the most extreme case was male (cases A, C and W), which represent the tallest of the three cases. Cases X and Z represent subjects of roughly average height who have strongly contrasting proportions. Case X represents a subject with long arms and legs and a short torso, while case Z represents a subject with a long torso, and short arms and legs. The male case X has a sitting height of 899 mm and a buttock-knee length of 649 mm, while case Z in contrast has a sitting height of 971 mm and a buttock-knee length of only 582 mm. In these two cases it was difficult to determine whether the male or female case was more extreme. So, following Zehner, both the male and female cases X and Z were retained for the final combined set of boundary cases, bringing the total number of cases to ten (see Table 8). These ten cases range in height from approximately 1500 mm to 1950 mm tall (based on the height of the nearest neighbours to female case Y and male case W) and represent the boundary envelope which describes 95% of the potential aircrew population. Supplementing these boundary cases, summary statistics for anthropometric clearance dimensions (see Table 9 and Table 10), such as buttock-popliteal length, were also calculated, to ensure, for example, the dimensions of the seat are appropriate. Together, Table 8, Table 9 and Table 10 (see also Appendix A) form a specification which describes an accommodation envelope that encloses 95% of the population.

5. Concluding Remarks

The Australian Defence Force will be acquiring a number of new vehicles in the near future. When acquiring a new aircraft numerous factors must be considered when determining the most suitable aircraft for the ADF. One very important consideration is the vehicle human machine interface. The vehicle should be designed to ensure a wide range of subjects can position the seat so that they have an appropriate internal and external field of view, can reach all the controls, and maintain a safe clearance of the vehicle structures. An anthropometric specification which describes the "hard to fit" members of the ADF population has been developed. This specification can be used to inform the acquisition of new vehicles or the upgrading of existing vehicles.

Acknowledgements

The data and software used for this analysis was kindly supplied by Dr Greg Zehner (Air Force Research Laboratory, Wright-Patterson Air Force Base, USA). Thanks also to Dr Robert King, Mr Ashley Arney and Dr Lynn Booth for their helpful feedback.

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Appendix A: Anthropometric Specification

The following tables describe an anthropometric specification that encloses 95% of the population.

Table A1 Combined male and female boundary cases (m – male, f – female) representing accommodation at the 95% level. All units are millimetres.

Measurement	Case A	Case B	Case C	Case D	Case W	Case X f	Case X m	Case Y	Case Z f	Case Z m
Buttock-knee length	682	569	636	516	677	619	649	526	544	582
Thumb-tip reach	900	713	842	657	895	777	854	663	697	772
Eye height, sitting	849	691	899	735	897	733	781	692	795	852
Knee height, sitting	629	490	592	452	629	538	590	454	484	538
Acromion height, sitting	635	509	676	555	675	539	580	515	604	639
Sitting height	968	796	1019	842	1018	841	899	796	907	971

Table A2 Male clearance dimensions for vehicle accommodation. All units are millimetres.

Dimension	5th Percentile	95th Percentile
Buttock-popliteal length	459	545
Knee height, standing	457	550
Bideltoid breath	443	531
Hip breadth, sitting	333	412
Thigh circumference	529	662
Foot length	246	292

Table A3 Female clearance dimensions for vehicle accommodation. All units are millimetres.

Dimension	5th Percentile	95th Percentile
Buttock-popliteal length	437	518
Knee height, standing	411	492
Bideltoid breath	385	460
Hip breadth, sitting	349	449
Thigh circumference	512	665
Foot length	220	256

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19. ABSTRACT

The Australian Defence Force (ADF) will be acquiring a number of vehicles in the near future. When acquiring a new vehicle, numerous factors must be considered when determining the most suitable option for the ADF. One very important consideration concerns the anthropometric accommodation aspect of the workstation. Ideally, the vehicle should safely accommodate a wide range of male and female body sizes, maximising the pool of potential users. This report provides an athropometric specification that can be used to support vehicle acquisitions and upgrades when no suitable data on the relevant ADF population is available.