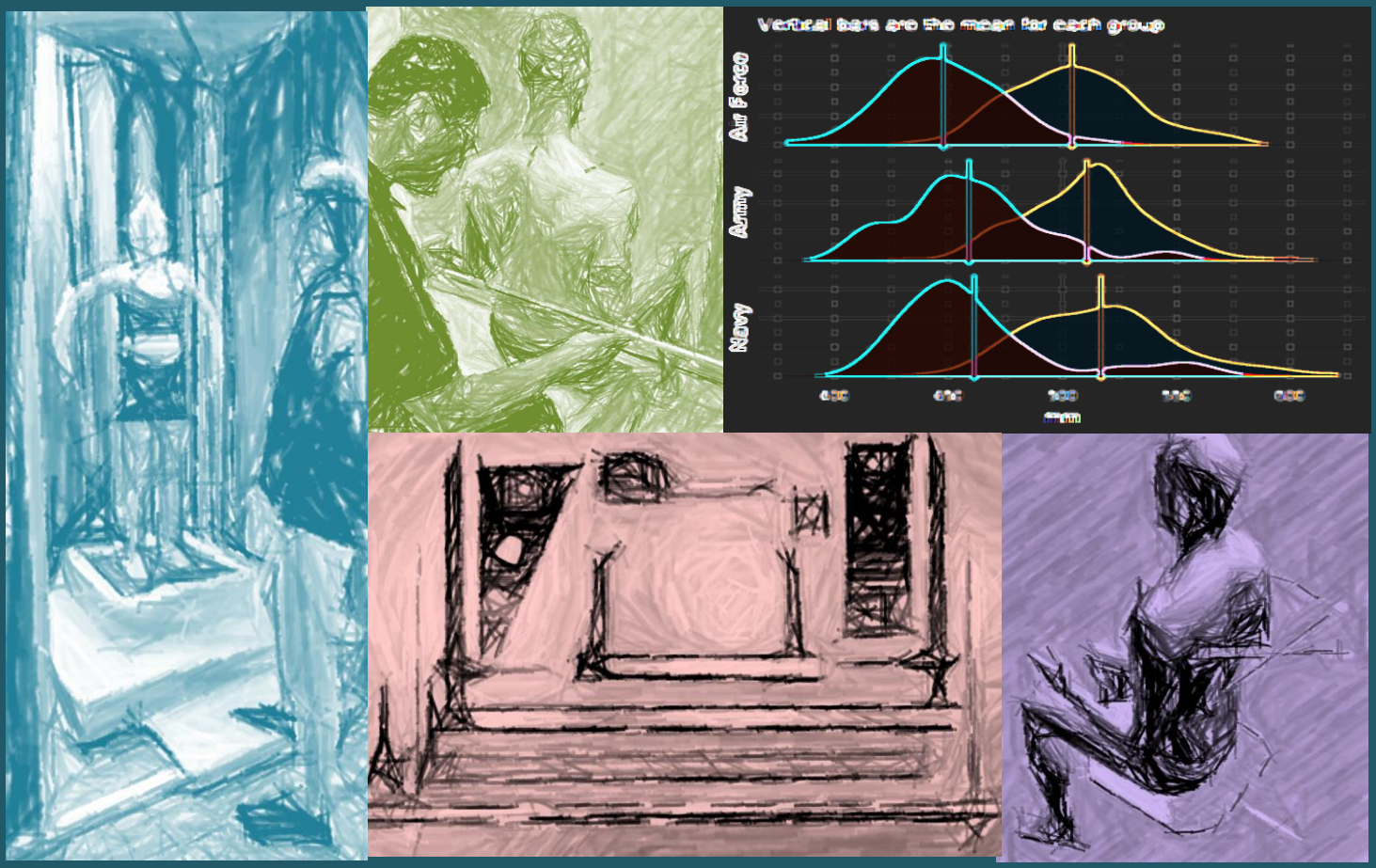
Three-Dimensional Physique Assessment in the Military: New Zealand Defence Force Anthropometry Survey Protocols and Summary Statistics



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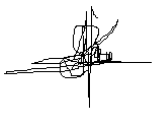
Dedication

We dedicate this book to Gloria, Alaane, Nathaniel, Oliver and Keanan Kolose for providing inspiration and encouragement for supporting Stephven in his PhD.

We also dedicate this book to all anthropometrists around the world of all ages. Leading a large-scale anthropometric survey is a challenge and privilege. May future generations learn, innovate, and carry on our legacy.



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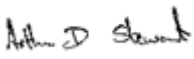
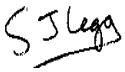


Dr Arthur Stewart



Professor Stephen Legg

Foreword

I have had the good fortune to have been part of Stephven's journey since his early anthropometry days in 2010 when I travelled to New Zealand as a Canadian Defence Scientist to instruct on and support the adoption of a multivariate cockpit accommodation methodology for RNZAF aircrew selection. As this time, it was evident that he possessed the necessary passion and intellectual curiosity that has led him to where he is today.

As Principal Investigator of the 2012 Canadian Forces Anthropometric Survey and Scientific Lead on the development of anthropometry tools and models to support the Canadian Armed Forces, I have always followed the mantra "We equip our soldiers to fight the enemy, not their equipment". Thus, it is every important to provide current and representative anthropometric data to scientists and decision makers within a military organization to best inform the specification, design, development and evaluation of military clothing, equipment platforms and workspaces.

Conducting a large-scale anthropometric survey is a complex and challenging endeavour that involves considerable investment in human and financial resources. Considering this, Stephven and his colleagues have compiled and presented a resource that provides an overview of the technical, methodological and logistic challenges that must be overcome to produce an anthropometric dataset that meets the diverse requirements of the end user as well as satisfies industry and international interoperability requirements.

This eBook is a recommended resource for anyone considering conducting an anthropometric survey involving measurement extraction from 3D body scanning technology, as it takes the reader into the detailed considerations that are seldom addressed in other publications. Stephven and his colleagues are to be commended for developing this accessible and complete introduction to the planning and implementation of anthropometric surveys.

Allan A. Keefe

Preface

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What it is about?

This book describes how to conduct a large-scale anthropometric survey in the military with a specific focus on the New Zealand Defence Force Anthropometry Survey. This book provides a historical introduction to surface kinanthropometry (Part I), 3D scanning technology (Part II) and an overview of military anthropometry surveys in Part IV. It also provides a description of the New Zealand Defence Force (NZDF) anthropometry survey in Part IV, conclusions in Part V and concludes with the measurement technique protocols and normative data for the NZDF kinanthropometry survey in Part VI.

While surface anthropometry has traditionally been used to assess body composition through the internationally recognised methodology of the International Society for the Advancement of Kinanthropometry (ISAK), the commercialisation of three-dimensional photometry (3D scanning) has led to the adoption of new and often non-standardised, measurement techniques.

We detail standardisation procedures for 3D scanning in terms of participant preparation, equipment calibration, test protocols, data reporting and data interpretation. We outline how 3D scanning works, what it is used to measure, and what the issues are surrounding its validity, practicality, and reliability. This book provides an essential reference for practitioners wishing to measure military physique. We have not presented 3-D assessment data (i.e. surface manifold, volumetric, symmetry or shape analysis). We have only extracted 1-D measures from 3D images in this eBook.

Why did we write it?

The purpose of this book is to educate other researchers who are planning to conduct a large-scale anthropometric survey using 3-D body scanning technology. The book forms part of Stephven's doctoral thesis that focusses on the implications of 3-D body scanning technology on the New Zealand Defence Force. Initially, Stephven's interest in 3D anthropometry stemmed from his work as a Science Researcher for the Defence Technology Agency (DTA) – the science and research branch of the New Zealand Defence Force. In that role, Stephven was responsible for testing the 3D body scanner, and the planning and implementation of the NZDF survey between 2013 and 2019. This study was the first, largest and the most comprehensive 3-D-based anthropometric survey in New Zealand. Therefore, in the absence of any formal anthropometric dataset of the New Zealand population, it is hoped that the normative anthropometry data will assist engineers, designers, clothing, health practitioners, sports researchers, and human factors and ergonomics practitioners in both New Zealand and abroad.

The biggest challenge with writing this book was identifying what content to present. Stephven had seven years of documents, and unpublished reports, all of which described an area of the study in detail. Stephven, his PhD supervision team, and his senior mentor overseas decided to develop these ideas into this text.

Acknowledgements

The authors acknowledge the anthropometry research community from academia and the military who have contributed to this book.

We wish to acknowledge and thank DTA, the NZDF Vice Chief of Defence (and individual service chiefs) and the NZDF Capability Branch whose funding, resources and support were fundamental to this project's initiation, implementation, and completion.

We thank all the NZDF survey participants, whose body shapes have contributed to our new data resource and sizing standard.

We acknowledge the NZDF anthropometric team for their tireless contribution and dedication to data collection activities. We acknowledge the perseverance and dedication provided by the NZDF anthropometry survey data collection leaders, analysis contractors and body scanner procurement staff: Mr Adam Dooley, Dr Samantha Rodrigues, Mr Hugh Terry, Mrs Savanah Purcell, Mr Luke Selway, Mr Deon Nathan and Dr Graham Fordy.

We acknowledge the individual base and camp senior leadership teams for assisting and facilitating the participant recruitment process; and providing accommodation for our data collection team during the survey. We also thank the staff from the RNZAF Aviation Medicine Unit and the AUT SPRINZ for the use of their facilities and resources for our study.

Thank you to our international collages Mr Allan Keefe (DRDC), Dr Nathan Daniel, Dr Mike Dale, Mr Tod Wachowicz (UniSA), Mr Alistair Furnell, Ms Jenna Coleman, Dr Peter Blanchonette (DSTG), Dr Brian Corner (USAFRL), Mr Tim Guenzel (Human Solutions Ltd) and Mr Phil Dench (Headus Ltd) for their continued support and training.

Finally, thank you to the models used in this document: Mr Adam Dooley and Dr Edward Ashworth, Miss Anja Zoeller, Dr Tom Stewart and Dr Darrell Bonetti.

Stephven's journey

My background is in the fields of psychology, ergonomics, and human factors. In 2013, whilst working for the New Zealand Defence Force (NZDF) I was tasked with planning and implementing an anthropometric survey of NZDF personnel. What initially started as a small-scale data collection for the NZ Army soon grew to a full-scale anthropometric survey for all three services.

Back when I was studying ergonomics and human factors, anthropometry was never my strongest subject. I was naïve because I did not fully understand the importance of anthropometric data in our every-day lives. I like many other people, viewed anthropometry and ergonomics as purely a tool for designing furniture and workspaces. This soon began to change. Over several years my appreciation of the importance of anthropometry in the military grew. This was shaped from many colourful (and sometimes passionate) conversations with users and operators from the NZDF and abroad. Everyone had something to say with regards to the fit of their uniforms, safety equipment, weapon systems, workshop equipment and so forth. Back then, my colleagues and I were unable to help as no anthropometric data of NZDF personnel existed at the time. Without this data, we would use overseas data (e.g. UK from *BodySpace* or Australian data) or design specific trials to capture anthropometric data on multiple occasions. One, up-to-date dataset would save a lot of time and resources.

Over time, I increased my anthropometric literacy. I discovered first hand that anthropometry can make lives easier, safer, and more efficient. For example, anthropometric data can help design better fitting body armour that can protect a soldier's vital organs. Incorrect anthropometric fit in the cockpit may result in pilots injuring their lower limbs during an emergency ejection. A solider may have a long-term lower limb injury due to incorrect fitting boots during a pack march. A sailor may have trouble escaping through a hatch that has not been designed specifically for the NZDF personnel body type. There are so many applications of anthropometry in the military but very few people understood its relevance, and even fewer possessed the knowledge to a) collect it and b) apply it to solve real-world problems. My earlier views on anthropometry had now changed. I was buoyed by the fact that we were making history for the NZDF. As I had many good friends in the NZDF, I also felt like this survey was my way of showing them my support.

In 2013 the NZDF purchased a 3D whole body laser scanner to assist with their data collection. This fuelled my passion for anthropometry x100 as the scanner added a 'cool' factor in my work. I spent 2 years learning about 3D body scanning and its application to anthropometry. With this intent and the need to improve my skills as an anthropometrist and researcher, I enrolled into the PhD program at Auckland University of Technology (AUT) Sports Performance Research Institute New Zealand (SPRINZ) and trained as a ISAK accredited anthropometrist in 2015. By working with NZDF, AUT, and international military partners, we were able to research, design and complete the NZDF anthropometry survey, New Zealand's first large scale 3D anthropometric survey in 2018.

This book represents my journey, several years in the making learning about 3D body scanners, anthropometry, and anthropometric surveillance in the military. It is hoped that this book will help future researchers (military or academia) prepare or have an appreciation of the knowledge and planning required to conduct a large-scale anthropometric survey. This book also represents how small military nations like New Zealand can conduct surveys compared to larger and more well-funded armed forces overseas.

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List of Abbreviations and Definitions

We have tried to avoid using abbreviations given it makes reading content harder for those unfamiliar with physique assessment. We have provided a list of commonly used abbreviations in the area to help readers.

3D	Three-Dimensional
ADF	Australian Defence Force
AUT	Auckland University of Technology
AUT	Auckland University of Technology
BMI	Body-Mass-Index
C2	Second Cervical Vertebra
CA	Cluster Analysis
CAF	Canadian Armed Forces
CART	Classification and Regression Tree
DOD HDBK	Department of Defence Handbook
DSTG	Defence Science and Technology Group
DTA	Defence Technology Agency
ISAK	International Society for The Advancement of Kinanthropometry
ISO	International Standards Organization
NZA	New Zealand Army
NZDF	New Zealand Defence Force
NZDFAS	New Zealand Defence Force Anthropometry Survey
PCA	Principal Component Analysis
PERSEL	Personnel Selection
RNZAF	Royal New Zealand Air Force
RNZN	Royal New Zealand Navy
SPRINZ	Sports Performance Research Institute of New Zealand
T2	Second Thoracic Vertebrae
TEM	Technical Error of Measurement
UniSA	University of South Australia

PART I – AN OVERVIEW OF KINANTHROPOMETRY STANDARDS AND PROTOCOLS

Stephven Kolose, Patria Hume, Arthur Stewart

Preface

Traditionally, anthropometric data are captured physically by trained anthropometrists, using various tools and in strict accordance with defined protocols. This Part (I) briefly reviews the literature on the key concepts of kinanthropometry and anthropometry. It also describes different physical measurement protocols and the advantages and disadvantages of traditional anthropometry. An understanding of these concepts is vital for large-scale anthropometric survey planning, especially since most surveys to date have relied largely on traditional anthropometric measurement.

Overview

There is no universally accepted protocol for three-dimensional (3D) human body scanning. This book has been produced as a call for international standards in 3D body scanning. Initial 3D body scanning protocols were lodged with the J.E. Lindsay Carter Anthropometry Archive in 2014 [1].

Throughout this book, 3D body scanning is discussed as a tool that captures, measures, or records anthropometric data. Three-dimensional body scanning uses laser, light or infra-red technologies to determine surface anthropometry characteristics such as body volume, segment lengths and girths. Body posture during scanning is important to ensure accurate measures can be made from the scan images. The images vary depending on the configuration, resolution, and accuracy of the scanner.

Scanning technology is expensive given the hardware and software required, and only provides surface anthropometry characteristics. For physique assessment including estimates of body composition, body size, and shape, the International Society for the Advancement of Kinanthropometry (ISAK) protocols should be followed. The advantages of the ISAK surface anthropometry methods are that assessments take approximately 10 minutes for a restricted profile, up to 40 minutes for a full profile, and the equipment is readily available, less expensive, and easily calibrated. The ISAK methods are valid and reliable if ISAK training is undertaken to ensure correct landmarking is performed.

Keywords

Kinanthropometry; Anthropometry; Measurements; Protocols; Three-dimensional; Body scanning; Body volume; Segment lengths; Girths; Laser; Technologies; Shape; Body posture; Images; Configuration; Resolution; Accuracy; Scanner; Physique; Equipment; Caliper; Landmarking; Skinfolds; Girths, Breadths, Circumference; Profile; International standard.

Introduction

What is Kinanthropometry and Anthropometry?

Kinanthropometry is the study of human size, shape, proportion, composition, maturation, and gross function. The term is named from the Greek root words kinein (to move), anthropos (human) and *metrikos* (the act of measuring) [2]. Anthropometry is part of the field known as kinanthropometry, which can be defined as: "The academic discipline which involves the use of anthropometric measures in relation to other scientific parameters and/or thematic areas such as human movement, physiology or applied health sciences" [3].

A pioneer of anthropometry, Quitelet in 1870 attempted to obtain measurements of the 'average' man to provide better-fitting uniforms for Napoleon's army. In the 1950's anthropometrics became a recognized scientific discipline. Today a more contemporary definition of anthropometry is: "*The scientific procedures and processes of acquiring surface anatomical dimensional measurements such as lengths, breadths, girths and skinfolds of the human body by means of specialist equipment*" [3].

Anthropometry is associated with measurements of body size, shape, strength, mobility, flexibility, working capacity [4] and the study of body dimensions (e.g. lengths, breadths, girths skinfolds) that utilize surface landmarks for reference [5]. Anthropometry is used in the design of vehicles, work sites, equipment, aircraft cockpits, clothing [6], sports science and ergonomics [7]. Anthropometric data provide designers with the physical and functional characteristics of potential end-users which can be applied to many design solutions. Poor quality, or a lack of anthropometric data, can result in failure to accommodate individuals in the workplace , customer dissatisfaction, and may lead to discomfort, accidents and injury [8].

Measurements

Anthropometric data comes in many forms that include one-, two- and three-dimensional data (Figure 1). One-dimensional (1D) data is identified easily as there is only one number (e.g., body height = 1670 mm) [8]. One-dimensional data are often captured using traditional anthropometry or 'direct' measurements obtained by a skilled anthropometrist. The measurements are captured using tools such as tapes, callipers, or a stadiometer. Two-dimensional (2D) anthropometry data have two dimensions (i.e. x and y) which can be extracted from a two-dimensional source such as a photograph. Digital photogrammetry is a method of measuring limb segment dimensions from photos [9]. Three-dimensional (3D) anthropometric data have three dimensions (i.e. x, y, z) which can be extracted from a 3D body scanner [10].

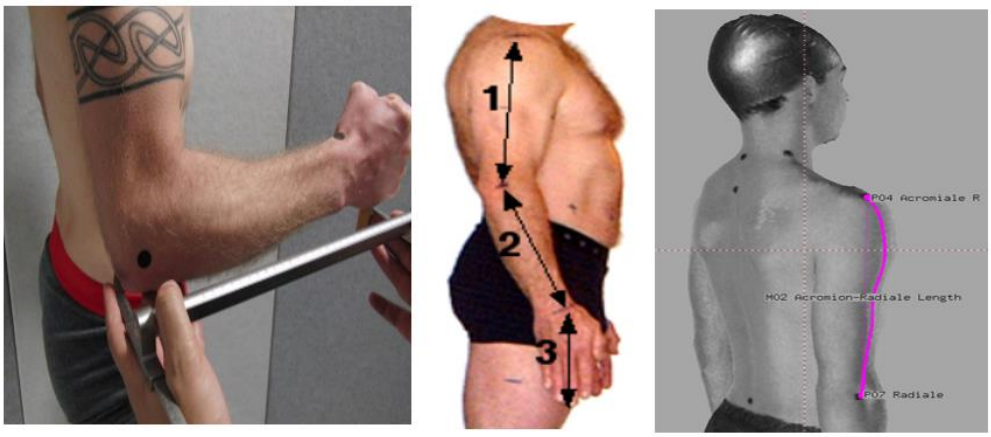

Figure 1. [Left to right] Examples of length measurements using 1D (Radiale-stylion length), 2D or photograph-based anthropometry (Acromiale-radiale length, radiale-stylion length and hand length) and 3D (acromiale-radiale length) data collection methods. Centre photo courtesy of Mellow, Hume [9].

The three types of anthropometric data rely on several important factors. The measures are acquired by skilled anthropometrists who are trained to use specialised equipment. All participants

must be minimally clothed or wear tight fitting garments. Most measurements require the location and placement of bone landmarks (especially for segment lengths). Measurements are generally conducted on one side of the body because fat patterning is largely symmetrical within measurement precision, however, muscle development can show marked asymmetry, especially in the upper limb. The survey purpose may require both, left, right, preferred, or non-preferred limb sides to be measured.

Measurement protocol

An anthropometric protocol or measurement profile (also referred to as a landmark profile) refers to instructions or guidelines on how to conduct anthropometric measurements. There are many anthropometric protocols in use today, each having bony landmark sites and measurement definitions [5]. The most well-known civilian and military protocols are:

- Military Handbook: Anthropometry of the U.S. Military Personnel [11]
- International Society for the Advancement of Kinanthropometry (ISAK) [12]
- Civilian American and European Surface Anthropometry Resource (CAESAR) [13]
- National Health and Nutrition Examination Survey (NHANES) [14]
- ISO 7250 standard [15]
- US Army Anthropometry Survey (ANSUR) [16].

We describe military anthropometry protocols and measurements later in this book. Despite the number of protocols there is no ‘universal anthropometric’ protocol. Such a title would be difficult as many existing protocols differ with respect to measurement and landmark terminology, definition, and implementation. For example, measurements such as height are also known as stature, sitting height can also be called seated height, and weight is also referred to as body mass. Stature can be ‘stretched’, via upward traction of the mandible by the measurer, which minimises diurnal height loss, or not stretched. Chest girth (or circumference) is defined by some protocols as the circumference around the scye or armpit (CAESAR) or at the level of the thelion or nipple (for males) (ANSUR and ISO 7250) (Figure 2). Chest circumference measurements can vary with the ISAK protocol – chest girth is recorded at end-tidal (fully exhaled breath) while other protocols [12] take the maximum circumference value.

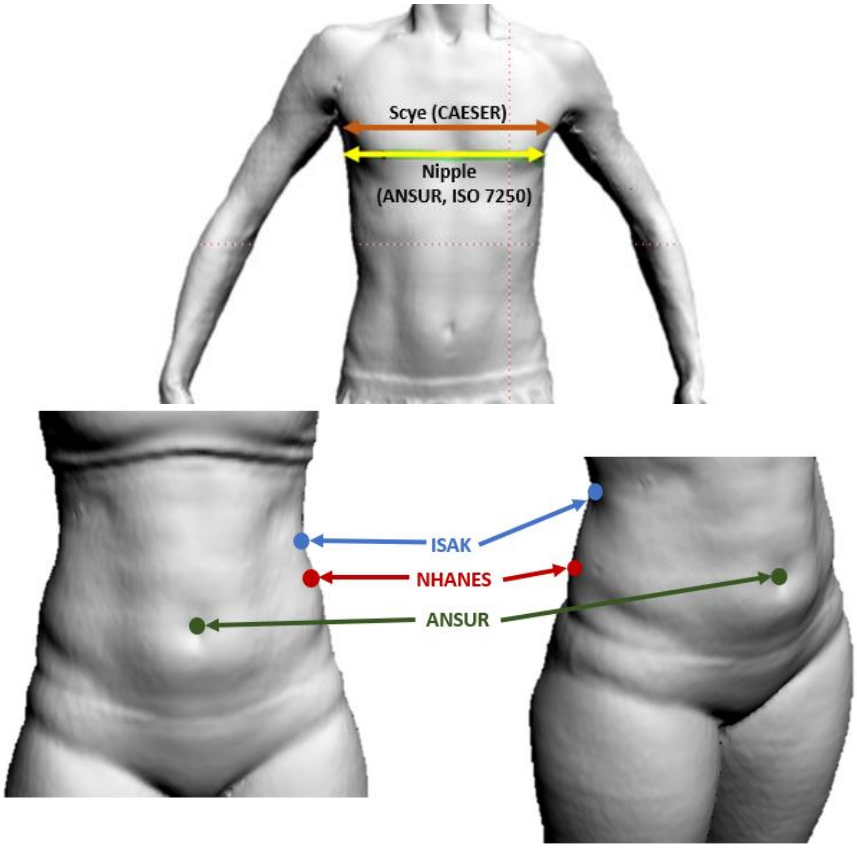

Figure 2. Differences in chest circumference (top) definitions when taken at the level of the scye (CAESAR) or nipple (ANSUR and ISO 7250). Waist girth (bottom) is taken at the level of the narrowest point of the waist between the lower costal (10th rib) border and the iliac crest in ISAK [12], at the point of the uppermost lateral border of the right ilium (in line with the midaxillary plane) in NHANES [14] and the level of the Omphallion (navel) in ANSUR [17].

Protocols such as ISAK and ISO 7250 are examples of internationally recognised, stand-alone anthropometric standards. However, a large proportion of the ISAK and ISO 7250 measurements (based on the civilian population) do not feature in various military anthropometry survey protocols such as ANSUR and vice-versa. The same can be said for measurements between ISAK (with origins in the field of human biology sport and exercise science) and ISO 7250 (an ergonomics-orientated protocol). For example, ISAK does not include ISO 7250 measurements such as popliteal height and elbow height which are critical to ergonomics workstation design [18]. Furthermore, the same issue of ambiguity of measurement names, landmarks and definitions persist. The differences between various protocols measurement terminology or definitions are likely discipline related.

Literature comparing existing anthropometric measurement protocols and standards is limited. Researchers have provided commentary on how future anthropometric protocols should be theorised, written, implemented and shared. The book chapter "Towards a generalised anthropometric language" [19] provides a Generalised Anthropometric Language (GAL) mechanism by which future protocols should be designed. It was recommended that the GAL would entail landmarks being defined by using a description of anatomical terms and sites, and a combination of dimensions would make up an anthropometric protocol. It was envisaged that the GAL would help establish links between protocols and therefore between studies. A well-defined GAL with syntactic rules would help instruct researchers to refine and explicitly record their techniques. It would also decrease the incompatibility and confusion that exists between researchers using different anthropometric protocols. We support this approach and have therefore produced this book as a call for international standards in 3D body scanning.

Traditional anthropometry standards and protocols

This next section discusses the most widely used traditional anthropometric measurement and landmarking protocols and standards for measuring civilians (i.e. military anthropometric protocols are covered in a later section).

The International Society for the Advancement of Kinanthropometry (ISAK)

The International Society for the Advancement of Kinanthropometry was formed in 1986 by experts in the fields of sport, exercise science and human biology seeking methods to standardise practice. This was a collective effort to limit vague and ill-defined definitions of previous protocols which did not allow for exact landmark location, delineation and a systematic approach to quality control [20].

The ISAK scheme became highly popular due to (at the time) several innovative features. For example, ISAK was one of the first schemes to introduce a teaching and practice structure based on a 4-level hierarchy of practitioner licensing, based on competency as assessed by a practical exam. As part of this process all measurers were required to pass error control targets in terms of reproducibility in a standardised setting [20]. While other schemes focus on the reproducibility of measurers within a single lab setting, the ISAK's inter-measurer and intra-measurer reliability protocols enabled comparisons of measurers across different lab settings. The ISAK scheme has a strict focus on identifying landmarks consistently and accurately to enable accurate measurements. ISAK was one of the first schemes to utilise raw data scores (as opposed to conversion into % fat values) as a result of strict protocol definitions and quality assurance of individual measures [20]. Compared to other anthropometric protocols, ISAK is very descriptive and is specific with regards to measurer, client and equipment positioning and recording. The accreditation or license period is 4 years plus an additional 6 months aside for levels 2 to 4 to complete their 20 practical profiles. The extension period is only 4 months for level 1 students to complete their profiles (as their profiles contain less measurements).

There are some disadvantages with the ISAK system. For example, measurers with little to no background in human biology may struggle with the anatomical terminology and the identification of landmark sites. The teaching structure in level 1 (beginner level) provides theory and practical sessions to ensure adequate understanding of anatomical bony locations and performance of measurements based on the landmarks. Success during the course comes down to practical experience and a firm grasp of terminology and fundamental skills.

Courses can be perceived as costly given the need for the limited number of ISAK level 3 or 4 instructors to travel for delivering courses. There is a substantial cost associated with purchasing anthropometry equipment for a full profile set of measurements. The standard anthropometry kit consists of small and large bone callipers, small and large sliding callipers, a segmometer, skin fold callipers and a metal girth tape (Figure 3). Weight scales, anthropometry box and stadiometers are purchased at additional cost to the standard anthropometry kit.

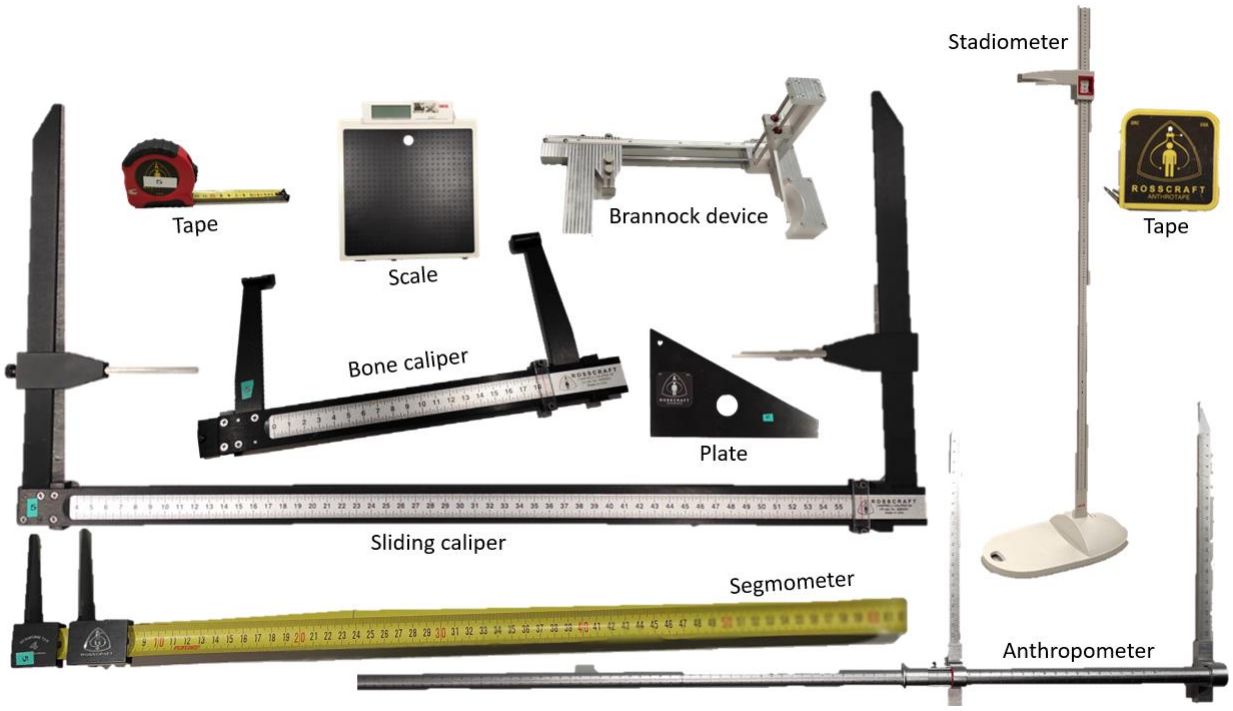

Figure 3. Common traditional anthropometry measurement tools.

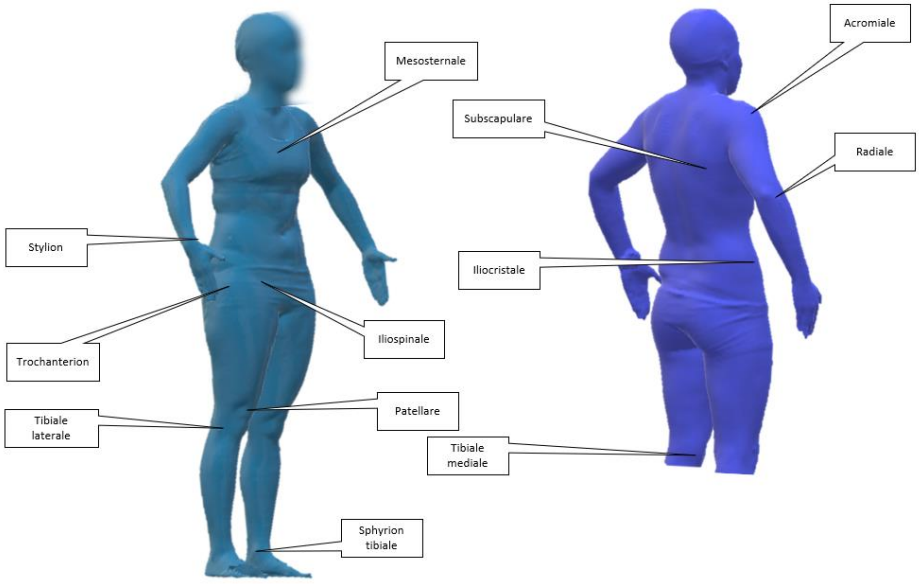

Figure 4. Boney landmarks used to help identify measurements in the full ISAK level 2, 3 and 4 profile.

The ISAK protocol consists of restricted (18 measurements taught in the level 1 course) and full (43 measurements taught in the level 2 course) profiles [21]. Both profiles consist of basic (mass, stature and sitting height, arm span), skinfolds (triceps, subscapular, bicep, iliac crest, supraspinale, abdominal, front thigh and medial calf), girths (arm flexed and tensed; waist gluteal and calf), and breadths (humerus and femur). The additional measures in the full profile include girths (head, neck, forearm, wrist, chest, thigh-gluteal, mid-thigh, ankle), breadths (biacromial, biiliocristal, bi-styloid, transverse chest, anterior-posterior chest, anterior-posterior abdominal), lengths (acromiale-radiale, radiale-stylion, midstylion-dactylion, trochanterion-tibiale laterale, tibiale mediale-sphyrion tibiale, foot) and heights (iliospinale, trochanterion, tibiale laterale). The ISAK full profile consists of 12 bony landmarks that are used to assist the measurement process (Figure 4).

Currently there is no publicly available database from ISAK that is accessible for comparison of body composition data.

Civilian American and European Surface Anthropometry Resource (CAESAR)

CAESAR was the first 3D whole-body surface anthropometry survey [22] of three civilian populations (United States of America, the Netherlands and Italy) conducted by the U.S. Air Force, Syntronics Inc, the Netherlands Organization for Applied Scientific Research (TNO) and a consortium of companies under the Society of Automotive Engineers (SAE) [23].

The CAESAR database consists of approximately 12,000 body scan images taken between 1998 and 2000 of over 4,000 men and women, aged 18–65, covering various weights, ethnic groups, geographic regions, and socio-economic status.

World Anthropometry Engineering Report (WEAR)

The WEAR web-portal was set up by experts in engineering anthropology to unify 145 anthropometric databases across 10 countries and six continents [24]. The web-based database of 3D size, shape, fit and performance data is maintained by members of the WEAR organisation [25].

The WEAR database includes 250,000 participants (men, women, and children, from civilian and military populations) with approximately 50 traditional anthropometric dimensions collected on each individual making over 12 million individual datum. Datasets date from the 1950s, with most post-1970, and more than 20 large datasets collected post-1990 [24].

The WEAR portal contains checklists for measurement validity (sampling, subject population, and secular change), comparability (definition of measurements), and accuracy (before, during, and after measurement capture), lessons learned, fit and accommodation maps, human size and shape information, 3D visualisation, statistical analysis tools and fit prediction models.

International Standards Organization (ISO)

The International Standards Organization describe anthropometric measurements, instruments, standard postures, clothing, and measurer training. ISO guidelines enable practitioners (especially ergonomists) to apply their knowledge to the geometric design of workplaces, tools, apparel and to enable comparison of anthropometric data from different international populations [26]. Example ISO standards with respect to anthropometry include:

- “ISO 15535: 2012 General requirements for establishing anthropometric databases” describes the general requirements for establishing anthropometric databases, their associated reports and measurements taken in accordance with ISO 7250-1. It provides information such as characteristics of the user population, sampling methods, measurement items and statistics, to make international comparison possible across various populations.
- “ISO 7250-1: 2017 Basic human body measurements for technological design - Part 1: Body measurement definitions and landmarks” serves as a basis for extracting one- and two-dimensional measurements from three-dimensional scans (specified in ISO 20685). It provides guidance on how to take anthropometric measurements and gives information to the ergonomist and designer on the anatomical and anthropometrical bases and principles of measurement, which are applied to design tasks. The standard is intended to be used in conjunction with national or international regulations or agreements to ensure coherence in defining population groups and to allow comparison of anthropometric data among member samples.

Advantages and disadvantages of traditional anthropometry

The advantage of traditional anthropometric protocols such as ISAK, ISO and CAESAR are that they have been developed by experts in the field. The protocols have been refined over time to increase accuracy and establish competency and efficiency when taking and recording measurements (for instance the technical error of measurement).

Traditional methods use measurement equipment that is easy to transport. Although the equipment can vary in design and build quality, accurate measurements can be obtained if the equipment is routinely maintained and calibrated, and the measurer is skilled and experienced in its use.

Traditional measurements require only enough space (e.g. a small office) to enable the participant and measurement technician to complete the anthropometric profile. The traditional anthropometrist is trained to utilise various structural features of a room to make measurements efficient. For example, utilizing the corners of a room as a 'zero' point for arm span measurements. Seated leg length measurements (e.g. buttock to heel) can be made with the participant sitting against a wall. The room ceiling can be used to conduct standing arm reach measurements. These room 'features' such as the location of windows or doors can influence how the anthropometrist sets up the equipment, or the order in which to take body measurements and landmarking. Whatever the environment, it is important that measurements can be made consistently with minimal changes between settings. Although the precise protocols are robust the timing is flexible.

With international accreditations like ISAK, accredited anthropometrists are trained to identify, implement, and record measurements consistently. This ensures that measurements are acquired in the same way with confidence.

There are, however, disadvantages of traditional anthropometry. Measurements can be subjective [27] and susceptible to human error. The experience, expectations, training, and accuracy of the measurer can influence the results [28]. Traditional measurements are subject to observer error in landmark location, participant positioning and instrument applications [29].

Traditional measurement surveys are also expensive to plan and conduct [5]. Costs include equipment hire or purchase, booking of the testing location, accommodation facilities and travel. Costs will vary depending on the sample size required, the number of landmarks and measurements required, and the availability and locality of participants and measurement personnel.

Despite the precision of a skilled anthropometrist, the use of traditional measurement tools to obtain measurements is time consuming (e.g. 40 minutes for a full profile) and at times, invasive for the participant [30]. Equipment has varying levels of precision with Harpenden skinfold callipers (Figure 5) enabling readings to 0.1 mm versus 0.5 mm for SlimGuide skinfold callipers. Tools such as the tape-based segmometer (Figure 5) can be fragile and bend or break after prolonged use. Tool-related maintenance tasks are required such as checking springs (coil properties may change with time or be affected by contaminants, including rust), lubrication of joints, bolt, or screw tightness.

Figure 5. Differences in Harpenden and Slim guide skinfold callipers and an example of a broken segmometer.

The high variability in intra and inter-observer traditional measurements [31] is increased for atypical body types [32, 33]. For example, in a study of intra-abdominal bleeding [34] there was a 6 cm difference in patient waist girth measurements across 10 measurers. Inter-observer variability using traditional measurements of thigh girth has been reported as 8.27% (4 cm difference) [35]. This contrasted with errors of 0.2–0.5 cm reported for the same measurement [28, 36, 37]. To minimise these errors, protocols such as ISAK suggest using multiple measurements with calculation of the mean or median. The differences between measurements must lie within an acceptable measurement limit depending on the type of measurement performed. In ISAK, these limits are <5% for skinfolds and <1% for all other measurements (e.g. breadths, girths, and lengths). Furthermore, the real virtue in tight error control is to become capable of detecting small changes in measurements which are real. The main disadvantage of taking multiple measurements is that it is time consuming [28, 38-40].

Traditional anthropometric protocols, while providing good accuracy for linear and circumference measurements, provides limited information for volume, area, body size and shape [28, 30, 41]. The use of anthropometry has stagnated [42] with static or one-dimensional measures. While the Whole-Body Surface Area (WBSA) equation [43] was based on one dimensional measurements, the three-dimensions of the body should be measured using techniques that provide three-dimensional outputs [30].

Summary

Kinanthropometry is a scientific field that is traditionally associated with physical or ‘hands on’ measurements conducted by experienced anthropometrists. No universal anthropometric protocol exists as many disciplines such as ergonomics, sports science, clothing design, and manufacturing have developed their own set of standards targeted to their own industry. Traditional methods have been tested, validated, and quantified to a point where measurement skills are taught internationally to practitioners. Despite their historical success in many larger-scale surveys, traditional anthropometric measures do possess shortcomings, many of which can be addressed with modern day technology. Part II of this book outlines the advantages and disadvantages of 3D body scanning and the implications for kinanthropometry.

PART II – AN OVERVIEW OF 3D BODY SCANNING TECHNOLOGY

Stephven Kolose, Patria Hume, Arthur Stewart, Grant Tomkinson

Preface

PART I described the key concepts of traditional anthropometric measurement. While this method has remained the 'gold standard' for population surveillance for many decades, a new technology has emerged that has the potential to revolutionise the way anthropometric data are measured. The purpose of PART II was to introduce 3D body scanning by focusing on different scanning technologies, 3D measurement validity, its applications, and a summary of the potential challenges. Knowing the strengths and limitations of this technology is crucial for 3D anthropometric survey planning.

Overview

Throughout this book, 3D body scanning is discussed as a tool that captures anthropometric data. This Part (II) summarises what 3D body scanners are, the applications, types of body scanning systems, associated software, validity, reliability, and challenges.

Keywords

3D body scanning, scanning applications, laser line, structured light, reliability, scan processing.

Introduction

What is 3D body scanning?

A whole-body scanner is an optical 3D measuring system that produces a digital copy of the surface geometry of the human body. The purpose of the 3D scan is to capture an outside surface of the body using optical techniques in tandem with light sensitive devices without the need to touch the body.

Commercially made full-body 3D body scanners were available since the late 1990s [44]. They were initially made for anthropometric research, the clothing industry (individual and tailored clothing) [45], the entertainment industry (special effects in movies), computer animation and medicine (e.g. prosthetics and plastic surgery) all with the purpose of measuring the human body [46]. As the technology developed, it was used by western countries for systematic anthropometric population measurement for clothing and textile design. Current 3D body scanning systems, designed by different manufacturers, differ in the number (and quality) of cameras, scanning range, light sources, and also in the sophistication of the accompanying computer programs used for visualization and measurement analysis [25].

Why Measure Physique Using 3D Scanning?

The introduction of 3D scanning reduced the need to have consistent physical contact with the body. However, surface markers can be placed on the body as reference points to check. Scanners vastly increase the range of possible measurements and create a permanent record of body size and shape that can be archived and revisited. This is advantageous for traditionally 'uncomfortable' measurements such as crotch height (where some anthropometric protocols require the measurer to place an anthropometer on the inferior-lateral aspect of the male genitalia). Even if participants are scanned in tight fitting garments, the measurements can still incur a systematic bias.

The availability of 3D whole body scanners provides the ability to take rapid simultaneous measurements, and automated data extraction and analysis. It has the potential to revolutionise surface anthropometry [47]. With these new capabilities, it is possible to easily quantify dimensions such as projected frontal areas, limb volumes, limb cross-sectional areas, and abdominal cross-sections and volumes. It is also possible to quantitatively describe shapes and shape changes. The main driver behind 3D scanner development has been the apparel industry. The technology can enable the possibility of creating garments on demand, tailored to optimize fit for each individual.

Three-dimensional body scanning has synergies with human factors, where humanoid manikins can be rescaled using the extracted measurements and animated to perform specific tasks and to interact with the built environment. For example, using 3D manikins in engineering software suites such as SolidWorks© (Dassault Systems, Vélizy-Villacoublay, France). These techniques are already being employed in military research and in the design of transportation and operator workspaces [47].

Applications

Clothing and apparel

The clothing and apparel industry invest heavily in the development and improvement of 3D body scanning technology, due to its many implications. For example, 3D body scanning can be used to record many clothing measurements such as sleeve in-seam and waist girth [48, 49]. The measurements can then be matched to existing clothing size characteristics, allowing clothing manufacturers and retail outlets to choose appropriate inventories for their target population [48, 49].

Health and medical

The health and medical sector regularly use 3D scanning and modelling technology. The 3D scanner can be used to create implants, gloves, body shape, and prosthetics [50], holograms for human body imaging and garment creation [51]; detecting scoliosis in patient‘s back shape or scanning human feet to detect anomalies [52-54]. Body scanning technology is useful for measuring body surface area [55, 56] which is useful for determining dosages of many drugs (e.g. anticancer drugs [57]), the design of restraints [58] and developing shape indexes to monitor secular trends in body shape and limb volumes [59].

Ergonomics and human factors

The use of 3D body scanners is widely used in the field of ergonomics and human factors. Body scan images can be imported, via human modelling programs, into virtual environments which have been scanned or created in computer-assisted design (CAD) applications, or in hybrid environments. With appropriate motion capture or task descriptions, the virtual bodies can be animated to perform specific tasks in a naturalistic way in a digital environment [60]. The user can also simulate whether the actions or tasks can lead to physical injury due to working in uncomfortable or awkward postures. Examples of popular DHM software are CATIA Human Builder (v5, Dassault Systems, Vélizy-Villacoublay, France), JACK (SIEMENS, Munich, Germany), V5 HUMAN and Realistic Anthropological Mathematical System for Interior comfort Simulation (RAMSIS, Human Solutions, Kaiserlauten, Germany) [61].

Sports science

Previous studies have shown that 3D body scanning is a useful tool in sports science research. The technology enables researchers to take multiple measurements of a larger number of athletes at any given time [30, 62] before various sports events. It also helps sports and exercise scientists to understand the physique specialisation for specific sports.

Other sports applications exist. For example, body scanners have been used to assess principal moments of inertia in elite athletes from gymnastics to ski jumping [63, 64], investigate how females' breast area measurements change, when wearing compression sports bras during running [65], inform 3D design and development of swimwear [66], develop sizing systems for football boots in the National Football League (NFL) [67] and assess performance errors in a golf swing [68]. It is also possible to quantify dimensions such as projected frontal areas (a critical factor in aerodynamic sports such as cycling and skiing)[69], limb volumes (which are strong predictors of sprint performance), limb cross-sectional areas (proportional to strength), and abdominal cross-sections and volumes (predictors of risk of diabetes and cardiovascular disease[70]) [71, 72]. It is possible to quantitatively describe shapes (and hence facilitate garment and equipment design) and shape changes (and hence describe what happens to the body during dietary and exercise interventions) [73].

3-D body scanners

Typically, 3D whole body scanners consist of at least one light source that projects a line or pattern on to the participants' body. Cameras record the image of the reflected light. On fixed laser scanners, the light source and camera both move in tandem (vertically) on the scanner pole. The images are then processed by computer software that is specifically designed to analyse the depth structure of the body surface (Figure 6). There are five common types of body scanners: laser line, structured pattern, multiview camera systems, millimetre wave systems and infrared systems. Each of these systems are discussed below.

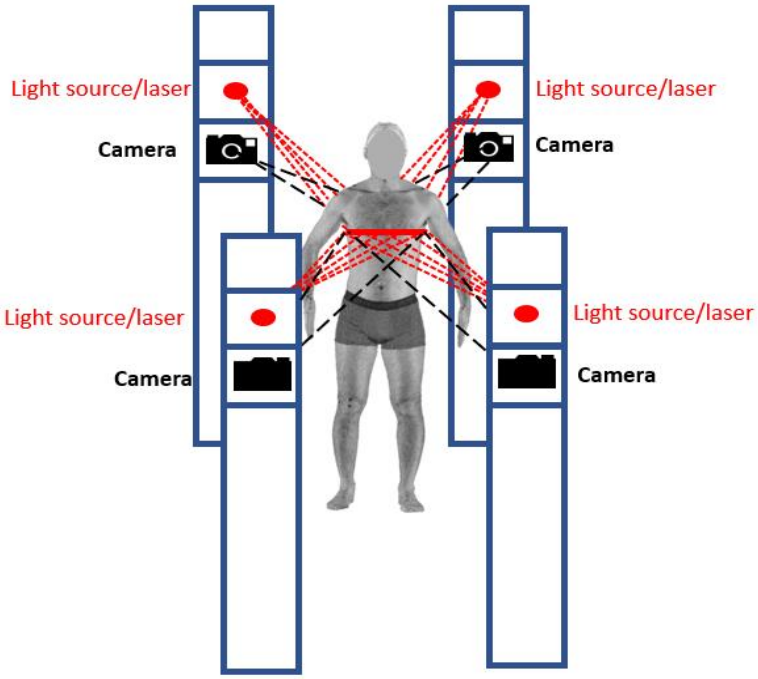

Figure 6. Typical layout of a 3D body scanner. The light source and camera are both mounted on a pole system. This is an example of a laser line system.

Laser line systems

Laser-based scanners use class 1 (eye safe, non-ionising) lasers to project light in an array beam onto the body surface from different sides. Multiple digital cameras capture the position of the projected light and software reconstructs the body contour of the acquired image via a mathematical algorithm which is based on triangulation. The system captures a series of surface points (typically between 700,000 and 1,000,000) with Cartesian coordinates.

Most systems house the sensor (laser) and cameras in four columns which are synchronized to scan the body from head-to-toe [47]. The column system is then enclosed in a curtain or fabric area for participant privacy.

The most popular laser line systems are the *WBX* or *WB4* (Cyberware, California. U.S.), *Vitus Smart XXL* (Human Solutions Ltd, Kaiserlauten, Germany) and the *Bodyline Scanner* (Hamamatsu Photonics, Hamamatsu, Japan) systems. The Cyberware WBX system shows good reliability and notably used in the movie industry as well as the Civilian American And European Surface Anthropometry Resource (CAESAR) survey which is often regarded as the first and largest civilian anthropometry survey to date [74].

The Vitus Smart XXL system is made in Germany and advertised as a portable device containing 4 poles (each with a laser scanning unit). These systems are often used in the Garment industry but are also used extensively by the US, Canadian, Australian and New Zealand Defence Forces.

Structured light

A cheaper alternative to laser scanning is white-light scanning. This technology is based on the use of projectors. They project a sequence of white-light stripes consisting of dots, bars, or any other light patterns on to the participant. The light pattern deforms as it falls on the body, and the resulting deformation is captured via cameras.

Structured light scanning systems are generally faster than laser line systems but take longer to process or extract measurements [48, 75]. The laser line system could also be considered a structured light pattern, but it has a strong time component because of its line sweep and therefore considered as a different class of light system. Compared to laser line, structured light systems have less moving

parts which increases the life cycle of the scanning system while also being safer for the participant [76] and more portable.

Some scanners in this category are fully automatic and autonomous. For example, the *NX-16* (TC^2, North Carolina, U.S.) system can be operated by the participant or person inside the scanner who presses a button located on holding levers inside the scanning cabin. Recorded messages and video presentations inside the cabin give additional information and instructions [77]. The TC^2 system utilises multiple optical lenses to produce a 3D surface geometry of the body. It can scan the whole body in approximately 8 seconds and produces 140 body measurements [27].

The *Triform* or *TriBody*™ (Wicks and Wilson-Crowley Company, Hampshire, UK) uses white light to capture the 3D scan data in 12 seconds using 8 camera views. Multiple stripes of white light are used to capture the 3D shape of the participant. The light contains no visible rays, lasers, or other radiation. The resulting images are analysed automatically using the TriBody software that produces a 3D point cloud model containing approximately 1.5 million Cartesian (XYZ) co-ordinates [27]. Other popular models include the Mephisto EX-pro and Gotcha systems (4ddynamics, Antwerp, Belgium), 3D *Mega Capturor II* (InSpeck 3D, Montreal, Canada), *Cartesian* (SpaceVision, Tokyo, Japan) and *SYMCAD* (TELMAT, France) systems. More recent models include the Size Stream® (TAL Group, North Carolina, US), Fit3D ® (Fit3D, Inc, California, US), the hand-held portable Artec L scanner (Artec Group, Luxembourg) and the home-based Naked Labs® Scanner (Naked Labs, San Francisco, US).

Multi-view cameras

Multi-view systems produce a 3D image that is acquired from two or more cameras. A stereo-camera records two images at the same time from a different viewpoint. Next, sophisticated matching algorithms determine corresponding points in the two images to compute their 3D coordinates, resulting in a dense 3D points cloud [77]. The advantage of a stereo-camera system is that no laser line or light pattern is transmitted, and no sunlight or extraneous light artefacts can disrupt the pattern. However, using the line or patterns enables a 3D image with higher resolution and accuracy [76, 78]. An example of a system that uses this technology is *Flex 8* (3dMDbody, Atlanta, U.S.).

Millimetre wave

This class of body scanning technology is like X-ray machines found at various airports around the world. For increased privacy, the participants are not required to remove any clothing.

Active scanners use the reflection patterns of millimetre waves that have been projected on the body [76, 78]. The ultra-high frequency radio waves penetrate participants clothing, reflects off the body, and are then collected by a transceiver and processed [77]. Passive scanners process the millimetre (or radiation) waves that are emitted by the human skin [76, 78]. Millimetre waves pass through most clothing ensembles but not the skin. Thus, the shape of the body can be captured without undressing. This offers an advantage in time and effort, but may introduce an ethical problem because of the explicit nature of the resultant image which views the body as naked [76, 78].

Infrared depth sensing technology

Infrared (otherwise termed as depth sensing) body scanners use nonvisible wavelengths. This technology is relatively new compared to previous body scanner models. Some infrared systems utilise what is known as ‘Time of Flight’ technology. This refers to the time that an infrared ray takes to travel to the nearest object in its field of view, and back to its sensor [79]. This technology is more cost effective and portable compared to other scanners. Research suggests that this technology is not as accurate as larger, more expensive fixed scanners [44]. However, models such as the recent Styku® S100 (Styku, Los Angeles, US) model demonstrated nearly perfect reliability with negligible systematic and random errors in a recent study [72]. The earliest (and most recognisable) form of this technology is the Microsoft Kinect sensor on the Microsoft Xbox console (Microsoft Corporation,

Redmond, WA, US). The technology is currently being used in today's high-end smartphones for taking depth-sensing photographs. For example, portrait mode which 'blurs' images in the background while accentuating the image of the object in focus.

Measurement extraction software

In addition to the hardware required to capture 3D scans, there must also be software dedicated than can interpret and extract body measurements. Some of the more commonly used systems are Cyberware's *DigiSize*, Headus' *CySize* (manual digital extraction) (Figure 7), Hamamatsu's *BodyLine Manager (discontinued)*, and Human Solutions' *ScanWorX* (offers both manual-digital and automatic-digital extraction). These programs can extract a large number of traditional measurements based on a known landmarking system or algorithm [21, 48]. These types of software can also measure contour distances, cross-sectional areas, surface areas and volumes [80].

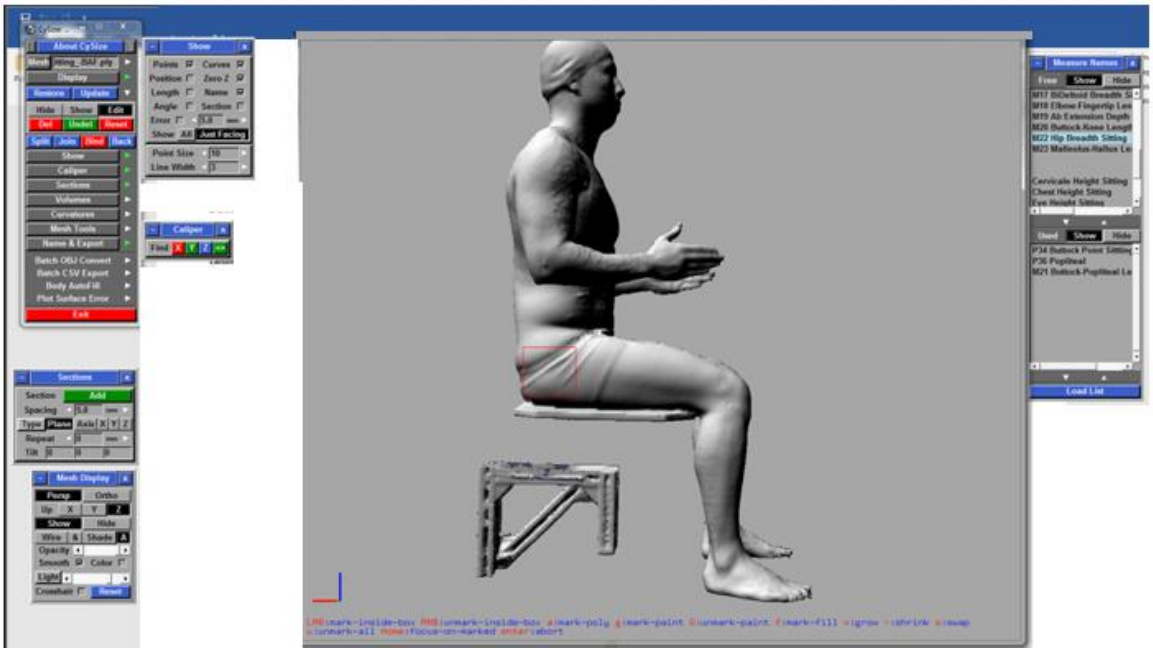

Figure 7. Headus' CySize output. Landmarks are placed physically, then identified and labelled digitally.

Like traditional anthropometry, 3D body scanning measurement extraction software requires landmarking. It would be sensible for all software to have a universal standard for identifying landmarks. Unfortunately, this is not the case as most software suites use different or ill-defined landmarks [21].

With regards to measurement extraction software, manufacturers may provide information about 'what' landmarking systems they use, but the process of 'how' the algorithms create measurements in line with those standards remain unclear due to commercial sensitivities. For example, the measurements in the automatic measurement function within *ScanWorX* (Figure 8) is based on a combination of ISO 7250:2010 and ISO 8559:1989 standards. Unfortunately, there is no validation research available assessing how well this software performs these measurements or what body types provide optimal landmark recognition and measurement accuracy.

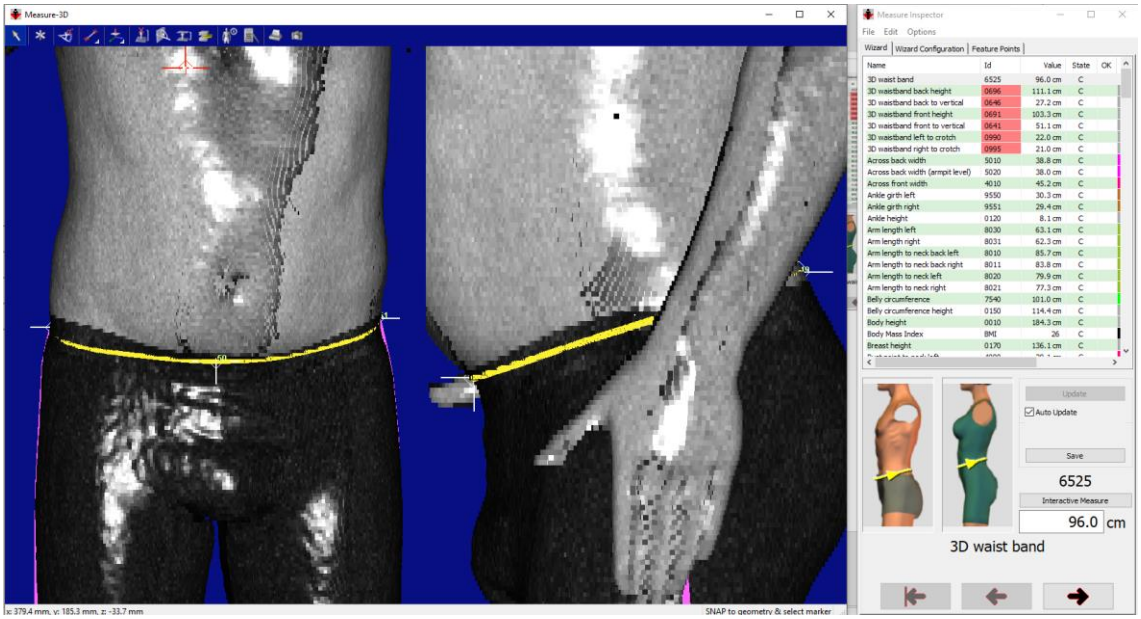

Figure 8. ScanWorX (Anthroscan) output showing the automatic measurement function.

Whatever system is used, it is imperative that the software can identify landmarks correctly. According to Buxton, Dekker [81] landmarks can be identified in three ways:

- Automatic landmark recognition (ALR) – this refers to extraction without human intervention using two methods:
  a. Template matching – The software creates a base template with all known measurements marked out. The template is then deformed to match the scan data. The system then extracts the XYZ co-ordinates of the known measurements.
  b. Curvature matching – The software detects known measurements based on surface shape. An area of the scan is isolated then a search is performed to identify a point based on slopes and gradients.
- Digital landmark recognition (DLR) – this refers to a user identifying locations and placing landmarks on the completed scan.
- Physical landmark recognition (PLR) – the user places landmarks (adhesive balsa triangles or reflective discs) on the participant before they are scanned. Using colour and texture recognition capabilities, the software can automatically identify these landmarks in XYZ space. The software can also be programmed to 'zone in' on special landmarks by recognizing features of the landmarks (e.g., zoom in on all objects that are 30 mm in diameter).

Validity

Many studies have investigated the reliability and/or validity of scan-derived measurements compared to more traditional (e.g. ISAK) systems. Body scanners have been shown to measure body volumes, circumferences and lengths more rapidly and accurately than traditional techniques [82]. Jaeschke, Steinbrecher [83] discovered strong correlations between automatic and traditional measurements for body height; however, the automatic measurements generally 'overestimated' most other measurements. Choi and Ashdown [84] demonstrated that automatic-derived measurements provided significantly larger values using traditional measurements for waist circumference. However, the differences in waist circumference may be the result of skin compression experienced during the traditional measurements [83]. Wells, Treleaven [40] found that traditional measurements were more accurate at predicting buttock girth and hip girth, while Glock, Vogel [59] found that body height, waist, upper arm, calf and hip circumference showed high validity for both traditional and body scanner methods. Zhang, Zheng [85] compared measurements obtained from the NX-16 TC^2 scanner with the equivalent tape measurements for the mid-arm, thigh, and ankle circumferences. All showed relatively high correlations (0.89, 0.90, and 0.93, respectively).

Wells, Stocks [86] compared the NX-16 (TC^2 scanner) with traditional measurements for chest, waist girth, waist width, waist depth, knee girth and calf girth on 1,484 children. All traditional measurements were successful, but the 3D scans were successful in only 71% of the children. The unsuccessful scans were attributed to body movement (inside the scanner during scanning) or the lack of calibration at the start of each data collection day [39].

The accuracy of the body scanned measurements can be influenced by procedural and postural issues. For example, Kuehnapfel, Ahnert [87] observed systematic differences for body height, waist girth and hip girth measurements. This was attributed to measurement errors with regards to participant posture and movement artefacts. Lu, Wang [88] found that scanning participants with their palms facing backwards reduced the differences between scan-derived measurements and equivalent traditional measurements. Lu and Wang [89] also found that that the scan-derived measurements can achieve satisfactory accuracy and precision if the variation caused by the participants scan posture is controlled. Adding supporting devices within the scanner helped ensure the participant maintained a consistent posture during the scan. The anthropometrist should be skilled in posturing the participant and prompting the participants with regards to breathing during the scan (e.g. hold their breath).

Challenges

The following will discuss several shortcomings of 3D body scanning with respect to collecting anthropometric data.

Cost

Compared to traditional techniques, body scanning systems are expensive. The costs of various scanning systems in 2013 ranged from US$10,000 to US$240,000 [76]. In comparison, a standard Anthropometry kit cost US$1,539 (e.g. RossCraft Centurion Kit http://www.thehumansolution.com/centurion-kit.html).

Identification of bone landmarks

Some landmarks will not show on digital scans as they may be obscured by skin, adjacent limbs, and superficial tissue. Examples are the acromion and the tibiale laterale, particularly in participants with significant muscular build. To help with identification, bone landmarks stickers or specialised markers are placed on the selected site to aid in post scan analysis [90].

Size, portability, and space requirements

Most whole-body scanners are bulky systems which require an area to suit its dimensions. The Vitus XXL scanner, for example, requires a height clearance of almost 3 m and a floor area of approximately 2.5 m^2 x 2.5 m^2. This is not ideal for typical office workspaces. In general, when compared to traditional techniques, 3D body scanners need a larger space to set up, take longer to physically set up, require competent trained scanner operators (unless the participant controls the scan like the TC^2 system), and time is needed for calibration and re-calibration.

Postures

Traditionally, anthropometric measurements are taken when the body is in anatomical position or like this position (Figure 9). For example, placement of the participant's head in the Frankfort plane, having arms relaxed by their side, both palms facing anteriorly, fingers extended towards the ground, and thumbs facing away from the body. This technique may not be useful for 3D scanning as the posture may obscure certain parts of the body from being scanned [30].

Many systems have a strict requirement for adopting certain postures in the scanner. Participants are required to adopt a static posture for a short amount of time. Automatically derived measurements can be dependent on the quality of the posture within the scanner. For example, some measurements are calculated based on Cartesian (XYZ) co-ordinates on the body. An incorrect posture can lead to

a shift in these co-ordinates. A classic example is body height. When standing in the Frankfort plane, the system may define height as the highest point on the head. If the participants posture was too far forward, then this point on the head may change, resulting in a different measurement.

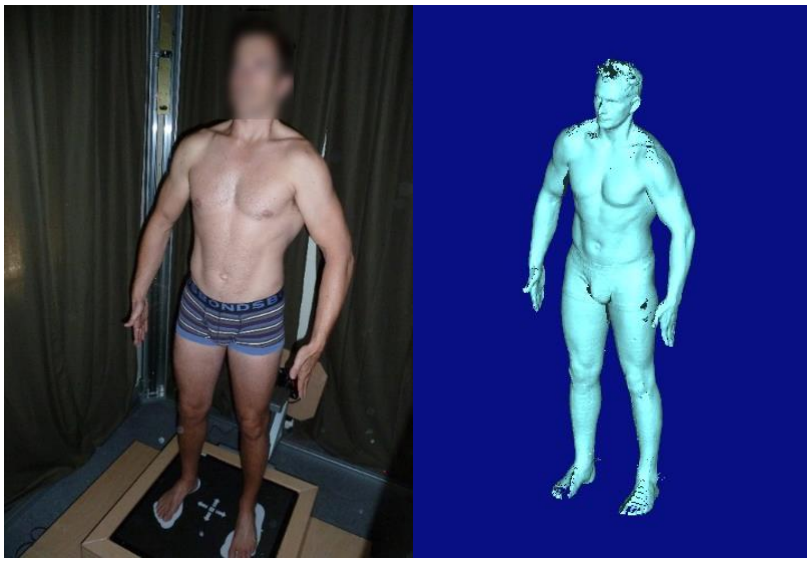

Figure 9. An example of a scan posture within the Vitus XXL. Body postures vary from participant to participant and if not controlled, is a potential source of measurement error.

Missing data due to shading

There are points on the body where the laser cannot detect. Examples include the armpit and crotch area, sides of the torso, and inside of the arms and legs [30]. There are problems with defining a person's correct height due to the amount of hair that rises above the scalp. Some scanners cannot differentiate between the hair and head [90]. Parts of the head can appear missing if reflected light from hair is not captured by the cameras, potentially making it impossible to identify the vertex, and therefore capture height.

Landmark extraction

Earlier we presented three methods in which landmarks can be identified using measurement extraction software (ALR, DLR and PLR). All have their limitations which must be considered prior to developing a survey protocol or procedures:

- The ALR method does not recognize variations in shapes and sizes [91] and only has pre-set measurements (e.g. it is difficult to add ad-hoc measurements) [81]. It is also difficult to locate landmarks accurately without palpation [30].
- With DLR, is the difficult to identify bony landmarks (e.g. acromion) on participants who may have a lot of adipose tissue or musculature on that area [81].
- With PLR, some landmarks require additional features to make them stand out in the scan. For example, one cannot use a flat disc landmark to identify the left-acromion, but instead, opt for a raised land marker to highlight this point to the user [91].
- PLR has additional time burden, feasibility issues, and the invasive nature of touching the participant.

Security and confidentiality

Another shortcoming of 3D body scanning revolves around the security and confidentiality of the participants scan images. For example, scan images are stored on computers which, if not appropriately protected, is potentially open to 'cyber-attack (e.g. 'hacked') through various connections to the internet [75]. People are also potentially identifiable from facial/bodily features or unique markings such as tattoos.

Summary

There are many uses for 3D body scanners today. From an anthropometric data collection perspective, 3D scanners can collect more measurement information on participants in much less time. The accuracy of 3D scanning is improving over time as the level and sophistication of technology increases. Furthermore, 3D body scanners are becoming more portable and accessible to the public (e.g. hand-held scanners). Despite several shortcomings, 3D scanners still deliver functionality that is simply not possible with traditional techniques, such as recording shape and volume information, and the ability review measurements retrospectively for verification and error control. Part III will now focus on how 3D body scanners contributed to various military anthropometric surveys.

PART III – AN OVERVIEW OF MILITARY ANTHROPOMETRY SURVEYS 2000–2020

Stephven Kolose, Patria Hume, Grant Tomkinson

Preface

PART II described how the introduction of 3D body scanning has changed the way in which anthropometric data are collected. Although traditional anthropometric data have been collected since the 1860s, and 3D body scanning technology was commercialised in the late 1990s, very few anthropometric surveys have used the technology. The purpose of PART III is to provide both a historical overview and a summary of contemporary anthropometric surveys in the military. This summary includes a comparison of sample methods, measurements (traditional and digital), 3D scanning technology, and key demographics. Importantly, the key challenges and future considerations for anthropometric military surveys are discussed.

Overview

The military has an extensive track record of conducting anthropometric surveys. Part III will discusses the importance of anthropometry for the military and summarises military anthropometric surveys. Measurements from these surveys were used to create a combined military anthropometric profile.

This review provides an overview of international military anthropometric surveys that have been conducted over the past two decades. The final reports, methods, and statistics and in some studies, the complete data set, are available online. However, some studies are not readily available due to confidentiality or proprietary reasons. Where information was available, we have described the 3D body scanning technology that was used, summarised the corresponding measurements and procedures, and summarised the findings in tables.

Keywords

Military, anthropometric surveys, 3D scanning.

Introduction

Anthropometry in the military has a long and comprehensive history. The combination of anthropometry, health and physical performance are still the primary focus in many military organisations today. These form the foundation of many military standards for selecting and retaining military personnel.

Anthropometric data is important for both military individuals and military populations. In the past, basic anthropometric measurements were used for accession, retention, and occupational assignment for 'individual' soldiers [92]. Therefore, an individual's occupation or trade within the military was partly determined based on their physical attributes. Of equal importance, for the successful design and fit of military clothing, personal protection equipment, workstations, anthropometric data of the 'whole population' is more important.

Anthropometry is potentially more important to the military than civilian populations. Due to the strict and sometimes dangerous operational requirements, incorrect anthropometric data can have a more direct and immediate effect on safety (e.g. poor ballistic or body armour coverage of vital body organs), performance (e.g. poor fitting footwear causing lower limb injuries during a pack march), and job performance for military personnel (e.g. long term injuries and neck pain in drivers and pilots).

Anthropometry is also important as equipment and technology must keep up with secular trends or 'growth' of humans over time, and can be used to estimate future body size and shape of successive generations of military personnel.

This has important implications for the design and acquisition of new military vehicles and the design of protective body equipment and clothing. Therefore, it is vital that regular anthropometric surveying of military personnel is conducted [93].

History

The first military survey was conducted during the American Civil War. The survey concentrated on stature, weight and body mass index to help identify recruits who may be malnourished, have tuberculous, or simply to identify factors that explain why soldiers may be unfit for military service [94].

In World War I, measurements such as chest circumference, body mass index (BMI), height, and weight were considered key indicators of soldier fitness for load-carrying, marching and fighting [95]. Men and women in the US Armed Forces were measured as early as 1942. At the end of World War II, the collection, analysis, and applications of anthropometric data were used increasingly for military research and development [95].

There have been numerous anthropometry surveys (mainly conducted in the US) in the military (Table 1) but not all are widely available.

Table 1. A chronological review of early military anthropometric surveys.

Year	Population	Sample size	Source	No. of measures
1861–65	US Volunteers	1,232,256	Gould (1869) [96]	(# not stated)
1863–65	US Draftees	501,068	Baxter (1875) [97]	(# not stated)
1917–18	US Draftees	1,961,692	Davenport & Love (1921) [98]	(# not stated)
1919	US Seperates	103,909	Davenport & Love (1921) [98]	(# not stated)
1946	US Army Men	105,062	Newman & White (1951)[99]	66
1946	US Army Women	8864	Randall & Munro (1949) [100]	66
1950	US Air Force Flyers	4063	Hertzberg et. al (1954) [101]	132
1959	US Army Aviators	500	US DOD HDBK 743A	(# not stated)
1964	US Navy Aviators	549	Gifford et. al (1965)[102]	98
1965	US Ground Personnel	3869	US DOD HDBK 743A [103]	161
1966	US Army Men	682	US DOD HDBK 743A [103]	73
1966	US Marines	2008	White & Churchill (1978) [104]	73
1966	US Army Basic Trainees	2639	US DOD HDBK 743A [103]	70
1967	US Air Force Flyers	2420	Grunhhofer & Kroh (1975)[105]	189
1968	US Air Force Women	1905	Clauser et al. (1972) [106]	139
1970	US Army Aviators	1482	Churchill et al. (1971)[107]	88
1977	US Army Women	1331	Churchill et al. (1977) [108]	(# not stated)
1988	US Army Men	1774	US DOD HDBK 743A [103]	240
1988	US Army Women	2208	US DOD HDBK 743A [103]	240
1989	US ANSUR I	3982	Gordon et. al (1989)[109]	108

Notable surveys

The 1946 US Army men survey was the first extensive anthropometric survey to be conducted. The purpose was to provide body size information for the design, sizing and tariffing of military clothing and personal equipment. The data were difficult to process as punch cards were used to store data.

The 1946 US Army women survey consisted of 5216 Women's Army Corps (WAC), officers, and enlisted woman, and 3648 army nurses. Data were collected using punch cards. At the time, no statistical analysis could be performed on the original data set until 1972 (when the data were transferred to magnetic tape and subsequently analysed by computer programs). The final number of participants for the survey was reduced to 8100 due to errors that were discovered in the original punch cards [11]. This is possibly one of the earliest examples of when computer processing power was used to assist the analysis of anthropometric data. It highlights a shift in technology, and the notion of measurement error, as evident in the punch card system [11].

The 1950 US Air Force flying personnel survey measured 4063 men across 14 Air Force bases. The survey consisted of 132 body measurements. The data for the survey were analysed before the introduction of modern computer facilities.

The 1966 US Basic Trainees Survey was the first to focus solely on new recruits. There are many advantages of measuring new recruits as analyses can be made on how their body shape can change through intensive military training. The disadvantage of measuring new recruits is that they do not represent the typical military body shape for those in service [11].

The 1970 US Army Aviators survey consisted of crew chiefs, door gunner mechanics, warrant officers and warrant officer candidate trainees, commissioned trainees and commissioned rated pilots. It was one of the first surveys to include both fixed-wing and rotary-wing pilots [11].

The 1988 US Men and Women surveys were the first major anthropometric survey in the US. Collectively, they consisted of over 132 body measures on 5499 males and 3485 females. This study deliberately over-sampled underrepresented demographic groups to predict increased number of personnel projected over several years. This was the first anthropometric database with completely commensurate data for men and women. It was also the first survey to use oversampling and statistical matching procedures to create working databases (those which can evolve with new data) to assess both present and future army populations [11]. Several observations can be made from these previous surveys. Over time:

- Anthropometric measurements progressed from individual (basing roles on physical attributes) to benefiting the wider population with regards to clothing and equipment
- Data collection and analysis has become increasingly sophisticated allowing for more in-depth analysis.
- Sample size has steadily declined as measurements become more defined and complex (potentially due to power analyses designed to detect meaningful differences between groups). Furthermore, the original surveys were based on basic height and weight measurements only.
- The number of females and ratio of females-to-males has steadily increased

To date, there has been little research that has focussed on comparing the methodology, results and lessons learnt from the various international military anthropometry surveys. Most of today's surveys are based on measurement protocols developed in the past (e.g., ANSUR II). Many surveys use a different set of tools (e.g., body scanners, traditional anthropometric tools or anthropometry measurement rigs) which makes inter-survey comparisons challenging. The surveys were conducted in different eras and possibly limited to technology and body of knowledge of that time (e.g., punch cards vs. magnetic tape vs. 3D scanning). Most of all, many reports and publications are not openly available due to copyright, confidentiality, security classification or age.

Challenges and trends

To address contemporary issues in military anthropometry and understand where the field is heading in the future, the International Ergonomics Association (IEA) congress and Defence Science and Technology Group (DST group) organised a workshop in 2015 [110].

The panel consisted of content experts in military anthropometry. The panel were also survey leaders for their respective countries. A summary [110] of the key findings were:

- 'What to measure'? Some surveys required an excessive number of measurements (despite the measurements being requested by the stakeholders in the consultation phase).
- All panel members agreed that anthropometric datasets required standardized measures and methods to promote interpretability within and between military forces.
- Research was needed to accurately describe encumbered soldiers. Many military organisations have their own clothing correction factors but the methods to obtain the measurements and the results are inconsistent between countries.
- Due to the continued advances in personal equipment and clothing, it may be more feasible to conduct smaller and more targeted surveys as opposed to large-scale surveys.

- There are many logistical challenges involved with capturing a representative sample. Oversampling is frequently used, but participants were often chosen based on their immediate availability.
- Measurement bookings required senior support at the outset of the survey, ideally from a uniformed and high ranking official.
- The panel discussed alternative sampling methods such as continuous sampling. That is, basing a body scanner at recruitment centres to capture body's during intake periods. Unfortunately, this would lead to an over representation or skew towards younger personnel.
- The ability to freely disseminate anthropometric data is difficult due to privacy concerns of the 3D scan data. Some surveys openly share their data (e.g., ANSUR) but only with a few countries. The panel believed that the availability (or lack) of such data directly impacts of the development of tools.
- More research should be concentrated on dynamic anthropometric data as opposed to data in a static position. However, this was deemed too difficult in terms of balancing multiple interactions between the participant (their shape and what they are wearing), their environment and tasks.
- There is difficulty translating anthropometric data into a usable medium for the designer or engineer. For example, some designers know that they need anthropometric data, but do not necessarily know how to use it. It was agreed that more tools are needed to address this issue. For example, basic software that looks at virtual fit testing versus standard anthropometry parametric model- based programs to represent 3D.
- There is a need to develop digital human modelling packages which are more realistic and offer more than just comparing linear or 1D measurements (e.g., girths, lengths, and breadths).
- There is a need to have anthropometric data incorporated into biomechanical models. Alternatively, it would be advantageous if digital modelling software can utilise data from different surveys or countries.

Secular trends of body dimensions are important to the military. Historically, these have focused on weight and height [111]. The most visible expression of the secular trend is the increase in adult height. To put things into perspective, the Netherlands is one of the tallest nations in the world. Between 1860 and 1990, the mean height of the Dutch population (men and women) increased by 16 cm (from 165 cm to 181 cm). By the year 2000, the average height for young men and women were 184 cm and 171 cm respectively [111, 112]. By comparison, people from South-east Asian countries (e.g., Indonesia) are regarded as some of the shortest in the world [113]. For example, the mean height for male Indonesian Army soldier was 169 cm while 90 percent of the Indonesian military were between 165 cm and 176 cm in height [114]. There have been limited studies looking at the secular trends for military personnel for measurements other than height and weight [93]. Tomkinson et al [93] identified positive secular trends in several absolute measurements related to platform fit and ergonomic design (e.g. stature, sitting height, buttock-knee length, and hip breadth). These changes have implications for military procurement.

In the military, certain platforms, vehicles, and aircraft can operate in service for decades. For example, the *F-111 Aardvark* (Royal Australian Air Force), *B-52 fixed wing* (United States Air Force) and *Sea King helicopter* (UK armed forces) were in service for 34 years, 55 years, and 40 years, respectively [115]. Over time, the anthropometric profile of people who operate such equipment can change. Ideally, the planning process for long-term military acquisitions (e.g., upgrading an Air force C-130 Hercules fleet, naval frigate or army tanks) should consider changes in the operator's body measurements over the lifetime of the platform or product. However, identifying secular changes is difficult for several reasons.

Secular trends are usually estimated from age-corrected data derived from temporally sequential studies from the 'same' population [92]. This is acceptable for countries that have a consistent history of anthropometric surveys such as the US, but not for countries that have conducted limited anthropometric surveys. The make-up of military anthropometry populations is based on ethnicity and immigration [92] of the country's current population. Meaningful changes in immigration may

influence the ethnic mix within the population (country). This in turn, will influence the military populations ethnic mix. Furthermore, increased height may be important for some military roles but not for others. For example, a 10-year, 10 mm difference in seated height may be irrelevant for clothing design, but it may be significant for a young Air Force cadet who is a borderline fit for their crew station anthropometry assessment. Alternatively, once accepted into the program, the cadet may end up flying an aircraft that was designed using anthropometric data that are several decades old [115]. Of greater concern, the cadet may have grown considerably over the course of their basic training.

To summarise, there are several trends and challenges in military anthropometry surveys. Small-scale rather than large-scale anthropometry surveys are potentially a more practical and viable alternative. This can help ease logistical burden. Sharing of anthropometric findings especially amongst military organisations is and will always be difficult. More research should be conducted on digital human modelling, dynamic and encumbered anthropometry, and sampling strategies/procedures that are 'military-friendly'. Secular trends of military personnel body sizes will have implications for future acquisition of equipment or platforms and may influence how they are operated.

The next part describes international military anthropometric surveys that have been conducted between 2000 and 2020. Many other studies were not available for review due to confidentiality or proprietary reasons.

Contemporary surveys

This section describes the measurements, technology and demographics used in eight international military anthropometric surveys conducted between 2000 and 2019. The surveys represent the few studies that are available to the public. The surveys covered are:

- 2006–7 Anthropometry Survey of UK military personnel
- 2010 Anthropometric Survey of Iranian Military Personnel
- 2012 Anthropometric Survey of U.S. Army Personnel (ANSUR II)
- 2012 Australian Warfighter Anthropometry Survey (AWAS)
- 2012 Canadian Forces Anthropometric Survey (CFAS)
- 2014 Anthropometric Survey of Brazilian Air Force
- 2015 Anthropometric Survey of the Royal Australian Navy (ASRAN)

The surveys are summarised according to purpose, sample size, measurement combination and demographic information in (Table 2).

Combined variable list

All measurements used in the surveys (except for the Iranian survey) were recorded and condensed (according to nomenclature) in Appendix A. This is not an official list, it is an interpretation of what a combined military measurement profile may look like. To the best of the authors' knowledge, the combined measurement list in Appendix A is the first published attempt at combining measurements from different military surveys over the past two decades.

The list also considers the Civilian American and European Surface Anthropometry Resource (CAESAR) dataset. Whilst not a military survey per se, CAESAR was added as a civilian comparison and because it is widely considered as the first and largest anthropometry survey to use 3D body scanning [116]. The demographic information for CAESAR will not be covered.

The following observations were made during the development and interrogation of the list in Appendix A. Measurement names and definitions varied from dataset to dataset. For example, foot

breadth horizontal (ANSUR and AWAS) versus foot breadth (CFAS). Furthermore, nomenclature is inconsistent, and measurements were not standardized between surveys:

- Dimension units such as girths and circumference differed amongst the datasets. For example, elbow girth (CFAS) versus elbow circumference (ANSUR)
- Most datasets take measurements from the right-hand side of the body. Some datasets took measurements on both the left- and right-hand side of the body (e.g. CAESAR and UK). This ultimately increased the number of measurements in their respective profile.
- Whilst body scanning technology was used, the measurement profiles still consisted of predominately physical measurements.

With the introduction of new, more advanced 3D body scanner systems, even more measurements may be conceived in the future. This will undoubtably make it difficult to compile a universal military anthropometric measurement profile as covered earlier in this book. Based on this evidence, the composition of future anthropometric measurement profiles (protocols) may continue to be 'stove-piped' within each country.

Table 2. Summary of selected anthropometric surveys conducted between 2000 and 2020 showing sample, measurement, demographic, and technology descriptives.

COUNTRY	SAMPLE PARAMETERS	# LM; P; DIGITAL (A, P, D)	ETHNICITY	TRADE	SCANNER
2002 Civilian American and European Surface Anthropometry Resource - CAESAR	4431 18 to 65 years 2094 Male 2332 Female 54% North America 28% Netherlands 18% Italy	99; 72; 40; (-, 99, -)	<u>North America:</u> 77% White 11% Black 12% Other <u>Netherlands:</u> 82% White 18% Other <u>Italy:</u> 96% Italian 4.0% Other	(# not stated)	Cyberware (US, ITA) WB4 Whole Body Scanner Laser <2mm Human Solutions, Vitus Pro Laser <2mm
2006-7 Anthropometry Survey of UK Military Personnel Tri-service	**2470** 17 to 55 years 2160 Male 311 Female 44% Army 26% Air Force 30% Navy	96; -; 18; (71, -, 6)	Only minority groups presented 1.5% Black 1.0% Caribbean 0.9% Black African 0.72% Fijian 0.2% Indian 0.16% East African 8.0% Gurkas	(# not stated)	Textile Clothing Technology Corporation [TC]² KX-16 Cyberware Laser Head Scanner Infrared Laser 1 mm
2010 Anthropometric Survey of Iranian Military Personnel	12635 18 to 30 years Male (# not stated) Female (# not stated)	90; -; 90; (-, -, -)	(# not stated)	(# not stated)	MANUAL ONLY
2012 Anthropometric Survey of U.S. Army Personnel - ANSUR II Army only	**7435** 17 – 58 years 7435 Male 3922 Female 64% Active Duty 33% National Guard 3% Reserves	135; 53; 94; (-, -, 41)	62% White 21% Black 11% Hispanic 3.0% Asian 1.0% Native American 1.0% Pacific Islander	27% Quartermaster supply 15% Signal, COMS & Info systems 10% Medical 8.0% Intelligence 8.0% Ordinance/Mechanical	Cyberware WBX and PX and INFOOT foot scanner Laser <2mm
2012 Australian Warfighter Anthropometry Survey - AWAS Army only	**2138** 18 to 40 years 1861 Male 277 Female	84; 25; 40; (-, 44, -)	<u>Country of birth</u> 92% Australia 1.3% New Zealand 1.3% Other 1.1% South-East Asia 1% Europe (ex. UK) 1% UK 0.7% Pacific Islands	24% Rifleman 7.6% Driver 5.9% Combat Engineer 5.7% Crewman ASLAV 5.0% Operator Supply 3.5% Operator Admin 3.4% Gun Number	Human Solutions, Vitus XXL Whole body scanner Laser 27 cm³

2012 Canadian Forces Anthropometry Survey - CFAS Tri service	**2205** 17 to 60 years 38.4% Army 21.9% Navy 39.7% Air Force 1890 Male 315 Female	91; 44; 48; (-, -, 43)	Racial distribution 92.7% Caucasian 2% Other 1% Black 0.8% Filipino 0.7% Latin American 0.6% Metis 0.6% Chinese	8.8% Pilot 8.4% Infantry 6.1% Aviation Technician 5.8% Combat Engineer 4.7% Crewman Armoured 4.1% Resource Support Clerk 3.9% Supply Technician 3.4% Air Combat Officer 2.9% Avionics System Tech	Human Solutions, Vitus XXL Whole body scanner Laser 27 cm³ Human Solutions, VITUS aHead Head Scanner Laser 30 cm³ FootIn3D Scanner Laser 35 cm³ VisImage Inc BoSS XXI Body Sizing system Photo
2014 Anthropometric Survey of Brazilian Air Force Air Force only	**2339** 16 to 52 years Brazilian Pilot population 44% Potential pilots 56% Current pilots 2133 Male 206 Female	39; -; 39; (-, -, -)	Racial distribution 72% White 22.3% Brown 4.4% Black 1% Asian 0.22% Indigenous 0.08% Other	Officers (top 4 only) 14.5% Transport 6.5% Fighter 5.7% Helicopter 4.1% Instructor Cadets and students 20.5% Trainees 8.7% Students 7.1% Admin 3.5% Infantry	MANUAL ONLY
2015 Anthropometric Survey of the Royal Australian Navy - ASRAN Navy only	**1332** 18 to 54 years 1090 Male 232 Female	87; 69; 43; (-, 44, -)			Human Solutions, Vitus XXL Whole body scanner Laser 27 cm³

Key: MEASUREMENTS: (#=total sample number, LM = landmarks, P = physical measures, D=digital measurements. ***Digital*** (A=Automatic, P = Post-processed, D = Derived). SCANNER (RES=Accuracy in mm or point cloud distance as points/per cm^2).

Summary of military surveys 2000 to 2019

2004-5 Australian Defence Anthropometric Personnel Testing (ADAPT) project

In 2004, the Australian Defence Force in conjunction with the University of South Australia (UniSA), Sinclair Knight Merz, Permian, the University of Ballarat, and the Australian Institute of Sport (AIS), conducted the Australian Defence Anthropometric Personnel Testing (ADAPT) study as part of the wider Australian Defence Force Aircrew (ADF) and Crewstation Anthropometry Project MIS 872 [117].

The project comprised three phases: (1) capturing 3D scans of crew stations using a seven-axis FARO *ScanArm* later used in CAD design programmes, (2) UniSA and AIS obtaining anthropometric data from current ADF aircrew and potential aircrew from young civilians from around Australia,

using principally 3D measures plus several physical measures, and (3) and integrating the crew station scan images with the 3D body scans in a software program called JACK. The JACK software animated the virtual bodies to simulate flight tasks in the cockpit [30].

The dataset was used to identify recruitment guidelines for aircrew, to optimise cockpit human-machine interface and improve the fit of clothing and equipment [118]. Prior to the ADAPT project the most recent ADF anthropometric survey was conducted in 1977, which comprised 30 measurements on 3,000 male military (across Air Force, Navy and Army) personnel.

The project used a Vitus XXL 3D whole body laser scanner (Vitus XXL, Human Solutions) with a resolution (point density) of 27 points/cm^2. Each scan took approximately 12 seconds resulting in 32 digital measurements with the aid of Physical Landmark Recognition (PLR; see PART II for a description of PLR). Four additional measurements (stretch stature, sitting height, buttock-knee length, and weight) resulted in 36 total measurements.

The project captured measurements for 1,510 male and female civilians (who were potential aircrew recruits or students or in their final year of high school between 18 to 30 years) and 255 current aircrew personnel from the RAAF (aged between 20 and 56 years).

The survey took 45 to 60 minutes to process each participant, with approximately 30 participants were processed each day. Each participant completed a questionnaire, including a section on clothing sizes [shoe size, dress and bra size (females) and shirt size (males)]. Participants then changed into form-fitting underwear and a latex swimming cap before their physical measurements were recorded. Next, 23 landmarks were placed on the body (these landmarks could not be accurately located by looking at the scan) [119, 120]. The participants were then scanned in the middle of the body scanner with their legs slightly spread apart and their arms slightly abducted away from their torso [120]. Digital measurements were extracted from the scans using specialist software tools (e.g. *CySize*™ and *Anthroscan*™) such as girths (using a simulated tape measure or contour), cross-sectional areas, volumes and distances between landmarks [120, 121].

2006–7 Anthropometry survey of UK military personnel

The survey was conducted by the QinetiQ Human Protection & Performance Enhancement Group on behalf of the Haldane–Spearman Consortium (H–SC) for the Ministry of Defence (MOD) Research Acquisition Organisation (RAO) [122].

Prior to this survey, the previous published dataset was the Defence Standard 00-25 Part 17 developed from surveys conducted between 1970 and 1995 [122]. The UK Ministry of Defence (MOD)-Industry Human Factors Integration (HFI) group planned to use this dataset to update Defence Standard 00-25 Part 17. DEF STAN 00-25 provides human factors design guidance (including anthropometric data) for use in the UK defence industry. The dataset was also designed to be used internally and by contractors designing and building military equipment (e.g., Human Factors Integration, development of Systems Requirements Documents (SRD), forecasting clothing purchases). It was envisaged that this information would reduce costs and post-production adaptations for equipment and vehicles by specifying adaptations prior to acceptance [122].

Two Textile Clothing Corporation [TC]² 3D body light scanners were used. The scanners used infrared as opposed to laser technology (see Part II for more information on this technology). Hundreds of thousands of data points were captured to produce a 3D representation of the body at an accuracy of ±1 mm. Each scan took 3 seconds in duration.

The survey comprised 96 measurements, 18 of which were collected physically, 71 using digital measurements and six were derived. The measurements were based on physical measurements used in a previous UK survey [123] and from ISO 8559 [124]. Several measurements were modified to meet scanner technology limitations. For example, the scanner could not detect bony landmarks

unless they were pre-landmarked by the scan operator. Head measurements were taken using a Cyberware Laser Head Scanner) as the 3D body scanner took limited head measurements [122].

Each scanning day consisted of eight, 1-hour sessions. Six participants were briefed at a time. At the brief they were required to fill in a demographic proforma. Next, participants were processed in pairs by two body scanner teams. At least one of each pair was head-scanned. Physical measurements were only taken when a scan could not extract the required measurement or when a scan-derived measurement was unobtainable. Participants were scanned once in a standing and once in a sitting position, with males wearing light grey briefs and females wearing a grey sports bra and skin-tone pants which were supplied by the project team. All data were validated before being entered onto the anthropometric database [122].

The survey of 2,470 personnel consisted of 2,160 male and 311 females. The sample was 44% Army, 26% Air Force and 30% Navy personnel ranging from 17 to 55 years of age. The sample also consisted of 188 Gurkas who were considered a significant ethic group with known anthropometric differences from the general UK army [122].

The final report did not provide a full breakdown of the participants by ethnicity or race. However, numbers were provided for minority ethnicities such as Black Caribbean, Black African, Fijian, Indian and East African. The report presented sample numbers for three groups that present different anthropometric data from rest of the armed forces. These groups were Aircrew (n = 126), Gurkas (n=188) and Royal Marines (n=181).

The report concluded with measurement profiles that included an illustration of the body scan output, descriptive statistics, and frequency tables by gender and service.

2010 Anthropometric Survey of Iranian Military Personnel

In 2010, the anthropometric characteristics of Iranian military personnel (aged 18 to 30 years) were reported [125]. The measurement protocol and definitions were based on the 2008 National Health and Nutrition Examination Survey (NHANES) [126]. The survey did not utilise a 3D body scanner, but rather 90 physical measurements using the NHANES protocol. The 12,635 participants were armed forces personal with a minimum of 10 years' experience. Participants were selected using systematic random sampling stratified by age. Further information relating to gender, trade and ethnicity was not provided. No measurement profile was provided. The report included summary statistics (mean, standard deviation, 5^{th} to 95^{th} percentiles) for each measurement and a multi-country (Iranian versus US, Australian and UK army) comparison table for stature, sitting height, upper limb and lower limb measures.

The first research on anthropometry and design in Iran's army was conducted in 1971 [127], where 7,784 Iranian soldiers were measured for military shoes and clothes. The next survey was conducted in 1995, with 2,130 personnel measured. The 2010 survey was to be the latest study focussing on ergonomics and anthropometric measures in the current military forces [125].

2012 Anthropometric Survey of U.S. Army Personnel (ANSUR II)

The 2012 Anthropometric Survey of US army personnel (ANSUR II) [16] is one of the most comprehensive anthropometric surveys in the military. Conducted by US Natick Soldier Research, Development and Engineering Centre (NSRDEC) between October 2010 and April 2012, the survey acquired anthropometric data for 1,090 males and 232 females to serve the Army's design and engineering needs. The sample represented the US Army Active Duty, Reserves, and National Guard. The dataset was also intended for equipment design, sizing, and tariffing applications with potential commercial, industrial, and academic applications.

The US army's previous anthropometric survey was conducted in 1987–88 which is commonly known as the U.S. Army Anthropometric Survey (ANSUR) or ANSUR I. ANSUR I consisted of 132 anthropometric dimensions on 8,997 personnel (5,506 male and 34,921 female). The processing time

for one individual was up to four hours to enable a large number of measurements to be taken [109]. The ANSUR I measurements were all captured physically with no 3D body scanning system. However, a device known as the Automated Headboard Device (AHD) was used to capture head and facial measurements.

The ANSUR II survey consisted of 94 physical measurements, and 39 derived measurements from 3D whole body (*Cyberware* WBX), INFOOT foot, and PX head scans (from I-WARE Laboratory, Osaka, Japan). The measurements were based on 51 physical landmarks. Both systems are laser scanners. The whole-body scanner was accurate to ±1 mm. Each scanner took approximately 15 to 20 seconds to complete. The whole-body scanner was controlled using the CyScan software in conjunction with an Enhanced Anthropometric Rating System (EARS) program. EARS was used as an evaluation step that would assist the scan operator with capturing high quality scans. Scan data were transferred to the system server through a local network, and were later backed up to DVD [128].

The 11,357 participants included 7,435 males and 3,922 females. The sample included Active Duty, National Guard, and Army Reserve Soldiers. Participants were between 17 to 58 years old. Sample breakdown by race consisted of White (62%), Black (21%), Hispanic (11%), Asian (3%), Native American (1%) and Pacific Islander (1%) respectively. Sample breakdown by trade or occupation (by order of most prominent) consisted of Quartermaster Supply (27%).

2012 Australian Warfighter Anthropometry Survey (AWAS)

The Australian Defence Force (ADF) Australian Warfighter Anthropometry Survey (AWAS) was run by the Defence Science and Technology Organisation (DSTO) Land Division in conjunction with the Australian Defence Test and Evaluation Office (ADTEO) and the School of Health Sciences at the University of South Australia between 2010 and 2012 [129].

The previous anthropometric survey was the Australian Tri-Service Anthropometric Survey in 1977 [130] which consisted of 3000 male ADF personnel aged 17-50 years. The survey also consisted of 1044 male Army personnel and utilised a total of 31 physical measurements [115].

The purpose of the AWAS survey was to gather comprehensive anthropometric data on a broadly representative sample of the (active forces) ADF Army personnel. It was envisaged the data could be used to optimise the design of clothing and protective equipment for sea and air vehicle platforms [117].

The AWAS used a 3D whole-body scanner (Vitus XXL, Human Solutions) to help collect digital anthropometric measurements. A total of 84 physical and digital measurements were collected per individual. The Vitus XXL scanner is a laser scanner with a scan resolution (point density) of 27 points/cm^2 and takes approximately 12 seconds to for a single scan.

Forty measures were taken physically, and the remainder were extracted from the digital scans. The 25 surface landmarks were placed on the participants skin (by the anthropometrists) using palpation of the skin. The measurement profile was derived from a review of Australian and international military anthropometric surveys, input from Australian clothing industry experts and the results of a validation trial [131].

Prior to undergoing measurements, all participants were given a brief where they were required to provide informed consent and complete a demographic questionnaire before they were assigned a 4–digit coding convention to anonymise their data. Participants were then escorted to a landmarking area and reminded of the procedures used for landmarking, physical measurement and/or 3D scanning [129].

At the body scanner, participants wore a swim cap to help locate the vertex and other reference points on the head. Once inside the scanner, participants were positioned in two standing postures and one sitting posture. The scan time was approximately 12 seconds per posture. The physical measurements were taken by ISAK Level 2 trained anthropometrists using traditional anthropometric measurement equipment. The anthropometrists had extensive training in the survey measurements [131].

The 2,138 participants included 1,861 males (87%) and 315 females (13%). In terms of country of birth, 92% of the sample was born in Australia, followed by New Zealand (1.3%), South-East Asia (1.1%), Europe-except UK (1%), UK (1%), and Other (1.3%). The main trades or occupations represented by the sample were Riflemen (24%), Drivers (7.6%), Combat engineers (5.9%), Crewmen (5.7%), Operator supply (5%), Operator admin (3.5%) and Gunners (3.4%).

2012 Canadian Forces Anthropometric Survey (CFAS)

The Canadian Forces Anthropometric Survey (CFAS) was conducted in 2012 by the Defence Research and Development Canada (DRDC) and Human Systems Incorporated. Prior to 2012, the Department of National Defence (DND) lacked up to date, accurate and representative anthropometric data of the Canadian Forces. The purpose of the survey was to update the anthropometric dataset and use it for the specification, evaluation, development, and acquisition of military equipment [132].

Prior to the 2012 survey, the two most recent anthropometric surveys in Canada were the Royal Canadian Air Force (RCAF) survey in 1985 (taking 73 physical measurements on 519 aircrew) and the Canadian Land Forces Survey in 1997 (140 measurements on 708 participants). The measures in 1997 consisted of a combination of physical measurements, 2D digital images of the foot and hand and 3D laser scans of the head [132].

The CFAS used four different types of scanning technology in addition to traditional methods to capture measurements for their respective protocol. The *VITUS* XXL Whole body scanner which has an accuracy of ±1 mm at a point density of 27 points/cm^2, the VITUS AHead Scanner (±1 mm accuracy at a point density of 30 points/cm^2) and the FootIn 3D (± 1 mm accuracy at a point density of 35 cm points/cm^2). A BoSS XXI Body sizing system was used to capture 2D whole body dimension data. The BoSS system used two digital cameras that take simultaneous pictures from the fontal and sagittal planes. Proprietary algorithms then interpreted the images to identify landmarks to make linear and circumferential measurements of the participant.

The total CFAS sample was 2,205 personnel (38.4% Army, 21.9% Navy and 39.7% Air Force) and consisted of 1,890 male and 315 female participants. The demographics in terms of race consisted of 92.7% Caucasian, 2% other, 1% Black, 0.8% Filipino, 0.7% Latin American, 0.6% Metis and 0.6% Chinese. The main trades represented were Pilots (8.8%), Infantry (8.4%), Aviation Technicians (6.1%), Combat Engineers (5.8%), Crewman (4.7%), Resource Support Clerks (4.1%), Supply Technicians (3.9%), Air Combat Officers (3.4%) and Avionics Technicians (2.9%).

2014 Anthropometric Survey of Brazilian Air Force

In 2014, researchers from the Brazilian Air Force University, New York University and Arizona State University conducted the first anthropometric survey on Brazilian Air Force pilots. The data were used for optimising aircraft cockpit design, uniform design, pilot accommodation, protective gear and digital human modelling [133].

There was previously no published anthropometric dataset for the Brazilian military. Only two anthropometric databases from Brazil were recorded in the literature both of which were based on the civilian population. The first database was developed in 1988 based on male industrial workers from Rio de Janeiro. The second database is from 2008 and based on eight anthropometric measurements taken from Aviation Transport Users (common passengers) [133].

The 2014 survey did not use a 3D whole-body scanner and was based on physical measures only. The survey consisted of 39 measurements that were adapted from Hotzman, Gordon [134]. The measurements were specifically relevant to the design of aircraft cockpits, protective gear, uniform sizing, and computerised digital human modelling [133]. The measurements were conducted by Brazilian military personnel who were responsible for administering the anthropometric measurements in the annual fitness test.

The survey procedure consisted of four independent measuring stations and two anthropometrists per station (alternating as measurer and recorder). Each team consisted of 12 people, with one 'substitute measurer' per station. The four measuring stations consisted of the following activities: a) landmarking, b) standing and seated measurements (depths, breadths, and lengths) conducted using a Beam calliper. The station included foot measurements using the modified Brannock device, standing and sitting measurements (heights and lengths) using the anthropometer, and circumferences and hand measurements using a Poech sliding calliper.

Seated measurements were taken on a table (70 cm in height) using two wooded boxes as a footrest, styrofoam pieces (to adjust feet up and down) and a wooden buttock plate. All measurements were taken on the right side of the body and recorded to the nearest millimetre. Measurements were recorded on a laptop and hand-written tables for back up. Outliers were determined in Excel™ using a filtering process based on previous studies and standards [11, 15].

The 2,339 aircrew (2,133 males and 206 females) were aged 16–52 years. With respect to distribution by race, 72.0% of participants were White, 22.3% Brown, 4.4% Black, 1.0% Asian, 0.2% Indigenous, and 0.8% Other. In terms of trades, the top four Officer trades represented were Transport (14.49%), Fighter (6.54%), Helicopter (5.69%) and Instructor (4.11%) pilots. Cadet and Student trades represented were Trainees (20.48%), Students (8.72%), Administration (7.14%) and Infantry (3.46%) personnel.

2015 Anthropometric Survey of the Royal Australian Navy (ASRAN)

The Anthropometric Survey of the Royal Australian Navy (ASRAN) was conducted in 2015 by the Maritime and Land Divisions of the Defence Science and Technology Group in conjunction with the University of South Australia. The purpose of ASRAN was to capture relevant (and update previous) Royal Australian Navy (RAN) anthropometric data to support the Australian Defence Force Maritime Procurement Programme and inform the development of a new habitability standard for the RAN [135-137].

The previous Royal Australian Navy anthropometric data were obtained in 2000, which consisted of 302 personnel (251 male and 51 females). As part of the scoping plan for the ASRAN, the 2000 RAN reference data were compared against international standards [138]. The findings showed that the 2000 reference data were inappropriate for the design of future marine platforms as well as several other issues. For example, the data were outdated, the female sample was small, and the data were not generalisable to the current RAN population (e.g. no submariners were included and the sample was not representative of all trades and age groups). Furthermore, the survey was conducted using physical measurements and presented results in only three percentile categories (5th, 50th, and 95th). The limited percentile data would not be helpful for designing equipment or platforms for a section of the population outside these values [135, 137]. For example, 99th percentile may be required by specialized populations such as aircrew or special forces. Outside of the 2000 RAN reference data the most recent anthropometric survey in the Australian Defence Force was the AWAS conducted in 2012 as described earlier in this section.

The technology used in ASRAN is identical to that used in the AWAS in 2012. Two Vitus XXL whole-body scanners (Human Solutions, Kaiserslautern, Germany) were used in conjunction with a team of anthropometrists for the physical measurements. The measurements used in ASRAN were similar but not the same to those used in the AWAS. The AWAS measurements were based on

measurements that were in-line with clothing and body armour design; the ASRAN measurements were prioritised on habitability and platform design. Stakeholder interviews, consultation and published reviews were used to select the final measurement list. This resulted in a total of 87 measurements per participant, comprising 43 physical and 44 digital measurements from 69 physical and digital landmarks [136].

The 1,332 personnel (1,090 males and 232 females) were aged 18 to 54 years. No further information regarding the participant or study demographics were available at the time of this review.

Summary

Part III provided a summary of eight military anthropometric surveys that were conducted over the past 20 years. To the best of our knowledge, these represent the most recent and publicly available military surveys.

It was apparent that equipment, clothing, platform, and workstation design were the driving force for these surveys. Many military organisations also wanted to 'update' their existing anthropometric datasets according to current best practise, in preparation for future equipment acquisition, and to support design, engineering, and human factors research.

Two surveys did not utilise 3D body scanning technology but instead used 'traditional' measurement profiles and protocols. Several used the same body scanning technology (e.g., Vitus XXL or TC²) each with their own protocols and procedures for measuring data. Despite the rapid increase in the development of 3D technology, anthropometric surveys appear to be still dominated by physical measures (as opposed to digital) and the surveys at the start and end of the decade still use similar body scanning technology (Vitus XXL or similar variation). This is further evidenced in Appendix A where most of the measurements in these survey protocols are physical. Surveys used a mixture of measurement definitions from different protocols (e.g., ANSUR II, NHANES, ISO 7250) or developed their own protocols. Even when 3D body scanning was used, measurement definitions were still based on physical (or 1D) measurement definitions (despite known issues with the accuracy of scanning technology). As a result, traditional 1D measurements captured by traditional survey protocols are not suitable for today's real-world problems. The use of 3D data may be more suitable and flexible to solve many contemporary design issues (e.g., using human 3D models to simulate real-world tasks in a virtual environment).

Some measurement teams have undergone extensive training by way of international accreditation (e.g., ISAK qualification/training) while others have learnt through internal training from senior anthropometrists. Some also conducted validation trials and assessed test-retest reliability of measurers before and during the surveys. There is no universal anthropometry qualification recommended by the military.

There was a greater number of males sampled in the surveys despite attempts to over-sample female participants. This is most likely a reflection of the male and female ratio in the military in general. The reporting of participant trades, ethnicity or racial distribution is not fully described in all survey reports that are publicly available. These characteristics are important (especially ethnicity) as they help describe the anthropometric differences of their respective population. The information can also be used to compare different surveys or better estimate temporal trends.

Part IV will describe the methodology of the 2016–2018 New Zealand Defence Force Anthropometry Survey.

PART IV - NEW ZEALAND DEFENCE FORCE (NZDF) KINANTHROPOMETRY SURVEY DEVELOPMENT

Stephven Kolose, Patria Hume, Grant Tomkinson, Tom Stewart

Preface

Part III summarised previous military anthropometric surveys. Many countries have a long history of conducting anthropometric surveys, with few using 3D body scanning technology until this past decade. The knowledge obtained from Parts II to IV provided a foundation for developing and implementing a modern 3D anthropometric military survey. The purpose of Part IV is to report on the development, methodology, implementation, and analysis of the New Zealand Defence Force Anthropometry Survey (NZDFAS), currently one of the most recent tri-service, 3D anthropometric surveys in the world. The resulting measurement protocols and summary statistics are presented in Part VI.

Overview

Part IV is a culmination of the material covered in Parts I to III of this book. We will discuss how the New Zealand Defence Force Anthropometry Survey (NZDFAS) was initiated, how the survey was designed, and how it was implemented. This was the first study of its kind in New Zealand. The purpose of this section is to document the methodology used for the NZDFAS and provide the reader with information on how to conduct a large-scale anthropometric study.

Keywords

New Zealand Defence Force, NZDF, anthropometry; survey

Introduction

Anthropometry in New Zealand

Prior to this study, data relating to the anthropometric dimensions of New Zealand Defence Force personnel (and New Zealanders in general) was limited. A comprehensive survey suitable for human engineering design and ergonomic applications had never been undertaken, despite unsuccessful attempts in the 1980s and 1990s [141]. Two previous New Zealand-based studies helped shape the current NZDFAS. Researchers previously relied on overseas data (e.g. Australian, US, or UK) due to the lack of NZ data. Slappendel and Wilson [142] derived anthropometric estimates for New Zealanders by applying ratio-scaled data from the British population [143] to NZ stature data collected during the 1990 Life in New Zealand (LINZ) Survey. The LINZ survey comprised 1,610 females and 1,405 males who were randomly selected from the electoral roll. The ratio-scaling technique was a proven method for obtaining anthropometric data at the time; however, the use of international data can result in inaccuracies due to the differences in body size and shape of the respective populations.

Prior to the NZDFAS, two highly regarded anthropometric studies were conducted in the NZDF, one in 2011 on the New Zealand (NZ) Army and the other in 1973 for the Royal New Zealand Air Force (RNZAF). In 2011, Baxter and Baxter [144] conducted a survey to obtain a preliminary dataset of the anthropometric characteristics of the feet of soldiers within the NZ Army. The sample consisted of 807 military personnel from two NZ Army camps, with an average individual measurement time of eight minutes. No demographic data (e.g., gender, trade) were recorded as the sole purpose of the data collection was to obtain as many participants as possible. The data consisted of boot sizes and foot measurements (breadth, width, circumference, and arch height) measured by a single researcher using a seamstress' tape measure. Data were entered into Excel (Microsoft) and analysed for descriptive statistics. The results were insightful as one in six soldiers were not provided with a boot that fit properly. This may have been attributed to the boots having designed for soldiers of European descent, who were anecdotally considered to have a 'narrow' profile foot compared to participants of Maori and Pacific Island descent. One in seven soldiers wore boots that were larger than required (in some cases up to three sizes bigger) to obtain a boot wide enough to fit. The average foot length (26.3 cm) was shorter than the average comparable boot dimension. The NZ Army had lower arch heights than the general NZ population which was attributed to the higher proportion of Maori and Pacific Islanders in the soldier sample (30%) compared to the NZ general population (15%). This study highlighted important findings: (1) the NZDF requires an anthropometric dataset that is representative of its population; and (2) anthropometric data are useful for understanding issues of fit (for current inventory and for estimating future inventory) and helping identify clothing and equipment that is both functional and fit for purpose (e.g. specific to the population body sizes, soldiers trade etc).

Perhaps the largest New Zealand military anthropometric survey (in both measurement and sample number) was conducted by Toulsen in 1971 [145] for the Royal New Zealand Air Force Aviation Medicine Unit (AMU) in Auckland. The study was based on 238 male Aircrew between the ages of 18 and 49 years, with the purpose of improving procurement of flying clothing size ranges and to compare New Zealand anthropometric data to international military populations. The study captured 62 measurements per participant. Despite the large participant sample size and number of measurements, few were aware of this study's existence because it was published as an internal AMU report [145]. Nonetheless, the study by Toulson fulfilled much of the criteria described in Part I of this book. That is, the study was conducted on a specific population (NZ Air Force crew), by experienced anthropometrists using proven methods and technology. Unfortunately, the data are now nearly 50 years old and may not be representative of the current NZDF.

New Zealand Defence Force

The NZDF, in partnership with the Ministry of Defence, is responsible for delivering Defence in New Zealand. In 2019, the NZDF had 9474 regular force (active or uniformed) personnel, and

comprised three services—the New Zealand Army (n=4705), the Royal New Zealand Air Force (n=2525), and the Royal New Zealand Navy (n=2244) *[146]*.

In 2008, the NZ Army requested that the Defence Technology Agency (DTA) initiate an anthropometric survey of its personnel. DTA, through Massey University, conducted an anthropometric pre-scoping study [141]. The main recommendations from the study were to i) form an anthropometry project scoping team to advise the NZDF on the development of a NZ Army anthropometry project, and ii) consider the purchase of a 3D body scanner to help automate data collection.

It was apparent that anthropometric data in the NZDF were required not just for the NZ Army, but for all three services. For example, anthropometric data for Naval lifeboat, bridge console, and bunk bed design; for RNZAF aircrew selection and helicopter seating; and for NZ Army vehicle design and uniform sizing.

The lack of NZDF (or NZ civilian population) data to inform these requests highlighted the need for a current anthropometric database. Knowing the current body size and shape of NZDF personnel helps to ensure that current and future military equipment can be identified and selected more accurately.

The NZDFAS was initiated and conducted by the Defence Technology Agency (DTA) which is the main provider of research, science, and technology support to the NZDF and Ministry of Defence. The survey was endorsed by the NZDF Vice Chief of Defence, Chief of Army, Chief of Air Force, and the Chief of Navy in 2015. Ethics approval for this work was provided by the Auckland University of Technology Ethics Committee (AUTEC). The funds to conduct the survey, including domestic travel and meals for the data collection team, were provided by the DTA. The study utilised a Vitus XXL 3D body scanner (Human Solutions Ltd, Germany) and associated software funded by NZDF Capability Branch in 2012.

Aim

The aim of the NZDFAS was to create a tri-service anthropometric body scan and measurement database to inform the size and fit of military clothing and equipment (personal protection devices and tools), and to support design and engineering decisions regarding operator fit within platforms (aircraft cockpit, land vehicle cabin, or ship control rooms) and other working areas (office space, classrooms, or individual workstations).

Methods

In 2016, a survey site scoping exercise identified suitable data collection facilities around New Zealand. The project involved four phases, which spanned from December 2013 to December 2019:

- Phase 1 (February 2014–August 2015): A suitable sample size, measurement profile, data collection team, body scanning process, and survey logistics (including travel and survey site) were identified.
- Phase 2 (September 2015–January 2016): A suitable data collection procedure was drafted and tested, measurements were validated, and the data collection team (anthropometrists) were trained.
- Phase 3 (February 2016–September 2016): Data collection activities were performed at nine NZDF locations throughout New Zealand. Additional data were collected in May 2018.
- Phase 4 (November 2016–August 2018): Data were processing, analysed, and reported.

Figure 10 provides a summary of the key activities during each phase. Each activity is explained in more detail throughout this part.

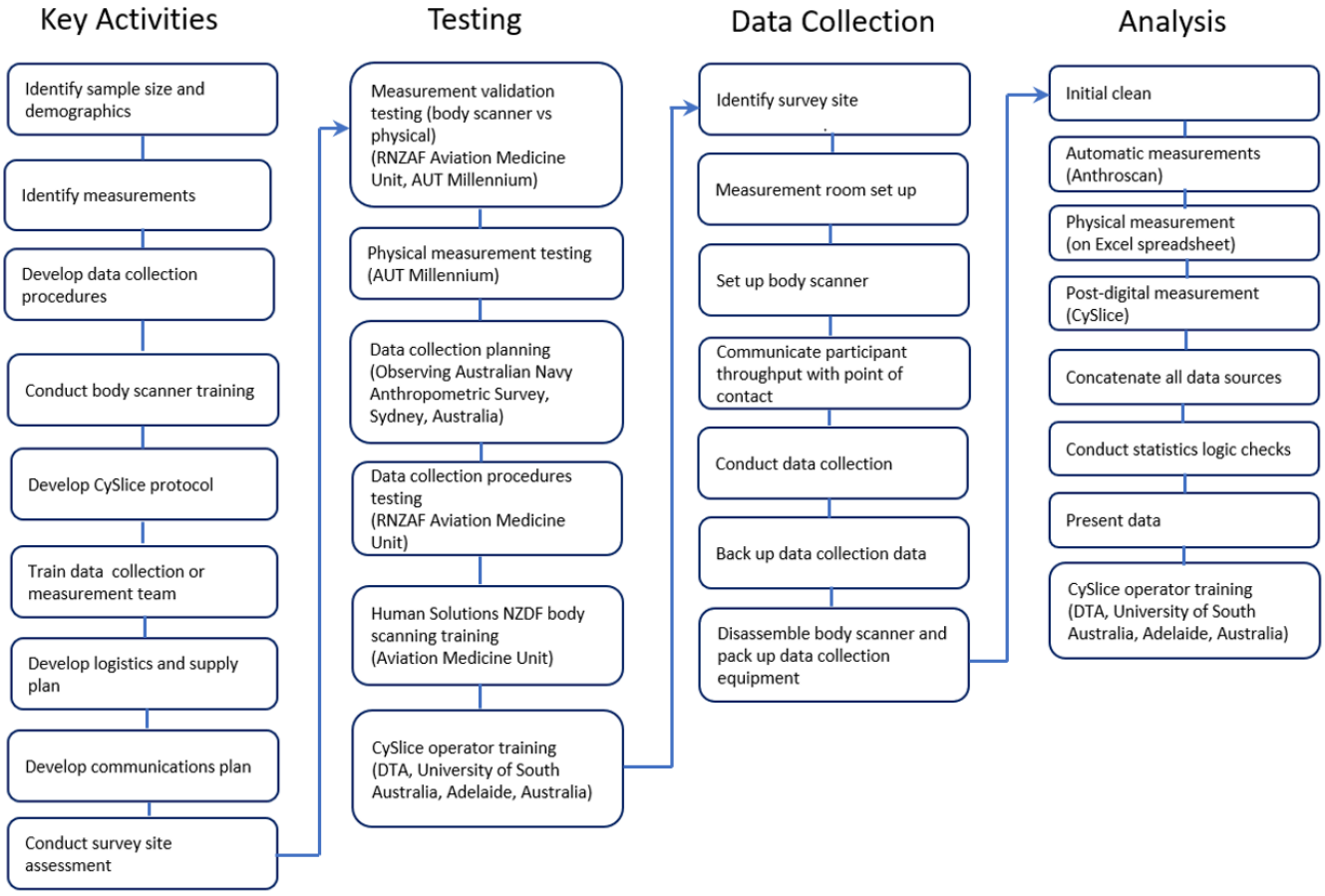

Figure 10. A summary of the key activities during each phase. Each activity is explained in more detail throughout this book. POC refers to 'Point of Contact'.

Personnel

To ensure participants completed the scanning requirements in as short a time as possible, while maintaining data integrity, a team of personnel with specific responsibilities were used at each data collection session. These roles and responsibilities and other support members are presented in Table 3 and Table 4 respectively.

Table 3. NZDFAS data collection team.

Role	Responsibilities
Team leader	• The survey protocol conduct • Data sampling site logistics (e.g., liaison and coordination with data collection site manager) • Overseeing transport, un/packing, dis/assembly, and calibration of scanner and all equipment • Recording any incidents on a Serious Events Register • Timekeeping for workflow • Ensuring that all data files are backed up regularly • Assisting other team members when required
Participant receptionist	• Greeting and briefing participants • Administering informed consent forms and demographic questionnaires • Collecting and filing all hard copies of paperwork • Assigning participants an ID number
Anthropometrists	• Locating and placing physical landmarks on participants • Taking physical measurements • Recording all measurements • Observing other anthropometrists to minimise mistakes • Escorting participants to the scanner technician
Scanner technicians	• Positioning participants in the correct postures for scanning • Operating the scanner system • Verifying the scanned images for correct posturing, landmark positioning and checking scan image quality. • Saving the scan

In addition to the data collection team the survey was supported by 61 NZDF staff.

Table 4. NZDFAS full support team (including data collection team).

Role	N	Responsibilities
Data collection team	21	Trained anthropometrists (i.e., 19 were trained at ISAK Level 2 and two were accredited at ISAK Level 1). • 16 were volunteers from the NZDF (e.g., science researchers from DTA, Medics and Personal Training Instructors) • 5 were contracted from the Auckland University of Technology (AUT) Sports Performance Research Institute New Zealand (SPRINZ).
Logistic support staff.	30	Logistic support staff: • 18 were points of contact (POC) at the nine NZDF establishments (consisting of members of the base leadership team, unit commanders, and Events and Human Resources staff). They were responsible for facilitating survey site bookings and managing participant throughput for the survey. • 6 were receptionists and scribes. • 2 were contractors employed to assist with data cleaning and analysis. • 3 were from the DTA Business services team responsible for travel bookings, supplies and logistics support. • 1 member provided specialist statistical support
Subject matter experts	10	International subject matter experts who assisted with various stages of the study: • Measurement/protocol development, validation, refinement, and CySize training (University of South Australia, Defence Science and Technology Organization, Australia), • Body scanner training, troubleshooting and hardware support (Human Solutions Ltd, Germany), • CySize analysis and software support (Headus Ltd, Australia). • Body scan file conversion and general project support (Defence Research and Development Canada).

Sampling

The minimum sample size to ensure valid statistical representation of body dimensions across the NZDF was determined using a power analysis equation from ISO 15535:2012 [147]. The equation was based on the probability that the survey population would provide sufficient fidelity to represent the true population between the 5^{th} and 95^{th} percentiles, with 95% confidence and 1% accuracy [147]. This is a common method applied by international military organizations in Australia [117] and Canada [41].

An internal validation trial in 2014 identified waist height as having the greatest coefficient of variation (12.9%). This coefficient was entered into the equation resulting in a minimum sample size of 1504 personnel. International military anthropometry experts recommended that the sample size should be 10% of the population, which equated to 947 given the NZDF population of 9474. The targeted sample size was then inflated to 15% (1421) personnel to oversample specific demographics such as females. Approximately 1421 personnel were randomly selected from a pool of 9474 in the NZDF personnel register. The data were then filtered according to participants who (1) resided at anyone of the nine main NZDF camps and bases, (2) were active service personnel, and (3) were regular force (or uniformed) personnel only (excludes civilian or reserved forces). These filters in addition to errors in the personnel database (e.g., personnel who either resigned or retired from the NZDF were still marked as ‘active’) resulted in a revised target of 1096 personnel or 11.5% of the current uniformed population.

A stratified sampling strategy was used to select the NZDF personnel to maintain an adequate balance among the three services and across gender and ethnicity groups (while purposive sampling occurred during the survey). To achieve this, the current proportions of Army (49%), Navy (27%), and Air Force (24%) personnel among the 9474 active uniformed population were applied to the survey sample of 1096. This resulted in target samples sizes of 535, 297, and 264 personnel from Army, Navy, and Air Force, respectively. Demographic proportions by trade, ethnicity, and gender were applied in a similar manner, resulting in the following initial survey target (Table 5)

Most role descriptions within the NZDF can be categorised into 10 major trade categories. The trade and sub-trade (e.g., Combat and Armourer) category definitions were obtained from the NZDF Defence careers website (www.defencecareers.mil.nz). The ethnicity categories were based on the New Zealand Census [148] (except for Pacific Islanders and Maori, which were combined in this study). Cross-referencing the census ethnicity categories with the 2015 NZDF personnel database identified six main ethnic groups within the NZDF. Of note, ‘NZ Europeans’ were classed as ‘European’ while ‘New Zealanders’ were categorised in the ‘Other’ category. The demographic targets were then applied to the nine NZDF base/camp locations to determine how many participants were required from each data collection location.

Table 5. NZDFAS target sample by demographics.

		NZDF Service by Gender						
		Army		Air Force		Navy		
Trade	**Ethnicity**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**TOTAL**
Combat	European	49	0	8	0	1	5	**63**
	Pacific							
	Maori	57	1	4	1	19	2	**84**
	Asian	4	0	0	0	9	0	**13**
	Latin Am	1	0	0	0	0	0	**1**
	African	2	0	0	0	1	0	**3**
	Other	45	0	6	2	34	6	**93**
Specialist	European	14	3	4	1	0	1	**23**
	Pacific							
	Maori	8	1	0	0	10	0	**19**
	Asian	1	0	0	0	0	0	**1**
	Latin Am	0	0	0	0	0	0	**0**
	African	0	0	0	0	0	0	**0**
	Other	9	4	4	2	0	1	**20**
Medical Health	European	9	6	2	1	3	3	**24**
	Pacific							
	Maori	4	2	0	0	3	1	**10**
	Asian	0	0	0	0	1	0	**1**
	Latin Am	0	0	0	0	0	0	**0**
	African	0	0	0	0	0	0	**0**
	Other	5	4	2	4	1	4	**20**
Apprentice	European	2	0	0	0	0	0	**2**
	Pacific							
	Maori	11	0	0	0	0	0	**11**
	Asian	1	0	0	0	0	0	**1**
	Latin Am	0	0	0	0	0	0	**0**
	African	0	0	0	0	0	0	**0**
	Other	14	0	0	0	0	0	**14**
Engineering/Technical	European	24	0	62	3	30	1	**120**
	Pacific							
	Maori	7	1	8	2	23	1	**42**
	Asian	1	0	3	0	13	0	**17**
	Latin Am	0	0	0	0	3	0	**3**
	African	1	0	0	0	0	0	**1**
	Other	19	0	44	3	25	2	**93**
Intelligence Information Technology and COMS	European	15	0	8	4	0	3	**30**
	Pacific							
	Maori	6	6	1	0	20	7	**40**
	Asian	0	0	1	0	0	0	**1**
	Latin Am	0	0	0	0	3	0	**3**
	African	1	0	0	0	2	0	**3**
	Other	11	1	7	0	0	4	**23**
Hospitality	European	9	3	0	1	0	3	**16**
	Pacific							
	Maori	5	3	0	0	16	7	**31**
	Asian	0	0	0	0	4	0	**4**
	Latin Am	0	0	0	0	0	0	**0**

	African	0	0	0	0	0	0	**0**
	Other	5	2	0	1	10	4	**22**
Logistics and Administration	European	22	5	11	5	0	3	**46**
	Pacific							
	Maori	18	7	2	2	0	3	**32**
	Asian	1	0	1	0	0	0	**2**
	Latin Am	0	0	0	0	0	0	**0**
	African	1	0	0	0	0	0	**1**
	Other	18	5	8	12	0	4	**47**
Aviation	European	0	0	15	2	0	0	**17**
	Pacific							
	Maori	0	0	2	0	0	0	**2**
	Asian	0	0	0	0	0	0	**0**
	Latin Am	0	0	0	0	0	0	**0**
	African	0	0	0	0	0	0	**0**
	Other	0	0	11	3	0	0	**14**
Other	European	35	5	0	0	0	0	**40**
	Pacific							
	Maori	10	1	0	0	0	0	**11**
	Asian	1	0	0	0	0	0	**1**
	Latin Am	0	0	0	0	0	0	**0**
	African	0	0	0	0	0	0	**0**
	Other	24	5	1	0	0	1	**31**
Gender total		**470**	**65**	**215**	**49**	**231**	**66**	
Service total		**535**		**264**		**297**		
Target total				**1096**				

Measurements

A systematic approach was used to identify measurements of interest for the NZDF. First, measurement profiles from the most recent large-scale military anthropometry surveys (United Kingdom, United States, Canada, and Australia) were extracted and recorded (n= 255).

Next, duplicate measurements were removed based on inconsistencies in nomenclature or measurement description (n=155). A criterion was applied in which measurements common to three or more country protocols were automatically selected (n=60). Sixteen additional NZDF measurement profiles (currently in use within the NZDF) were added. For example, measurements used in RNZAF Personnel and Selection (PERSEL) assessments; and measurements equivalent to the NZDF clothing (shirt and trouser specifications) for recruitment clothing sizing activities. Ten measurements were later added from standards such as ISO 7250 [147, 149-152] and DEF STAN 00-250 leaving a draft list of 86 measurements for the NZDFAS profile.

The draft list of measurements was reviewed by content experts. The physical (traditional) measurements were peer-reviewed by an ISAK Level 3 criterion anthropometrist from the J.E. Lindsay Carter Kinanthropometry Clinic and Archive (JELCKCA) at AUT. To determine the most valid, reliable, and feasible method of obtaining the body measures in the NZDFAS, a content expert in 3D body scanning from the University of South Australia (UniSA) advised the project on the best method to collect each measurement (automatically using the body scanner software, physically using traditional tools or post-processed using a third-party software). Measurements identified as potential automatic measurements were taken forward for subsequent validation.

It was important that the NZDFAS profile incorporated as many automatic measurements as possible to reduce participant burden and limit the number of physical measurements. Anthroscan has the ability to obtain 160 automated measurements [153], however, only 23 of the 160

measurements were common within the 86 identified initially. The remaining 63 measures were derived by either physical or post processed methods. The accuracy of the 23 measurements required a separate validation. Measurements that did not pass validation were either derived physically, post-processed, or removed from the study entirely.

Measurement validation

Two validation studies were conducted to assess the accuracy of automatic measurements derived from the body scanning process. The first utilised 3D body scan data from a population of UniSA students (n = 90). The measurements were processed using the Anthroscan© automated measurement software. The results were then compared to physical measurement data captured by ISAK Level 2 and 3 accredited anthropometrists (UniSA). The second validation study involved comparing additional automatic measurements with their equivalent physical measurements in 12 NZDF and AUT personnel. The validation criteria were as follows, if the mean percentage difference between automatic and physical measurements were <5% then the automatic measure was considered acceptable.

Of the 23 measurements validated, 12 passed the 5% criteria while 11 measurements where still accepted due to special circumstances. Head circumference and bust chest girth was not within the <5% threshold (7.7% and 5.4% mean difference) but was still added as an automatic measurement to reduce participant burden. Crotch length was not validated but was included in the automatic measurements as it was deemed too intrusive for physical measurement. Ankle girth, while <5% threshold during the validation testing activities, was added to the automatic measurement list to reduce participant measurement time. Weight was measured by the SECA scale that is built into the scanner platform and was calibrated with a 20 kg weight prior to each testing session. Neck girth (opting to use neck girth base instead), shoulder length (no relevant design application), and waist height omphallion (opting for waist girth) were removed from the list. Vertical trunk circumference was measured using post-processing methods as it was deemed too invasive for physical measurement (Table 6).

Based on the validation results (Table 6), a draft measurement list and protocol was peer-reviewed by content experts from the AUT SPRINZ and UniSA. This consultation led to a refined measurement protocol outlining how each measure was to be conducted using a body scanner, traditional anthropometry techniques, or advanced 3D processing software. To assist with the decision-making process, the project focussed on deriving as many measurements using the body scanner (whether automatic or post-processed) as possible to reduce participant throughput and increase participant numbers.

Measurements that could not be performed consistently (e.g., the Vitus XXL produces low resolution images for hands, fingers, and feet therefore) or practically (e.g., arm span, reaches or buttock to heel length extend limbs outside the available scanning range) with the body scanner were conducted physically (n=25). The remaining 38 measurements, three (discarded) automatic measurements and a late addition (shoulder elbow length) formed the final 42 measurements to be derived at the post-processing stage. The final NZDFAS measurement profile consisted of 84 measurements. See Figure 11 for a breakdown of the measurement identification, validation, and selection process.

Table 6. NZDFAS automatic measurement validation results.

Measurement (mm)	N	% difference	Decision
1. Body height	12	1.0	Validation pass
2. Breast height	12	1.4	Validation pass
3. Buttock girth	20	2.7	Validation pass
4. Buttock height	12	0.1	Validation pass
5. Calf girth	45	0.2	Validation pass
6. Elbow girth	12	3.0	Validation pass
7. Knee height	12	1.5	Validation pass
8. Neck girth base	40	0.8	Validation pass
9. Suprasternale height	12	1.2	Validation pass
10. Thigh girth	38	1.8	Validation pass
11. Waist girth	12	3.1	Validation pass
12. Wrist girth	12	2.0	Validation pass
13. Ankle girth	N/A	N/A	Not validated – accepted to reduce measurement time.
14. Crotch length	-	-	Not validated – accepted as not practical for physical measurement.
15. Weight	N/A	N/A	Not validated – 100% accuracy compared to SECA manual scale.
16. Bust/chest girth	12	5.4*	Validation fail – accepted to reduce measurement time.
17. Head circumference	12	7.7*	Validation fail – accepted to reduce measurement time.

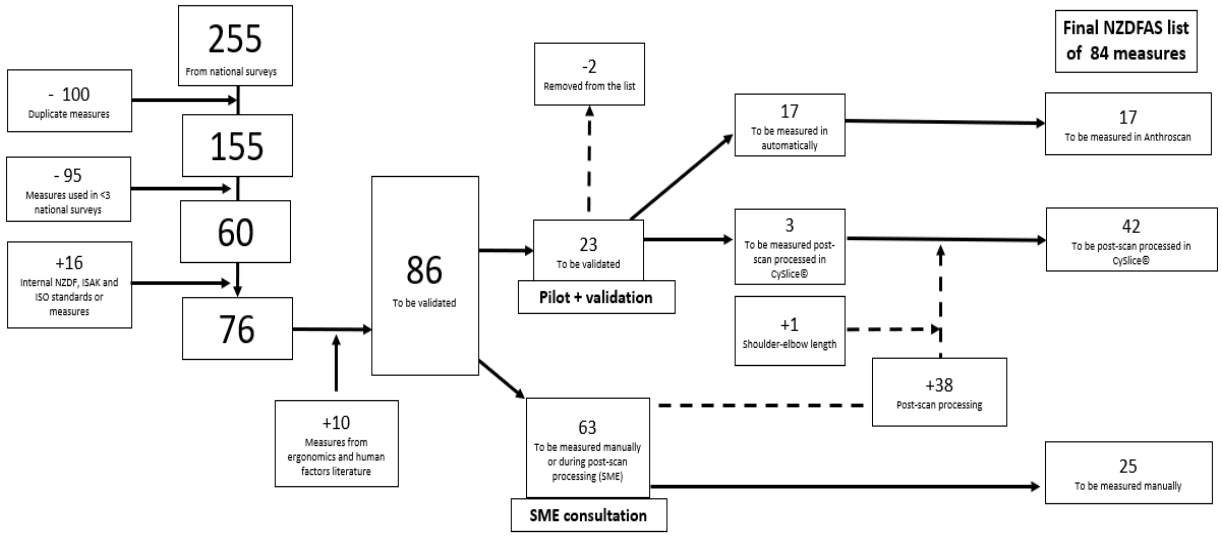

Figure 11. NZDFAS Measurement selection and testing process.

Measurement extraction tools

The survey consisted of three important measurement extraction tools and methods.

Physical (traditional) anthropometry measurements

The physical measurements utilised a stadiometer, anthropometry box, tapes, rulers, and various calipers following 2001 International Society of Kinanthropometry (ISAK), 2012 Australian Warfighter Anthropometry Survey (AWAS), 2012 Canadian Forces Anthropometric Survey (CFAS), 2011 UK military ISO 7250-1, Human Solutions and JIS Z 8500:2002[154] protocols and standards. Anthropometrists were members of the NZDF and AUT who were trained to ISAK Level 1, 2, and 3 standards.

The measurement equipment was loaned from the AUT SPRINZ and calibrated before each data collection exercise. Figure 12 shows an example of how the measurement room was arranged, although the layout varied depending on the location constraints.

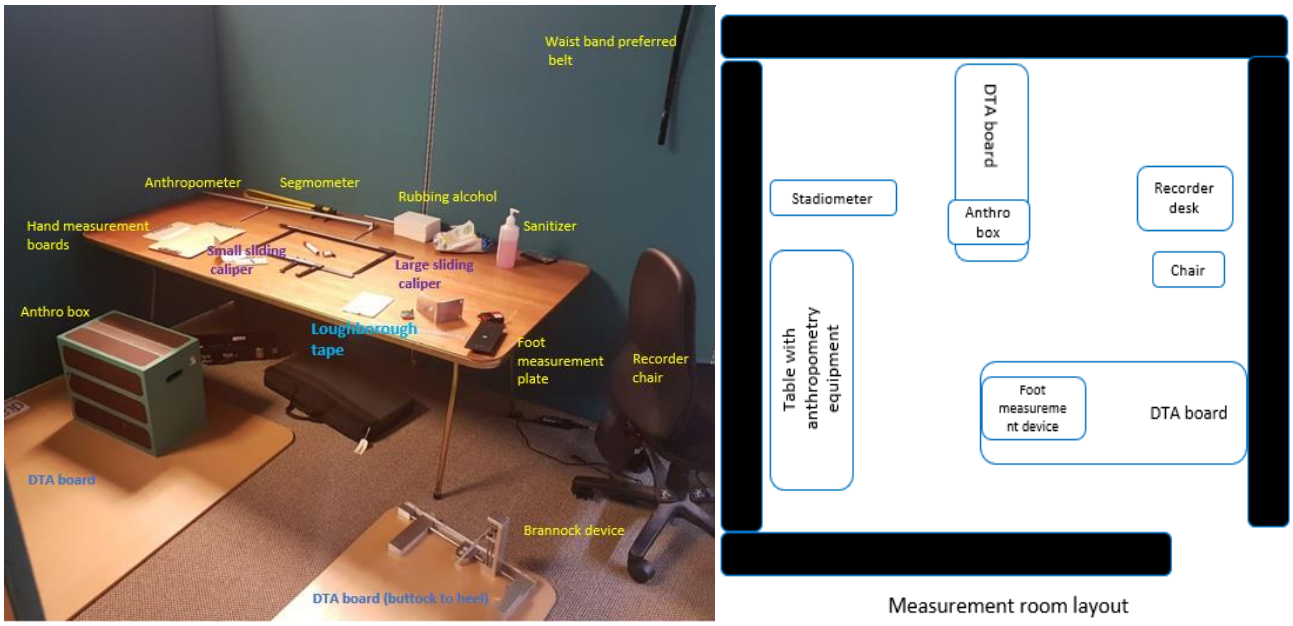

Figure 12. Measurement room equipment layout.

Automatic measurement (using Anthroscan software)

A Human Solutions Vitus XXL whole body laser scanner was used to scan each participant. The scanner projects non-ionising laser light onto the body with the reflection captured by cameras as a series of points (between 700,000 and 1,000,000), each with cartesian coordinates which are sewn together to create a ‘digital statue’. The scanner is an eye-safe Class 1 visible non-ionising red laser light and was manufactured in compliance with the regulations of the U.S. Food and Drug Administration pertaining to laser safety (21CFR1040.10 and 21CDR1040.11) [155].

The scanner was calibrated at the start of every data collection day. The weight scale (built into the platform) was calibrated each day using a 20 kg weight. Individual laser height alignment was calibrated during the setup at each new location.

Seventeen automatic measurements were extracted using software called Anthroscan (Figure 13). After extraction, the scan operator checked each scan image to confirm that the measurements were successfully captured. Examples of automation errors are a circumference line height that is higher or lower than the intended location (e.g. thigh girth) or a circumference line around both left and right thighs as opposed to one. These errors can be fixed by the operator post-scan using various Anthroscan software tools.

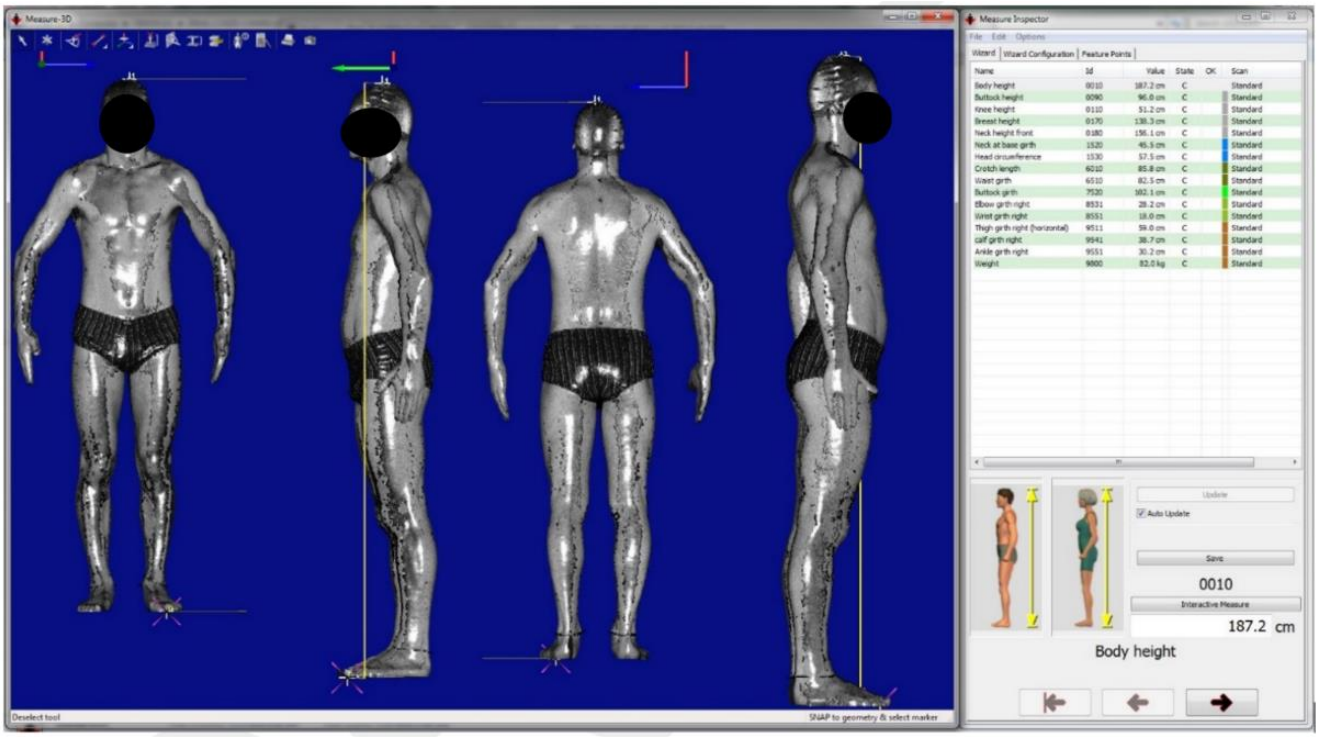

Figure 13. Anthroscan automatic measurement software.

Digital measurements (using CySize software)

CySize is a third-party software used by various military research organizations such as the Defence Science Technology Group in Australia (Figure 14). CySize is a powerful and accurate tool for analysing 3D data. It provides more in-depth measurement functionality (and tools) than Anthroscan and can be used to make almost any measurement on the body providing the scan image quality is clear. The NZDFAS CySize measurement process is primarily based on the AWAS Landmarking and Measurement manual [156]. The 42 measurements extracted using CySize are those which cannot be performed with acceptable accuracy automatically; or too slow to measure physically (e.g. some measurements may require pre-requisite landmarks further increasing measurement time such as vertical trunk circumference). This method allowed the operator to extract these measurements post-survey.

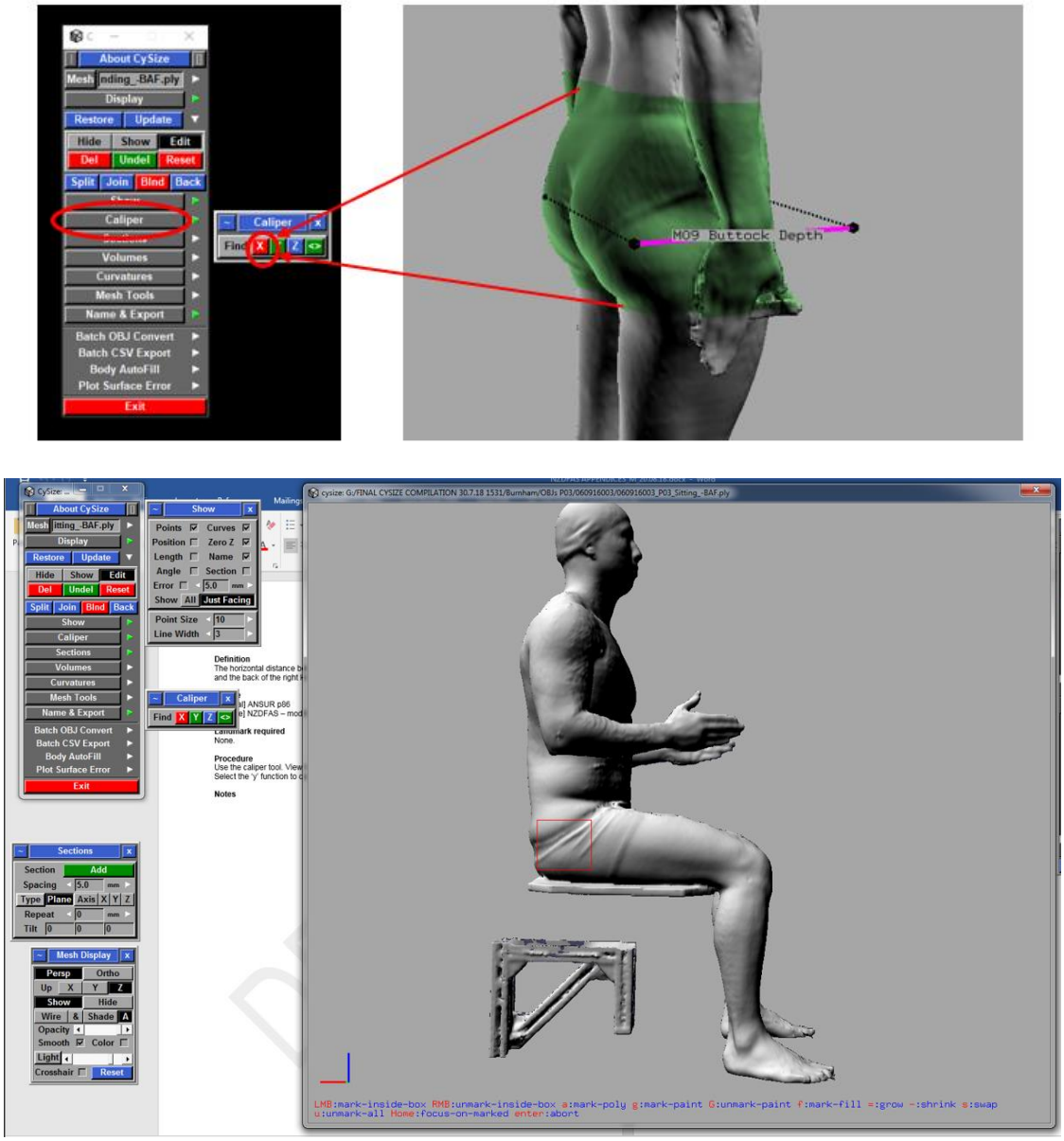

Figure 14. CySize (Headus Ltd) measurement software. [Top] The user can select any region of the body (green) then use the various CySize tools to determine the maximum depth within the region (using the 'x' caliper function). [Bottom] CySize contains various landmark, measurement extraction tools and image enhancement functions to obtain clear measurements.

Logistics and supply plan

The NZDFAS data collection activities occurred between February and September 2016. The measurement team was selected based on their geographical posting (as opposed to having one dedicated team for all survey locations). This was designed to minimise travel and accommodation costs. It also meant that the measurement team had a representative who was familiar with the base/camp surroundings and their peers (participants). The measurement team stayed on site at either the Officers' Mess or transit barracks. Two project leads travelled to all the survey locations by van. All trial equipment (physical measurement tools and the body scanner) was transported in this van. Supplies, such as disinfectant wipes, landmarking stickers and stationery was delivered to pre-selected bases ahead of time.

Communications plan

Prior to the study, an NZDFAS administration order was sent to all site (Point of Contacts) POCs. This order formally documented the dates, participant targets and site requirements needed for each survey.

Two weeks prior to the survey, the project lead and site POC liaised to confirm target participants numbers, and that the site, accommodation, meals, and IT requirements were ready for the survey team. Within 7 days of the survey, the participant was given an information sheet relating to the survey. Participants were able to volunteer through an expression of interest to their unit commander, or by making a booking using an online system that was based on the defence force intranet. The participant list constantly changed, as some participants volunteered on the day, while others withdrew due to operational priorities in advance. This made achieving the sampling targets very challenging and managing these required a high degree of flexibility with respect to planning participant and survey team rosters. There were occasions when available time slots could not be filled, despite regular communication with the POC. Sampling methods worked for better for some services better than others. For example, the online booking system (where participants picked and chose times based on a live booking system managed by the POC) was more popular with Air Force personnel compared to Navy personnel. Purposive sampling (e.g., relying on POCs to identify participants within their line of command who met specific demographic targets) achieved a greater response rate for Army participants compared to Air Force and Navy. Overall, the most challenging service to survey was the Navy because (1) there is only Naval base in New Zealand and (2) a large proportion of Naval personnel are based on ships that are away from the base for months at a time hence the Navy achieving 44% of its original target.

The project lead and site POC were in regular communication throughout the survey to manage any issues. Post-survey, the POC and base commander were emailed a summary of the survey operation, results achieved (e.g., numbers surveyed) and gratitude for their cooperation and support. The relationship between the survey team and the POC is the most critical aspect for the survey.

Survey site assessment

Prior to data collection, the survey lead travelled to each base, and identified the most suitable location to conduct the survey. It was important that the physical measurement rooms had no windows (or at least had the ability to cover windows), be private (free from normal walking traffic), be near the body scanner and briefing rooms, have sufficient space (2.5 m x 2.5 m minimum) for three people including the measurer and scribe, and have appropriate heating or cooling devices. The body scanner room required a ceiling height of at least 3 metres to accommodate the scanner poles, have a floor space of 3.5 m x 3.5 m, provide enough room for a desk and chair, and have lights that can be turned off.

Data collection took place within offices, hangers, training centres, conferences centres, and gymnasiums across nine bases and camps throughout New Zealand. Changing room facilities are important but not crucial as participants were able to get changed inside the body scanner. Ideally, all rooms (one briefing, two physical measurement, and a body scanner facility) are close together to facilitate throughput.

Survey protocol

Data collection consisted of five stages that took between 35 and 45 minutes to complete per participant.

Stage 1: Briefing and informed consent (10 minutes)

Prior to their visit, all participants were issued with an information sheet and consent form via email. This contained information about the study aims and methods, and pre-testing instructions (e.g., instructions on level of hydration and food intake, clothing, and pre-testing exercise). Upon arrival, the receptionist greeted the participants at the reception desk (Figure 15). Hard copies of the information sheet and consent form were also available at the reception desk. The brief was conducted ‘one-to-one’ or in large groups depending on the participant numbers per session.

Each participant was verbally informed of the measurement procedures and their rights as volunteers. Participants informed of their right to withdraw at any time without prejudice. Participants were given the option to be measured by a male or female anthropometrist. Participants were also given the opportunity to have a support person with them during measurement. Participants were assured that their personal information (demographic or body scan) will be kept private in a secure location, and not shared with their peers, commanding officers, or other parties without the participant's explicit permission.

After providing written informed consent, participants completed a short demographic questionnaire and were assigned a unique identification number using a 6-digit coding convention. The consent form was the only document linking each participant's identification number to their name. Records and scan images for personnel in the NZ Special Air Service (SAS) were stored separately with defining features (tattoos) altered for privacy.

All participant demographic information in NZDFAS was recorded electronically using a complementary software program for *Anthroscan*^{TM} called *Personal Data* (*PEDA)*. The demographic information from PEDA was later integrated with the participants body scans according to their 6-digit ID number.

Figure 15. NZDFAS survey reception.

Stage 2: Change to form-fitting clothing (5 minutes)

Participants were then shown to a private changing area so they could change into light coloured sports or undergarments (tight-fitting briefs for men, and high-rise underpants and stretch midriff tops for women). Participants wore their own underwear, provided it was deemed acceptable for scanning by an anthropometry team member. It was recommended that light coloured clothing (e.g. white, silver, light shade) was worn with minimal thickness to follow the natural contours of the body. The light colours provide optimal reflection during the scanning process While the colour of the clothing was strictly enforced in the information sheet, not all participants adhered. Participants were not turned away if they wore the incorrect coloured or slightly incorrect fitting undergarments for scanning. In our study, dark coloured undergarments did not affect the measurement results (automatic or post processed) if the scan image showed the appropriate location of the landmarks (in which white stickered landmarks were used on dark clothing). Shoes, socks, and jewellery were removed, and if necessary, participants tied up their hair. All participants wore a tight swim cap on their head. All personal belongings were stored in a large plastic container for safekeeping (one container per participant).

In locations where changing rooms and measurements rooms were far apart, the anthropometrists would work together ensuring that no non-surveying team members were in close vicinity. Participants were not permitted to enter or leave the changing area, measurement room or scanning area until they were authorised by their anthropometrist. If there were any delays, then they wore their Personal Training (PT) gear until it was time to move station.

Stage 3: Landmarking (8 minutes) and physical measurements (20 minutes)

Next the participants were landmarked (see Figure 16 and Figure 17). The landmarks served two purposes for the NZDFAS: (1) to aid identifying and recording physical measurements, and (2) for identifying and implementing digital measurements after the scan. Prior to landmarking, all participants were reminded of the procedures via a series of photos describing the landmarks and the three postures they were required to assume during landmarking, physical measurement, and 3D scanning.

The required landmarks were marked on participants by trained anthropometrists. The anthropometrist were either an accredited ISAK Level 2 anthropometrist or have received suitable training from a qualified Level 3 or 4 anthropometrist or senior staff member [157]. Participants were given the option of being measured by an all-female or all-female measurement team if required. For optimal results and to minimise measurement error, a pair of anthropometrists were assigned to one participant. One was the designated landmarker and measurer, the other an observer. Printed instruction booklets (containing all the landmarking and measurement procedures) were provided for reference for the survey team. The measurement room also had a poster describing the appropriate scan posture for the participant. To identify each skeletal reference point, each landmark was physically located by palpation on the body surface. They were then marked as a 'cross' using a pen. When landmarking was complete, anthropometrists re-checked the placement of their landmarks before ticking the corresponding box on the datasheet to signify that the landmarks have been located.

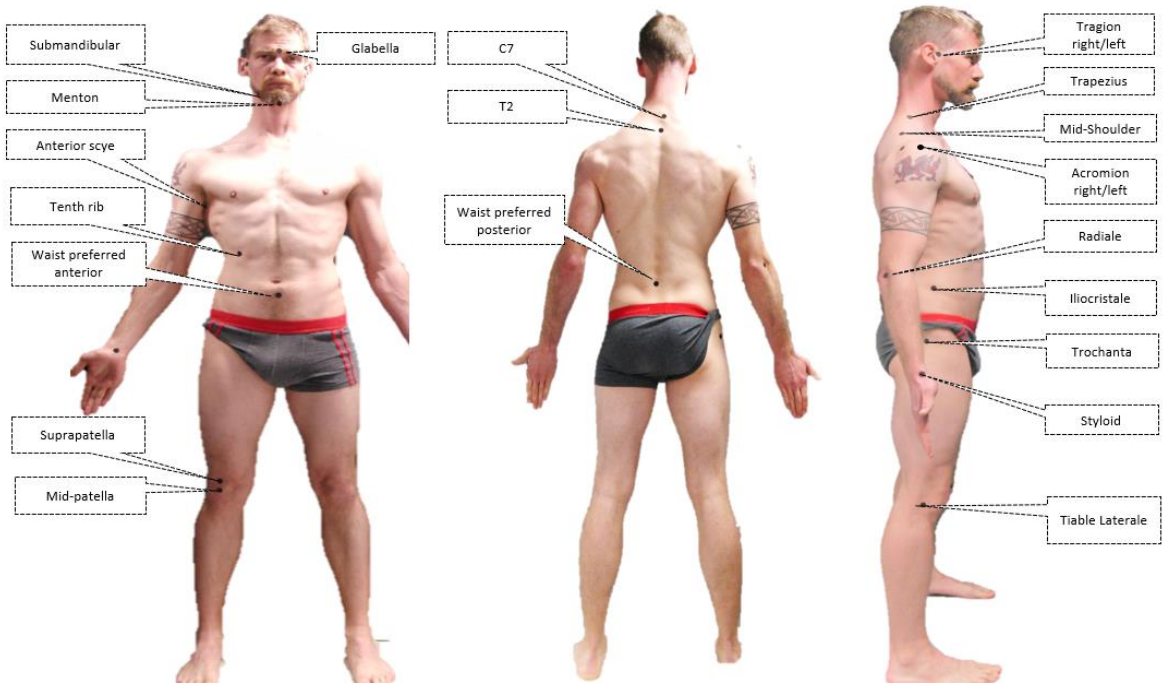

Figure 16. NZDFAS landmarks required for physical measurements. These measurements have a dual-purpose of they can also be used for digital measurements except for menton, sellion, submandibular, tragion (right and left) and trapezius.

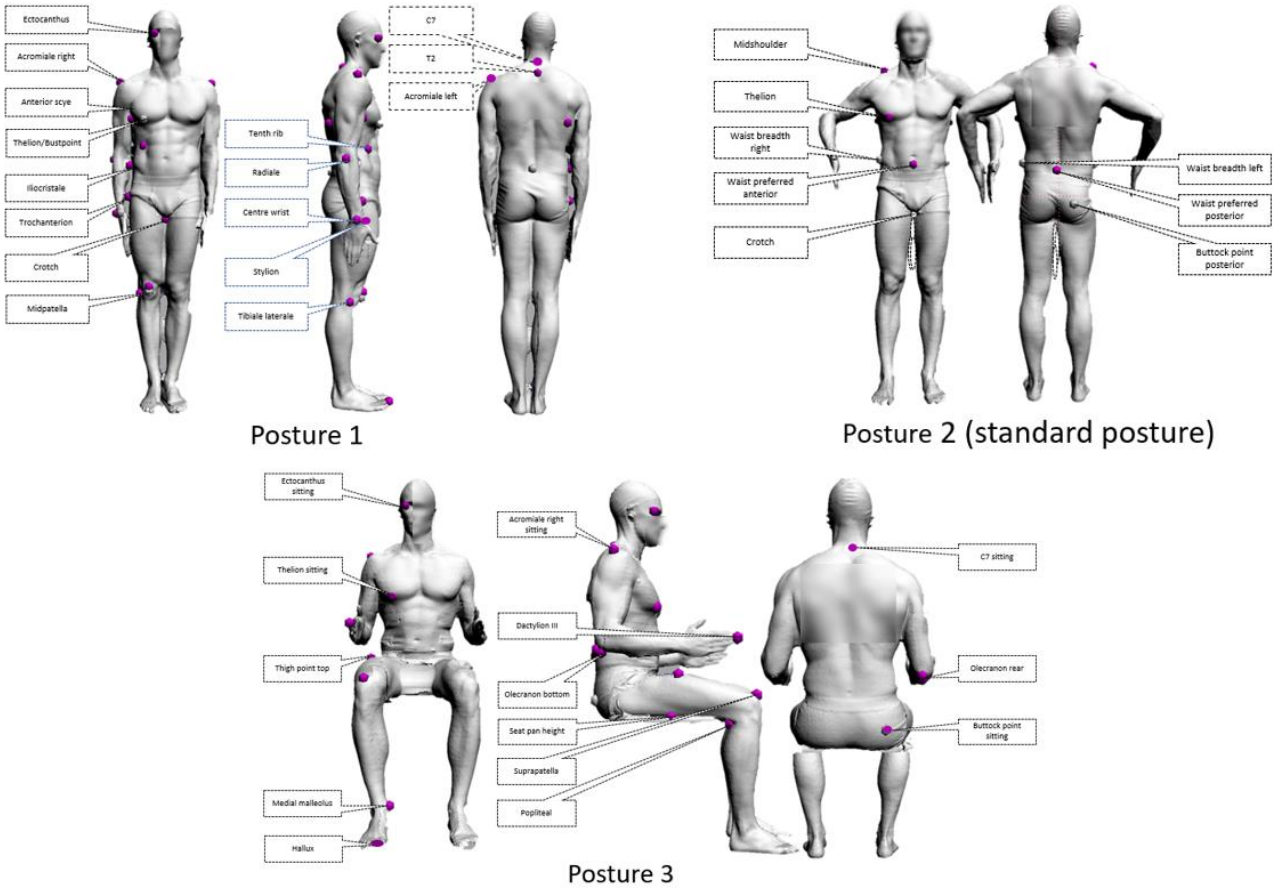

Figure 17. Some of the physical landmarks are converted to 'digital' landmarks (purple dot) which in turn, are used to identify and record digital measurements during post-processing.

Next, the anthropometric team conducted the physical measurements (Figure 18) One anthropometrist acted as the recorder. Each measurement was repeated twice and entered into an Excel spreadsheet. Following the completion of all 25 physical measurements, a review of the datasheet was conducted. Measurements falling outside of normative bounds were re-checked by the anthropometrist, with a third measurement taken if the first and second measurements differed by more than 1%. Note, a higher tolerance of 5% was used as the test-retest difference for index finger reach, thumb tip reach, grip reach, elbow-grip length, elbow rest height standing, bicep circumference flexed, and arm span.

All measurements were taken on the right side of the body only as per ISAK protocol [21]. If the participant had an injury on the right side, then the measurement would be taken on the left side, and a note explaining this change was recorded in their data sheet. Due to time restrictions, no skinfold measurements were taken during the NZDFAS. After the measurements, the recorder disinfected all equipment in preparation for the next participant.

Figure 18. NZDFAS physical measurements. All 25 physical measurements were measured with traditional anthropometric tools.

Stage 4: Scanning (15 minutes)

After the physical measurements, participants proceeded to the scanning area (Figure 19). Participants were shown three postures to adopt during the scan. Posture 1 required participants to stand erect (with head in the Frankfort plane) with feet together, arms straight and relaxed to the side with palms facing medially with fingers fully extended and thumbs facing anteriorly at right angles to the fingers. Posture 2 required participants to stand in the same position but with feet shoulder width apart, and the arms abducted away from the area with a 45° bend in the elbow and forearms vertically positioned (i.e., perpendicular to the ground). Posture 3 required participants to be seated, in an erect seating posture and the head in Frankfort plane. The arms were bent to 90° at the elbow with the base of the forearm in line with the thighs. Fingers were extended at 90° to the thumb. Feet were flat against the ground with both feet facing anteriorly at less than shoulder width apart. The seat was adjusted at a height that facilitated a 90° knee bend.

For optimal scan results, the timing of the prompt must be clear, consistent, and accurate. Movement during the scan can result in inaccurate automatic and digital measurements [47]. The most obvious errors in post-processing occurred when participants were standing in an asymmetric stance (altering the x,y,z coordinates) with an offset vertical back and neck alignment.

At the start of the scan, participants were asked to breathe in, breath out slowly, and then hold their breath for 10 seconds. The breath was held (after fully exhaled) when the laser was between the shoulders and the mid-thigh region, to minimise movement artefacts. Normal breathing resumed after the scan was completed.

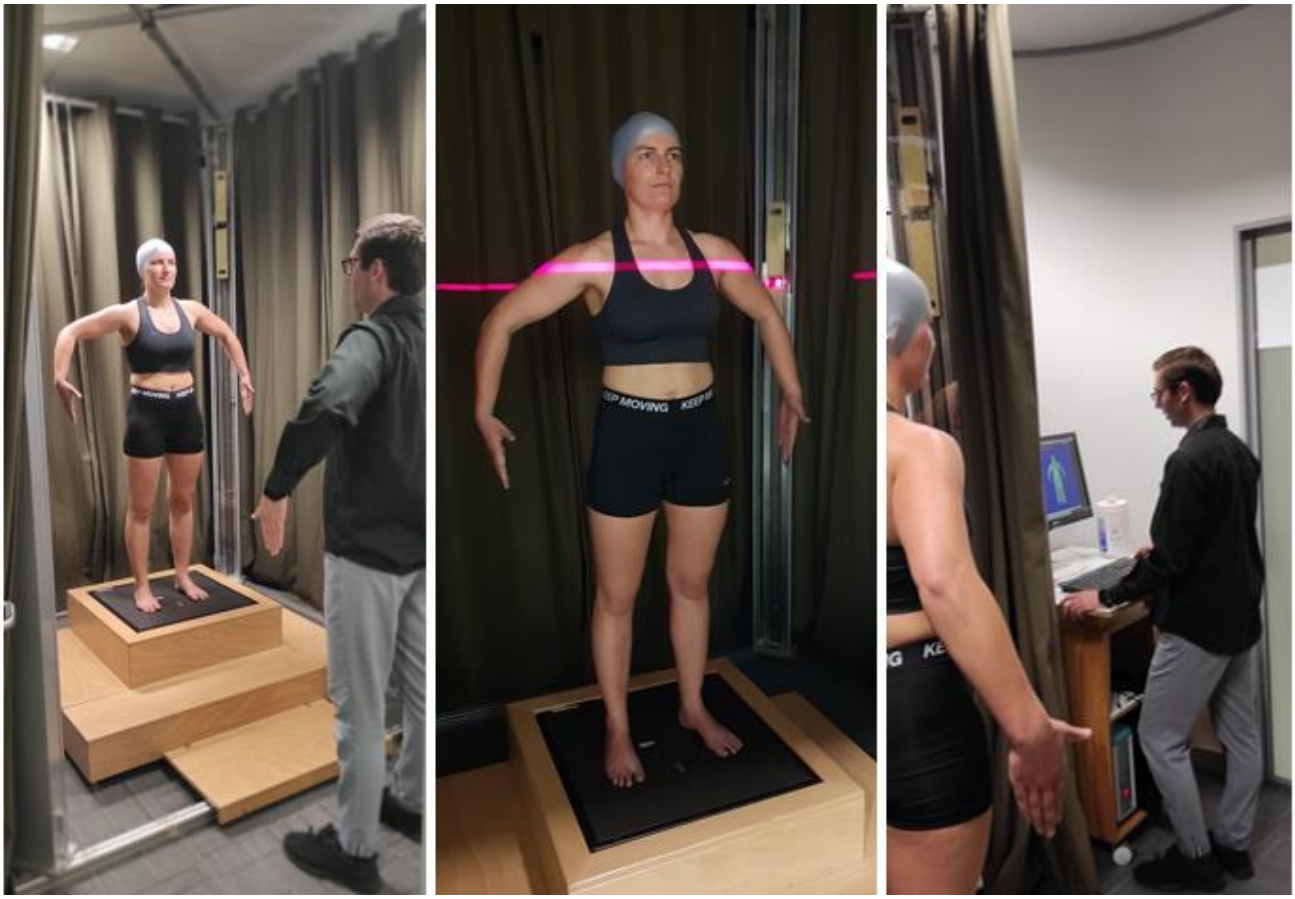

Figure 19. Body scanning process (left to right) posturing, body scan and checking and processing. Note that the lights are turned off during an actual scan. Light clothing is also desired, if not available than dark clothing will suffice.

The first two scan postures were from a standing position (Figure 20). The final scan, in a seated position, was taken using the body scanner platform seat. The seat was height adjustable and could be removed from the platform. Participants were positioned so that their buttocks and upper thighs were completely on the seat surface. The technician ensured that their knees were bent to 90° with both feet flat on the floor and facing forward. Foot stools were available but were rarely required. It was important that there was enough distance between the elbows and the lateral side of the torso. A 3D phenomenon known as 'webbing' may appear on the body scan if the elbows are too close to the body. Scanning only commenced when the technician was satisfied with the posture. Each scan lasted approximately 12 seconds and produced a 3D image of the participant. After each scan, participants relaxed their posture while the technician visually inspected their scan image. The operator checked each individual scan for a) presence of all stickered landmarks, b) correct posture, and c) that all necessary scan files (e.g. weight file from the in-built scale). If the technician was not happy with the scan results, then the scan was repeated.

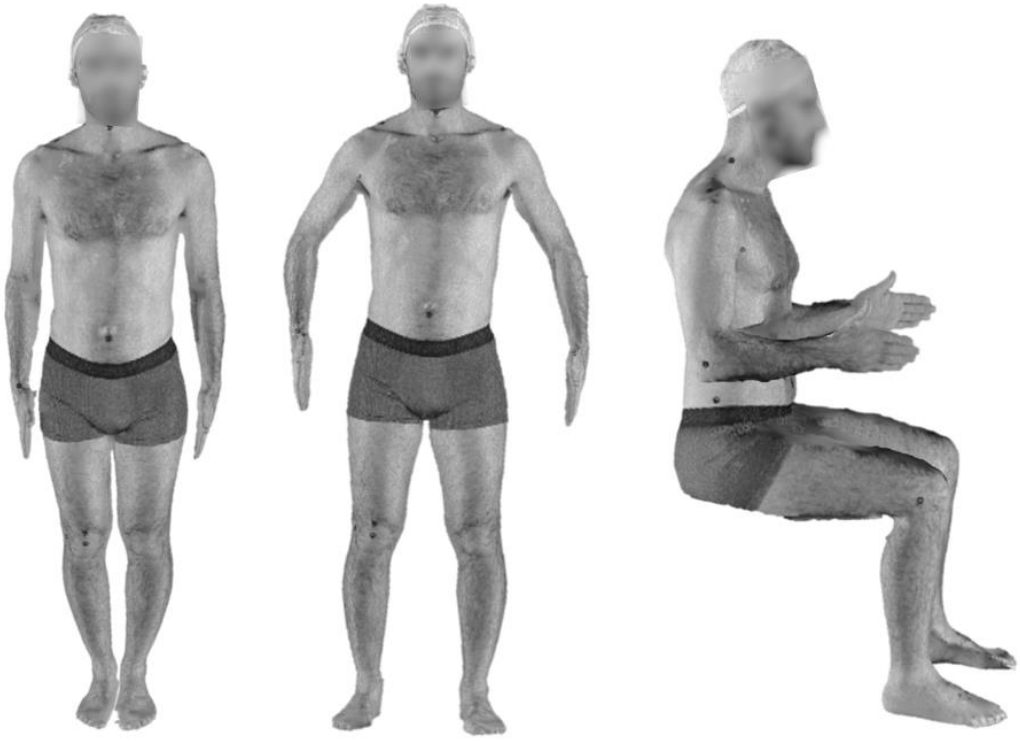

Figure 20. The three scanning postures: Posture 1 (left), Posture 2 (centre) and seated Posture 3 (right). The black stickers represent the stickered landmarks required for the digital measurements.

Figure 20 shows the three scanning postures. From left to right: Posture 1 (feet together, arms straight at the side, fingers flat and extended with palms facing towards the inner thigh), Posture 2 or standard pose (feet shoulder width apart while pointing forward, arms out to the side with a 45° elbow bend, both forearms vertical, fingers extended and palms facing the thigh), and Posture 3 or sitting pose (elbows and knees bent to 90°, back erect, both knees are aligned vertically above feet, knees slightly apart, both palms facing medially, fingers fully extended, and thumbs towards the ceiling). All three postures required the participant's head to be in the Frankfurt plane.

Stage 5: Participants get changed back into their regular clothing (5 minutes)

After scanning was complete, the survey team would remove and dispose of the landmark stickers and wipe the penned landmarks with skin appropriate alcohol wipes. Participants were ushered back to the changing area where they changed back into their clothes. The participant was then directed back to reception area with their completed datasheet and belongings, and then released from the data collection process.

Privacy and data management

Participant names were replaced with the identifier code administered during the brief. This code was used to label all data associated with the participant. The project lead was the only individual with the master spreadsheet linking the participant's name, service number and identifier code. During the project, only the project lead and named investigators had access to the data collected.

All electronic data were stored on password protected computers at AUT and will be held for 10 years. Paper-based data (informed consent forms) were stored in a secure location at DTA. Following the 10-year storage period, all hard copies of data will be destroyed (shredded).

At the completion of each data collection day, the raw body scan data and digital demographic data was copied to three 3 TB external hard drives. Each individual participant file was approximately 400 MB. This consisted of body scan data (bsf, obj, ply, and demographic files), excel files (physical measurements and outputs from the Anthroscan automatic measurement function). Survey data were not transmitted over the internet.

Analysis

Initial clean

After the completion of the survey, all raw data (e.g. demographics in PEDA format, physical excel data and raw body scan data) were saved into folders (based on the unique identifier code) and by survey site (e.g. Whenuapai). An audit was conducted to ensure all necessary files were present. Any missing files were investigated further. Examples of errors were misspelled participant service numbers, identifier numbers, the absence of the weight file, or files being misplaced (saved in another participant's folder).

Automatic measurement

The body scan images were uploaded to a Human Solutions Anthroscan© scan database. Anthroscan utilises proprietary algorithm and measurement definitions derived from ISO 7250 and ISO 8559 to automatically detect the required 17 measurements. All three scan postures (postures 1 to 3) were uploaded along with the demographic (PEDA) information for each participant. To extract the automatic measurements, the operator followed Section 6.5 (Running an Automated Measurement) of the Anthroscan User Manual [17]. Note, the automatic measurements are conducted on scan posture 2 only (Figure 21). Scan postures 1 and 3 were uploaded for reference only. The operator then checked each scan for measurement errors, such as the positioning of the hair bun during head circumference measurements. Table 7 shows common issues and how they were rectified. All measurements were then exported to an Excel spreadsheet using the export function. This was combined with their corresponding demographic information that included participant ID, service number, location, gender, trade, ethnicity, age, service, handedness, years of service, and uniform sizing information.

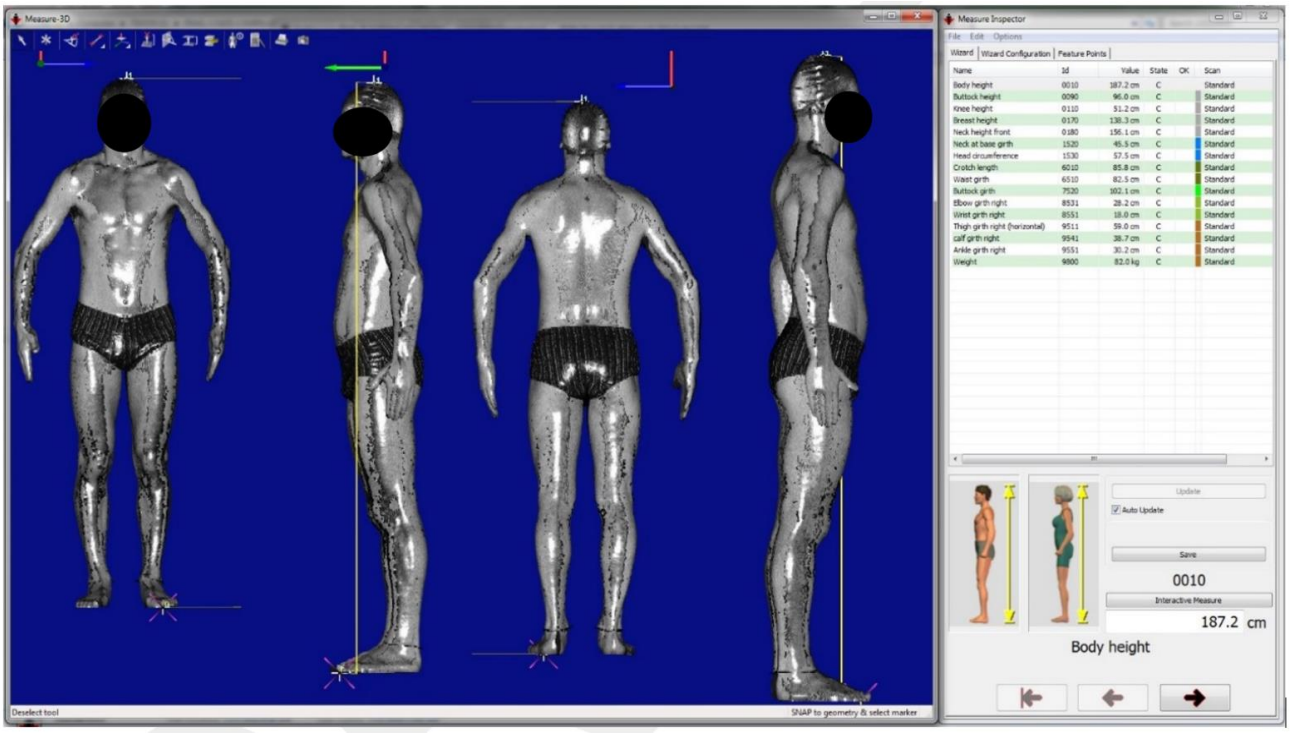

Figure 21. Output of Anthroscan automatic measurement based on scan posture 2.

Table 7. Automatic measurements analysis challenges and solutions.

Issue	Solution
Head circumference – for many of the female participants the head circumference line was drawn around a hair bun. This exaggerated their head circumference results. The line may also be crooked (see photos A and B Figure 22)	• Skip this measure as moving the line above or below the hair bun will render this measure inconsistent with the definition. • If the line is crooked, then adjust by moving the front or back of the line until it is horizontal to the ground. • For future data collection ensure the hair bun is below eye height.
Neck base girth – the line drawn by the software does not follow the natural curvature of the base of the neck (see photo C Figure 22).	• Adjust by moving the measurement line until it conforms to the shape of the neck.
Crotch length – if participants are wearing loose fitting shorts it will affect the accuracy of this measurement. Close fitting undergarments were recommended but not all participants wore these during the assessment (see photo D in Figure 22).	• If the shorts are too loose then skip this measure. • For future data collection, ensure participants are wearing the appropriate undergarment.

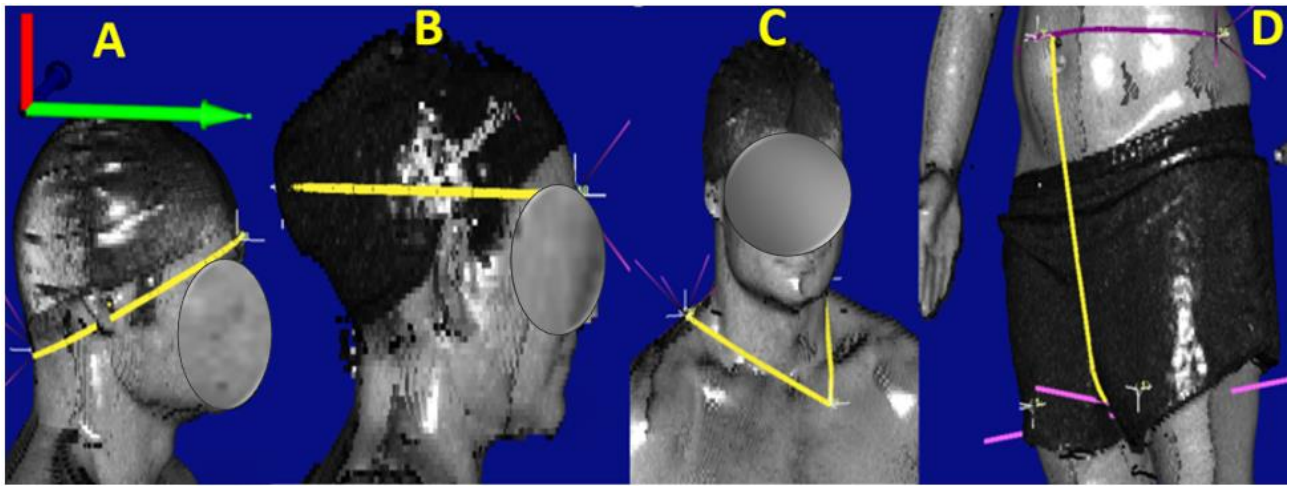

Figure 22. Examples of measurements which required checking, adjustments, or in extreme cases, removal. In photo A the yellow line should be horizontal, in B the yellow line is drawn around the hair bun, in C the yellow line does not conform to the base of the neck, and in D the loose-fitting shorts prevented an accurate crotch measurement.

Physical measurements

Participants' individual physical measurements were recorded in an Excel spreadsheet (example in Table 8) displays the percentage difference between the first and second measurements. If this was outside the respective tolerances, then the '3rd measure required?' column read "Yes"(and a median is calculated as opposed to a mean). The tolerances and correction factors were reviewed and approved by a Level 3 anthropometrist from AUT.

Table 8. Part of the physical measurement's spreadsheet used during data collection.

	ID Code: 150618002	Req. Criteria	Raw Measurement			% difference	3rd Measure?	Median	Median+ correction
	Measurer initials: SK		1	2	3				
1	Seated height	1%	96.9	96.8		-0.1%	No	96.9	96.9
2	Head length	1%	20.1	20.3		1.0%	No	20.2	20.2
3	Head breadth	1%	15.5	15.6		0.6%	No	15.6	15.6
4	Bizygomatic breadth	1%	13.2	13.2		0.0%	No	13.2	13.2
5	Bitragion mandibular arc	1%	31.8	32.2	31.5	1.3%	Yes	31.8	31.8
6	Interpapillary breadth	5%	5.8	5.7		-1.7%	No	5.8	5.8
7	Index finger reach	5%	88.4	90.2		2.0%	No	89.3	90.4
8	Thumb tip reach	5%	85.9	84.0		-2.2%	No	85.0	86.1
9	Grip reach	5%	79.3	78.7		-0.8%	No	79.0	79.4
10	Elbow-grip length	5%	38.4	37.6		-2.1%	No	38.0	37.3
11	Elbow rest height standing	5%	70.3	70.3		0.0%	No	70.3	110.6
12	Forearm - forearm breadth	1%	55.3	58.2	53.6	5.2%	Yes	55.3	55.3
13	Bicep circumference, flexed	5%	38.5	37.9		-1.6%	No	38.2	38.2
14	Arm span	5%	192.6	192.3		-0.2%	No	192.5	192.5
15	Buttock-heel length	1%	107.4	108.0		0.6%	No	107.7	107.7
16	Index finger breadth distal	1%	1.6	1.6		0.0%	No	1.6	1.6
17	Index finger breadth proximal	1%	2.0	1.9	2.0	-5.0%	Yes	2.0	2.0
18	Hand breadth	1%	8.5	8.5		0.0%	No	8.5	8.5
19	Palm length	1%	12.7	13.0		2.4%	Yes	12.9	12.9
20	Hand length	1%	21.8	22.1		1.4%	Yes	22.0	22.0
21	Hand circumference	1%	20.9	21.1		1.0%	No	21.0	21.0
22	Foot length	1%	27.4	27.7	27.5	1.1%	Yes	27.5	27.5

23	Ball of foot length	1%	20.0	19.8		-1.0%	No	19.9	19.9
24	Foot breadth	1%	10.2	9.9	9.8	-2.9%	Yes	9.9	9.9
25	Ball of foot circumference	1%	25.4	24.9	24.6	-2.0%	Yes	24.9	24.9

Digital (CySize) measurements

Extensive research has been conducted on finding the most suitable scan posture to extract each CySize measure. Each measurement and associated landmark are recorded in one of three scan postures (Posture 1, 2, or 3). This is to ensure that the measurements are made in the most logical position. For example, buttock to knee length can only be found when the participant is in a sitting position (Posture 3) and not standing as in Postures 1 and 2. Ectocanthus (an indicator for standing eye height) is recorded in Posture 1 where both feet are together. In Posture 2, feet are shoulder width apart which is not consistent with this measurement definition. For consistency, each measure is only recorded from one posture. Some landmarks such as ectocanthus can be used in multiple measurements (e.g. Eye height standing or sitting). The 42 measurements represent measurements that could not be recorded either accurately or quickly using physical or automatic methods.

Measurements extracted using CySize were based on the methodology developed by UniSA [117, 156]. If no instructions existed (due to differences in measurement lists between Australia and New Zealand) then DTA developed a new procedure for the measure. The procedures for all CySize measurements are detailed within the Measurements and Normative data section at the end of this book. There were various challenges with the CySize assessment that needed to be addressed (Table 9).

A total of 42 measurements were recorded using CySize software developed by Headus Ltd, Australia. CySize has been used successfully by various international military organisations, most notably in Australia. The software has tools that can extract accurate measurements from 3D point cloud image files. Many of these tools are not part of the 3D body scanner software.

This section is designed for operators who are trained to use CySize. For users who are new to this software, please read resources [117, 156] that provide comprehensive instructions on how to prepare data files, identify and save landmarks and measurements [158]. Before using CySize, raw image scan files from the 3D body scanner software (Anthroscan) must be converted into a form that is usable in CySize [140]. Figure 24 provides a summary of the NZDFAS CySize process.

Table 9. CySize challenges and solutions.

Issue	Solution
Difficulty in seeing all landmarks clearly. Some landmarks are obstructed from view due to a digital phenomenon or artefact known as 'webbing'. Webbing occurs when two points of the body are too close together and the software connects the two with a 'web'-like feature as a by-product of the surface reconstruction (see items labelled A in Figure 23)	• Re-calculate the automatic body auto-fill function. Modify starting position from a different point on the slice. • Zoom in on the webbing, sometimes there are small 'holes' where the digital tape can still pass through unimpeded providing it is still in the approximate vicinity. • Alternatively, take the measure above or below the webbing, providing it still meets requirements in the measurement protocol definition. • If the webbing is too extensive, skip this measurement.
The surface mesh can appear to have a 'hole' in the skin or a 'laceration' type effect (see item B Figure 23)	• Recalculate auto body fill. • If this problem persists, skip this measure. • This is an artefact of the merging of scan patches and could be corrected in Anthroscan.
Unknown artefact or objects in the scan. For example, see item labelled C in Figure 23.	• Recalculate auto body fill. • Try an alternative location. For example, the purple patch (patch C in Figure 23) hinders placement of the Seat pan height landmark. Try finding this on the opposite side of the seat pan. In this case, only the Y coordinate of the landmark is required – regardless of the horizontal location on the seat pan. • If in doubt, skip this measure.
Inter-operator reliability – the difference in how each operator interprets a landmarking location.	• Regular meetings (weekly or fortnightly) to communicate concerns or discrepancies. • Development of an issues register that the lead researcher will check and provide feedback on. • The lead researcher conducted regular checks of the CySize measurer's landmark positioning and measurement positions.
Participant scan images are off-axis (i.e. not in an x, y, z compatible position). This can be partly due to incorrect body posturing (by the scan operator) within the scanner. For example, a participant may be facing slightly to the right, or body 'hunched' forward, left, or right. This often happens when participants are not placed in the Frankfort[1] plane in the scanner.	• CySize has developed an x, y, z correction tool. This allows the image to be re-aligned to the correct plane prior to taking measurements. • If body posture is extremely off-axis then consider skipping this individual. This can be addressed with using a third party tool such as *Meshlabs (ISTI-CNR, Krnataka, India).*

[1] The Frankfort plane refers to a straight, horizontal line between the Orbitale (bottom edge of the eye socket) and the Tragion (the notch superior to the tragus of the ear). This is the correct head position for measuring height [9].

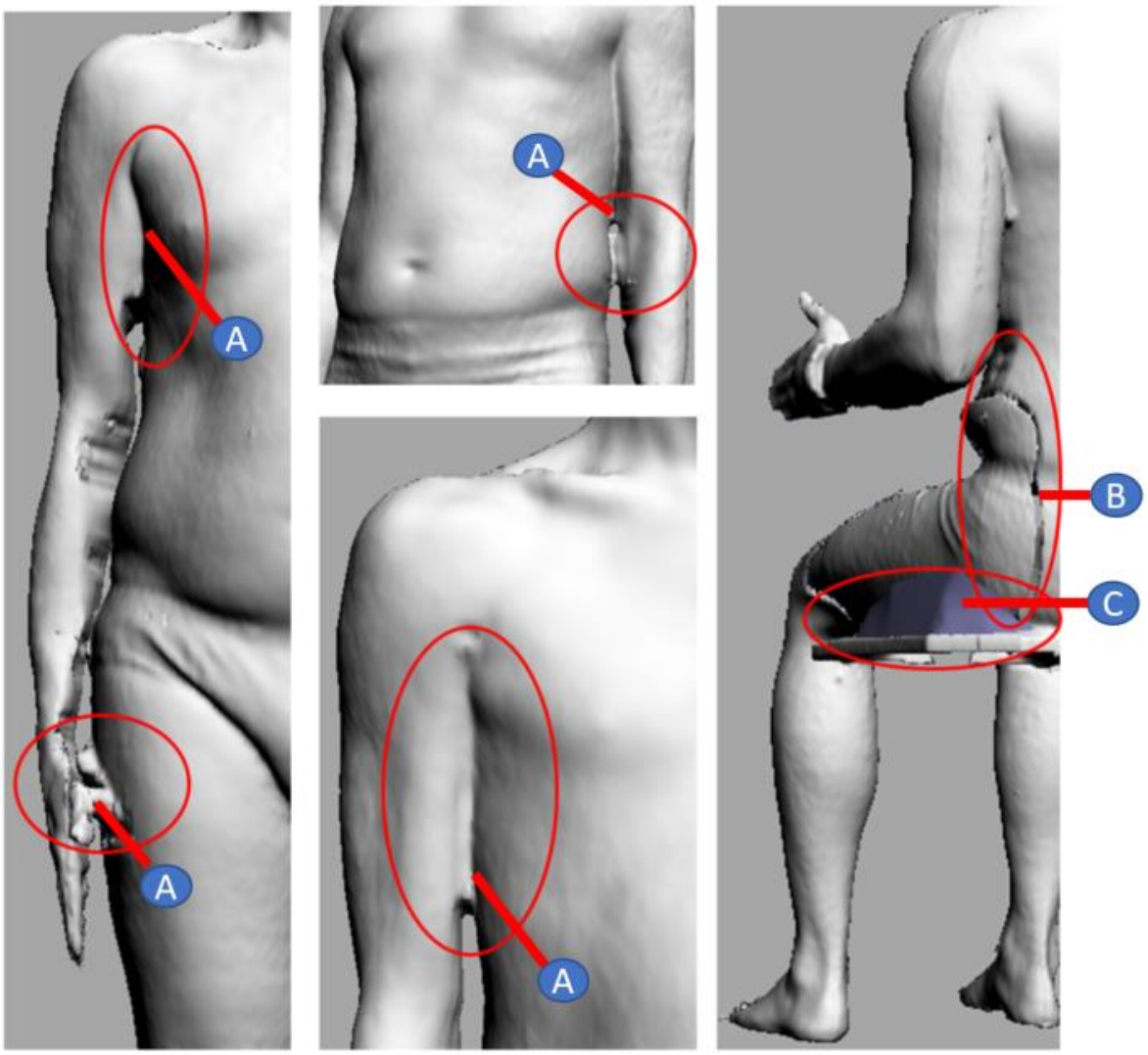

Figure 23. Common artefacts with CySize analysis: webbed skin (A), holes on the surface (B) or unknown objects (C).

ANALYSIS: EXTRACTING DIGITAL (CYSLICE) MEASUREMENTS PROCEDURE

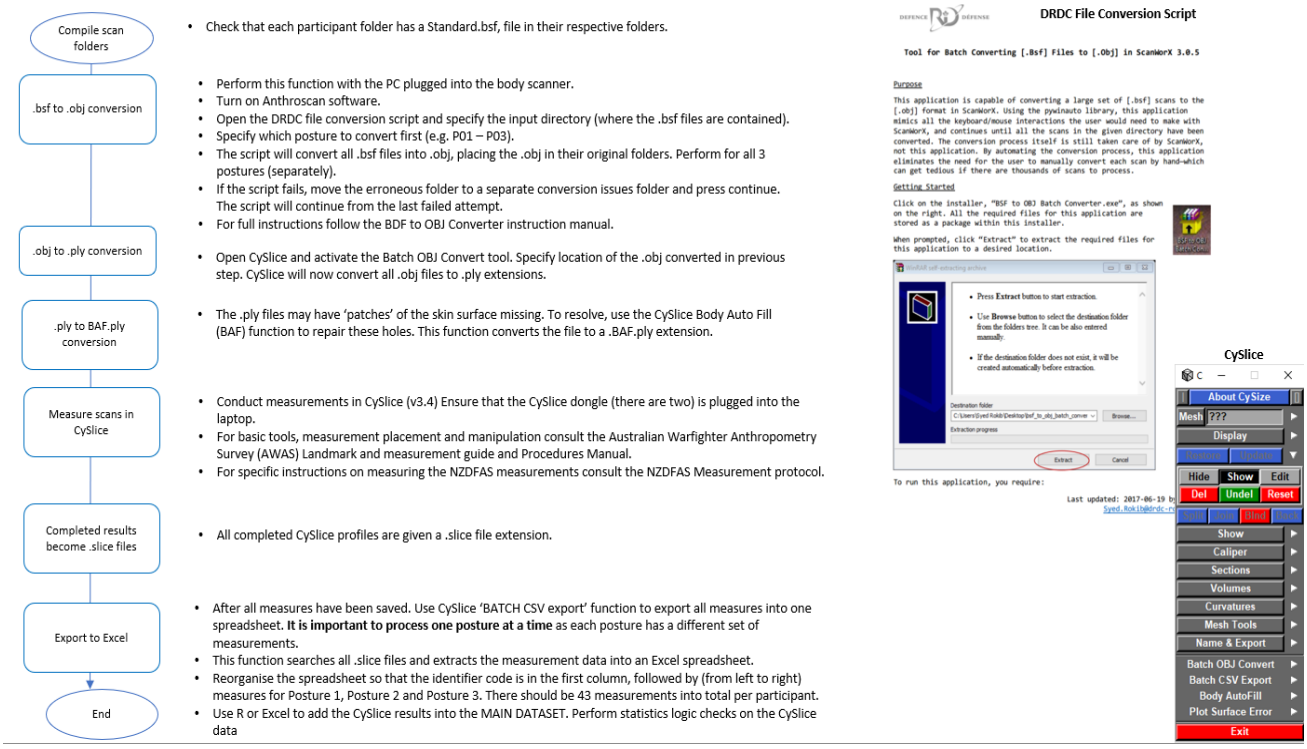

Figure 24. The NZDFAS CySize measurement process.

Concatenate all data

Once all measurements were completed, the CySize results were combined with the demographic, physical, and automatic data to form the full NZDFAS dataset.

Statistics and logic checks

A series of data preparation steps (Figure 25) were then performed using the R statistical software:

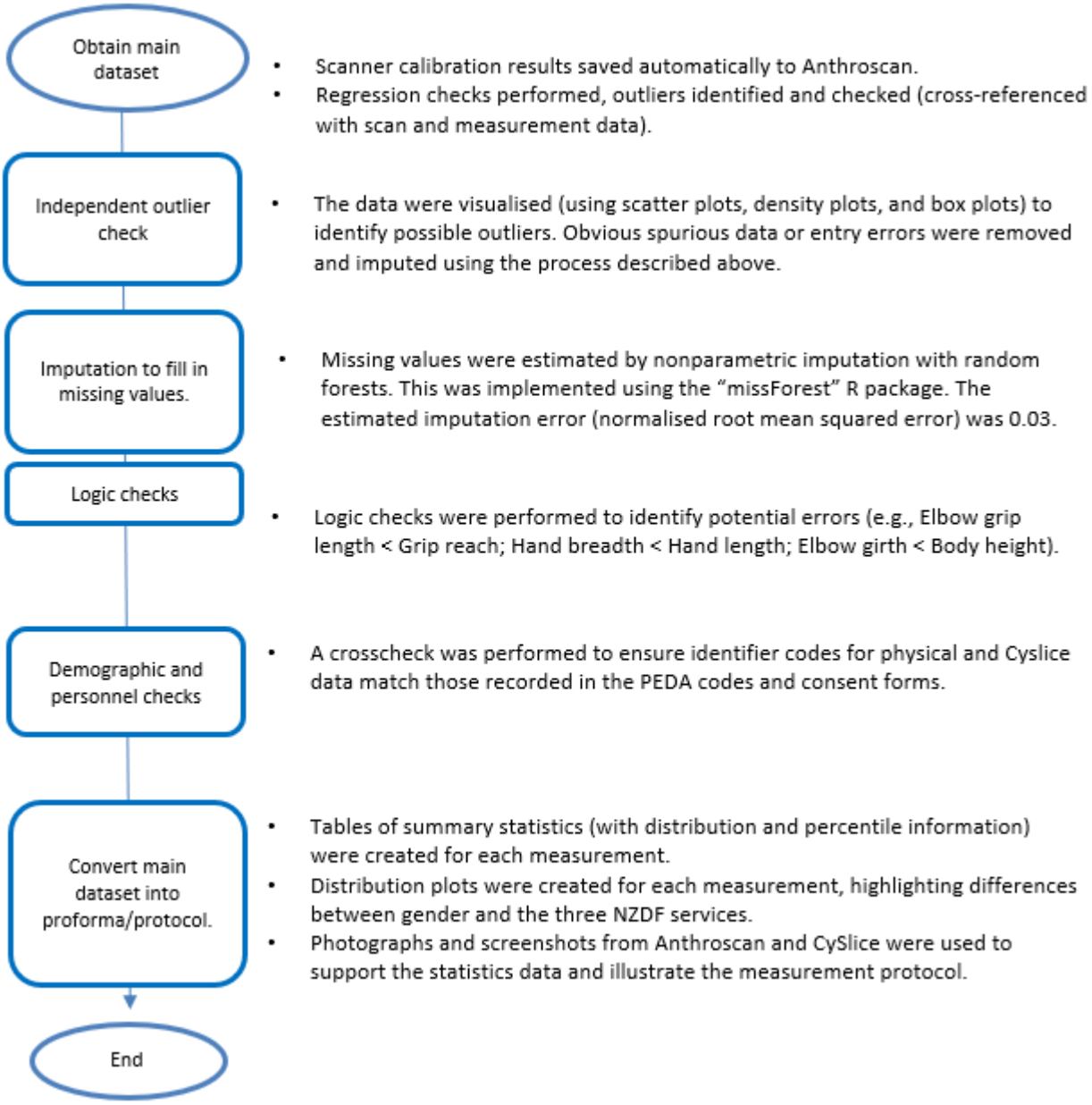

Figure 25. Final check procedures for the NZDFS data

Summary

This section described the methodology of the 2016–2018 New Zealand Defence Force Anthropometry. The methodology was consistent with previous military surveys with the exception of automated and some post-processed measurements. As this was the first study of its kind in New Zealand, it is hoped that future surveys will build and improve on these methods to suit the future needs of the New Zealand Defence Force.

PART V – CONCLUSIONS

The purpose of this book was to educate other researchers who are planning on conducting a large-scale anthropometry survey using 3-D body scanning technology. This was achieved by describing the fundamental concepts (with examples) of anthropometry, 3D body scanning, military anthropometric surveys. These concepts helped shape the methodology of the New Zealand Defence Force Anthropometric Survey in Part IV.

Part I introduced Kinanthropometry and anthropometry. Early anthropometric measurements were mostly conducted by hand using traditional tools. There are many anthropometric protocols in existence but still there is no universal protocol. One of the reasons is that different disciplines may require different sets of measurements which has resulted in standards targeted for their own industry. Part II described the different types of 3D body scanning technology (e.g. laser, structured, multiview, millimeter wave and infrared), its applications in various industries (i.e. clothing, health, ergonomics and sports science) and described its advantages (e.g. the ability to take rapid, automated measurements, and increased number of measurements) and disadvantages (e.g. cost, lack of landmarking, missing data, security and confidentiality) compared to traditional measurement techniques. Part III summarised eight of the most recent (and publicly available) military anthropometric surveys conducted within the last two decades. The purpose of this was to understand how anthropometric surveys utilised traditional and 3D body scan measurements. The table in Appendix B provided one of the first published attempts at combining variables from multiple military surveys that have used body scanning technology. Part IV described the methodology of the 2016-18 New Zealand Defence Force Anthropometric Survey which was developed based on the information in Parts I to III. The survey culminated in a comprehensive measurement protocol and summary statistics presented in Appendix B.

The following are key observations from the NZDFAS survey in relation to the topics presented in Parts I to III. It is hoped that future researchers will take these factors into consideration when planning their respective surveys.

Validating measurements is an important part of the survey planning process and should never be taken lightly. This is particularly important when attempting to use automated measurements. Despite the accuracy claims by various 3D body scanner manufacturers, it is important to conduct your own validation. That is, benchmarking the performance of the scanner output against a known ‘gold standard’ in our case this was physical measurements. Furthermore, we recommend the following:

- Conduct the validation under supervision of a criterion measurer (e.g. ISAK level 3+ or an experienced anthropometrist)
- Compare measurements that have the same measurement definitions (e.g. if the scanner system records chest girth at thelion height then the physical measurement should also be taken at this point)
- Consider the effect of scan posture in the validation process (e.g. some scanner systems capture height from a posture that requires feet shoulder width apart, while traditional definitions may require feet together)
- Incorporate redundancies should measurements fail initial validation. For example, if the automated measurement fails, consider capturing it physically or post-processed depending on how much time you have with (a) the participant (b) your survey team
- Whilst some measurements could fail the validation, determine whether the failure criteria is meaningful in the context of the application of the measurement. For example, is 5% error for sleeve length necessarily negative from a clothing design perspective?

If possible, leverage information, techniques, and datasets from other surveys or even better, personnel who led their respective studies. The NZDFAS would not have been possible without the support from various international military organisations. Every project lead has a story to tell and developed methods that worked well for them (and can talk about those which did not). From our experience, the international military anthropometry research community is very welcoming to new

and inexperienced members. While it is nice to receive, it is also important to give, share and relay your own findings where possible (depending on your organisation), military anthropometry is very much a team effort.

Training the data collection is very important. Depending on the organisation, anthropometry teams are either trained internally (in-house) or trained by external agencies such as ISAK. Anecdotally, more organizations are opting to train their data collection teams with ISAK. However, it must be advised that most military anthropometric measurements (e.g. ANSUR II and all protocols that are based on it) are very different to ISAK. Measurement differences aside, one of the most important benefits of training military anthropometrists through ISAK is measurement etiquette. ISAK is excellent at teaching the fundamentals of measuring (e.g. how to use calipers and tapes accurately and efficiently). The breadth of teaching material covered in the ISAK course curriculum is a must for new military anthropometrists.

In terms of selecting an anthropometry team, consider selecting individuals who are good team players with social skills. Sometimes these traits are just as important as measurement accuracy. From experience, I have witnessed a lot of complacency (e.g. high 'ego' leading to avoiding measurement duties) within our best or most accurate measurers, while other (less accurate) team members worked tirelessly and were more committed to the cause. Therefore, managing these dynamics within your data collection is important for ensuring the quality of the measurement outputs while avoiding fatigue (which may lead to increased errors and reduced accuracy).

Finally, if you are new to leading anthropometric surveys be prepared to make mistakes, a lot of mistakes. In my case, I experienced a lot of 'trial and error' at almost every stage of the project. Therefore, when planning initial project timelines, it is vital that this 'learning phase' is built in at every phase of the project (e.g. training, scanner familiarisation, analysis, measurement identification and validation). From discussions with fellow national survey leads, the completion of a large-scale anthropometric survey (from project initiation to submission of final report) can take anywhere up 5 to 6 years depending on funding and resources available. The NZDFAS project took approximately 5 years to complete. For a country with an active service population of around 9,000 this (compared to larger nations) was relatively a slow burn. However, it was a big learning curve for all involved which will serve the NZDF well for future surveys. Accounting for this 'learning phase' is extremely important.

In conclusion, 3D body scanning shows enormous potential for assisting military anthropometric surveys. While many surveys still take predominately physical or traditional measurements, the uptake of 3D body scanning is steadily increasing amongst military nations and their respective surveys. The NZDFAS produced New Zealands first 3D anthropometric dataset that is now available to the NZDF and comparable to international militaries. It is important that we build on this body of work for future anthropometric surveys in New Zealand to ensure that anthropometric data is applied correctly to ergonomic, engineering and design problems. We hope that future researchers can use this material, methods and subsequent lessons to plan surveys for their respective organisations.

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149. International Standardization Organization, *General Requirements for Establishing Anthropometric Databases*. 2012, International Standards Organization (ISO): Geneva, Switzerland.
150. DEF STAN 00-250, *Human Factors for Designers of Systems.* 2008, UK Defence Standardization.
151. International Organization for Standardization, *ISO 7250-1-2008. Basic Human Body Measurements for Technological Design.* 2008, International Organization for Standardization: Geneva.
152. International Organization for Standardization, *Basic Human Body Measurements for Technological Design: Body Measurement Definitions and Landmarks*. 2008: International Organization for Standardization.
153. Human Solutions Group, *Anthroscan: Definition of Body Measurements*. 2013, Human Solutions Group.: Kaiserslautern, Germany.
154. JIS-Z 8500, *Ergonomics - Basic Human Body Measurements for Technological Design*. 2002, Japanese Standards Association: Tokyo, Japan.
155. Tomkinson, G.R., et al., *Australian Warfighter Anthropometry Survey (AWAS): Landmarking and Measurement Manual*. 2012, Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

156. Tomkinson, G.R., et al., *Australian Warfighter Anthropometry Survey (AWAS): Landmarking and Measurement Manual.* 2012, Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia: Adelaide, Australia.
157. Stewart, A.D., et al., *International standards for anthropometric assessment*. 2011, Lower Hutt, New Zealand: ISAK. 125.
158. Tomkinson, G.R., et al., *AWAS Methods, Temporal Changes and Summary Statistics*. 2012, Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia: Adelaide, Australia.

PART VI - MEASUREMENTS AND NORMATIVE DATA FOR THE NEW ZEALAND DEFENCE FORCE (NZDF) KINANTHROPOMETRY SURVEY

Stephven Kolose, Patria Hume, Grant Tomkinson, Arthur Stewart, Tom Stewart, Stephen Legg

Introduction

Data are for 1,003 (791 male and 212 female) New Zealand military personnel who had 84 physique measures obtained manually using surface anthropometry and digitally using a 3D body scanner.

How to read the proformas

The physique proformas have been created from data from the 1,003 (791 male and 212 female) New Zealand military personnel who had 85 physique measures obtained manually using surface anthropometry and digitally using a 3D body scanner. The purpose of these proformas is to provide a clear and concise record of the measurement protocol used for each physique variable, and the data summary statistics. The data is the newest and most comprehensive anthropometric dataset of New Zealanders. To assist with the application of the data for research purposes (e.g. for ergonomics, health research or design activities etc) each body measurement proforma (comprising of two pages) was developed to be used as a quick reference guide. The first page of each proforma presents general information regarding the origin of each measurement, instructions on how to capture the landmarks and measurements and an illustration of the measurement.

The key for interpreting the information on the first page (see Figure 26 for an example):

1. Measurement name.
2. Whether the measure is a physical (manual anthropometric), automatic (computer calculated), or digital measurement (using computer software), and the units.
3. Measurement equipment used (e.g. Physical, Anthroscan automatic or CySize tool).
4. The source of the measurement definition.
5. The measurement definition.
6. Landmark(s) required. Note that automatic measures do not require landmarks.
7. Posture required refers to a) specific postures for the physical measurements and b) body scan postures 1 to 3.
8. The procedure describes the steps that the assessor, body scan operator or CySize operator must perform to extract the measurements.
9. Full citation of the protocols named in the 'Source' section.
10. Notes refer to special instructions that the assessor must consider. These instructions are those which do not fit under the previous headings.

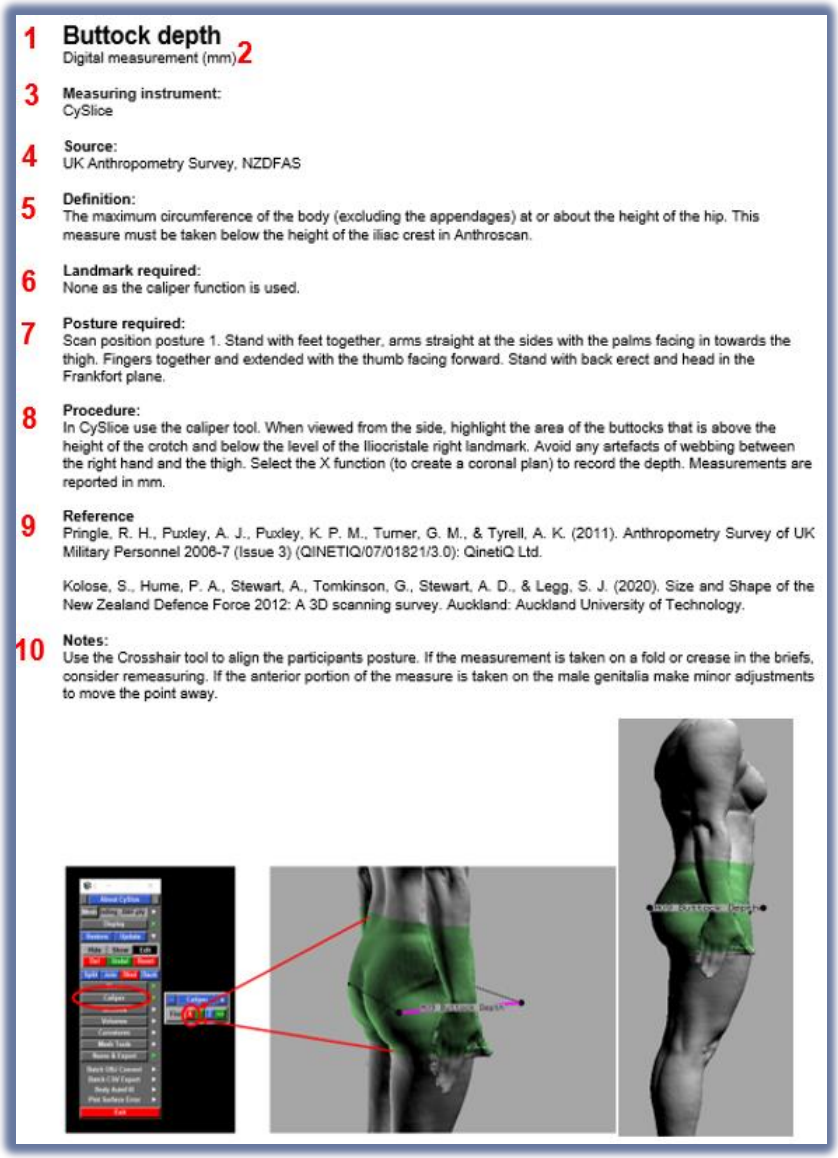
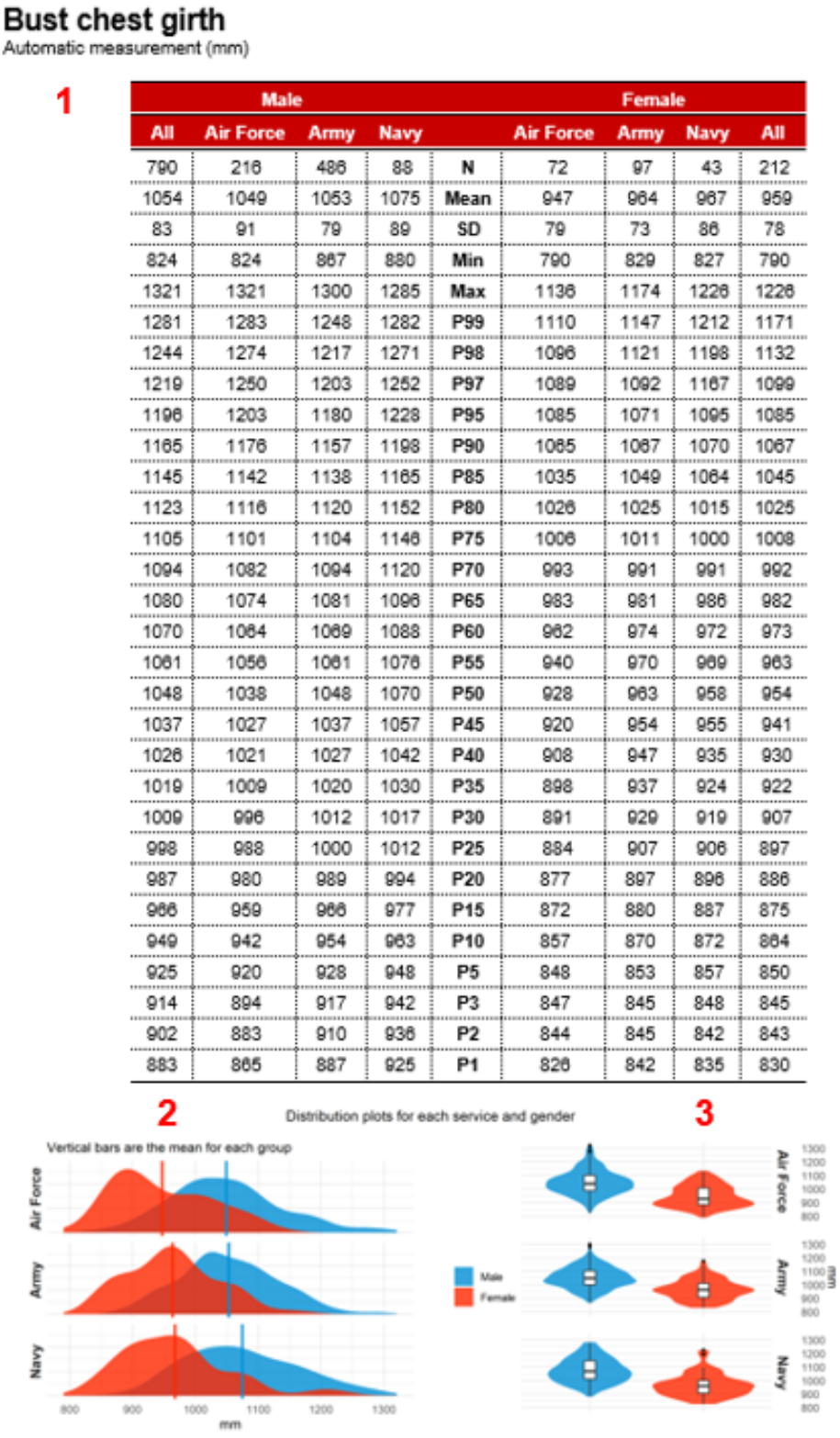


Figure 26. Example of the first page of proforma content.



The second page of each proforma presents (see Figure 27):

- Summary statistics table (e.g., showing sample size, mean, standard deviation, minimum, maximum, and percentiles [1–99]).
- A density plot which shows the measurement distribution. The vertical bars represent the sample mean.
- A violin plot (with a built-in boxplot) is an alternative view of the measurement distribution.

Both the density and violin plots show data for gender (male, female) and service type (Army, Air Force or Navy).

Figure 27. Example of Page 2 of proforma content.

Abdominal extension depth sitting - Post-processed measurement (mm)

Measuring instrument:
CySize. Measurements should be in mm.

Source:
ANSUR.

Definition:
The horizontal distance between the Abdominal Point Anterior and a point on the back at the same level.

Landmark required:
None.

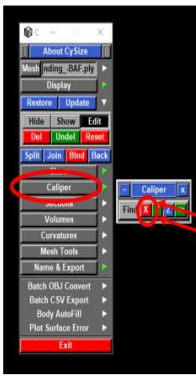
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

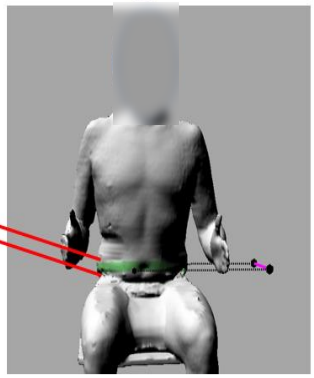
Procedure:
In CySize use the caliper tool. View from the front. Create a rectangle at the same level as the Omphalion. Select the X function (to create a coronal plan) to record the depth. Measurements are reported in mm.

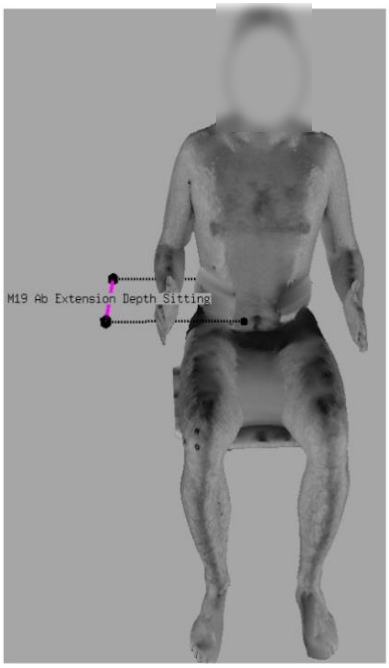
Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S. (p46).

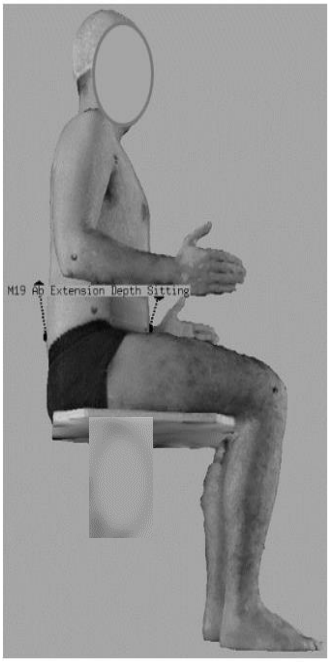
Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
The Omphalion is often obscured due to shadowing caused by the hands. If the Omphalion is not visible, then skip this measure.



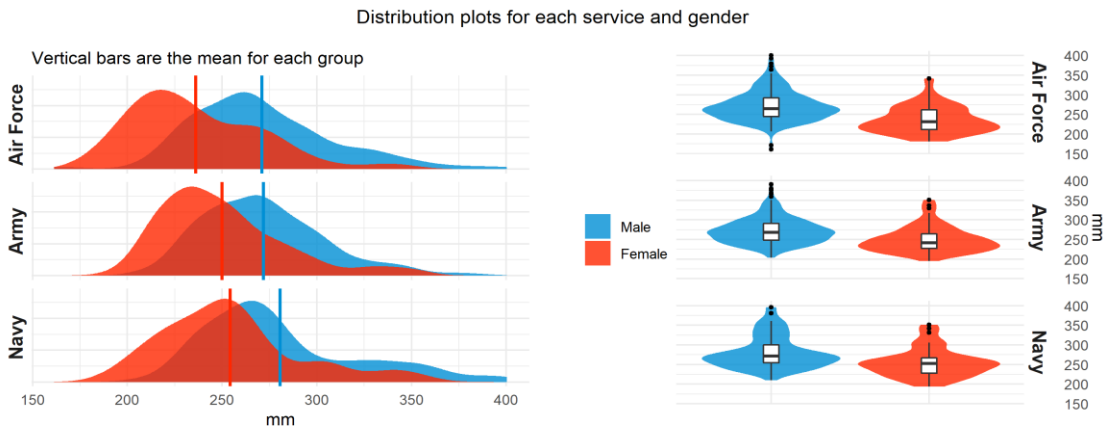






Abdominal extension depth sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
273	271	272	281	**Mean**	236	250	254	246
35	38	33	41	**SD**	34	33	37	35
161	161	203	210	**Min**	181	195	194	181
400	400	390	396	**Max**	342	351	352	352
379	379	366	396	**P99**	338	351	348	350
359	362	350	385	**P98**	324	338	343	341
350	353	344	368	**P97**	306	331	339	335
340	340	335	359	**P95**	293	320	329	312
322	326	313	347	**P90**	280	294	306	292
307	310	305	332	**P85**	271	280	293	279
299	298	297	317	**P80**	267	273	274	271
292	292	291	300	**P75**	261	265	266	264
285	286	285	285	**P70**	252	259	261	259
280	278	281	278	**P65**	241	255	259	254
275	273	276	276	**P60**	235	252	256	252
271	268	272	274	**P55**	234	248	253	246
267	265	268	271	**P50**	231	242	252	240
265	262	265	266	**P45**	224	238	249	235
261	259	262	264	**P40**	220	235	242	233
256	254	256	259	**P35**	218	233	239	230
251	251	251	258	**P30**	216	232	234	225
248	244	248	254	**P25**	211	227	228	220
243	239	244	245	**P20**	209	223	226	216
237	236	238	240	**P15**	202	218	219	213
232	229	233	237	**P10**	200	215	213	209
227	223	227	233	**P5**	193	210	208	201
222	218	223	231	**P3**	187	209	203	197
218	215	219	230	**P2**	186	208	200	194
210	207	213	227	**P1**	185	204	197	187



Acromiale height sitting - Post-processed measurement (mm)

Measuring instrument:
CySize. Measurements should be in mm.

Source:
AWAS, NZDFAS.

Definition:
The vertical distance between a sitting surface and the Thigh Point Top landmark.

Landmark required:
Acromiale Right and Seat Pan Height landmarks.

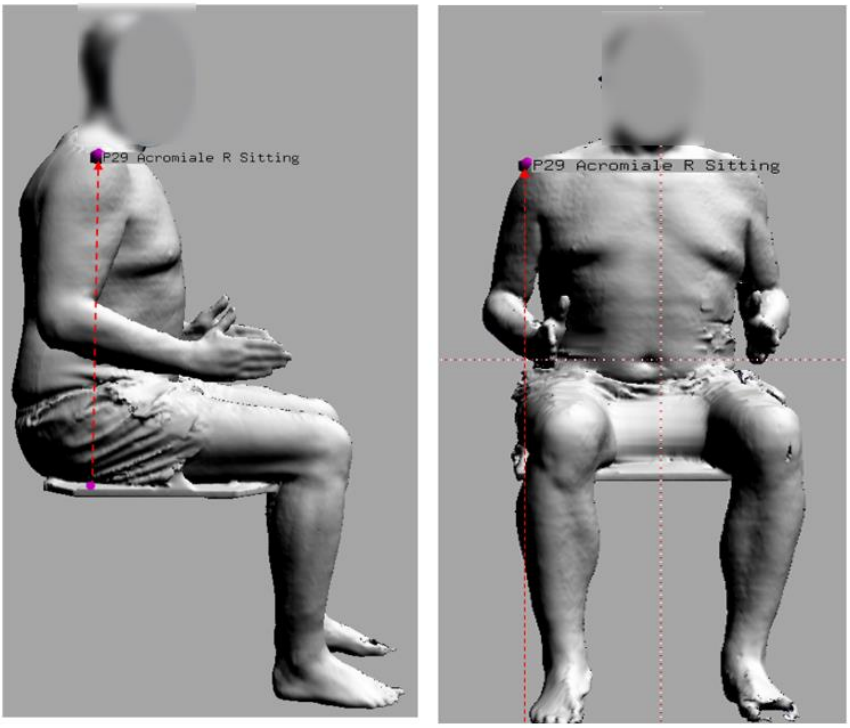
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb pointing forward.

Procedure:
The acromiale points may be misplaced or difficult to see. With "Colour" mode off, follow the bony ridge of the top shoulder. These points should be located at the end of this ridge (i.e. the ‘drop off’ point) on the most lateral aspect of the acromion. This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Acromiale landmark (the superior aspect of the most lateral part of the acromion border) minus the Y coordinate (mm on the Y or vertical axis) of the Seat Pan Height (top edge or surface of the body scanner seat) landmark in Posture 3. This calculation is performed in Excel. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

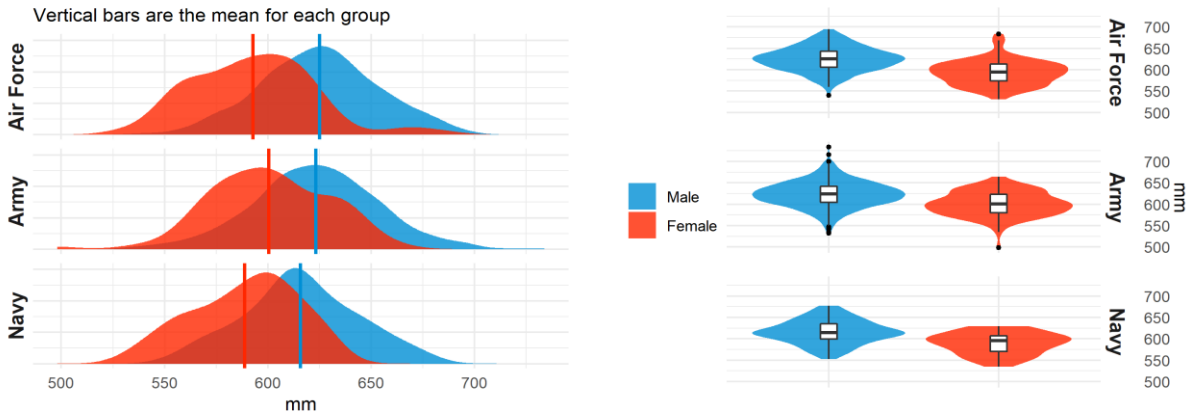
Notes:
Ensure that the participant is sitting erect.



Acromiale height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
623	625	623	616	**Mean**	593	600	589	595
30	28	30	28	**SD**	29	29	25	29
532	540	532	552	**Min**	531	498	535	498
734	695	734	678	**Max**	683	664	630	683
694	687	695	674	**P99**	673	655	629	665
683	680	688	670	**P98**	667	650	628	653
678	678	681	668	**P97**	661	648	627	648
673	676	674	662	**P95**	633	645	627	640
659	662	659	650	**P90**	622	636	621	633
654	656	654	646	**P85**	616	634	617	625
647	649	648	639	**P80**	615	629	608	619
642	643	642	635	**P75**	613	623	606	614
637	639	638	628	**P70**	611	615	604	611
634	634	634	625	**P65**	603	611	602	606
630	632	631	619	**P60**	599	606	599	603
626	629	626	617	**P55**	597	603	596	600
622	625	624	614	**P50**	594	600	595	596
619	622	620	613	**P45**	589	596	585	593
615	617	616	610	**P40**	585	593	585	588
612	615	612	608	**P35**	582	589	581	585
608	610	608	605	**P30**	576	585	577	580
604	605	604	599	**P25**	573	580	570	576
599	601	600	592	**P20**	564	576	563	571
593	597	593	588	**P15**	559	574	559	564
584	589	584	579	**P10**	558	565	553	558
574	576	572	568	**P5**	553	562	548	552
567	574	564	567	**P3**	552	551	542	548
561	571	558	564	**P2**	545	547	539	540
552	560	550	561	**P1**	537	533	537	535

Distribution plots for each service and gender



Acromiale height - Post-processed measurement (mm)

Measuring instrument:
CySize. Measurements should be in mm.

Source:
AWAS.

Measuring instrument:
Anthropometry tape.

Definition:
The vertical distance from the standing surface to Acromiale R.

Landmark required:
T2 landmark.

Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
See). This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Acromiale landmark in Posture 1 (see Appendix A in Kolose, et. al., 2020; or Tomkinson et al., 2012). Measurements are reported in mm.

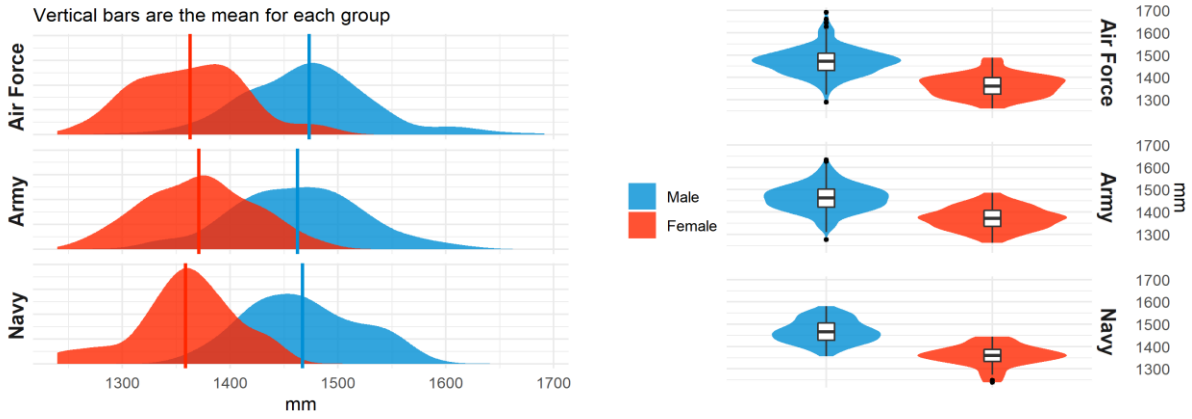
Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes
None.

Acromiale height summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1466	1473	1463	1467	**Mean**	1363	1371	1359	1366
60	62	60	52	**SD**	50	50	47	50
1276	1289	1276	1356	**Min**	1261	1262	1240	1240
1691	1691	1634	1580	**Max**	1489	1486	1444	1489
1618	1642	1603	1568	**P99**	1484	1478	1441	1482
1599	1620	1592	1561	**P98**	1477	1474	1438	1473
1588	1612	1579	1558	**P97**	1469	1458	1436	1460
1565	1590	1564	1553	**P95**	1447	1452	1431	1445
1540	1543	1537	1542	**P90**	1418	1435	1422	1431
1525	1529	1523	1531	**P85**	1405	1426	1400	1418
1514	1515	1511	1516	**P80**	1402	1417	1396	1405
1504	1508	1502	1505	**P75**	1399	1408	1388	1399
1496	1498	1495	1498	**P70**	1392	1396	1381	1391
1488	1493	1486	1483	**P65**	1387	1385	1375	1384
1481	1485	1478	1474	**P60**	1377	1382	1367	1379
1472	1479	1469	1467	**P55**	1371	1378	1363	1373
1467	1472	1464	1466	**P50**	1362	1372	1360	1366
1459	1467	1454	1458	**P45**	1355	1370	1358	1359
1450	1460	1446	1450	**P40**	1351	1358	1353	1355
1442	1453	1437	1441	**P35**	1341	1349	1352	1347
1433	1445	1431	1436	**P30**	1330	1342	1341	1337
1425	1430	1422	1428	**P25**	1326	1334	1334	1330
1416	1422	1412	1424	**P20**	1312	1327	1329	1326
1406	1414	1402	1415	**P15**	1307	1320	1321	1314
1393	1402	1388	1402	**P10**	1301	1306	1298	1301
1371	1381	1365	1388	**P5**	1292	1290	1274	1287
1352	1363	1344	1380	**P3**	1280	1285	1255	1274
1341	1359	1335	1374	**P2**	1269	1276	1248	1262
1327	1330	1326	1367	**P1**	1262	1265	1244	1261

Distribution plots for each service and gender



Acromiale-radiale length - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ISAK, AWAS.

Definition:
The point-to-point distance between the digitally extracted Acromion Right and Radiale landmarks. Note that despite the appearance of a contour distance in the figure, CySize extracts this measurement as a point-to-point distance.

Landmark required:
Acromiale Right and Radiale Right landmarks.

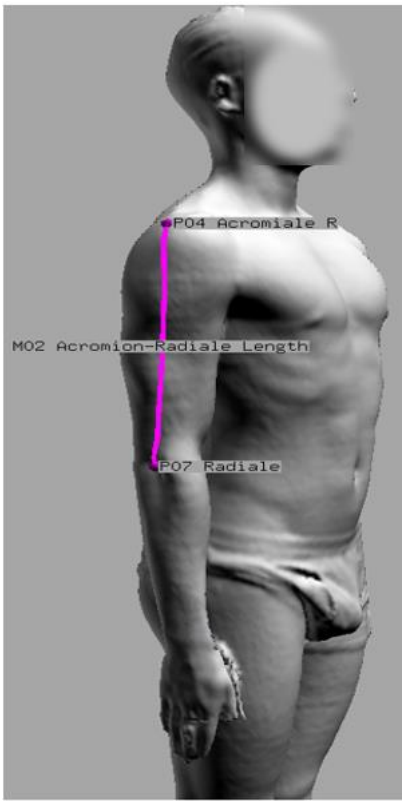
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

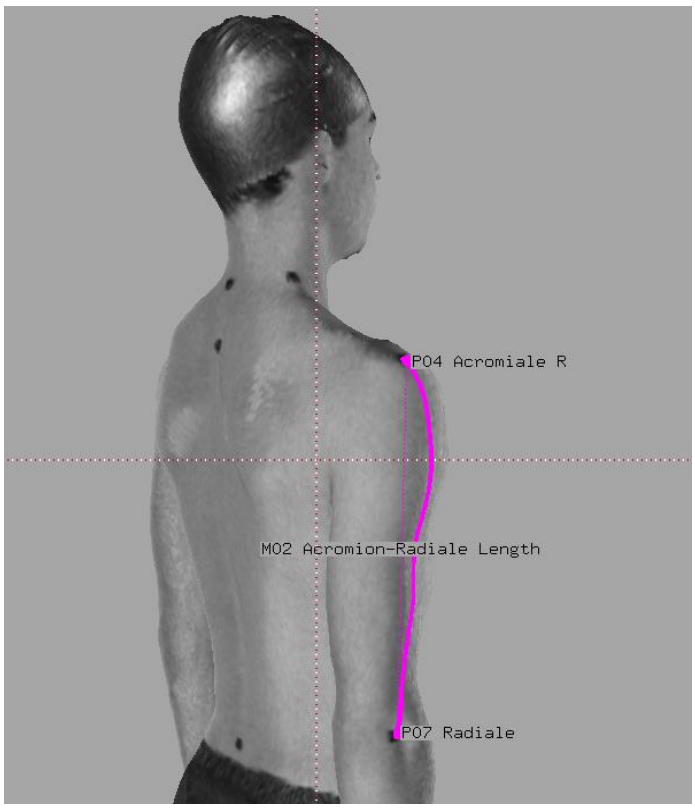
Procedure:
Identify and select the digital Acromiale Right, centre wrist and Radiale (point at the proximal and lateral border of the head of the radius) landmarks. Look for the stickered Radiale landmark and skip this landmark if it is absent as it will be extremely difficult to identify by sight. See AWAS Section 7.2.20 of the Procedures Manual (Tomkinson et al., 2012). Measurements are reported in mm.

Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
None.

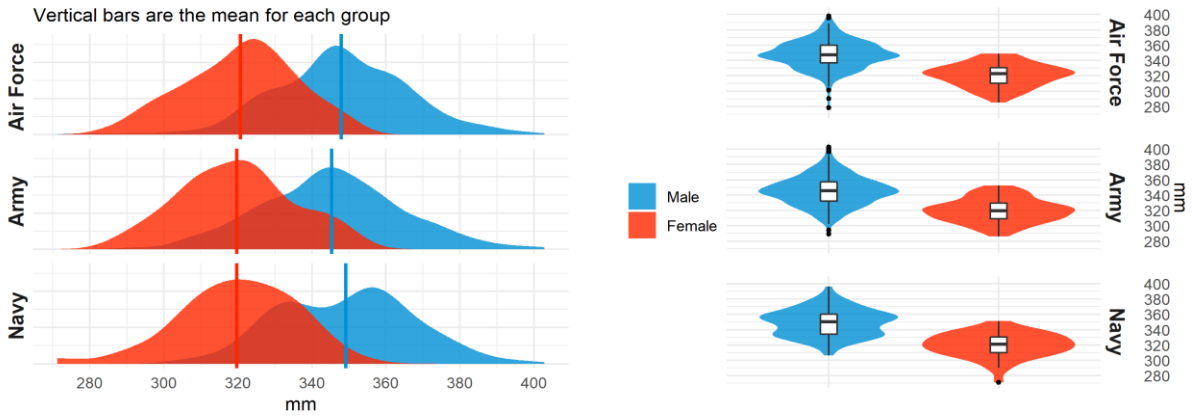




Acromiale-radiale length summary statistics- Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
346	348	345	349	**Mean**	321	320	320	320
19	18	19	18	**SD**	15	15	16	15
278	278	289	306	**Min**	285	286	271	271
403	398	403	396	**Max**	349	352	351	352
392	388	392	386	**P99**	349	351	348	350
386	386	385	383	**P98**	348	349	345	349
383	383	383	381	**P97**	347	348	343	348
377	376	377	377	**P95**	345	347	342	345
371	370	371	372	**P90**	338	342	338	341
365	365	365	367	**P85**	336	338	335	337
362	363	360	363	**P80**	333	332	335	333
359	360	357	360	**P75**	331	330	331	330
356	358	354	359	**P70**	329	326	329	328
353	354	352	357	**P65**	327	325	327	326
350	351	349	356	**P60**	324	324	324	324
348	349	347	353	**P55**	323	322	323	323
346	348	346	350	**P50**	323	319	321	321
345	346	343	349	**P45**	321	318	318	318
342	345	341	344	**P40**	319	316	317	317
340	343	339	340	**P35**	315	313	314	314
337	341	336	336	**P30**	313	311	313	312
333	337	332	334	**P25**	310	309	310	309
330	333	329	332	**P20**	308	307	308	308
328	329	326	331	**P15**	305	304	306	305
323	325	321	328	**P10**	299	300	301	299
317	321	313	322	**P5**	297	296	291	296
311	316	310	320	**P3**	292	291	290	291
307	311	306	318	**P2**	292	290	287	290
305	302	305	311	**P1**	290	289	279	287

Distribution plots for each service and gender



Ankle girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Human Solutions

Definition:
Horizontal circumference measured at the height of the medial condyle of the tibia. The circumference is measured parallel to the standing surface.

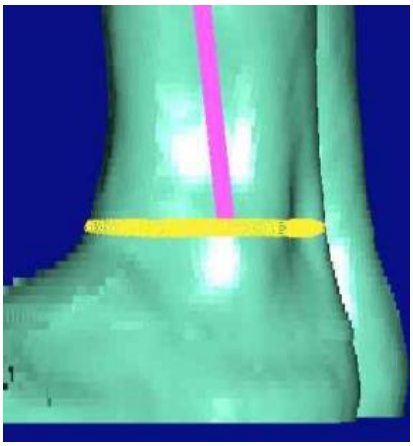
Landmark required:
None.

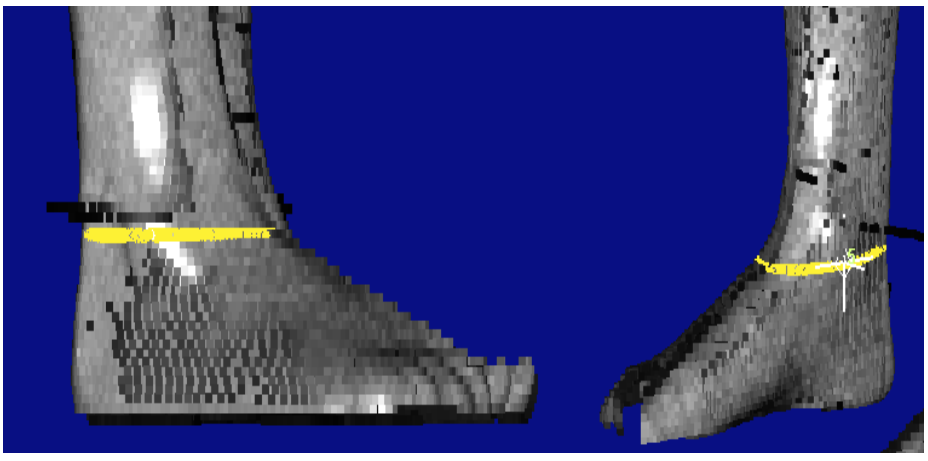
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
Check that the digital tape (yellow line below) is complete (no areas missing) and horizontal. Use software to correct the tape where appropriate.

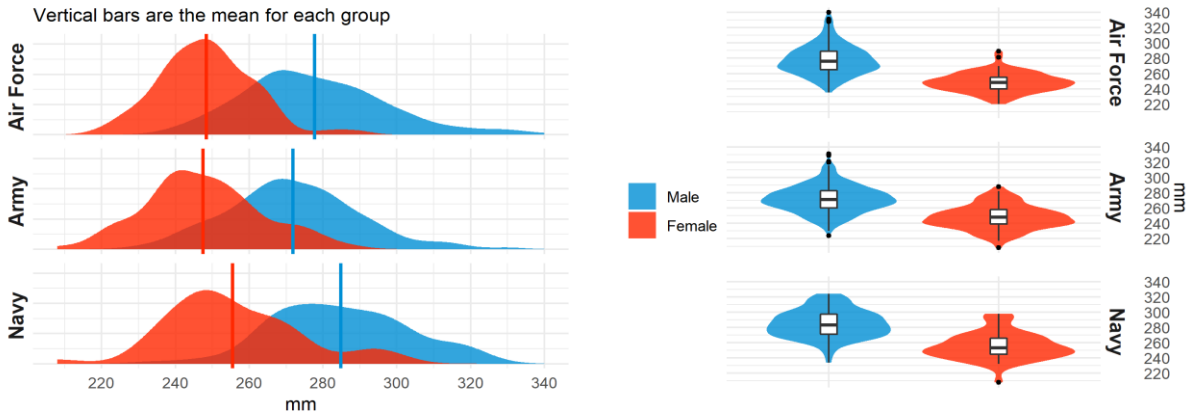




Ankle girth summary statistics- Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
275	278	272	285	**Mean**	248	248	255	249
19	19	18	18	**SD**	13	16	18	16
224	235	224	234	**Min**	220	208	208	208
340	340	331	324	**Max**	289	288	298	298
325	331	317	321	**P99**	284	282	298	291
318	327	314	319	**P98**	277	279	297	289
315	319	309	318	**P97**	270	278	295	282
309	312	302	317	**P95**	266	275	291	276
299	302	294	311	**P90**	264	270	276	270
294	298	290	302	**P85**	262	263	272	265
290	292	286	300	**P80**	259	259	269	262
286	289	283	297	**P75**	255	258	266	258
283	287	280	294	**P70**	254	254	264	256
281	284	278	292	**P65**	252	251	260	254
278	281	276	289	**P60**	251	251	256	251
276	278	273	286	**P55**	249	249	254	250
273	276	271	283	**P50**	248	248	253	248
271	273	269	281	**P45**	247	243	250	247
269	271	267	279	**P40**	245	241	250	245
267	268	265	277	**P35**	243	240	247	242
265	266	263	275	**P30**	241	240	246	241
263	265	260	271	**P25**	240	239	244	240
260	263	258	269	**P20**	239	236	242	238
256	258	254	266	**P15**	236	233	239	235
251	255	249	265	**P10**	234	227	237	232
245	249	243	261	**P5**	228	223	233	226
242	246	241	254	**P3**	226	222	232	223
240	244	238	248	**P2**	226	221	228	221
235	242	234	245	**P1**	224	217	218	217

Distribution plots for each service and gender



Arm span - Physical measurement (mm)

Measuring instrument:
This measure can be done in any number of ways. A clear section of wall is required that is flat and at least 2.5 m wide. A wall chart or blank sheet of paper (approximately 0.5 m x 1 m) can be temporarily fixed to the wall. The paper must be positioned 1.5 m from the left edge of the wall (it is rare to have someone an arm span of 1 m). A large whiteboard is also ideal. In the absence of a wall chart, paper, or a whiteboard then a pencil and rubber (to remove markings) will suffice.

Source:
ANSUR.

Definition:
The perpendicular distance between the dactylia of the left and right arms with the arms outstretched horizontally, i.e. the distance from the tip of the middle finger (dactylion) of one hand to the other.

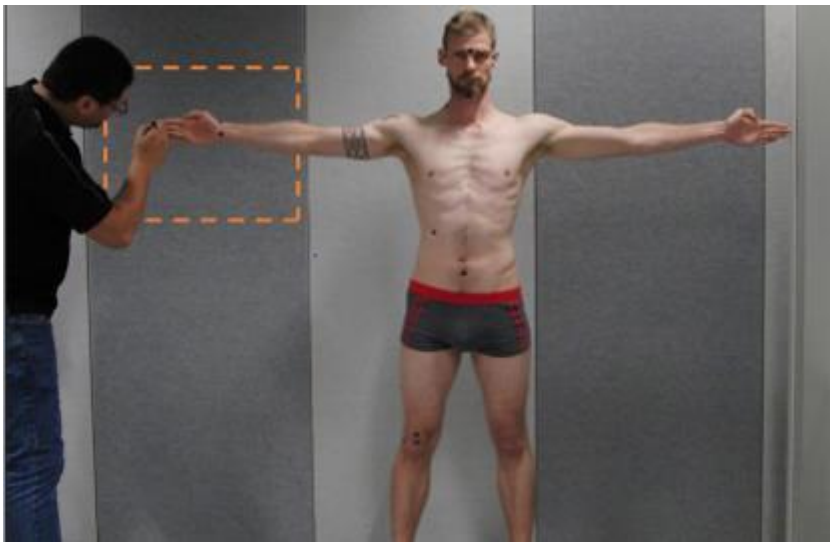
Landmark required:
None.

Posture required:
The participant stands erect against a wall with feet together, facing the clinician and with their arms raised to the horizontal (90 degree angle to the body). The heels, buttocks, and upper back, together with dorsal aspects of the arms should contact the wall. Participants stand with arms stretched out at. The left dactyllion will be pressed against the edge of the wall. The right dactylion should be in front of the wall chart, paper or whiteboard. The participant inspires maximally and will stretch out their arms while maintaining contact with the wall edge.

Procedure:
The assessor stands in front of the participants right hand. The assessor will prompt the participant to stretch as far as possible while the scribe holds the participant's right wrist. The measure will be taken by scribing a dot on the wall at the tip of the right dactylion. The participant will step away. With the scribe's assistance, a builder's tape is used to measure the distance of the marking from the edge of the wall. Measure to the nearest 0.1 cm. The easiest way to conduct this measurement is to have a chart strip attached to the wall close to a corner where one finger is placed. A non-permanent marker pen is used to mark the distance to the other finger.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

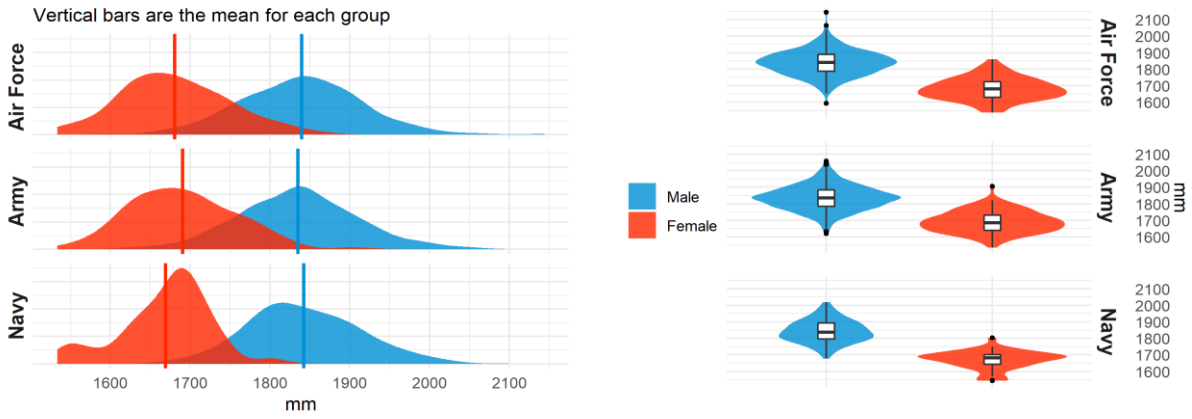
Notes:
Before taking the reading, with the tape stretched out, ask the participant to check if the tape is horizontal. Some rooms may have obstructions on the wall (e.g. coat hanger, window, shelf etc) that may affect the ability to take accurate measures. Note that individuals with a marked kyphosis cannot be measured accurately.



Arm span summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1837	1840	1835	1843	**Mean**	1681	1690	1669	1683
75	78	75	69	**SD**	68	66	56	65
1593	1593	1620	1678	**Min**	1538	1534	1544	1534
2144	2144	2058	2020	**Max**	1860	1906	1802	1906
2021	2034	2019	1998	**P99**	1831	1824	1780	1821
1998	2001	1994	1984	**P98**	1816	1820	1758	1818
1986	1982	1986	1978	**P97**	1813	1817	1747	1813
1965	1965	1963	1955	**P95**	1802	1797	1739	1795
1931	1929	1928	1934	**P90**	1761	1776	1726	1771
1910	1910	1910	1908	**P85**	1752	1766	1717	1751
1898	1900	1892	1901	**P80**	1737	1750	1709	1735
1885	1888	1883	1893	**P75**	1724	1732	1702	1721
1875	1877	1870	1878	**P70**	1713	1718	1696	1712
1862	1866	1857	1864	**P65**	1710	1711	1694	1706
1852	1857	1852	1857	**P60**	1688	1706	1689	1695
1844	1847	1842	1847	**P55**	1683	1695	1685	1687
1837	1841	1836	1837	**P50**	1680	1685	1681	1682
1828	1832	1828	1827	**P45**	1670	1675	1677	1672
1820	1823	1818	1818	**P40**	1660	1671	1666	1666
1810	1813	1808	1809	**P35**	1648	1658	1663	1656
1799	1800	1795	1804	**P30**	1639	1650	1647	1647
1787	1788	1785	1797	**P25**	1630	1638	1642	1636
1776	1775	1775	1791	**P20**	1627	1631	1631	1630
1763	1759	1761	1775	**P15**	1619	1624	1618	1620
1742	1743	1738	1765	**P10**	1608	1616	1585	1610
1719	1720	1718	1741	**P5**	1576	1591	1548	1576
1702	1699	1700	1725	**P3**	1556	1577	1545	1558
1680	1683	1679	1716	**P2**	1547	1571	1545	1545
1663	1671	1660	1701	**P1**	1541	1566	1544	1543

Distribution plots for each service and gender



Axilla height - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR.

Definition:
The vertical distance between a standing surface and the Anterior-Scye-on-the-Torso landmark.

Landmark required:
Axilla right landmark.

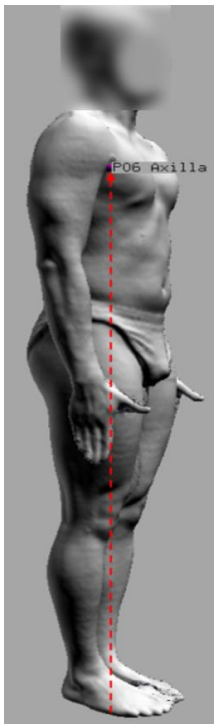
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

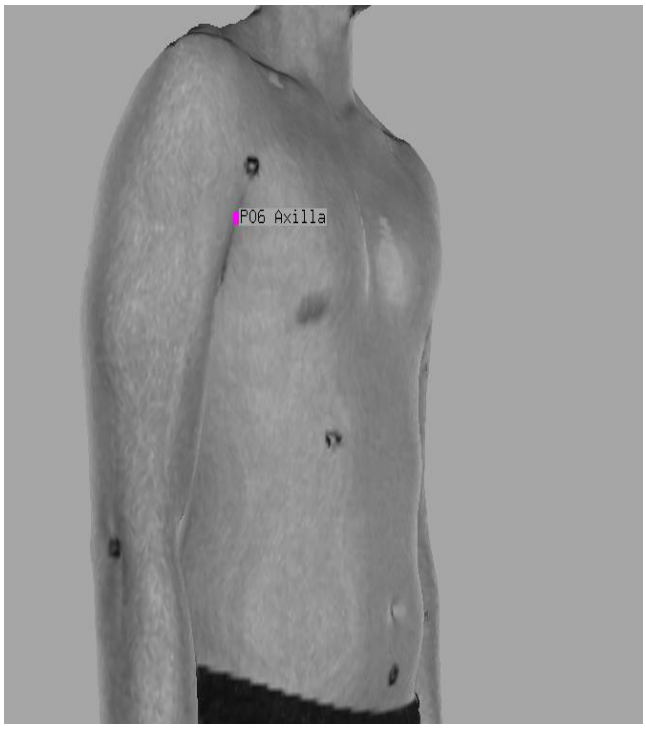
Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Axilla landmark (cavity beneath the junction of the arm and shoulder in the anterior aspect) in posture 1. Look for the stickered landmark. This landmark is generally missing, difficult to see or misplaced. As an aid, visualize a caliper branch coming up from the bottom of the armpit. Place the landmark point on the area of the arm where this branch would make contact. See Appendix A in Kolose, et. al. (2020). Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S. (p46).

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
None.

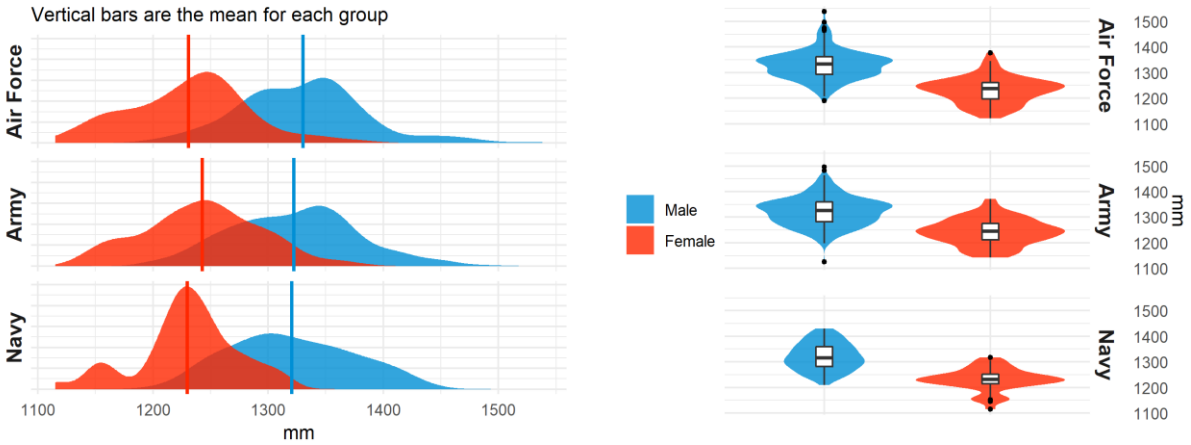




Axilla height summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
1324	1330	1322	1320	**Mean**	1231	1243	1230	1236
55	55	56	53	**SD**	52	51	44	50
1126	1190	1126	1209	**Min**	1122	1143	1115	1115
1538	1538	1495	1430	**Max**	1376	1372	1317	1376
1464	1474	1454	1427	**P99**	1354	1360	1312	1358
1448	1468	1444	1419	**P98**	1342	1350	1307	1344
1438	1451	1434	1414	**P97**	1337	1330	1305	1328
1416	1436	1415	1410	**P95**	1314	1316	1300	1312
1392	1390	1392	1393	**P90**	1291	1309	1285	1301
1377	1377	1376	1384	**P85**	1276	1295	1270	1287
1364	1367	1364	1366	**P80**	1263	1287	1263	1274
1360	1361	1359	1359	**P75**	1261	1275	1252	1265
1354	1356	1351	1354	**P70**	1257	1267	1249	1258
1346	1350	1345	1338	**P65**	1253	1257	1244	1253
1340	1343	1339	1335	**P60**	1247	1252	1239	1249
1334	1340	1333	1324	**P55**	1243	1251	1234	1244
1327	1333	1326	1315	**P50**	1237	1245	1231	1239
1316	1325	1315	1309	**P45**	1230	1241	1229	1233
1309	1314	1308	1302	**P40**	1222	1232	1224	1227
1301	1306	1299	1295	**P35**	1214	1223	1222	1220
1294	1300	1291	1288	**P30**	1210	1216	1216	1214
1284	1294	1282	1282	**P25**	1196	1211	1215	1209
1276	1285	1274	1274	**P20**	1183	1205	1205	1198
1266	1276	1261	1258	**P15**	1173	1184	1198	1175
1254	1267	1252	1252	**P10**	1157	1171	1163	1164
1237	1244	1234	1241	**P5**	1150	1158	1152	1152
1229	1233	1227	1237	**P3**	1144	1151	1147	1147
1218	1224	1218	1235	**P2**	1132	1150	1141	1144
1205	1215	1201	1231	**P1**	1124	1145	1128	1126

Distribution plots for each service and gender



Biacromial breadth - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ISAK, AWAS

Definition:
The point-to-point distance between the digitally extracted Acromion, Right and Acromion, Left landmarks. Note that despite the appearance of a contour distance in the figure, CySize extracts this measurement as a point-to-point distance.

Landmark required:
Acromiale Right and Acromiale Left landmarks.

Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
Identify and select the digital Acromiale Right and Acromiale Left landmarks. AWAS Section 7.2.8 of the Procedures Manual (Tomkinson et al., 2012). Measurements are reported in mm.

Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

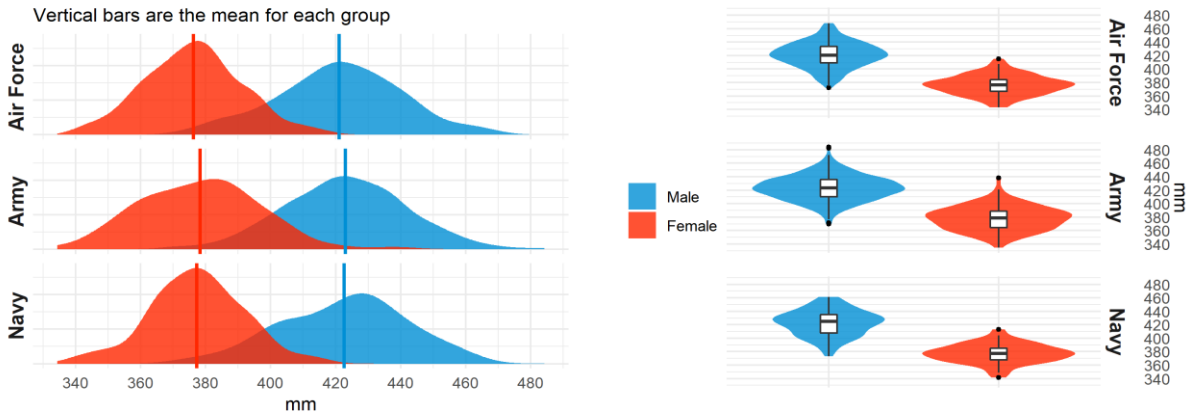
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
In the absence of a landmark, use knowledge of anatomical features to identify the correct location. For example, follow the ridge of the clavicle.

Biacromial breadth summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
422	421	423	423	**Mean**	376	378	377	377
19	19	19	19	**SD**	15	18	15	16
370	372	370	373	**Min**	343	334	342	334
484	468	484	461	**Max**	415	438	413	438
466	464	467	460	**P99**	410	422	409	415
460	460	460	458	**P98**	407	415	406	412
458	458	458	457	**P97**	406	410	403	407
454	451	454	453	**P95**	398	405	398	404
446	444	448	446	**P90**	396	402	394	397
441	441	442	443	**P85**	392	397	393	394
438	437	438	439	**P80**	389	393	389	391
435	434	436	435	**P75**	384	389	385	388
432	431	433	432	**P70**	383	388	384	385
430	429	430	430	**P65**	381	386	382	384
428	426	428	430	**P60**	380	384	380	381
425	424	425	428	**P55**	379	381	379	379
422	421	423	425	**P50**	376	378	377	377
420	420	421	421	**P45**	374	376	376	376
419	418	419	419	**P40**	373	374	374	374
416	415	416	418	**P35**	371	370	373	371
413	412	414	412	**P30**	369	368	370	368
410	409	410	408	**P25**	367	364	368	366
406	406	407	405	**P20**	364	362	366	363
403	401	404	402	**P15**	361	359	364	360
398	396	399	397	**P10**	358	356	362	357
390	387	393	390	**P5**	353	349	353	351
385	384	389	386	**P3**	350	347	350	348
383	382	384	381	**P2**	347	347	348	345
378	378	379	380	**P1**	344	344	345	343

Distribution plots for each service and gender



Bicep girth flexed - Physical measurement (mm)

Measuring instrument:
Anthropometric tape.

Source:
ISAK.

Definition:
The circumference of the arm perpendicular to the long axis of the arm at the level of the peak of the contracted Biceps Brachii when the upper arm is raised anteriorly to the horizontal.

Landmark required:
None.

Posture required:
The participant stands with the right shoulder and elbow flexed at a 90 degree angle to the body. The assessor stands on the right ride of the participant facing directly towards their outer bicep.

Procedure:
The measurement is taken at the widest point of the bicep when the muscle is at maximum tension. Ensure the tape applies light pressure or minimal skin indentation. Measurements are reported in mm.

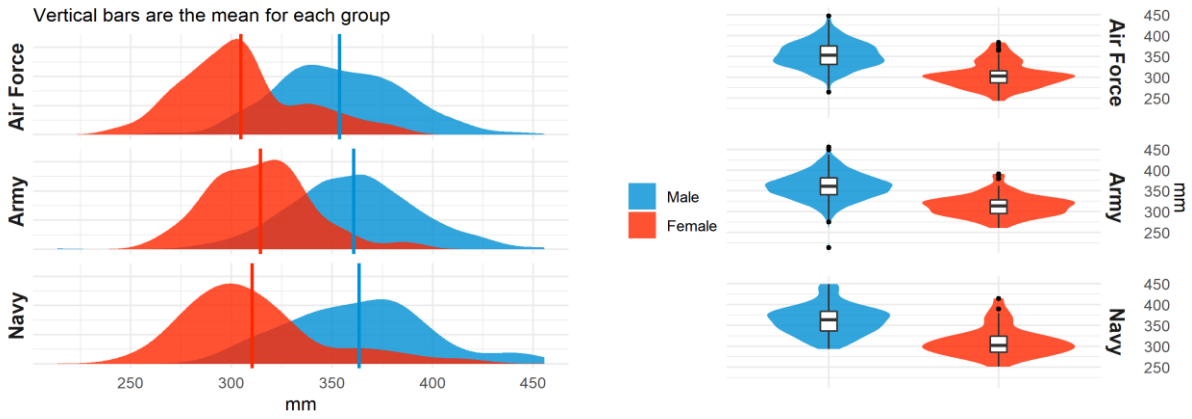
Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

Notes:
The measure can be taken either seated or standing depending on how tall the participant is relative to the assessor.
Check the tape follows the curvature of the skin, with minimal ‘gaps’ between the tape and the skin.

Bicep girth flexed summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
359	354	361	364	**Mean**	305	315	310	310
32	31	32	35	**SD**	30	25	34	29
214	264	214	294	**Min**	242	260	251	242
456	447	456	449	**Max**	384	391	415	415
438	427	435	446	**P99**	379	387	404	389
429	415	426	445	**P98**	374	380	394	383
422	414	422	442	**P97**	369	364	387	379
415	406	416	431	**P95**	360	356	379	363
401	394	402	403	**P90**	345	343	362	352
390	386	392	393	**P85**	339	334	337	337
385	381	386	386	**P80**	332	332	327	332
381	375	382	384	**P75**	316	328	324	326
376	371	376	381	**P70**	312	326	318	324
370	367	371	378	**P65**	309	324	315	317
367	362	368	375	**P60**	306	322	311	314
364	356	365	367	**P55**	304	315	307	310
359	352	361	364	**P50**	302	314	302	307
355	348	356	360	**P45**	300	311	301	304
350	342	352	354	**P40**	295	309	297	301
346	340	348	349	**P35**	292	302	296	296
342	336	345	345	**P30**	287	300	293	294
337	330	341	336	**P25**	286	296	286	291
332	328	336	334	**P20**	280	293	285	286
327	324	329	326	**P15**	275	289	280	282
320	316	322	317	**P10**	269	286	275	275
306	304	309	308	**P5**	266	277	270	268
303	302	304	305	**P3**	259	271	265	265
298	301	298	304	**P2**	254	270	261	261
290	292	290	301	**P1**	249	267	256	252

Distribution plots for each service and gender



Bideltoid breadth sitting - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ANSUR, NZDFAS

Definition:
The maximum horizontal distance between the lateral margins of the upper arms on the deltoid muscles.

Landmark required:
None. This is performed using the Caliper function of CySize.

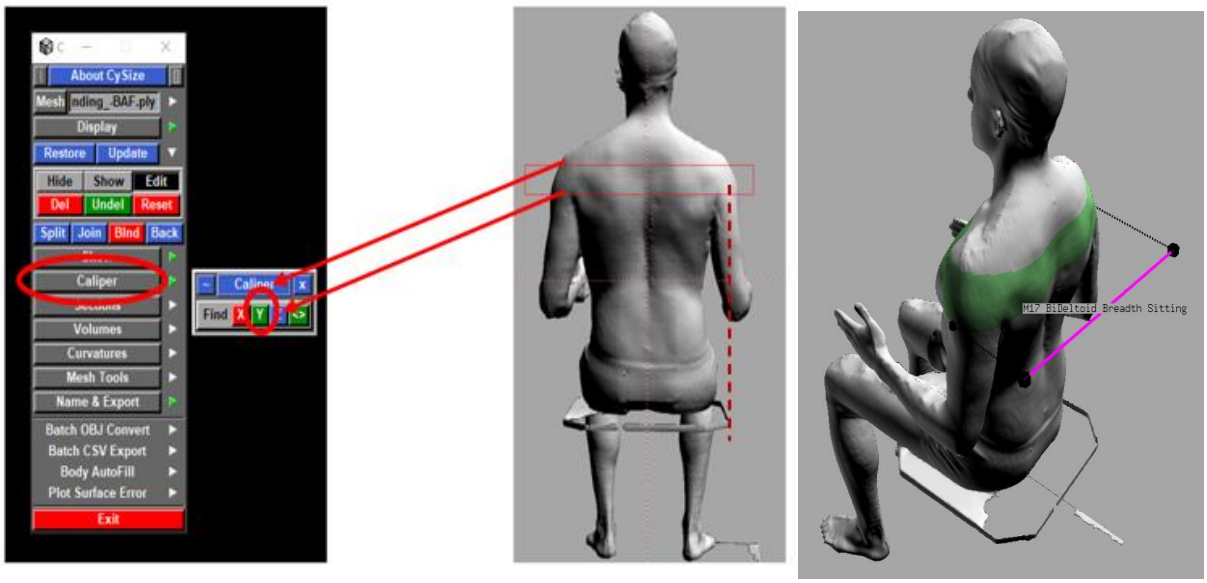
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot). Ensure that the arms (triceps when viewed posteriorly) are hanging vertically (as much as possible).

Procedure:
In CySize use the caliper tool. This can be viewed from the front or the back of the participant. Highlight a horizontal line that is lower than the Acromiale but higher than the Axilla landmarks. Select the Y function (to create a coronal plane) to calculate and record the breadth. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

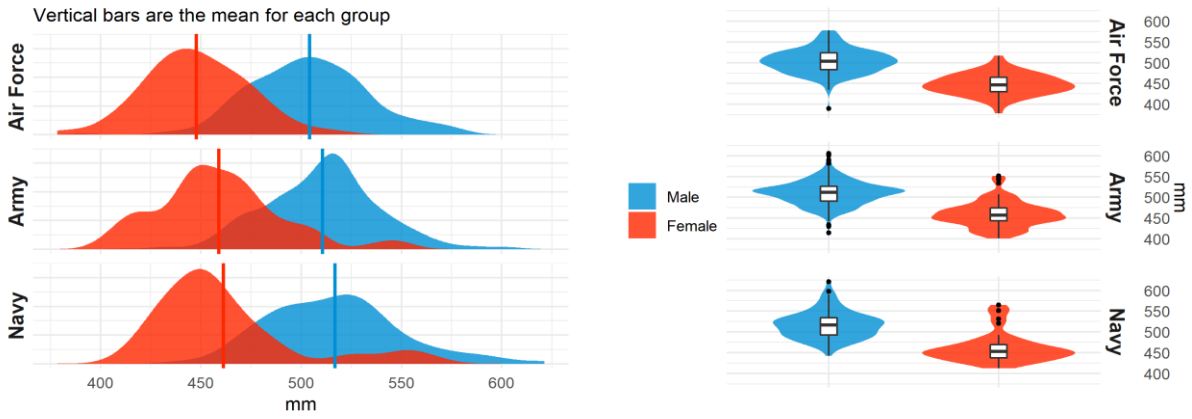
Notes:
Use the Crosshair tool to align the participant. Another method is to view the participant from the side view, then highlight a square rectangle on the around the most lateral centre of the deltoid.



Bideltoid breadth sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
510	504	511	517	**Mean**	448	459	461	456
29	29	28	33	**SD**	26	31	36	31
390	390	414	442	**Min**	378	401	412	378
621	578	606	621	**Max**	518	552	564	564
588	575	587	600	**P99**	508	548	559	551
575	569	571	592	**P98**	500	544	554	547
567	562	565	590	**P97**	493	536	551	533
560	557	557	576	**P95**	488	507	549	507
547	543	546	560	**P90**	478	498	515	493
537	531	538	547	**P85**	474	489	485	482
531	527	532	538	**P80**	470	479	477	475
527	524	526	534	**P75**	465	475	470	471
523	518	523	530	**P70**	461	470	466	467
519	514	520	528	**P65**	458	467	461	464
516	511	517	527	**P60**	452	465	458	458
514	507	515	518	**P55**	449	460	455	455
511	504	512	516	**P50**	447	457	453	452
507	500	510	511	**P45**	443	453	450	449
503	496	505	509	**P40**	441	449	448	447
498	493	502	499	**P35**	436	446	446	444
495	490	497	496	**P30**	434	444	444	440
490	484	491	493	**P25**	430	443	437	436
485	479	488	490	**P20**	427	436	436	430
478	473	480	483	**P15**	424	427	432	427
472	469	473	477	**P10**	419	419	427	420
464	462	465	471	**P5**	410	414	425	412
460	457	461	466	**P3**	406	410	421	410
454	453	454	464	**P2**	399	408	419	406
442	436	450	460	**P1**	390	405	415	401

Distribution plots for each service and gender



Bitragion mandibular arc - Physical measurement (mm)

Measuring instrument:
Anthropometric tape. Before measuring, ensure that the metal tape surface is not damaged and the scale is clear, and the tape can be retracted freely. There are various models. Tapes used in the NZDFAS were Cesorf and Rosscraft. Measurements are in mm.

Source:
ANSUR.

Definition:
The surface distance between the right and left tragion landmarks across the submandibular landmark is measured with a tape. The head is in the Frankfort plane, and the teeth are lightly occluded.

Landmarks required:
Tragion left and right, Submandibular.

Posture required:
Sitting. The measure can also be taken while standing depending on the height of the assessor relative to the participant.

Procedure:
The participant sits erect, looking straight ahead with any headwear/eyewear removed. The assessor stands in front and slightly to the side of the participant. With the thumb and index finger place the 0 point of the tape against the Tragion right landmark (the 0 rests in the middle of the landmark sticker). The assessor uses their left thumb to hold the tape to the skin (at the 0 point) and extends the tape under the throat towards the Tragion right landmark. The opposite index finger is used to hold the tape to Tragion left. The measure is read from the scale pressed on Tragion Right. The centre of the tape must run through the Submandibular landmark. Measure to the nearest mm.

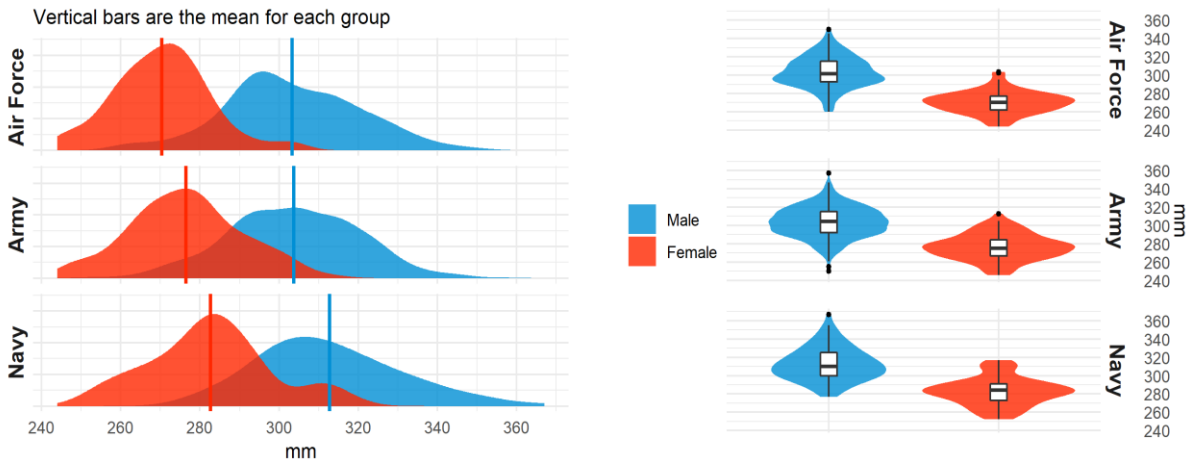
Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Notes:
The position of the head has no influence on the measurement. Ensure that the jaw is still and the head is in the Frankfort plane. Take care when placing the tape against the skin.

Bitragion mandibular arc summary statistics - Physical measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
305	303	304	313	**Mean**	270	276	283	276
17	17	17	18	**SD**	12	14	15	14
250	260	250	277	**Min**	244	246	252	244
367	350	357	367	**Max**	304	313	317	317
346	343	343	357	**P99**	303	305	315	312
340	337	336	352	**P98**	299	304	313	310
336	335	334	350	**P97**	294	303	312	305
333	330	330	346	**P95**	290	300	311	301
325	325	325	337	**P90**	283	295	305	294
323	322	320	331	**P85**	281	292	295	290
320	317	318	327	**P80**	280	290	293	285
315	315	315	325	**P75**	277	284	291	284
315	312	314	320	**P70**	275	284	289	281
311	310	310	318	**P65**	275	280	285	280
309	306	308	315	**P60**	273	280	285	279
305	305	305	312	**P55**	272	278	285	277
304	301	304	310	**P50**	270	275	284	275
302	300	301	310	**P45**	270	275	280	274
300	297	300	307	**P40**	267	273	280	271
296	295	296	304	**P35**	265	270	279	270
295	295	295	301	**P30**	265	270	276	268
293	293	292	300	**P25**	262	266	273	266
290	290	290	300	**P20**	260	265	269	265
288	288	287	295	**P15**	259	263	268	260
284	284	284	292	**P10**	256	260	261	259
275	275	275	286	**P5**	251	252	259	252
274	271	273	283	**P3**	247	250	256	250
270	265	270	282	**P2**	246	248	255	248
265	263	265	280	**P1**	245	247	254	246

Distribution plots for each service and gender



Bizygomatic breadth - Physical measurement (mm)

Measuring instrument:
Small bone caliper. The Rosscraft small bone caliper is 18 cm with pressure plates that are 10 mm diameter. Before measuring, the distance between the plates when touching should be verified as 0 cm to ensure it has been assembled correctly.

Source:
ANSUR.

Definition:
The maximum horizontal breadth between the most lateral aspects of the Zygons left and right.

Landmark required:
Zygon left and right.

Posture required:
The participant sits erect, looking straight ahead with glasses removed.

Procedure:
The assessor stands in front and slightly to the side of the participant. This measurement can be taken sitting or standing depending on the height of the assessor relative to the participant. The caliper is placed at a 45° angle. Opening the caliper beyond the anticipated distance, rest the device on the back of the hands and using the thumbs and index fingers, use the long finger (middle finger) to palpate the skin and visually identifying the most lateral aspect of the Zygion Left and Zygion Right. When identified, slowly move the plates towards one another until they rest on this point. Record the measurement to 0.1 cm or 0.05 cm precision.

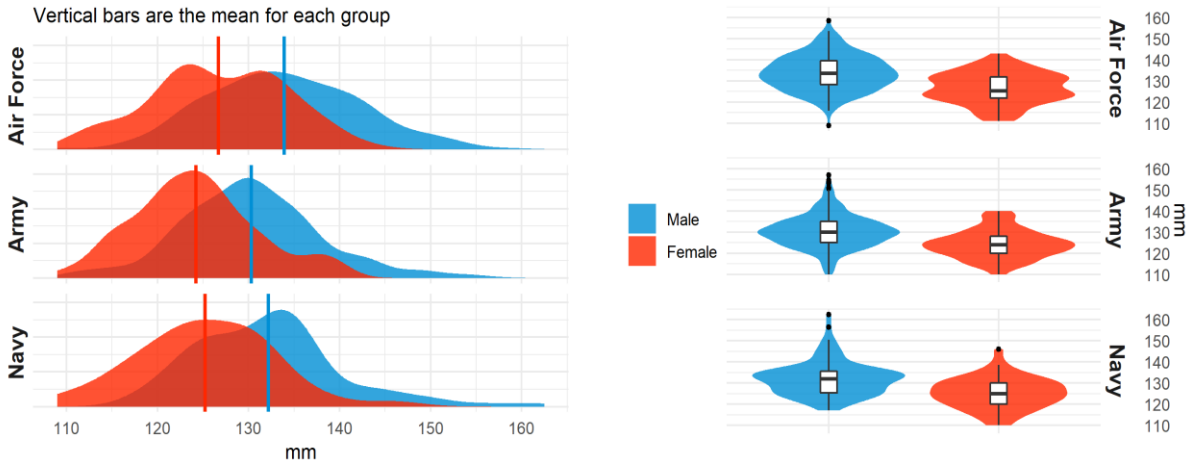
Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Notes:
The caliper branches must be placed on the skin, but not indent the skin. The position of the head has no influence on the measurement. If the participant's Zygion distance is greater than the length of the small bone caliper considering using the large sliding caliper. For the NZDFAS, the small bone caliper was used instead of the large sliding caliper (more traditional tool for this measurement) as the assessor had a greater level of control and avoided potential injuries to the eye (sharp end of the large sliding caliper prongs).

Bizygomatic breadth summary statistics - Physical measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
131	134	130	132	**Mean**	127	124	125	125
8	8	8	8	**SD**	7	7	7	7
109	109	110	117	**Min**	111	110	110	110
162	158	157	162	**Max**	143	140	146	146
153	153	151	157	**P99**	141	140	143	140
150	152	149	152	**P98**	139	139	140	139
149	150	148	150	**P97**	139	138	138	139
145	148	144	147	**P95**	138	138	136	138
142	144	140	143	**P90**	136	132	133	134
140	143	137	137	**P85**	134	132	132	132
138	141	136	136	**P80**	133	129	130	132
136	140	135	136	**P75**	132	128	130	130
135	138	134	135	**P70**	131	127	130	130
134	137	132	134	**P65**	130	126	129	128
133	136	132	134	**P60**	130	126	127	126
132	135	131	132	**P55**	128	125	126	126
131	134	130	132	**P50**	125	124	125	125
130	132	129	132	**P45**	125	123	124	124
129	132	128	130	**P40**	125	122	124	123
128	130	128	129	**P35**	123	122	123	122
127	129	126	128	**P30**	123	120	122	122
126	128	125	125	**P25**	122	120	120	120
125	126	124	125	**P20**	122	119	119	120
124	125	123	125	**P15**	120	117	118	118
122	124	121	123	**P10**	117	115	116	115
120	122	118	121	**P5**	114	114	115	114
117	120	115	120	**P3**	113	114	111	113
115	118	114	120	**P2**	112	113	110	111
112	117	112	119	**P1**	112	110	110	110

Distribution plots for each service and gender



Body height - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
Vertical height from standing surface to the visual top of the head. The vertical distance is measured between the standing surface and the top of the head.

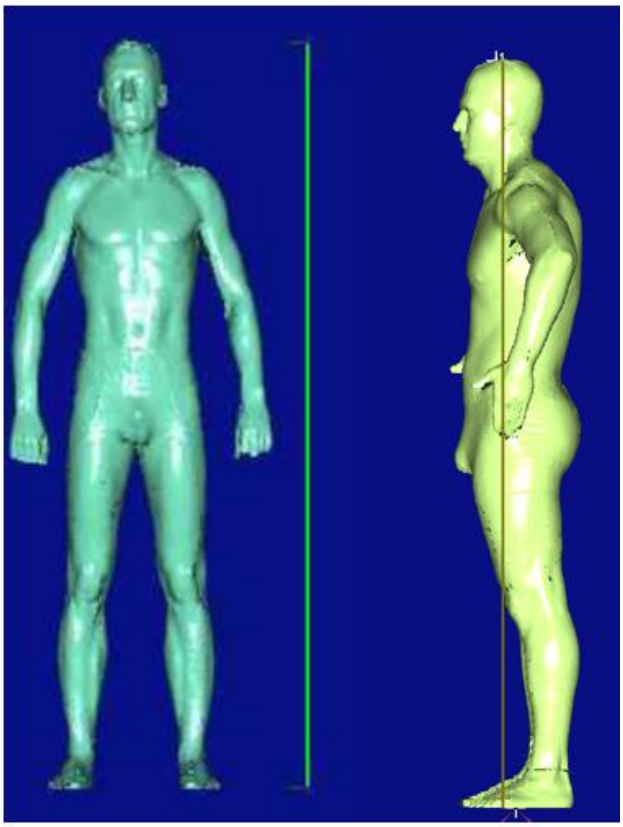
Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

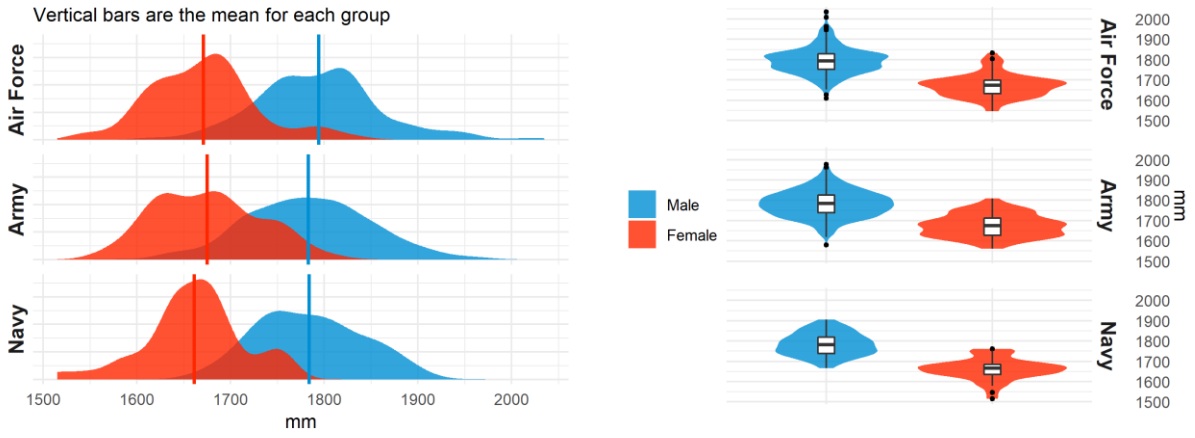
Notes:
Check that the head is in the Frankfort position. If not, the height is measured near the rear of the head, then remove this measure. Anthroscan takes body height with legs positioned shoulder-width apart. Traditional protocols have legs and feet together. The Anthroscan method was used to represent a more 'natural' standing position.
Eye height (Ectocantus) in CySize is taken from the Posture 1 (feet together position).



Body height summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1786	1794	1783	1784	**Mean**	1671	1675	1661	1671
65	67	66	56	**SD**	57	56	53	55
1579	1609	1579	1666	**Min**	1546	1561	1515	1515
2035	2035	1977	1905	**Max**	1832	1810	1761	1832
1954	1962	1941	1899	**P99**	1812	1796	1758	1803
1930	1953	1918	1887	**P98**	1799	1786	1754	1793
1915	1937	1908	1883	**P97**	1793	1773	1753	1785
1897	1918	1891	1876	**P95**	1789	1763	1753	1762
1868	1877	1868	1858	**P90**	1732	1753	1731	1753
1851	1851	1851	1851	**P85**	1715	1746	1704	1731
1836	1833	1842	1833	**P80**	1699	1730	1696	1712
1825	1828	1825	1820	**P75**	1698	1713	1684	1699
1818	1825	1818	1811	**P70**	1696	1699	1681	1698
1811	1818	1810	1804	**P65**	1690	1698	1676	1689
1803	1811	1801	1801	**P60**	1681	1687	1674	1681
1793	1803	1793	1786	**P55**	1681	1681	1673	1674
1785	1793	1785	1782	**P50**	1674	1674	1666	1674
1778	1785	1773	1771	**P45**	1666	1667	1658	1666
1764	1777	1764	1763	**P40**	1658	1655	1651	1652
1760	1764	1755	1753	**P35**	1647	1643	1646	1644
1752	1760	1746	1746	**P30**	1641	1634	1641	1638
1739	1753	1738	1739	**P25**	1632	1627	1634	1633
1731	1745	1723	1739	**P20**	1620	1626	1634	1626
1720	1731	1713	1731	**P15**	1616	1618	1616	1618
1706	1720	1705	1713	**P10**	1608	1609	1597	1608
1683	1691	1676	1706	**P5**	1597	1592	1580	1587
1667	1677	1656	1690	**P3**	1581	1585	1556	1579
1652	1668	1644	1684	**P2**	1560	1578	1542	1563
1639	1653	1633	1673	**P1**	1547	1569	1528	1547

Distribution plots for each service and gender



Breast height - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
The vertical height of the front breast/chest circumference level (code 4510 or 4515) to the standing surface.

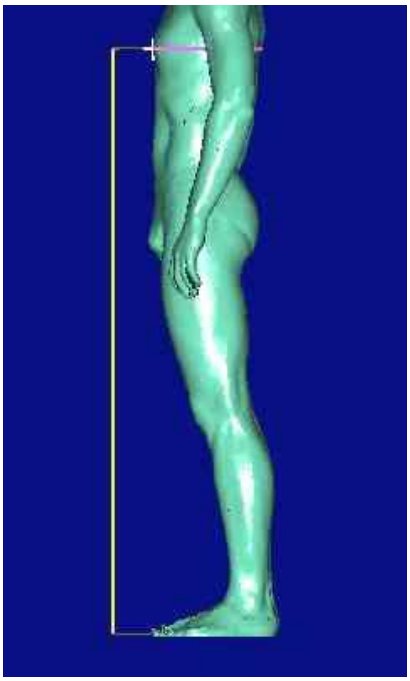
Landmark required:
None.

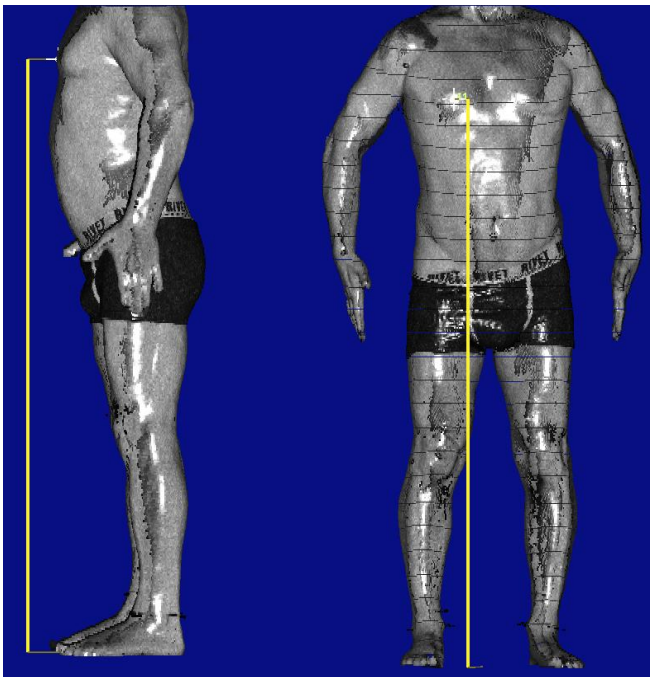
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
None.

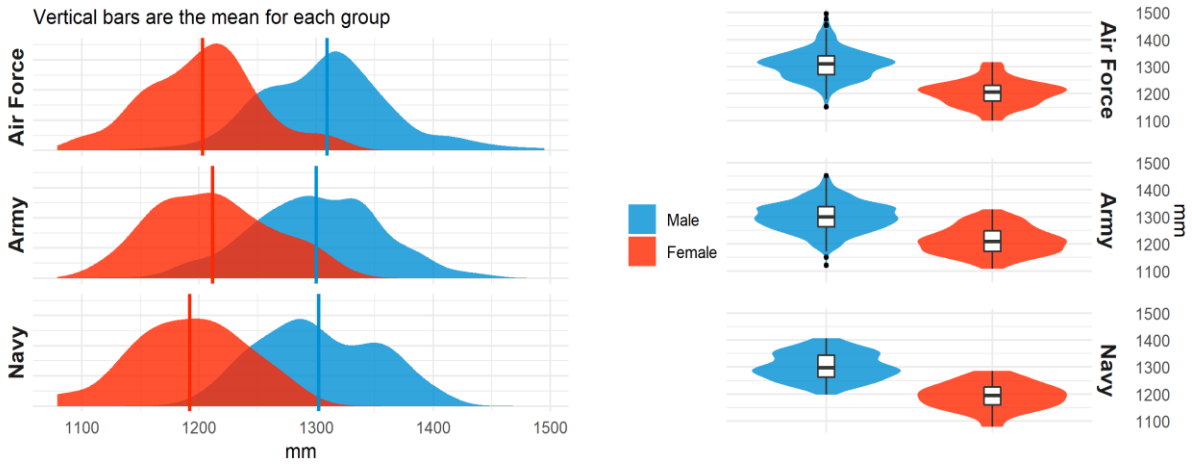




Breast height summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1303	1309	1300	1302	**Mean**	1203	1212	1192	1205
54	55	55	50	**SD**	48	50	48	49
1121	1151	1121	1198	**Min**	1100	1108	1079	1079
1495	1495	1451	1406	**Max**	1317	1327	1285	1327
1434	1454	1427	1400	**P99**	1315	1314	1280	1314
1421	1436	1410	1398	**P98**	1308	1304	1276	1303
1407	1427	1397	1397	**P97**	1300	1303	1272	1301
1393	1409	1390	1384	**P95**	1290	1299	1266	1294
1371	1373	1371	1366	**P90**	1256	1286	1257	1272
1357	1360	1353	1361	**P85**	1245	1270	1240	1256
1345	1346	1343	1358	**P80**	1234	1256	1233	1247
1339	1339	1338	1344	**P75**	1230	1249	1226	1234
1334	1333	1332	1336	**P70**	1227	1237	1218	1229
1325	1323	1325	1325	**P65**	1223	1226	1211	1223
1317	1321	1317	1307	**P60**	1216	1222	1207	1216
1310	1315	1307	1303	**P55**	1211	1214	1202	1211
1303	1310	1300	1298	**P50**	1205	1209	1195	1206
1296	1307	1293	1292	**P45**	1200	1206	1186	1198
1289	1299	1287	1285	**P40**	1195	1195	1179	1192
1281	1288	1279	1280	**P35**	1187	1186	1170	1182
1274	1280	1272	1274	**P30**	1179	1179	1168	1175
1264	1271	1263	1263	**P25**	1172	1172	1160	1169
1256	1262	1255	1257	**P20**	1158	1168	1151	1160
1247	1252	1244	1245	**P15**	1154	1158	1146	1154
1234	1245	1230	1242	**P10**	1144	1153	1134	1144
1213	1231	1206	1227	**P5**	1131	1137	1123	1130
1199	1211	1194	1223	**P3**	1107	1128	1095	1119
1193	1209	1189	1217	**P2**	1102	1122	1085	1104
1180	1184	1180	1208	**P1**	1101	1118	1082	1100

Distribution plots for each service and gender



Bust chest girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
The circumference of the chest is measured across the Bust Point (females) or Thelion (males) landmarks. The circumference is measured parallel to the standing surface.

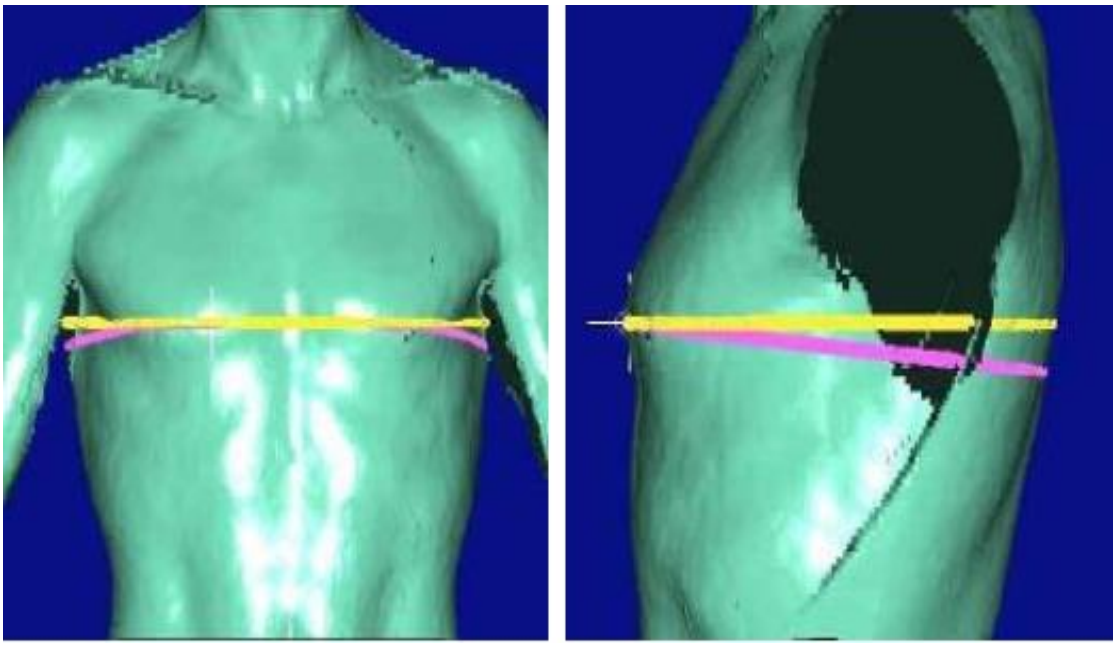
Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
The Thelion (nipple) or bust point (most anterior point of bra/bust) is located visually. For males, it is the centre of right nipple. For females, eyeball most anterior point from the side. Then add 'X-loop' to identify the most protruding point within that area. This is difficult especially with females with thick pad bras. See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

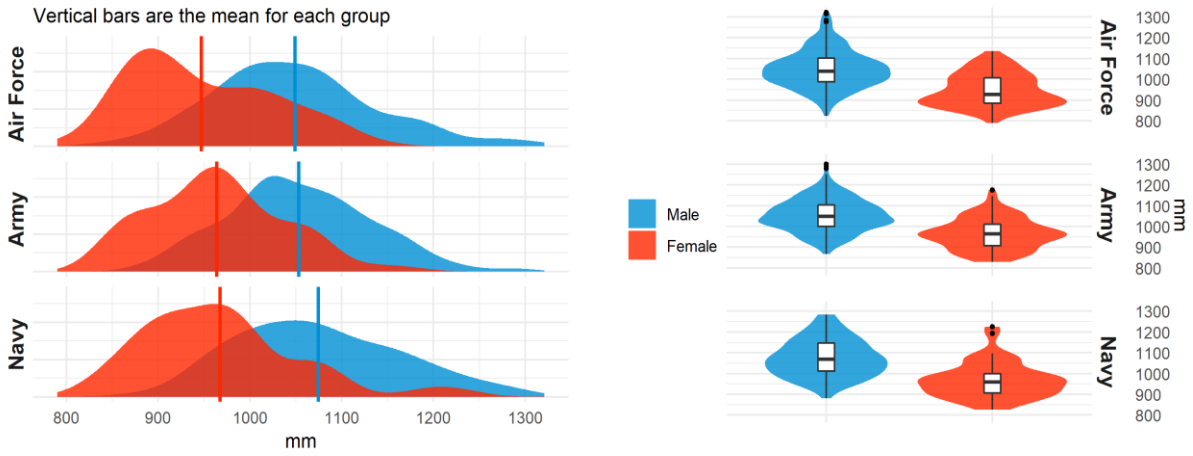
Notes:
Check that the digital tape (yellow line below) is horizontal and that it does not pass around the left and right arms. If so, skip this measure. Ensure that the arms are abducted sufficiently away from the body. This must be explained clearly during the posturing phase.



Bust chest girth summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
1054	1049	1053	1075	**Mean**	947	964	967	959
83	91	79	89	**SD**	79	73	86	78
824	824	867	880	**Min**	790	829	827	790
1321	1321	1300	1285	**Max**	1136	1174	1226	1226
1281	1283	1248	1282	**P99**	1110	1147	1212	1171
1244	1274	1217	1271	**P98**	1096	1121	1198	1132
1219	1250	1203	1252	**P97**	1089	1092	1167	1099
1196	1203	1180	1228	**P95**	1085	1071	1095	1085
1165	1176	1157	1198	**P90**	1065	1067	1070	1067
1145	1142	1138	1165	**P85**	1035	1049	1064	1045
1123	1116	1120	1152	**P80**	1026	1025	1015	1025
1105	1101	1104	1146	**P75**	1006	1011	1000	1008
1094	1082	1094	1120	**P70**	993	991	991	992
1080	1074	1081	1096	**P65**	983	981	986	982
1070	1064	1069	1088	**P60**	962	974	972	973
1061	1056	1061	1076	**P55**	940	970	969	963
1048	1038	1048	1070	**P50**	928	963	958	954
1037	1027	1037	1057	**P45**	920	954	955	941
1026	1021	1027	1042	**P40**	908	947	935	930
1019	1009	1020	1030	**P35**	898	937	924	922
1009	996	1012	1017	**P30**	891	929	919	907
998	988	1000	1012	**P25**	884	907	906	897
987	980	989	994	**P20**	877	897	896	886
966	959	966	977	**P15**	872	880	887	875
949	942	954	963	**P10**	857	870	872	864
925	920	928	948	**P5**	848	853	857	850
914	894	917	942	**P3**	847	845	848	845
902	883	910	936	**P2**	844	845	842	843
883	865	887	925	**P1**	826	842	835	830

Distribution plots for each service and gender



Buttock depth - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
UK Anthropometry Survey, NZDFAS

Definition:
The maximum circumference of the body (excluding the appendages) at approximately hip height. This measure must be taken below the height of the iliac crest in Anthroscan.

Landmark required:
None as the caliper function is used.

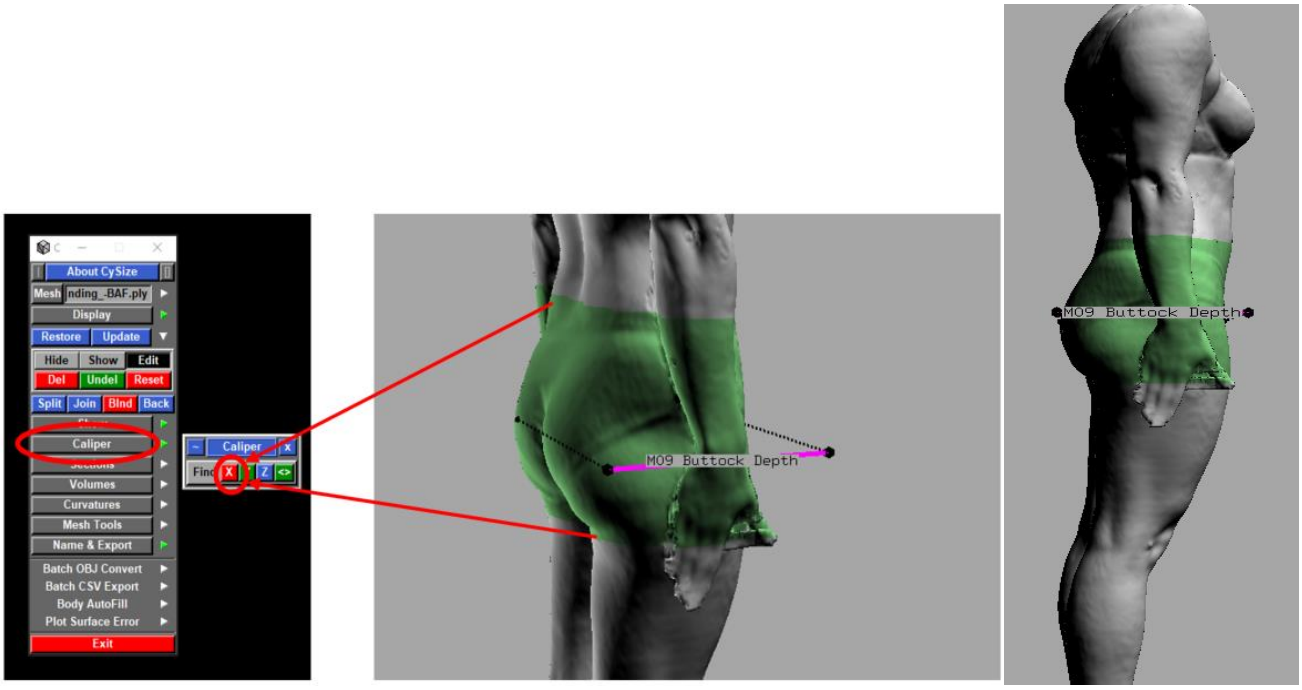
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
In CySize use the caliper tool. When viewed from the side, highlight the area of the buttocks that is above the height of the crotch and below the level of the Iliocristale right (most superior point on iliac crest) landmark. If the landmark is not present, this point can still be identified depending on bone structure and body type of the participant (e.g. lean). Avoid any artefacts of webbing between the right hand and the thigh. Select the X function (to create a coronal plan) to record the depth. Measurements are reported in mm.

Reference:
Pringle, R. H., Puxley, A. J., Puxley, K. P. M., Turner, G. M., & Tyrell, A. K. (2011). Anthropometry Survey of UK Military Personnel 2006-7 (Issue 3) (QINETIQ/07/01821/3.0): QinetiQ Ltd.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

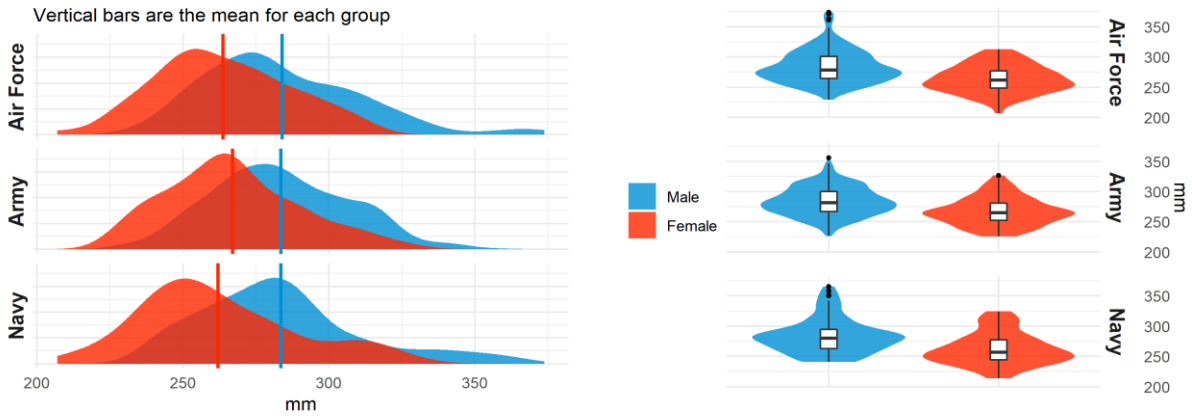
Notes:
Use the Crosshair tool to align the participants posture. If the measurement is taken on a fold or crease in the briefs, consider remeasuring. If the anterior portion of the measure is taken on the male genitalia make minor adjustments to move the point away.



Buttock depth summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
284	284	284	284	**Mean**	264	267	262	265
25	27	24	28	**SD**	23	23	27	24
227	229	227	241	**Min**	207	226	214	207
374	374	356	365	**Max**	313	327	325	327
356	370	341	359	**P99**	309	322	321	321
341	362	332	353	**P98**	307	315	317	314
335	343	327	351	**P97**	307	313	315	313
326	330	322	340	**P95**	305	309	313	309
317	320	315	324	**P90**	296	299	307	297
311	311	311	311	**P85**	290	291	289	291
305	307	305	300	**P80**	285	288	281	285
300	301	300	295	**P75**	277	281	277	279
295	296	296	291	**P70**	276	276	274	276
291	292	291	288	**P65**	273	271	265	271
287	286	288	286	**P60**	269	269	262	268
283	281	285	283	**P55**	264	267	259	265
281	279	282	280	**P50**	262	265	257	263
278	276	279	278	**P45**	257	263	255	260
275	274	276	276	**P40**	255	262	253	256
272	272	272	272	**P35**	254	257	248	255
269	268	270	267	**P30**	250	254	247	252
266	265	267	263	**P25**	248	252	244	248
262	260	264	261	**P20**	246	247	241	245
258	257	258	257	**P15**	241	242	239	241
253	253	253	249	**P10**	235	238	233	237
247	248	248	244	**P5**	230	233	230	231
244	244	244	243	**P3**	227	231	220	229
241	242	240	242	**P2**	226	231	216	226
236	239	235	241	**P1**	220	230	215	218

Distribution plots for each service and gender



Buttocks girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan

Definition:
The circumference is measured at the height of the most posteriorly protruding surface of the buttocks when gluteal muscles are relaxed. The circumference is measured parallel to the standing surface.

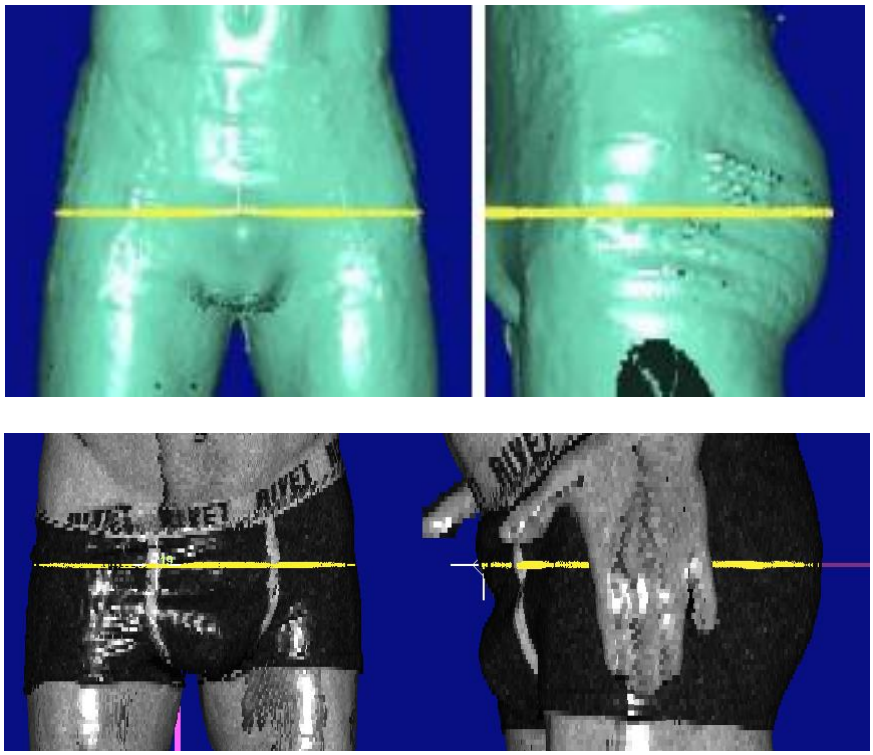
Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward. Measurements are reported in mm.

Procedure:
See Section 6 of Human Solutions (2015).

Reference
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

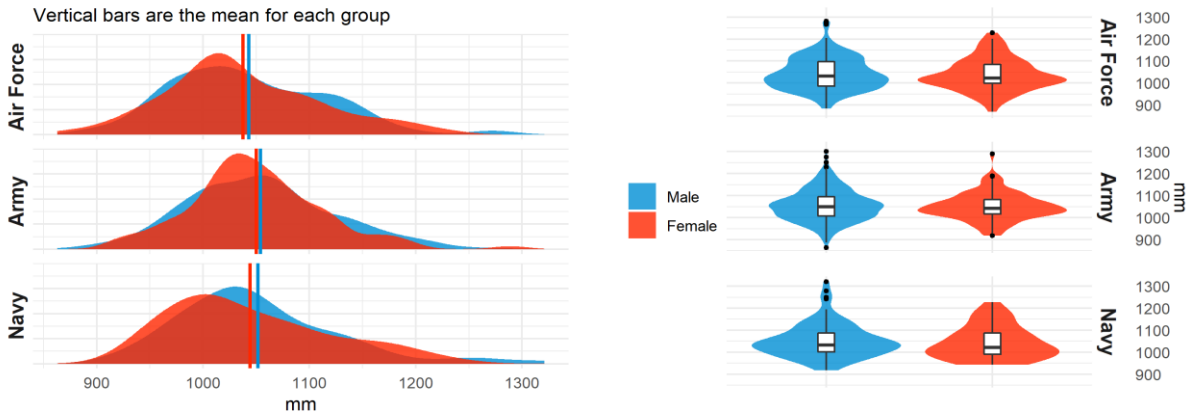
Notes:
Check that the digtial tape is horizontal and that it does not pass around the hands.



Buttocks girth summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
1051	1043	1054	1052	**Mean**	1037	1050	1044	1045
72	74	70	77	**SD**	73	62	75	69
863	884	863	917	**Min**	870	919	944	870
1321	1281	1301	1321	**Max**	1228	1289	1228	1289
1254	1268	1226	1284	**P99**	1209	1193	1211	1225
1214	1199	1211	1258	**P98**	1196	1188	1195	1189
1200	1183	1200	1245	**P97**	1187	1178	1189	1188
1175	1155	1178	1188	**P95**	1176	1162	1186	1174
1144	1138	1148	1143	**P90**	1138	1122	1159	1132
1128	1126	1129	1125	**P85**	1114	1112	1124	1117
1111	1109	1114	1108	**P80**	1088	1099	1110	1097
1096	1098	1096	1088	**P75**	1084	1082	1086	1085
1082	1080	1084	1072	**P70**	1075	1072	1074	1073
1071	1065	1074	1064	**P65**	1054	1067	1069	1064
1063	1053	1066	1057	**P60**	1036	1060	1051	1053
1053	1040	1058	1046	**P55**	1028	1051	1032	1040
1045	1031	1050	1033	**P50**	1023	1042	1022	1035
1035	1022	1044	1030	**P45**	1018	1039	1020	1025
1026	1018	1032	1029	**P40**	1014	1035	1011	1021
1018	1008	1021	1022	**P35**	1008	1024	1000	1017
1010	999	1012	1008	**P30**	1004	1021	994	1009
1001	987	1007	1001	**P25**	998	1017	990	1002
989	977	995	987	**P20**	986	1009	986	991
977	969	982	979	**P15**	962	992	965	982
966	962	971	972	**P10**	954	974	955	960
948	945	949	949	**P5**	928	960	954	948
933	925	935	944	**P3**	921	933	947	930
918	916	921	933	**P2**	911	930	945	925
903	897	903	918	**P1**	895	927	944	919

Distribution plots for each service and gender



Buttock-heel length - Physical measurement (mm)

Measuring instrument:
Standard builders' tape, two measurement plates (or Rosscraft headboard plates).

Source:
Canadian Land Forces Survey 1997.

Definition:
The distance between the most posterior aspect of the buttock (right leg and sitting) to the inferior-posterior aspect of the calcaneus.

Landmark required:
None.

Posture required:
The participant sits on the floor with their right leg outstretched with toes pointing towards the ceiling. The posterior aspect of the buttock is against the wall (as much as physically possible). For increased comfort, the left leg can be folded while waiting for the measurement to start. During the time of measurement, the participant is required to sit erect with their hands resting on their thighs.

Procedure:
The assessor kneels beside the participant and in front of the foot. The scribe will be in the same osition but next to the hip region. Both participant and assessor are facing the same direction.

The scribe will place one plate perpendicular to the most posterior aspect of the buttock (not the wall). The assessor will place a second plate perpendicular to the heel of the outstretched foot. The flat 'zero' mark of the tape is pressed firmly against the plate near the buttock. The assessor will place the second plate against the heel with the edge resting (foot side) of the tape. The participant is prompted to *"please sit up straight, right leg flat to the floor and point your right foot to the ceiling*". A reading is taken immediately after the prompt to avoid physical discomfort. Measure to the nearest 0.1 cm.

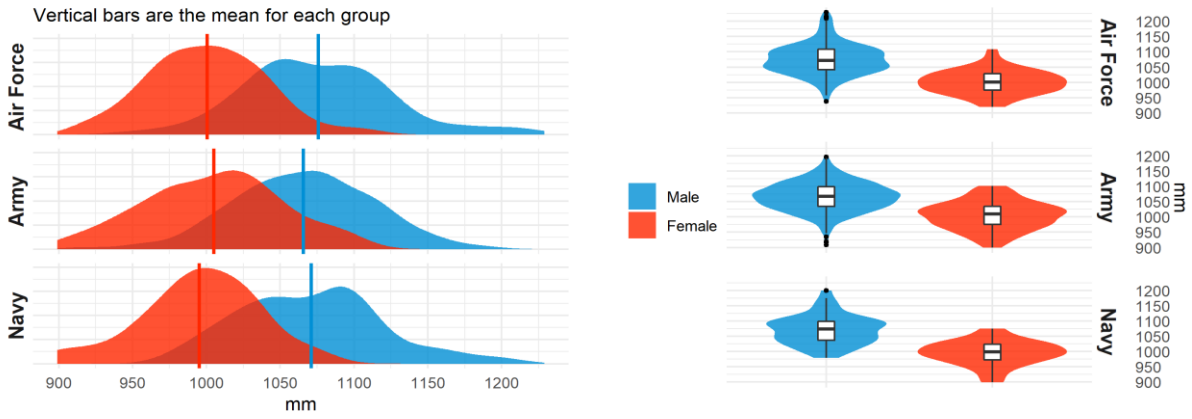
Reference:
Chamberland, A., Carrier, R., Forest, F. and Hachez, G. (1998). *1997 Anthropometric Survey of the Land Forces. Final Report.* 1998, Department of National Defence, Canada.: Ontario, Canada. p. DCIEM-98-CR-15.

Notes:
It is important that both measurement plates are held in a perpendicular (not angled) to avoid erroneous values. Another method is to use a small right-angled plate to ensure the plate is exactly vertical. This measure is highly reliant on the flexibility of the participant hence the measurements need to be swift and precise. Ensure that the tape is 'straight' and runs parallel to the participant's leg. For increased accuracy place the tape as close to the leg as possible.

Buttock-heel length summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1069	1076	1066	1071	**Mean**	1000	1005	995	1001
49	51	48	48	**SD**	39	46	40	43
909	938	909	980	**Min**	919	900	899	899
1229	1229	1196	1200	**Max**	1108	1102	1074	1108
1196	1214	1175	1199	**P99**	1098	1101	1073	1100
1175	1203	1160	1180	**P98**	1084	1091	1072	1090
1163	1190	1154	1167	**P97**	1070	1090	1067	1087
1149	1170	1142	1159	**P95**	1064	1084	1056	1074
1128	1135	1125	1128	**P90**	1043	1063	1038	1053
1116	1121	1115	1113	**P85**	1040	1050	1033	1042
1109	1113	1108	1104	**P80**	1034	1042	1026	1035
1102	1108	1099	1098	**P75**	1028	1035	1024	1032
1094	1102	1091	1095	**P70**	1019	1030	1018	1024
1088	1093	1084	1091	**P65**	1015	1024	1012	1018
1081	1088	1078	1087	**P60**	1009	1018	1007	1012
1076	1083	1073	1080	**P55**	1005	1011	1001	1009
1069	1071	1067	1073	**P50**	1001	1010	998	1002
1062	1064	1060	1062	**P45**	996	1001	993	998
1055	1060	1054	1054	**P40**	990	995	990	990
1049	1051	1047	1048	**P35**	981	983	985	983
1043	1048	1040	1045	**P30**	977	977	980	977
1037	1042	1035	1036	**P25**	975	975	973	974
1029	1037	1026	1027	**P20**	972	967	965	968
1021	1026	1019	1021	**P15**	960	952	958	957
1009	1016	1005	1010	**P10**	952	943	949	948
992	998	990	1001	**P5**	940	926	926	927
984	988	976	989	**P3**	928	919	907	920
971	978	962	987	**P2**	923	912	900	914
954	959	952	984	**P1**	920	909	899	901

Distribution plots for each service and gender



Buttock height - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
The vertical height of the Buttock Circumference measurement of the standing surface.

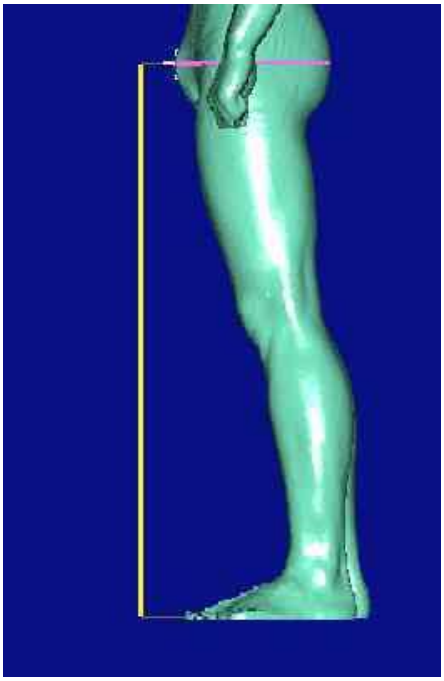
Landmark required:
None.

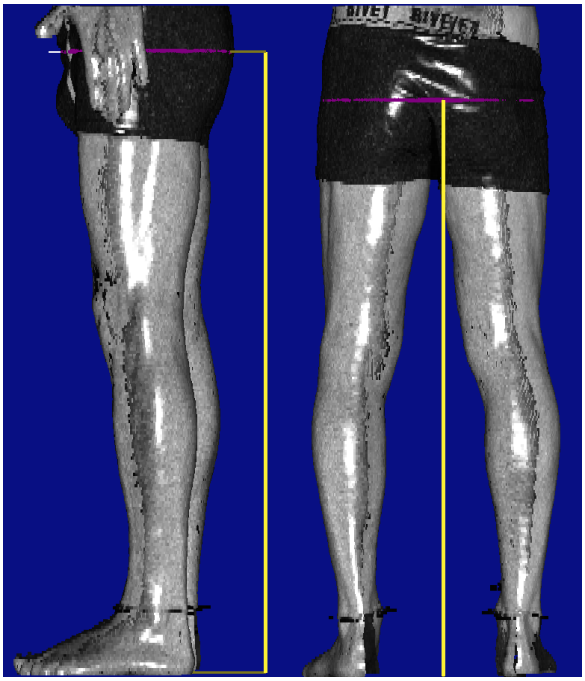
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms hanging vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
None.

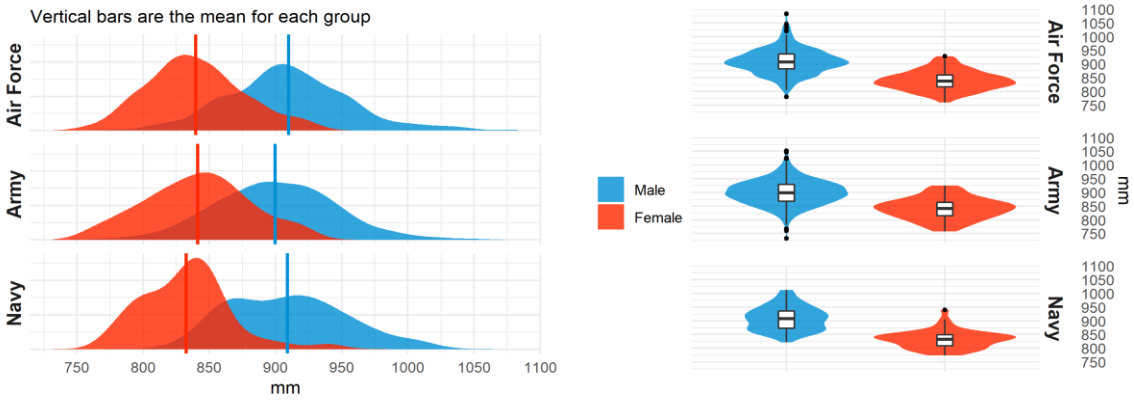




Buttock height summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
904	910	900	909	**Mean**	840	841	832	839
46	47	46	44	**SD**	36	39	33	37
732	781	732	822	**Min**	759	758	774	758
1083	1083	1052	1012	**Max**	928	925	940	940
1023	1035	1014	1008	**P99**	920	919	925	924
1006	1022	997	1003	**P98**	917	918	911	918
997	1006	987	1001	**P97**	915	916	900	916
982	990	976	983	**P95**	906	913	884	909
960	962	956	966	**P90**	887	889	861	887
949	954	945	954	**P85**	882	881	858	877
940	948	938	946	**P80**	868	875	852	865
932	936	929	936	**P75**	860	864	849	861
927	930	924	932	**P70**	856	862	845	856
920	924	918	928	**P65**	851	857	844	851
915	919	913	918	**P60**	846	852	842	846
908	912	906	914	**P55**	840	847	838	843
904	907	898	908	**P50**	838	842	832	838
897	905	894	903	**P45**	834	837	831	834
892	898	888	898	**P40**	827	834	828	829
887	893	883	885	**P35**	825	826	823	825
880	888	876	875	**P30**	822	819	815	819
873	883	868	873	**P25**	817	815	809	814
864	869	862	867	**P20**	811	807	802	807
857	860	853	861	**P15**	801	799	796	797
848	853	842	855	**P10**	793	789	794	792
831	838	828	849	**P5**	788	777	783	781
819	825	816	846	**P3**	779	768	780	775
815	817	807	843	**P2**	777	764	778	769
796	809	793	833	**P1**	772	764	776	764

Distribution plots for each service and gender



Buttock-knee length sitting - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR, NZDFAS

Definition:
Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the mid-point of the popliteal fossa (vertically) in line with Pternion (back of the foot). The horizontal distance between a buttock plate placed at the most posterior point on the buttock and the knee point anterior landmark.

Landmark required:
None.

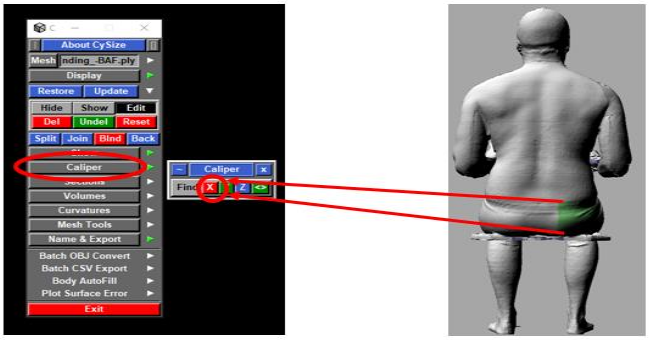
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

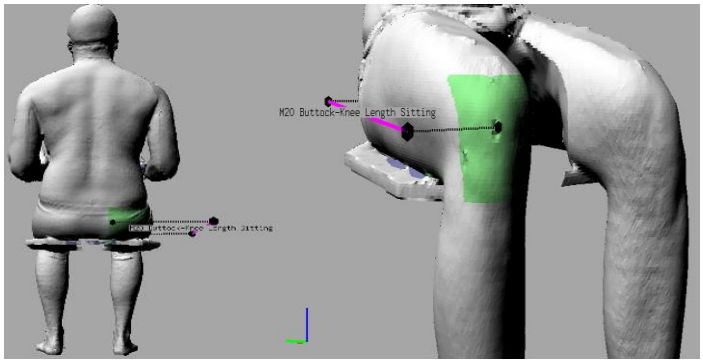
Procedure:
In CySize use the caliper tool. View from the back of the participant. Highlight the right buttock as below. When the view is rotated to the front view the anterior aspect of the knee will also be highlighted. Select the X function (to create a coronal plan) to record the length. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
An alternative method is to view the participant from the right-side view, then highlight a narrow rectangle starting from the most posterior aspects of the right buttock to the most anterior aspect of the right knee then select the ‘x’ function.

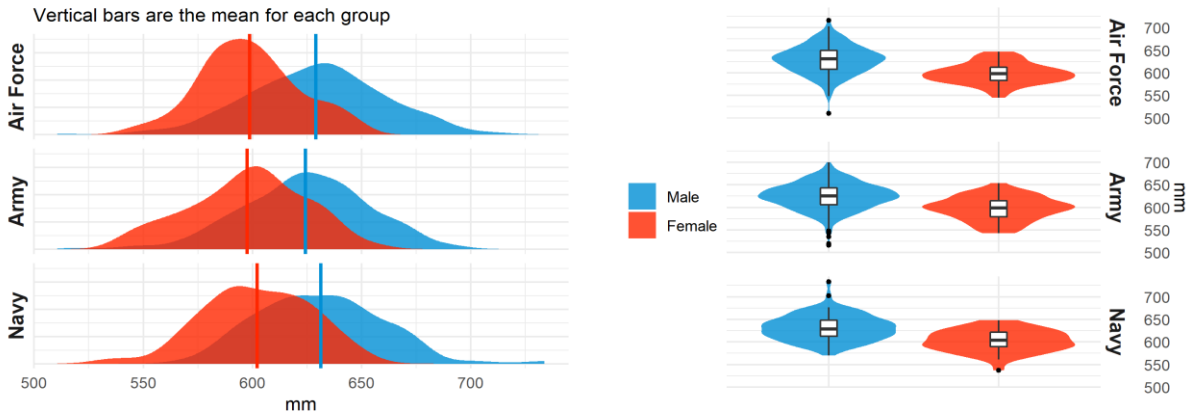




Buttock-knee length sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
626	629	624	631	**Mean**	599	598	602	599
30	32	29	29	**SD**	23	26	24	25
511	511	517	570	**Min**	545	542	537	537
734	716	700	734	**Max**	647	654	648	654
690	700	687	706	**P99**	646	653	647	648
683	688	678	683	**P98**	645	641	646	646
679	684	675	676	**P97**	643	638	643	642
674	680	672	672	**P95**	638	637	637	637
664	667	662	668	**P90**	633	630	631	632
657	661	654	661	**P85**	622	628	628	627
651	654	648	654	**P80**	616	622	624	622
646	649	644	648	**P75**	612	615	621	615
641	644	640	644	**P70**	608	610	617	611
638	640	636	641	**P65**	605	607	612	607
634	637	632	639	**P60**	602	606	610	606
630	634	628	636	**P55**	599	602	607	602
627	631	626	629	**P50**	598	599	604	599
623	627	622	625	**P45**	596	598	595	597
620	623	619	622	**P40**	592	594	592	592
616	618	615	618	**P35**	588	590	591	590
612	613	611	616	**P30**	586	585	591	587
607	608	605	612	**P25**	583	580	590	583
601	604	600	606	**P20**	581	576	581	578
596	598	595	599	**P15**	578	568	576	575
588	589	587	598	**P10**	576	560	575	567
580	579	578	588	**P5**	565	550	567	556
570	574	569	586	**P3**	558	546	563	550
562	561	562	585	**P2**	554	544	557	545
548	551	547	582	**P1**	550	544	547	544

Distribution plots for each service and gender



Buttock-popliteal length sitting - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ANSUR, NZDFAS

Definition:
Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot). The horizontal distance between a buttock plate placed at the most posterior point on either buttock and the back of the right knee (the popliteal fossa at the dorsal juncture of the calf and thigh).

Landmark required:
Buttock Point Sitting and Popliteal landmarks.

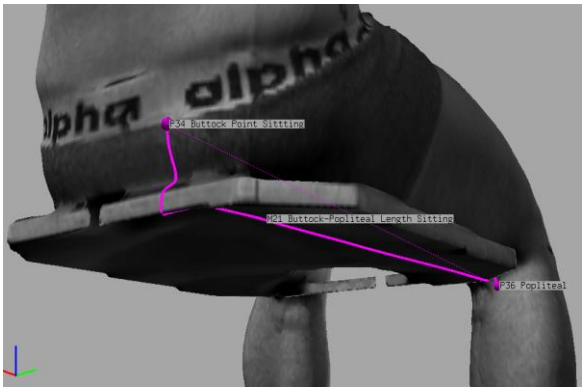
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

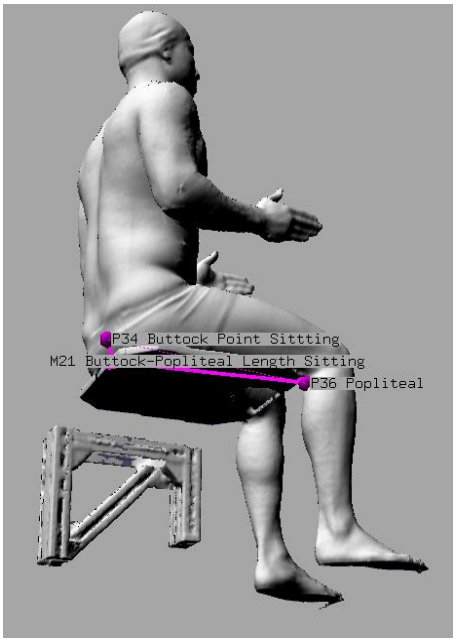
Procedure:
This measure is the point to point distance between the Buttock Point Sitting and Popliteal landmarks. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
Note the illustration below does not show the ‘point to point’ line. The result will be correct upon final measurement export.

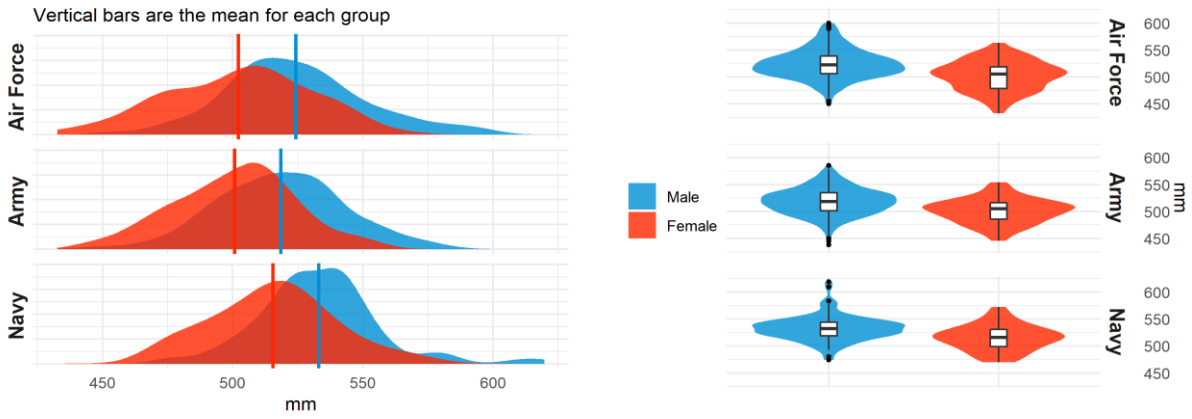




Buttock-popliteal length sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
522	524	519	533	**Mean**	502	501	516	504
26	27	25	24	**SD**	28	23	24	25
438	450	438	474	**Min**	433	446	470	433
620	600	586	620	**Max**	563	554	573	573
586	595	576	611	**P99**	554	550	568	561
579	588	571	590	**P98**	548	548	564	553
573	584	567	581	**P97**	545	545	560	549
566	575	560	576	**P95**	543	538	555	544
554	562	552	556	**P90**	539	527	544	537
547	552	544	552	**P85**	532	523	538	530
541	546	538	546	**P80**	527	518	532	524
537	539	534	544	**P75**	519	516	531	520
534	535	531	543	**P70**	516	512	525	517
531	532	528	539	**P65**	513	509	523	514
528	529	525	537	**P60**	511	508	521	511
525	525	522	537	**P55**	508	506	518	509
521	522	518	532	**P50**	505	505	516	507
518	518	516	528	**P45**	501	499	514	503
515	516	513	526	**P40**	498	495	511	499
512	513	509	525	**P35**	495	492	509	496
508	509	505	523	**P30**	488	490	504	492
505	506	501	519	**P25**	478	486	499	488
501	504	497	517	**P20**	476	479	496	479
496	499	494	511	**P15**	473	475	491	476
490	493	488	507	**P10**	468	470	482	470
480	481	480	497	**P5**	456	462	477	463
474	476	472	493	**P3**	449	458	476	456
470	473	467	489	**P2**	447	454	474	450
460	463	457	480	**P1**	442	446	472	446

Distribution plots for each service and gender



Calf girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan.

Source:
UK Anthropometry Survey, Anthroscan.

Definition:
The maximum circumference of the calf while standing with legs straight, feet apart with weight evenly distributed).

Landmark required:
None.

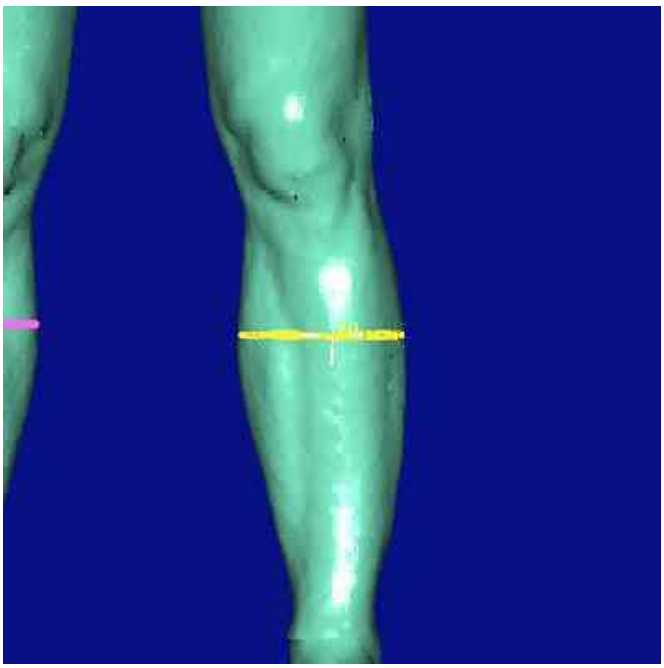
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

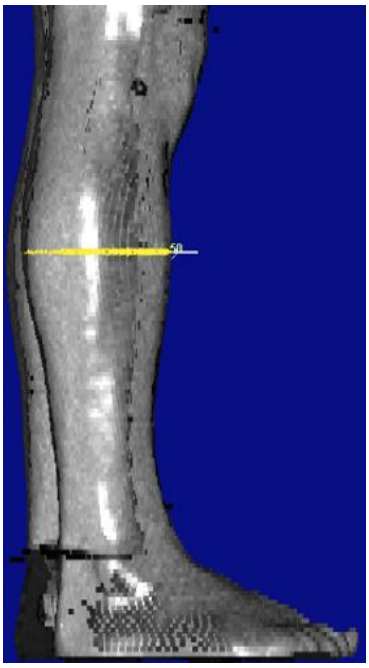
Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Pringle, R. H., Puxley, A. J., Puxley, K. P. M., Turner, G. M., & Tyrell, A. K. (2011). Anthropometry Survey of UK Military Personnel 2006-7 (Issue 3) (QINETIQ/07/01821/3.0): QinetiQ Ltd.

Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
Check the digtial tape (yellow line below) is horizontal and uniform around the calf. Confirm visually that the tape passes around the widest point of the calf whilst checking the tape value (increase or decrease) at the bottom of the window.

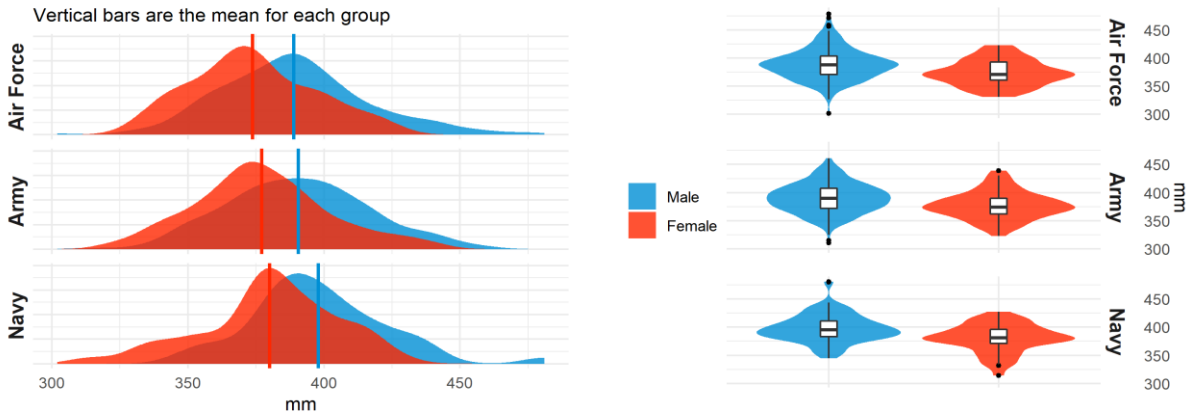




Calf girth summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
391	389	391	398	**Mean**	374	377	380	377
27	27	26	25	**SD**	23	25	25	24
302	302	311	345	**Min**	331	323	314	314
481	478	461	481	**Max**	423	439	427	439
457	458	451	480	**P99**	421	439	423	430
448	454	446	453	**P98**	420	431	420	427
442	444	441	440	**P97**	419	428	417	423
438	439	437	437	**P95**	416	424	415	418
425	424	424	431	**P90**	403	411	412	411
418	416	417	422	**P85**	398	402	406	401
412	408	413	418	**P80**	395	395	400	396
407	403	408	411	**P75**	393	390	396	393
403	400	404	407	**P70**	382	388	395	388
400	396	401	405	**P65**	379	385	387	384
396	392	397	400	**P60**	376	382	386	381
393	390	393	397	**P55**	374	377	383	378
390	388	390	395	**P50**	371	374	381	375
387	386	387	392	**P45**	371	374	378	374
384	382	383	390	**P40**	368	371	378	371
381	377	380	387	**P35**	365	370	376	369
377	374	376	385	**P30**	362	365	375	365
373	371	372	384	**P25**	360	362	371	361
369	367	368	380	**P20**	353	357	360	356
363	360	363	377	**P15**	348	352	354	351
358	357	356	370	**P10**	343	346	344	345
350	349	349	359	**P5**	339	338	335	338
346	346	346	353	**P3**	338	336	333	335
342	338	341	352	**P2**	337	334	329	332
335	333	335	351	**P1**	335	324	322	325

Distribution plots for each service and gender



Cervicale height sitting - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR, NZDFAS.

Definition:
The vertical distance between the seated surface and the Cervicale landmark.

Landmark required:
Seventh cervical vertebra C7 and Seat Pan landmark.

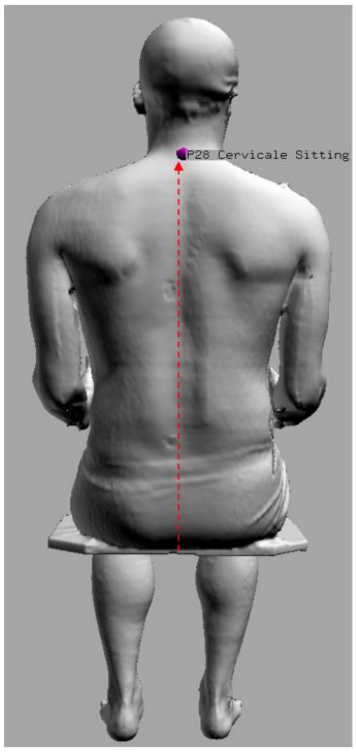
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

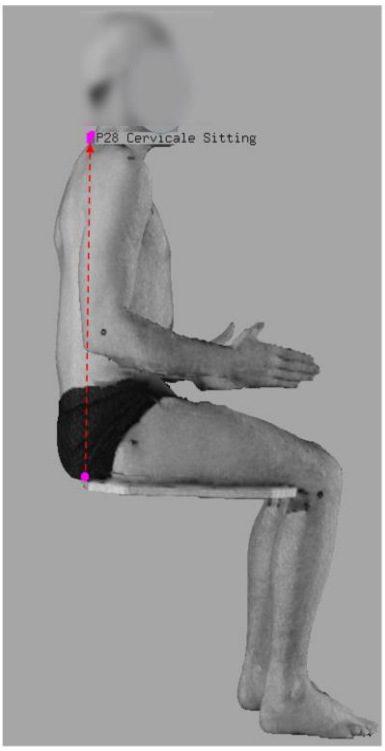
Procedure:
Look for the highest landmark on the upper back and look for the stickered landmarks. This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the C7 landmark minus the Y coordinate (mm on the Y or vertical axis) of the Seat pan landmark in Posture 3. This calculation is performed in Excel. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
None.

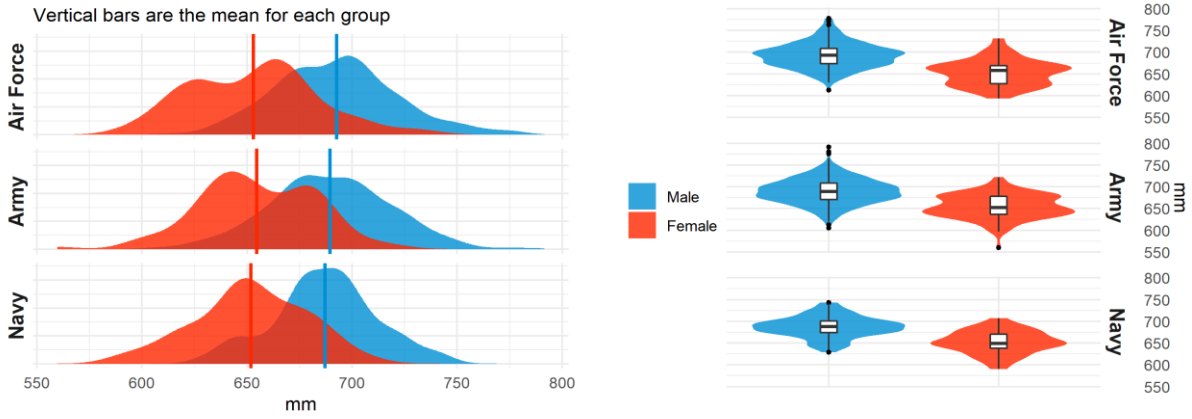




Cervicale height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
690	693	689	687	**Mean**	653	655	652	653
29	29	29	24	**SD**	30	28	26	28
605	613	605	629	**Min**	594	560	590	560
792	778	792	743	**Max**	732	722	707	732
759	770	755	741	**P99**	729	711	702	721
751	757	747	739	**P98**	719	709	697	709
745	752	744	734	**P97**	706	699	694	705
738	745	737	726	**P95**	702	694	691	698
725	729	726	719	**P90**	695	687	685	687
720	723	720	711	**P85**	679	684	680	681
713	716	714	706	**P80**	675	679	676	678
708	709	709	701	**P75**	669	678	671	675
703	705	704	697	**P70**	667	675	667	669
700	702	701	695	**P65**	666	671	661	666
697	699	697	693	**P60**	662	660	658	660
694	697	693	692	**P55**	660	658	652	658
690	693	689	688	**P50**	658	652	650	653
686	690	685	683	**P45**	652	650	649	649
681	684	681	681	**P40**	646	645	646	645
678	679	677	678	**P35**	636	641	645	642
675	676	675	676	**P30**	633	640	643	637
672	673	671	674	**P25**	627	637	638	635
668	669	666	672	**P20**	624	636	629	629
661	663	659	663	**P15**	620	629	623	624
654	656	654	656	**P10**	616	623	618	618
644	646	642	644	**P5**	611	609	609	609
637	643	635	643	**P3**	603	601	601	600
631	639	630	640	**P2**	600	599	597	599
625	634	623	634	**P1**	598	596	594	594

Distribution plots for each service and gender



Chest breadth - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS, NZDFAS.

Definition:
The maximum horizontal breadth at the height of Bust point, Right (females) or Thelion, Right (males).

Landmark required:
None.

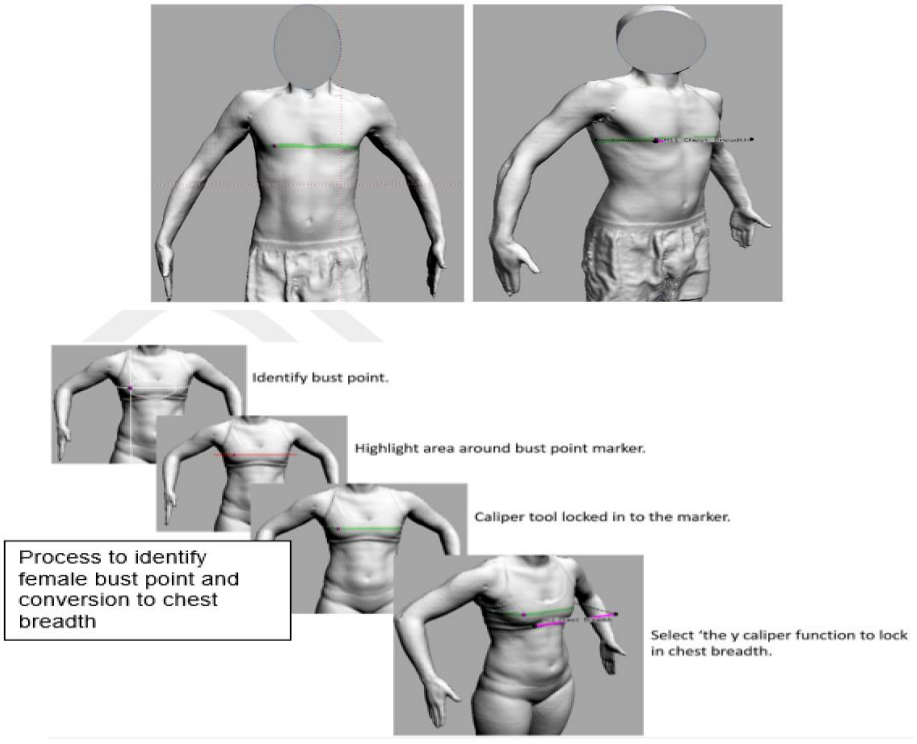
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
Use the caliper tool. Highlight a thin horizontal line across the chest. Ensure that the line passes through the centre of the Thelion right (male) and the bust point right (female). Best from the front. Use Y axis caliper. Chest breadth may also encompass the Latissimus dorsi muscle region. It may be easier to identify and place a marker on Thelion right. Then using the caliper tool highlight a thin line above and below the marker. For female participants, first identify the Best point then use the caliper to highlight a thin line above and below the marker then use the caliper tool to identify the chest breadth (see process below for females). Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

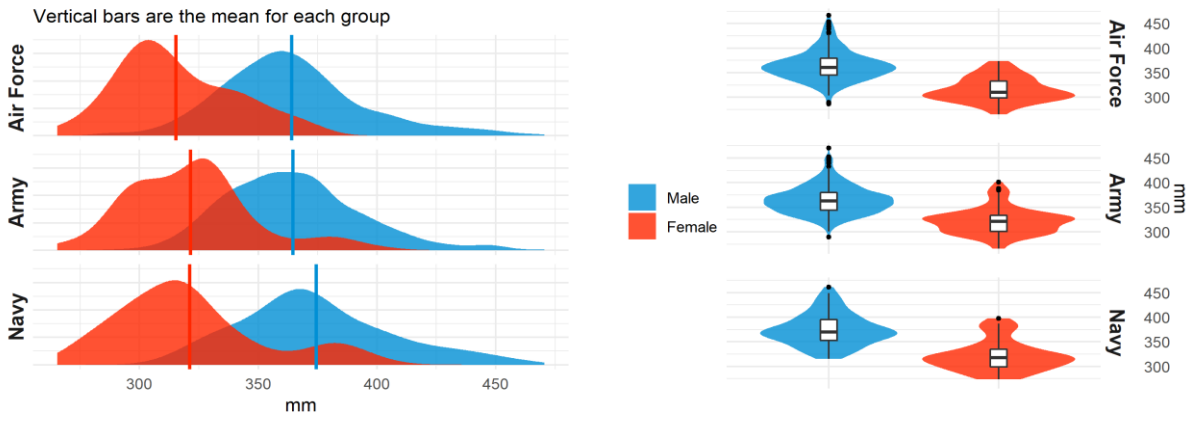
Notes:
None.



Chest breadth summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
366	364	365	374	**Mean**	315	321	321	319
29	30	28	32	**SD**	25	26	31	27
287	287	290	315	**Min**	265	265	274	265
470	467	470	461	**Max**	374	401	397	401
449	449	447	450	**P99**	371	388	393	388
442	441	435	448	**P98**	368	386	388	386
431	432	426	443	**P97**	367	385	386	382
420	422	415	435	**P95**	361	376	382	375
404	404	402	421	**P90**	350	353	378	355
395	392	392	407	**P85**	343	342	350	343
388	383	387	400	**P80**	340	337	340	339
381	379	379	395	**P75**	333	333	335	333
377	375	376	386	**P70**	326	331	324	329
373	371	373	379	**P65**	321	328	322	327
370	368	370	377	**P60**	316	328	321	323
366	364	366	375	**P55**	314	326	319	320
363	361	363	370	**P50**	310	322	318	317
360	358	358	366	**P45**	307	319	316	313
356	355	356	364	**P40**	306	313	312	309
353	352	352	363	**P35**	302	310	307	307
350	349	349	361	**P30**	300	307	302	302
345	345	344	353	**P25**	299	300	299	299
341	340	340	348	**P20**	297	298	297	297
337	336	336	342	**P15**	295	295	294	295
331	330	331	334	**P10**	287	293	288	289
324	321	324	328	**P5**	282	285	278	282
317	316	319	324	**P3**	280	283	278	278
316	310	316	321	**P2**	273	276	277	274
308	304	311	318	**P1**	267	270	276	268

Distribution plots for each service and gender



Chest depth - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS, NZDFAS.

Definition:
The horizontal distance between the Bust point (females) or Thelion (males), and the point on the dorsal surface at the same level, in the sagittal plane.

Landmarks required:
Thelion Bust point and Thelion Bust point projected landmarks.

Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
This measure is a derived measure (post analysis) that was not part of the original CySize protocol. This procedure is performed in an Excel spreadsheet by adding the X coordinates for Thelion Bust point and Thelion Bust point projected to create a straight-line distance. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

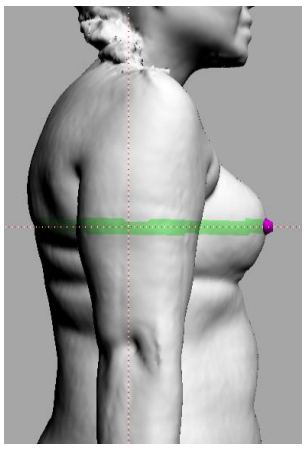
Notes:
All future Chest depth measurements should use the caliper tool. First identify the Thelion landmark. View the participant from the side. Use the Crosshair tool to correctly align the participants' posture. Highlight an area that is immediately above and below the Thelion landmark. Select the X function (to create a coronal plan) in the Caliper tool to calculate the depth.

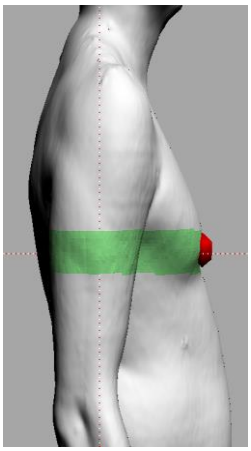
There are three options for this measurement:

1. The anterior-posterior distance in a sagittal plane as described.

2. The point to point distance at the same level (i.e. on a transverse plane, but not in a sagittal plane).

3. The perpendicular planar distance which represents the theoretical minimum space occupancy for a person between the most anterior and most posterior points on the torso.

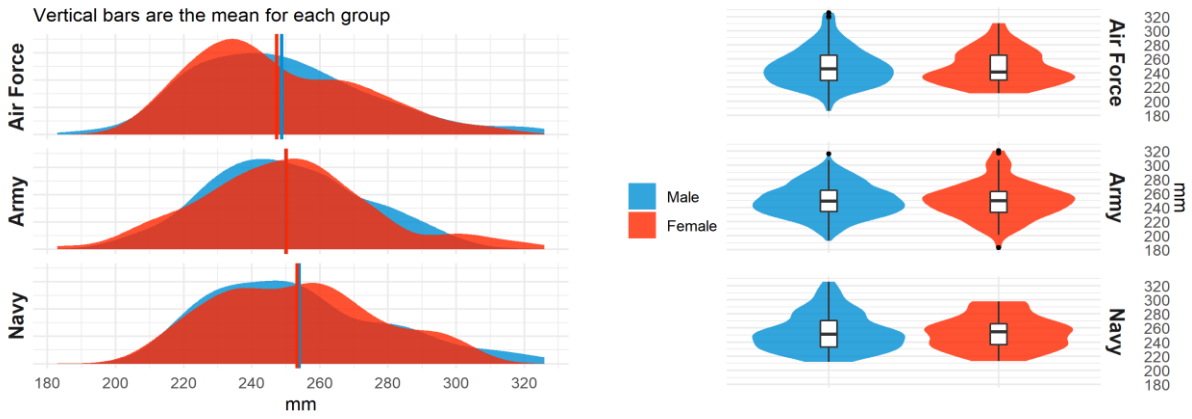




Chest depth summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
250	249	250	254	**Mean**	247	250	253	250
24	26	23	26	**SD**	24	26	24	25
186	186	193	212	**Min**	211	183	213	183
326	326	316	326	**Max**	310	321	298	321
315	320	301	318	**P99**	308	317	298	310
304	317	296	315	**P98**	302	308	297	306
298	310	293	311	**P97**	296	305	297	301
292	297	289	304	**P95**	287	301	297	297
283	284	281	288	**P90**	283	279	289	283
277	278	276	284	**P85**	273	274	278	274
271	268	270	279	**P80**	268	271	273	271
265	265	265	271	**P75**	265	263	266	265
262	260	262	261	**P70**	261	260	264	261
258	255	259	258	**P65**	257	258	261	258
254	253	255	255	**P60**	248	256	259	256
251	249	251	253	**P55**	244	254	257	252
248	246	249	251	**P50**	241	250	255	247
245	242	246	248	**P45**	239	246	251	244
242	239	243	245	**P40**	236	244	243	240
238	236	239	238	**P35**	234	241	239	238
236	233	236	237	**P30**	232	237	237	235
233	229	234	233	**P25**	230	233	237	232
229	225	230	231	**P20**	227	231	233	230
226	222	227	229	**P15**	222	224	229	223
221	219	222	223	**P10**	221	217	222	220
215	215	214	221	**P5**	215	210	219	213
210	211	209	219	**P3**	214	205	218	211
206	205	206	218	**P2**	213	204	217	210
203	199	203	217	**P1**	212	201	215	205

Distribution plots for each service and gender



Chest height sitting - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR, NZDFAS.

Definition:
The vertical distance between a horizontal sitting surface and the chest point anterior landmark.

Landmarks required:
Thelion (male)/Bust point (female) and Seat Pan top landmark.

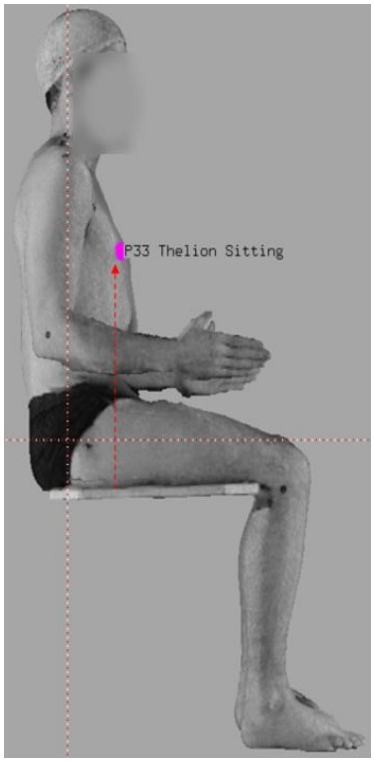
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Thelion landmark in posture 3 minus the Y coordinate (mm on the Y or vertical axis) of the Seat pan marker. This calculation is performed in an Excel spreadsheet. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

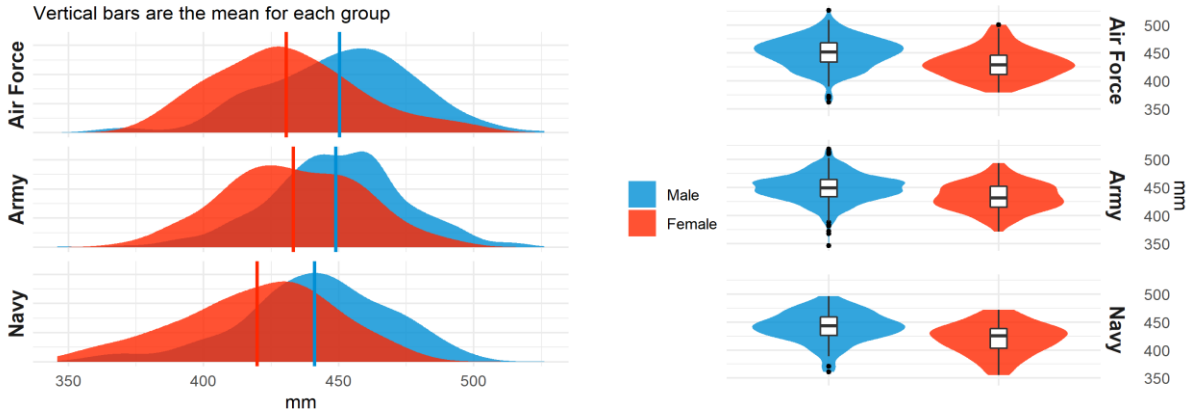
Notes:
Ensure that the participant is sitting erect (and not leaning forward).



Chest height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
448	450	449	441	**Mean**	431	433	420	430
26	28	25	27	**SD**	27	25	28	27
346	362	346	361	**Min**	379	372	355	355
526	526	518	497	**Max**	500	493	472	500
508	508	510	491	**P99**	496	487	470	493
498	500	498	490	**P98**	491	483	467	486
495	497	495	486	**P97**	486	477	466	480
491	492	491	481	**P95**	480	474	462	473
481	483	480	475	**P90**	464	463	452	463
474	478	473	470	**P85**	457	458	447	457
469	472	467	465	**P80**	451	456	440	452
465	468	464	459	**P75**	446	452	438	447
463	465	462	455	**P70**	444	448	437	444
460	463	459	452	**P65**	441	444	433	441
456	460	456	447	**P60**	434	441	428	436
453	455	453	445	**P55**	431	435	427	431
449	452	449	443	**P50**	429	432	425	428
446	449	446	439	**P45**	425	428	419	426
443	446	443	437	**P40**	424	426	413	424
439	441	441	433	**P35**	422	422	411	420
436	436	437	428	**P30**	415	420	408	415
432	433	434	426	**P25**	412	415	404	411
428	426	430	422	**P20**	408	412	397	408
422	420	424	417	**P15**	403	409	388	403
415	414	417	405	**P10**	398	400	382	395
406	408	407	394	**P5**	390	392	369	387
396	402	399	382	**P3**	388	388	365	382
390	393	394	371	**P2**	388	386	363	380
372	372	387	370	**P1**	385	384	359	368

Distribution plots for each service and gender



Crotch height - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
AWAS.

Definition:
The vertical distance between the standing surface and the digitally identified crotch landmark.

Landmark required:
Crotch landmark.

Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
The Crotch landmark is the inferior point of the groin, on the right side of the male genitalia (if obstructing). With "Colour" mode off, identify the point on the crotch that a caliper coming in from the bottom would hit first (angle participant so that you are viewing their crotch from their foot). Add X-axis and Y-loops. Ensure the point marker is not on the upper thigh. Skip if it is unclear (due to crotch webbing caused by the upper thighs being too close together) or if the participant is wearing loose or 'baggy' shorts. Check from the side view using the Wire mesh mode. As measured in AWAS Section 7.1.19 of the Procedures Manual (Tomkinson et al., 2012). Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

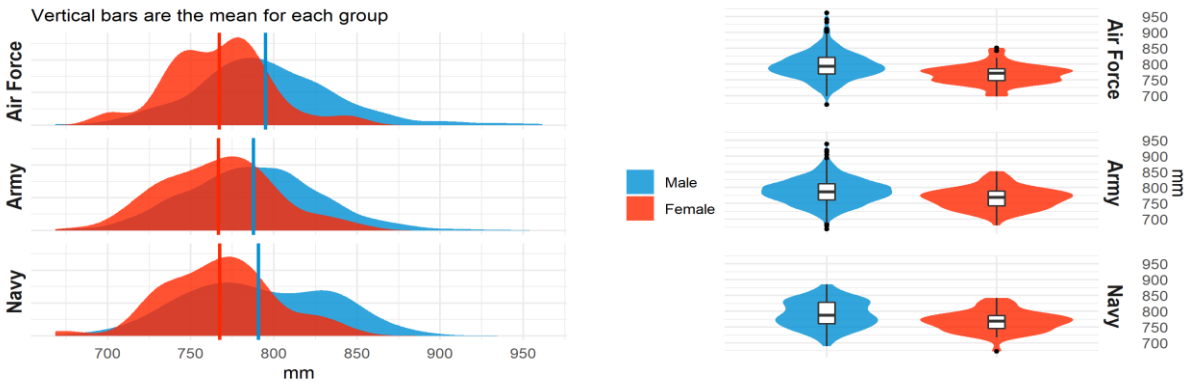
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
None.

Crotch height summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
790	795	788	791	**Mean**	767	767	767	767
42	44	41	43	**SD**	31	34	34	33
668	671	668	689	**Min**	698	680	673	673
962	962	938	886	**Max**	851	852	842	852
904	929	888	870	**P99**	845	848	837	847
882	906	876	867	**P98**	842	836	832	842
869	890	868	864	**P97**	838	832	830	834
860	868	856	858	**P95**	819	831	827	829
841	848	838	842	**P90**	798	805	814	803
832	835	829	839	**P85**	794	798	793	796
824	825	820	834	**P80**	789	793	792	792
816	821	812	828	**P75**	784	789	786	787
809	815	808	817	**P70**	782	783	783	782
805	806	804	810	**P65**	778	779	780	779
799	801	798	806	**P60**	777	777	777	777
794	796	792	791	**P55**	774	771	770	773
788	793	787	787	**P50**	770	768	769	769
784	787	782	781	**P45**	765	764	763	763
779	783	779	776	**P40**	756	758	761	758
774	777	772	771	**P35**	755	751	757	754
768	774	767	766	**P30**	749	749	749	749
763	768	761	760	**P25**	747	742	746	744
756	763	754	751	**P20**	742	736	737	739
747	756	743	748	**P15**	739	731	733	733
737	741	737	736	**P10**	734	725	728	728
726	727	725	729	**P5**	720	714	726	714
716	722	715	717	**P3**	704	711	719	706
710	716	710	713	**P2**	701	705	710	703
703	706	703	706	**P1**	699	703	692	698

Distribution plots for each service and gender



Crotch length - Automatic measurement (mm)

Measuring instrument:
Anthroscan.

Source:
Anthroscan, UK Anthropometry Survey.

Definition:
The minimum surface distance between front waist level and back waist, (Code 6510) via the crotch.

Landmark required:
None.

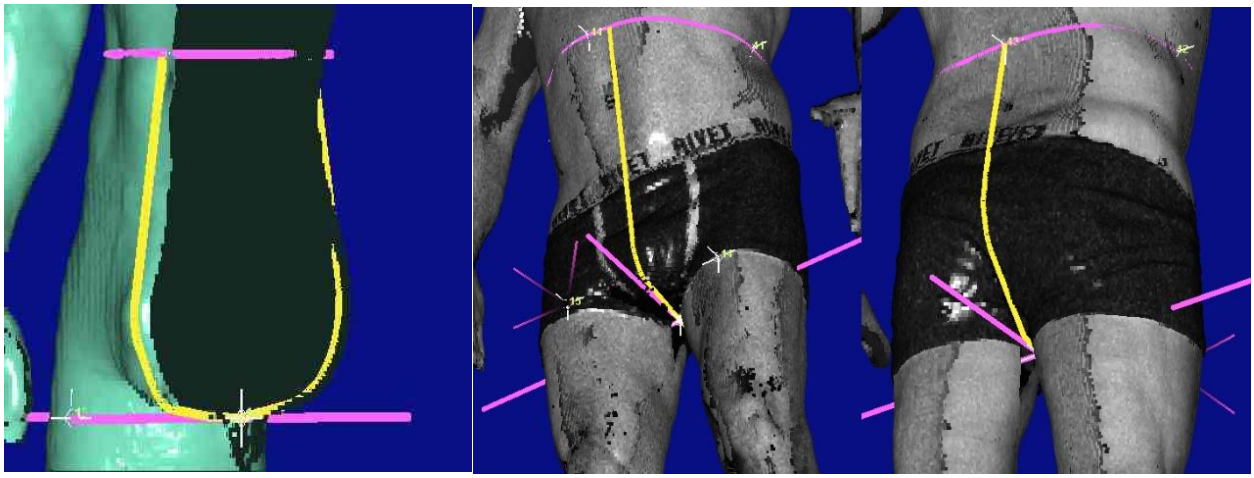
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb pointed forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Pringle, R. H., Puxley, A. J., Puxley, K. P. M., Turner, G. M., & Tyrell, A. K. (2011). Anthropometry Survey of UK Military Personnel 2006-7 (Issue 3) (QINETIQ/07/01821/3.0): QinetiQ Ltd.

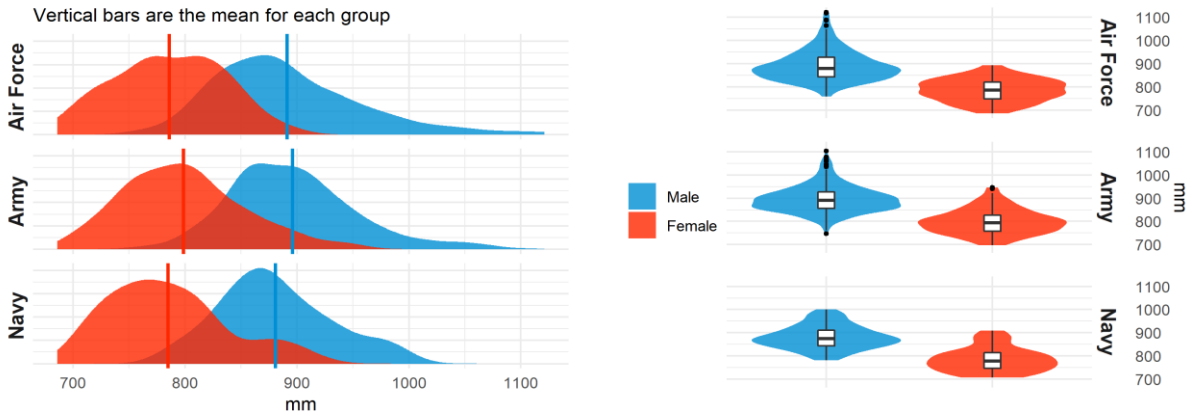
Notes:
Check that the digital tape (yellow line below) is vertical on both the anterior and posterior ends.



Crotch length summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
893	891	896	881	**Mean**	786	799	785	792
59	66	57	50	**SD**	49	54	53	52
747	758	747	781	**Min**	686	697	707	686
1121	1121	1104	1000	**Max**	893	947	908	947
1065	1088	1064	987	**P99**	886	941	904	920
1047	1060	1046	984	**P98**	878	923	900	898
1029	1045	1029	983	**P97**	870	900	895	897
1003	1020	1005	978	**P95**	856	897	885	887
971	981	970	950	**P90**	848	867	869	861
951	958	951	936	**P85**	838	851	828	849
937	939	939	924	**P80**	831	846	817	834
926	928	927	911	**P75**	820	827	814	820
917	916	919	902	**P70**	817	820	808	816
907	902	911	894	**P65**	810	813	802	810
900	894	904	884	**P60**	803	808	791	804
892	886	898	878	**P55**	798	802	786	796
886	878	891	874	**P50**	785	794	777	790
878	874	883	869	**P45**	776	791	769	780
872	868	876	867	**P40**	770	781	766	773
867	862	870	859	**P35**	767	775	762	767
859	851	862	852	**P30**	763	766	753	763
852	843	856	844	**P25**	748	758	746	756
845	837	851	839	**P20**	742	756	740	745
837	831	844	834	**P15**	726	746	728	738
825	818	832	825	**P10**	722	737	722	724
808	806	816	804	**P5**	706	720	716	712
802	800	803	798	**P3**	700	709	712	707
795	789	798	792	**P2**	699	707	710	703
778	776	779	787	**P1**	695	705	709	698

Distribution plots for each service and gender



Crotch waist preferred anterior - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS, NZDFAS.

Definition:
The surface distance between the Crotch and Waist preferred anterior landmark.

Landmarks required:
Crotch and Waist preferred anterior landmarks.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

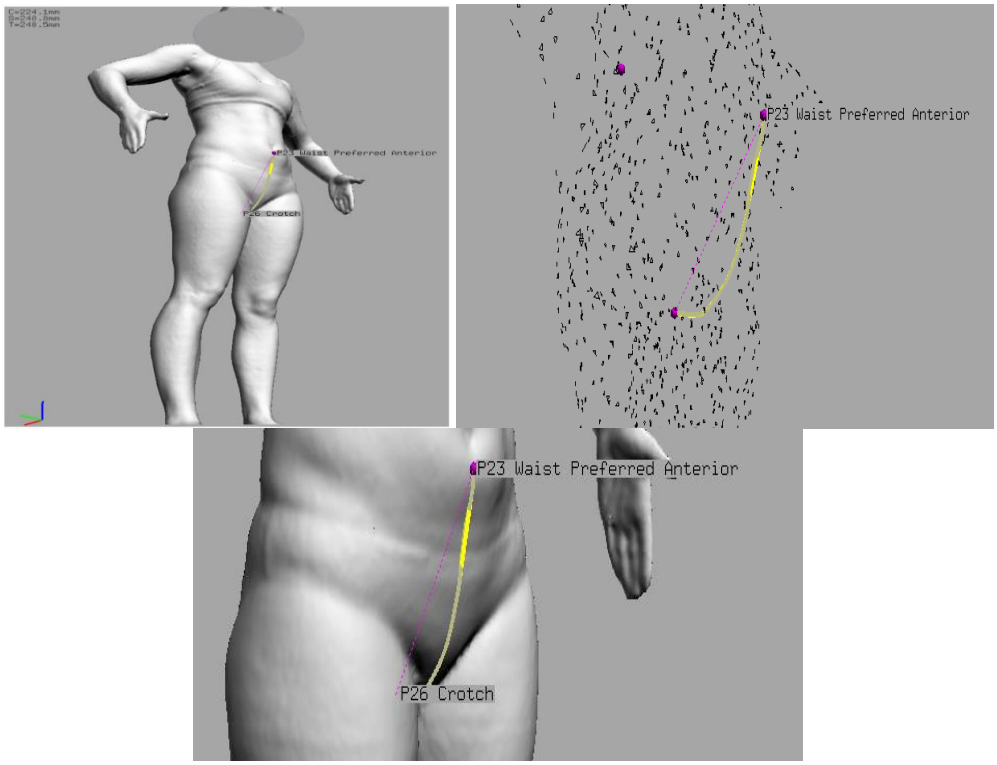
Procedure:
This measure is the surface distance (a function that mimics an anthropometric tape) between the Crotch and Waist preferred anterior landmarks. Measurements are reported in mm.

References:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

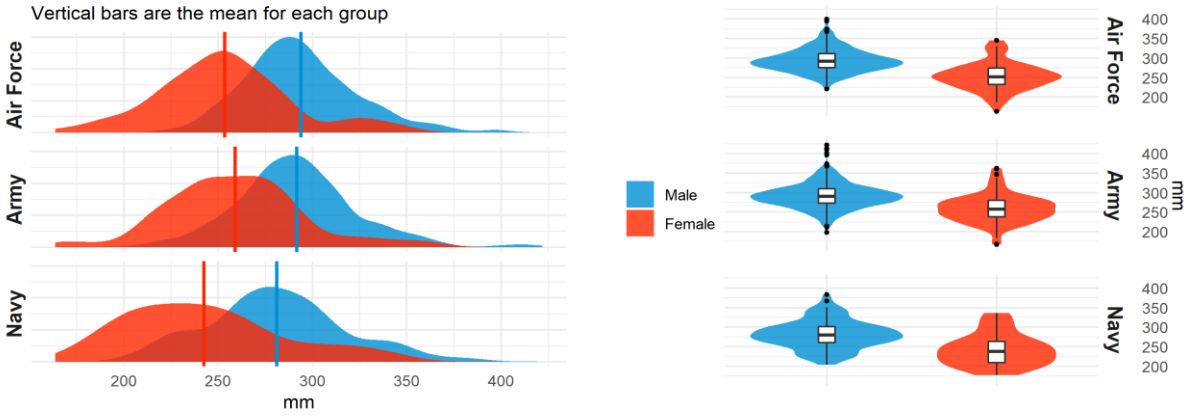
Notes:
If crotch cannot be identified, then it will not be possible to acquire this measure.



Crotch waist preferred anterior summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
291	294	292	281	**Mean**	254	259	242	254
32	30	32	37	**SD**	36	36	41	38
198	221	198	204	**Min**	164	168	177	164
422	399	422	383	**Max**	345	362	337	362
385	373	397	369	**P99**	345	360	335	347
367	366	365	355	**P98**	339	348	333	344
357	360	357	349	**P97**	329	340	331	335
348	347	351	345	**P95**	324	328	326	327
334	335	333	332	**P90**	290	298	303	302
321	322	320	315	**P85**	283	288	287	286
314	316	313	305	**P80**	278	284	268	282
309	311	310	301	**P75**	274	280	263	275
303	306	304	297	**P70**	265	275	260	270
299	300	300	294	**P65**	262	271	256	264
296	297	296	288	**P60**	257	267	248	261
293	294	294	281	**P55**	254	263	240	256
290	291	290	279	**P50**	252	258	237	252
286	288	287	277	**P45**	250	254	234	249
282	284	283	273	**P40**	247	249	228	243
279	281	279	266	**P35**	242	243	224	239
276	278	277	262	**P30**	237	240	213	236
272	275	272	260	**P25**	232	238	209	230
267	270	268	253	**P20**	226	232	206	223
261	266	262	240	**P15**	221	222	205	217
253	259	254	231	**P10**	212	218	196	207
240	250	241	223	**P5**	194	211	192	195
232	247	235	222	**P3**	189	200	183	187
224	242	226	219	**P2**	188	182	179	180
221	237	220	210	**P1**	180	168	178	169

Distribution plots for each service and gender



Crotch waist preferred posterior - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
AWAS, NZDFAS.

Definition:
The surface distance between the Crotch and Waist preferred posterior landmark.

Landmarks required:
Crotch and Waist preferred posterior landmarks.

Posture required:
Scan position posture 2 Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

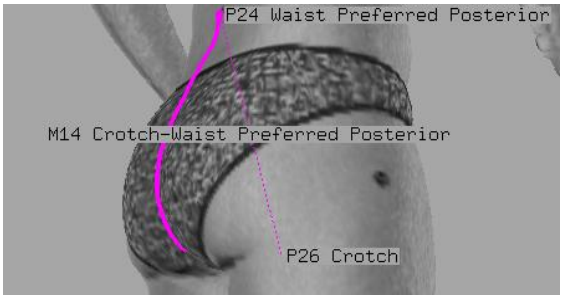
Procedure:
This measure is the tape distance between the Crotch and Waist preferred posterior landmarks. Measurements are reported in mm.

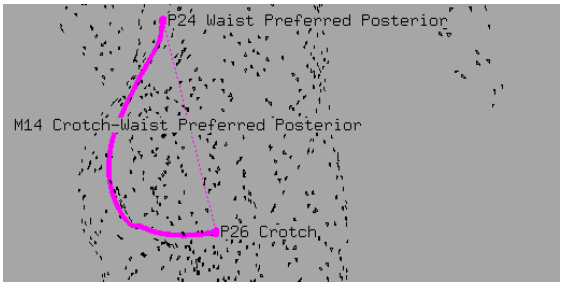
Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

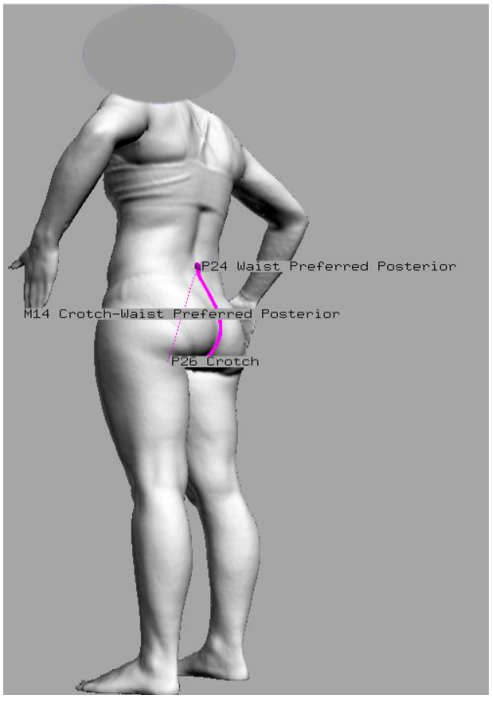
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
If crotch cannot be identified, then this measure will not be possible.



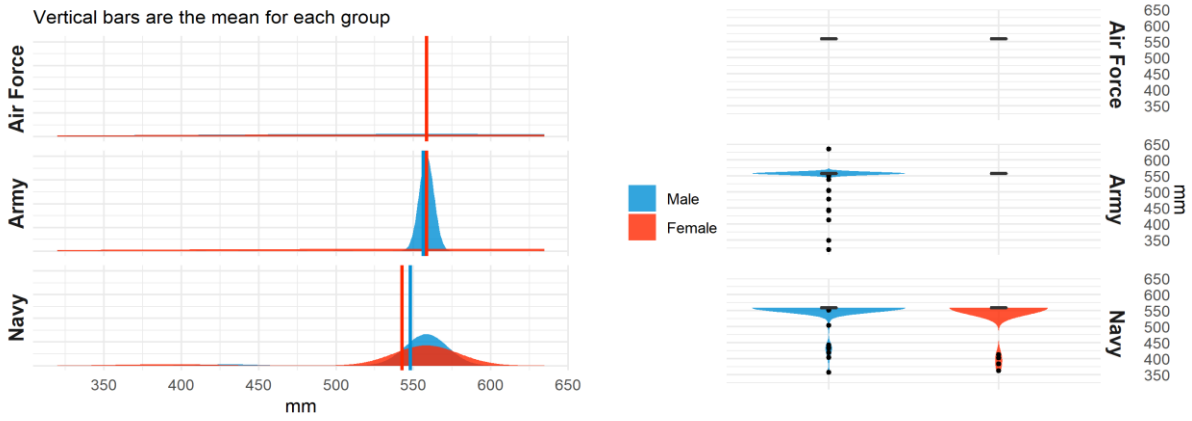




Crotch waist preferred posterior summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
556	558	556	548	**Mean**	558	558	543	555
19	0	18	37	**SD**	0	0	50	23
320	558	320	357	**Min**	558	558	362	362
635	558	635	558	**Max**	558	558	558	558
558	558	558	558	**P99**	558	558	558	558
558	558	558	558	**P98**	558	558	558	558
558	558	558	558	**P97**	558	558	558	558
558	558	558	558	**P95**	558	558	558	558
558	558	558	558	**P90**	558	558	558	558
558	558	558	558	**P85**	558	558	558	558
558	558	558	558	**P80**	558	558	558	558
558	558	558	558	**P75**	558	558	558	558
558	558	558	558	**P70**	558	558	558	558
558	558	558	558	**P65**	558	558	558	558
558	558	558	558	**P60**	558	558	558	558
558	558	558	558	**P55**	558	558	558	558
558	558	558	558	**P50**	558	558	558	558
558	558	558	558	**P45**	558	558	558	558
558	558	558	558	**P40**	558	558	558	558
558	558	558	558	**P35**	558	558	558	558
558	558	558	558	**P30**	558	558	558	558
558	558	558	558	**P25**	558	558	558	558
558	558	558	558	**P20**	558	558	558	558
558	558	558	558	**P15**	558	558	558	558
558	558	558	558	**P10**	558	558	558	558
558	558	558	438	**P5**	558	558	403	558
558	558	558	428	**P3**	558	558	388	558
548	558	556	415	**P2**	558	558	380	558
441	558	473	398	**P1**	558	558	371	404

Distribution plots for each service and gender



Elbow girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan.

Source:
Anthroscan, CFAS.

Definition:
Elbow perimeter measured on the right arm with a line passing the olecranon and the antecubital fossa (arm front hollow).

Landmark required:
None.

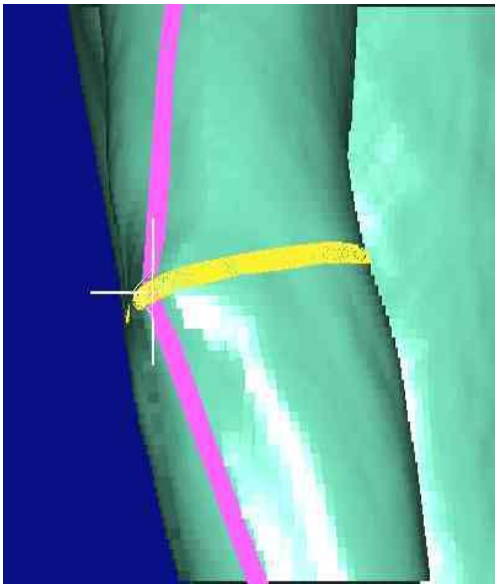
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

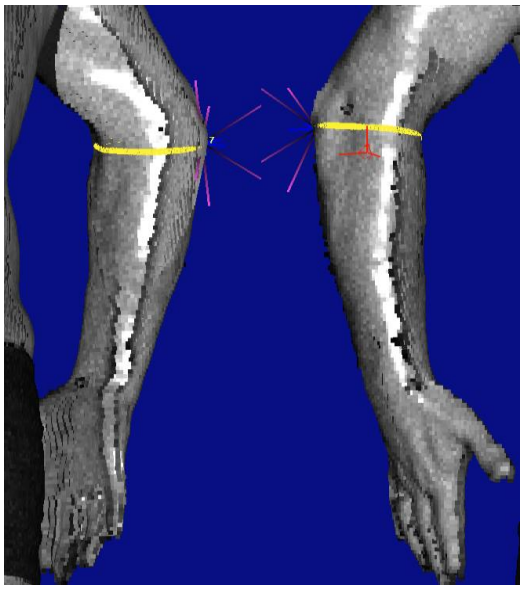
Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Keefe, A., H. Angel, and B. Mangan, 2012 Canadian Forces Anthropometric Survey (CFAS) – Final report. 2015, Défense Research and Development Canada: Toronto, Canada.

Notes:
Check that the digital tape (yellow line below) is horizontal, ideally passing through the inner crease of the elbow and the olecranon process (tip of the elbow). The accuracy of this measurement is affected by the degree of flexion at the elbow.

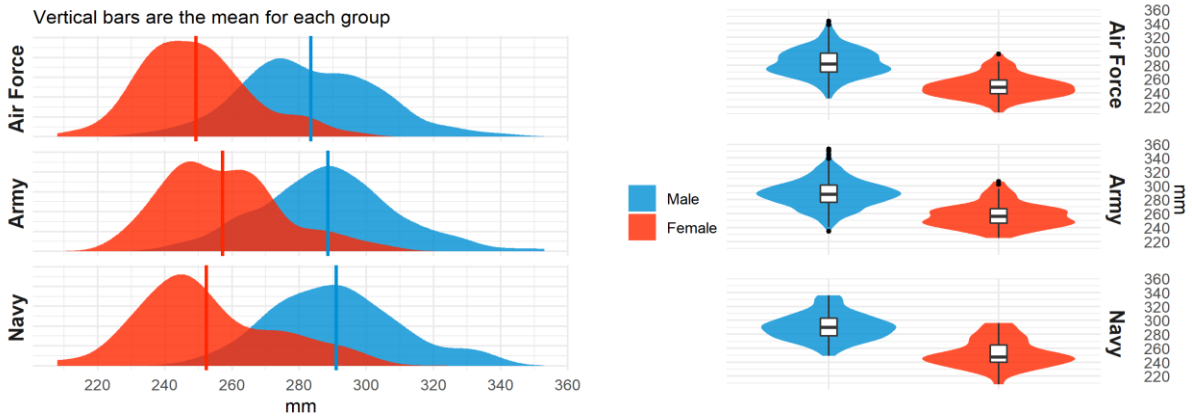




Elbow girth summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
287	283	289	291	**Mean**	249	257	252	254
20	20	20	19	**SD**	16	17	20	18
232	232	235	249	**Min**	212	225	208	208
353	343	353	336	**Max**	296	306	296	306
338	334	340	335	**P99**	288	302	296	296
331	326	331	334	**P98**	284	296	295	296
328	324	328	331	**P97**	283	293	294	293
324	316	324	329	**P95**	282	289	291	287
312	308	314	316	**P90**	272	282	277	277
308	305	309	309	**P85**	265	271	277	271
303	300	304	307	**P80**	262	269	272	268
300	297	301	303	**P75**	258	267	264	264
297	294	298	300	**P70**	255	265	258	262
294	292	295	296	**P65**	254	263	254	258
292	288	293	294	**P60**	252	261	252	255
290	285	291	292	**P55**	250	258	248	254
287	282	288	290	**P50**	248	256	247	250
285	278	286	289	**P45**	247	252	247	248
282	277	284	285	**P40**	243	250	246	247
279	274	281	282	**P35**	242	248	243	246
277	272	278	279	**P30**	240	246	243	243
274	270	276	278	**P25**	239	246	240	241
271	267	272	275	**P20**	236	242	238	239
266	264	267	271	**P15**	234	240	233	236
262	261	263	269	**P10**	231	238	231	233
256	253	257	263	**P5**	228	234	228	230
251	248	253	258	**P3**	223	230	226	227
248	245	248	257	**P2**	222	229	222	225
243	240	245	256	**P1**	219	228	215	222

Distribution plots for each service and gender



Elbow grip length - Physical measurement (mm)

Measuring instrument:
Measurement rod, and a narrow cylindrical object with a known diameter such as a whiteboard pen. Full-length anthropometer, ideally made of solid steel. The anthropometer typically comes in 4 sections. When combined, one end of the rod contains a stationary or fixed arm or 'prong', the other prong is free to move up and down while at a right angles to the rod. There are typically two anthropometer scales that run opposite each other.

Source:
ISO 7250.

Definition:
The horizontal distance from a back wall to the grip centre point (defined as the centre of a measurement rod with a known diameter) grip with elbow bent at a 90 degree angle.

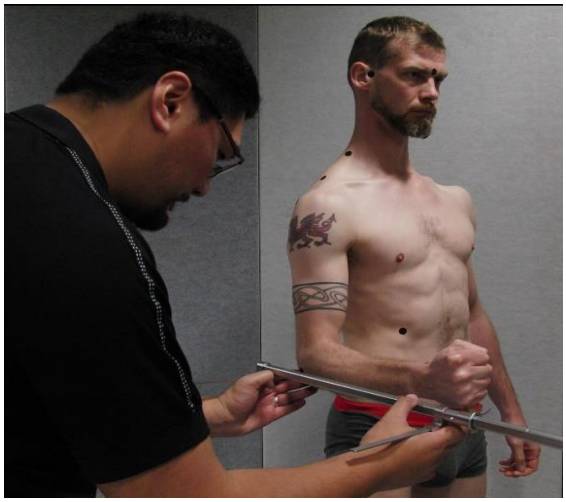
Landmark required:
None.

Posture required:
The assessor stands to the right side of the participant in front of the elbow. This position enables the assessor to support the weight of the anthropometer evenly, and be in a position to see both prongs (the fixed end and the measurement end).

Procedure:
The 'inside' edge of the fixed prong touching the most posterior inferior aspect of the elbow (Olecranon), to the inside edge of the sliding prong touching the most anterior surface of the measurement rod. Extend the opposite prong 5 cm beyond the rod. Slowly push the prong towards the rod until it touches it. Check that anthropometer shaft is vertical, its arm is horizontal and then take the reading to the nearest 0.1 cm. Subtract the known radius of the measurement rod from the measurement (the measure should be from the Olecranon to the centre of the rod).

Reference:
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

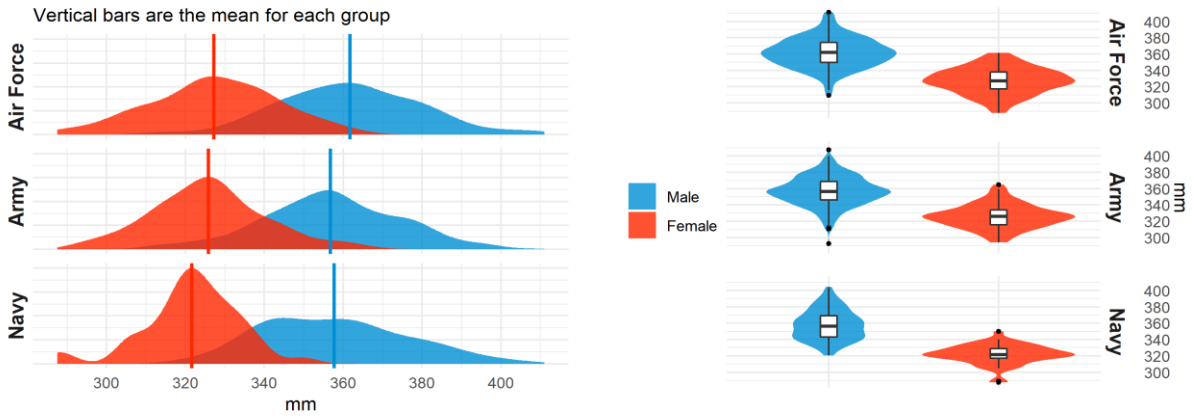
Notes:
The right arm must be at a 90 degree angle. If the elbow position is difficult to locate, palpate the elbow with the left middle finger whilst holding the anthropometer horizontally (like Head depth caliper technique). The rod must be held tight and in a vertical position. If not, the rod will be unstable. This will result in the prong 'pushing' the rod backwards thus giving a false reading. Lengthen or shorten the anthropometer (by adding or removing sections of the rod) to suit the arm length of the participant. Ensure the prong is based securely, and square to the wall for stability. Be aware of handling the prong tip to avoid injuring the participant. The scribe observes and confirms whether the participant's arm is straight and horizontal to the floor immediately before the reading. The anthropometer and arm centre should be at the same height.



Elbow grip length summary statistics - Physical measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
358	362	357	358	**Mean**	327	326	322	325
18	18	18	18	**SD**	16	14	12	15
292	310	292	320	**Min**	288	294	288	288
411	411	408	404	**Max**	361	365	350	365
400	408	396	399	**P99**	360	360	346	360
396	402	394	396	**P98**	357	359	342	359
392	397	390	392	**P97**	354	358	340	354
387	390	385	388	**P95**	353	349	338	350
381	384	379	384	**P90**	348	344	335	344
378	380	376	378	**P85**	342	341	333	340
374	378	372	376	**P80**	340	337	331	338
370	374	368	369	**P75**	338	334	329	335
367	370	366	366	**P70**	337	331	327	332
364	367	363	364	**P65**	335	329	326	329
362	366	360	362	**P60**	331	328	324	328
360	363	358	360	**P55**	328	327	323	327
358	362	356	356	**P50**	327	326	322	326
356	359	356	354	**P45**	326	324	321	324
354	357	352	351	**P40**	325	323	320	322
351	355	350	348	**P35**	322	321	320	321
349	352	348	345	**P30**	321	318	318	318
346	349	346	343	**P25**	317	316	317	316
344	346	343	341	**P20**	313	314	314	314
340	343	339	339	**P15**	310	312	311	311
336	340	336	337	**P10**	305	307	307	306
329	334	326	333	**P5**	302	303	305	303
324	329	321	327	**P3**	297	299	293	296
320	327	318	327	**P2**	293	297	289	294
314	316	312	325	**P1**	290	294	288	289

Distribution plots for each service and gender



Elbow rest height standing - Physical measurement (mm)

Measuring instrument:
Anthropometer and anthropometry box. The stadiometer sits on the anthropometric box which is aligned with its long axis vertically.

Source:
ISO 7250.

Definition:
The horizontal distance from the back of the elbow to the grip with elbow flexed at a right angle.

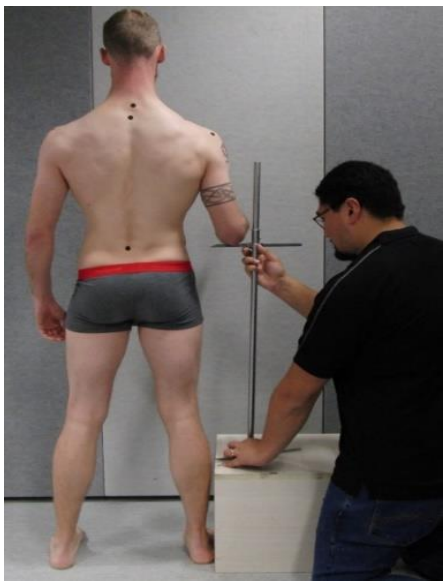
Landmark required:
None.

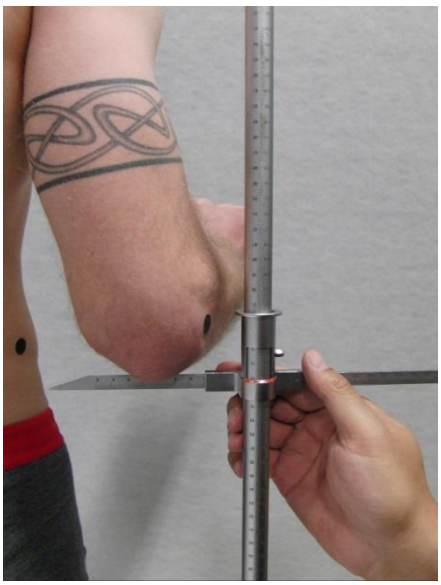
Posture required:
The participant stands with feet together to the left side of the anthropometry box (outer right leg touching the left side of the box) with their arm in a 90 degree angle. The assessor kneels behind the participant and the box. Both participant and assessor are facing the same direction.

Procedure:
Measure from the most inferior surface of the elbow (Olecranon) to the most superior surface of the anthropometry box when the participant is at "end tidal" of the breathing cycle. Ensure the measure is taken from the 'outside' or superior edge of the sliding prong (whilst touching the olecranon). Measure to the nearest 0.1 cm. Apply a correction factor for elbow grip height = Olecranon to anthropometry box surface distance + anthropometer prong/arm width + box height.

Reference:
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

Notes:
If the anthropometry box is too short consider using another object such as a sturdy desk or table. Make sure the fixed prong outer surface is square with the surface of the anthropometry box. Ensure the anthropometer is vertical. Participants with a wider than normal Lattisimus Dorsi have elbows abducted from the body altering the height of the elbow. Take the measure at 'end tidal' to avoid inaccuraices due to breathing (vertical movements to the torso caused by fluctuations in the diaphragm). Participants are encouraged to relax throughout. The long axis of the tricep should ideally be perpendicular to the anthropometry box surface. However, the long axis of the triceps will only be perpendicular to the box surface if the participant is sufficiently slender or lean to enable the arm to hang vertically, a condition which is not the case in the example depicted.

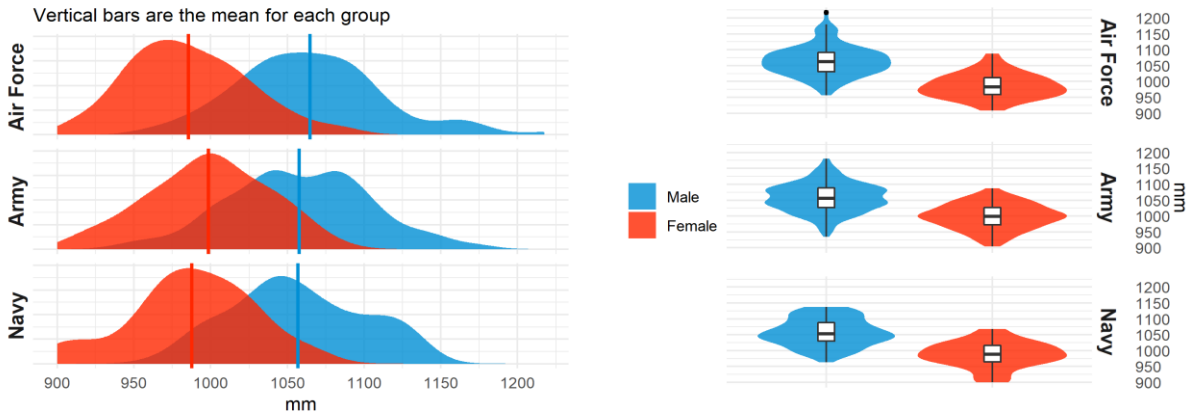




Elbow rest height standing summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1059	1065	1058	1057	**Mean**	986	998	988	992
46	47	46	43	**SD**	39	40	40	40
934	956	934	964	**Min**	908	904	900	900
1218	1218	1181	1138	**Max**	1087	1087	1068	1087
1173	1180	1165	1134	**P99**	1081	1073	1065	1078
1162	1172	1150	1134	**P98**	1072	1070	1061	1069
1150	1166	1148	1129	**P97**	1062	1065	1058	1064
1138	1161	1137	1125	**P95**	1050	1060	1054	1059
1116	1120	1114	1122	**P90**	1035	1050	1031	1044
1105	1106	1103	1111	**P85**	1022	1041	1026	1034
1096	1096	1096	1100	**P80**	1016	1034	1022	1026
1090	1092	1089	1088	**P75**	1012	1027	1016	1020
1084	1088	1083	1080	**P70**	1007	1023	1008	1011
1078	1078	1078	1071	**P65**	999	1011	1003	1008
1072	1075	1072	1064	**P60**	992	1008	999	1002
1065	1068	1065	1058	**P55**	987	1004	996	998
1057	1062	1056	1052	**P50**	983	999	989	992
1051	1057	1050	1049	**P45**	976	995	984	988
1046	1050	1044	1044	**P40**	973	991	978	981
1040	1044	1038	1038	**P35**	967	986	975	974
1034	1039	1034	1033	**P30**	962	979	972	971
1029	1031	1026	1030	**P25**	959	972	964	964
1021	1026	1017	1020	**P20**	950	964	962	959
1011	1018	1009	1010	**P15**	947	956	953	950
1001	1007	999	997	**P10**	943	948	934	942
985	994	984	990	**P5**	925	929	907	924
975	982	969	986	**P3**	924	922	904	918
963	978	959	984	**P2**	917	918	903	909
955	964	952	982	**P1**	911	917	901	905

Distribution plots for each service and gender



Eye height - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ISO 7250, NZDFAS

Definition:
The vertical distance from the floor to the lateral corner of the eye. The head is in the Frankfort plane.

Landmark required:
Ectocanthus landmark (lateral coroner of the right eye).

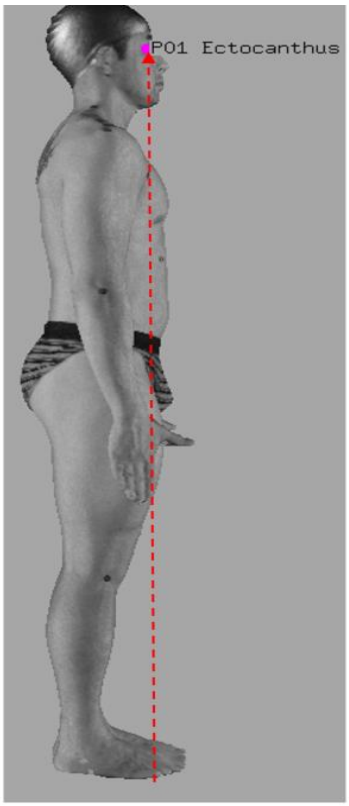
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Ectocanthus landmark. Ensure that the point marker is NOT on the crease of the eye. Measurements are reported in mm. Located visually.

Reference:
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

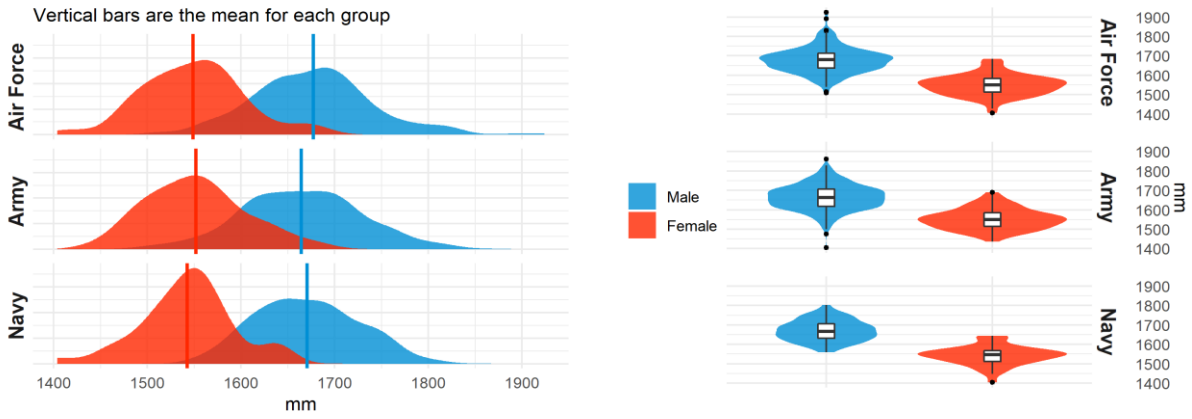
Notes:
Ensure that the participant stands erect without ‘hunching’.



Eye height summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1669	1677	1664	1671	**Mean**	1549	1552	1543	1549
64	65	65	54	**SD**	54	54	50	53
1404	1508	1404	1559	**Min**	1406	1436	1405	1405
1924	1924	1862	1804	**Max**	1684	1691	1645	1691
1824	1830	1817	1789	**P99**	1679	1678	1643	1677
1809	1823	1799	1768	**P98**	1673	1671	1641	1669
1795	1815	1790	1760	**P97**	1666	1657	1640	1659
1774	1794	1768	1756	**P95**	1646	1643	1638	1640
1751	1754	1751	1746	**P90**	1614	1624	1594	1621
1732	1734	1731	1734	**P85**	1592	1611	1588	1596
1719	1723	1716	1719	**P80**	1586	1591	1572	1587
1709	1713	1707	1707	**P75**	1583	1584	1568	1581
1701	1704	1699	1696	**P70**	1576	1577	1563	1571
1693	1700	1691	1691	**P65**	1568	1568	1561	1565
1685	1692	1681	1686	**P60**	1565	1561	1552	1561
1678	1684	1674	1681	**P55**	1557	1554	1549	1554
1667	1679	1663	1667	**P50**	1551	1550	1546	1549
1659	1669	1656	1659	**P45**	1540	1544	1543	1543
1651	1661	1647	1651	**P40**	1536	1537	1536	1536
1643	1651	1637	1645	**P35**	1529	1529	1532	1529
1634	1643	1628	1640	**P30**	1518	1521	1522	1519
1625	1636	1619	1632	**P25**	1513	1515	1512	1513
1615	1625	1612	1619	**P20**	1504	1504	1511	1504
1606	1612	1602	1611	**P15**	1495	1495	1499	1495
1593	1601	1585	1603	**P10**	1482	1486	1484	1482
1568	1571	1556	1592	**P5**	1474	1475	1464	1471
1549	1566	1546	1579	**P3**	1472	1464	1451	1464
1541	1559	1524	1571	**P2**	1446	1463	1440	1448
1515	1541	1506	1565	**P1**	1421	1451	1422	1428

Distribution plots for each service and gender



Eye height sitting - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS.

Definition:
Sitting surface to the Ectocanthus landmark.

Landmark required:
Ectocanthus.

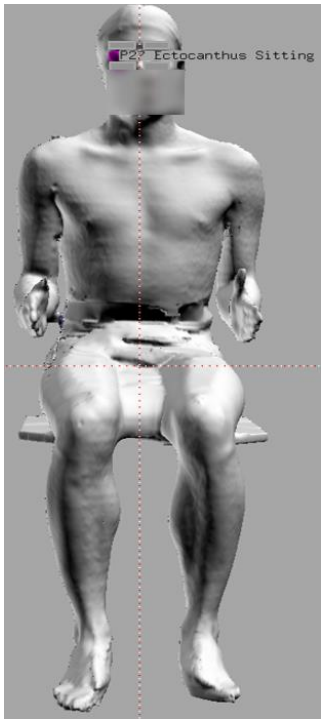
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

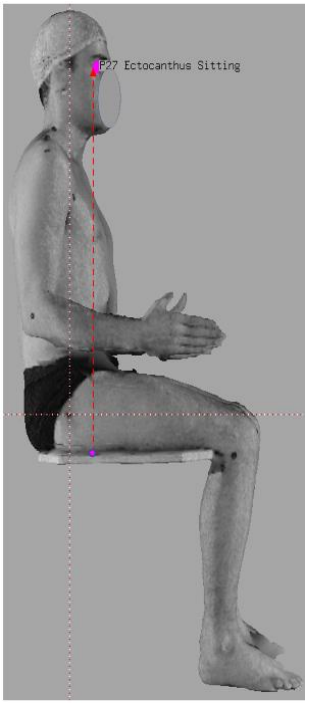
Procedure:
In CySize use the Y coordinate (mm on the Y or vertical axis) of Ectocanthus. Measurements are reported in mm.

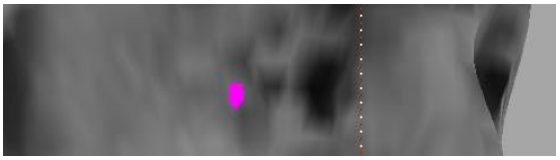
Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
Ensure that the participant is sitting erect ideally with the head in the Frankfort plane.



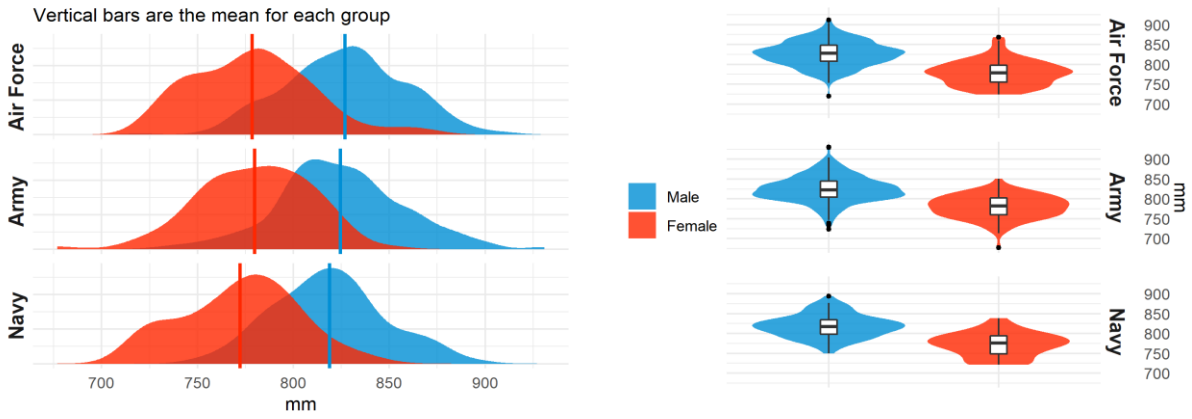




Eye height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
825	827	825	819	**Mean**	778	780	772	778
32	31	33	29	**SD**	31	30	30	30
720	720	724	750	**Min**	724	677	722	677
931	912	931	894	**Max**	868	851	839	868
901	893	903	879	**P99**	863	834	833	850
891	888	895	877	**P98**	855	829	826	838
886	882	888	875	**P97**	844	825	823	829
880	876	882	873	**P95**	827	823	820	824
866	867	867	860	**P90**	811	817	808	812
860	862	860	847	**P85**	809	809	799	808
851	856	851	841	**P80**	805	806	795	804
844	849	845	834	**P75**	797	802	794	798
839	840	839	832	**P70**	792	796	789	794
836	838	836	828	**P65**	787	793	786	789
831	836	830	827	**P60**	785	789	780	786
828	832	827	820	**P55**	782	786	778	783
824	828	823	817	**P50**	778	782	776	778
819	823	818	815	**P45**	776	777	770	776
815	820	815	813	**P40**	774	773	768	772
812	814	811	808	**P35**	764	767	765	766
808	810	807	804	**P30**	761	764	758	761
804	808	804	798	**P25**	755	760	749	758
800	801	800	794	**P20**	748	756	746	750
795	794	796	787	**P15**	744	751	735	745
784	784	785	783	**P10**	739	745	725	738
773	776	772	776	**P5**	732	731	723	728
764	771	762	766	**P3**	732	726	722	724
759	771	755	765	**P2**	731	721	722	722
749	763	745	762	**P1**	729	712	722	722

Distribution plots for each service and gender



Foot ball circumference - Physical measurement (mm)

Measuring instrument:
Anthropometry tape.

Source:
AWAS.

Definition:
The circumference around the first metatarsophalangeal protrusion and fifth metatarsophalangeal protrusion

Landmarks required:
None.

Posture required:
The participant assumes a relaxed standing position with the feet comfortably apart and body weight evenly distributed. The arms are hanging by the sides.

Procedure:
The assessor visually inspects the foot for the first and fifth metatarsophalangeal protrusion before placing the tape around these sites. The tape may require constant adjusting and will require a few prompts to the participant to raise their foot, reposition the tape then lower the foot. Take the reading to the nearest 0.1 cm. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

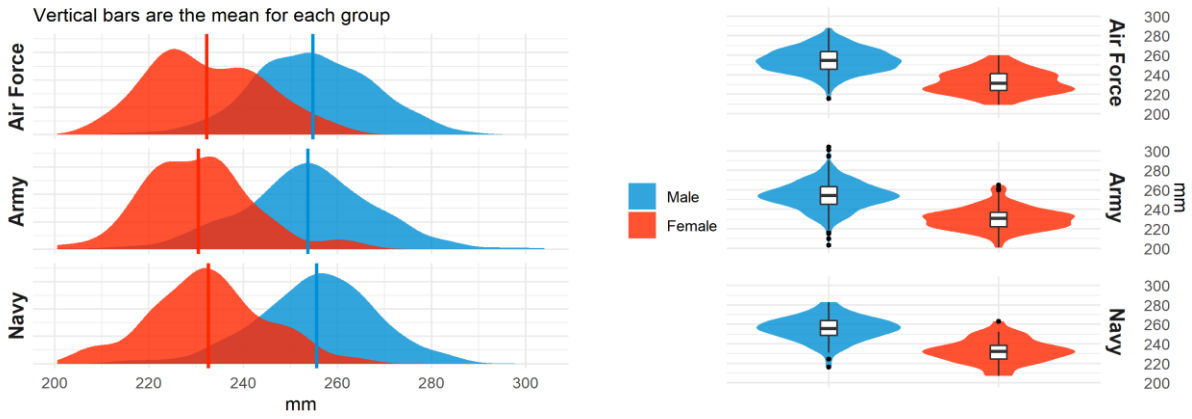
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
The first and fifth metatarsophalangeal protrusions are not necessarily horizontal in position, therefore the tape may not be perpendicular to the long axis of the foot.

Foot ball circumference summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
254	255	254	256	**Mean**	232	230	233	232
14	13	14	13	**SD**	12	12	12	12
203	216	203	216	**Min**	209	200	207	200
304	288	304	283	**Max**	260	265	263	265
285	281	286	283	**P99**	259	261	259	261
283	279	284	281	**P98**	257	260	254	260
280	278	280	278	**P97**	255	258	252	257
276	276	275	275	**P95**	252	248	252	252
271	270	272	271	**P90**	249	244	249	247
268	268	268	266	**P85**	245	241	245	244
265	265	265	265	**P80**	242	238	243	241
263	264	263	264	**P75**	241	237	238	239
261	262	260	263	**P70**	240	235	238	237
259	260	258	260	**P65**	238	234	236	235
257	257	257	259	**P60**	235	233	235	234
256	256	255	257	**P55**	234	232	233	232
254	255	254	256	**P50**	231	231	232	231
253	253	253	255	**P45**	228	228	231	229
251	252	251	254	**P40**	227	226	230	227
250	250	250	252	**P35**	226	225	229	226
248	247	248	250	**P30**	225	224	228	225
246	245	245	248	**P25**	224	222	224	223
244	245	243	245	**P20**	222	221	222	222
240	244	240	243	**P15**	220	220	221	220
236	240	235	240	**P10**	219	218	219	218
231	235	230	235	**P5**	214	214	211	214
228	232	226	233	**P3**	212	213	209	211
226	229	225	229	**P2**	211	210	208	209
220	226	219	223	**P1**	210	206	207	207

Distribution plots for each service and gender



Foot ball length - Physical measurement (mm)

Measuring instrument:
Brannock device – AUT SPRINZ clinic.

Source:
ANSUR.

Definition:
The distance from the back of the heel to the landmark at the first metatarsophalangeal protrusion is measured with the Brannock device. The participant stands erect with the right foot in the Brannock device and the other foot on a board of equal height. Body weight is distributed equally on both feet. The medial side of the right foot is parallel with the long axis of the device.

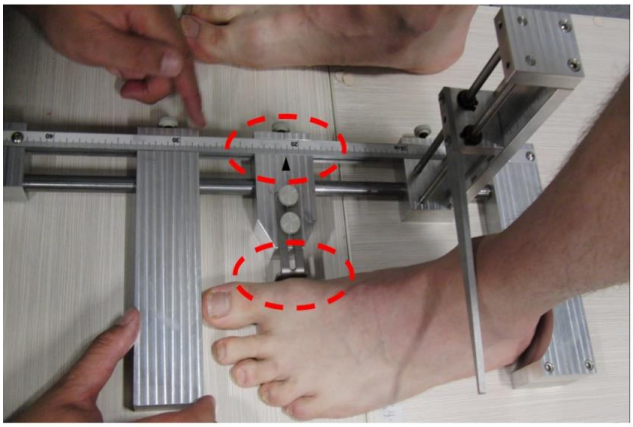
Landmarks required:
None.

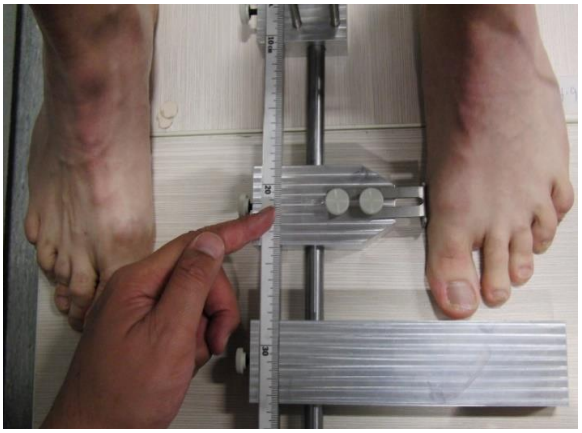
Posture required:
The participant assumes a relaxed standing position with the feet comfortably apart and body weight evenly distributed. The arms are hanging by the sides. The assessor will be kneeling and often change position to ensure the foot is positioned correctly.

Procedure:
The heel is pressed lightly against the rear (curved) plate of the device, the side-sliding plate is positioned until it lightly touches the fifth metatarsophalangeal protrusion site (observed visually). An extension latch can also be used for increased accuracy. Take the reading when the etched marker (depicted as a black triangle below) meets the scale. Take the reading to the nearest 0.1 mm. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Notes:
If the participant has a right foot injury then use the left foot. This may require a change of Brannock device type as in the figure.

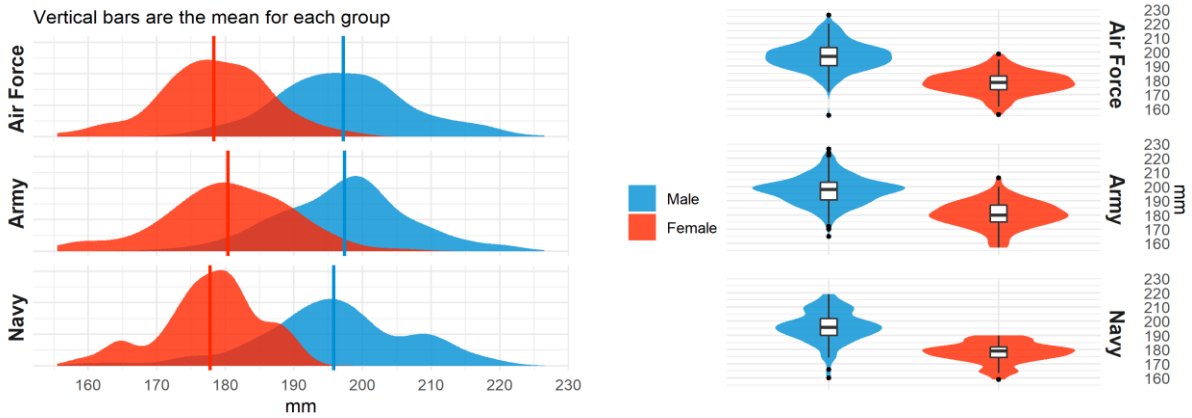




Foot ball length summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
197	197	197	196	**Mean**	178	180	178	179
10	10	10	11	**SD**	8	9	7	9
156	156	165	160	**Min**	156	157	159	156
226	226	226	219	**Max**	198	206	190	206
221	220	221	218	**P99**	196	200	190	198
219	218	219	217	**P98**	194	196	190	196
217	217	216	214	**P97**	193	196	189	194
214	215	214	213	**P95**	190	195	188	192
210	210	210	210	**P90**	188	191	187	190
207	207	207	208	**P85**	185	190	186	188
204	204	204	207	**P80**	185	188	183	186
203	203	203	202	**P75**	183	187	182	185
202	202	202	200	**P70**	183	185	181	183
200	200	201	199	**P65**	182	184	181	182
200	200	200	198	**P60**	180	183	180	181
198	198	199	196	**P55**	179	181	180	180
197	197	198	196	**P50**	178	180	179	180
196	195	197	195	**P45**	177	180	177	178
195	195	196	194	**P40**	177	179	177	177
194	194	194	192	**P35**	175	177	176	176
192	192	193	190	**P30**	175	176	175	175
190	190	191	190	**P25**	174	175	174	174
190	190	190	190	**P20**	172	174	173	173
187	188	187	186	**P15**	171	172	171	171
185	186	185	183	**P10**	169	170	166	169
181	182	181	175	**P5**	164	164	165	164
178	179	179	174	**P3**	162	160	164	161
176	178	177	172	**P2**	162	159	163	159
174	176	174	165	**P1**	160	157	161	158

Distribution plots for each service and gender



Foot breadth - Physical measurement (mm)

Measuring instrument:
Small bone caliper.

Source:
AWAS.

Definition:
The maximum horizontal distance between the first metatarsophalangeal protrusion and fifth metatarsophalangeal protrusion.

Landmarks required:
None.

Posture required:
The participant assumes a relaxed standing position with the feet comfortably apart and weight evenly distributed. The arms are hanging by the sides. The assessor will be kneeling in front and slightly to the side of the participant.

Procedure:
The caliper arms are held with the thumb and index finger. The assessor visually inspects the foot for the first and fifth metatarsophalangeal protrusion before placing the caliper plates on the sites. The plates are pressed firmly together. Take the reading to the nearest 0.1 cm. Measurements are reported in mm.

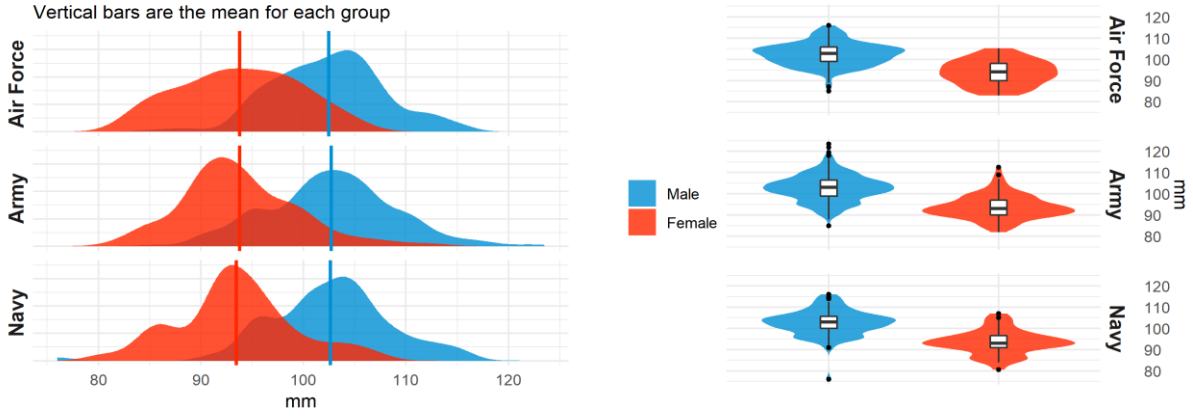
Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
The first and fifth metatarsophalangeal protrusions may differ both distally in their elevation above the standing surface, therefore the calipers may offset both in a transverse plane and a coronal plane

Foot breadth summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
103	102	103	103	**Mean**	94	94	93	94
6	5	6	6	**SD**	6	6	6	6
76	85	85	76	**Min**	83	82	80	80
124	116	124	116	**Max**	105	112	107	112
117	115	118	115	**P99**	105	109	106	107
115	114	116	115	**P98**	104	107	105	106
114	113	115	114	**P97**	104	106	105	105
112	112	113	112	**P95**	103	104	104	104
110	109	110	110	**P90**	101	100	101	101
108	108	109	108	**P85**	100	99	99	100
107	106	108	107	**P80**	99	99	97	99
106	106	106	106	**P75**	98	97	96	97
106	105	106	105	**P70**	97	96	95	96
105	105	105	105	**P65**	96	95	95	95
104	104	104	104	**P60**	96	94	95	95
103	103	104	103	**P55**	95	94	94	94
103	103	103	103	**P50**	94	93	93	93
102	102	102	102	**P45**	93	92	93	93
102	101	102	102	**P40**	92	92	92	92
100	100	100	100	**P35**	91	91	92	92
100	100	100	100	**P30**	91	91	92	91
99	99	99	100	**P25**	90	90	91	90
97	98	97	97	**P20**	88	90	89	90
96	97	95	97	**P15**	87	89	87	88
95	95	95	95	**P10**	85	88	86	86
93	95	92	95	**P5**	85	85	85	85
91	94	91	94	**P3**	84	85	84	84
90	93	90	92	**P2**	84	85	83	84
89	89	90	89	**P1**	84	83	82	83

Distribution plots for each service and gender



Foot length - Physical measurement (mm)

Measuring instrument:
Brannock device – AUT SPRINZ clinic. Measurements are in mm.

Source:
ISAK, ANSUR.

Definition:
Distance from the Akropodion (the tip of the longest toe — which may be the first or second phalanx) to the Pternion (most posterior point on the calcaneus of the foot).

Landmarks required:
None.

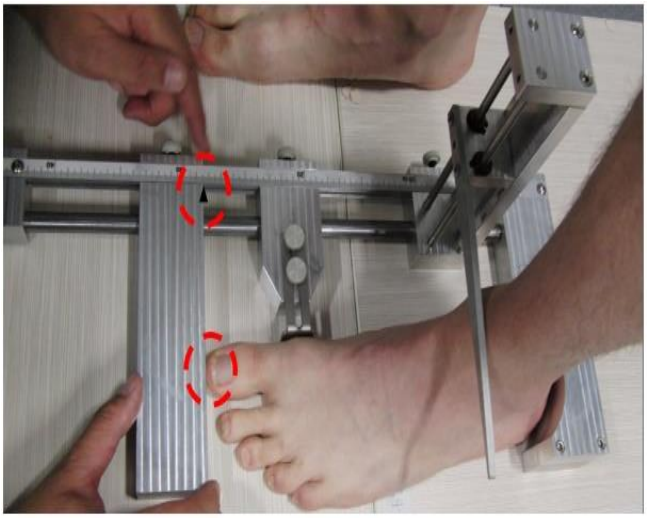
Posture required:
The participant assumes a relaxed standing position with the feet comfortably apart and weight evenly distributed. The arms are hanging by the sides. It is more convenient for the assessor if the participant stands on the box during this measurement. The assessor will be mostly kneeling but must change position to ensure the participant's foot is positioned correctly.

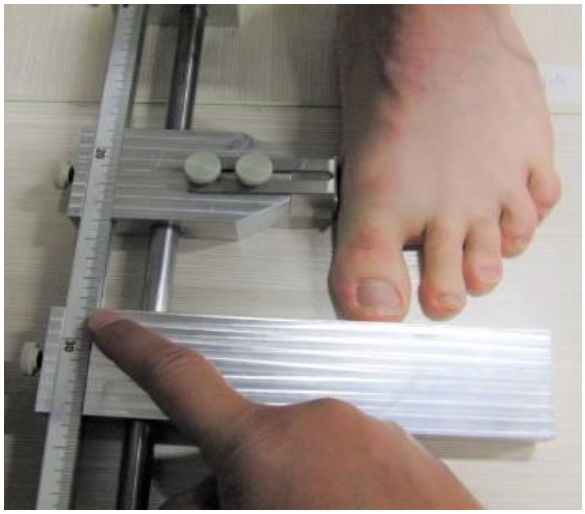
Procedure:
The heel is pressed lightly against the rear (curved) plate of the device, the sliding plate is moved towards the tip of the tip of the longest toe — which may be the first or second phalanx protrusion. Ensure that there is contact between the toe and the device, but with minimal pressure. The reading is taken where the sliding plate edge meets the scale. Take the reading to the nearest 0.1 cm. Measurements are reported in mm.

Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Notes:
If the participant has a right foot injury then use the left foot. This may require a change of Brannock device type as in the figure.

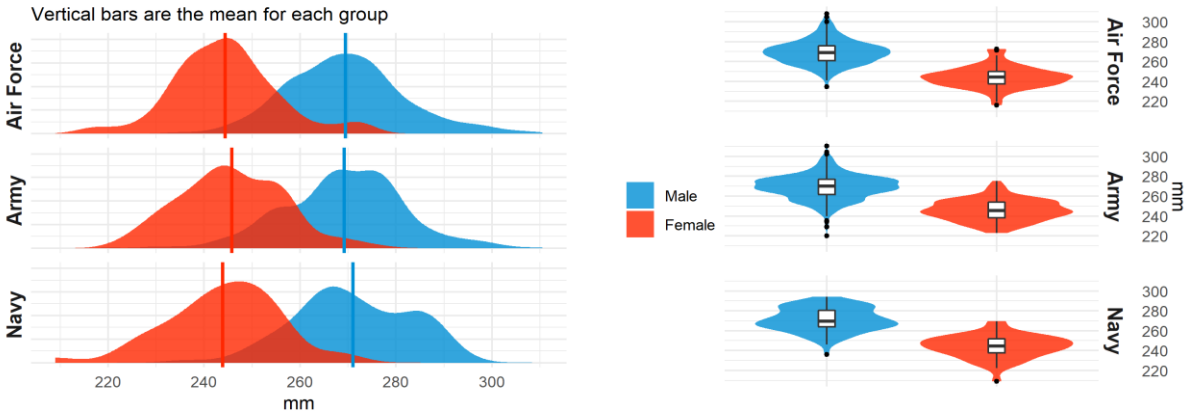




Foot length summary statistics - Physical measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
269	270	269	271	**Mean**	244	246	244	245
12	12	13	12	**SD**	11	11	12	11
220	234	220	236	**Min**	216	223	209	209
310	308	310	294	**Max**	273	276	270	276
299	300	299	291	**P99**	273	270	268	272
296	298	296	291	**P98**	272	269	267	270
294	296	294	290	**P97**	271	268	265	269
290	292	289	288	**P95**	264	264	259	264
285	285	284	287	**P90**	256	257	256	257
281	281	280	286	**P85**	254	256	255	256
280	278	279	284	**P80**	252	256	253	254
277	276	277	281	**P75**	250	254	252	252
276	275	276	278	**P70**	248	253	250	250
274	274	275	276	**P65**	247	250	249	249
273	272	273	274	**P60**	246	248	248	247
271	271	271	272	**P55**	246	246	246	246
270	269	270	270	**P50**	244	246	244	245
268	267	268	269	**P45**	243	244	244	244
266	266	267	267	**P40**	241	244	242	242
265	265	266	266	**P35**	240	242	241	241
264	264	264	264	**P30**	239	240	239	239
262	261	262	264	**P25**	238	238	238	238
259	259	259	262	**P20**	236	237	234	236
256	257	256	260	**P15**	234	234	233	234
254	256	254	256	**P10**	233	232	228	231
250	251	250	253	**P5**	229	230	226	227
246	248	245	250	**P3**	226	227	223	226
245	246	243	249	**P2**	222	226	220	223
241	245	239	245	**P1**	218	224	215	220

Distribution plots for each service and gender



Forearm-fingertip length - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
CySize

Definition:
The horizontal distance from the posterior elbow to the tip of the middle finger, with elbow flexed to a 90 degree angle to the hand, extended.

Landmark required:
Olecranon rear (right) and Dactylion III landmark.

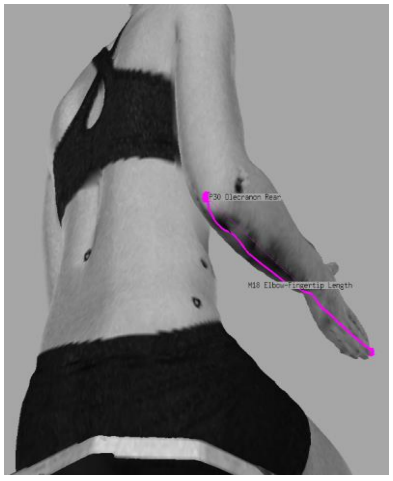
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

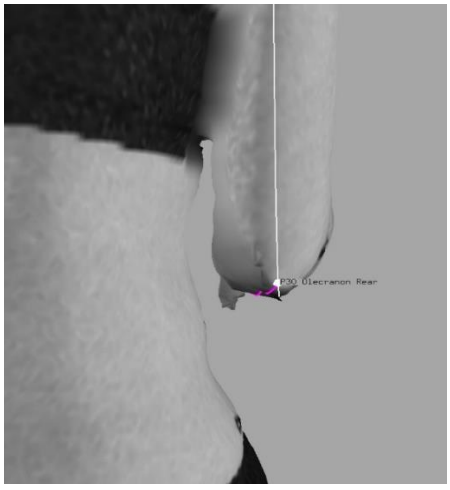
Procedure:
This measure is the point-to-point distance between the Olecranon rear and Dactylion III (tip of the longest finger) landmarks. For the Centre of Dactylion III tip use X loop to narrow down to point but do not include fingernail. Measurements are reported in mm.

Reference:
DOD-HDBK-743. Military Handbook: Anthropometry of U.S. Military Personnel (13 FEB 1991). Department of Defense. United States.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
The olecranon bottom landmark is somewhat subjective. Check from the rear view that the olecranon landmark is in line with the ‘belly’ of the triceps and mid-line of the posterior aspect of the arm (see example below).

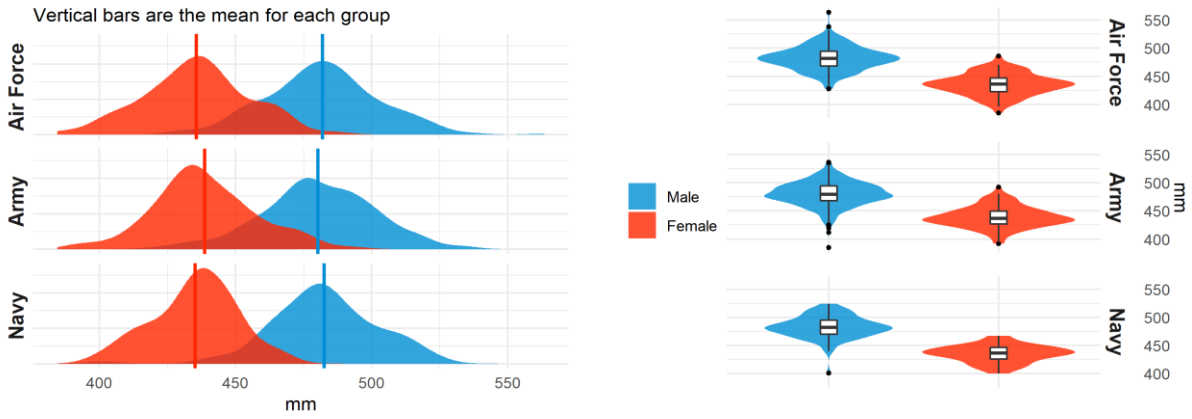




Forearm-fingertip length summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
481	482	480	483	**Mean**	436	439	435	437
21	21	21	20	**SD**	19	19	15	18
384	428	384	401	**Min**	385	392	400	385
564	564	536	524	**Max**	486	492	467	492
528	530	529	522	**P99**	475	481	465	480
522	524	521	519	**P98**	469	478	464	473
519	521	518	516	**P97**	468	473	463	472
515	518	515	513	**P95**	466	472	460	469
508	511	506	509	**P90**	463	463	450	462
502	503	502	503	**P85**	457	458	449	456
498	500	498	498	**P80**	451	451	448	450
494	494	494	495	**P75**	447	450	446	448
491	491	491	491	**P70**	444	448	442	445
489	489	489	488	**P65**	442	444	440	442
486	486	486	485	**P60**	439	441	439	440
483	484	482	483	**P55**	437	438	437	437
481	482	480	482	**P50**	436	436	436	436
478	479	478	480	**P45**	434	435	436	435
477	477	476	479	**P40**	433	433	434	433
474	475	473	477	**P35**	430	432	433	432
472	473	471	474	**P30**	426	430	428	428
468	468	468	470	**P25**	423	427	426	426
465	466	464	468	**P20**	421	425	422	422
460	459	460	466	**P15**	416	422	418	418
455	455	454	460	**P10**	410	416	413	415
447	450	444	458	**P5**	404	411	410	406
439	444	437	445	**P3**	402	404	407	403
433	439	432	443	**P2**	399	402	405	400
428	431	425	435	**P1**	393	393	402	394

Distribution plots for each service and gender



Forearm-forearm breadth - Physical measurement (mm)

Measuring instrument:
Anthropometer or large sliding caliper, and anthropometric box.

Source:
ANSUR; AWAS.

Definition:
The maximum horizontal distance across the upper body between the lateral surfaces of the forearms, when seated with elbows flexed at a 90 degree angle.

Landmark required:
None.

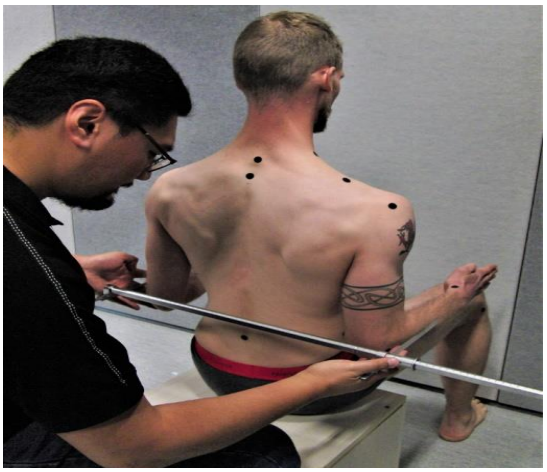
Posture required:
The participant sits erect, looking straight ahead, on the anthropometry box. The shoulders and upper arms are relaxed, and the forearms and hands are extended forward horizontally with the palms facing each other (i.e. the elbow angle is at a 90 degree angle). The elbow and index finger are aligned horizontally on each arm. The assessor kneels behind the participant and the box. Both participant and assessor are facing the same direction.

Procedure:
The participant is asked to take a deep breath in, then slowly breathe out. The assessor applies traction to their wrists to extend their arm in sequence with the breathing motion. Measure from the most lateral points of the forearm region when the participant is at "end tidal" in the breath cycle. Ensure the measure is taken from the 'outside' or superior edge of the sliding prong (whilst touching the forearms). Measure to the nearest 0.1 cm. Measurements are reported in mm.

Reference
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

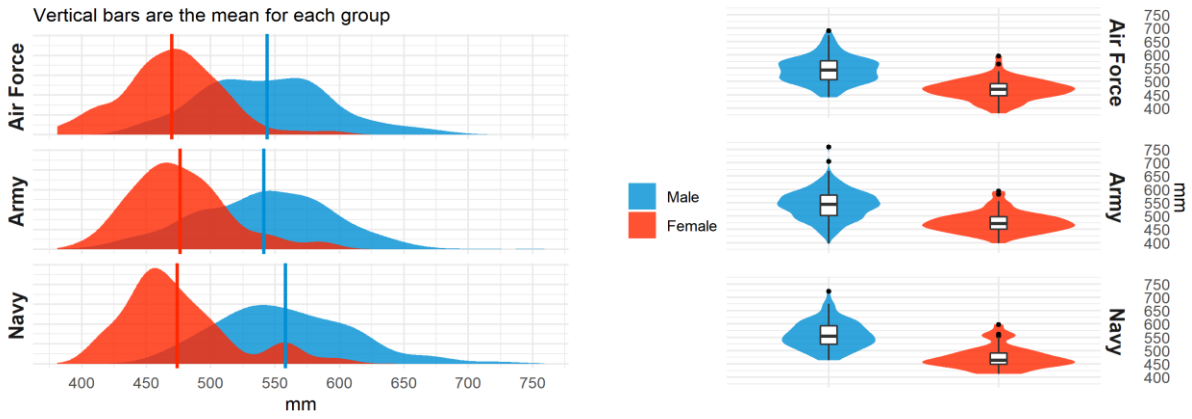
Notes:
Participants with a wider than normal Lattisimus Dorsi have elbows abducted from the body and variability in the positioning of the elbows. Participants' forearms can differ in muscle and adipose tissue mass, affecting the measurements. The use of the anthropometer or large sliding caliper varies according to the forearm-forearm distance of the participant. Generally, use a large sliding caliper for forearm-forearm distances of 56 cm or less. For all other purposes, use an anthropometer. Take the measure at 'end tidal' position to avoid inaccuraices due to breathing (vertical movements to the torso caused by fluctuations in the diaphragm).



Forearm-forearm breadth summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
544	544	541	558	**Mean**	470	476	474	474
52	50	53	51	**SD**	39	38	42	39
396	440	396	463	**Min**	381	398	412	381
759	690	759	722	**Max**	595	593	597	597
669	672	653	682	**P99**	574	584	582	592
653	657	644	671	**P98**	554	581	567	577
643	651	635	666	**P97**	537	559	561	561
629	630	627	651	**P95**	527	547	560	552
610	606	607	617	**P90**	512	520	545	518
595	588	593	613	**P85**	506	511	509	511
585	582	584	601	**P80**	500	501	500	501
579	577	578	593	**P75**	492	497	491	495
573	572	572	585	**P70**	487	494	485	489
565	565	565	573	**P65**	481	486	480	485
558	557	556	568	**P60**	478	481	473	479
550	549	549	561	**P55**	475	476	468	474
545	542	544	554	**P50**	470	472	463	471
538	536	537	546	**P45**	467	468	460	467
531	528	530	540	**P40**	460	463	459	460
524	519	524	533	**P35**	455	457	451	457
516	513	514	530	**P30**	452	456	450	452
507	507	502	523	**P25**	447	451	448	448
498	501	494	518	**P20**	444	445	445	444
489	492	484	505	**P15**	432	440	442	437
479	484	474	495	**P10**	414	432	427	428
456	462	449	481	**P5**	407	425	419	414
448	455	442	477	**P3**	404	420	416	411
441	451	432	471	**P2**	395	412	415	405
431	445	425	465	**P1**	386	410	413	399

Distribution plots for each service and gender



Grip reach - Physical measurement (mm)

Measuring instrument:
Measurement rod, as a cylindrical object with a 1 cm diameter such as a whiteboard pen. Full-length anthropometer, ideally made of solid steel. The anthropometer typically comes in 4 sections. When combined, one end of the rod contains a stationary or fixed arm or prong, the other prong is free to move up and down while at a right angle to the rod. There are typically two rod scales that run opposite each other.

Source:
ISO 7250.

Definition:
The horizontal distance from a back wall to the axis of the hand, with the arm extended horizontally and anteriorly.
The objective is to measure the distance between the wall and the grip centre point (defined as the centre of a measurement rod with a known diameter).

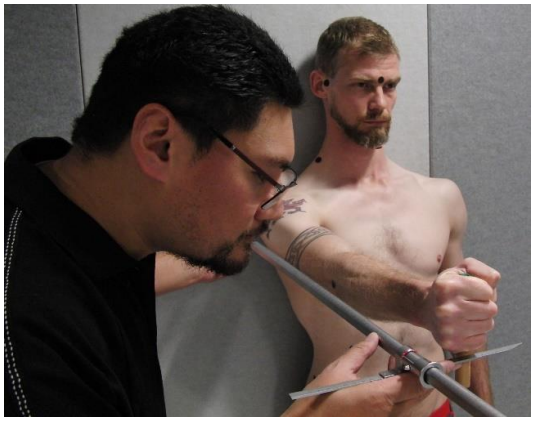
Landmark required:
None.

Posture required:
The participant stands erect against a wall with both the left and right shoulder blades touching the wall. Their right arm is raised as straight as possible anteriorly at a 90 degree angle to the body. Their arm must be in a relaxed and 'natural' position (i.e. do not ask them to fully reach forward or retract their shoulder/deltoid against the wall). They hold the measurement rod in a vertical orientation tight with their right hand (palm facing medially) outstretched. The assessor stands to the right side of the participant in front of the elbow. This position enables the assessor to support the weight of the anthropometer evenly, and be in a position to see both prongs (the fixed end and the measurement end).

Procedure:
The measure is taken at the most anterior face of the measurement rod immediately below the hand. Place the outer edge of the fixed prong against the wall. Extend the opposite prong 5 cm beyond the rod. Slowly push the prong towards the rod until it touches it. Check that both the arm and anthropometer are straight then take the reading to the nearest 0.1 cm. Apply a correction factor for grip reach = Wall to rod anterior face distance – (Rod diameter in cm/2).

Reference
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

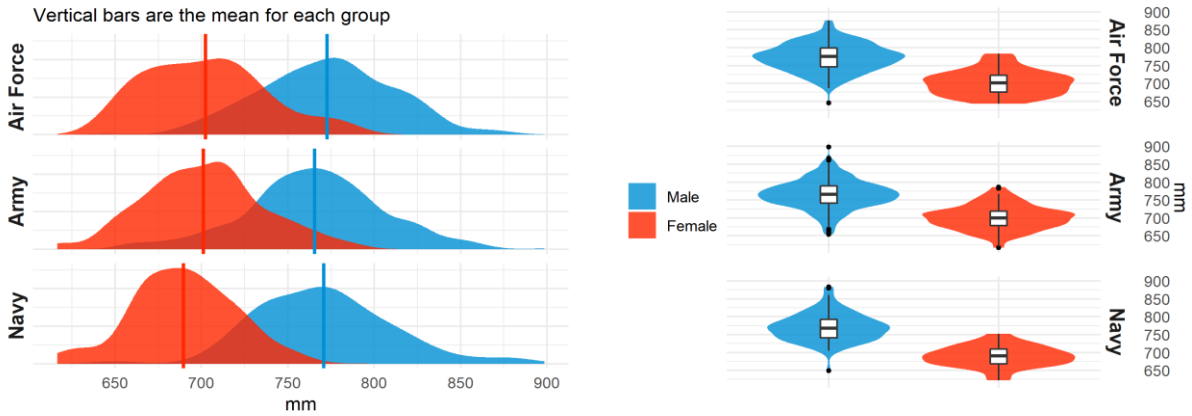
Notes:
The rod must be held tight and in a vertical position. If not, the rod will be unstable. This will result in the prong 'pushing' the rod backwards thus giving a false reading. Lengthen or shorten the anthropometer (by adding or removing sections of the rod) to suit the arm length of the participant. Ensure the prong is based securely, and square to the wall for stability. Be aware of handling the prong tip to avoid injuring the participant. The scribe observes and confirms whether the participant's arm is straight and horizontal to the floor immediately before the reading. The anthropometer and arm centre should be at the same height. Ensure the data spreadsheet has the appropriate correction factor for the length of the anthropometer. Measurements are reported in mm.



Grip reach summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
768	773	765	771	**Mean**	702	701	689	699
40	39	40	39	**SD**	35	34	29	34
646	646	654	650	**Min**	644	616	622	616
898	876	898	883	**Max**	783	786	752	786
862	865	855	880	**P99**	781	783	751	782
852	851	851	866	**P98**	779	769	749	777
843	835	843	852	**P97**	777	766	744	767
831	832	830	836	**P95**	770	763	730	759
821	821	820	821	**P90**	748	748	726	743
809	814	805	808	**P85**	738	736	722	732
800	808	796	802	**P80**	729	726	713	724
792	798	789	793	**P75**	722	718	710	719
786	792	785	786	**P70**	720	716	703	715
781	786	779	781	**P65**	715	714	699	713
777	782	774	777	**P60**	712	712	695	709
772	778	770	773	**P55**	705	706	691	702
768	775	766	768	**P50**	701	700	690	698
764	768	761	766	**P45**	696	697	687	692
758	764	756	762	**P40**	688	690	683	689
754	758	752	752	**P35**	685	688	677	685
748	753	746	748	**P30**	680	682	670	680
743	746	742	742	**P25**	676	678	668	675
738	740	736	738	**P20**	670	673	666	669
731	734	728	733	**P15**	662	667	666	666
719	723	713	730	**P10**	659	658	665	658
703	712	696	716	**P5**	655	649	639	649
692	702	683	713	**P3**	652	648	629	645
682	695	675	710	**P2**	649	642	625	639
664	693	660	698	**P1**	646	619	624	622

Distribution plots for each service and gender



Hand breadth - Physical measurement (mm)

Measuring instrument:
The Small bone caliper was used for NZDFA as opposed to the more traditional Segmometer. The Segmometer is not suitable for this measure as it requires firm pressure on the bone sites. The tape may also have a propensity to 'bend'. Measurements are in mm.

Source:
ANSUR, AWAS, CFAS.

Definition:
The breadth of the right hand between the metacarpale II and metacarpale V.

Landmarks required:
None.

Posture required:
The participant places the palm on a table with the fingers together and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers are placed on a flat surface 8 mm higher than the table. The assessor stands facing the participant, perpendicular to the long axis of the hand.

Procedure:
The caliper plates are placed on the metacarpale II and metacarpale V. To ensure that outside surface of the hand is flat (thus reducing the 'cupping' propensity of the hand), a specially designed measurement board (of 8 mm thickness) was developed using stationary clipboards. The hand was placed so that the palm rested on the table surface while the fingers rested on the boards. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

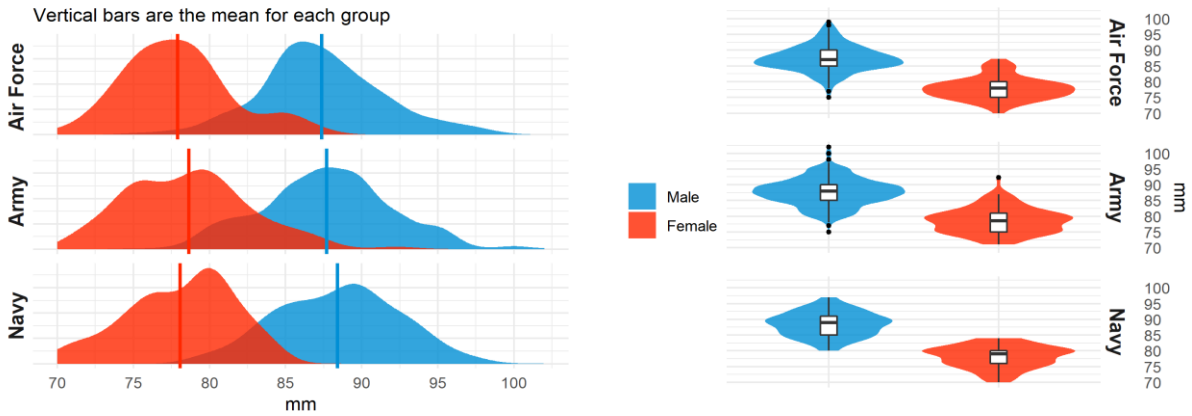
Keefe, A., H. Angel, and B. Mangan, 2012 Canadian Forces Anthropometric Survey (CFAS) – Final report. 2015, Défense Research and Development Canada: Toronto, Canada.

Notes:
The caliper plates need to be applied firmly to the bony sites to compress the overlying soft tissue.

Hand breadth summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
88	87	88	88	**Mean**	78	79	78	78
4	4	4	4	**SD**	4	4	4	4
75	75	75	80	**Min**	70	71	70	70
102	99	102	97	**Max**	87	92	84	92
97	97	98	97	**P99**	86	87	84	87
96	97	96	96	**P98**	86	87	84	87
95	96	95	95	**P97**	85	87	84	86
95	95	95	95	**P95**	85	86	83	85
93	92	93	93	**P90**	83	84	82	83
92	91	92	93	**P85**	81	83	82	82
91	90	91	92	**P80**	80	82	81	81
90	90	90	91	**P75**	80	81	80	80
90	89	90	90	**P70**	79	80	80	80
89	88	89	90	**P65**	79	80	80	80
89	88	89	90	**P60**	79	80	80	79
88	87	88	89	**P55**	78	79	79	79
88	87	88	89	**P50**	78	79	79	78
87	87	87	88	**P45**	77	78	78	78
87	86	87	87	**P40**	77	78	77	77
86	86	86	87	**P35**	76	77	77	76
85	85	86	86	**P30**	76	76	76	76
85	85	85	85	**P25**	75	75	76	75
85	85	84	85	**P20**	75	75	75	75
83	84	83	84	**P15**	75	75	74	75
82	82	82	83	**P10**	74	74	74	74
81	81	80	82	**P5**	73	72	72	72
80	80	80	81	**P3**	72	72	71	72
80	80	80	80	**P2**	72	72	71	72
79	78	79	80	**P1**	71	72	70	71

Distribution plots for each service and gender



Hand circumference - Physical measurement (mm)

Measuring instrument:
Anthropometric tape. Before measuring, ensure that the metal tape surface is not damaged and the scale is clear, and the tape can be retracted freely. There are various models. Tapes used in the NZDFAS were Cesorf and Rosscraft.

Source:
ANSUR.

Definition:
The circumference of the right hand is measured with a tape passing over the landmarks at metacarpale II and metacarpale V. The participant places the palm on a table with the fingers together and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers lie on a flat surface 8 mm higher than the table.

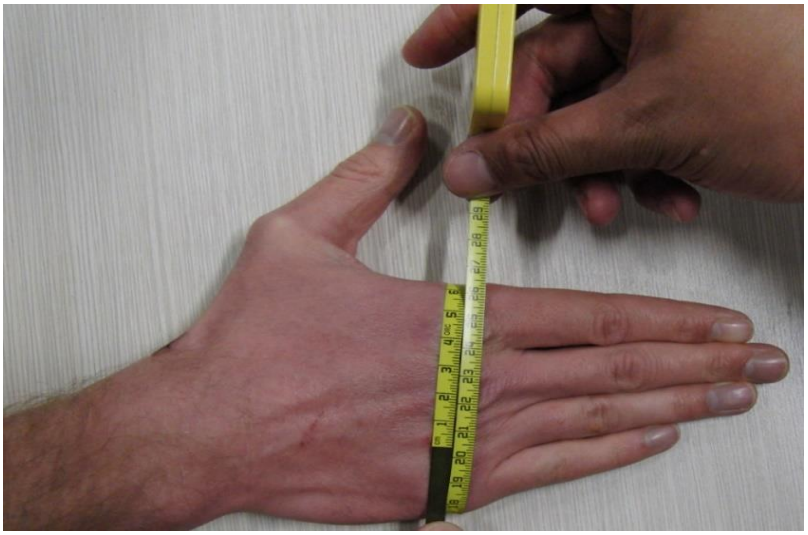
Landmark required:
None.

Posture required:
The participant places the palm on a table with the fingers together and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers lie on a flat surface 8 mm higher than the table. The assessor stands facing the participant, perpendicular to the hand. Measurements are reported in mm.

Procedure: The tape is placed around the palm passing through the metacarpale II and metacarpale V. To ensure that outside surface of the hand is flat (thus reducing the 'cupping' propensity of the hand), a specially designed measurement board (of 8mm thickness) was developed using stationary clipboards. The hand was placed so that the palm rested on the table surface while the fingers rested on the boards.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

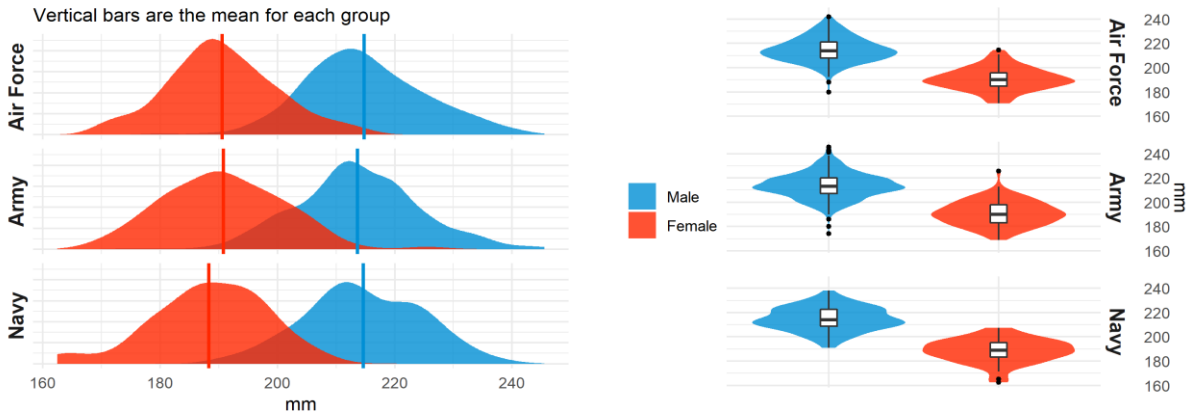
Notes:
Check that the palm is flat against the table surface. Ensure the tape conforms to the skin surface without indentation.



Hand circumference summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
214	215	214	215	**Mean**	191	191	188	190
10	10	11	10	**SD**	9	10	10	10
174	180	174	191	**Min**	170	169	162	162
246	242	246	238	**Max**	214	226	208	226
239	239	239	235	**P99**	212	213	206	213
236	236	236	233	**P98**	211	208	205	210
234	235	234	231	**P97**	210	208	204	208
232	233	232	230	**P95**	206	207	203	206
228	229	227	227	**P90**	202	204	199	203
225	226	224	225	**P85**	200	201	197	200
222	224	222	224	**P80**	199	199	197	199
220	221	220	223	**P75**	196	198	195	196
219	220	219	222	**P70**	195	195	195	195
218	218	218	219	**P65**	194	195	192	194
216	216	216	216	**P60**	193	193	192	192
215	215	215	215	**P55**	190	191	191	191
214	214	213	214	**P50**	190	190	189	190
212	213	212	213	**P45**	189	190	187	189
211	212	211	211	**P40**	188	189	186	188
210	210	210	211	**P35**	187	187	186	187
209	209	209	210	**P30**	186	185	185	185
207	208	207	209	**P25**	185	183	183	184
206	206	205	206	**P20**	183	182	180	182
204	205	203	205	**P15**	182	181	179	181
201	204	200	201	**P10**	180	178	177	178
198	199	197	200	**P5**	176	175	172	175
195	197	195	197	**P3**	173	174	167	172
194	196	194	195	**P2**	172	172	165	171
190	193	190	193	**P1**	171	171	164	169

Distribution plots for each service and gender



Hand length - Physical measurement (mm)

Measuring instrument:
Segmometer.

Source:
ANSUR.

Definition:
The length of the right hand between the stylion landmark on the wrist and the tip of the middle finger is measured with a Segmometer. The participant places the hand on the table (palm facing up) with the fingers together and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers lie on a flat surface 8 mm higher than the table.

Landmark required:
None.

Posture required:
The participant places the lateral surface of the right forearm and the back of the right-hand flat against the table surface. The palm is open and facing up. Fingers and thumb are together. The assessor stands facing the participant, perpendicular to the hand.

Procedure:
Measurement is taken on the palmar surface of the hand between the mid-stylion landmark and the tip of the Dactylion (middle finger). The fixed end of the segmometer is placed on the centre wrist landmark, the sliding end is pressed lightly against the tip of the middle finger. Measurements are reported in mm.

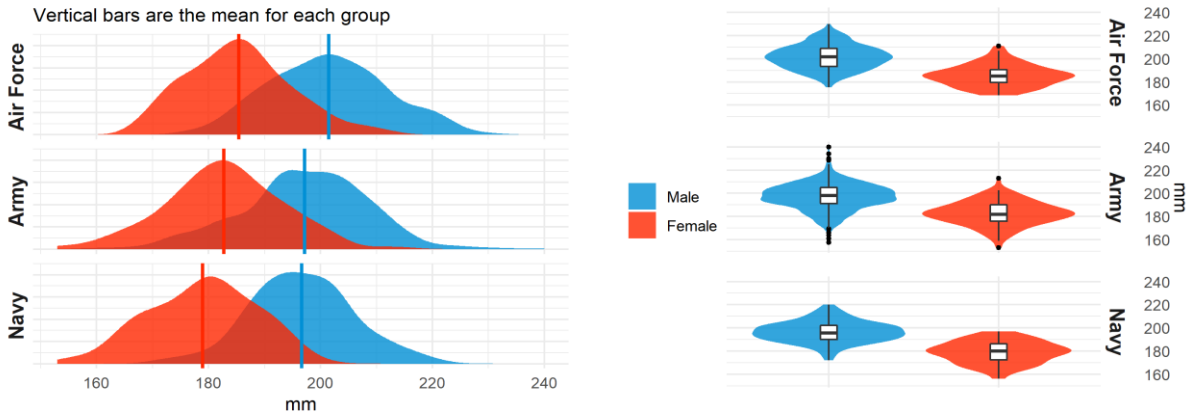
Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Notes:
Ensure that the palm and all fingers are together and rigid (no cupping of the hands). Ensure the back of the hand and fingers are fully extended and flat against the table surface. Ensure that the measure is on the distal finger surface and not the fingernail.

Hand length summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
198	201	197	197	**Mean**	185	183	179	183
11	10	12	9	**SD**	9	10	9	10
158	176	158	172	**Min**	168	153	156	153
240	230	240	220	**Max**	211	213	197	213
224	223	225	217	**P99**	208	203	196	207
221	222	220	216	**P98**	206	202	194	202
219	222	216	215	**P97**	204	201	193	201
216	220	214	211	**P95**	201	200	192	200
211	216	210	209	**P90**	198	195	191	195
210	212	209	205	**P85**	194	194	190	193
207	210	206	204	**P80**	193	191	187	191
205	209	205	202	**P75**	190	190	186	190
204	207	203	201	**P70**	189	187	184	188
202	205	202	200	**P65**	188	186	182	186
201	204	200	199	**P60**	187	185	181	185
200	202	199	198	**P55**	186	184	181	184
199	202	198	196	**P50**	185	182	180	183
197	200	196	195	**P45**	184	182	179	182
195	199	195	194	**P40**	183	180	178	180
194	197	194	193	**P35**	181	180	175	180
193	195	192	192	**P30**	180	178	175	178
191	194	191	190	**P25**	179	176	172	176
190	192	189	190	**P20**	177	174	169	174
187	190	185	188	**P15**	175	173	169	173
184	188	182	186	**P10**	174	170	166	170
180	185	176	184	**P5**	172	166	164	166
176	184	174	180	**P3**	170	163	164	164
174	182	173	178	**P2**	169	162	163	163
171	180	169	175	**P1**	169	159	159	159

Distribution plots for each service and gender



Head breadth - Physical measurement (mm)

Measuring instrument:
Large sliding caliper. This has two straight branches attached to a rigid scale that allow measurements of large bone or soft tissue to be measured to 0.1 or 0.05 cm. Before measuring, the distance between the branches should be verified to ensure it has been assembled correctly.

Source:
ISO 7250, ANSUR.

Definition:
Maximum horizontal breadth of the head above the ears, measured perpendicular to the mid-sagittal plane. This measurement is taken from behind the participant. The scale end of the caliper is above the participants' head with the reading made from behind the participant.

Landmark required:
None.

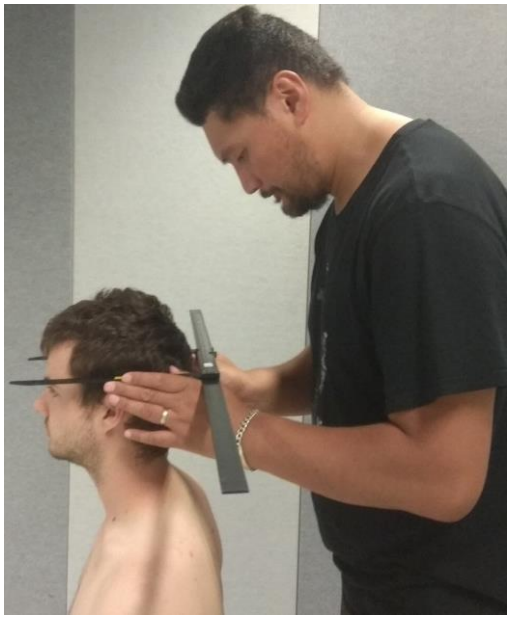
Posture required:
The participant sits erect, looking straight ahead with eyewear removed. The assessor stands behind the participant and observes the head at eye level. The scale side of the caliper is above the participants head and facing towards the rear.

Procedure:
Viewed directly from in behind, identify the most lateral aspects of the head. Opening the large sliding caliper beyond the anticipated distance, and bracing the fingers on the skull surface above each ear, slowly move the branches towards one another until they rest on the skin surface no lower than the height of the Helix (top of the ear). Record the measurement to 0.1 cm or 0.05 cm precision. Measurements are reported in mm.

Reference:
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

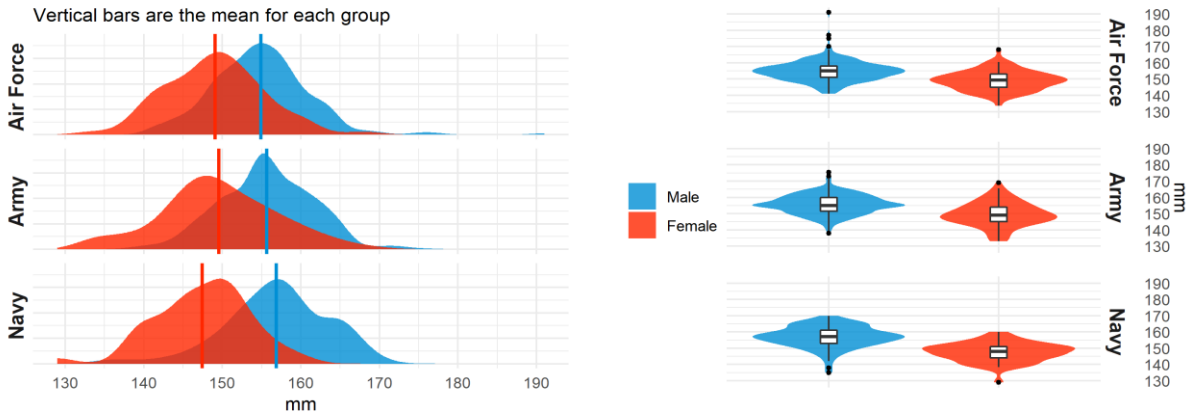
Notes:
This is a boney measurement with a limited depth of superficial tissue. The position of the head has no influence on the measurement.



Head breadth summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
156	155	156	157	**Mean**	149	150	147	149
6	6	6	7	**SD**	6	7	6	7
135	141	138	135	**Min**	134	133	129	129
191	191	176	170	**Max**	168	169	160	169
170	174	170	168	**P99**	163	166	159	165
168	168	166	168	**P98**	160	165	158	163
166	165	166	167	**P97**	160	164	157	162
165	164	165	166	**P95**	160	162	156	160
163	162	163	165	**P90**	156	159	155	158
162	160	162	164	**P85**	155	157	152	155
160	160	160	163	**P80**	154	156	152	154
160	158	160	161	**P75**	153	154	151	153
158	158	159	160	**P70**	152	153	151	152
158	157	158	159	**P65**	151	152	150	151
157	156	157	159	**P60**	150	151	150	150
156	155	156	158	**P55**	150	150	149	150
155	155	155	157	**P50**	149	149	148	149
155	154	155	156	**P45**	148	148	147	148
154	154	154	156	**P40**	148	148	146	148
154	152	154	155	**P35**	147	147	146	146
152	152	153	154	**P30**	146	146	145	146
152	151	152	153	**P25**	145	145	144	145
150	150	150	152	**P20**	144	144	143	144
150	149	150	151	**P15**	142	143	141	142
148	148	148	149	**P10**	142	141	140	141
146	145	146	146	**P5**	140	137	139	138
145	144	145	143	**P3**	139	135	139	136
143	143	144	141	**P2**	139	134	137	134
141	142	142	138	**P1**	137	133	133	133

Distribution plots for each service and gender



Head girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan.

Source:
Anthroscan.

Definition:
Maximal circumference around the cranium at the level of the forehead. The measurement passes in a sagittal plane just above the bony brow ridges and across the external occipital protuberance (the most protruding point of the back of the head). The measurement is close to horizontal when the head is positioned in the Frankfort plane.

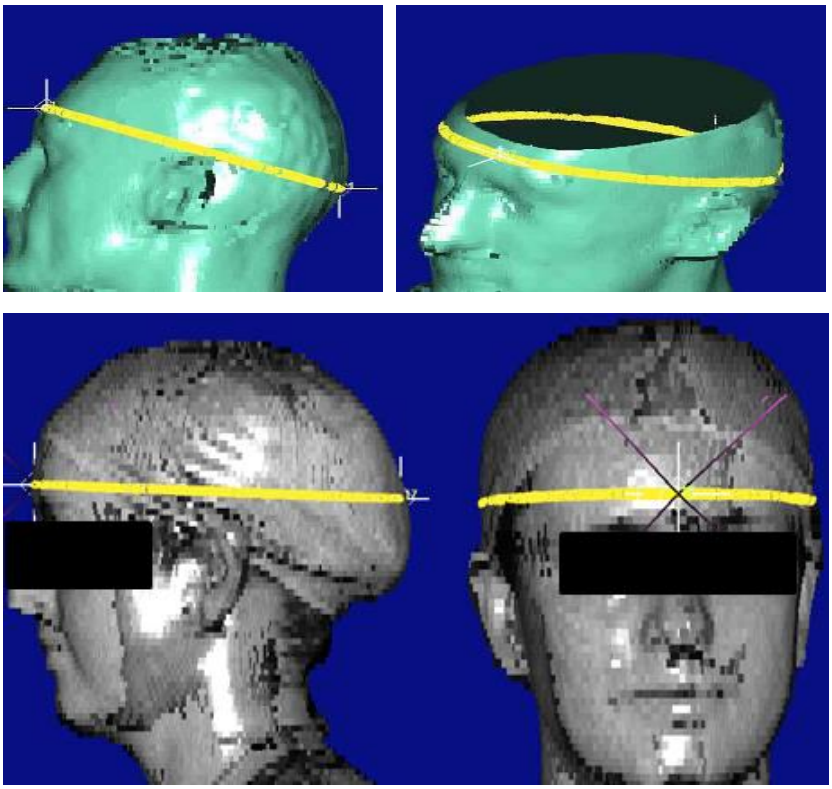
Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

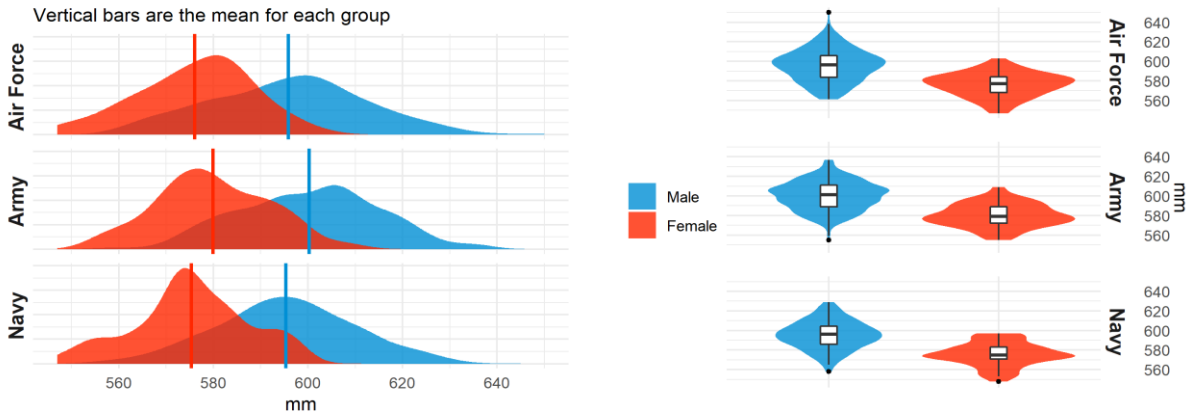
Notes:
Check that the tape is horizontal at the bony brow ridge. For females, check the tape is not hindered by hair arrangement. Ideally, females should have their hair bun below the top of the ear, or alternatively gathered above the measurement plane. Unless one of these conditions is met, then this measurement cannot be taken. If the head is oriented high or low (looking up or down) or in a position other than Frankfort position, then manoeuvre the tape accordingly.



Head girth summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
599	596	600	595	**Mean**	576	580	575	578
15	17	15	14	**SD**	12	12	12	12
555	561	555	558	**Min**	547	555	548	547
650	650	637	629	**Max**	603	609	597	609
634	631	635	625	**P99**	599	608	597	603
628	629	629	623	**P98**	597	604	597	598
626	626	627	622	**P97**	596	599	597	598
623	623	624	621	**P95**	595	598	596	597
618	617	619	612	**P90**	590	596	592	594
614	613	616	612	**P85**	588	593	588	590
612	610	613	608	**P80**	586	590	585	589
609	606	611	604	**P75**	584	589	583	586
607	604	608	603	**P70**	582	587	582	584
605	602	607	600	**P65**	582	583	579	582
603	601	605	598	**P60**	581	582	577	581
601	599	603	597	**P55**	579	580	575	579
599	596	601	596	**P50**	577	579	575	578
597	594	598	593	**P45**	576	578	574	576
595	592	596	592	**P40**	573	577	573	575
593	590	594	590	**P35**	572	574	572	573
591	587	593	589	**P30**	571	574	572	572
588	584	589	586	**P25**	568	572	571	571
585	580	586	584	**P20**	566	571	565	568
581	578	584	579	**P15**	563	569	564	565
578	573	580	577	**P10**	559	566	558	562
573	568	576	572	**P5**	555	560	554	557
570	566	574	569	**P3**	551	558	553	554
568	564	573	566	**P2**	549	557	552	553
564	562	569	564	**P1**	548	556	550	548

Distribution plots for each service and gender



Head length - Physical measurement (mm)

Measuring instrument:
Large sliding caliper. This has two straight branches attached to a rigid scale that allow measurements of large bone or soft tissue to be measured to 0.1 or 0.05 cm. Before measuring, the distance between the branches should be verified to ensure it has been assembled correctly.

Source:
ISO 7250.

Definition:
The straight line distance between the glabella and the opistocranion (the posterior extremity of the longest diameter of the skull, measured from the glabella). The position of the head has no influence on the measurement.

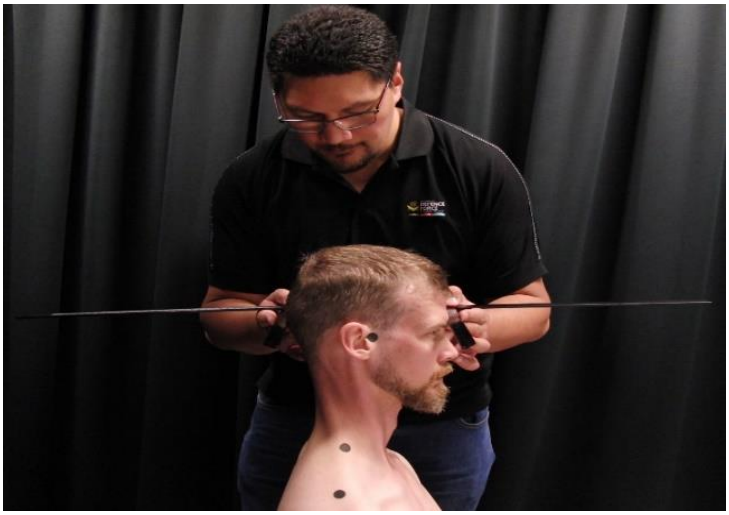
Landmark required:
None.

Posture required:
The participant sits erect, looking straight ahead with eyewear removed. The assessor stands at the side of the participant and observes the head in the Frankfort plane.

Procedure:
Viewed directly from the side. Opening the large sliding caliper beyond the anticipated distance, rest the device on the back of the hands and using the thumbs and index fingers, slowly move the branches towards one another until the anterior branch lightly touches the glabella landmark. Hold this in position. The posterior branch should then be aligned with and moved towards the opistocranion until it touches. It may help to palpate the opsticranion with either the second or third finger of the posterior hand. Record the measurement to 0.1 cm or 0.05 cm precision. Measurements are reported in mm.

Reference:
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

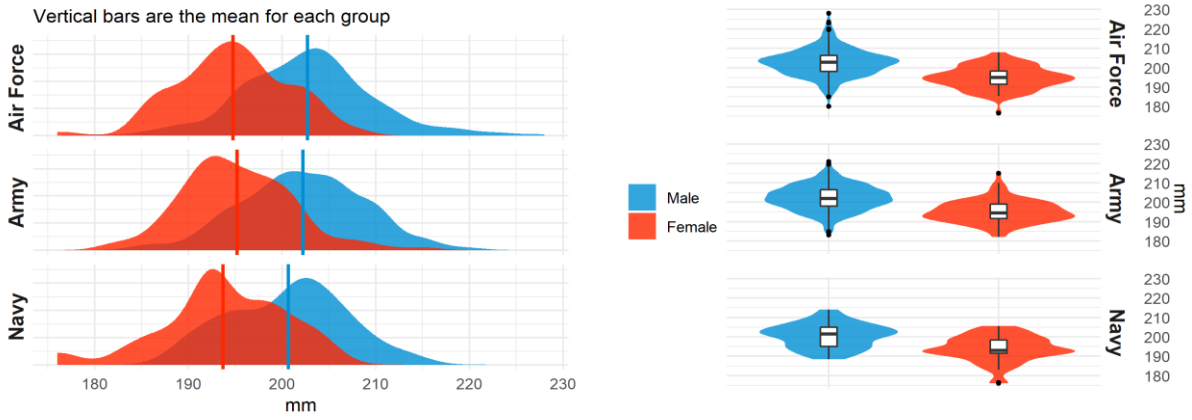
Notes:
This is a soft tissue measurement; therefore, the caliper branches must be placed on the skin, but not indent the skin.
The position of the head has no influence on the measurement.



Head length summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
202	203	202	201	**Mean**	195	195	194	195
7	7	7	6	**SD**	6	6	7	6
180	180	183	188	**Min**	176	182	176	176
228	228	221	214	**Max**	208	215	206	215
219	223	217	214	**P99**	207	210	205	208
216	219	215	213	**P98**	205	209	204	207
215	218	215	212	**P97**	204	207	204	206
213	214	212	210	**P95**	204	205	203	204
210	211	210	208	**P90**	203	202	203	202
209	209	210	206	**P85**	202	201	200	201
208	208	208	206	**P80**	200	200	199	200
206	206	206	205	**P75**	198	199	198	199
206	206	206	204	**P70**	197	198	198	198
205	205	205	203	**P65**	197	197	197	197
204	204	204	203	**P60**	196	196	195	196
203	204	203	202	**P55**	196	196	194	195
202	203	202	202	**P50**	195	194	193	194
202	202	202	201	**P45**	194	194	192	194
200	201	200	200	**P40**	193	193	192	193
200	200	200	199	**P35**	193	192	192	192
199	199	199	197	**P30**	192	192	192	192
198	198	198	195	**P25**	191	192	192	192
196	197	197	195	**P20**	190	191	189	190
195	196	195	194	**P15**	189	190	187	189
194	195	194	192	**P10**	187	188	185	187
192	191	192	190	**P5**	186	187	183	186
190	189	190	190	**P3**	186	186	178	184
188	189	188	190	**P2**	186	184	176	183
186	186	186	189	**P1**	183	182	176	177

Distribution plots for each service and gender



Hip breadth sitting - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ANSUR, NZDFAS.

Definition:
The horizontal distance in a coronal plane between two parallel sagittal planes defining the left and right lateral extent of a seated participant with knees together. a “buttock plate” placed at the most posterior point on either buttock and the back of the right knee (the popliteal fossa at the dorsal juncture of the calf and thigh).

Landmark required:
None.

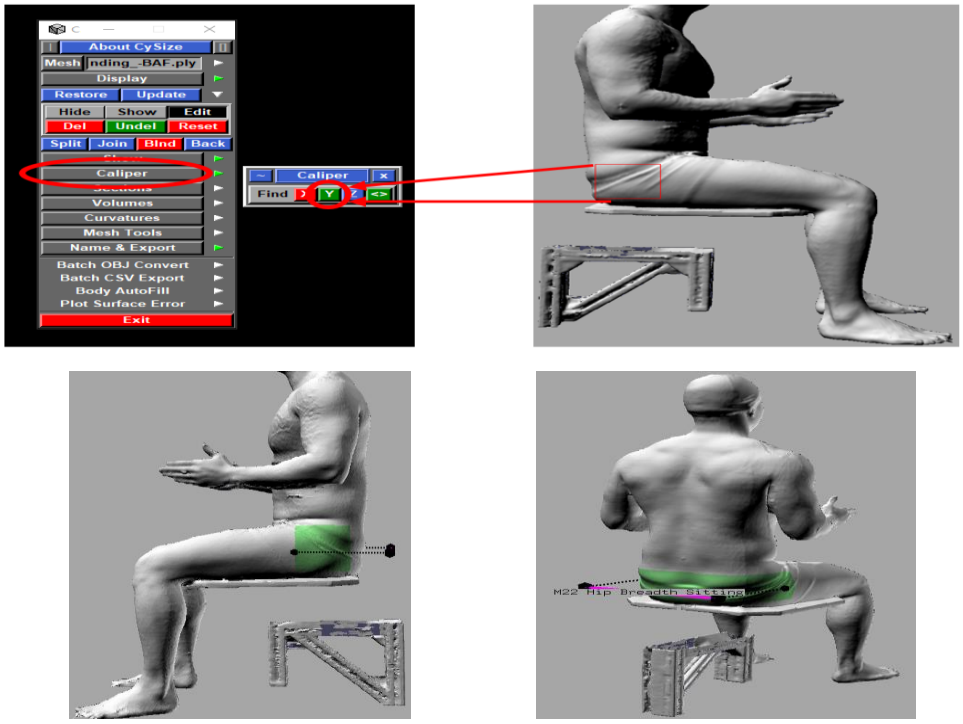
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

Procedure:
In CySize use the caliper tool. View from the right side of the participant. Highlight the hip and upper thigh area. Select the Z function (to identify the breadth along a coronal plane) to calculate the breadth. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

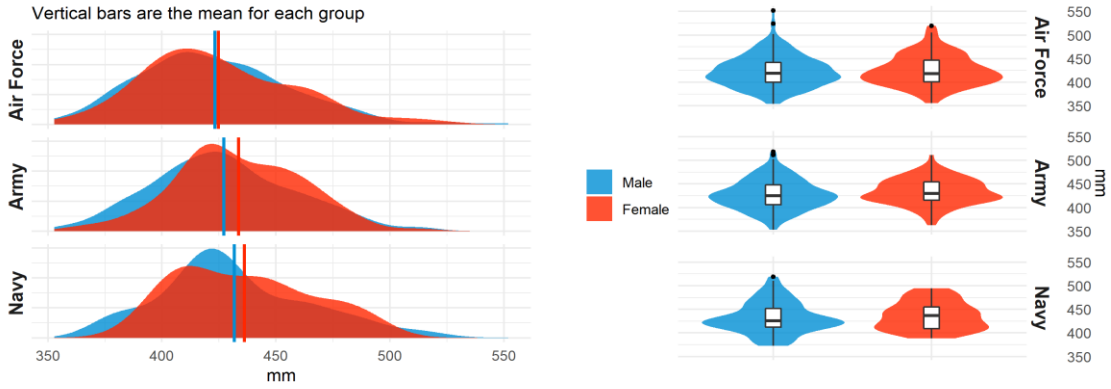
Notes:
Another method is to view from the back and highlight the left and right buttocks. However, this should be used with caution as the caliper may highlight areas of the midthigh. This is caused by participants who sit in a ‘wide’ stance i.e. their knees are pointing laterally as opposed to straight forward.



Hip breadth sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
427	423	427	432	**Mean**	425	434	436	431
32	34	31	33	**SD**	33	27	29	30
353	354	353	372	**Min**	356	363	388	356
552	552	518	519	**Max**	520	512	494	520
512	521	512	511	**P99**	509	489	492	504
496	494	494	508	**P98**	501	484	490	493
489	486	487	498	**P97**	494	483	488	488
483	482	482	489	**P95**	474	477	487	482
470	465	471	480	**P90**	467	469	478	471
462	460	461	467	**P85**	461	463	474	464
454	449	455	462	**P80**	457	457	464	460
447	442	448	451	**P75**	447	454	455	451
440	440	441	446	**P70**	435	448	449	447
436	435	436	436	**P65**	433	446	447	444
431	429	432	432	**P60**	430	443	445	436
428	424	428	429	**P55**	422	433	441	432
424	419	425	426	**P50**	418	430	436	428
421	415	422	423	**P45**	417	426	428	424
417	411	418	420	**P40**	413	424	421	419
412	407	414	418	**P35**	410	421	420	418
409	405	410	417	**P30**	404	418	414	414
405	400	406	412	**P25**	400	416	409	411
400	394	401	408	**P20**	400	412	407	405
393	388	395	402	**P15**	396	411	405	401
386	382	387	388	**P10**	390	400	403	396
377	376	378	381	**P5**	380	392	400	386
374	372	374	378	**P3**	375	382	395	381
367	362	367	375	**P2**	371	381	393	376
361	360	362	374	**P1**	365	370	391	369

Distribution plots for each service and gender



Hip breadth standing - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
JIS Z 8500, AWAS.

Definition:
The maximum horizontal distance in a coronal plane between the right and left protrusions of the hip.

Landmark required:
None.

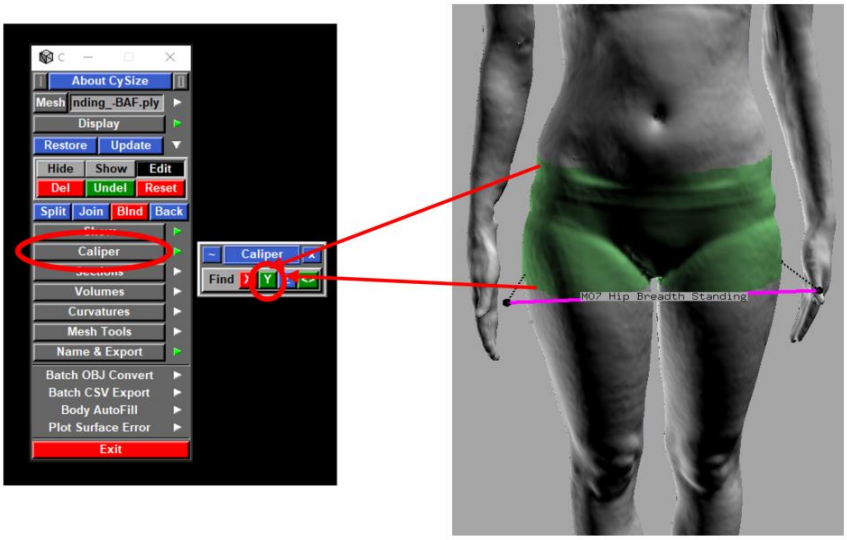
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
In CySize use the caliper tool. View from the right side. Highlight an area from the back or the front, at a height between the iliocristale and crotch landmark. Take care not to select any webbing that may exist between the thigh and the hands. Select the Y function (to create a coronal plan from the front view) to calculate breadth. Measurements are reported in mm.

Reference:
JIS Z 8500 Ergonomics Basic Human Body Measurements for Technological Design (2002). Japanese Industrial Standard: Tokyo, Japan.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

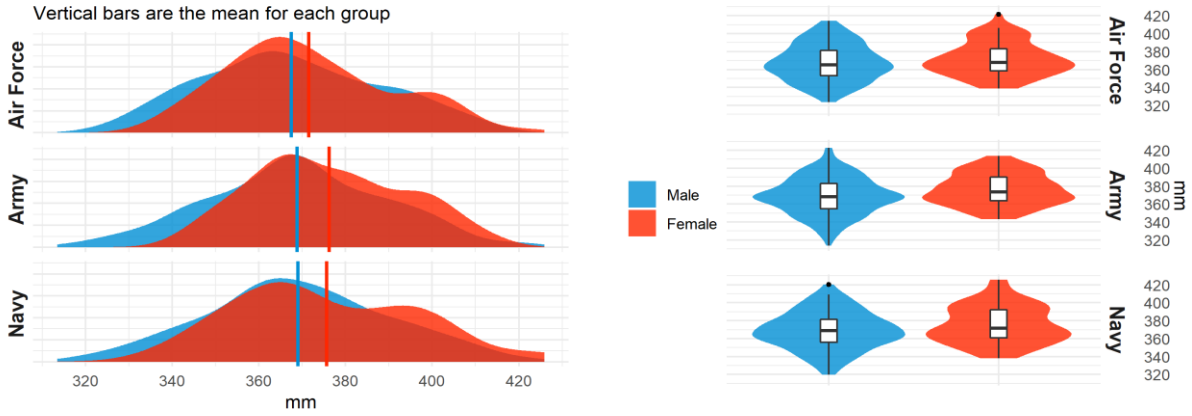
Notes:
Use the Crosshair tool to align the participant's posture. Ensure clothing is smooth at the defined measurement points.



Hip breadth standing summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
368	367	369	369	**Mean**	372	376	376	375
21	21	21	21	**SD**	19	17	21	19
314	324	314	320	**Min**	339	343	338	338
423	414	423	420	**Max**	421	414	426	426
415	410	417	410	**P99**	411	411	424	420
409	408	410	409	**P98**	405	410	422	411
407	407	405	408	**P97**	403	409	417	408
403	403	403	406	**P95**	403	404	404	403
396	396	397	395	**P90**	401	400	401	401
391	392	391	394	**P85**	396	398	400	399
388	388	387	387	**P80**	387	395	397	394
383	381	383	381	**P75**	383	390	392	389
379	379	380	380	**P70**	379	384	389	383
375	375	375	376	**P65**	378	382	386	381
372	371	372	373	**P60**	373	380	380	378
370	368	371	371	**P55**	369	379	372	374
368	365	368	369	**P50**	368	374	371	371
366	364	367	364	**P45**	367	371	369	369
363	360	365	363	**P40**	366	369	367	367
361	358	362	361	**P35**	363	368	365	366
358	356	358	360	**P30**	361	365	363	364
355	353	355	356	**P25**	358	364	361	361
350	347	351	352	**P20**	356	361	359	358
346	345	346	347	**P15**	353	358	354	355
342	341	342	342	**P10**	351	354	350	351
334	334	334	336	**P5**	345	349	347	346
331	333	330	331	**P3**	341	348	345	344
327	332	326	328	**P2**	341	346	343	343
324	328	323	325	**P1**	340	344	340	340

Distribution plots for each service and gender



Hip girth maximum - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
AWAS.

Definition:
The maximum horizontal circumference of the body (excluding the appendages) at or about the height of the hip. This measure must be taken below the height of the iliac crest.

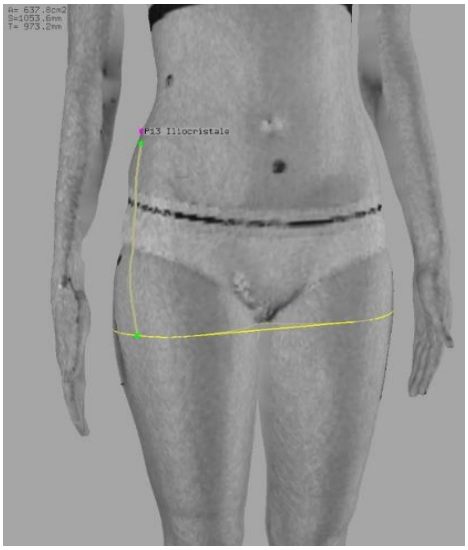
Landmark required:
None.

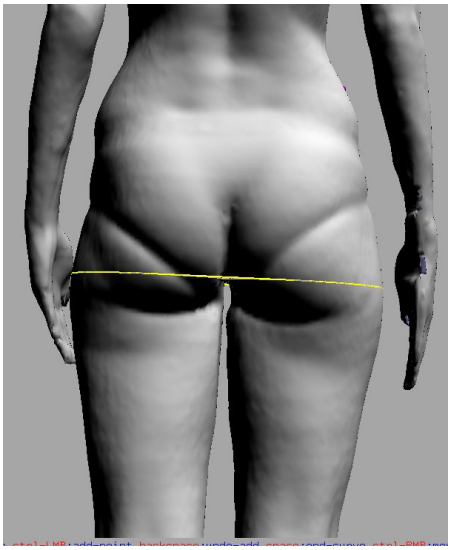
Posture required:
It is vital that the participant is wearing smooth, well fitted clothing to reduce measurements error (e.g. clothing creases). Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
Eyeball the hip region. Add two-point markers, one above and one below this region (green dots on the image) what is clearly the widest part. Join the two points, press spacebar, add Z-loop on guideline (i.e. forming a dotted line). Toggle between the min/max girth by pressing Shift with '- 'or '+' key. If circumference is incomplete (i.e. only covering a part of the cross-section), press = with the cursor on the guideline. Check that the measure has been recorded by placing the cursor on the dotted line and then pressing 'i' to bring up measurements text view. Next, press 't' (for toggle) to see the measurements. Save by double clicking Hip girth (on the names list window) then single click on the 'dotted' line and then Space bar to save. As per AWAS section 7.2.16 of the Procedures Manual (Tomkinson et al., 2012). Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
If the measure is taken on a fold or crease in the briefs, consider remeasuring.

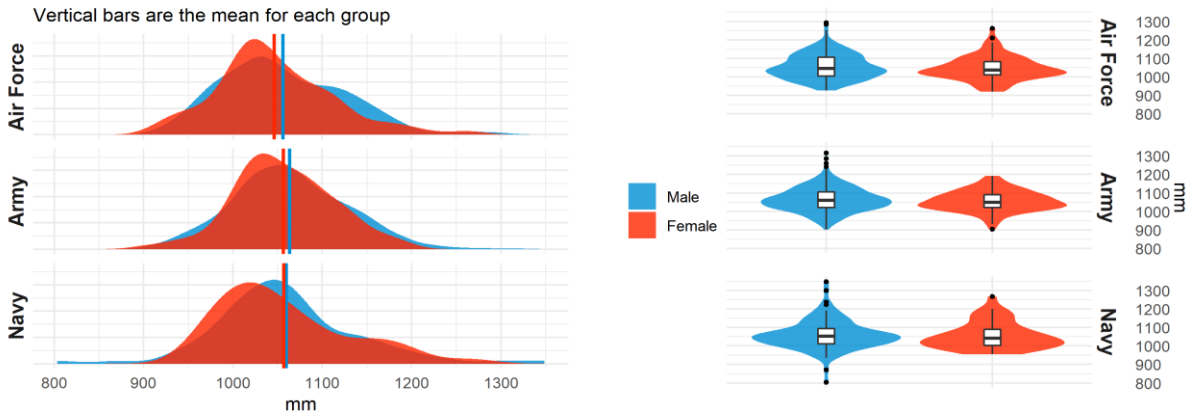




Hip girth maximum summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1061	1056	1064	1060	**Mean**	1046	1057	1057	1053
68	69	65	83	**SD**	66	56	73	63
803	926	902	803	**Min**	920	903	955	903
1349	1292	1315	1349	**Max**	1262	1193	1267	1267
1244	1251	1226	1306	**P99**	1225	1183	1239	1209
1210	1196	1197	1253	**P98**	1200	1174	1211	1197
1191	1184	1190	1229	**P97**	1185	1163	1200	1185
1177	1171	1176	1192	**P95**	1168	1151	1195	1172
1149	1147	1149	1159	**P90**	1124	1128	1168	1135
1132	1129	1132	1142	**P85**	1109	1115	1147	1116
1118	1117	1118	1116	**P80**	1098	1102	1112	1102
1106	1107	1106	1094	**P75**	1082	1091	1090	1089
1092	1092	1093	1081	**P70**	1070	1085	1078	1080
1080	1075	1083	1072	**P65**	1061	1077	1072	1071
1072	1067	1074	1064	**P60**	1050	1069	1051	1061
1063	1052	1068	1056	**P55**	1042	1061	1047	1050
1054	1044	1059	1052	**P50**	1036	1050	1042	1046
1048	1036	1051	1046	**P45**	1029	1046	1031	1035
1039	1032	1045	1035	**P40**	1024	1036	1023	1030
1032	1025	1036	1031	**P35**	1019	1033	1020	1024
1024	1017	1028	1024	**P30**	1013	1028	1012	1020
1016	1005	1021	1012	**P25**	1010	1020	1003	1012
1008	994	1012	1005	**P20**	1002	1013	995	1006
992	983	1002	992	**P15**	987	1007	991	997
978	974	982	979	**P10**	970	998	979	985
958	958	959	945	**P5**	944	974	968	960
943	950	948	939	**P3**	938	954	967	944
938	940	938	919	**P2**	928	939	964	938
926	935	928	862	**P1**	921	931	960	922

Distribution plots for each service and gender



Iliocristale height - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ANSUR, NZDFAS.

Definition:
The vertical distance between a standing surface and the right Iliocristale landmark.

Landmark required:
Iliocristale landmark.

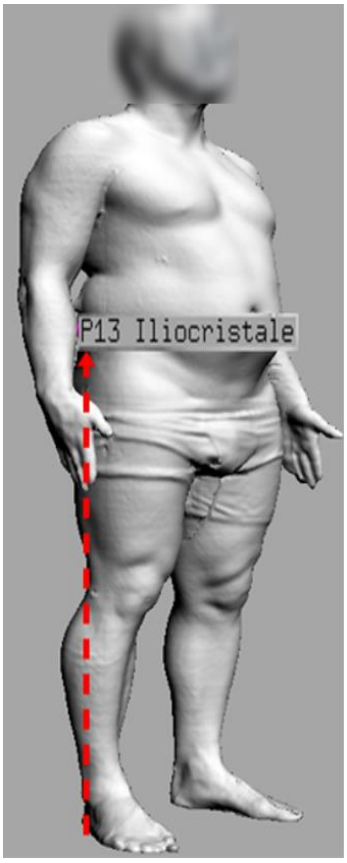
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Iliocristale landmark in posture 1. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

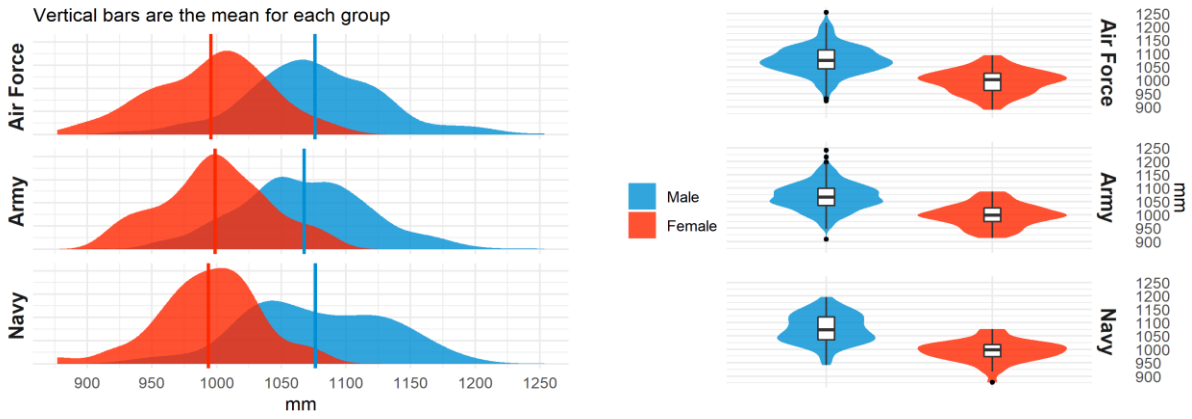
Notes:
None.



Iliocristale height summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1071	1076	1068	1077	**Mean**	996	999	994	997
52	53	51	55	**SD**	45	41	40	42
909	922	909	941	**Min**	889	914	877	877
1254	1254	1242	1195	**Max**	1093	1088	1076	1093
1196	1212	1185	1180	**P99**	1085	1085	1075	1085
1179	1201	1175	1175	**P98**	1080	1083	1073	1081
1174	1192	1170	1171	**P97**	1077	1079	1069	1077
1160	1173	1156	1161	**P95**	1064	1069	1058	1069
1135	1136	1131	1146	**P90**	1050	1054	1036	1053
1124	1125	1117	1136	**P85**	1038	1039	1027	1038
1115	1118	1109	1128	**P80**	1033	1032	1021	1031
1106	1114	1099	1121	**P75**	1026	1025	1018	1025
1097	1101	1094	1113	**P70**	1020	1020	1014	1019
1090	1092	1088	1100	**P65**	1013	1010	1013	1012
1082	1086	1081	1094	**P60**	1009	1005	1004	1007
1076	1077	1074	1081	**P55**	1004	1002	998	1003
1069	1073	1066	1073	**P50**	1002	999	998	998
1062	1068	1058	1064	**P45**	996	996	993	996
1055	1063	1053	1054	**P40**	992	993	987	991
1050	1057	1047	1048	**P35**	986	988	981	984
1044	1050	1042	1040	**P30**	972	979	977	977
1037	1042	1035	1035	**P25**	961	974	973	970
1030	1035	1028	1031	**P20**	954	964	964	960
1020	1029	1015	1024	**P15**	949	951	958	951
1008	1014	1004	1019	**P10**	934	942	948	940
987	984	987	998	**P5**	923	927	924	926
972	971	972	972	**P3**	904	926	918	917
965	969	963	962	**P2**	902	925	910	914
954	942	956	953	**P1**	898	917	894	902

Distribution plots for each service and gender



Index finger breadth distal - Physical measurement (mm)

Measuring instrument:
Small bone caliper. The Rosscraft small bone caliper is 18 cm with pressure plates that are 10 mm diameter. Before measuring, the distance between the plates when touching should be verified as 0 cm to ensure it has been assembled correctly.

Source:
JIS Z 8500.

Definition:
The maximum distance between medial and lateral surfaces of the second finger in the region of the joint between middle and distal phalanges. The participant holds the forearm horizontal with hand stretched out flat and fingers spread, palm up.

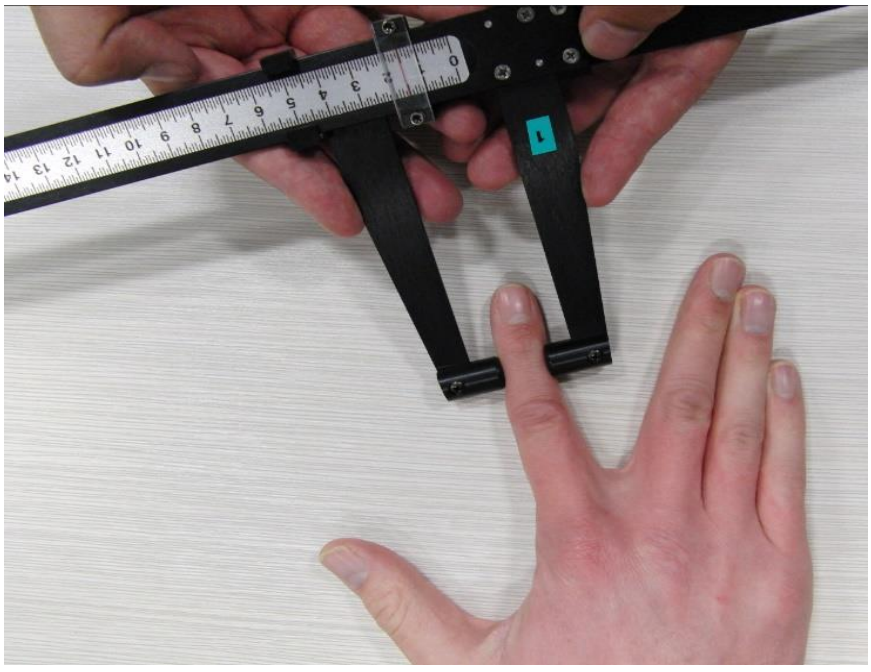
Landmark required:
None.

Posture required:
Participants are seated at a table. The right hand is placed palm down on a measurement board. The centre wrist and medial side of the forearm are flat on the table. Fingers are spread apart. The assessor stands next to the hand (facing the participant).

Procedure:
The plates of the small caliper are pressed firmly on the left and right side of the joint between the middle and distal phalanges. Measurements are reported in mm.

Reference:
JIS Z 8500 Ergonomics Basic Human Body Measurements for Technological Design (2002). Japanese Industrial Standard: Tokyo, Japan.

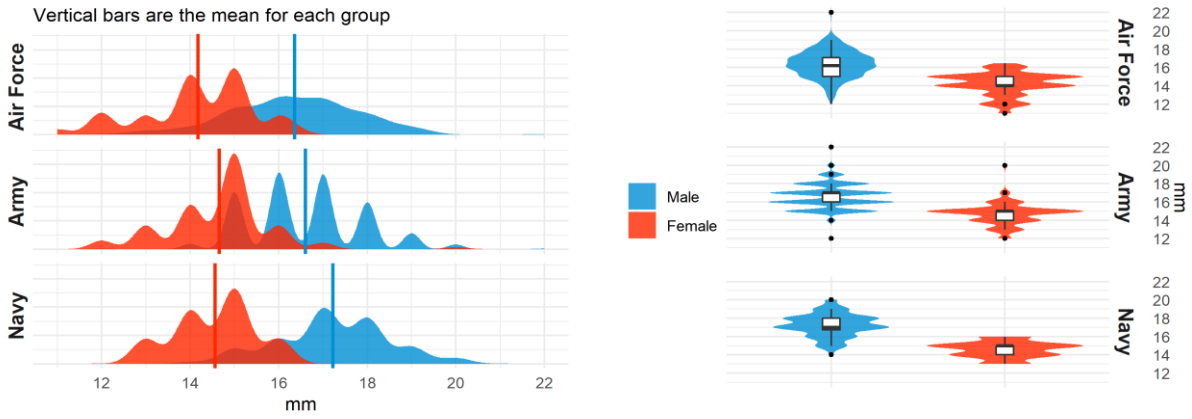
Notes:
For greatest accuracy press firmly in this measure. Ensure that the palm and all fingers are pressed flat against the table.



Index finger breadth distal summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
17	16	17	17	**Mean**	14	15	15	14
1	1	1	1	**SD**	1	1	1	1
12	12	12	14	**Min**	11	12	13	11
22	22	22	20	**Max**	16	20	16	20
20	19	20	20	**P99**	16	17	16	17
19	19	19	20	**P98**	16	17	16	16
19	19	19	19	**P97**	16	17	16	16
19	19	19	19	**P95**	16	16	16	16
18	18	18	19	**P90**	16	16	16	16
18	18	18	18	**P85**	15	16	15	15
18	18	18	18	**P80**	15	15	15	15
17	17	17	18	**P75**	15	15	15	15
17	17	17	18	**P70**	15	15	15	15
17	17	17	18	**P65**	15	15	15	15
17	17	17	18	**P60**	15	15	15	15
17	17	17	17	**P55**	14	15	15	15
17	16	17	17	**P50**	14	15	15	15
16	16	16	17	**P45**	14	15	15	15
16	16	16	17	**P40**	14	15	14	14
16	16	16	17	**P35**	14	14	14	14
16	16	16	17	**P30**	14	14	14	14
16	15	16	17	**P25**	14	14	14	14
15	15	15	16	**P20**	13	14	14	14
15	15	15	16	**P15**	13	13	14	13
15	15	15	16	**P10**	12	13	13	13
15	14	15	15	**P5**	12	13	13	12
14	13	15	15	**P3**	12	12	13	12
14	13	15	15	**P2**	11	12	13	12
14	13	14	15	**P1**	11	12	13	12

Distribution plots for each service and gender



Index finger breadth proximal - Physical measurement (mm)

Measuring instrument:
Small bone caliper. The Rosscraft small bone caliper is 18 cm with pressure plates that are 10 mm diameter. Before measuring, the distance between the plates when touching should be verified as 0 cm to ensure it has been assembled correctly.

Source:
JIS Z 8500.

Definition:
The maximum distance between medial and lateral surfaces of the second finger in the region of the joint between middle and proximal phalanges. The participant holds the forearm horizontal with hand stretched out flat and fingers spread, palm up.

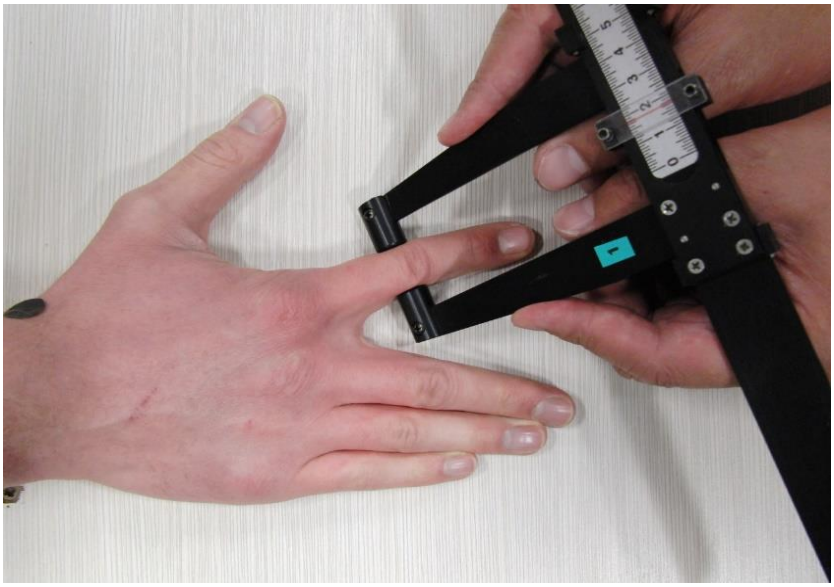
Landmark required:
None.

Posture required:
Participants are seated at a table. The right hand is placed palm down on a measurement board. The centre wrist and medial side of the forearm are flat on the table. Fingers are spread apart. The assessor stands next to the hand (facing the participant).

Procedure:
The plates of the small caliper are pressed firmly on the left and right side of the joint between the middle and proximal phalanges. Measurements are reported in mm.

Reference:
JIS Z 8500 Ergonomics Basic Human Body Measurements for Technological Design (2002). Japanese Industrial Standard: Tokyo, Japan.

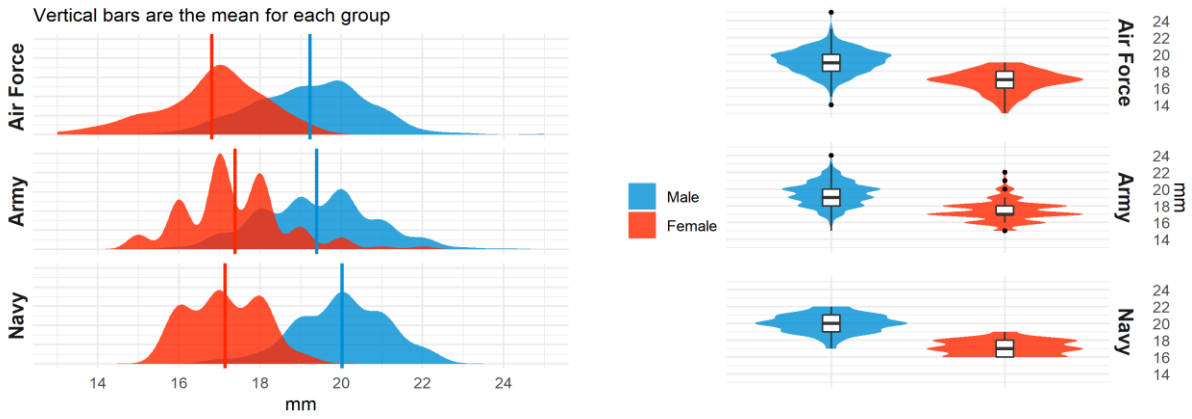
Notes:
For greatest accuracy press firmly in this measure. Ensure that the palm and all fingers are pressed flat against the table.



Index finger breadth proximal summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
19	19	19	20	**Mean**	17	17	17	17
1	1	1	1	**SD**	1	1	1	1
14	14	15	17	**Min**	13	15	16	13
25	25	24	22	**Max**	19	22	19	22
23	23	23	22	**P99**	19	21	19	20
22	22	22	22	**P98**	19	20	19	20
22	22	22	22	**P97**	19	20	19	19
22	21	22	22	**P95**	19	20	18	19
21	21	21	21	**P90**	18	19	18	18
21	21	21	21	**P85**	18	18	18	18
21	20	20	21	**P80**	18	18	18	18
20	20	20	21	**P75**	18	18	18	18
20	20	20	21	**P70**	17	18	18	18
20	20	20	20	**P65**	17	18	18	18
20	20	20	20	**P60**	17	18	17	17
20	20	20	20	**P55**	17	17	17	17
20	19	19	20	**P50**	17	17	17	17
19	19	19	20	**P45**	17	17	17	17
19	19	19	20	**P40**	17	17	17	17
19	19	19	20	**P35**	17	17	17	17
19	19	19	19	**P30**	16	17	17	17
18	18	18	19	**P25**	16	17	16	16
18	18	18	19	**P20**	16	16	16	16
18	18	18	19	**P15**	15	16	16	16
18	17	18	19	**P10**	15	16	16	16
17	17	17	18	**P5**	15	16	16	15
17	17	17	18	**P3**	14	15	16	15
17	16	17	18	**P2**	14	15	16	15
16	16	16	17	**P1**	14	15	16	14

Distribution plots for each service and gender



Index finger reach - Physical measurement (mm)

Measuring instrument:
Full-length anthropometer, ideally made of solid steel. The anthropometer typically comes in 4 separate sections. When combined, one end of the rod contains a stationary or fixed arm or prong, the other prong is free to move up and down while at a right angle to the rod. There are typically two scales on the rod that run opposite to each other.

Source:
CFAS.

Definition:
The horizontal distance between the vertical plane of the back and the tip of the right index finger.

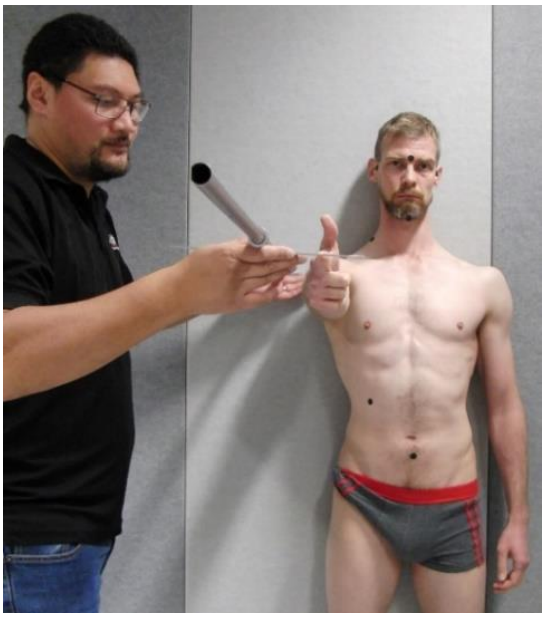
Landmark required:
None.

Posture required:
The participant stands erect against a wall with both the left and right shoulder blades touching the wall. Their right arm is raised as straight as possible to the front at a 90 degree angle to the body with the index finger pointing medially to the opposite wall. Their arm must be in a relaxed and 'natural' position (i.e. do not ask them to fully reach forward or retract their shoulder/deltoid against the wall). The assessor stands to the right side of the participant in front of the elbow. This position enables the assessor to support the weight of the anthropometer evenly, and be in a position to see both prongs (the fixed end and the measurement end).

Procedure:
Place the outer edge of the fixed prong against the wall. Extend the opposite prong 50 mm beyond the fingertip. Slowly push the prong towards the hand until it touches the tip of the index finger. Check that both the arm and anthropometer are straight and horizontal then take the reading to the nearest 0.1 cm. Measurements are reported in mm.

Reference:
Keefe, A., H. Angel, and B. Mangan, 2012 Canadian Forces Anthropometric Survey (CFAS) – Final report. 2015, Defense Research and Development Canada: Toronto, Canada.

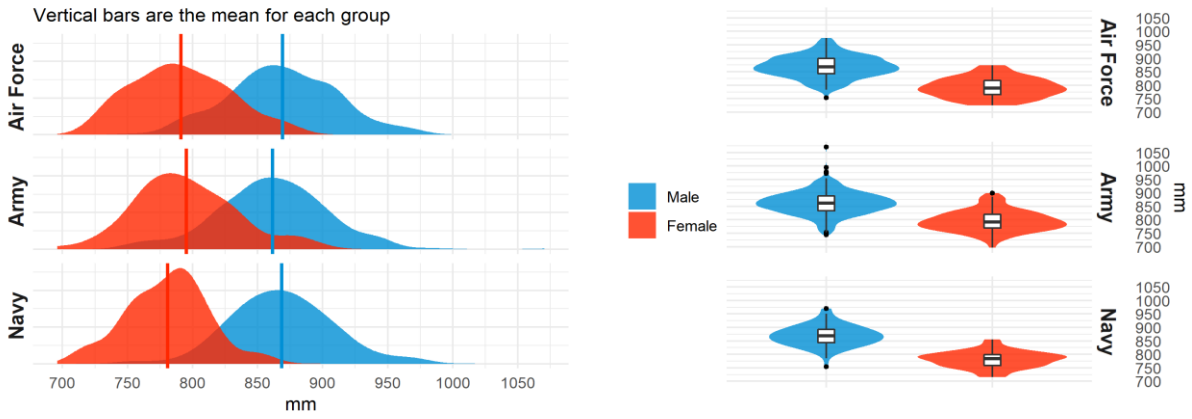
Notes:
Lengthen or shorten the anthropometer (by adding or removing sections of the rod) to suit the arm length of the participant. Ensure that the prong is based securely, and square to the wall for stability. Be aware of handling the prong tip to avoid injuring the participant. Ask the scribe to observe and confirm whether the participant's arm is straight and horizontal to the floor immediately before taking the reading. The anthropometer and the centre of the arm should be at the same height.



Index finger reach summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
864	869	861	869	**Mean**	791	795	781	791
42	41	43	39	**SD**	37	39	31	37
744	754	744	754	**Min**	724	696	716	696
1070	976	1070	970	**Max**	874	898	855	898
967	966	953	970	**P99**	872	886	851	884
950	959	947	956	**P98**	870	885	847	874
945	949	942	945	**P97**	867	880	840	872
934	938	934	933	**P95**	857	873	822	857
915	916	912	916	**P90**	836	842	817	836
906	909	904	904	**P85**	831	834	809	828
898	906	894	900	**P80**	825	828	802	820
891	900	888	893	**P75**	818	820	798	815
884	890	883	885	**P70**	810	814	795	807
879	883	876	881	**P65**	802	805	794	801
874	878	871	878	**P60**	799	801	791	798
869	874	866	872	**P55**	795	796	789	794
864	869	862	868	**P50**	789	792	784	789
858	861	856	862	**P45**	782	788	781	784
854	857	850	857	**P40**	780	782	773	780
850	854	847	854	**P35**	776	777	769	774
844	849	842	849	**P30**	771	773	764	770
838	842	834	843	**P25**	766	770	759	766
830	835	828	838	**P20**	756	762	756	759
823	829	820	832	**P15**	749	759	749	753
812	814	810	825	**P10**	742	753	747	748
795	796	790	810	**P5**	735	734	724	733
784	794	771	806	**P3**	732	733	720	732
769	789	766	799	**P2**	732	731	719	723
757	784	755	781	**P1**	729	716	717	717

Distribution plots for each service and gender



Interpupillary breadth - Physical measurement (mm)

Measuring instrument:
A standard transparent ruler. The transparency enables the assessor to place the ruler close to the eyes without contact.

Source:
ANSUR, AWAS.

Definition:
The distance between the Centre of the Pupil R) and the Centre of the Pupil L.

Landmark required:
None.

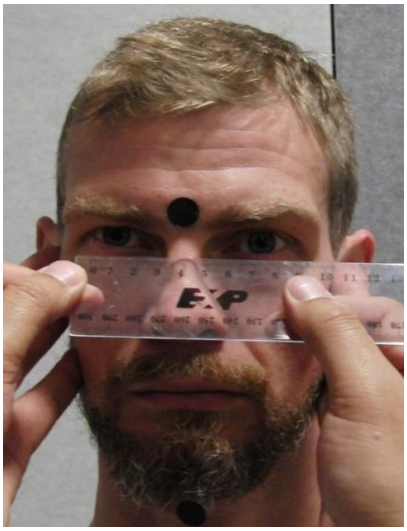
Posture required:
The participant stands erect, with gaze focussed on a hypothetical position on the wall behind the assessor, with glasses removed. The assessor stands in front and slightly to the side of the participant.

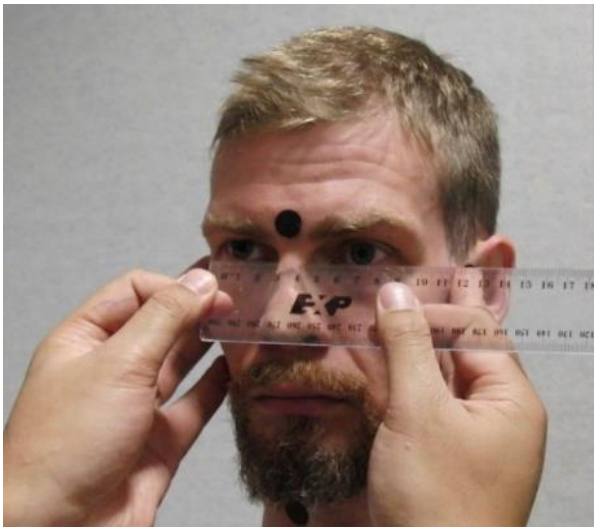
Procedure:
Place the ruler directly in front of the nose with the zero point of the ruler in line with the centre of the left Pupil. For stability and safety, hold the ruler with the thumb and index finger and use the middle fingers to anchor the hands to the head. Take the reading at the centre of the right pupil. Movement of the eyes must be kept to a minimum. Measure to the nearest 0.1 cm. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
The position of the head has no influence on the measurement. Ensure that the jaw is still and the head is in the Frankfort plane.

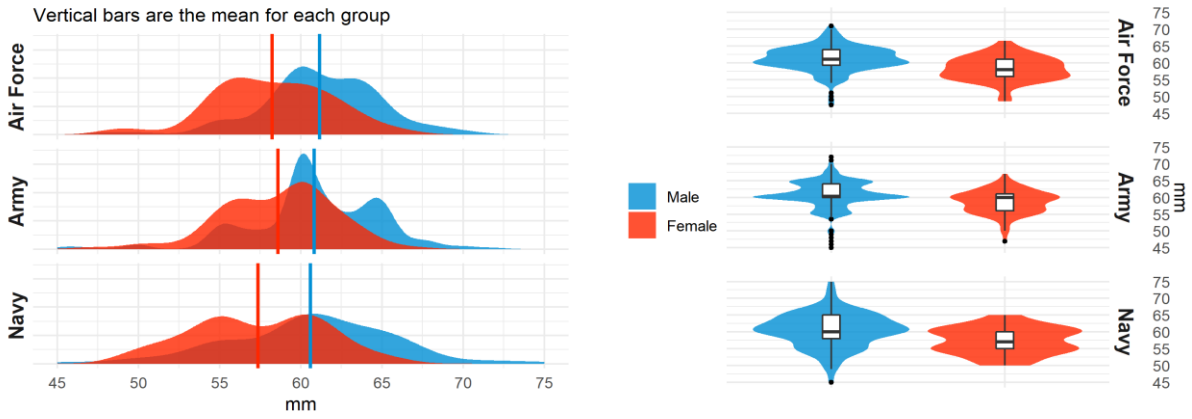




Interpupillary breadth summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
61	61	61	61	**Mean**	58	59	57	58
4	4	4	5	**SD**	4	3	4	4
45	48	45	45	**Min**	48	47	50	47
75	71	72	75	**Max**	66	67	65	67
70	70	70	72	**P99**	65	65	65	65
69	69	68	71	**P98**	65	65	65	65
68	68	68	69	**P97**	65	64	64	65
67	67	67	67	**P95**	63	64	63	64
65	65	65	66	**P90**	63	63	62	63
65	64	65	65	**P85**	62	62	62	62
64	64	64	65	**P80**	61	61	61	61
64	64	64	65	**P75**	61	61	60	61
63	63	63	63	**P70**	60	60	60	60
62	63	62	62	**P65**	60	60	60	60
62	62	62	62	**P60**	59	60	60	60
61	62	61	61	**P55**	59	60	58	60
61	61	60	60	**P50**	58	60	57	59
60	61	60	60	**P45**	58	59	57	58
60	60	60	60	**P40**	57	58	55	57
60	60	60	60	**P35**	56	57	55	57
60	60	60	60	**P30**	56	57	55	56
60	59	60	58	**P25**	56	56	55	55
58	59	58	55	**P20**	55	56	55	55
57	58	57	55	**P15**	55	55	53	55
55	57	55	55	**P10**	55	55	52	54
55	55	55	52	**P5**	54	53	50	52
51	54	52	51	**P3**	50	51	50	50
50	52	50	50	**P2**	49	50	50	50
48	49	47	48	**P1**	49	50	50	49

Distribution plots for each service and gender



Knee circumference - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS, NZDFAS.

Definition:
The circumference of the knee at the height of the digitally extracted Midpatella landmark.

Landmark required:
Midpatella landmark.

Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

Procedure:
As per AWAS Section 7.2.28 of the Procedures Manual (Tomkinson et al., 2012). Alternatively, use CySize to draw an X-axis (a digital circumference) around the Midpatella (anterior point midway between the top and bottom of the right patella) landmark. Look for the stickered landmark (kneecap mid-point). If absent the midpoint may still be derived by placing the point marker in the centre of the knee, then use an X-axis loop. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

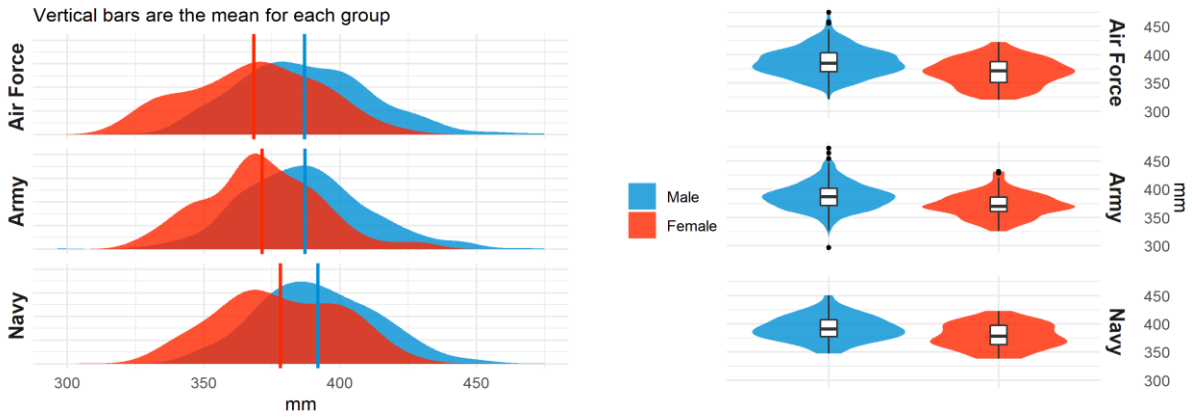
Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
Ensure that there is no ‘webbing’ (a digital error that occurs when parts of the body are too close together and the software interprets this as one item) between the left and right knee. If so, then skip this measure.

Knee circumference summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
388	387	387	392	**Mean**	368	371	378	372
24	25	24	21	**SD**	24	21	22	22
296	321	296	348	**Min**	320	326	338	320
475	475	472	450	**Max**	422	432	423	432
447	454	447	441	**P99**	416	429	420	423
441	438	443	433	**P98**	412	422	416	420
435	433	438	430	**P97**	409	413	414	413
429	429	428	428	**P95**	405	403	409	408
418	419	417	419	**P90**	396	396	406	401
412	411	411	415	**P85**	395	391	402	396
406	406	405	410	**P80**	389	388	401	391
402	403	401	407	**P75**	388	386	397	388
399	400	397	402	**P70**	382	382	392	385
395	396	394	400	**P65**	377	378	389	380
392	393	392	395	**P60**	374	376	383	377
389	389	389	392	**P55**	372	372	381	372
387	385	386	391	**P50**	371	370	378	371
383	382	383	389	**P45**	367	368	370	368
381	379	380	384	**P40**	363	367	370	367
378	376	378	382	**P35**	360	365	368	364
374	372	374	379	**P30**	356	362	366	362
371	370	371	377	**P25**	351	360	363	356
368	367	367	375	**P20**	345	352	360	351
364	361	363	369	**P15**	340	348	355	347
360	357	360	367	**P10**	334	344	351	343
351	348	353	358	**P5**	331	339	341	334
346	346	345	353	**P3**	329	334	339	331
344	345	343	351	**P2**	327	332	339	330
339	344	335	349	**P1**	324	331	338	326

Distribution plots for each service and gender



Knee height - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
The vertical height of the front level of the knee girth height (codes 9520/9521) to the standing surface.

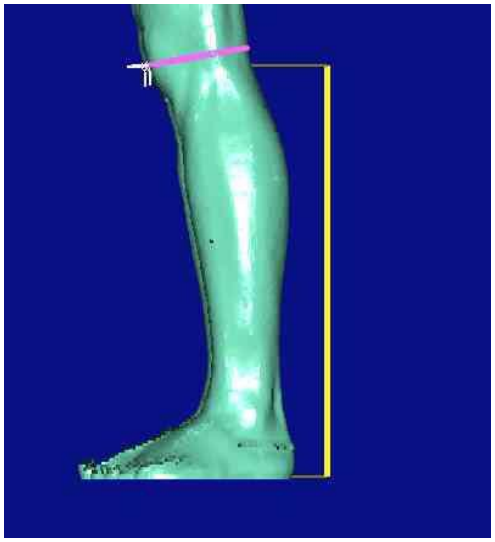
Landmark required:
None.

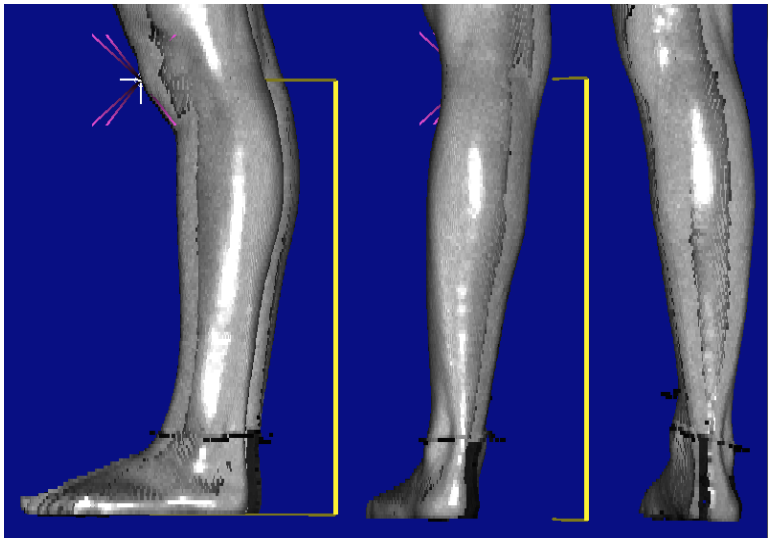
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
None.

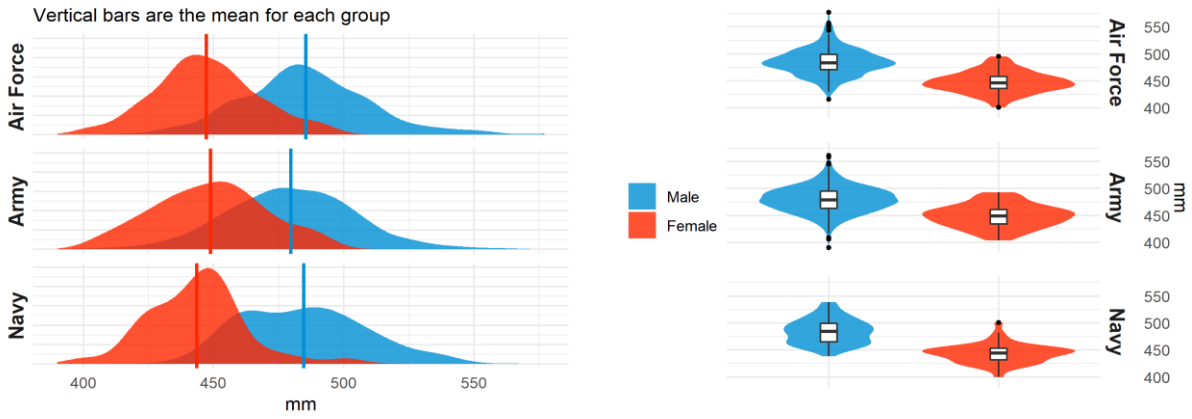




Knee height summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
482	485	480	485	**Mean**	447	449	444	447
25	25	25	23	**SD**	20	21	18	20
390	416	390	438	**Min**	401	404	400	400
577	577	561	539	**Max**	495	493	501	501
545	552	541	537	**P99**	491	491	493	493
536	545	532	535	**P98**	489	490	485	490
532	536	526	534	**P97**	488	488	479	488
524	528	521	524	**P95**	483	487	472	485
512	514	510	515	**P90**	473	476	459	473
506	509	504	508	**P85**	470	471	457	468
501	506	500	504	**P80**	462	467	454	462
497	499	495	499	**P75**	458	461	453	459
494	496	492	497	**P70**	457	459	450	457
491	494	489	495	**P65**	454	457	450	454
488	490	486	489	**P60**	451	455	448	452
484	487	483	487	**P55**	448	452	447	450
482	484	479	484	**P50**	446	449	444	447
478	482	476	481	**P45**	445	445	443	445
476	480	474	479	**P40**	441	444	441	442
473	476	471	472	**P35**	440	440	439	440
469	474	467	466	**P30**	438	437	435	436
465	471	463	465	**P25**	436	434	432	434
461	464	459	462	**P20**	432	430	427	430
457	459	454	459	**P15**	427	426	424	425
452	454	449	456	**P10**	423	420	423	422
442	447	441	453	**P5**	417	414	418	415
436	439	435	451	**P3**	414	409	416	410
434	436	430	449	**P2**	409	407	413	407
424	432	423	444	**P1**	404	407	406	404

Distribution plots for each service and gender



Knee height sitting - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
CFAS, NZDFAS.

Definition:
The vertical distance between a footrest surface and the Suprapatella landmark.

Landmark required:
Suprapatella landmark.

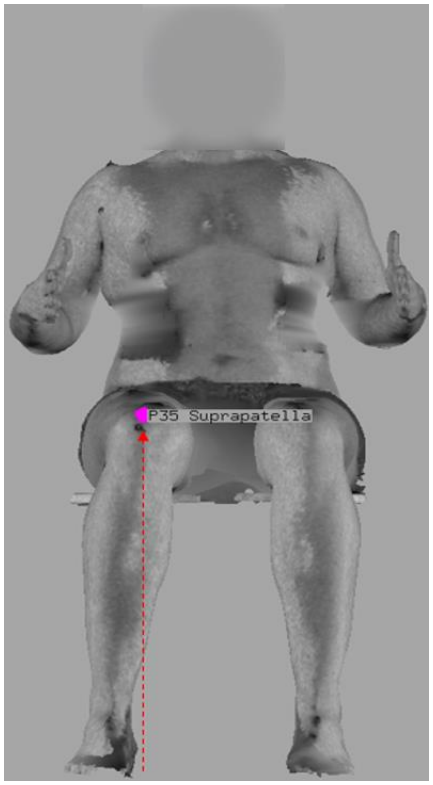
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

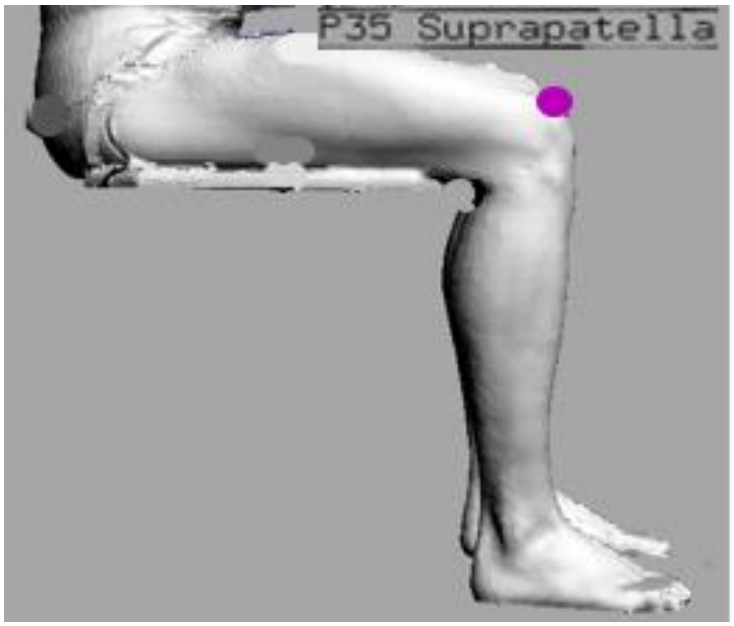
Procedure:
This measure is represented by the Y coordinate (mm on the vertical axis) of the Suprapatella landmark in posture 3. Measurements are reported in mm.

Reference:
Keefe, A., H. Angel, and B. Mangan, 2012 Canadian Forces Anthropometric Survey (CFAS) – Final report. 2015, Defense Research and Development Canada: Toronto, Canada.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
None

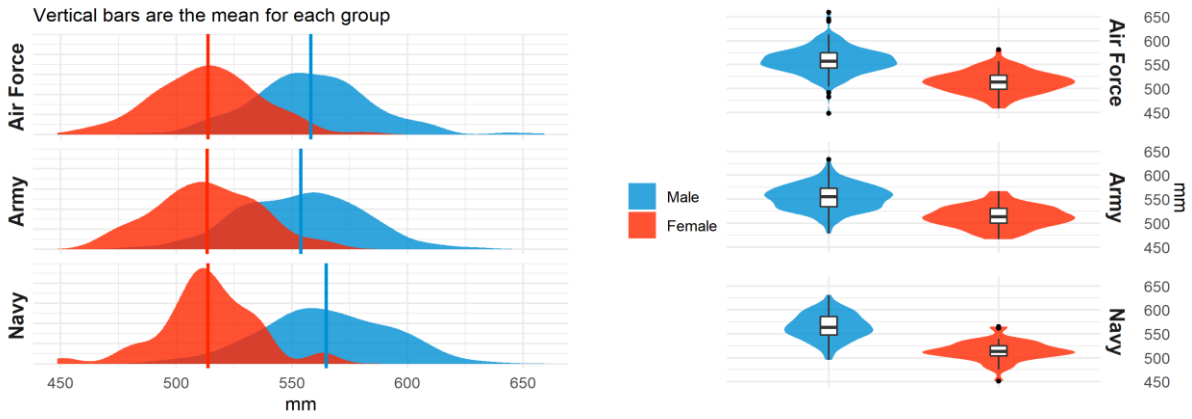




Knee height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
556	558	554	565	**Mean**	514	513	514	514
27	28	27	27	**SD**	23	22	21	22
448	448	478	496	**Min**	458	466	451	451
659	659	633	631	**Max**	581	567	565	581
617	637	615	618	**P99**	564	563	564	565
611	612	608	612	**P98**	556	561	562	562
608	610	604	610	**P97**	553	560	556	559
599	605	595	608	**P95**	550	549	539	550
591	592	587	599	**P90**	545	538	536	539
583	583	581	595	**P85**	534	536	534	536
578	578	577	590	**P80**	532	534	530	532
574	575	573	586	**P75**	528	531	525	528
570	571	569	580	**P70**	525	526	523	525
567	568	564	574	**P65**	521	522	520	522
563	565	561	572	**P60**	519	517	516	518
560	560	558	568	**P55**	517	516	514	516
557	557	555	563	**P50**	514	514	513	514
553	553	551	560	**P45**	510	510	512	510
549	551	547	557	**P40**	508	508	510	508
546	549	543	554	**P35**	508	504	509	506
542	545	538	550	**P30**	502	502	507	502
537	543	534	548	**P25**	498	500	504	500
533	537	531	545	**P20**	494	495	501	496
528	533	526	537	**P15**	491	490	498	491
523	524	522	530	**P10**	488	482	488	485
513	514	510	523	**P5**	477	477	481	476
506	511	504	517	**P3**	473	473	476	473
502	507	501	507	**P2**	468	471	471	470
492	494	491	504	**P1**	463	470	461	465

Distribution plots for each service and gender



Medial malleolus-hallux length - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
NZDFAS.

Definition:
The distance between the centre of the Medial Malleolus and the tip of the Hallux (big toe).

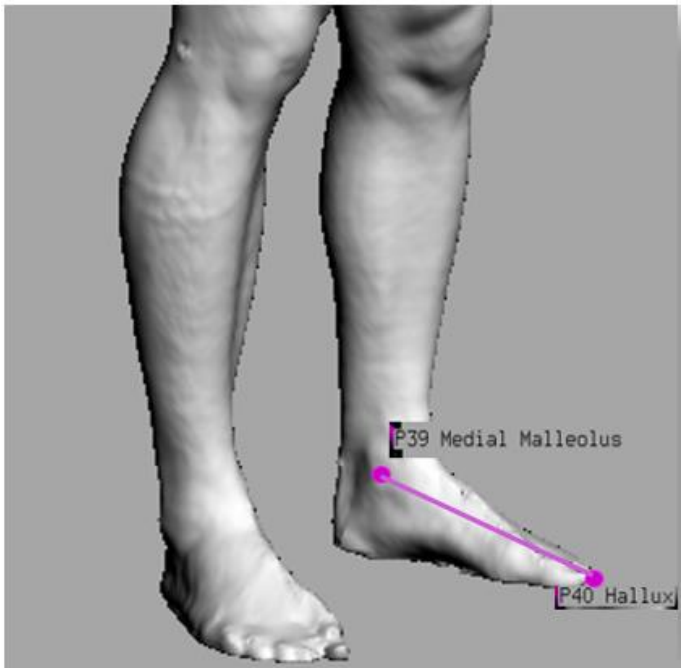
Landmark required:
Medial Malleolus and Hallux landmarks.

Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

Procedure:
This measure is the point to point distance between the Medial Malleolus (inner ankle) and Hallux (most anterior point of the big toe) landmarks. For the Medial Malleolus place point on medial surface of inner ankle. Use Y loop to identify the most medial protruding point of the malleolus. For the Hallux place point on anterior surface of Hallux. Use X loop to identify this. Measurements are reported in mm.

Reference:
Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

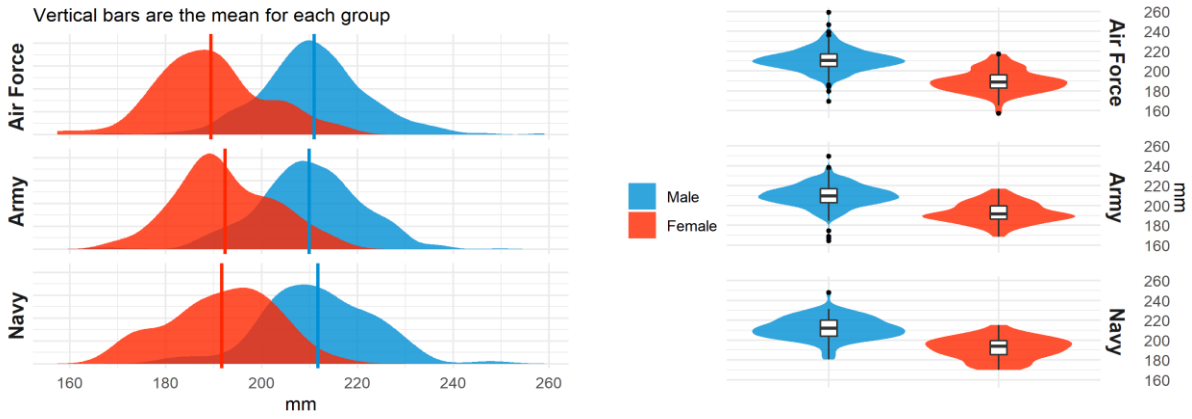
Notes:
The scan quality is often poor for feet and hands. If the Hallux is not visible, then skip this measure. The Malleolus can be identified visually but for accuracy, place a point in the centre and identify the most lateral aspect using the Y section tool. The Y section tool identifies the ‘peak’ or the widest point of the media Malleolus.



Medial malleolus-hallax length summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
210	211	210	212	**Mean**	189	192	192	191
11	12	11	11	**SD**	11	10	11	11
164	169	164	180	**Min**	157	169	170	157
259	259	250	248	**Max**	217	217	215	217
237	239	236	233	**P99**	215	214	212	215
233	236	230	231	**P98**	214	213	209	214
230	234	229	230	**P97**	213	212	208	213
229	229	227	230	**P95**	208	211	208	208
224	224	224	225	**P90**	204	206	204	205
222	222	221	224	**P85**	204	204	203	204
219	219	219	222	**P80**	198	202	201	201
217	217	217	220	**P75**	196	200	199	199
216	216	215	217	**P70**	193	198	199	197
214	214	214	215	**P65**	192	196	197	194
213	213	213	214	**P60**	191	193	195	193
212	212	211	213	**P55**	190	192	194	192
210	210	210	212	**P50**	189	191	194	191
209	209	209	210	**P45**	188	191	190	189
208	208	207	208	**P40**	186	189	190	188
207	207	206	207	**P35**	185	188	187	187
205	206	205	205	**P30**	183	187	186	186
204	204	203	204	**P25**	183	186	185	184
202	203	202	203	**P20**	181	185	183	183
200	201	200	202	**P15**	179	183	179	181
197	197	196	200	**P10**	177	180	175	178
193	193	192	194	**P5**	174	178	174	174
189	192	189	190	**P3**	172	175	173	172
187	189	188	185	**P2**	168	172	172	171
184	185	185	183	**P1**	163	171	171	169

Distribution plots for each service and gender



Neck girth base - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
Circumference measurement at the level of the base of the neck, just on the transition between the torso and neck.

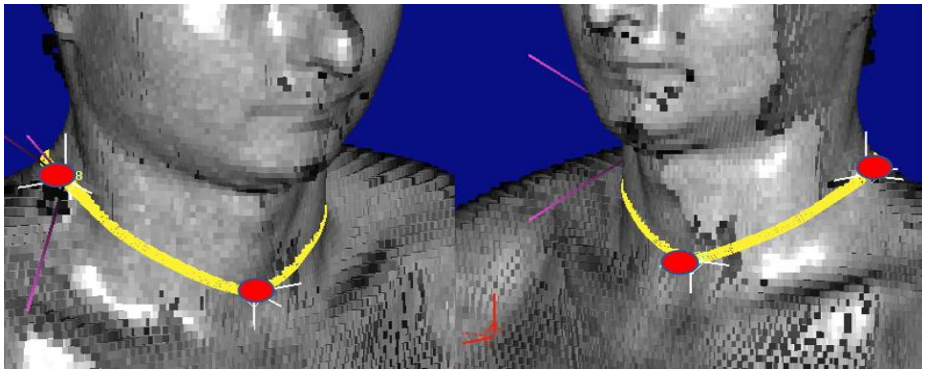
Landmark required:
None.

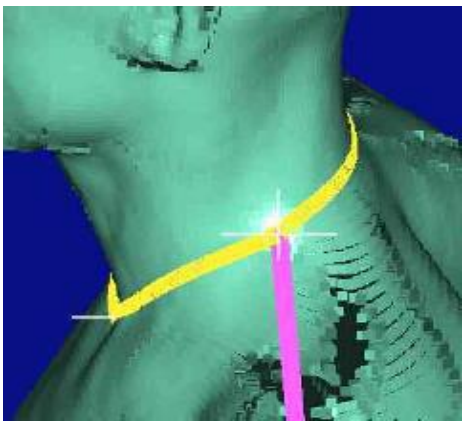
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

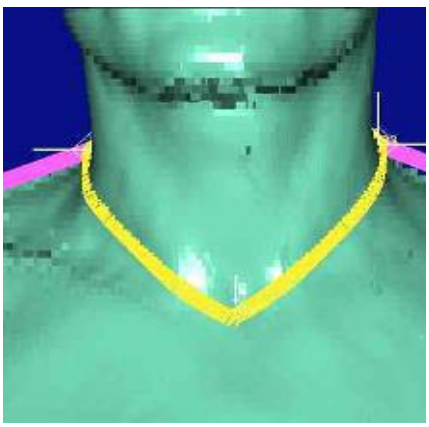
Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
This measure often requires slight adjustment as sometimes the software produces a sharp ‘edge’ at the base of the throat (it does not behave like a standard tape). To adjust, place the cursor on the tape (depicted as red dots), left mouse click and hold, then manually move the tape to create a more round profile. The tape can also be adjusted using points on the left and right side of the neck (to conform around the nect circumference).



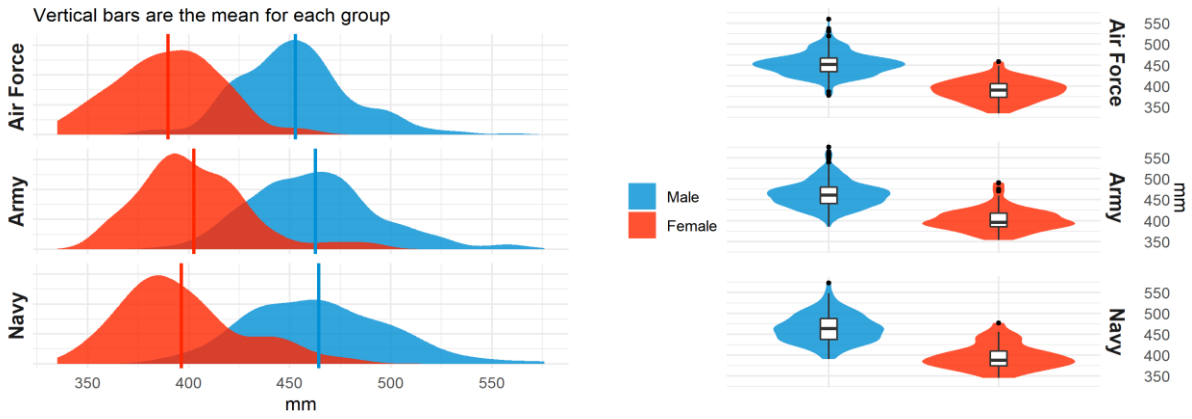




Neck girth base summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
460	453	463	464	**Mean**	390	403	396	397
32	28	32	35	**SD**	26	27	30	28
378	378	385	391	**Min**	335	354	346	335
576	560	576	573	**Max**	458	490	477	490
557	529	559	551	**P99**	452	489	468	477
536	518	541	541	**P98**	441	476	459	468
526	508	526	531	**P97**	430	471	454	457
518	502	522	519	**P95**	426	446	449	443
502	492	504	509	**P90**	421	431	441	429
491	480	495	501	**P85**	418	425	430	422
484	473	486	495	**P80**	410	422	416	418
478	467	480	487	**P75**	405	418	409	414
473	464	476	480	**P70**	404	415	405	408
469	461	473	474	**P65**	402	409	403	405
465	457	469	468	**P60**	400	406	399	402
462	454	464	466	**P55**	393	402	396	398
458	452	461	463	**P50**	390	396	388	395
455	449	458	460	**P45**	387	395	387	391
450	445	454	455	**P40**	384	394	385	388
446	443	448	448	**P35**	381	391	384	385
443	438	444	441	**P30**	376	389	383	383
438	435	441	438	**P25**	372	385	374	378
434	428	436	433	**P20**	368	382	372	375
428	424	429	431	**P15**	362	377	369	370
422	420	423	426	**P10**	355	371	366	364
415	414	416	417	**P5**	350	364	355	355
409	409	412	405	**P3**	343	361	353	352
404	400	405	402	**P2**	340	359	352	349
397	387	403	398	**P1**	337	359	349	342

Distribution plots for each service and gender



Palm length - Physical measurement (mm)

Measuring instrument:
Segmometer.

Source:
ISO 7250.

Definition:
Distance from a line drawn between the styloid processes mid-stylion landmark to the proximal finger crease of the middle finger on the palm of the hand.

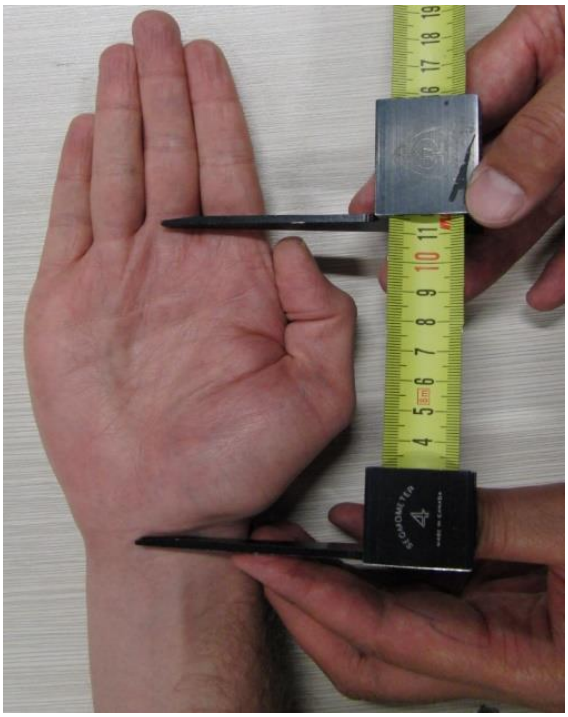
Landmark required:
None.

Posture required:
The participant places the lateral surface of the right forearm and the back of the right-hand flat against the table surface. The palm is open and facing up. Fingers and thumb are together. The assessor stands in a position that is perpendicular to the hand.

Procedure:
Measurement is taken on the palmar surface of the hand between the mid-stylion landmark and the proximal crease of the middle finger. The fixed end of the segmometer is placed on the centre wrist landmark, the sliding end is on the crease. Measurements are reported in mm.

Reference:
ISO 7250-1. Basic Human Body Measurements for Technological Design. 2008, International Organization for Standardization: Geneva.

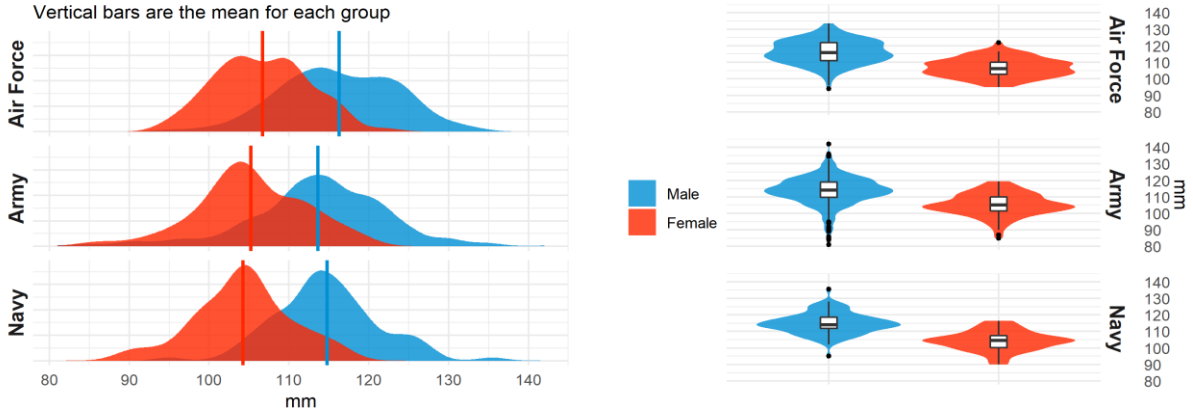
Notes:
Ensure that the palm and all fingers are together and rigid (no cupping of the hands).
Ensure the back of the hand and fingers are flat against the table surface.



Palm length summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
114	116	114	115	**Mean**	107	105	104	106
8	7	9	7	**SD**	6	7	6	6
81	94	81	95	**Min**	95	85	90	85
142	134	142	136	**Max**	122	119	116	122
133	132	135	129	**P99**	118	119	116	119
130	130	130	127	**P98**	116	119	116	117
130	130	130	127	**P97**	116	117	115	116
126	127	126	126	**P95**	116	116	114	116
124	125	123	124	**P90**	114	114	112	114
122	124	122	121	**P85**	113	112	111	112
121	123	120	119	**P80**	111	111	109	111
120	122	119	118	**P75**	110	110	108	110
119	120	118	117	**P70**	110	109	106	109
117	120	117	116	**P65**	110	107	105	108
116	118	116	116	**P60**	109	106	105	106
115	117	115	115	**P55**	108	105	105	106
115	116	114	114	**P50**	106	105	104	105
114	115	113	114	**P45**	105	104	104	104
113	114	112	113	**P40**	105	104	104	104
112	114	112	112	**P35**	104	103	103	103
111	112	110	112	**P30**	103	102	102	103
110	111	110	112	**P25**	103	102	100	102
109	110	108	109	**P20**	102	101	99	101
107	109	106	109	**P15**	101	99	99	100
105	107	103	107	**P10**	100	97	98	98
100	105	97	105	**P5**	98	93	94	96
96	103	93	104	**P3**	97	93	92	93
94	101	91	103	**P2**	96	90	91	91
90	100	89	101	**P1**	95	87	90	90

Distribution plots for each service and gender



Popliteal height sitting - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR, NZDFAS.

Definition:
The vertical distance from a footrest surface to the back of the right knee (the popliteal fossa at the dorsal juncture of the calf and thigh).

Landmark required:
Popliteal landmark.

Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

Procedure:
The Popliteal is the crease between the bottom of the thigh and top of the calf on right leg when in seated position. With "Colour" mode off, this point is best accessed when viewed from inferior e.g. looking up to the knee crease as if viewed from the participants heel. The marker should be placed in the middle of the crease. The measure is represented by the Y coordinate (mm on the vertical axis) of the Popliteal landmark in posture 3. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

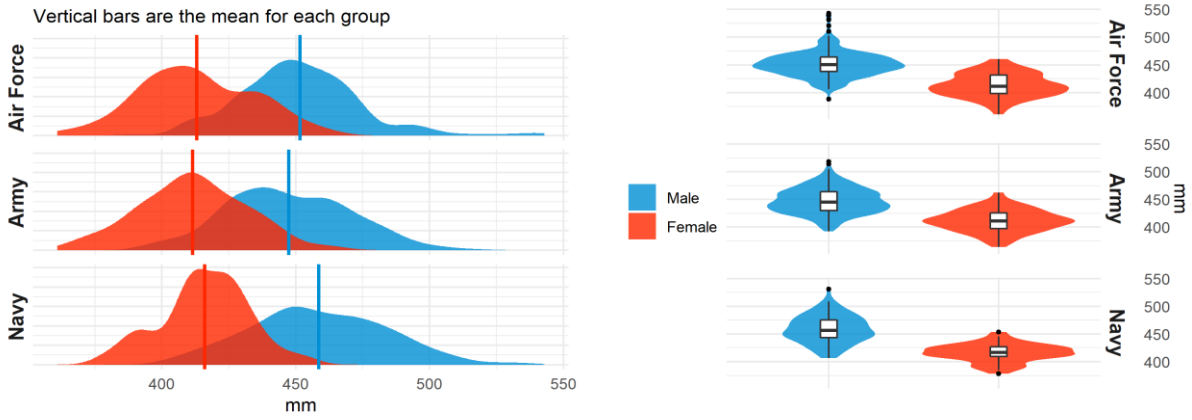
Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
Ensure that the popliteal landmark is placed in the centre (underneath) the thigh and not on the lateral side (near the tibiale laterale). Use different views (e.g. wire view) to increase visibility. If not visible remove this measure.

Popliteal height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
450	452	447	459	**Mean**	413	412	416	413
24	23	23	25	**SD**	21	20	16	20
388	388	392	406	**Min**	361	364	379	361
543	543	518	531	**Max**	460	463	454	463
509	530	503	512	**P99**	458	460	450	459
502	508	495	508	**P98**	455	448	447	453
496	498	491	505	**P97**	451	446	444	448
490	492	486	500	**P95**	447	443	440	445
480	476	478	490	**P90**	438	436	435	437
474	470	472	485	**P85**	437	434	431	435
469	468	468	481	**P80**	435	428	427	431
465	464	464	475	**P75**	431	425	427	427
462	461	461	473	**P70**	424	422	426	423
459	459	458	469	**P65**	418	418	423	419
455	455	453	466	**P60**	416	415	422	417
451	452	449	461	**P55**	414	413	419	414
448	450	445	456	**P50**	411	411	416	412
445	448	442	452	**P45**	410	409	414	411
442	445	440	450	**P40**	407	408	412	409
440	443	437	448	**P35**	401	405	411	406
437	440	434	446	**P30**	400	402	410	402
432	438	430	444	**P25**	398	397	409	399
429	432	427	437	**P20**	395	394	405	395
426	429	424	432	**P15**	394	392	398	393
422	426	420	426	**P10**	389	386	392	388
413	414	412	417	**P5**	380	377	388	380
409	411	404	413	**P3**	378	373	386	375
404	411	402	412	**P2**	373	372	384	373
398	408	397	411	**P1**	367	371	381	370

Distribution plots for each service and gender



Radiale-stylion length - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ISAK, AWAS.

Definition:
The point-to-point distance between the digitally extracted Radiale and Stylion landmarks. Note that despite the appearance of a contour distance in the figure, CySize extracts this measurement as a point-to-point distance.

Landmark required:
Radiale right and Stylion right landmarks.

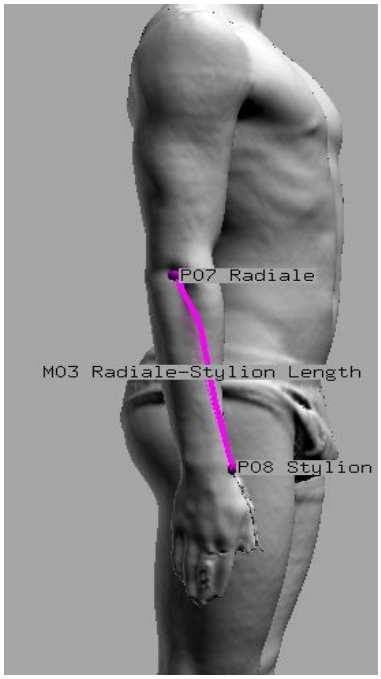
Posture required:
Scan position posture 1. Stand with feet together, arms straight at the sides with the palms facing in towards the thigh. Fingers together and extended with the thumb facing forward. Stand with back erect and head in the Frankfort plane.

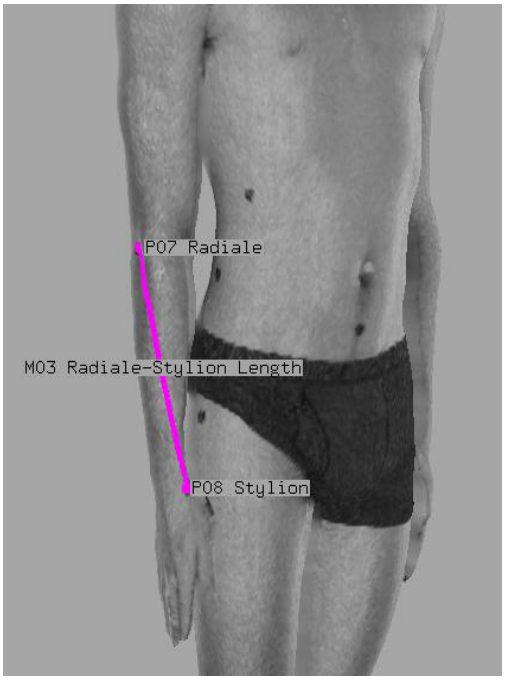
Procedure:
Identify and select the digital Radiale right and Stylion (most distal point on the lateral margin of the styloid process of the radius) right landmarks. Look for the stickered landmark and skip if absent. Measurements are reported in mm.

Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
Ignore the curved line produced by CySize. The export function will correct this to the point to point distance.

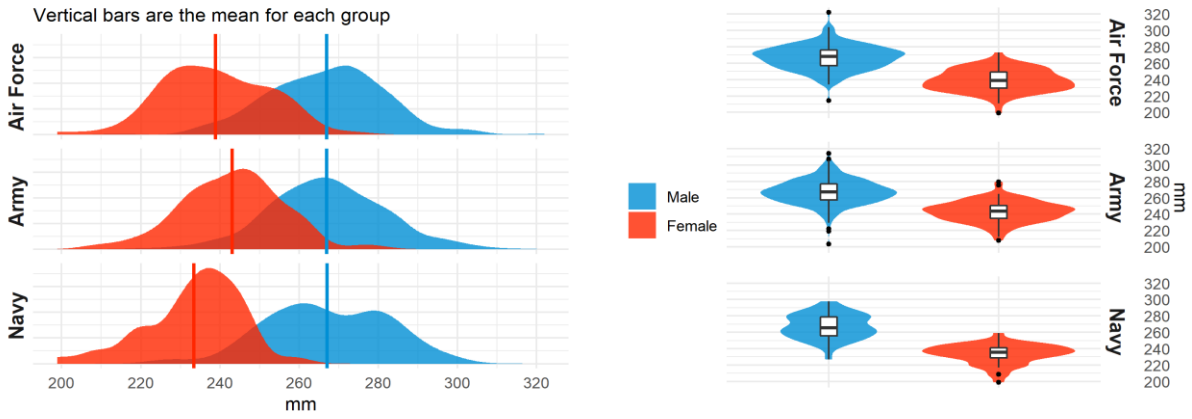




Radiale-stylion length summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
267	267	267	267	**Mean**	239	243	233	240
15	15	15	15	**SD**	14	13	12	13
204	215	204	227	**Min**	199	208	199	199
322	322	314	298	**Max**	273	279	259	279
303	303	302	297	**P99**	266	276	255	272
298	300	299	296	**P98**	262	266	251	263
296	295	296	294	**P97**	259	262	249	261
291	289	292	289	**P95**	259	261	247	260
285	284	285	286	**P90**	256	260	246	257
283	282	283	283	**P85**	255	255	245	254
279	279	279	281	**P80**	251	252	244	251
277	276	277	279	**P75**	249	251	241	249
275	275	274	278	**P70**	247	250	241	247
273	273	272	276	**P65**	244	248	239	245
270	272	270	272	**P60**	240	247	237	243
269	270	268	267	**P55**	240	245	236	241
267	268	267	266	**P50**	239	244	236	240
265	265	265	264	**P45**	237	242	235	238
263	264	263	262	**P40**	234	241	233	236
261	261	261	261	**P35**	232	238	230	235
259	259	259	259	**P30**	230	236	230	233
257	257	257	256	**P25**	229	235	229	230
255	254	255	254	**P20**	228	233	223	229
252	252	253	251	**P15**	226	230	220	227
249	249	250	248	**P10**	224	229	218	223
243	243	242	245	**P5**	220	222	210	218
239	238	239	242	**P3**	218	219	209	214
236	237	236	237	**P2**	214	217	207	209
230	236	230	228	**P1**	208	212	203	208

Distribution plots for each service and gender



Seated height - Physical measurement (mm)

Measuring instrument:
Stadiometer and anthropometry box. Only the bottom half of the stadiometer is required unless the participant has a sitting height in excess of 1300 mm. The stadiometer sits on the anthropometry box on its long axis.

Source:
ISAK.

Definition:
The height from the sitting platform to the Vertex® when the head is held in the Frankfort plane. The technique uses stretched stature methods to avoid repeated measures having to be taken as near as possible to the same time of day as the original measurement.

Landmark required:
None.

Posture required:
The participant is seated on a measuring box or level platform. Their arms and hands are by relaxed by their side. The assessor stands in front of the participant and observes at eye level the head in the Frankfort plane. The scale end of the caliper is near the participants head.

Procedure:
The participant is instructed to take and hold a deep breath, and while keeping the head in the Frankfort plane, the assessor applies gentle upward lift through the mastoid processes. Both thumbs of the assessor are below each Orbitale, and the index fingers are placed below the base of the skull. The recorder places the headboard firmly down on the Vertex®, crushing the hair as much as possible. Care must be taken to ensure the participant does not contract the gluteal muscles nor push with the legs. Measurements are reported in mm.

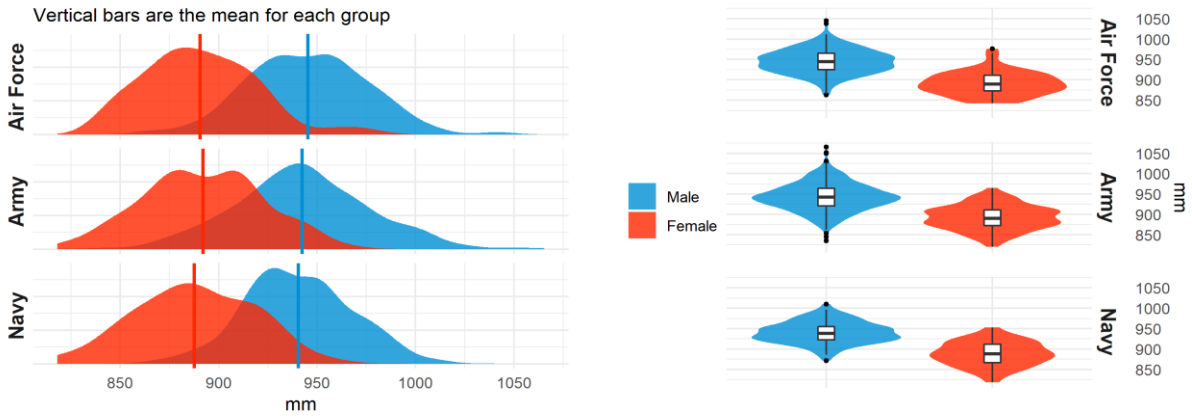
Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

Notes:
If the anthropometry box is too short consider using another object such as a sturdy desk or table.
Their knees should be at a right angle. If the seat surface dost not enable this angle, then ask the participant to sit straight with their back straight and against the Stadiometer (without leaning on it). The posterior-inferior end of the buttocks must be pushed back against the base of the ruler (as far as their body allows). Care must be taken to ensure the participant does not contract the gluteal muscles nor push with the legs.

Seated height summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
943	945	942	940	**Mean**	891	892	888	891
33	30	35	27	**SD**	29	30	30	30
836	863	836	871	**Min**	842	820	818	818
1066	1045	1066	1010	**Max**	976	965	952	976
1026	1011	1026	998	**P99**	969	951	945	964
1010	1007	1012	990	**P98**	962	950	938	952
1005	998	1007	988	**P97**	953	948	934	949
998	994	1002	985	**P95**	932	941	929	940
986	984	988	976	**P90**	924	935	925	927
976	976	978	972	**P85**	918	920	921	919
970	972	970	963	**P80**	915	916	914	915
964	965	964	955	**P75**	911	911	912	911
959	961	958	953	**P70**	902	910	909	909
954	957	953	951	**P65**	901	907	895	904
950	954	950	949	**P60**	896	904	894	899
945	951	944	945	**P55**	892	899	892	893
942	945	942	938	**P50**	890	890	888	889
938	941	939	932	**P45**	885	885	886	885
933	936	933	931	**P40**	879	883	880	880
931	932	930	929	**P35**	877	879	875	878
926	928	926	927	**P30**	875	874	874	874
922	925	921	922	**P25**	872	873	866	872
916	920	915	919	**P20**	866	867	862	865
910	914	908	915	**P15**	859	861	856	859
902	909	900	911	**P10**	855	852	849	851
890	898	886	899	**P5**	848	844	845	845
883	890	878	890	**P3**	845	840	836	842
875	886	874	889	**P2**	844	834	831	836
868	872	868	884	**P1**	843	827	824	828

Distribution plots for each service and gender



Shoulder-elbow length - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ANSUR, NZDFAS.

Definition:
The distance between the right acromion landmark and the right olecranon bottom landmark.

Landmark required:
Acromiale Right and Olecranon bottom (right) landmark.

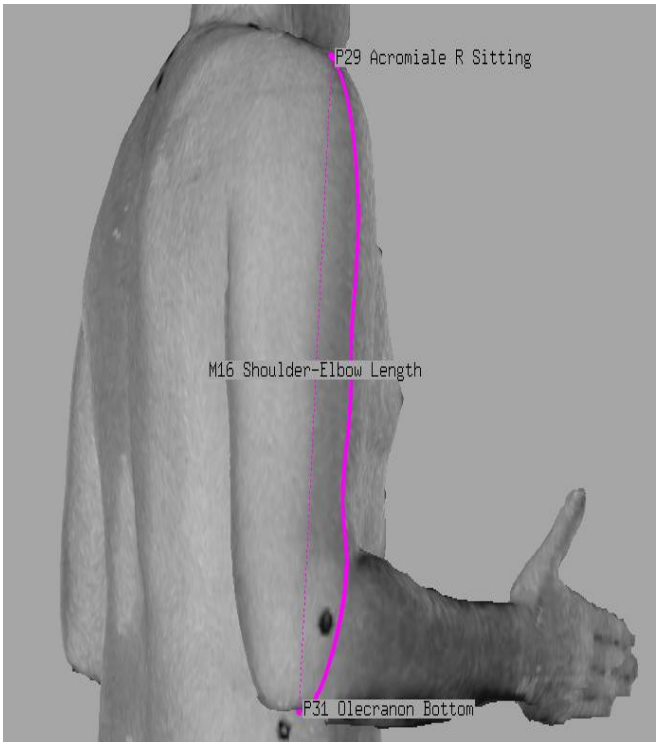
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

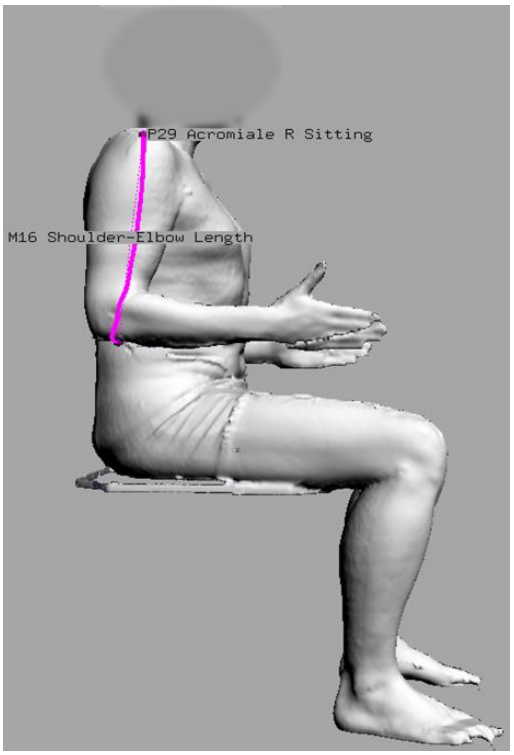
Procedure:
This measure is the point to point distance between the Acromiale Right and Olecranon bottom (right) landmark. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
None.

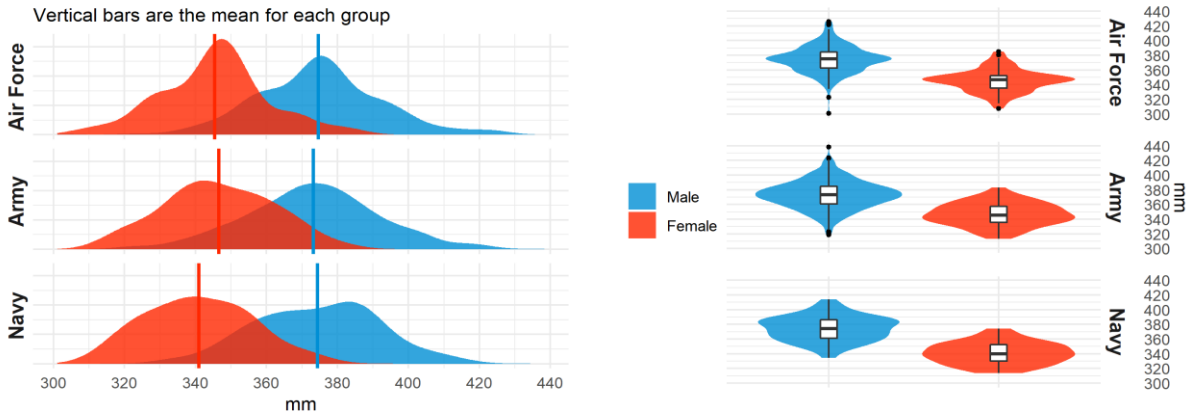




Shoulder-elbow length summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
374	375	373	374	**Mean**	345	347	341	345
19	18	19	17	**SD**	15	15	15	15
301	301	319	334	**Min**	307	313	314	307
438	426	438	414	**Max**	385	383	374	385
419	423	419	411	**P99**	382	380	372	380
414	415	415	408	**P98**	379	376	371	376
409	411	408	405	**P97**	375	374	369	374
404	403	404	403	**P95**	370	370	365	370
397	397	398	394	**P90**	367	368	358	367
392	393	392	390	**P85**	358	363	356	361
388	389	388	388	**P80**	356	361	353	357
385	385	385	386	**P75**	352	357	352	355
382	382	382	385	**P70**	351	356	351	353
380	379	380	382	**P65**	350	353	347	351
378	378	378	381	**P60**	349	350	344	349
376	376	376	377	**P55**	347	348	342	347
374	375	373	374	**P50**	347	346	340	345
372	373	371	374	**P45**	345	344	339	343
370	372	369	369	**P40**	343	342	337	341
368	370	367	367	**P35**	342	340	336	339
365	367	365	365	**P30**	341	339	331	337
361	362	361	361	**P25**	335	336	330	334
358	360	358	358	**P20**	334	334	327	331
355	357	354	357	**P15**	329	331	325	329
350	353	348	353	**P10**	327	326	322	325
344	346	342	348	**P5**	322	321	320	320
338	342	337	346	**P3**	316	319	317	317
335	341	335	341	**P2**	315	318	315	315
328	334	327	335	**P1**	312	315	314	314

Distribution plots for each service and gender



Sitting elbow rest height sitting - Post-processed measurement (mm)

Measuring instrument: CySize

Source:
ANSUR, NZDAS.

Definition:
The vertical distance between a sitting surface and the olecranon, bottom landmark on the flexed right elbow.

Landmark required:
Olecranon bottom and Seat pan height landmarks.

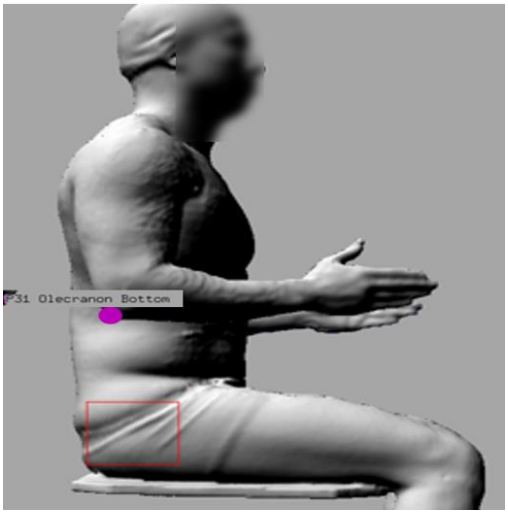
Posture required:
Scan position posture 3.

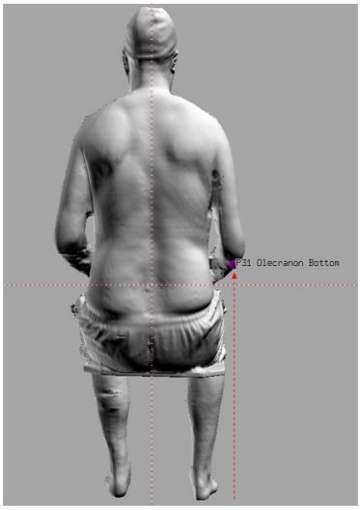
Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Olecranon bottom landmark minus the Y coordinate of the Seat pan height landmark in posture 3. Measurements are reported in mm.

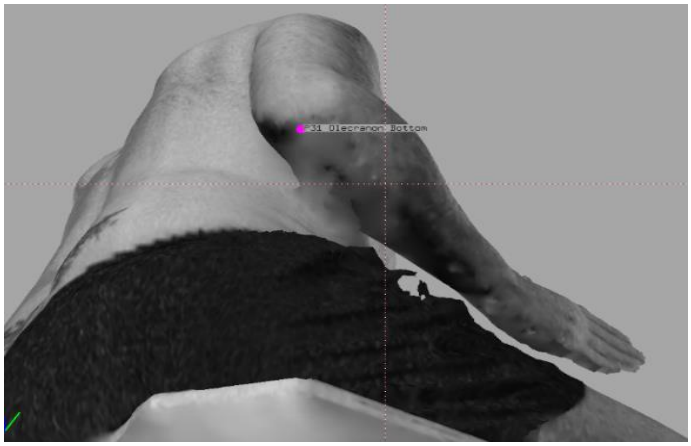
Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
Ensure that the forearm is horizontal and parallel with the ground.



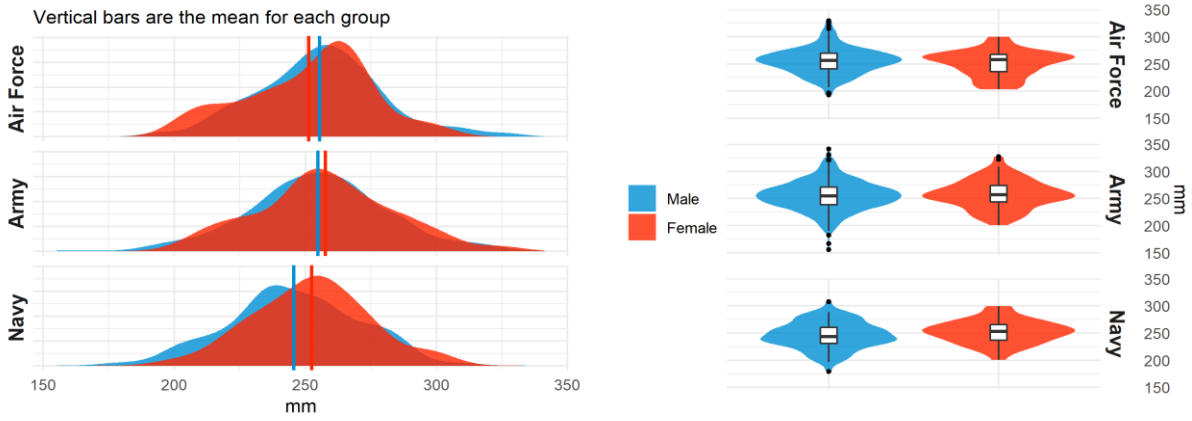




Sitting elbow rest height sitting summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
254	256	255	246	**Mean**	251	258	252	254
26	24	27	25	**SD**	24	26	22	25
155	193	155	179	**Min**	204	201	201	201
341	330	341	308	**Max**	300	327	300	327
320	319	321	291	**P99**	300	322	299	308
311	309	315	287	**P98**	297	309	299	302
308	308	309	287	**P97**	294	304	297	300
298	297	299	285	**P95**	289	302	291	298
287	282	288	280	**P90**	274	290	277	286
279	277	283	272	**P85**	269	286	273	277
275	273	276	268	**P80**	268	279	270	273
270	270	271	260	**P75**	267	274	265	268
266	266	267	258	**P70**	266	269	262	267
264	264	264	254	**P65**	263	265	259	263
260	261	261	252	**P60**	261	263	258	261
257	258	257	250	**P55**	259	260	255	258
254	257	255	243	**P50**	258	257	253	256
252	253	252	241	**P45**	256	253	252	253
248	251	249	239	**P40**	249	251	248	251
244	248	245	236	**P35**	247	250	245	248
241	244	242	234	**P30**	238	247	243	244
237	241	238	231	**P25**	236	243	237	237
233	235	235	229	**P20**	232	234	235	233
228	232	228	219	**P15**	222	230	230	226
220	223	221	213	**P10**	215	222	224	220
209	217	209	204	**P5**	208	215	219	211
204	212	203	200	**P3**	207	210	215	209
198	208	198	197	**P2**	205	210	212	207
193	198	192	195	**P1**	204	209	207	204

Distribution plots for each service and gender



Sleeve outseam - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR, AWAS.

Definition:
The contour (surface) distance between the digitally extracted Acromion Right and Centre Wrist marker landmarks, passing over the Radiale landmark.

Landmark required:
Digitally extracted Acromiale R and Centre Wrist and Radiale landmarks.

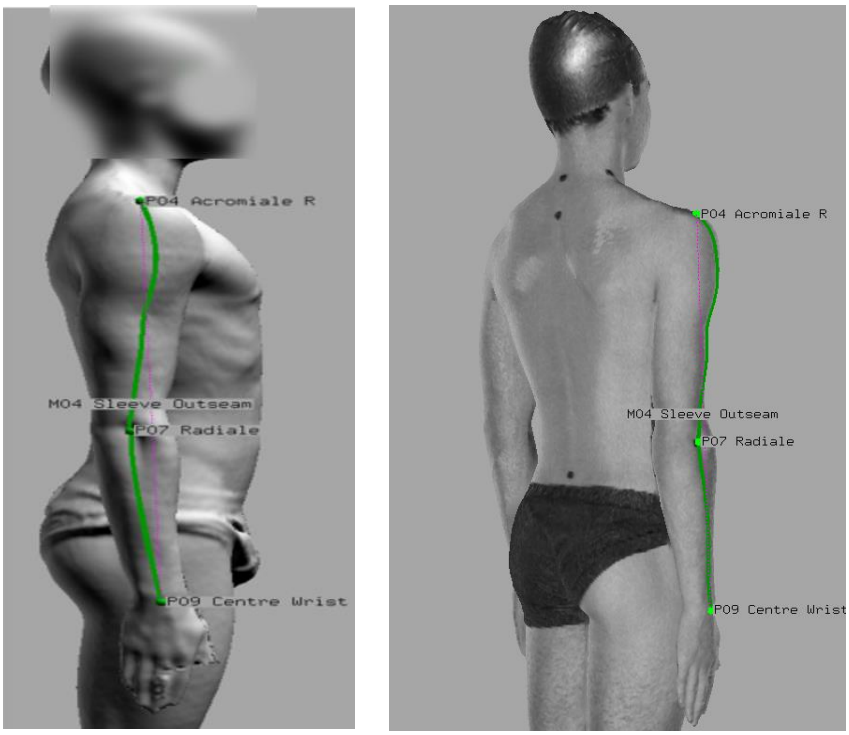
Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Procedure:
Identify and select the digital Acromiale R, Centre Wrist (centre point of the right wrist) and Radiale landmarks. Measurements are reported in mm. For the Centre Wrist add 'Z-loop' around the Stylion landmark. Visually identify the mid-point at the top of the wrist (when viewed straight on from the side). Look for the stickered landmark and skip if absent. This landmark is reliant on the presence of the Stylion.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

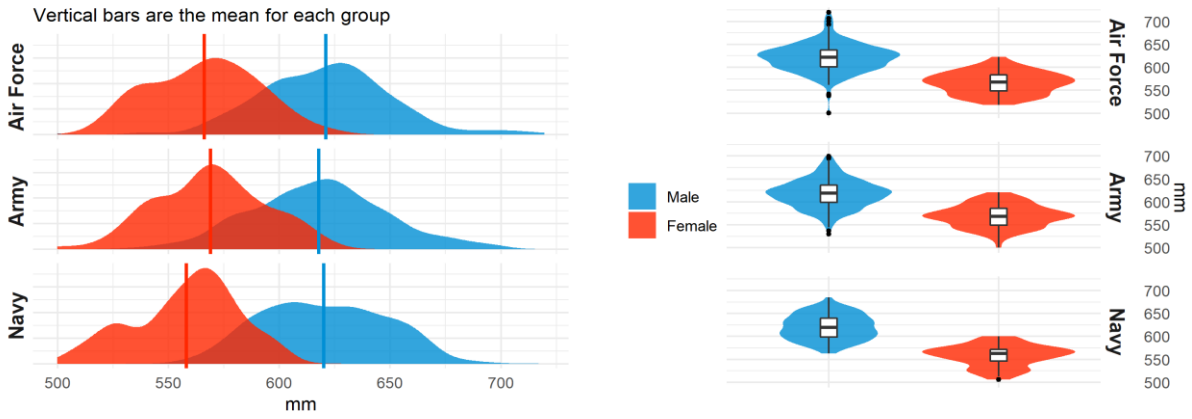
Notes:
None.



Sleeve outseam summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
619	621	618	620	**Mean**	566	569	558	566
30	30	30	27	**SD**	24	25	23	24
501	501	530	563	**Min**	518	500	506	500
720	720	699	685	**Max**	623	621	600	623
695	706	692	667	**P99**	617	619	598	618
685	693	684	664	**P98**	611	614	597	613
678	681	679	663	**P97**	606	612	596	608
669	668	671	662	**P95**	604	608	595	606
657	657	655	660	**P90**	596	605	585	597
649	648	649	651	**P85**	591	597	580	591
644	644	643	648	**P80**	587	590	577	587
637	638	637	640	**P75**	583	586	572	582
634	636	632	635	**P70**	580	582	571	578
630	631	629	634	**P65**	576	577	570	575
626	629	624	628	**P60**	574	575	566	571
623	626	622	626	**P55**	569	571	563	569
620	622	619	619	**P50**	568	568	563	567
615	618	614	612	**P45**	565	566	561	565
612	615	611	610	**P40**	562	565	556	563
607	610	606	608	**P35**	558	563	551	558
603	603	603	604	**P30**	552	558	549	552
599	601	599	599	**P25**	548	550	547	548
594	598	593	593	**P20**	540	545	535	544
587	592	585	589	**P15**	537	543	528	538
581	584	578	586	**P10**	534	538	525	533
573	574	571	581	**P5**	530	531	517	526
566	570	562	575	**P3**	526	529	514	524
560	567	557	572	**P2**	525	525	512	517
548	545	548	569	**P1**	522	517	509	514

Distribution plots for each service and gender



Suprasternale height - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
The vertical height of the nape landmark to the standing surface.

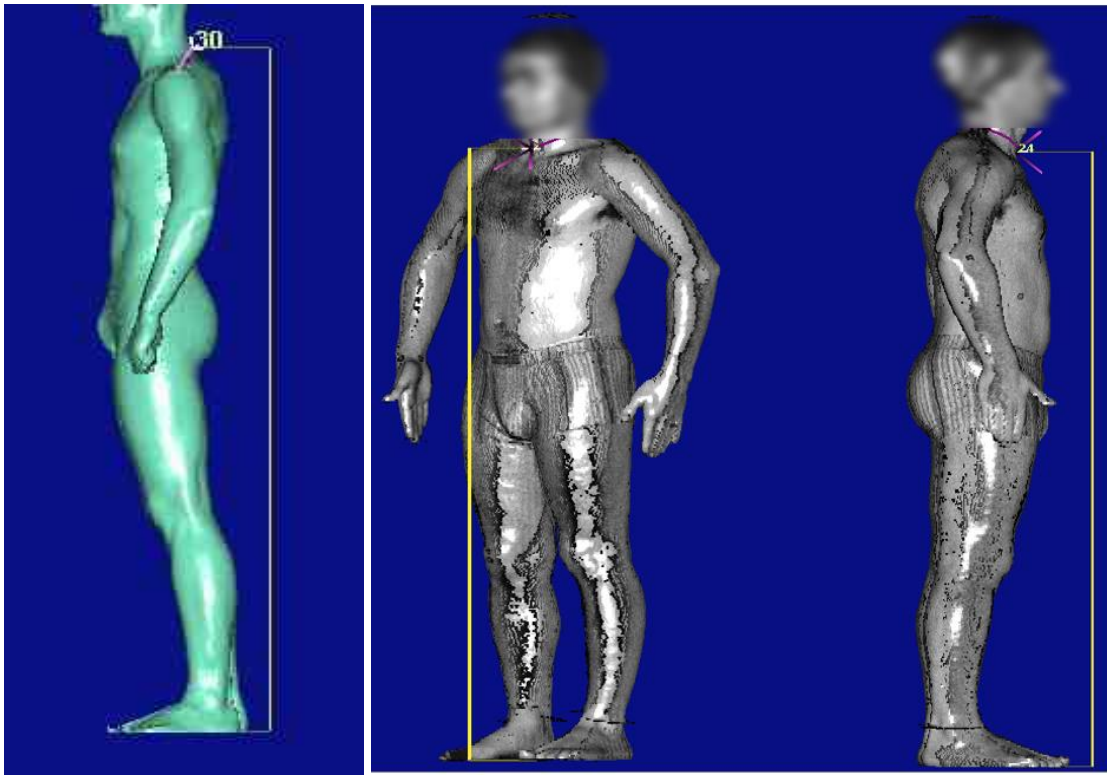
Landmark required.
None.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

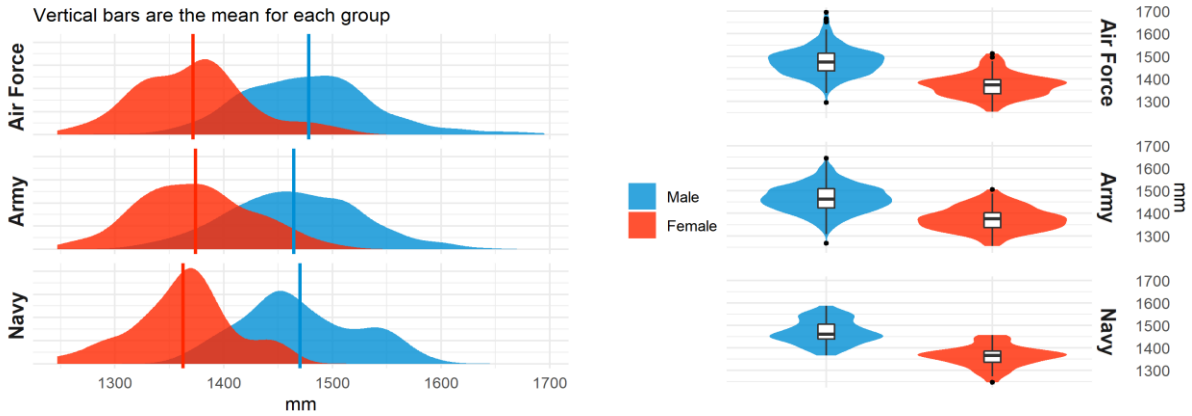
Notes:
Ensure the participant stands straight (ideally in Frankfort position).



Suprasternale height summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1469	1478	1465	1470	**Mean**	1372	1374	1363	1371
61	62	61	53	**SD**	52	52	47	51
1268	1294	1268	1366	**Min**	1254	1254	1247	1247
1695	1695	1644	1587	**Max**	1511	1506	1457	1511
1616	1661	1604	1577	**P99**	1500	1489	1454	1495
1602	1619	1596	1571	**P98**	1488	1479	1450	1478
1588	1616	1583	1560	**P97**	1478	1468	1448	1474
1567	1579	1562	1554	**P95**	1472	1464	1445	1461
1547	1560	1542	1551	**P90**	1435	1442	1424	1438
1528	1529	1522	1543	**P85**	1416	1433	1404	1428
1517	1522	1514	1526	**P80**	1405	1424	1390	1409
1511	1514	1509	1505	**P75**	1396	1402	1386	1400
1502	1507	1500	1497	**P70**	1392	1400	1381	1392
1493	1500	1488	1486	**P65**	1388	1390	1378	1388
1482	1495	1479	1478	**P60**	1384	1384	1373	1381
1475	1485	1473	1471	**P55**	1377	1377	1370	1377
1467	1475	1464	1460	**P50**	1373	1375	1366	1373
1459	1470	1456	1457	**P45**	1370	1364	1363	1366
1452	1460	1448	1450	**P40**	1356	1356	1359	1358
1445	1452	1441	1446	**P35**	1347	1351	1356	1351
1438	1446	1432	1442	**P30**	1344	1343	1341	1342
1427	1435	1424	1439	**P25**	1333	1337	1336	1336
1417	1423	1413	1422	**P20**	1326	1328	1330	1326
1409	1416	1403	1413	**P15**	1319	1319	1321	1319
1395	1410	1388	1405	**P10**	1316	1313	1299	1311
1373	1383	1366	1392	**P5**	1296	1295	1284	1291
1362	1375	1352	1383	**P3**	1281	1284	1276	1277
1352	1366	1342	1374	**P2**	1277	1269	1269	1270
1334	1353	1332	1373	**P1**	1269	1267	1258	1256

Distribution plots for each service and gender



T2 height - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
AWAS, NZDFAS.

Definition:
Standing surface to T2 landmark. Identified as the Y coordinate (mm on the Y or vertical axis) of the T2 landmark.

Landmark required:
Second thoracic vertebra T2 landmark.

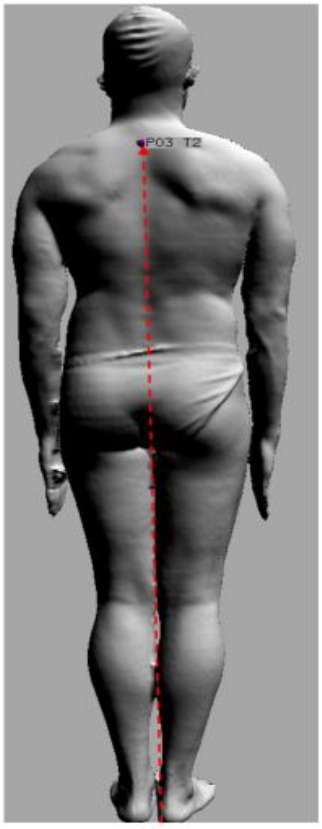
Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

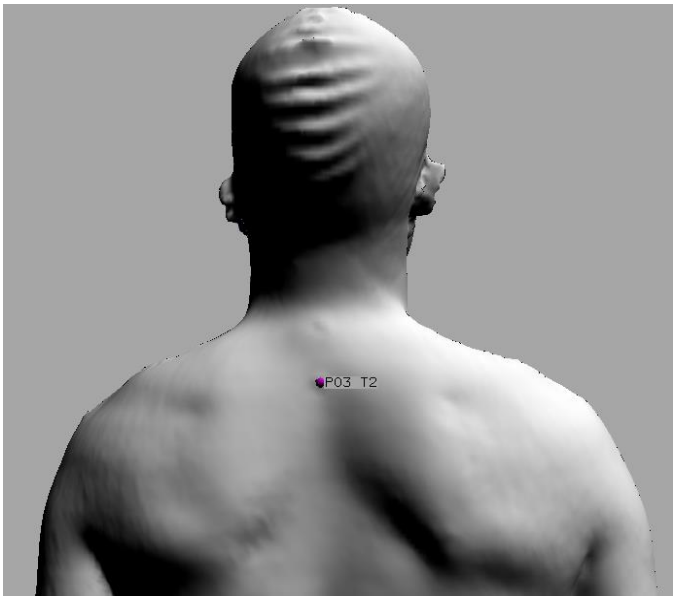
Procedure:
Use the second highest landmark on the upper back. See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Notes:
None.

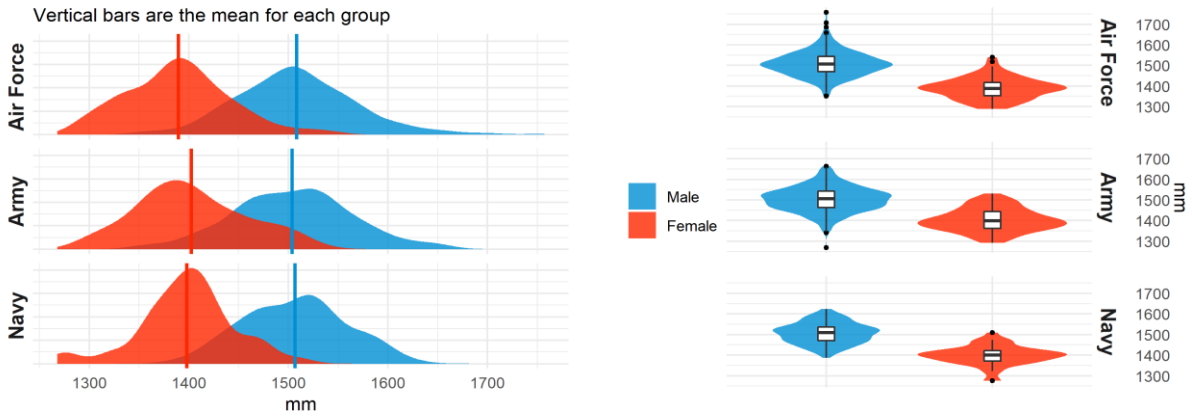




T2 height summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1505	1509	1504	1507	**Mean**	1390	1403	1398	1397
60	62	61	51	**SD**	52	55	48	53
1268	1352	1268	1386	**Min**	1289	1292	1275	1275
1757	1757	1664	1624	**Max**	1539	1532	1509	1539
1652	1681	1645	1606	**P99**	1524	1511	1495	1517
1642	1652	1637	1600	**P98**	1508	1510	1480	1509
1623	1634	1624	1598	**P97**	1493	1509	1474	1507
1604	1613	1602	1588	**P95**	1474	1502	1474	1493
1580	1582	1580	1577	**P90**	1450	1480	1461	1472
1565	1567	1563	1561	**P85**	1439	1466	1438	1452
1553	1555	1553	1549	**P80**	1429	1451	1426	1439
1542	1543	1542	1536	**P75**	1417	1443	1421	1428
1534	1535	1534	1533	**P70**	1410	1428	1419	1419
1526	1525	1528	1526	**P65**	1406	1416	1411	1410
1520	1517	1521	1523	**P60**	1399	1408	1407	1406
1512	1510	1514	1518	**P55**	1396	1403	1404	1401
1506	1506	1506	1509	**P50**	1388	1399	1400	1396
1499	1502	1496	1504	**P45**	1382	1391	1400	1389
1490	1494	1488	1494	**P40**	1379	1385	1392	1383
1482	1485	1480	1480	**P35**	1377	1378	1385	1378
1474	1476	1471	1476	**P30**	1364	1372	1382	1372
1466	1469	1463	1470	**P25**	1354	1362	1371	1362
1457	1458	1455	1466	**P20**	1339	1359	1366	1357
1445	1446	1443	1446	**P15**	1333	1351	1358	1344
1431	1436	1427	1442	**P10**	1328	1335	1355	1330
1409	1415	1405	1422	**P5**	1304	1319	1322	1306
1397	1406	1388	1417	**P3**	1302	1305	1288	1302
1381	1389	1376	1416	**P2**	1301	1303	1276	1301
1361	1371	1358	1410	**P1**	1297	1301	1276	1289

Distribution plots for each service and gender



Tenth rib height - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS, NZDFAS.

Definition:
The standing surface to the 10th rib landmark vertical distance.

Landmark required:
Tenth rib landmark.

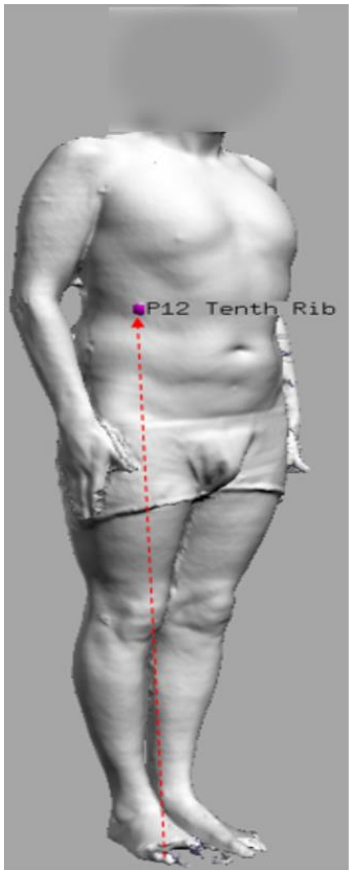
Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the tenth rib landmark in posture 1. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

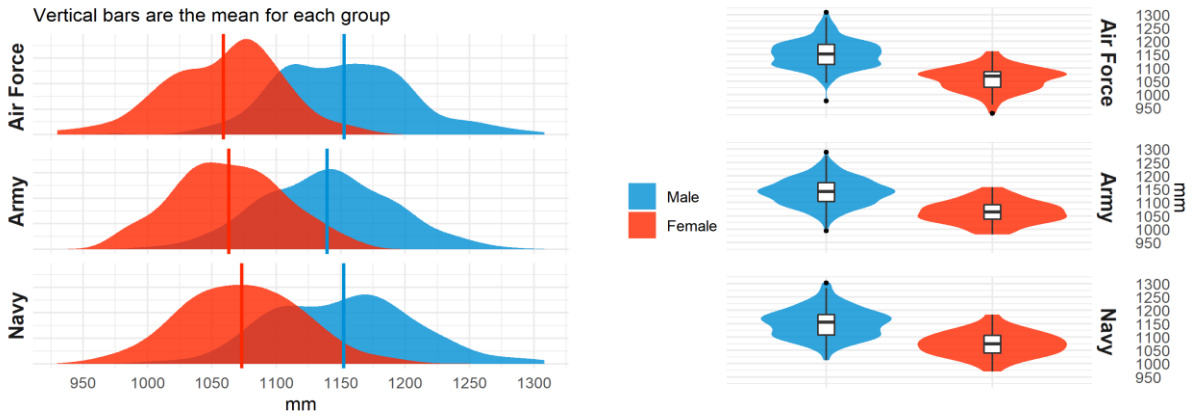
Notes:
If the landmark is not present, then skip this measure. Ensure that the landmark is not confused with the Iliocristale landmark.



Tenth rib height summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1145	1153	1140	1152	**Mean**	1059	1063	1073	1064
52	52	51	55	**SD**	45	42	45	44
976	976	994	1012	**Min**	930	980	971	930
1308	1308	1289	1303	**Max**	1162	1157	1185	1185
1268	1284	1254	1286	**P99**	1153	1154	1173	1157
1255	1264	1244	1272	**P98**	1146	1153	1160	1153
1244	1259	1237	1253	**P97**	1138	1137	1151	1147
1233	1243	1221	1236	**P95**	1122	1132	1138	1134
1208	1212	1204	1224	**P90**	1109	1123	1131	1121
1197	1200	1194	1208	**P85**	1102	1106	1119	1107
1188	1194	1183	1193	**P80**	1095	1098	1109	1101
1180	1188	1174	1185	**P75**	1085	1092	1105	1093
1173	1181	1166	1178	**P70**	1081	1085	1099	1085
1163	1173	1158	1176	**P65**	1077	1082	1089	1082
1156	1165	1151	1168	**P60**	1074	1074	1084	1076
1151	1156	1146	1162	**P55**	1072	1066	1079	1071
1144	1152	1141	1155	**P50**	1070	1064	1074	1066
1138	1145	1134	1146	**P45**	1064	1056	1065	1062
1130	1137	1127	1138	**P40**	1051	1047	1063	1054
1123	1127	1121	1126	**P35**	1042	1043	1054	1044
1116	1117	1112	1117	**P30**	1035	1039	1045	1039
1107	1113	1103	1108	**P25**	1028	1037	1040	1035
1101	1108	1095	1103	**P20**	1023	1026	1036	1026
1092	1103	1086	1094	**P15**	1014	1023	1030	1022
1079	1097	1075	1089	**P10**	1002	1010	1022	1008
1063	1078	1056	1071	**P5**	990	993	1006	992
1050	1066	1045	1064	**P3**	966	984	998	984
1044	1051	1039	1059	**P2**	963	983	991	980
1027	1045	1026	1044	**P1**	953	981	981	964

Distribution plots for each service and gender



Thigh clearance - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS, NZDFAS.

Definition:
The vertical distance between a horizontal sitting surface and the Thigh Point Top landmark.

Landmark required:
Thigh Point Top and Seat Pan Height landmarks.

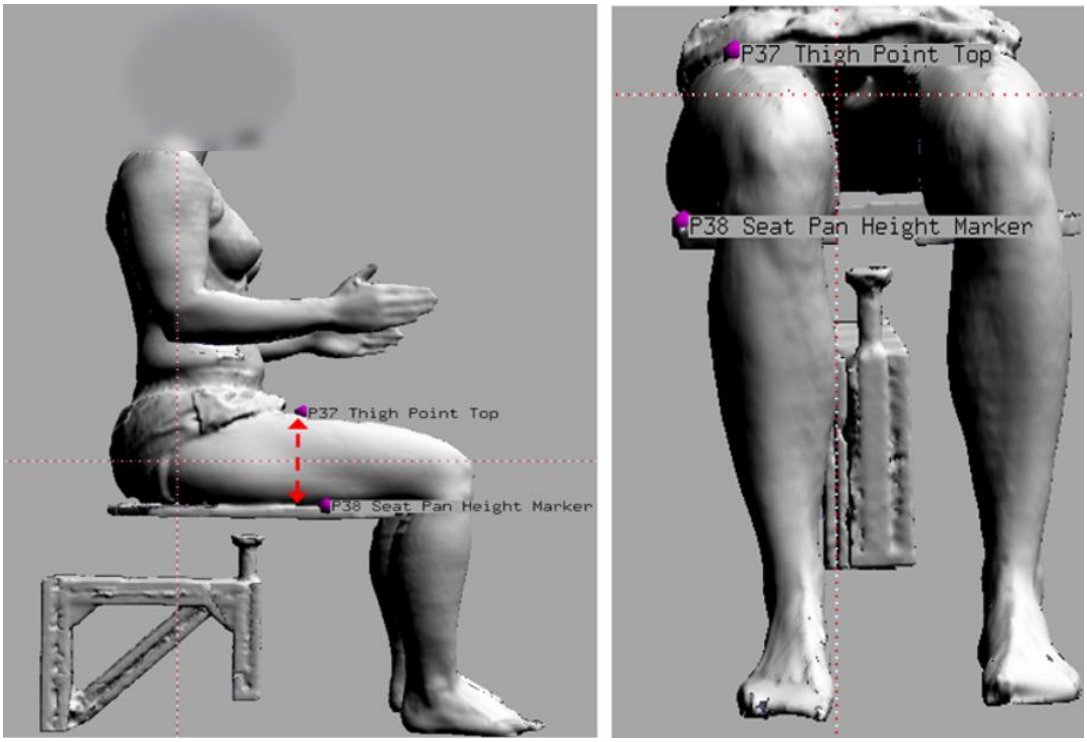
Posture required:
Scan position posture 3. Ensure that the participant is sitting with their knee bent at a 90˚angle. This can be done by moving the body scanner seat up or down. This can also be facilitated by aligning the popliteal fossa (vertically) in line with Pternion (back of the foot).

Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Thigh Point Top (most superior point of the middle surface of the right thigh) landmark minus the Y coordinate of the Seat Pan Height landmark in posture 3. This calculation is performed in an Excel spreadsheet. Ensure that the seat height is positioned so that the legs are at a 90 degree angle and that the popliteal is not contacting the front edge of the seat. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

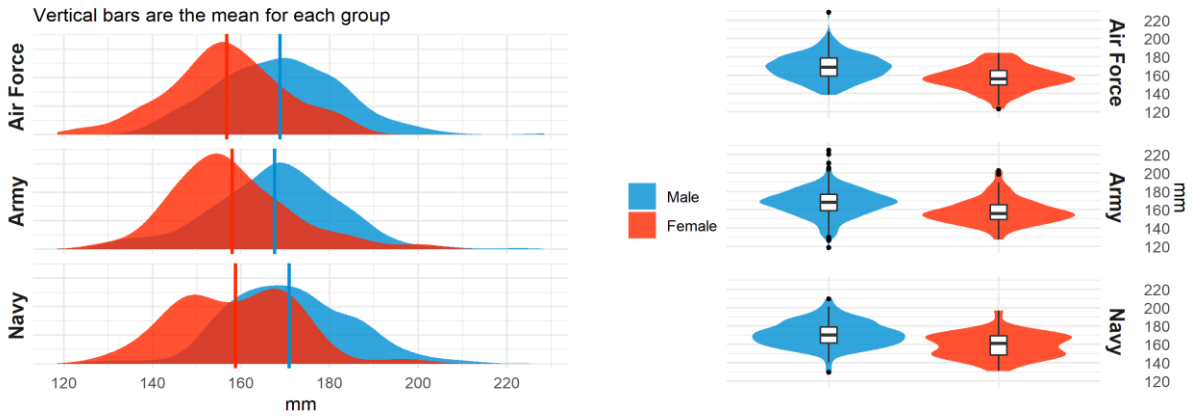
Notes:
It is important that the participant is seated with their legs at right angles. Before the scan, raise or lower the seat until the bottom of the right thigh is horizontal and parallel to the floor. Next, ensure that the popliteal fold is in vertical line with the back of the heel. Ensure both feet are facing forward.



Thigh clearance summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
168	169	168	171	**Mean**	157	158	159	158
15	14	15	14	**SD**	13	14	13	13
118	138	118	130	**Min**	123	127	131	123
228	228	225	209	**Max**	184	203	197	203
204	201	204	202	**P99**	183	199	190	196
198	198	196	199	**P98**	182	190	183	187
195	196	193	197	**P97**	182	188	179	183
191	191	189	193	**P95**	179	182	175	181
186	186	185	187	**P90**	173	176	172	174
183	182	182	186	**P85**	170	171	171	171
180	181	180	185	**P80**	167	168	170	169
178	179	177	179	**P75**	165	166	169	166
175	175	175	176	**P70**	162	163	169	164
174	173	173	175	**P65**	161	161	165	162
172	172	171	174	**P60**	160	159	163	160
170	171	170	172	**P55**	158	157	162	158
168	168	168	170	**P50**	156	156	161	156
167	168	167	168	**P45**	155	155	155	155
165	165	166	167	**P40**	154	153	154	154
163	163	163	165	**P35**	154	153	151	153
161	161	161	163	**P30**	151	151	150	150
159	159	159	161	**P25**	149	149	148	149
157	156	156	160	**P20**	146	147	147	147
154	154	153	157	**P15**	145	146	146	146
150	151	149	155	**P10**	139	143	143	142
144	146	141	153	**P5**	136	140	138	137
139	144	136	151	**P3**	133	137	137	136
136	143	133	148	**P2**	130	136	136	132
132	142	132	139	**P1**	126	131	133	128

Distribution plots for each service and gender



Thigh girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Anthroscan.

Definition:
Maximum horizontal circumference measurement around the left leg beneath crotch. The circumference is measured parallel to the standing surface.

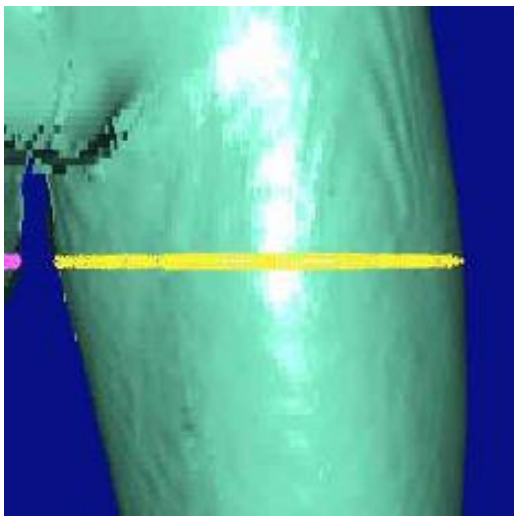
Landmark required:
None.

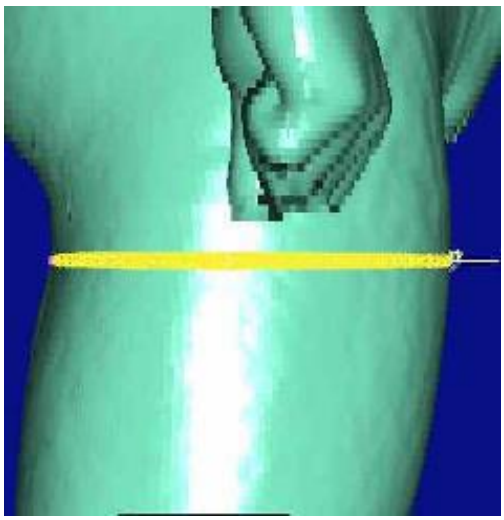
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

Notes:
Check that the digital tape (yellow line below) is horizontal. Sometimes the software will draw the girth around both legs if they are too close together. Check that the tape follows the curvature of the thigh. Sometimes the tape can be 'bent' (picture far right) possibly due to drawing around an unknown object of the artefact.The tape should be below the gluteal fold when viewed from the side. If not, adjust accordingly.

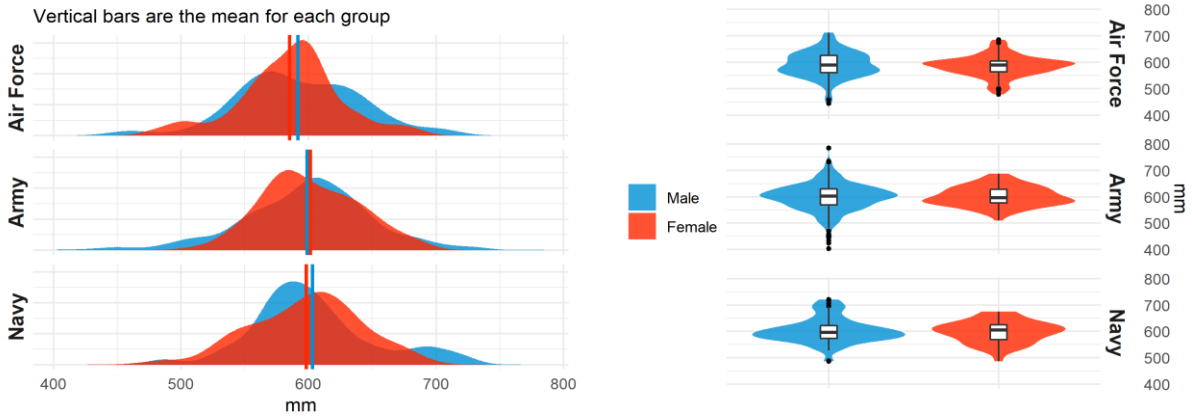




Thigh girth summary statistics - Automatic measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
597	592	599	603	**Mean**	585	602	598	595
51	49	52	48	**SD**	40	37	42	40
403	444	403	486	**Min**	478	510	487	478
785	713	785	720	**Max**	685	687	675	687
717	707	722	720	**P99**	678	686	674	684
707	698	707	717	**P98**	672	680	673	675
696	691	693	709	**P97**	666	673	672	673
683	667	682	696	**P95**	649	665	669	665
658	652	657	680	**P90**	635	652	649	645
644	641	644	653	**P85**	617	642	636	637
635	635	636	632	**P80**	610	637	630	629
628	626	630	622	**P75**	605	628	625	621
622	619	624	616	**P70**	602	622	620	613
615	612	617	610	**P65**	599	614	617	609
610	605	611	603	**P60**	597	610	610	603
604	596	606	599	**P55**	593	603	607	599
599	589	602	596	**P50**	590	597	605	596
593	581	598	592	**P45**	584	592	597	590
587	575	592	589	**P40**	580	587	595	585
579	571	585	582	**P35**	575	583	586	582
572	567	578	577	**P30**	570	580	581	576
568	560	569	574	**P25**	563	576	568	571
560	554	561	570	**P20**	559	572	563	564
549	546	549	567	**P15**	551	565	549	558
540	539	538	550	**P10**	538	557	540	545
512	518	508	537	**P5**	506	544	537	533
499	504	496	528	**P3**	500	538	531	514
483	470	483	517	**P2**	496	533	522	505
456	459	450	488	**P1**	489	532	505	494

Distribution plots for each service and gender



Thumb tip reach - Physical measurement (mm)

Measuring instrument:
Full-length anthropometer, ideally made of solid steel. The anthropometer typically comes in 4 separate sections. When combined, one end of the rod contains a stationary or fixed arm or prong, the other prong is free to move up and down while at a right angle to the rod. There are typically two scales on the rod that run opposite to each other.

Source:
ANSUR.

Definition:
The horizontal distance from a back wall to the tip of the right thumb.

Landmark required:
None.

Posture required:
The participant stands erect against a wall with both the left and right shoulder blades touching the wall. Their right arm is raised as straight as possible to the front at a 90 degree angle to the body. Their arm must be in a relaxed and 'natural' position (i.e. do not ask them to fully reach forward or retract their shoulder/deltoid against the wall). They form a relaxed but extended 'pinch' position with the tips of their thumb gently touching the index finger with the palm facing down (index finger superior to thumb). The assessor stands to the right side of the participant in front of the elbow. This position enables the assessor to support the weight of the anthropometer evenly and be in a position to see both prongs (the fixed end and the measurement end).

Procedure:
Place the outer edge of the fixed prong against the wall. Extend the opposite prong 5 cm beyond the fingertip. Slowly push the prong towards the hand until it touches the tip of the thumb (excluding the fingernail). Check that both the arm and anthropometer are straight and horizontal then take the reading to the nearest 0.1 cm. Measurements are reported in mm.

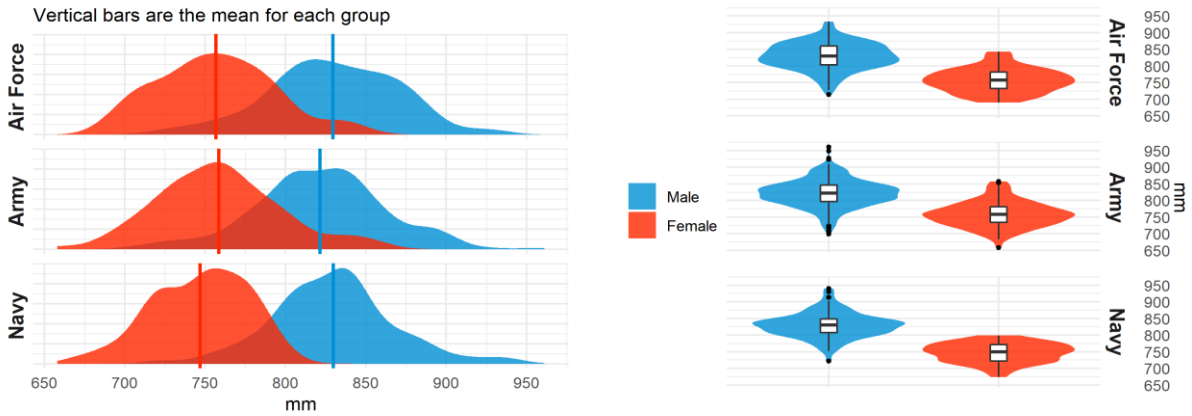
Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Notes:
Lengthen or shorten the anthropometer (by adding or removing sections of the rod) to suit the arm length of the participant. Ensure the prong is based securely, and square to the wall for stability. Be aware of handling the prong tip to avoid injuring the participant. Ask the scribe to observe and confirm whether the participant's arm is straight and horizontal to the floor immediately before taking the reading. The anthropometer and arm centre should be at the same height. Ensure that the data spreadsheet has the appropriate correction factor for the length of the anthropometer.

Thumb tip reach summary statistics - Physical measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
825	830	822	830	**Mean**	757	759	747	756
41	41	41	38	**SD**	36	39	29	36
700	714	700	722	**Min**	690	658	674	658
961	934	961	940	**Max**	842	857	798	857
924	926	910	932	**P99**	841	854	795	847
905	910	904	918	**P98**	837	848	792	839
899	899	899	907	**P97**	833	839	790	836
891	888	892	890	**P95**	825	836	787	820
878	879	873	878	**P90**	796	803	781	798
866	870	861	864	**P85**	792	797	776	791
858	866	852	854	**P80**	787	787	774	782
850	860	846	849	**P75**	782	781	771	779
844	853	842	842	**P70**	776	778	768	772
839	846	837	840	**P65**	768	767	759	768
835	840	832	838	**P60**	765	763	754	763
830	835	826	836	**P55**	762	761	753	760
825	829	823	830	**P50**	757	758	750	755
820	822	817	827	**P45**	748	755	748	750
814	818	811	820	**P40**	746	750	745	747
810	814	806	814	**P35**	744	740	737	741
804	810	802	811	**P30**	736	737	724	736
800	803	798	807	**P25**	732	734	722	731
794	798	788	801	**P20**	723	727	721	723
786	791	782	798	**P15**	713	722	721	718
774	779	772	785	**P10**	711	712	714	711
755	761	752	773	**P5**	703	702	695	700
742	745	738	759	**P3**	697	694	693	694
731	742	727	753	**P2**	696	690	690	691
723	729	721	749	**P1**	694	683	682	685

Distribution plots for each service and gender



Tibiale laterale height - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ISAK, NZDFAS.

Definition:
The vertical distance between a standing surface and the Tibiale laterale landmark.

Landmark required:
Tibiale laterale.

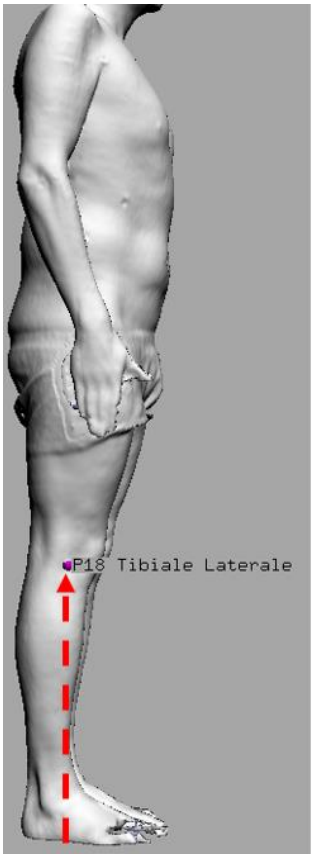
Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Tibiale laterale (most superior point on the lateral border of the head of the tibia) landmark in posture 1. Look for the stickered landmark (side of knee) and skip if absent. Measurements are reported in mm.

Reference:
Marfell-Jones, M.J., A.D. Stewart, and J.H. De Ridder, International Standards for Anthropometric Assessment. 2012.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

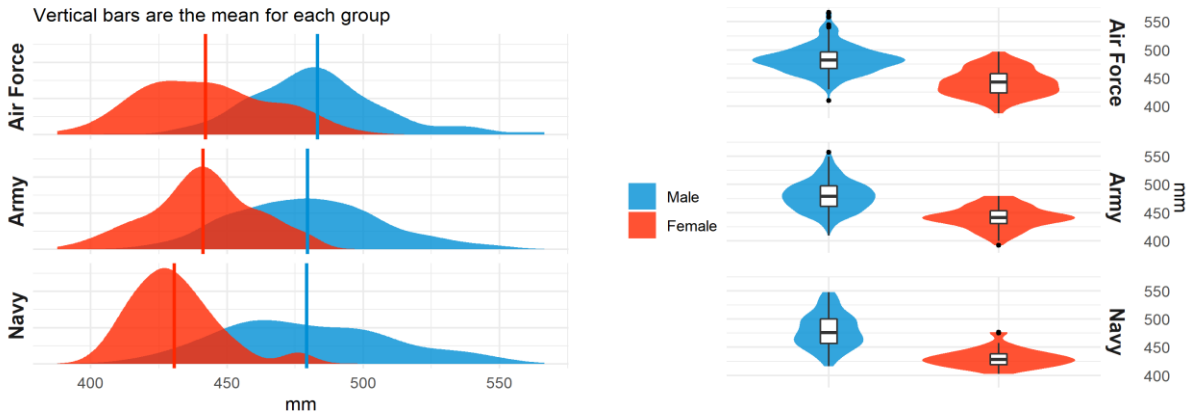
Notes:
None.



Tibiale laterale height summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
481	483	480	479	**Mean**	442	441	431	439
27	25	27	30	**SD**	24	19	16	21
409	410	409	416	**Min**	388	392	403	388
566	566	557	548	**Max**	497	479	477	497
549	556	549	547	**P99**	489	479	476	483
541	544	539	542	**P98**	485	479	476	479
538	541	533	540	**P97**	483	479	471	479
530	532	527	533	**P95**	480	475	457	477
515	514	514	525	**P90**	474	466	448	470
507	506	506	509	**P85**	472	463	445	463
501	500	502	506	**P80**	466	456	440	457
498	496	498	500	**P75**	458	454	438	451
493	492	493	497	**P70**	454	449	438	448
490	489	490	493	**P65**	449	447	434	446
486	486	486	486	**P60**	447	445	432	444
482	484	482	478	**P55**	444	443	430	441
480	482	479	476	**P50**	443	442	429	438
476	479	475	473	**P45**	436	439	427	436
473	477	471	467	**P40**	433	438	426	433
469	474	468	464	**P35**	430	436	424	431
465	471	464	460	**P30**	428	433	421	428
462	467	461	457	**P25**	424	431	419	425
457	462	456	453	**P20**	420	427	418	421
452	459	451	449	**P15**	419	421	416	418
447	455	446	443	**P10**	414	416	413	414
439	446	439	435	**P5**	407	409	410	409
435	442	434	431	**P3**	404	404	409	404
431	436	429	425	**P2**	404	401	408	403
424	433	424	423	**P1**	399	400	405	400

Distribution plots for each service and gender



Trochanterion height - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
ANSUR, AWAS, NZDFAS.

Definition:
The vertical distance between a standing surface and the Trochanterion landmark.

Landmark required:
Trochanterion.

Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

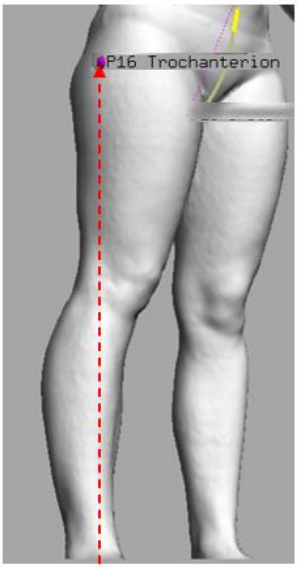
Procedure:
This measure is represented by the Y coordinate (mm on the Y or vertical axis) of the Trochanterion (most superior point on the greater trochanter of the femur) landmark in posture 1. Look for the stickered landmark (right hip close to pant line) and skip if absent. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

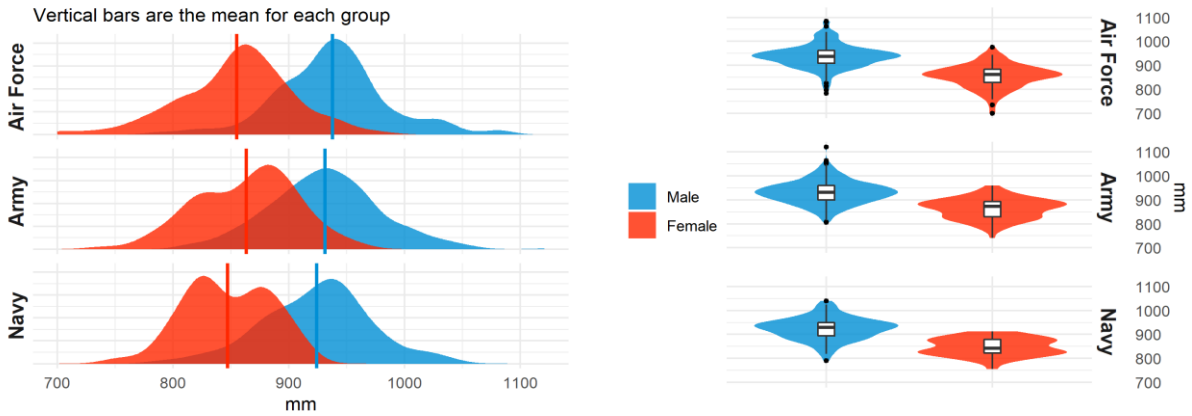
Notes:
This requires the participant to be scanned with feet together and cannot be measured when a participant is scanned in a wide stance.



Trochanterion height summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
932	938	931	924	**Mean**	855	863	847	857
48	49	48	47	**SD**	49	43	37	44
783	783	805	791	**Min**	700	740	755	700
1121	1084	1121	1039	**Max**	975	959	912	975
1049	1078	1045	1026	**P99**	952	954	909	953
1038	1039	1034	1021	**P98**	943	940	907	942
1030	1037	1027	1018	**P97**	942	937	905	936
1016	1029	1013	1000	**P95**	933	932	903	931
993	995	993	977	**P90**	908	915	897	907
976	981	977	972	**P85**	899	905	881	900
966	966	968	956	**P80**	892	899	879	894
960	962	960	950	**P75**	884	893	878	886
954	957	954	947	**P70**	877	887	876	881
948	951	948	944	**P65**	871	883	870	878
942	946	941	937	**P60**	865	879	862	874
937	941	935	933	**P55**	863	876	855	866
932	938	931	929	**P50**	861	873	842	862
928	934	925	921	**P45**	857	862	835	857
922	930	920	918	**P40**	851	856	829	849
916	923	913	910	**P35**	846	846	829	841
909	920	908	901	**P30**	841	835	827	831
901	908	900	894	**P25**	828	830	822	827
894	900	892	886	**P20**	812	824	817	820
883	894	882	876	**P15**	808	817	812	811
873	883	870	869	**P10**	799	809	800	801
852	864	852	843	**P5**	775	791	794	782
840	841	842	832	**P3**	760	781	792	776
830	827	831	820	**P2**	745	779	785	761
816	814	819	816	**P1**	725	773	770	742

Distribution plots for each service and gender



Vertical trunk circumference - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
AWAS.

Definition:
The circumference of the trunk on a plane passing through the Crotch landmark and over Bust point (females)/Thelion (males), Midshoulder, and Buttock Point, Posterior landmarks.

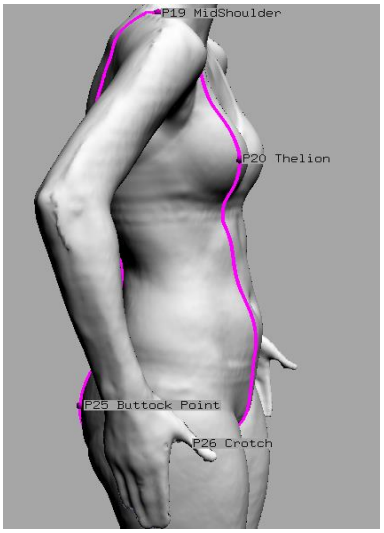
Landmark required:
Crotch, Thelion (males)/Bust point (females), Midshoulder and Buttock Point posterior landmarks.

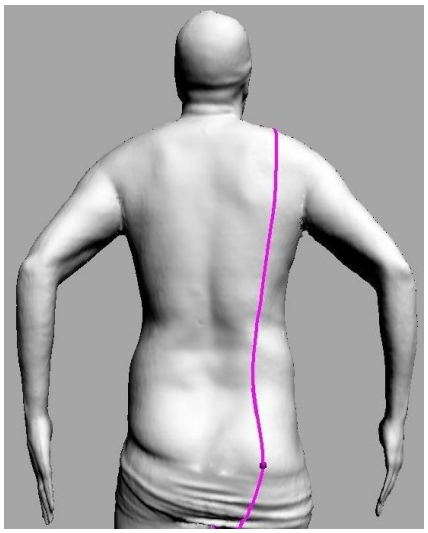
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

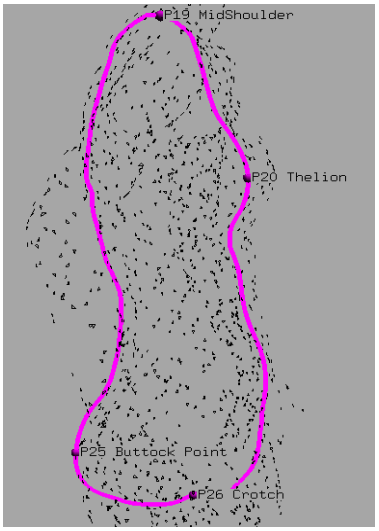
Procedure:
The Midshoulder is the top of the right shoulder midway between Trapezius Point and Acromiale right landmarks. Look for the stickered landmark (midpoint on right shoulder) and if the landmark is missing place a landmark on the midway point between the neck/trap crease and acromion. The Buttock Point is the most posterior point of the right buttock. View from the side. Place the point marker on the most posterior-protruding region of the right buttock. Add X-loop around the point to refine the point. Skip if the participant is wearing baggy shorts. If there is no clear protrusion or sign of curvature change to rear view (view from the back). Place a point marker in the centre of the right buttock then use a X-loop to refine the point. As per AWAS Section 7.2.13 of the Procedures Manual (Tomkinson et al., 2012). Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Notes:
If crotch cannot be identified, then this measure will not be possible.



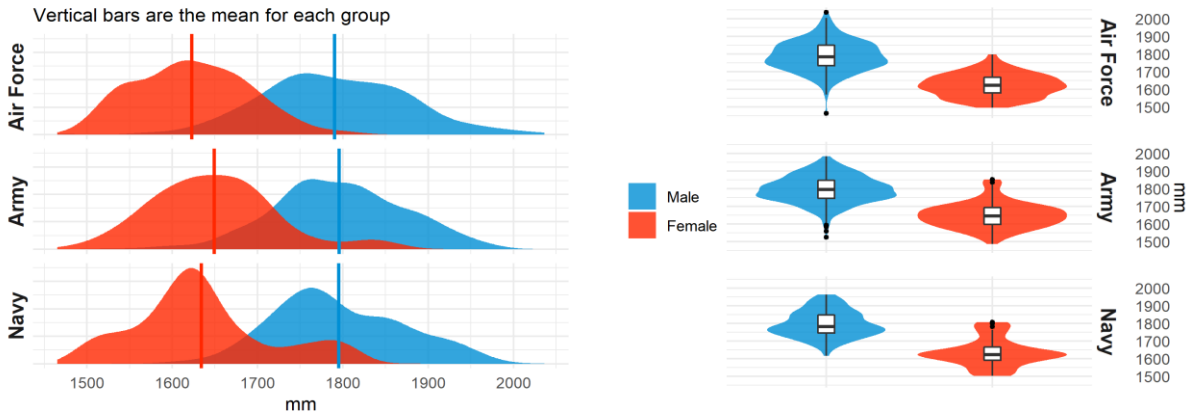




Vertical trunk circumference summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1794	1790	1796	1795	**Mean**	1623	1649	1634	1637
79	86	77	74	**SD**	65	73	79	72
1465	1465	1524	1616	**Min**	1497	1487	1503	1487
2036	2036	1984	1963	**Max**	1798	1852	1806	1852
1968	1999	1967	1952	**P99**	1769	1851	1803	1834
1950	1967	1944	1940	**P98**	1747	1836	1799	1811
1940	1957	1937	1934	**P97**	1734	1825	1797	1798
1929	1934	1926	1930	**P95**	1730	1778	1795	1765
1898	1893	1899	1908	**P90**	1702	1726	1758	1728
1879	1878	1881	1873	**P85**	1692	1710	1724	1703
1862	1861	1864	1860	**P80**	1678	1700	1686	1693
1849	1851	1848	1848	**P75**	1669	1692	1665	1681
1836	1838	1836	1840	**P70**	1661	1681	1644	1671
1825	1826	1824	1827	**P65**	1649	1673	1639	1661
1813	1813	1814	1801	**P60**	1641	1665	1636	1647
1802	1798	1804	1792	**P55**	1624	1658	1631	1640
1790	1785	1794	1780	**P50**	1623	1644	1623	1631
1779	1774	1783	1771	**P45**	1612	1636	1620	1623
1769	1764	1772	1769	**P40**	1604	1627	1618	1618
1759	1751	1763	1759	**P35**	1596	1618	1606	1610
1752	1745	1755	1757	**P30**	1588	1612	1599	1598
1742	1734	1746	1744	**P25**	1581	1598	1590	1589
1732	1726	1735	1732	**P20**	1552	1584	1579	1580
1718	1708	1721	1720	**P15**	1549	1579	1553	1561
1694	1687	1699	1713	**P10**	1536	1564	1543	1544
1672	1657	1673	1689	**P5**	1530	1539	1513	1530
1651	1637	1656	1675	**P3**	1522	1532	1506	1518
1632	1629	1640	1671	**P2**	1520	1526	1503	1513
1605	1586	1604	1659	**P1**	1512	1516	1503	1503

Distribution plots for each service and gender



Waist breadth - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
ANSUR, NZDFAS.

Definition:
The maximum horizontal breadth of the waist in a transverse plane at the level of Omphalion.

Landmark required:
None.

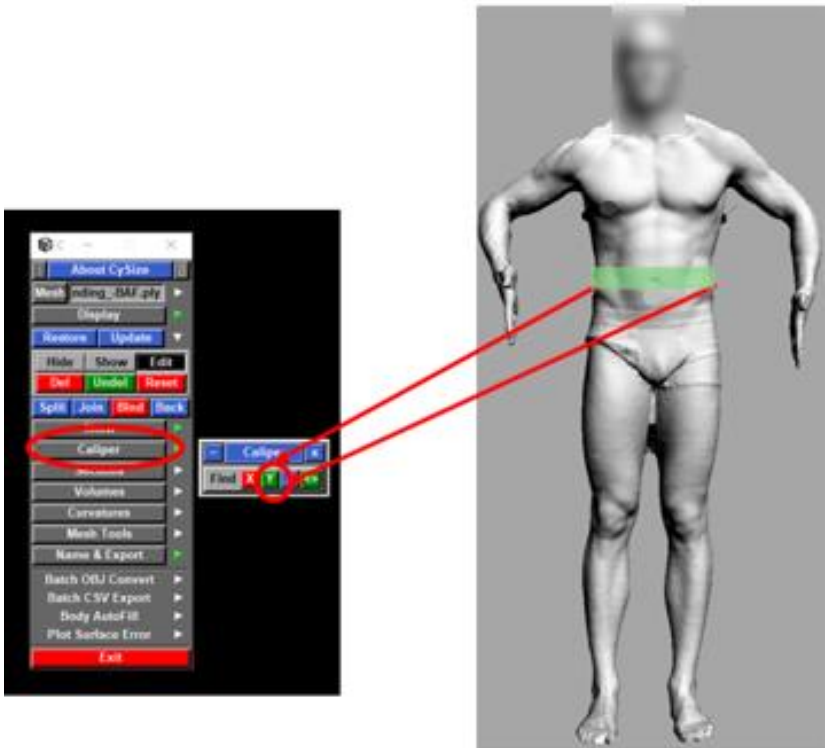
Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
Using the caliper tool highlight across the omphalion as close to the omphalion as possible. Best viewed from the front. Use the Y axis caliper (to create a 'digital' circumference) to identify and record the measurement. Beware of hand webbing. If present, skip both breadth markers. Use only if the Omphalion is visible. Omphalion is not a landmark in this posture as it is located visually. Measurements are reported in mm.

Reference:
Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B., Carson, J.M., Venezia, J.C., Rockwell, B.M., Mucher, M., Kristensen, S., 2014. 2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics., Natick Soldier Research, Development of Engineering Center, Yellow Springs, Ohio, U.S.

Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

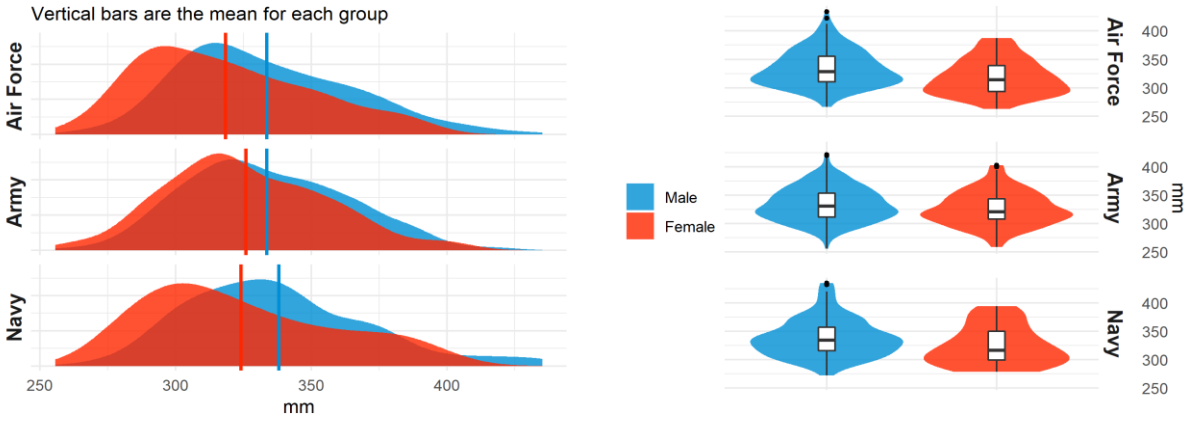
Notes:
None.



Waist breadth summary statistics - Post-processed measurement (mm)

Male					Female			
All	Air Force	Army	Navy		Air Force	Army	Navy	All
790	216	486	88	**N**	72	97	43	212
334	334	334	338	**Mean**	318	326	324	323
31	32	30	34	**SD**	31	30	34	31
256	266	256	272	**Min**	263	259	279	259
435	434	422	435	**Max**	387	403	394	403
414	413	405	432	**P99**	387	400	392	394
404	405	394	423	**P98**	386	395	390	389
394	401	391	416	**P97**	384	384	389	387
386	392	385	402	**P95**	378	375	388	380
376	378	373	380	**P90**	357	363	378	367
368	369	366	371	**P85**	354	359	366	357
361	361	361	369	**P80**	350	352	357	353
355	355	354	357	**P75**	339	344	350	344
350	348	350	348	**P70**	333	342	338	339
344	343	345	343	**P65**	328	339	330	332
340	338	340	342	**P60**	322	330	326	327
335	333	335	338	**P55**	316	324	323	322
331	328	331	334	**P50**	314	321	316	318
326	324	326	332	**P45**	311	319	311	315
322	320	323	324	**P40**	305	317	307	311
319	317	320	322	**P35**	299	311	301	308
316	313	316	318	**P30**	296	310	300	301
311	310	311	316	**P25**	293	308	300	299
307	306	307	308	**P20**	289	300	298	295
303	303	303	304	**P15**	287	297	288	291
297	298	297	300	**P10**	285	291	284	286
291	291	290	295	**P5**	280	285	281	281
285	288	284	291	**P3**	276	280	279	279
282	283	282	288	**P2**	273	271	279	272
273	274	274	283	**P1**	269	267	279	268

Distribution plots for each service and gender



Waist circumference preferred - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
AWAS.

Definition:
The horizontal circumference of the torso at the height of the Waist Preferred Posterior landmark.

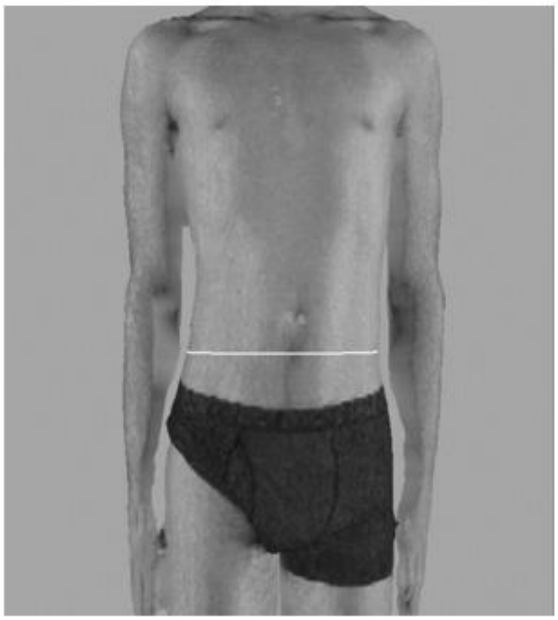
Landmark required:
Waist circumference posterior preferred.

Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Procedure:
Use CySize to create an X section loop (a 'digital' circumference) around the Waist Preferred Posterior landmark (preferred waist location for belts/trousers on posterior). Look for the stickered landmark (lower back) and skip if absent as there is no way to determine this feature. Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

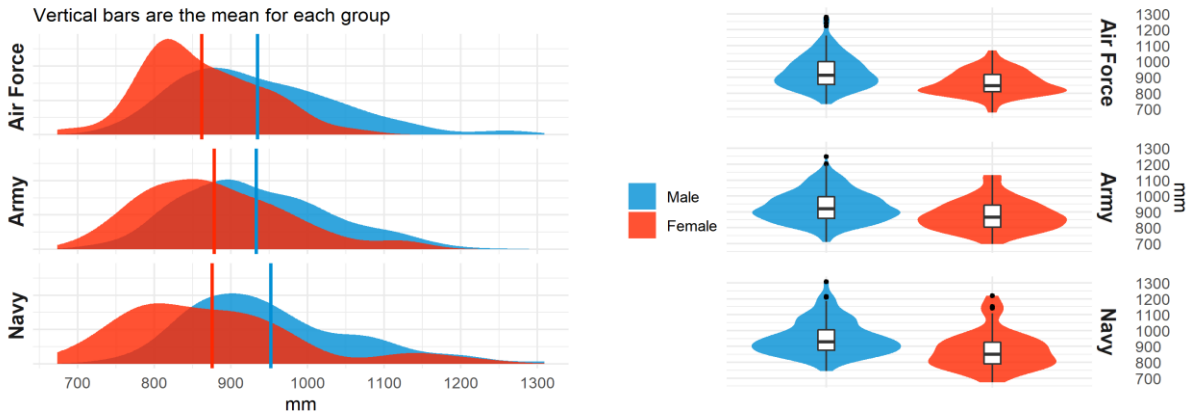
Notes:
Use the Crosshair tool to align the participant in the correct X, Y, and Z plane. This measurement will be repeated if the participant is not standing vertical, due to postural sway.



Waist circumference preferred summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
935	935	933	952	**Mean**	862	878	875	872
102	106	98	109	**SD**	76	95	120	95
709	732	709	746	**Min**	677	696	673	673
1309	1280	1248	1309	**Max**	1070	1133	1219	1219
1211	1262	1169	1227	**P99**	1045	1131	1191	1140
1164	1205	1149	1211	**P98**	1021	1123	1162	1129
1144	1150	1127	1195	**P97**	1002	1109	1149	1108
1121	1131	1113	1160	**P95**	987	1039	1138	1033
1077	1076	1072	1095	**P90**	965	1002	992	985
1044	1044	1040	1071	**P85**	949	969	970	965
1019	1025	1015	1049	**P80**	927	953	956	947
998	998	996	1004	**P75**	917	942	927	928
982	985	980	985	**P70**	892	923	921	912
966	963	967	972	**P65**	886	904	905	897
951	949	951	954	**P60**	877	892	894	885
934	933	933	940	**P55**	855	873	881	873
920	912	919	928	**P50**	846	867	850	855
908	906	908	922	**P45**	833	855	843	847
897	892	897	912	**P40**	828	849	826	834
887	882	888	895	**P35**	822	835	811	823
874	868	874	880	**P30**	815	817	795	814
860	856	860	875	**P25**	808	804	790	804
847	842	846	863	**P20**	803	794	777	793
834	830	831	846	**P15**	793	787	766	785
816	816	813	841	**P10**	786	770	759	771
794	800	792	819	**P5**	768	745	720	747
775	773	773	803	**P3**	752	732	717	725
767	768	765	789	**P2**	725	730	710	716
747	762	741	780	**P1**	698	721	691	698

Distribution plots for each service and gender



Waist depth standing - Post-processed measurement (mm)

Measuring instrument:
CySize

Source:
NZDFAS.

Definition:
The maximum depth of the waist area located between the iliocristale and tenth rib. Measurement taken at the point of ‘end-tidal’ expiration.

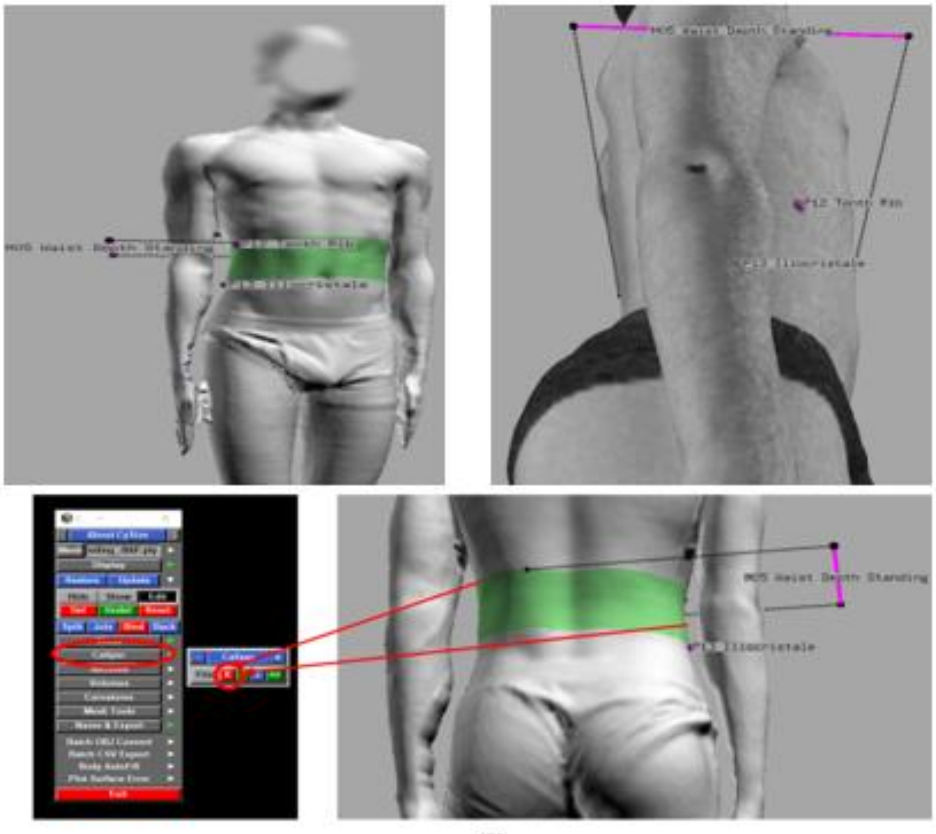
Landmark required:
None.

Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Procedure:
Use the CySize caliper tool to highlight waist area between iliocristale and the tenth rib. Select the X function (to create a coronal plan) to record the depth measure. Measurements are reported in mm.

Reference:
Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

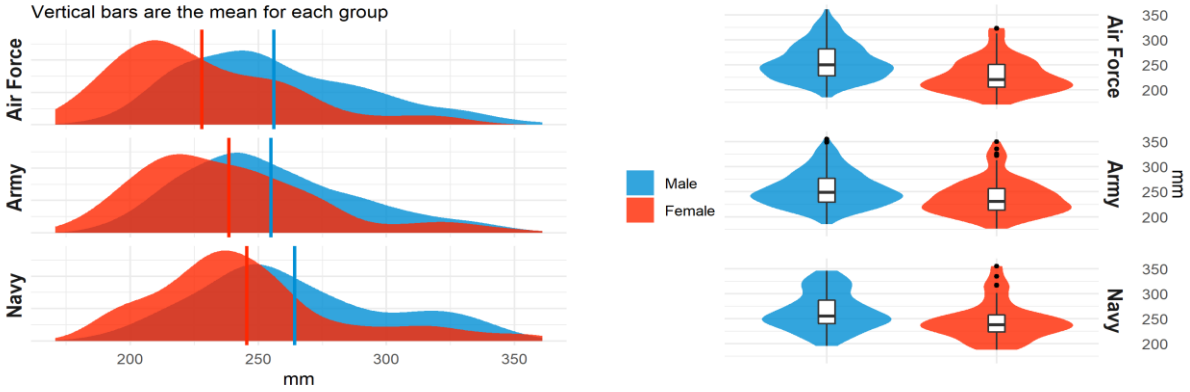
Notes:
If the tenth rib and/or iliocristale landmark is missing, the measure can be determined by identifying the distance between the Omphalion and Omphalion projected to the back.



Waist depth standing summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
256	256	255	264	**Mean**	228	239	246	236
35	36	34	37	**SD**	34	35	38	36
184	184	185	195	**Min**	171	176	188	171
361	361	356	346	**Max**	323	350	355	355
345	345	342	344	**P99**	323	337	346	336
336	332	335	338	**P98**	318	327	338	326
331	330	331	334	**P97**	311	324	330	323
326	326	320	330	**P95**	294	315	317	315
307	304	305	321	**P90**	265	278	299	278
294	295	291	313	**P85**	261	272	277	268
286	285	285	301	**P80**	258	265	261	261
278	282	277	287	**P75**	251	256	258	255
272	273	269	279	**P70**	241	250	254	250
265	264	264	273	**P65**	236	247	251	246
260	260	259	266	**P60**	230	242	247	240
255	253	254	261	**P55**	222	240	239	236
250	250	249	256	**P50**	221	230	238	230
247	247	245	252	**P45**	217	227	236	226
242	242	242	247	**P40**	211	225	235	222
239	238	239	247	**P35**	210	219	232	219
236	235	234	243	**P30**	207	215	226	214
230	228	229	240	**P25**	205	214	224	210
225	223	225	237	**P20**	201	211	218	206
221	220	221	227	**P15**	196	206	211	201
214	216	214	220	**P10**	191	198	201	196
209	209	208	212	**P5**	188	196	196	190
203	205	202	207	**P3**	184	189	194	188
200	201	198	203	**P2**	179	187	192	185
195	196	194	199	**P1**	175	184	190	177

Distribution plots for each service and gender



Waist girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Human Solutions.

Definition:
The circumference of the waist is measured at the height of the natural waist (maximum identation when viewed from the front). The circumference is measured parallel to the standing surface.

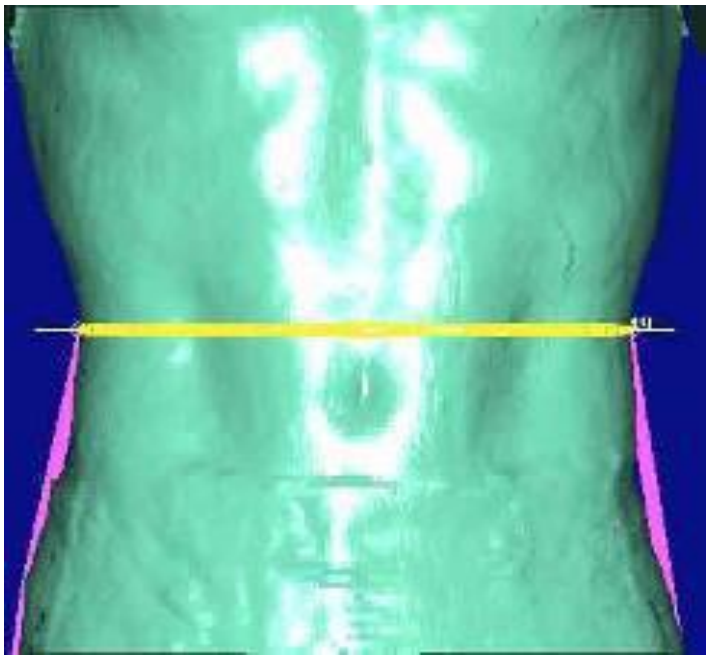
Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

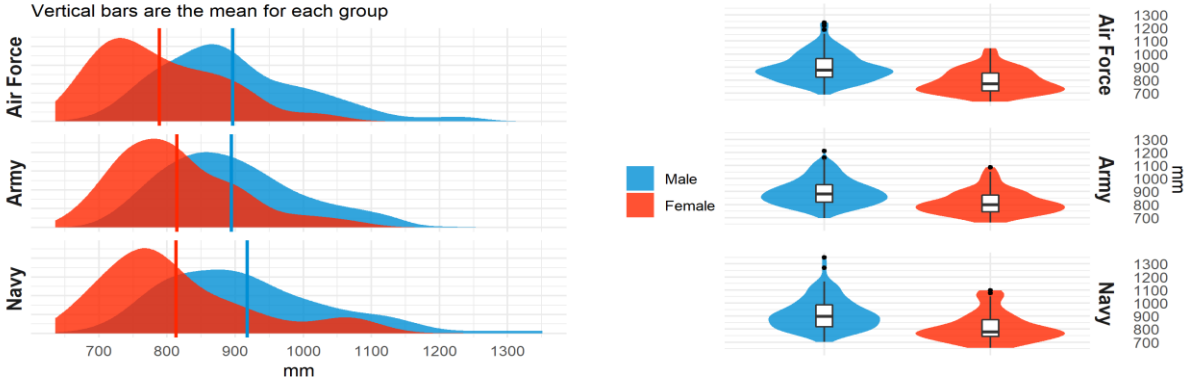
Notes:
Visually check that the digital tape (yellow line below) is horizontal. If there is no natural indentation (most narrow point of the waist) then consider A) removing this measurement or B) drag the yellow line so that it is positioned above the iliocristale and below the 10th rib (or bottom of the rib cage if it is visable).



Waist girth summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
898	897	895	917	**Mean**	789	815	813	806
105	108	100	122	**SD**	91	90	110	95
689	689	696	701	**Min**	636	662	656	636
1351	1241	1210	1351	**Max**	1044	1086	1096	1096
1168	1233	1134	1281	**P99**	1021	1054	1088	1073
1134	1176	1123	1193	**P98**	1006	1048	1079	1050
1122	1134	1111	1150	**P97**	990	1013	1069	1046
1093	1092	1086	1127	**P95**	932	1002	1050	1003
1046	1042	1042	1092	**P90**	910	921	973	927
1013	1012	1004	1035	**P85**	888	908	917	904
982	980	977	1015	**P80**	871	885	889	882
959	966	953	986	**P75**	854	872	872	869
940	931	938	960	**P70**	837	843	829	839
921	911	921	936	**P65**	816	825	818	823
907	902	907	916	**P60**	799	820	803	814
896	890	896	908	**P55**	786	812	794	799
884	876	882	898	**P50**	772	799	778	792
870	870	869	889	**P45**	757	793	776	777
858	858	855	869	**P40**	744	778	768	767
846	846	844	852	**P35**	738	768	758	757
836	836	835	839	**P30**	731	760	752	744
820	822	820	819	**P25**	719	745	744	738
805	804	805	810	**P20**	708	738	730	727
790	787	792	796	**P15**	699	733	712	710
775	771	775	786	**P10**	690	715	701	701
754	751	752	770	**P5**	671	702	685	682
742	742	742	763	**P3**	661	680	676	672
729	736	729	761	**P2**	661	675	670	662
718	713	721	747	**P1**	654	671	663	661

Distribution plots for each service and gender



Waist height preferred - Post-processed measurement (mm)

Measuring instrument:
CySize.

Source:
AWAS.

Definition:
The vertical distance between the standing surface and the digitally extracted Waist Preferred, Anterior landmark.

Landmark required:
Waist height preferred anterior landmark.

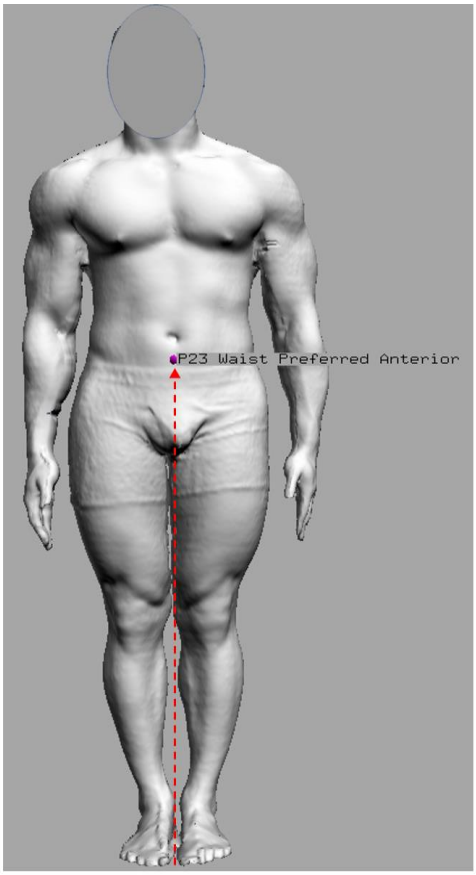
Posture required:
Scan position posture 1. Kolose, S., Hume, P.A., Tomkinson, G.R., Stewart, A., Stewart, T., Legg, S.J. (2021). Three-dimensional physique assessment in the military: New Zealand Defence Force Anthropometry Survey protocols and summary statistics., SPRINZ: Auckland, New Zealand.

Procedure:
As measured in AWAS Section 7.1.19 of the Procedures Manual (Tomkinson et al., 2012). Measurements are reported in mm.

Reference:
Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012a). Australian Warfighter Anthropometry Survey (AWAS): Landmarking and measurement manual. Adelaide, Australia: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

Tomkinson, G. R., Daniell, N., Dale, M., & Bowler, T. (2012b). Australian Warfighters Anthropometry Survey (AWAS). Procedures Manual. Adelaide, Australia.: Health and Use of Time Group, Sansom Institute for Health Research, University of South Australia.

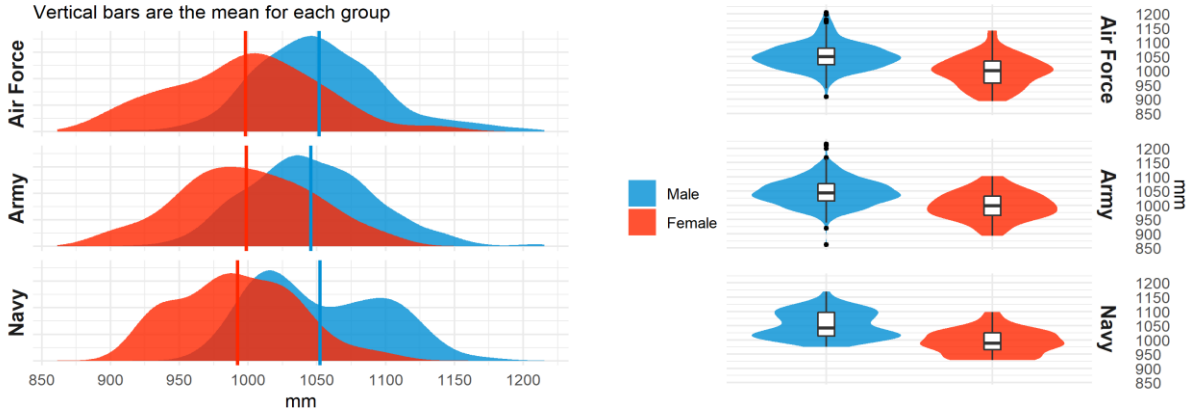
Notes:
None.



Waist height preferred summary statistics - Post-processed measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
1048	1052	1046	1052	**Mean**	998	999	992	997
47	47	47	46	**SD**	54	48	42	49
861	909	861	975	**Min**	893	892	929	892
1215	1204	1215	1170	**Max**	1141	1103	1098	1141
1170	1178	1155	1143	**P99**	1133	1101	1089	1103
1152	1167	1144	1135	**P98**	1113	1099	1081	1098
1141	1158	1138	1133	**P97**	1089	1089	1072	1089
1129	1139	1124	1126	**P95**	1078	1077	1056	1077
1109	1108	1106	1112	**P90**	1061	1060	1037	1058
1096	1094	1091	1107	**P85**	1052	1051	1032	1050
1086	1086	1082	1101	**P80**	1040	1041	1029	1037
1079	1080	1076	1097	**P75**	1034	1032	1024	1030
1072	1073	1068	1081	**P70**	1025	1027	1019	1024
1063	1063	1062	1075	**P65**	1017	1019	1012	1016
1058	1058	1057	1067	**P60**	1009	1010	1000	1008
1051	1053	1049	1056	**P55**	1007	1002	996	1002
1045	1049	1043	1042	**P50**	1000	999	988	997
1038	1043	1037	1034	**P45**	994	992	983	991
1034	1037	1033	1029	**P40**	992	983	983	984
1029	1033	1026	1021	**P35**	983	976	978	979
1021	1027	1020	1018	**P30**	971	972	972	972
1015	1021	1015	1013	**P25**	957	965	965	964
1008	1013	1005	1006	**P20**	949	961	947	953
1001	1007	997	1005	**P15**	940	952	938	942
991	998	987	1001	**P10**	920	938	934	932
978	988	976	990	**P5**	912	918	930	918
972	972	968	985	**P3**	906	905	930	907
963	964	959	982	**P2**	899	901	930	902
954	956	951	976	**P1**	894	898	930	895

Distribution plots for each service and gender



Weight body mass - Automatic measurement (kg)

Measuring instrument:
Anthroscan software.

Source:
Human Solutions.

Definition:
Body mass as assessed by standing weight in kilograms acquired using load cell integrated into the scanner platform.

Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

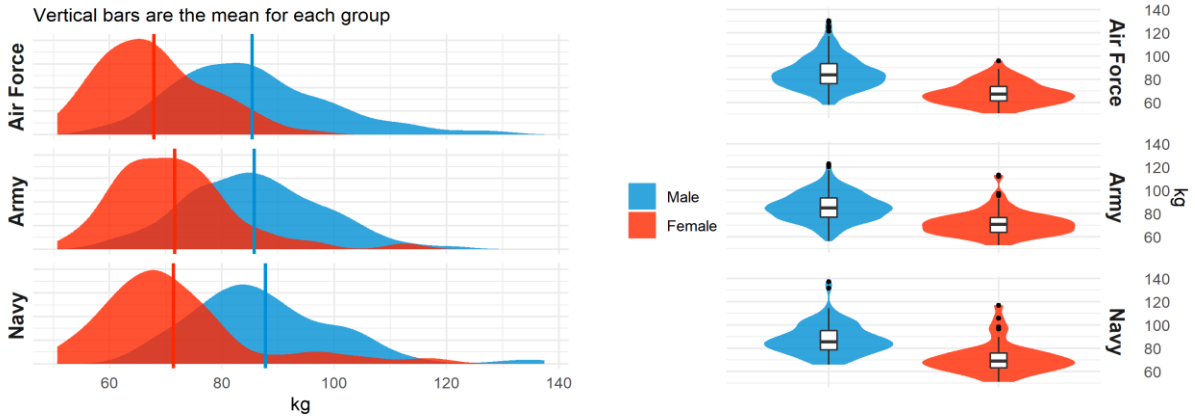
Notes:
From time to time the SECA scales underneath the platform can fail to record the weight value. Prior to scanning

- Ensure that the scale is plugged into the wall and the wall switch is activated.
- Prior to performing the calibration (at the start of each data collection day), weigh the orange calibration pole by placing it in the middle of the black platform. The SECA scale LCD unit should read 6.6 kg every time. Values above or below this may indicate a hardware or software issue thus manual laser realignment is required.
- If the 'weight.raw' file is not created by Anthroscan (see participants scan folder) after a scan, try the following remedies (in no order)
    - Remove and re-plug all connections which include the following:
        - Power cable entry into the black scale platform.
        - Network cable port in the black scale platform.
        - Serial port cable from the serial port of the PC and the serial adapter (black square box that resides underneath the platform).
    - Press and hold the 'TARE' button for 3 seconds then release.
    - Re-start the body scanner power unit and scanner PC.
    - If weight recording errors persist, record the weight from the SECA scale LCD. These can be entered manually into Anthroscan later. **It is important to constantly check the participant folder after each scan to make sure the weights.raw file is created.**

Weight body mass summary statistics - Automatic measurement (kg)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
86	85	86	88	**Mean**	68	72	71	70
13	14	12	13	**SD**	10	11	14	11
56	58	56	66	**Min**	51	53	51	51
137	130	123	137	**Max**	96	113	117	117
121	125	115	133	**P99**	91	112	112	111
114	120	112	119	**P98**	88	99	108	98
112	114	109	112	**P97**	87	96	104	96
108	112	106	107	**P95**	85	90	98	89
102	103	102	104	**P90**	82	85	88	83
99	99	99	102	**P85**	78	80	79	80
96	97	96	99	**P80**	77	78	77	77
94	93	93	95	**P75**	74	77	76	76
91	90	91	92	**P70**	72	76	74	74
90	88	90	91	**P65**	70	74	72	73
88	87	88	88	**P60**	69	73	71	71
86	85	87	87	**P55**	68	71	69	70
85	84	85	85	**P50**	67	71	69	69
83	82	84	85	**P45**	65	69	68	68
82	81	82	83	**P40**	65	68	68	66
80	79	81	82	**P35**	63	66	65	65
78	77	79	80	**P30**	62	65	64	64
76	76	77	79	**P25**	61	64	63	63
75	74	75	78	**P20**	59	63	62	62
73	71	73	76	**P15**	58	62	60	60
71	70	71	72	**P10**	57	60	59	58
67	67	66	69	**P5**	55	58	55	56
64	64	64	69	**P3**	53	56	53	54
62	61	62	68	**P2**	52	54	53	53
60	60	60	67	**P1**	51	54	52	51

Distribution plots for each service and gender



Wrist girth - Automatic measurement (mm)

Measuring instrument:
Anthroscan software.

Source:
Human Solutions.

Definition:
Circumference of wrist at the level of the styloid processes of the radius and ulna, with the hand outstretched, and straight with fingers closed.

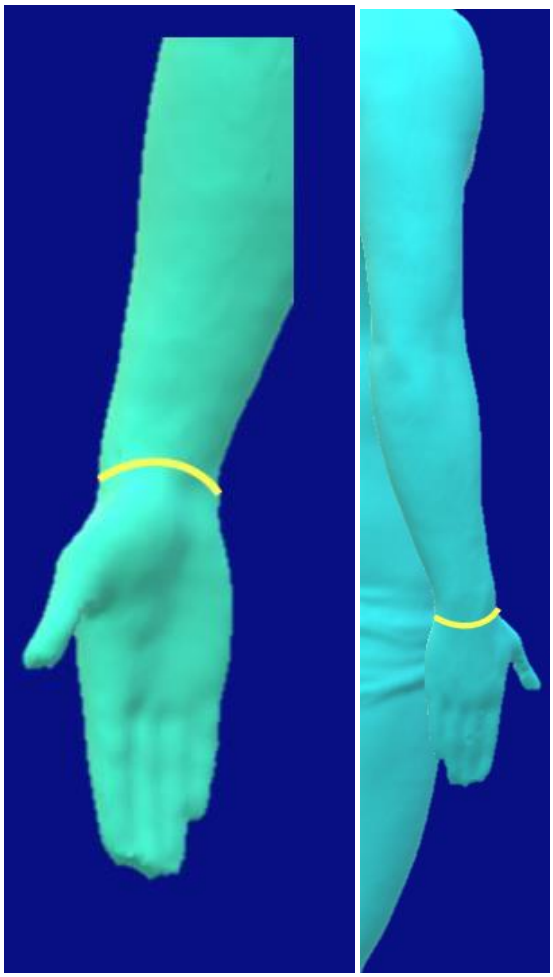
Landmark required:
None.

Posture required:
Scan position posture 2. Stand with feet shoulder width apart, trunk and head are erect with eyes looking forward. The upper arms are abducted away from the body with the forearms handing vertically. All fingers are together and extended with the palm facing (medially) the thigh and the thumb facing forward.

Procedure:
See Section 6 of Human Solutions (2015). Measurements are reported in mm.

Reference:
Human Solutions, 2015. Anthroscan user guide version 3. Human Solutions GmbH, Kaiserslautern, Germany.

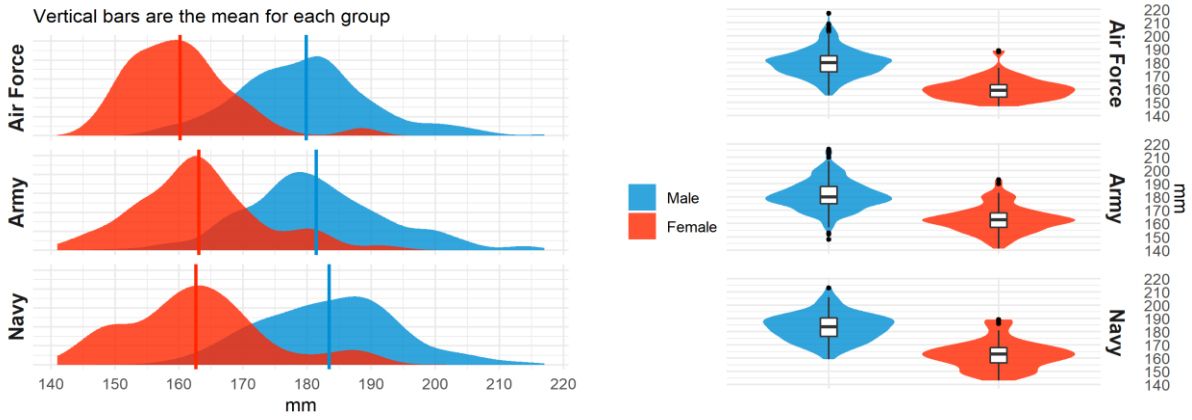
Notes:
Ensure the yellow line is perpendicular to the long axis of the forearm.



Wrist girth summary statistics - Automatic measurement (mm)

Male					Female			
All	**Air Force**	**Army**	**Navy**		**Air Force**	**Army**	**Navy**	**All**
790	216	486	88	**N**	72	97	43	212
181	180	181	183	**Mean**	160	163	163	162
11	10	11	10	**SD**	8	10	11	10
148	155	148	159	**Min**	147	141	143	141
217	217	216	213	**Max**	189	193	189	193
213	206	213	207	**P99**	188	190	189	189
205	205	205	205	**P98**	183	184	188	188
204	203	204	204	**P97**	176	183	187	185
201	200	201	201	**P95**	172	181	186	181
195	193	197	195	**P90**	170	178	175	173
192	189	193	194	**P85**	167	172	170	170
190	187	190	191	**P80**	166	170	170	169
188	185	188	190	**P75**	163	168	168	167
186	184	186	189	**P70**	163	166	166	165
184	183	184	188	**P65**	163	165	165	164
183	182	183	187	**P60**	161	164	164	163
182	181	182	186	**P55**	160	163	164	163
180	180	180	184	**P50**	159	163	163	161
179	179	179	182	**P45**	158	162	161	161
178	177	178	181	**P40**	158	161	160	159
177	176	177	179	**P35**	156	160	159	158
176	175	176	178	**P30**	156	159	158	157
174	173	175	176	**P25**	154	157	156	156
172	171	173	173	**P20**	153	155	153	154
170	170	170	172	**P15**	152	153	150	153
168	167	168	170	**P10**	152	152	148	151
165	164	165	167	**P5**	150	148	147	148
162	161	162	165	**P3**	149	146	147	147
159	159	159	165	**P2**	148	146	146	146
158	158	157	163	**P1**	147	144	145	144

Distribution plots for each service and gender



Appendix A Combined variables list

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Abdomen/buttock depth		D				
Abdominal extension depth, sitting		D	P	P		P
Abdominal link			Ded			
Acromial height		D	P		P	
Acromial height left or right						
Acromial height standing left or right	D L/R					
Acromial height, sitting	P					
Acromial height, sitting left or right	D L/R		Ded	P	P	P
Acromial to elbow length		Ded				
Acromial to wrist length left or right		D L/R				
Acromion height				P		P
Acromion-axilla length			Ded			
Acromion-radiale length			P	D	D	D
Acromion-radiale length left or right	D L/R					
Acromion-wall depth					P	
Across back breadth (across base of scyes)		D				
Across back width						
Across front width						
Ankle bone height (inside) or left (uk)		D				
Ankle bone height (outside) or right (uk)		D				
Ankle breadth					D	
Ankle circumference	P	D	P	D	D	D
Ankle circumference at ankle bones		D				
Ankle circumference height		D				
Ankle circumference left			P			
Ankle depth						
Ankle height				D	D	D
Arm inseam left or right	D L/R					
Arm inseam right	D					
Arm length			Ded		P	
Arm length (shoulder elbow)	P					
Arm length (shoulder wrist)	P					
Arm length (spine wrist)	P					
Arm span						

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Armscye circumference (scye circumference over acromion)	P					
Axilla height			P			
Axilla height		D				
Axilla height left	D					
Axilla height right	D					
Axilla height right						
Axillary arm circumference					P	
Axilla-waist length (omphalion)			Ded			
Back length				D		D
Back waist length (cervicale to waist following contour over shoulder blade)		D				
Back width				D		D
Ball of foot circumference			P			
Ball of foot length			P	D		D
Biacromial breadth digital	D	D		D		D
Biacromial breadth physical			P	P	P	
Biceps breadth, flexed						
Biceps circumference flexed			P	P		P
Biceps depth						
Bicristal breadth	D		P	P		P
Bideltoid breadth		D	P	P	P	P
Bigonial breadth	D					
Bi-lateral femoral epicondyle breadth sitting	D					
Bi-lateral humeral epicondyle breadth sitting	D					
Bimalleolar breadth			P			
Bispinous (iliac spine) breadth	D					
Bitragion						
Bitragion breadth	D				D	
Bitragion chin arc			P			
Bitragion coronal arc					P	
Bitragion frontal arc						
Bitragion submandibular arc			P	D		D
Bitragion subnasale arc						
Bi-trochanteric breadth sitting	D					
Bi-trochanteric breadth standing	D					
Bizygomatic breadth	P		P	P	P	P
Body depth						
Body mass index					P(der)	
Breast/bust prominence		D				

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Bust level				D		D
Bust/chest circumference	P					
Bust/chest circumference under bust	P					
Bust point breadth		D				
Bustpoint bustpoint breadth	D				D	
Buttock circumference		D	P	P	P	P
Buttock depth			P		D	
Buttock height*		D	P		D	
Buttock to trochanter length	D					
Buttock-knee length	P	D	P	P	P	P
Buttock-popliteal length		D	P	P	P	P
Calf breadth						
Calf circumference		D	P	D	D	D
Calf depth						
Calf height		D			D	
Calf link			Ded			
Cervicale height	D	D	P	P	D	P
Cervicale height, sitting			Ded			
Cervicale to breast point		D				
Cervicale to waist		D				
Cervicale wrist length					P	
Chest breadth			P	P	P	P
Chest bust height (at nipple) height		D				
Chest circumference			P	P	P	P
Chest circumference at axilla		D				
Chest circumference at scye						
Chest circumference below breast				P		P
Chest depth		D	P	P	D	P
Chest girth (chest circumference at scye)	P					
Chest height	D	D	P		D	
Chest height, sitting			Ded			
Chest level				D		D
Chest/bust circumference at nipple						
Chest-waist drop (omphallion)			Ded			
Chin height		D				
Clavicle link			Ded			
Crotch height	P	D	P	P	P	P
Crotch length		D				
Crotch length anterior (omphallion)			Ded			
Crotch length omphallion			P	D		D

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Crotch length posterior omphallion			P			
Dactyllion height			Ded			
Dactyllion reach from wall			Ded			
Deltoid point height						
Ear breadth			P			
Ear length			P			P
Ear length above tragion						
Ear protrusion			P			
Ecto-orbitale to top of head						
Elbow breadth						
Elbow circumference		D			D	
Elbow depth						
Elbow fully bent, circumference		P				
Elbow functional reach		P				
Elbow girth					P	
Elbow height sitting (comfortable) left or right	D L/R					
Elbow height sitting right	P					
Elbow height standing left or right	D L/R					
Elbow rest height				P		
Elbow rest height, sitting		P	P		P	P
Elbow rest height, standing		Ded	Ded			
Elbow to elbow breadth						
Elbow-centre of grip length						
Elbow-wrist length			Ded			
Eye height			Ded			
Eye height, sitting	P	D	P	P	P	P
Eye height, standing		Ded			P	
Face length	P					
Femoral epicondyle lateral left (or right) to malleolus lateral left (or right)	D L/R					
Foot breadth					P	
Foot breadth horizontal			P	P		P
Foot breadth left	D L/R					
Foot breadth right	D					
Foot length	P		P	D	P	D
Forarm-center of grip length			P			
Forearm circumference		D				
Forearm circumference flexed			P	P		P
Forearm circumference right						
Forearm depth						
Forearm fingertip length						

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Forearm-forearm breadth			P	P		P
Forearm-hand length			P			
Functional grip reach			Ded			
Functional leg length			P			
Functional reach - seated		D				
Gluteal furrow height						
Hand breadth	P	P	P	D	P	D
Hand circumference	P	P	P	D	P	D
Hand depth						P
Hand length	P	P	P	D	P	
Hand thickness at metacarpale iii						
Head breadth	P	P	P	D	P	D
Head breadth sitting						
Head circumference (physical)	P	P	P	P		P
Head circumference (scanned)		D				
Head length	P	P	P	D	D	P
Heel ankle circumference			P			
Heel breadth			P			
Heel instep circumference						
Heel instep circumference		D				
Heel instep circumference right						
Height sitting						
Helmet rim to top of head						
High hip				D		D
Hip				D		D
Hip breadth			P		P	
Hip breadth standing		D				
Hip breadth, sitting	P	D	P	P	P	P
Hip circumference (maximum height)	P					
Hip circumference (maximum)	P					
Hip height						
Hip level female				D		D
Hip level male				D		D
Illiocristale height			P	P	D	P
Index finger breadth, distal						P
Index finger breadth, proximal						
Index finger length					P	
Index finger reach			Ded			
Infraorbital height sitting left	D					

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Infraorbital height sitting right	D					
Infraorbital height standing left	D					
Infraorbital height standing right	D					
Inter-elbow span		P				
Interpupillary breadth		P	P	P	P	P
Interpupillary distance	D					
Interscye distance	D					
Interscye i			P		D	
Interscye ii			P			
Knee breadth						
Knee circumference		D		D	D	D
Knee circumference right						
Knee fully bent circumference		P				
Knee height		D				
Knee height midpatella			P		D	
Knee height right						
Knee height sitting	P	D	P	P	P	P
Knee height standing left	D					
Knee height standing right	D					
Knee level				D		D
Lateral femoral epicondyle height			P		D	
Lateral malleolus height			P		D	
Leg length (outside)						
Lower leg length						
Lower thigh circumference			P			
Malleolus height lateral left	D					
Malleolus height lateral right	D					
Malleolus height medial left	D					
Malleolus height medial right	D					
Maximum hip circumference				D		D
Menton to top of head						
Menton-sellion height			P	D	P	
Menton-sellion length						D
Mid thigh breadth						
Mid thigh circumference						
Mid thigh circumference		D				
Mid thigh circumference right						
Mid thigh depth						
Mid thigh height		D				

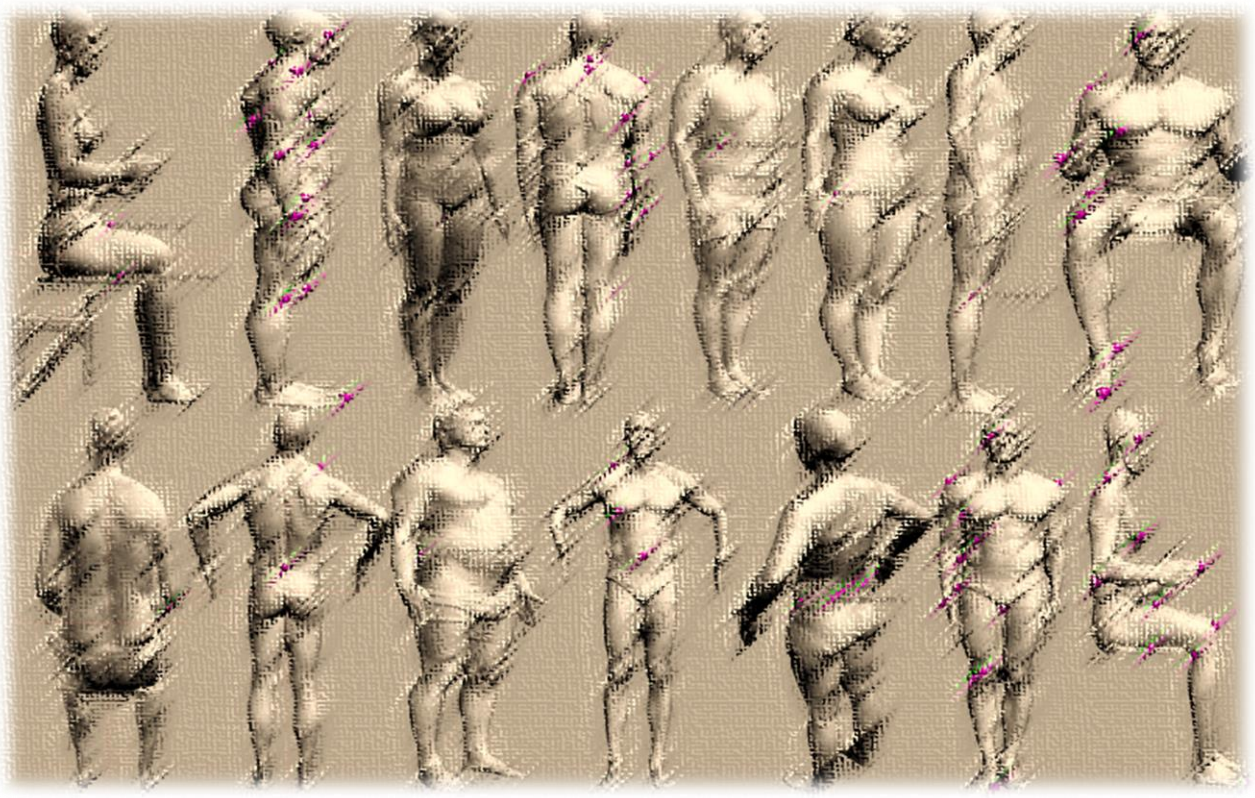
MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Mid thigh height right						
Midshoulder height, sitting		D				
Mouth width						
Nape to bustpoint thelion length				D	D	D
Nape to waist centre back				D		D
Nape to waist over bust				D		D
Neck base circumference	P				D	
Neck base height, front		D				
Neck breadth						
Neck circumference		D	P	D	D	D
Neck circumference base			P	P		P
Neck depth						
Neck height	D					
Neck height, font						
Neck height, right						
Neck height, side		D				
Neck link			Ded			
Neck-buttock length			Ded			
Neck-gluteal furrow						
Neck-scye length			Ded			
Outside leg length				D	P	D
Outside leg length		D				
Outside leg length right						
Overhead fingertip reach						P
Overhead fingertip reach, sitting			P			
Palm length			P			
Pelvic link			Ded			
Popliteal height		D	P	P	P	P
Pupil to vertex		Ded				
Radiale-styllion length			P	D	D	D
Radiale-styllion length left	D					
Radiale-styllion length right	D					
Rise (omphallion)			Ded			
Sagittal arc					P	
Scye circumference					P	
Scye depth				D		D
Seat angle				D		D
Seat level				D		D
Sellion supramenton length	D					
Sellion-back of head						
Sellion-top of head						
Shoulder breadth (bideltoid)	P					
Shoulder circumference			P			
Shoulder drop		D				
Shoulder drop right						

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Shoulder height (90cm from mid-line)		Ded				
Shoulder height sitting						
Shoulder height standing						
Shoulder length			P	P	D	P
Shoulder slope (degree)						
Shoulder waist length (natural indentation)						
Shoulder-elbow length			P			
Shoulder-waist length (omph)			Ded			
Side back waist to ground left		D				
Side back wait to ground right						
Side waist to hip		D				
Side waist to hip right						
Sitting height	P	D	P	P	P	P
Sleeve inseam			Ded			
Sleeve length spine-elbow						
Sleeve length spine-scye						
Sleeve length spine-wrist			P			
Sleeve outseam			P	D	D	D
Sleeve outseam left	D					
Sleeve outseam right	D					
Span			P		P	
Sphyrion height, left or right	D L/R					
Spine to elbow (bent)		P				
Spine to scye (half back)		P				
Spine to wrist		P				
Stature	P	P	P	P	P/D	P
Stomach depth (to individuals back) - abdominal extension depth - seated		D				
Stomach depth (to wall)		D				
Stool height		D				
Strap length					D	
Subscapular skinfold	P					
Substernale height				P		
Suprasternale height	D		P	P	D	P
Suprasternale height, sitting			Ded			
Suprasternale tenth rib length			Ded			
Suprasternale waist (omph) length			Ded			
T2 height				P		
Tenth rib height			P	P	D	

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Thelion-thelion breadth						
Thigh breadth						
Thigh circumference			P	D	D	D
Thigh circumference (max gluteal fold level)		D				
Thigh circumference maximum	P					
Thigh clearance			P	P	P	P
Thigh clearance height		D				
Thigh depth, crotch						
Thigh height		D				
Thigh link			Ded			
Thorax depth at nipple						
Thorax link			Ded			
Thumb breadth						
Thumbtip reach	P		P	P	P	P
Thumbtip reach extended					P	
Tibial height			P			
Torso length						D
Total crotch length	P					
Tragion height			Ded			
Tragion height, sitting			Ded			
Tragion-top of head			P			
Triceps skinfold	P					
Trochanter height, left or right	D L/R				D	
Trochanter to femoral epicondyle lateral, left or right	D L/R					
Trochanter to seated surface, left or right	D L/R					
Trochanterion height			P	D		D
Underbust chest circumference height		D				
Underbust circumference		D				
Underbust circumference height		D				
Upper arm (biceps) circumference		D				
Upper arm circumference right						
Vertical functional reach sitting		P				
Vertical functional reach standing		Ded				
Vertical grip reach			Ded			
Vertical grip reach down			Ded			
Vertical grip reach, sitting			Ded			

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Vertical index fingertip reach			Ded			
Vertical index fingertip reach sitting			Ded			
Vertical thumbtip reach, sitting			Ded			
Vertical thumb tip reachdown						
Vertical trunk circumference	P	D	P		P	
Vertical trunk circumference right						
Vertical trunk circumference, wide				D		D
Vertical wrist height						
Vertex-eye height						
Vertex-mid shoulder height						
Waist (natural) circumference		D				
Waist back length (cervicale to waist)	D					
Waist back length (natural indentation)					D	
Waist back length omphallion			P		D	
Waist back vertical omphallion			Ded			
Waist breadth			P			
Waist circumference omphallion			P	P	P/D	P
Waist circumference preferred	P			D		D
Waist depth			P		D	
Waist front length	P					
Waist front length, (natural indentation)					D	
Waist front length, omphalion					D	
Waist front length, sitting			P			
Waist height (natural indentation)		D			D	
Waist height omphallion			P		D	
Waist height preferred	P					
Waist level centre back				D		D
Waist level centre front				D		D
Waist-buttock drop (omphallion)			Ded			
Waist-hip distance				D		D

MEASUREMENTS/ SURVEY	CAESAR 2002 (Civilian) [139]	UK 2007 (Tri service) [122]	ANSUR 2012 (Army) [16]	AWAS 2012 (Army) [140]	CFAS 2012 (Tri service) [41]	ASRAN 2015 (Navy) [110]
Waist-waist omphallion over shoulder			Ded			
Weight	P	P	P	P	P	P
Wrist breadth						
Wrist centre grip distance						P
Wrist centre thumb tip distance						P
Wrist circumference		D	P	D	D	D
Wrist depth					D	
Wrist height			P			
Wrist wall length					P	
Wrist-centre of grip						
Wrist-index finger length						
Wrist-thumb tip length						
Total measures	99	95	135	84	95	86



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