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## Australian Defence Force Anthropometry: A Summary of Historic Surveys

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#### ABSTRACT

Over the last seventy years a number of anthropometric (body size) surveys of Australian Defence Force (ADF) groups have been conducted. Typically, the main goal of these surveys has been to inform the design and sizing of clothing, while the main goal of a smaller number of surveys has been to inform the design of workstations. The purpose of this report is to summarise the populations sampled, methodologies used, measurements taken and key results of all formally reported and catalogued ADF anthropometric surveys.

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# Australian Defence Force Anthropometry: A Summary of Historic Surveys

## **Executive Summary**

An understanding of body dimensions (anthropometry) is extremely important in the military environment. Current day male and female Australian Defence Force (ADF) personnel must wear a range of clothing, footwear, and protective equipment, including helmets, respirators, body armour and protective eyewear. Protective equipment must conform closely to the 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 male and female members of the ADF. Clearly, up to date information on the size and shape of male and female ADF personnel is required to optimise the design and sizing of clothing and protective equipment and to ensure a sufficient quantity of each size is kept in stock. ADF personnel may also be required to travel in or operate a range of land, sea and air vehicles, such as submarines, ships, armoured personnel carriers, and aircraft.

The Department of Defence is planning to acquire a number of new platforms in the coming years with the total cost for many of these acquisitions exceeding one billion dollars. If the Department of Defence can influence the design of these new vehicles, data on the size of the current ADF population is required to ensure the vehicle is designed to maximise the percentage of ADF personnel who can safely operate or travel in the vehicle. On the other hand, if the vehicle is an existing design and is acquired "off the shelf", with the design guided by anthropometric data from another country's population, data on the ADF population is required to determine the percentage of personnel that will be safely accommodated in the vehicle.

To support the acquisition of clothing, protective equipment and vehicles a number of anthropometric surveys of Australian military groups have been conducted over the past seventy years. Typically, the main goal of these surveys have been to inform the design and sizing of clothing worn by personnel, while the main goal of a smaller number of surveys have been informing the design of workstations. The purpose of this report is to summarise the populations sampled, methodologies used, measurements taken and key results of all formally reported and catalogued ADF anthropometric surveys that were conducted at least ten years ago.

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# Glossary

ADF	Australian Defence Force
CAESAR	Civilian American and European Surface Anthropometry Resource
ISAK	International Society for the Advancement of Kinanthropometry
RAAF	Royal Australian Air Force
RAF	Royal Air Force
RAN	Royal Australian Navy
USAF	United States Air Force

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## 1. Introduction

An understanding of the size and shape of the Australian population is vital for the optimal design and sizing of everything from clothing and footwear, to motor vehicles and public transport. An understanding of body dimensions (formally referred to as anthropometry) is especially important in the military environment. Current day male and female Australian Defence Force (ADF) personnel must wear a range of clothing, footwear, and protective equipment, including helmets, respirators, body armour and protective eyewear. Protective equipment, like the body armour shown in Figure 1, must conform closely to the 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 male and female members of the ADF. Clearly, up to date information on the size and shape of male and female ADF personnel is required to optimise the design and sizing of clothing and protective equipment and to ensure a sufficient quantity of each size is kept in stock.



Figure 1: Body armour has to be designed to protect the vital organs. Photo: ADF

ADF personnel may also be required to travel in or operate a range of land, sea and air vehicles, such as submarines, ships, armoured personnel carriers, and aircraft. The Department of Defence is planning to acquire a number of new platforms in the coming years with the total cost for many of these acquisitions exceeding one billion dollars. If the Department of Defence can influence the design of these new vehicles, data on the size of the current ADF population is required to ensure the vehicle is designed to maximise the percentage of ADF personnel who can safely operate or travel in the vehicle. On the other

hand, if the vehicle is an existing design and is acquired "off the shelf", with the design guided by anthropometric data from another country's population, data on the ADF population is required to determine the percentage of personnel that will be safely accommodated in the vehicle.

To support the acquisition of clothing, protective equipment and vehicles a number of anthropometric surveys of Australian military groups have been conducted over the past seventy years. Given the cost and logistical challenges associated with large-scale surveys conducted at multiple military bases around Australia, it is instructive to consider why it has been necessary to conduct multiple surveys of the ADF population. The three key drivers for new surveys are discussed below. The first driver is the increasing size of the population, which is referred to as a secular trend [see, for example, Cole (2003), Greiner & Gordon (1990), Greiner & Gordon (1993), and Tomkinson, Clark & Blanchonette (2010)]. In the civilian world, mean increases in stature of up to three centimetres a decade have been observed, with one centimetre a decade increases in height typical for many western countries. In addition, in many countries, increases in weight have been occurring at a greater rate than stature, with the resultant increases in the rates of overweight and obesity. The increase in the mean height and body mass of male Australian Army personnel over a nearly fifty year period is presented in Figure 2 and Figure 3, respectively. Since 1958 male Army personnel have grown from an average height of just under 172 cm to nearly 179 cm tall. Given these increases, using decades old anthropometric data would most likely result in many accommodation issues for larger personnel.



Figure 2: The change in mean stature of male Army personnel between 1958 and 2004.

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Figure 3: The change in mean mass of male Army personnel between 1958 and 2004.

Another driver to periodically update the anthropometric data is the increasing variety of equipment worn by personnel, and the increasing complexity of the environments they work in. For example, modern personnel, depending on operational requirements, must wear a range of protective body armour, along with a range of other protective equipment such as ballistic protection spectacles and gloves. To ensure the optimal design and sizing of this equipment a wide variety of anthropometric data are required, hence modern anthropometric surveys are taking many more measurements than in years past.

The third main driver is the expansion of the roles played by women in the ADF. With the long service lives of many items of equipment and vehicles, females may have to use equipment or operate vehicles designed solely for men. As a women of 50th percentile stature is approximately the same stature as a 5th percentile male, it has been traditionally assumed a significant number of women should be accommodated in the clothing, equipment and vehicles designed for 5th to 95th percentile men. Furthermore, it has been assumed that women can be considered to be scaled-down men, that is, a male and female of the same height, should have the same proportions. While it is true that women can be considered scaled-down men for some dimensions, women are, in fact larger in some dimensions than men of a similar stature and weight. As Robinette (1995) showed using US military data, a female with the same height and weight as a male has a hip breadth on average nearly 5 cm greater, while the male's shoulder breadth is on average just over 2.5 cm larger. These proportional differences between the sexes have resulted in many problems when attempting to fit females in items of clothing or equipment developed with only males in mind. For example, a qualitative survey of anti-G suit fit reported that 29% of the females surveyed had to have their suit modified, compared to only 9% of the males

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(Ripley, Solana, & Hill, 1994). Furthermore, a study that compared the G-tolerance levels of males and females, reported that the fact that the G-suits were designed based on male anthropometric data may have contributed to the reduced orthostatic tolerance of the females (Fischer, Wiegman, & Bauer, 1992). Given these gender based differences it is important current data is available on the female population as well as the male population.



*Figure 4: A greater number of females are taking on a diverse range of roles in the ADF. Photo: ABIS Hayley Clarke* 

Given the key drivers described above, a number of anthropometric surveys of ADF groups have been conducted over the past seventy years to support the design of clothing, protective equipment and vehicles. The goal of this report is to summarise the key information from the reports describing historical (completed at least 10 years ago) anthropometric surveys of ADF groups to ensure the methodologies and key results of these surveys are available in a single report.

# 2. ADF Anthropometric Surveys

A search of the online defence information network catalogue, along with a number of databases, revealed that nine surveys of ADF personnel have been conducted<sup>1</sup>. Largely, the primary purpose of these surveys was to provide guidance on clothing sizes, and the relative proportion of the population for which each size was required. A smaller number of surveys have focused more on workstation and footwear design. These surveys are summarized below in chronological order.

## 2.1 1958 Australian Army Male Survey

In the late 1950s, an anthropometric survey was conducted by the Department of Supply Design and Inspection Branch, and the Australian Army Operational Research Group. In total, 3540 male members of the Australian Regular Army were measured, which represented approximately 16% of the full-time male Army population (Aird, Bond, & Carrington, 1958). All corps in the Army were represented in the survey and the measured personnel ranged in age from 17 to 56 years old. The main purpose of the survey was to provide guidance on the number of clothing sizes required and the relative proportion of each size required. Fourteen clothing relevant measurements<sup>2</sup> (see Table 1) were taken on each subject, including stature, chest circumference, neck circumference, waist circumference, hip circumference and foot length. The measurements were taken by a tailor or under the supervision of a tailor, with measurements recorded to the nearest 1/8th of an inch (3.2 mm), and weight recorded to the nearest pound (0.46 kg). In addition, the age, rank, and corps were also recorded. Furthermore, at the request of the Director General of Medical Services, a number of additional measurements were also taken for medical and anthropometric purposes (Carrington, 1959). These measurements (see Table 1), which were taken by unit medical personnel, included interpupillary distance, sitting height, and abdominal depth. Measurements were taken manually with a ruler, tape measure and calipers by unit medical personnel who had received instruction on taking the measurements accurately. The bulk of the data gathered during the survey was published as frequency tables to support the design and sizing of clothing, along with summary statistics for some of the measurements. Summary statistics of the key measurements are presented in Table 23.

<sup>&</sup>lt;sup>1</sup> It is possible that other surveys have been conducted, but any findings associated with such surveys have not been formally reported and catalogued.

<sup>&</sup>lt;sup>2</sup> The measurements taken in the survey are reported using the terminology used in the survey report.

<sup>&</sup>lt;sup>3</sup> Different surveys typically reported different summary statistics.

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Measurement	Number	Measurement
Height	16	Anterior arm reach
Chest	17	Total span
Waist	18	Elbow-seat
Half back to wrist	19	Crotch height
Natural waist length	20	Buttock-knee length
Full back length	21	Patella height
Seat	22	Sitting height
Inside Leg	23	Bi-deltoid
Neck Size	24	Chest depth
Head Size	25	Bi-iliac
Hand length	26	Abdominal depth
Hand width	27	<b>Bi-trochanteric</b>
Foot length	28	<b>Bi-tragion</b>
Foot width	29	Interpupillary distance
Weight	30	Chin-neck-projection
	Measurement Height Chest Waist Half back to wrist Natural waist length Full back length Seat Inside Leg Neck Size Head Size Hand length Hand width Foot length Foot width Weight	MeasurementNumberHeight16Chest17Waist18Half back to wrist19Natural waist length20Full back length21Seat22Inside Leg23Neck Size24Head Size25Hand length26Hand width27Foot length28Foot width29Weight30

Table 1:Measurements taken in the 1958 Australian Army male survey.

Table 2:	Selected summary statistics from the 1958 Australian Army male survey. All units are
	millimetres.

Measurement	Mean	Standard Deviation
Height	1739	57
Head Circumference	572	17
Neck size	392	23
Chest	977	65
Waist	827	90
Seat	975	67
Hand Length	190	11
Hand Width	98	7
Foot Length	267	11
Foot Width	99	11

## 2.2 1968 Australian Army (Body Dimensions) Male Survey

In the late 1960s, the Headquarters Australian Army Inspection Service was directed by the Master General of Ordnance to conduct a survey of male Australian Army personnel (Headquarters Army Inspection Service, 1970). The initial goal of the survey was to measure 4000 male personnel, with the final number measured 3695. The subjects, which were selected to give a representative cross section of Army males, had a range of roles, including apprentices and recruits. The purpose of the survey was to provide guidance on clothing and equipment sizing and the number of each size required. In total, 26 measurements (see Table 3) were taken on each subject, including stature, weight, and chest and waist circumference. The measurements were taken with a height standard, anthropometer and circumeter, with measurements recorded to the nearest 0.5 cm. The data was checked for errors by comparing the measurement with the other measurements taken on the subject, along with a comparison to the measurement statistics of the whole sample for that particular dimension. It was reported that errors associated with recording the measurements was the largest source of errors. When a number of similar errors were found, an effort was made to correct the data rather than delete it from the dataset. The measurements, which were recorded on paper forms, were then transferred to punch cards, and then to magnetic tape for analysis. The results of the survey were presented as histograms and tables of percentiles for each individual dimension. In addition, frequency tables of key clothing dimensions chest and waist circumference, and waist and hip circumference were also listed. Summary statistics for some of the key measurements are shown in Table 4.

Number	Measurement	Number	Measurement
1	Weight	14	Head circumference
2	Height	15	Neck circumference
3	Cervical height	16	Arm scye
4	Posture incline measurement	17	Cross back width
5	Back waist length	18	Middle upper arm circumference
6	Outside leg	19	Wrist circumference
7	Inside leg to knee	20	Chest circumference
8	Knee to calf	21	Waist circumference
9	Inside leg to ankle	22	Hip circumference
10	Underarm to elbow	23	Middle thigh circumference
11	Underarm to wrist	24	Knee circumference
12	Upper arm length	25	Calf circumference
13	Outer arm length	26	Ankle circumference

 Table 3:
 Measurements taken in the 1968 Australian Army male survey.

Measurement	5th Percentile	50th Percentile	95th Percentile
Height	1640	1730	1840
Weight (kg)	56.5	68.5	84.0
Head circumference	535	560	585
Neck circumference	335	360	390
Chest circumference	860	945	1055
Waist circumference	690	770	920
Hip circumference	860	930	1030
Outside leg	980	1055	1125

Table 4:Key summary statistics from the 1968 Australian Army male survey. All units are<br/>millimetres unless indicated otherwise.

## 2.3 1968 Australian Army (Foot Dimensions) Male Survey

In the late sixties a comprehensive survey of the foot dimensions of 3695 male personnel representative of the Army population was undertaken (Headquarters Army Inspection Service, 1968). The purpose of the survey was to provide guidance on the design of shoe lasts, the range of footwear sizes required, along with the percentage of each size required. In total, 28 foot measurements were taken on both feet, including seven girth, seven height, nine length and five width measurements (see Table 5). The measurements were taken using a range of equipment including tape measures, a height gauge and specialised foot measurement plate. The measurements were taken by a team of footwear technicians from the Design and Development Section of Headquarters Army Inspection Service. Initially, the measurements were transcribed on paper forms, before being transferred to Hollerith punch cards, and, finally, transferred to magnetic tape for statistical analysis. Summary statistics for key dimensions are presented in Table 6.

Number	Measurement	Number	Measurement
1	Back curve	15	Ankle length
2	Calf girth	16	Boot heel length
3	Calf height	17	Instep length
4	Ankle girth	18	Inside joint length
5	Ankle height	19	Highest toe length
6	Boot heel girth	20	Foot length
7	Boot heel height	21	Fifth toe length
8	Long heel girth	22	Outside joint length
9	Instep girth	23	Plantar arch height
10	Instep height	24	Seat width
11	Joint girth diagonal	25	Instep width
12	Joint height	26	Joint width diagonal
13	Joint girth horizontal	27	Stick width
14	Seat length	28	Toe height

 Table 5:
 Measurements taken in the 1968 foot dimensions Australian Army male survey.

Table 6:Summary statistics for key dimensions from the 1968 Australian Army foot dimensions<br/>survey. All units are millimetres.

Measurement	Mean	Minimum	Maximum
Calf girth	283	252	314
Foot length	264	246	287
Instep length	151	136	166
Instep width	82	70	92
Ankle girth	224	202	247

## 2.4 1971 RAAF Male Aircrew Survey

A survey of current aircrew and cadets was conducted by the Institute of Aviation Medicine in the early 1970s. The main goal of the survey was to provide a representative sample of the aircrew population to support equipment design. The secondary goals of the survey were to determine if there were substantial differences in the size of the different aircrew categories, to determine if there were significant correlations between the

measurements taken in the survey, and to determine if there were differences in the size of RAAF, Royal Air Force (RAF) and United States Air Force (USAF) aircrew (Aircraft Research and Development Unit, 1973). In total, six RAAF bases were visited over a ten month period starting in November 1971. Eighteen measurements (see Table 7) were taken on a randomly selected sample of 97 male cadets and 385 male aircrew. The measurements were taken by the same team of four anthropometrists at each location. Measurements taken included stature, sitting height and chest circumference. Body dimensions were recorded to the nearest millimetre and weight to the nearest 0.5 kg. Up to six subjects could be measured each hour. With the identification of a number issues with the analysis and reporting of the survey data by staff at the Aeronautical Research Laboratory, the data was reanalysed (Hendy, 1976). Following the elimination of subjects who had incomplete or bad data, the number of subjects with valid and complete data was reduced to 462. In addition to the summary statistics provided in the report, the raw measurement data for each subject are also available. Statistics published for each dimension were the mean, standard deviation, range of the data, coefficient of skewness and kurtosis, a table of percentiles, a histogram and cumulative histogram and the mean value of each measurement as a function of age. The key summary statistics from this survey are summarised in Table 8. A statistical comparison of the aircrew groups found that the only group that differed across many dimensions was the cadets, who tended to be smaller than the other aircrew for mass and girth related dimensions.

Number	Measurement	Number	Measurement
1	Mass	10	Functional arm reach
2	Stature	11	Vertical trunk circumference
3	Sitting height	12	Chest circumference
4	Eye height, sitting	13	Waist circumference
5	Acromial height, sitting	14	Buttock circumference
6	Elbow rest height	15	Head circumference
7	Crotch height	16	Head breadth
8	Buttock-heel length	17	Bideltoid breadth
9	Buttock-knee length		

Table 7: Measurements taken in the 1971 Royal Australian Air Force male survey.

Measurement	Mean	Standard Deviation	Minimum	5th Percentile	95th Percentile	Maximum
Stature	1773	58	1615	1676	1869	1909
Mass (kg)	76.9	10.3	49.5	59.9	93.9	106.5
Sitting height	921	33	812	867	975	1010
Eye height, sitting	805	33	712	750	859	937
Acromial height, sitting	607	31	501	555	658	707
Functional arm reach	806	36	703	747	865	915
Buttock-knee length	610	27	519	565	655	755
Head circumference	582	15	535	558	606	625
Bideltoid breadth	473	23	405	435	510	538
Chest circumference	973	64	805	868	1078	1197
Waist circumference	854	76	680	729	979	1115
Buttock circumference	982	57	838	888	1076	1152

 Table 8:
 Summary of some of the key anthropometric measurements from the 1971 RAAF survey for aircrew. All units are millimetres unless indicated otherwise.

## 2.5 1977 Australian Defence Force Survey

The last comprehensive tri-service survey of ADF personnel took place in 1977 (Hendy, 1979). In contrast to previous surveys which focussed on gathering data to support the design and sizing of clothing, this survey focussed on gathering data to support the design of equipment and 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 100-200 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 (shown in Table 9). The subjects measured were all male and were employed full time and had ranks up to Lieutenant Colonel or equivalent. Data was gathered in each mainland state or territory, except South Australia, Western Australia and the Northern Territory. If a selected subject was not available a subject from the same group who was within two years of the age of the original subject was selected. The substitution rate for the survey was 40.7 percent (in 3.7 percent of cases the subject or a suitable replacement was not available). This survey took 32 measurements (see Table 10) on 2945 male personnel, including stature, sitting height, bi-deltoid breadth, chest circumference, and hand length. Equipment used for the survey included sliding calipers, hand cone, foot box, and specially built anthropometric measuring rig. The measurement data was error checked using a number of procedures, including examining rank ordered

measurement values to determine if there were any obvious errors in the maximum and minimum values, comparing of the magnitude of the measurements (for example, stature greater than sitting height), examining ratios of values for consistency (for example, the ratio of foot length to foot breadth), and checking measurement values to see if they lay within the bounds of those from other surveys. Following a statistical comparison of the 18 groups, the groups with a strong commonality were combined with the final number of groups being reduced to eight. A summary of some of the key measurements for the entire sample is shown in Table 11.

Army	Group Size
Weapon Users	177
Transportation	188
Clerks and Others	190
Aviation	88
Catering	190
Technical Personnel	211
Navy	Group Size
Clearance Divers	82
Consolidation	185
Catering	155
Fleet Air Arm	178
Submariners	169
Air Force	Group Size
Air Traffic Controllers	129
Aircrew	190
Electronic Musterings	165
Other Technical Musterings	167
Transportation	114
Catering	198
Miscellaneous	169

 Table 9:
 Groups surveyed in the 1977 Australian Defence Force male survey.

Number	Measurement	Number	Measurement
1	Foot length	17	Eye height, sitting
2	Foot breadth	18	Shoulder height, sitting
3	Hand length	19	Acromial height, sitting
4	Palm length	20	Elbow rest height
5	Hand breadth	21	Popliteal height
6	Thumb length	22	Bideltoid breadth
7	Inner hand grip diameter	23	Hip breadth
8	Head circumference	24	Functional reach
9	Neck circumference	25	Buttock-knee length
10	Chest circumference	26	Thigh clearance height
11	Waist circumference	27	Stool height
12	Buttock circumference	28	Stature
13	Vertical trunk circumference	29	Crotch height
14	Buttock-heel length	30	Chest depth
15	Mass	31	Head breadth
16	Sitting height	32	Inner-elbow breadth

 Table 10:
 Measurements taken in the 1977 Australian Defence Force male survey.

Measurement	Mean	Standard deviation	Minimum	5th Percentile	95th Percentile	Maximum
Stature	1750	62	1546	1648	1853	1962
Mass (kg)	75.6	11.2	46.0	59.0	95.5	133.0
Sitting Height	913	33	796	858	966	1031
Eye height, sitting	804	32	687	751	856	923
Shoulder height, sitting	654	27	548	610	698	742
Head circumference	574	16	506	548	600	634
Neck circumference	386	22	322	353	426	518
Chest circumference	984	74	798	875	1119	1302
Waist circumference	878	94	641	745	1048	1383
Buttock circumference	978	64	792	879	1087	1353
Buttock-knee length	602	26	523	559	645	700
Popliteal length	448	23	367	412	487	535
Foot length	265	12	225	245	285	305
Foot breadth	99	5	81	91	107	119
Hand length	192	9	161	178	206	220
Hand breadth	82	4	67	75	89	99

 Table 11:
 Summary of some key anthropometric measurements from the 1977 ADF survey. All units are millimetres unless indicated otherwise.

## 2.6 1981 Australian Army Male Survey

In 1981, an anthropometric survey of 21,154 male members of the Australian Army was conducted by the Clothing Design and Development Group of Headquarters Logistics Command (King & O'Leary, 1983). The driver for this survey was the mismatch between the clothing size roll, which was developed based on a late 1960s survey of the Army population and the actual demand for each size. A preliminary survey of about 300 male personnel conducted in 1980 confirmed the mismatch between the size of personnel and the clothing sizing based on the 1960s data. The report summarising the methodology and results of this survey also states that surveys of females and males were conducted in 1953 and 1954, respectively, although no reference is provided for these surveys and a search of the Defence library catalogue and other databases did not find any reports. The goal of the survey was to measure as many members of the Army as reasonably possible. This approach was taken given what the authors reported were the potential shortcomings of a survey of a random selection of the Army population, for example, the unavailability of

randomly selected subjects due to leave or participation in an exercise. In total, 21,154 males were measured out of a total population of approximately 30,000 personnel. Personnel selected to take the 16 clothing related measurements were trained in the correct procedures over a two day period. In total, 56 personnel who had no previous experience taking anthropometric measurements were allocated to take the measurements in the seven military districts within Australia. Measurements taken included: height, cervical height, knee height, head circumference, chest circumference, waist circumference and weight (see Table 12). The measurement data for each subject was then manually punched onto computer cards and a computer program was used to detect outliers, with any outliers deleted from the final dataset. Table 13 lists summary statistics for the key body dimensions.

Number	Measurement	Number	Measurement
1	Height	9	Waist circumference
2	Cervical height	10	Seat circumference
3	Outseam	11	Back width
4	In-seam	12	Sleeve length
5	Knee height	13	Underarm to wrist length
6	Head circumference	14	Wrist circumference
7	Neck circumference	15	Weight
8	Chest/bust circumference		

Table 12: Measurements taken in the 1981 Australian Army survey.

Table 13: Summary statistics for the 1981 Australian Army male survey. All units are millimetres unless specified otherwise.

Measurement	Mean	Standard Deviation	Minimum	Maximum
Height	1754	64	1528	2020
Head circumference	573	17	480	650
Neck circumference	389	24	252	500
Chest circumference	978	72	602	1292
Waist circumference	845	85	551	1285
Seat circumference	967	62	662	1310
Weight (kg)	74.9	10.5	35.0	135.0

## 2.7 2000 Royal Australian Navy Male and Female Survey

The Royal Melbourne Institute of Technology was contracted to measure a sample of Royal Australian Navy (RAN) personnel based at HMAS Cerberus in Victoria over a seven week period in 1999 (Royal Australian Navy, 2000). The goal of the survey was to provide data to support equipment and workstation design for the RAN. Using the International Society for Kinanthropometry (ISAK) protocol (ISAK, 2001), thirty measurements (listed in Table 14) were taken manually on 302 personnel, 251 males and 51 females. The measurements were taken by a team of nine (seven males and two females) level one accredited ISAK anthropometrists who had received one and a half days of training by a level three accredited ISAK anthropometrist on the 30 measurements. The measurements were taken with a range of equipment, including calipers, scales, tape measures and anthropometers. It took approximately thirty minutes to process each subject. Each measurement was taken twice and at the conclusion of the survey the technical error of measurement was calculated for each dimension. The summary statistics for several key measurements are shown in Table 15 (male) and Table 16 (female).

Number	Measurement	Number	Measurement
1	Stretch stature	16	Head length
2	Eye height	17	Head breadth
3	Shoulder height	18	Elbow span
4	Elbow height	19	Hand length
5	Hip height	20	Hand breadth
6	Knuckle height	21	Hand thickness
7	Fingertip height	22	Max Span of hand
8	Knee height	23	Forward grip reach
9	Ankle height	24	Vertical grip reach
10	Sitting height	25	Arm span
11	Max body breadth	26	Mid-thigh girth
12	Abdominal depth	27	Foot length
13	Vertical reach	28	Foot breadth
14	Chest depth	29	Crotch height
15	Hip breadth	30	Weight

Table 14: Measurements taken in the 2000 Royal Australian Navy male and female survey.

Measurement	Mean	Standard Deviation	5th Percentile	95th Percentile
Stretch stature	1781	68	1679	1899
Weight (kg)	76.5	10.9	49.2	96.6
Sitting height	928	43	861	994
Eye height	1667	65	1563	1771
Shoulder height	1455	63	1364	1562
Hip height	1081	51	1004	1170
Hand length	196	9	183	214
Hand breadth	106	9	90	119
Arm span	1812	79	1682	1932
Foot length	271	14	250	294
Foot breadth	105	6	96	117

Table 15:Summary of key male anthropometric measurements from the 2000 RAN survey. All<br/>units are millimetres unless indicated otherwise.

Table 16:Summary of key female measurements from the 2000 RAN survey. All units are<br/>millimetres unless indicated otherwise.

Measurement	Mean	Standard deviation	5th Percentile	95th Percentile
Stretch stature	1644	70	1517	1762
Weight (kg)	65.4	9.3	52.5	80.8
Sitting height	860	44	798	934
Eye height	1533	67	1411	1635
Shoulder height	1343	77	1231	1462
Hip height	991	52	910	1092
Hand length	179	10	164	198
Hand breadth	91	5	82	100
Arm span	1650	90	1645	1806
Foot length	238	14	215	262
Foot breadth	92	7	81	103

## 2.8 2004 Australian Army Male Survey

A survey of Australian Army soldiers was conducted in the early 2000s (2001, 2003 and 2004) (Jaffrey, Roberts, & Brady, 2007). In total, a convenience sample of 244 male subjects from the first and second battalions of the Royal Australian Regiment were surveyed by a team from James Cook University. This sample represented about 30% of the total population of the two battalions. The main purpose of the survey was to inform the design of packs. Using the International Society of Kinanathropometry protocol (ISAK, 2001), thirty measurements (see Table 17) were taken on most of the subjects, including stature, sitting height, weight, chest circumference, hand length, and waist circumference. Summary statistics for the key measurements are presented in Table 18.

Number	Measurement	Number	Measurement
1	Stature	17	Mid-stylion-dactylion length
2	Body mass	18	Iliospinale height
3	Head girth	19	Trochanterion height
4	Neck girth	20	Trochanterion-tibiale length
5	Arm girth (relaxed)	21	Tibiale-laterale height
6	Arm girth (flexed)	22	Tibiale mediale-sphyrion tibilale length
7	Forearm girth	23	Biacromial breadth
8	Wrist girth	24	Biiliocristal breadth
9	Chest girth	25	Foot length
10	Waist girth	26	Sitting height
11	Gluteal girth	27	Transverse chest
12	Thigh girth	28	Anterior-posterior chest depth
13	Calf girth	29	Biepicondylar humerus breadth
14	Ankle girth	30	Biepicondylar femur breadth
15	Acromiale-radiale length	31	Back length
16	Radiale-stylion length	32	Neck width

*Table 17: Measurements taken in the 2004 Australian Army male survey.* 

Measurement	Mean	5th Percentile	95th Percentile
Stature	1789	1678	1903
Weight (kg)	81.2	64.7	99.4
Sitting height	914	854	972
Neck girth	384	353	418
Chest girth	983	886	1096
Waist girth	834	743	945
Gluteal girth	1001	899	1105
Foot length	266	243	287
Acromiale-radiale length	342	311	372
Radiale-stylion length	266	242	288

Table 18:Summary statistics of key measurements from the 2004 Army male survey. All units<br/>are millimetres unless indicated otherwise.

## 2.9 2005 Aircrew and Potential Aircrew Male and Female Survey

The MIS 872 Aircrew and Crewstation Anthropometry project surveyed a sample of the potential aircrew recruit population (males and females 18-30 years old, who had passed year 12) during 2004 and 2005. To ensure the survey captured an appropriate cross-section of young Australians, the survey team measured volunteers in Perth, Adelaide, Melbourne, Canberra, Sydney and Brisbane. In total, they measured 1510 males and females. They also visited several military bases, measuring about 250 aircrew (less than ten were female). Unlike previous surveys, in which measurements were taken manually using anthropometers, calipers and tape measures, this survey used a three-dimensional laser scanner to capture a digital "statue" of the subjects. The scanning unit itself is roughly the size of a telephone booth. The unit is made up of a platform with a tower at each of the four corners, which contains a laser and two cameras. The system can be dismantled and transported to a new location as required, although it can take several hours to reassemble and calibrate the system. In total, it took about 45 to 60 minutes to process each volunteer, and approximately 30 subjects could be processed in a standard work day. Initially, each subject completed a questionnaire, including a section on clothing sizes [shoe size, dress and bra size (females) and shirt size (males)] (Olds et al., 2004). Following this, the subject then changed into form-fitting underwear and a latex swimming cap (so the shape of the head could be captured as well). A number of manual measurements were then taken on the subject, including stretch stature, stretch sitting height, and weight. Following this, a number of small triangular landmarkers were placed on 23 body landmarks, including nuchale, cerivcale, radiale right and knee crease right. These landmarkers were placed on the body as these landmarks could not be accurately located by looking at the scan. For this survey, the landmarks used were the same as the

Civilian American and European Surface Anthropometry Resource (CAESAR) survey (Blackwell et al., 2002). The subject then stood in the centre of the scanning station, with their legs slightly spread apart and their arms slightly abducted away from their torso. A stripe of horizontal red laser light passed down the subject from head to toe in about 10 seconds. The cameras in each of the four towers observed the distorted stripe of light as it pass down the body, and using triangulation, a high resolution digital point cloud model of the subject was created, which contained about 650,000 points. Measurements can be extracted from the scans using specialist software tools, such as girths (simulated tape measure or contour), cross-sectional areas, volumes, and distances between landmarks (Olds et al., 2004). Thirty six measurements listed in Table 19 are available (Singh & Smith, 2008). Summary statistics for key measurements for male civilians, female civilians and male aircrew are presented in Table 20, Table 21 and Table 22, respectively.

Number	Measurement	Number	Measurement
1	Stretch stature	19	Acromiale-radiale length
2	Weight	20	Radiale-stylion length
3	Stretch sitting height	21	Eye spacing
4	Head length	22	Bigonial breadth
5	Head circumference	23	Head width
6	Mouth width	24	Biiliocristal breadth
7	Vertex-eye height	25	Hand breadth
8	Vertex-mid shoulder height	26	Upper leg length
9	Chest circumference	27	Bimalleolar breadth
10	Waist breadth	28	Foot length
11	Waist circumference	29	Foot breadth
12	Buttock circumference	30	Lower leg length
13	Leg length	31	Nipple spacing
14	Hand length	32	Face height
15	C7-Iliac crest height	33	Bitrochanteric breadth
16	Biacromial breadth	34	Bispinous breadth
17	Biepicondylar femur breadth	35	Sellion-nuchale length
18	Biepicondylar humerus breadth	36	Head length planar

Table 19: Measurements taken in the 2005 survey.

Measurement	Mean	Standard deviation	Minimum	5th Percentile	95th Percentile	Maximum
Stretch stature	1788	69	1559	1674	1907	2010
Weight (kg)	75.4	10.9	48.1	60.0	94.4	125.9
Stretch sitting height	939	37	805	877	999	1047
Waist circumference	819	77	659	722	952	1260
Buttock circumference	990	61	822	907	1096	1271
Acromiale-radiale length	330	19	263	298	361	388
Radiale-stylion length	271	14	224	248	294	313
Upper leg length	433	28	344	386	475	527
Lower leg length	432	25	350	390	472	535

Table 20:Summary statistics for some selected measurements for civilian males 18-30 years old.<br/>All units are millimetres unless indicated otherwise.

Table 21:Summary statistics for some selected measurements for civilian females 18-30 years old.All units are millimetres unless indicated otherwise.

Measurement	Mean	Standard deviation	Minimum	5th Percentile	95th Percentile	Maximum
Stretch stature	1662	68	1474	1550	1771	1914
Weight (kg)	62.1	10.5	39.1	48.2	81.0	130.6
Stretch sitting height	879	37	759	818	938	990
Waist circumference	739	81	587	638	889	1283
Buttock circumference	988	76	809	883	1121	1445
Acromiale-radiale length	298	19	240	266	330	358
Radiale-stylion length	248	15	203	224	272	298
Upper leg length	396	33	311	344	450	523
Lower leg length	395	26	325	354	439	498

Measurement	Mean	Standard deviation	Minimum	5th Percentile	95th Percentile	Maximum
Stretch stature	1799	63	1539	1710	1904	1975
Weight (kg)	82.6	10.7	58.6	67.8	101.6	118.2
Stretch sitting height	937	34	846	887	994	1013
Waist circumference	886	80	653	766	1032	1155
Buttock circumference	1026	54	884	946	1118	1213
Acromiale-radiale length	334	18	279	304	368	390
Radiale-stylion length	275	13	239	254	298	307
Upper leg length	436	30	341	383	477	509
Lower leg length	437	23	373	402	476	501

 Table 22:
 Summary statistics for some selected measurements for male aircrew. All units are millimetres unless indicated otherwise.

# 3. Concluding Remarks

To support the design of clothing, equipment and vehicles a number of anthropometric surveys of ADF groups have been completed over the past seventy years. The bulk of these surveys were conducted using traditional manual measurement techniques, with the primary goal of most of these surveys being the design and sizing of clothing. Of the formally reported and published surveys only two surveys, which were conducted in the late 1990s and early 2000s, included females. With the development of three dimensional scanning technologies in recent years, the potential utility of anthropometric data is expanding with developments such as biofidelic manikins and virtual prototyping becoming commonplace. Given the ongoing changes in the height and weight of personnel, surveys will need to be conducted periodically to ensure valid data is available for the ADF population to optimise the design of clothing, protective equipment and work environments.

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Over the last seventy years a been conducted. Typically, the r	number of nain goal c	anthropometric (bod of these surveys has b	y size) surveys been to inform t	of Au the des	stralian Defe sign and sizi	ence Force (ADF) groups have ing of clothing, while the main this report is to summarize the		

been conducted. Typically, the main goal of these surveys has been to inform the design and sizing of clothing, while the main goal of a smaller number of surveys has been to inform the design of workstations. The purpose of this report is to summarise the populations sampled, methodologies used, measurements taken and key results of all formally reported and catalogued ADF anthropometric surveys.