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

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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.

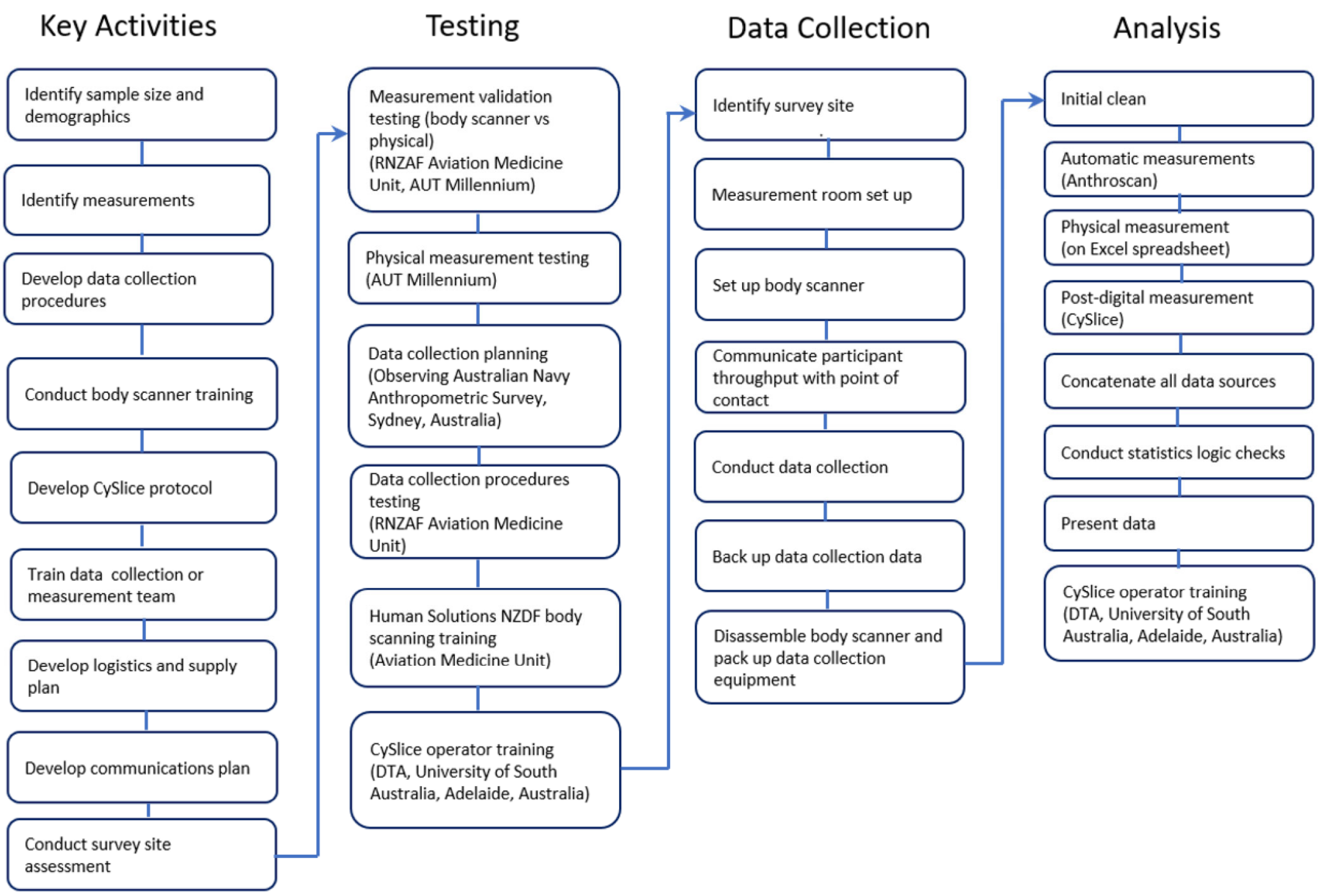


Figure 10. A summary of the key activities during each phase. Each activity is explained in more detail throughout this book. POC refers to 'Point of Contact'.

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 5th and 95th 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.

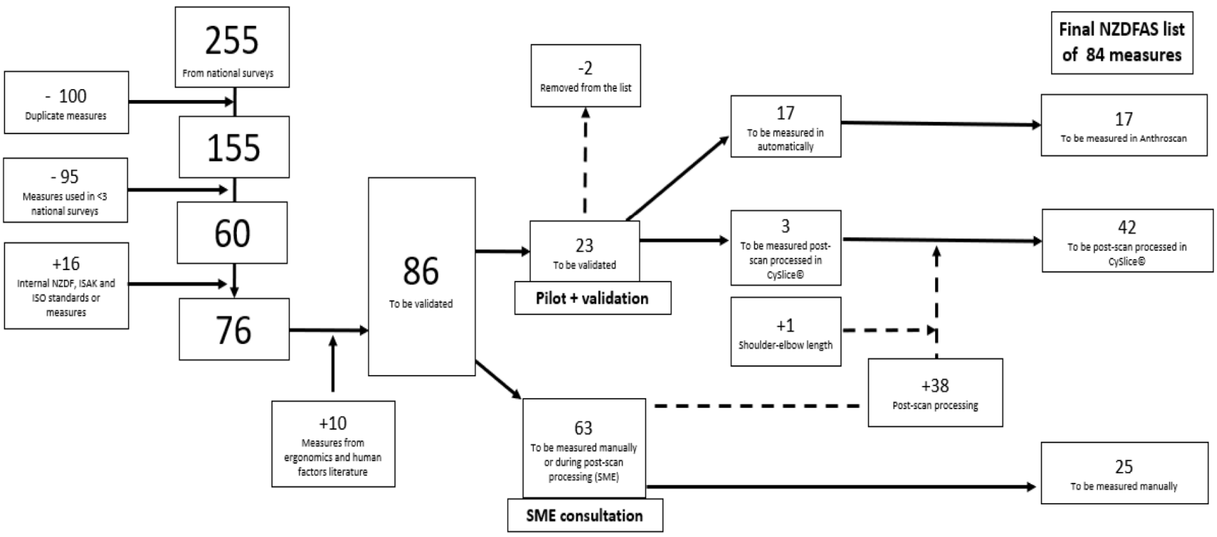


Figure 11. NZDFAS Measurement selection and testing process.

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.

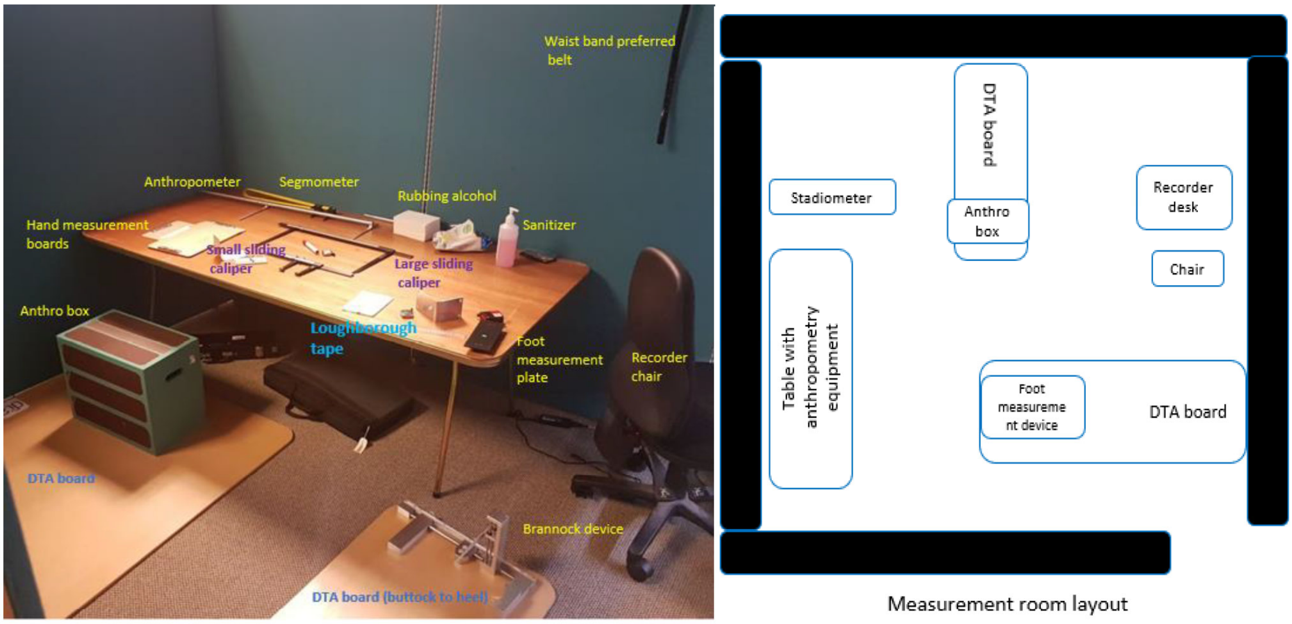


Figure 12. Measurement room equipment layout.

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.

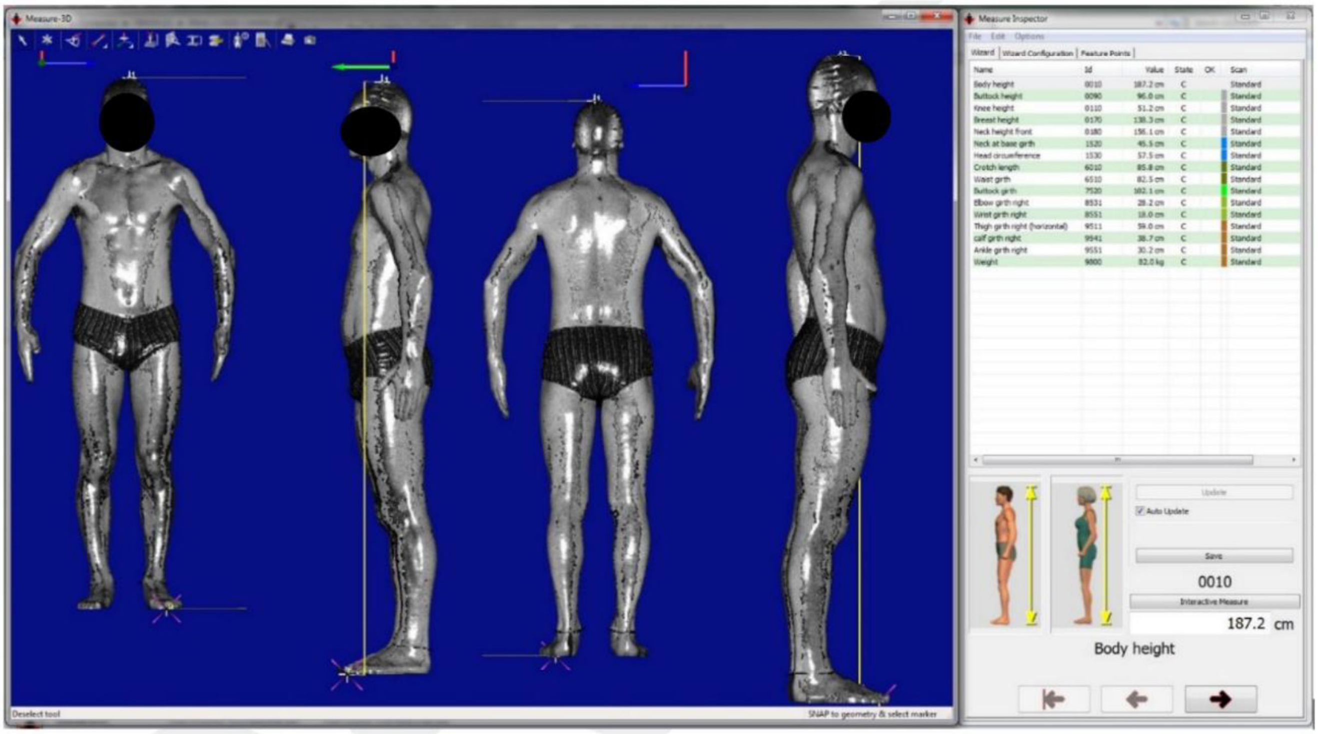


Figure 13. Anthroscan automatic measurement software.

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.

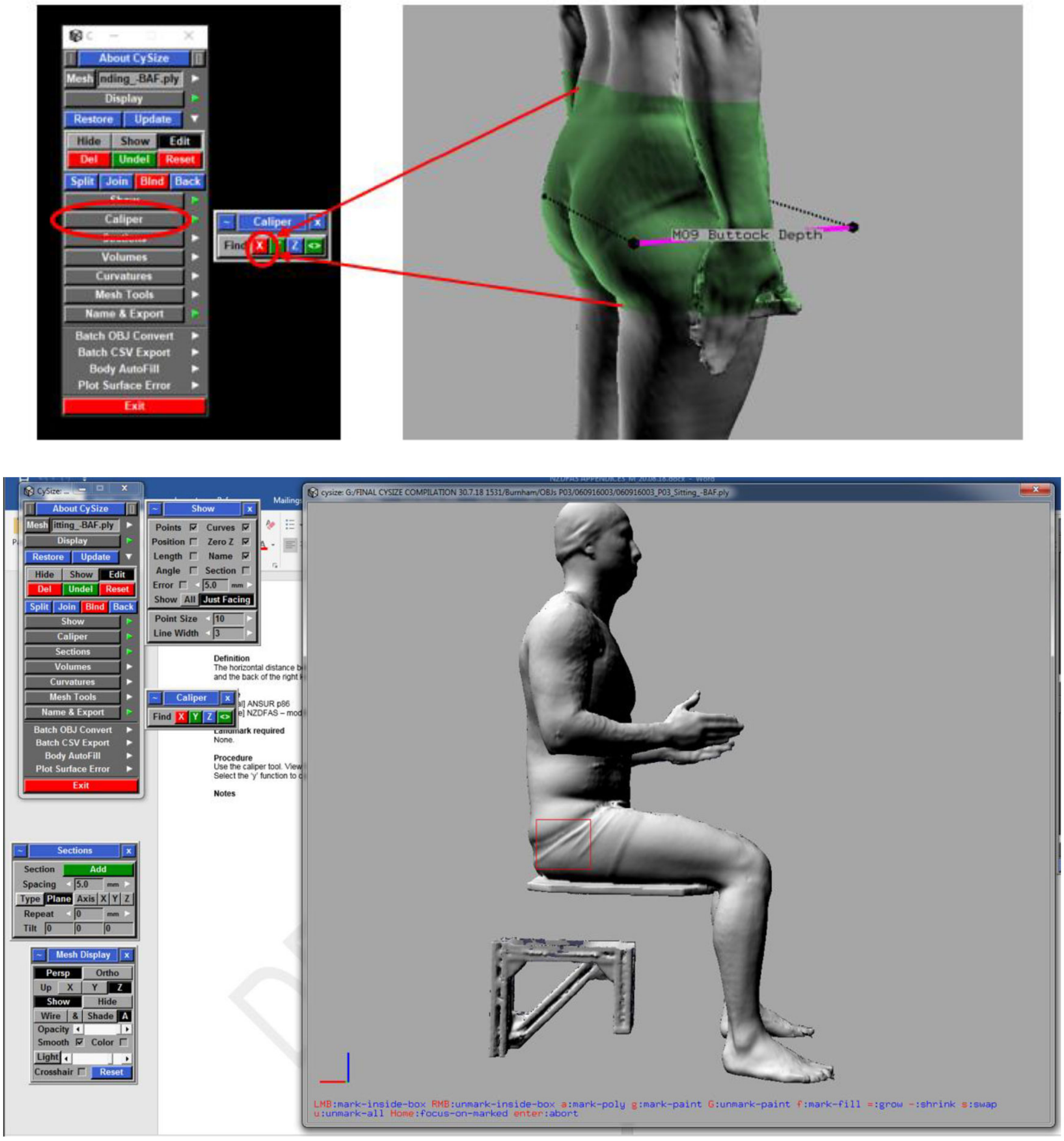


Figure 14. CySize (Headus Ltd) measurement software. [Top] The user can select any region of the body (green) then use the various CySize tools to determine the maximum depth within the region (using the 'x' caliper function). [Bottom] CySize contains various landmark, measurement extraction tools and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

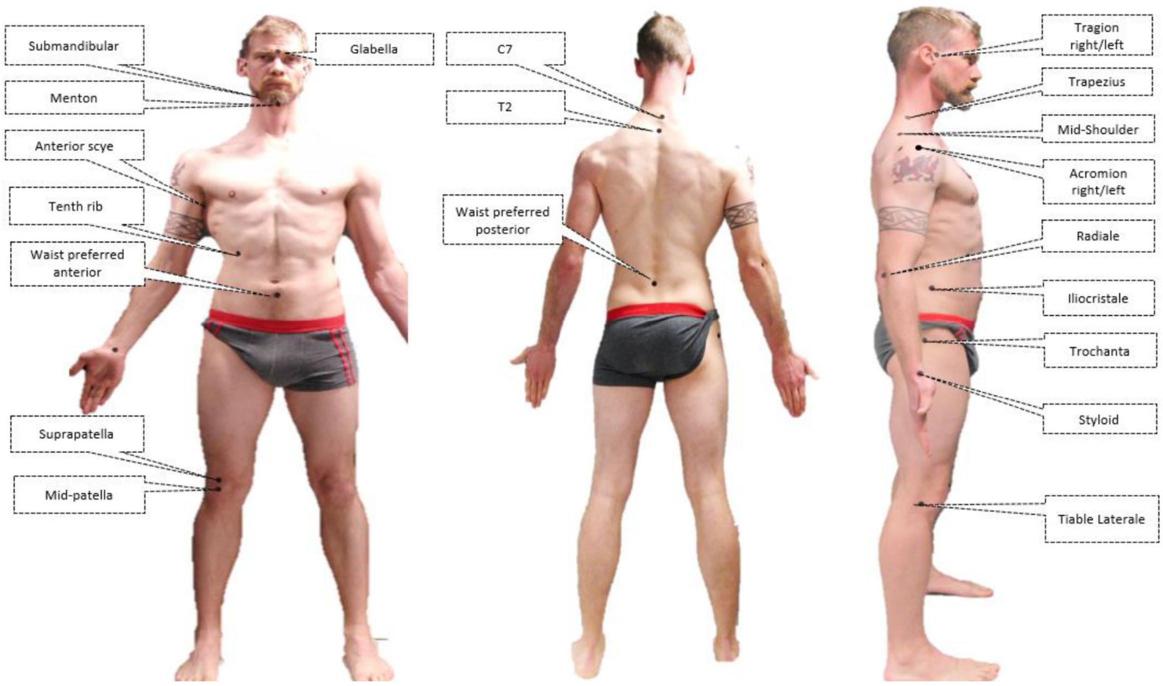


Figure 16. NZDFAS landmarks required for physical measurements. These measurements have a dual-purpose of they can also be used for digital measurements except for menton, sellion, submandibular, tragion (right and left) and trapezius.

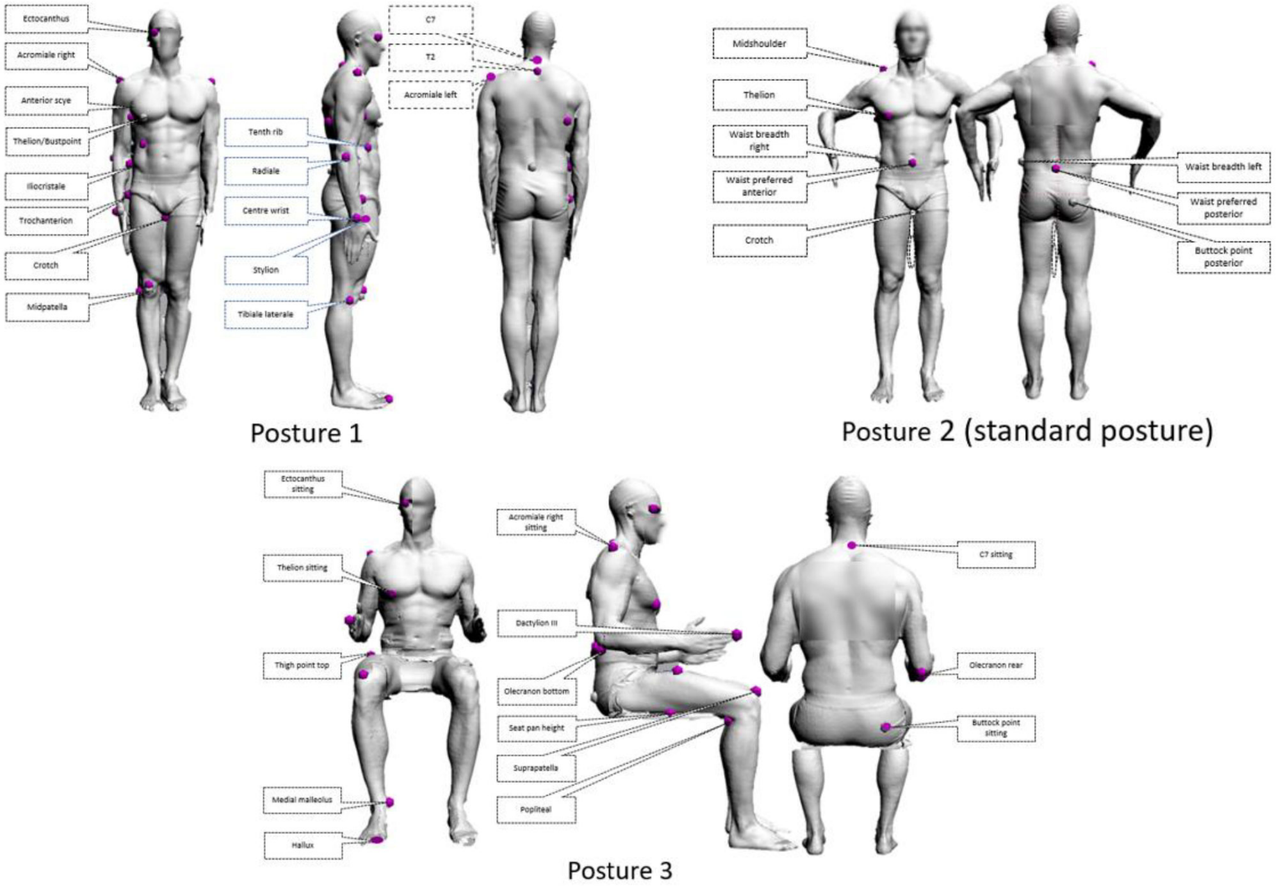


Figure 17. Some of the physical landmarks are converted to 'digital' landmarks (purple dot) which in turn, are used to identify and record digital measurements during post-processing.

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.

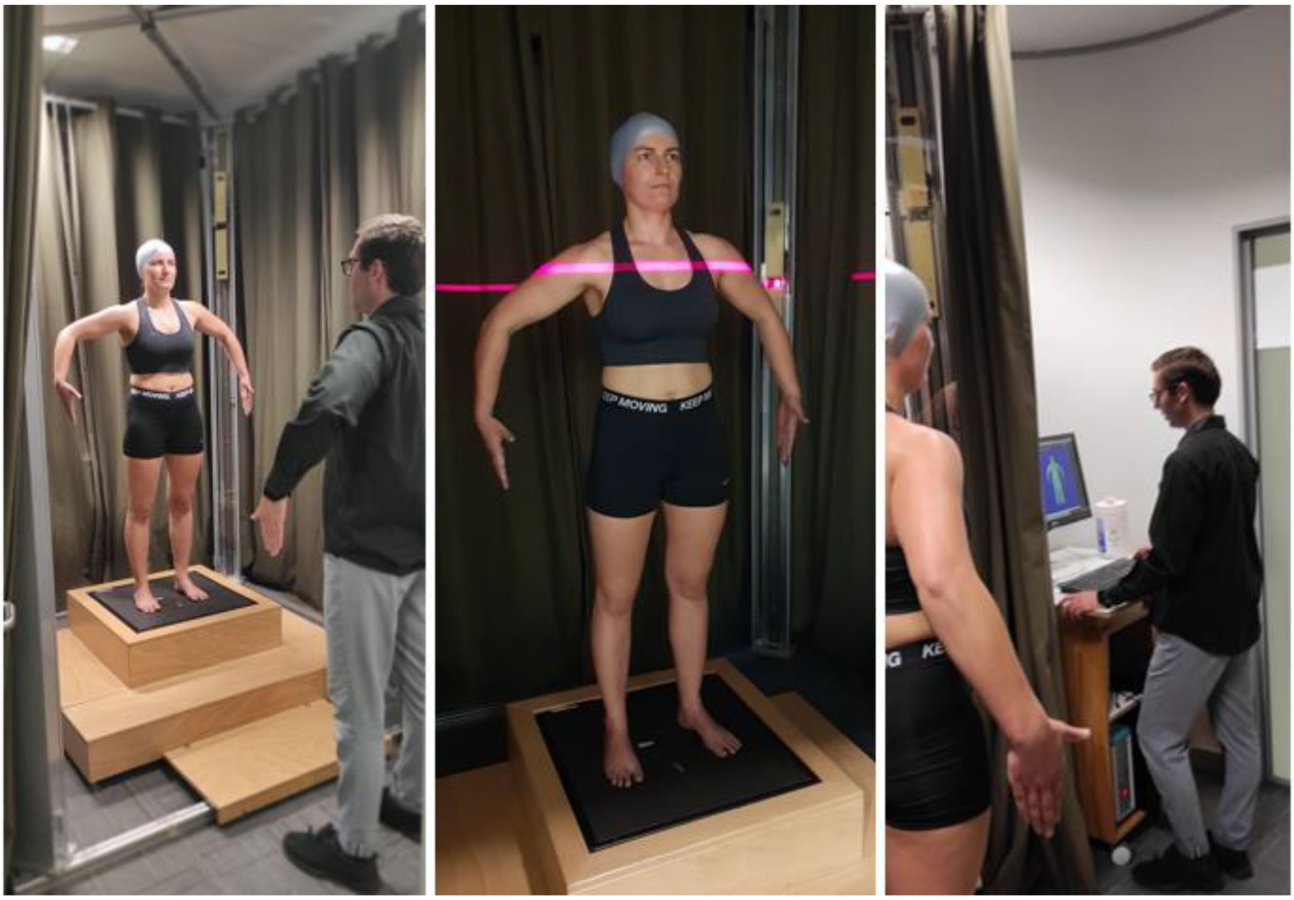


Figure 19. Body scanning process (left to right) posturing, body scan and checking and processing. Note that the lights are turned off during an actual scan. Light clothing is also desired, if not available than dark clothing will suffice.

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.

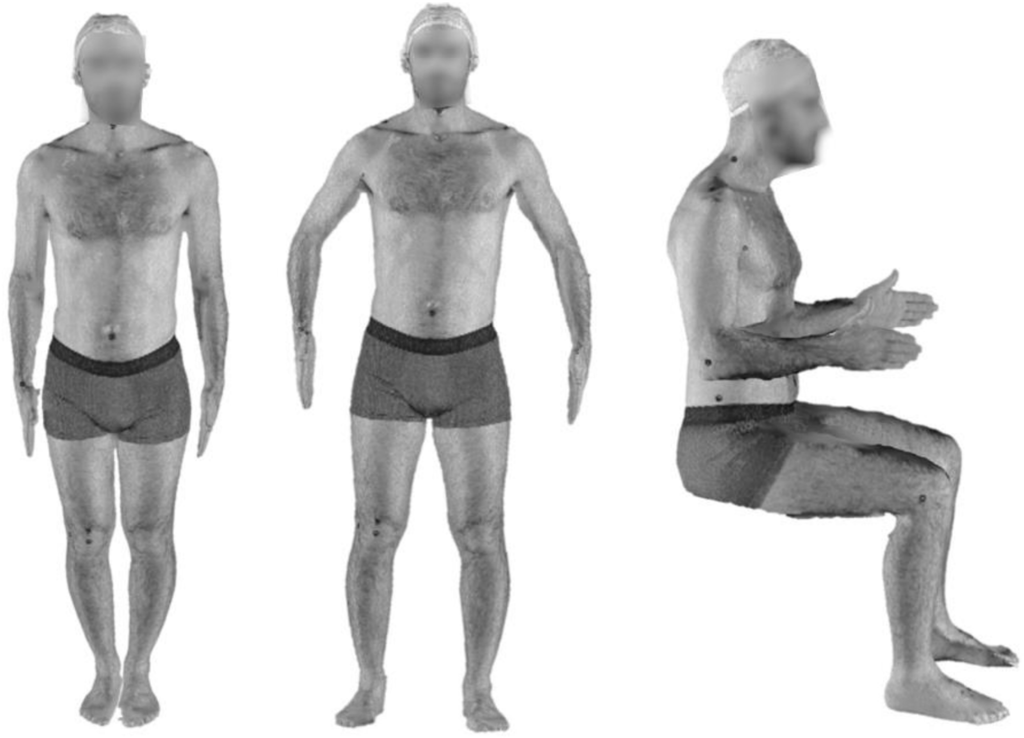


Figure 20. The three scanning postures: Posture 1 (left), Posture 2 (centre) and seated Posture 3 (right). The black stickers represent the stickered landmarks required for the digital measurements.

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.

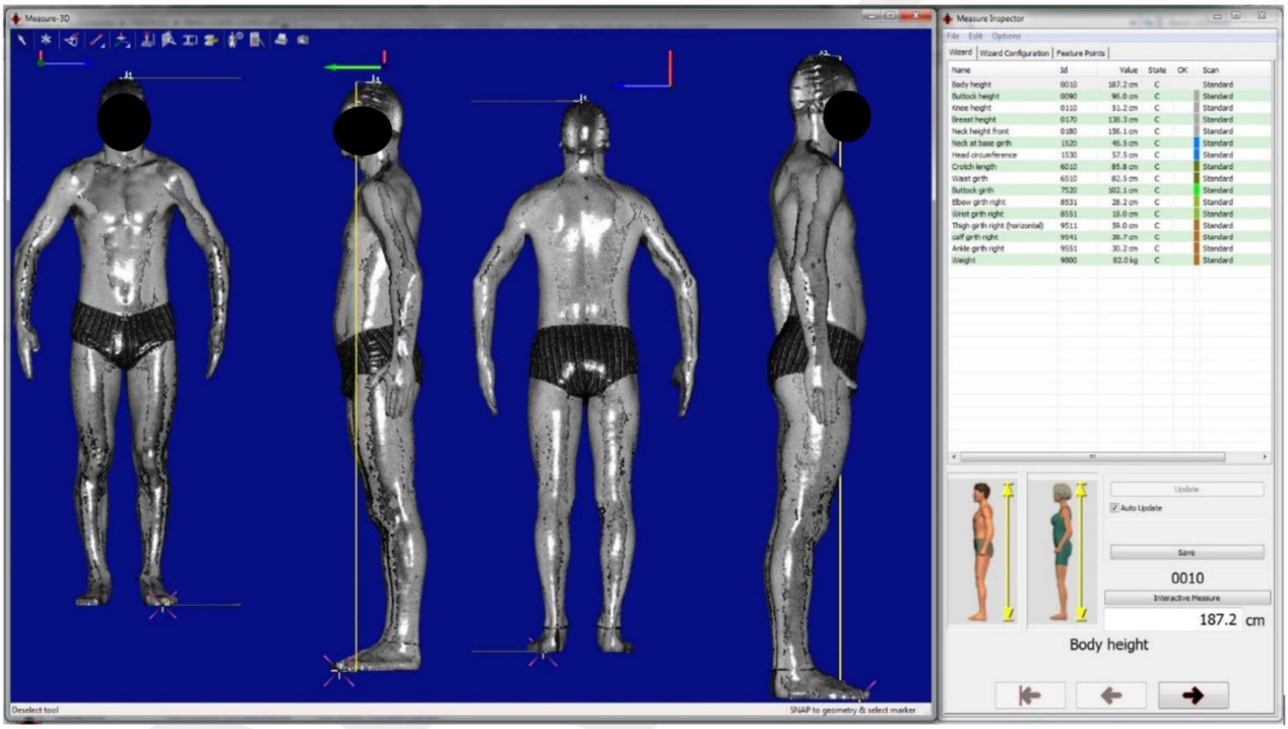


Figure 21. Output of Anthroscan automatic measurement based on scan posture 2.

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.

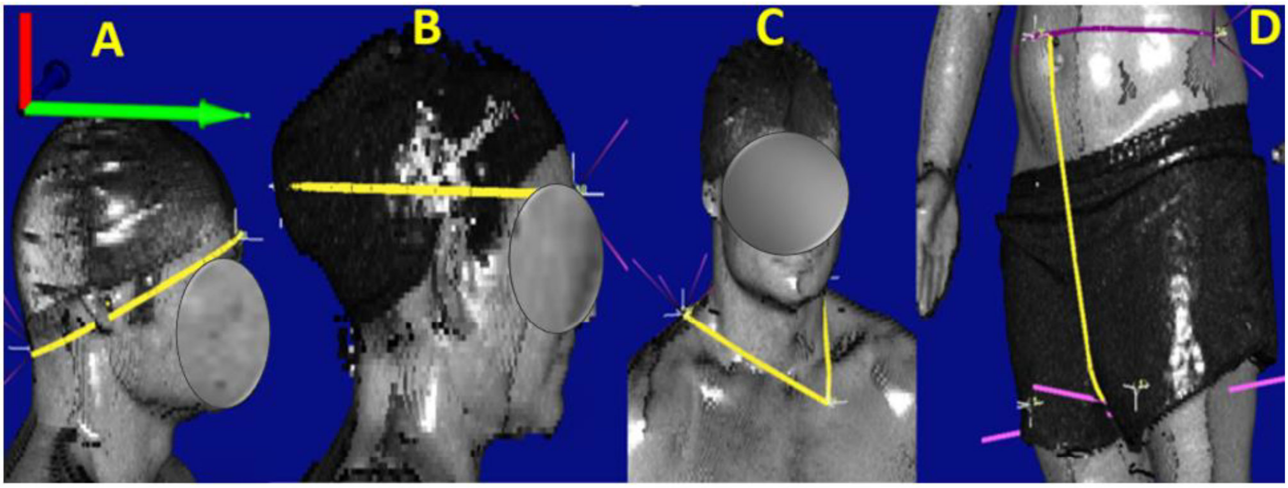


Figure 22. Examples of measurements which required checking, adjustments, or in extreme cases, removal. In photo A the yellow line should be horizontal, in B the yellow line is drawn around the hair bun, in C the yellow line does not conform to the base of the neck, and in D the loose-fitting shorts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

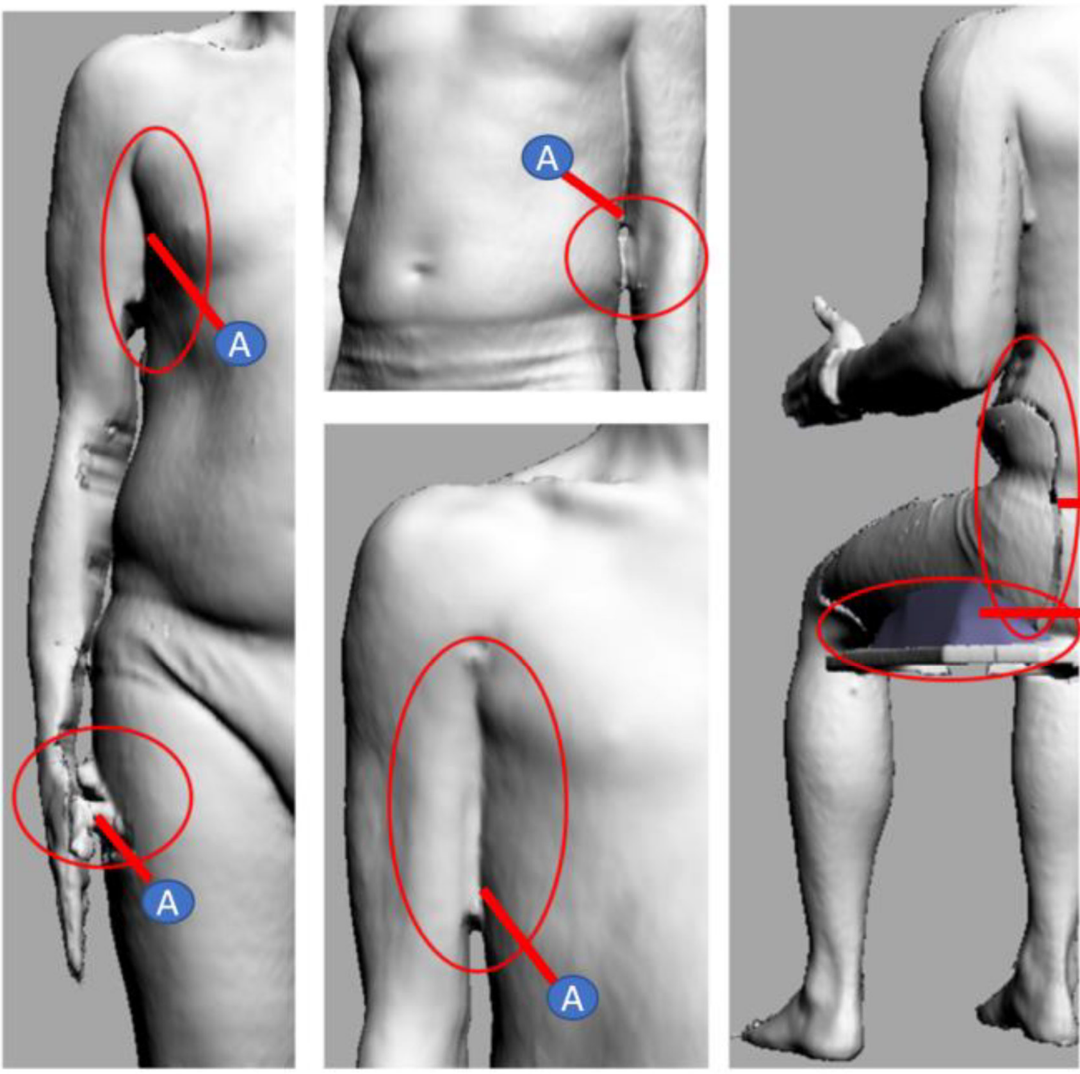


Figure 23. Common artefacts with CySize analysis: webbed skin (A), holes on the surface (B) or unknown objects (C).

ANALYSIS: EXTRACTING DIGITAL (CYSLICE) MEASUREMENTS PROCEDURE

Compile scan folders
- Check that each participant folder has a Standard.bsf, file in their respective folders.

.bsf to .obj conversion
- Perform this function with the PC plugged into the body scanner.
- Turn on Anthroscan software.
- Open the DRDC file conversion script and specify the input directory (where the .bsf files are contained).
- Specify which posture to convert first (e.g. P01 – P03).
- The script will convert all .bsf files into .obj, placing the .obj in their original folders. Perform for all 3 postures (separately).
- If the script fails, move the erroneous folder to a separate conversion issues folder and press continue. The script will continue from the last failed attempt.
- For full instructions follow the BDF to OBJ Converter instruction manual.

.obj to .ply conversion
- Open CySlice and activate the Batch OBJ Convert tool. Specify location of the .obj converted in previous step. CySlice will now convert all .obj files to .ply extensions.

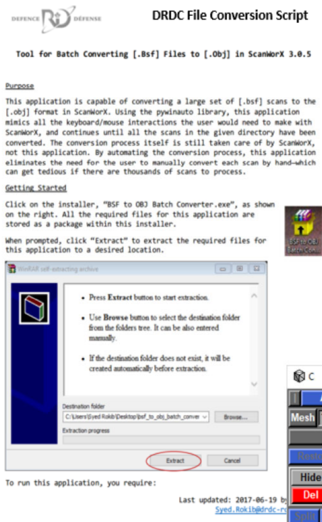
.ply to BAF.ply conversion
- The .ply files may have 'patches' of the skin surface missing. To resolve, use the CySlice Body Auto Fill (BAF) function to repair these holes. This function converts the file to a .BAF.ply extension.

Measure scans in CySlice
- Conduct measurements in CySlice (v3.4) Ensure that the CySlice dongle (there are two) is plugged into the laptop.
- For basic tools, measurement placement and manipulation consult the Australian Warfighter Anthropometry Survey (AWAS) Landmark and measurement guide and Procedures Manual.
- For specific instructions on measuring the NZDFAS measurements consult the NZDFAS Measurement protocol.

Completed results become .slice files
- All completed CySlice profiles are given a .slice file extension.

Export to Excel
- After all measures have been saved. Use CySlice 'BATCH CSV export' function to export all measures into one spreadsheet. **It is important to process one posture at a time** as each posture has a different set of measurements.
- This function searches all .slice files and extracts the measurement data into an Excel spreadsheet.
- Reorganise the spreadsheet so that the identifier code is in the first column, followed by (from left to right) measures for Posture 1, Posture 2 and Posture 3. There should be 43 measurements into total per participant.
- Use R or Excel to add the CySlice results into the MAIN DATASET. Perform statistics logic checks on the CySlice data

End



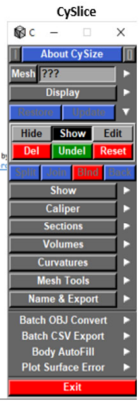


Figure 24. The NZDFAS CySize measurement process.

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:

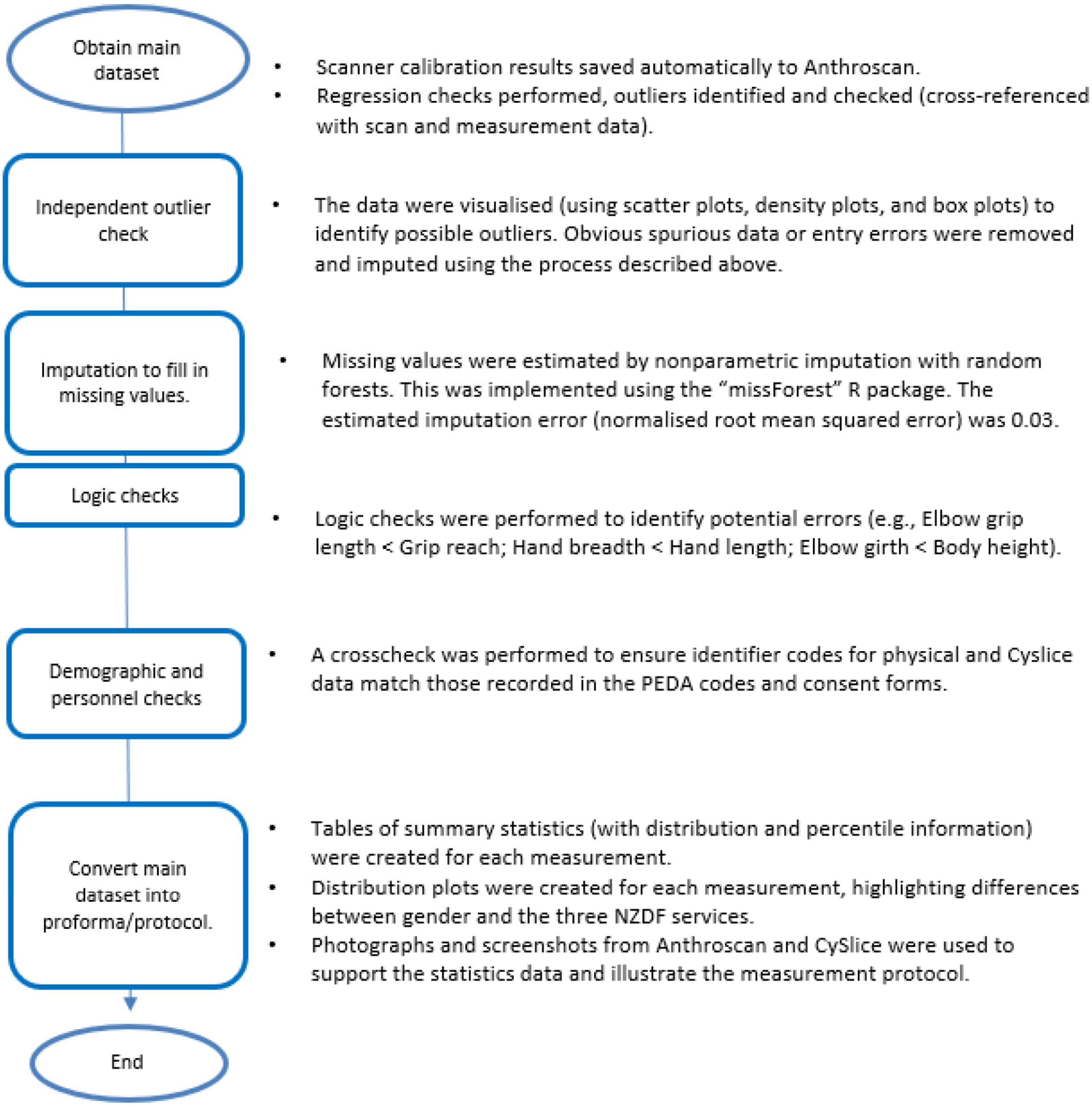


Figure 25. Final check procedures for the NZDFS data

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.