New Zealand Defence Force Anthropometry Survey 2016-2018: Final Report

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Abstract

For over a decade, there has been an increasing demand for NZDF body size data. However, the New Zealand Defence Force has never had an accurate and comprehensive tri-service anthropometric (body size) database. In response, the Defence Technology Agency or DTA (now called 'Defence Science and Technology' or DST) conducted the New Zealand Defence Force Anthropometry Survey (NZDFAS). The aim of this survey was to gather comprehensive anthropometric data to develop an NZDF body scan and measurement database. The NZDFAS will inform NZDF system specifications, design, development and evaluation, and address human systems integration and human performance and health queries. This report describes the methods used to collect 85 manual (traditional anthropometry) and digital anthropometric measurements, on 1,000 NZDF Regular Force personnel (21% female, 79% male), between March 2016 and June 2018. The report also presents the normative summary statistics for each measure. The data is currently being used by the NZDF and data can be accessed through the DST Human Sciences Programme.

Executive Summary

Background

Over the last decade, the Defence Technology Agency (DTA), now called Defence Science and Technology (DST), has fielded a number of requests from various units within the New Zealand Defence Force (NZDF) for anthropometric data. For example, data has been requested to support weapon systems, air, land and maritime platform design, and personal protective equipment decisions. Due to a lack of quality NZDF anthropometric data, referrals to other countries' population data have been provided. Of all the Five Eyes (FVEY) nations (New Zealand, Australia, Canada, UK and USA), New Zealand was the only country that did not have an anthropometry body measurement database. To provide the NZDF with accurate data, and to bring the NZDF in line with international anthropometry research, an up-to-date and representative body measurement database was required. From 2016-2018, DTA conducted the largest and most comprehensive anthropometric survey in the NZDF and New Zealand.

Aim

The aim of the survey was to create an up-to-date, tri-service, anthropometric body scan and measurement database for the NZDF. This report details the study background, the methodology used in the survey and the results of the data collection activities.

Results

A review of military anthropometry surveys and international standards identified the potential body measures to be included in the New Zealand Defence Force Anthropometric Survey (NZDFAS). These measures were assessed by subject matter experts to identify the appropriate method for collecting measurement data (i.e. manual techniques, automated 3-D scanning software, or interactively post-processing of 3-D scans using specialised software). A total of 85 anthropometric measures (including weight) were selected for the final dataset. Of these, 25 were to be measured using manual or traditional anthropometry measures, 17 using automated 3-D scanning software and 43 using interactive 3-D post processing software. To support the implementation of the survey and data collection, 21 NZDF personnel were trained to be accredited anthropometrists.

Data collection spanned a period of eight months and was conducted at nine NZDF sites – Whenuapai, Philomel, Papakura, Waiouru, Linton, Ohakea, Trentham, Woodbourne and Burnham.

The survey measured 1,000 Regular Force personnel (211 females, 789 males; mean age 31.3±10 years; age range 18-69 years) from all three services (28.8% Air Force, 58.0% Army, 13.2% Navy), representing 11% of the Regular Force at the time of the survey. Body

measurements were taken manually, using traditional anthropometry methods, followed by a 3-D body scan in a Vitus XXL 3-D body scanner. Participants were also asked to provide comfort ratings for their service combat shirt and trouser and to comment on any issues of body fit with regards to equipment, uniform, platforms, etc.

The overall target for obtaining a representative proportion of female participants was exceeded, but Navy personnel were under-represented for both males and females. Although original target numbers for trade and ethnicity were not met, trades and ethnicities are proportionally represented in the final sample. However, trades that represent the 'front line', such as Combat trades, were under-represented and may form the focus for future immediate surveys.

For all 85 body dimensions, the average measurement was larger for males than females except for 'hip breadth', 'hip breadth, sitting' and 'elbow rest height, sitting'. No statistical significance was found for key measures across the three services, indicating that the NZDFAS may be applied in its entirety to Air Force, Army, or Navy design or acquisition projects. Summary statistics for all measures are provided in Appendix I and should be used for descriptive purposes only. Where relationships between multiple measures are involved (multivariate data), access to the raw dataset is required. In this case, advice should be sought from the DST Human Sciences Programme.

It should be noted that some measures in the database were missing data, particularly in the case of the scan-derived measures. While some gaps can be addressed via mathematical modelling techniques, to avoid these issues and improve scan quality, future surveys should ensure that participants wear form-fitting underwear and adopt the correct posture during scans. The use of an alternate scan posture or a different measurement technique may be more appropriate in some cases.

Conclusion

The NZDFAS is the first and largest tri-service anthropometry study to date in the NZDF. The NZDFAS database can now be used to inform system specifications, design, development and evaluation, and address human systems integration and human performance and health queries. Data will facilitate the assessment of work activities and operator issues within confined platforms (i.e. vehicles, aircraft, ships, military workstations) and inform the sizing and fit of military clothing and equipment, particularly new acquisitions. NZDF data will be compared with overseas data where appropriate. It is recommended that requests for data be discussed in the first instance with the DST Human Sciences Programme, to ensure correct identification, interpretation and use of database information.

Contents

1 Introduction

The New Zealand Defence Force Anthropometry Survey (NZDFAS) is a large-scale, tri-service, anthropometric study of New Zealand's military personnel. The survey was endorsed by Vice Chief of the Defence Force, Chief of Army, Chief of Air Force, and Chief of Navy in 2015. The first of its kind, the survey's aim was to capture a representative sample of the NZDF, with a target of 1,096 members of the Regular Forces across nine defence locations. The data collected would be used to support future capability decision making and other human performance, human engineering, clothing, and health-related research.

The survey was led by the Defence Technology Agency (DTA) Operations Analysis and Human Systems group (OAHS)[1] and implemented with the help of qualified and trained anthropometrists from the NZDF and Auckland University of Technology (AUT). The main data collection period occurred between March 2016 and September 2016. A follow-up data collection activity occurred at Papakura Military Camp in June 2018. The survey had ethics approval from the Auckland University of Technology Ethics Committee (14/126 NZDF anthropometry survey: Variations in Kinanthropometry and implications for the New Zealand Defence Force).

The aim of the survey was to develop a database of representative and up-to-date, tri-service, anthropometric measurements and 3-D body scans of NZDF Regular Force personnel.

2 Background

In 2015, data relating to the anthropometric dimensions of NZDF personnel, and New Zealanders in general, were extremely limited and a comprehensive survey suitable for human engineering design and ergonomic applications had never been undertaken. As no 'New Zealand' data existed, researchers typically relied on data from military allies (e.g. Australia, US or UK). To address this gap, some researchers generated New Zealand data based on overseas datasets. For example, Slappendel and Wilson derived anthropometric estimates for New Zealanders by 'ratio scaling' British data [1] against stature data collected during the health check examination of the Life in New Zealand (LINZ) survey in 1990. The LINZ survey collected data from 1,610 females and 1,405 males, randomly selected from the electoral rolls [2]. The use of overseas data and ratio scaling can result

[1] Now called the Defence Science and Technology (DST) 'Human Sciences Programme' (HSP)

in large inaccuracies due to body shape and size differences between different populations and ethnicities.

The largest New Zealand military anthropometry survey was conducted in 1974 by the Royal New Zealand Air Force (RNZAF) Aviation Medicine Unit (AMU) in Auckland. The purpose of this survey was to better inform the procurement of flying clothing size ranges and to compare New Zealand anthropometry data to international military organisations. The study measured 238 male Aircrew between the ages of 18 and 49 years and captured 62 measurements per participant. Despite the large scale (high number of participants) and breadth (high number of measurements) of this study, few people knew of its existence as it was only published as an internal report [3].

An anthropometric survey of feet was conducted on members of the New Zealand Army in 2011 to provide a normative set of data to support the specification and development of footwear [4]. Four measurements (foot length, breadth, circumference and arch height) were obtained from a convenience sample of 807 New Zealand Army Regular Force personnel. Unfortunately, no demographic data were recorded so it is not possible to identify if the sample was representative of the New Zealand Army or if there were differences between demographic groups (e.g. men and women). Results of this study suggest that the arch height of the New Zealand Army is different from the general population and that approximately 50% of soldiers were wearing the wrong size boot. Despite a lack of demographic data, the authors speculate that the differences in foot characteristics demonstrated by the New Zealand Army may be due to the greater prevalence of Māori and Pacific Islanders.

Since 2013, DTA has received many anthropometry-related requests from the NZDF including:

- Arm length dimensions for the In-Service Weapons Upgrade Program (ISWRUP);
- Weight and sitting hip breadth data for the new Navy lifeboat;
- Standing eye height, functional reach and reach envelope measurements for the Navy bridge console design;
- Height and weight data for Navy bunk bed sizes;
- Weight and seated measurements (e.g. hip breadth, knee length and knee height) for the NH90 cabin seat;
- Assistance with taking RNZAF aircrew anthropometry measurements.

The lack of NZDF (or NZ civilian population) data to inform these requests highlighted the need for a database of up-to-date NZDF anthropometric data, and trained personnel to collect and interpret the information. This backed up a 2008 scoping study conducted by Professor Stephen Legg at Massey University [2] which recommended i) the creation of a trained anthropometry team and ii) the procurement of a 3-D body scanner to help automate anthropometry data collection. As a result, in 2013, DTA purchased the Human Solutions Vitus XXL 3-D Body Laser scanner. In preparation for an NZDF-wide Anthropometry Survey, 18 NZDF personnel were trained and accredited as International Society for the Advancement of Kinanthropometry (ISAK) Level 2 anthropometrists.

This report describes the background to the development of the NZDF Anthropometry Survey (NZDFAS), the methodology used and the results of each phase of the survey. Recommendations for future directions are provided.

3 Methods

3.1 Measurement selection

In 2014, DTA conducted a review of international military anthropometric surveys and NZDF requirements to identify the most appropriate body measurements for the New Zealand Defence Force Anthropometry Survey (NZDFAS). This list of measures was assessed to determine if these measures could feasibly be obtained by 3-D body scans using automated, or semi-automated, data processing techniques. To support this assessment, three validation trials were conducted to compare automated measurements extracted from 3-D body scans to manual measurements on select anthropometric measures [5]. As a result, a total of 85 NZDFAS body measurements were identified, with 17 to be extracted automatically using Anthroscan software (Human Solutions GmbH, Kaiserslautern, Germany), 25 manually using traditional tapes and callipers, and 43 semi-automatically using CySize software (Headus 3D Pty, Orchard Part, Australia). The final list was reviewed by an ISAK Level 4 Anthropometrist[2] and international subject matter experts in 3-D body scanning. The final list of measures is provided in Table 1.

[2] ISAK Level 4 is the most senior level in the ISAK anthropometry accreditation scheme and is reserved for a relatively small group of internationally recognised anthropometrists. It represents a criterion anthropometrist and recognises the following: (i) several years of experience in taking ISAK-approved body measurements, (ii) a high level of theoretical knowledge, (iii) involvement in teaching/examining ISAK courses and workshops, (iv) involvement in large anthropometric research projects, and (v) a significant publication record in anthropometry.

Table 1. Full list of NZDFAS body measurements.

Anthroscan Automated measures (17)	**Manual measures (25)**	**CySize Digital measures (43)**
Ankle Circumference	Arm Span	Abdominal Extension Depth, Sitting
Buttock Circumference	Ball Of Foot Circumference	Acromial Height
Buttock Height	Ball Of Foot Length	Acromial Height, Sitting
Calf Circumference	Biceps Circumference, Flexed	Acromiale-Radiale Length
Chest/Bust Circumference	Bitragion Submandibular Arc	Axilla Height
Chest/Bust Height	Bizygomatic Breadth	Biacromial Breadth
Crotch Length	Buttock-Heel Length	Bideltoid Breadth
Elbow Circumference	Elbow-Grip Length	Buttock Depth
Head Circumference	Elbow Rest Height, Standing	Buttock-Knee Length
Knee Height	Foot Breadth	Buttock-Popliteal Length
Neck Circumference, Base	Foot Length	Cervicale Height
Stature	Forearm-Forearm Breadth	Cervicale Height, Sitting
Suprasternale Height	Functional Grip Reach	Chest Breadth
Thigh Circumference	Hand Breadth	Chest Depth
Waist Circumference, Natural Indentation	Hand Circumference	Chest Height, Sitting
Weight	Hand Length	Crotch Height
Wrist Circumference	Head Breadth	Crotch-Waist Length Preferred, Anterior
	Head Length	Crotch-Waist Length Preferred, Posterior
	Index Finger Breadth, Distal	Elbow-Fingertip Length
	Index Finger Breadth, Proximal	Elbow Rest Height, Sitting
	Index Finger Reach	Eye Height
	Interpupillary Breadth	Eye Height, Sitting
	Palm Length	Hip Breadth, Sitting
	Sitting Height	Hip Breadth, Standing
	Thumbtip Reach	Hip Circumference, Maximum
		Iliocristale Height
		Knee Circumference
		Knee Height, Sitting
		Malleolus-Hallux Length
		Popliteal Height
		Radiale-Stylion Length
		Second Thoracic Vertebrae (T2) Height
		Shoulder-Elbow Length
		Sleeve Outseam
		Tenth Rib Height
		Thigh Clearance
		Tibiale-Laterale Height
		Trochanterion Height
		Vertical Trunk Circumference
		Waist Breadth
		Waist Circumference, Preferred
		Waist Depth
		Waist Height Preferred, Posterior

3.2 Sample identification

A minimum sample size that ensures a valid representation of body dimensions across the NZDF was determined using a power analysis equation from ISO 15535:2006 [6]. The formula, provided in Equation 1, is based on the probability that a survey population will provide sufficient fidelity to represent the true population in question, between the 5th and 95th percentiles, with 95% confidence and 1% relative accuracy. This is a common method applied by other international military organisations [7], 8].

$$N = \left(\frac{1.96 \times CV}{a}\right)^2 \times 1.534^2 \quad (1)$$

ISO 15535:2006 sample size estimate.

Where:

N = the minimum sample size;

1.96 = the critical *z* value from a standard normal distribution for a 95% confidence interval;

CV = the coefficient of variation for the measure to be assessed;

a = the percentage of relative accuracy required (typically 1%).

Note that this formula was applied to each measure indicated in Table 1 to determine the minimum sample size for that measure. Typically, the Coefficient of Variation (CV) is obtained from a previous survey of similar demographics. As no recent anthropometry data existed for the NZDF, the measure that obtained the greatest CV% in the NZDFAS validation study [5] was used[3]. This measure was Waist Height (CV 12.9%), which generated a minimum required sample size of 1,504 (17% of the NZDF population) for the study. An assessment of the CVs of 140 measures in the 1997 Canadian Land Forces Survey demonstrated that a sample size of 1,000 for each sex was sufficient to achieve 1% relative accuracy for 131 male and 126 female measures [9]. Examples of measures common to the NZDFAS requiring a sample size greater than 1,000 include Elbow Rest Height, Waist Circumference, Waist Depth and Weight. If a relative accuracy of 2% was deemed to be acceptable, then all measures of the NZDFAS could be adequately represented by a sample size of 1,000 males and 1,000 females. Achieving the ISO recommended sample size for both sexes is challenging for the NZDF as it would require measuring almost every woman in the NZDF and approximately 13% of all men. Advice from international partners recommended a minimum sample size of 10% of the total population. To capture more participants and to mitigate against potential non-respondents and withdrawals, a target of 15% was set for the NZDF survey. When applied

[3] Note that the validation study contained only 12 participants. The Waist Height CV of 12.9% observed in the validation study was much greater than the 5.1% seen in ANSUR II [15, 16].

to the 2015 NZDF Regular Force population of 8,885, the 15% target was equivalent to 1,333 personnel.

A random sampling strategy was used to select the 1,333 personnel to receive an invitation to participate, with the three services, the nine camps/bases, gender, ethnicity, and trades across the NZDF all appropriately represented. Of the selected personnel, only 1,096 (82%) could be contacted. Thus, the survey target was readjusted to 1,096 personnel or 12% of the NZDF population. Of those who could not be contacted, errors in personnel records, posting cycles and personnel leaving the organisation accounted for lack of contact information. Inclusion criteria for personnel included being a member of the Regular Force and being based at one of the camps/bases included in the survey plan (see Section 3.4).

3.3 Data collection team

The NZDFAS data collection team consisted of 21 personnel made up of DTA Scientists and NZDF Physical Training Instructors (PTIs) and Medics. The team was trained and accredited to ISAK Level 2, with two individuals at ISAK Level 1. The ISAK accreditation, commonly used for anthropometric assessments, ensured that all team members were able to locate specific human anatomical landmarks and take accurate measurements within specified technical errors of measurement [10]. Team members also completed a conversion course, run by DTA, to learn the NZDFAS landmarks and measurements, which differ from ISAK measurements.

Training was complete when participants achieved satisfactory inter-rater reliability (within 2%) with the Lead Researcher, who was an experienced ISAK Level 2 anthropometrist. The Lead Researcher provided regular feedback to the technical team throughout data collection to ensure quality control.

Nine team members were also trained as body scanner operators. At any one data collection site, the minimum data collection team consisted of six personnel (one receptionist, two ISAK Level 2 qualified measurers, two data recording scribes and one body scanner operator).

3.4 Location and set-up

3.4.1 Survey locations and venues

The survey was conducted at the following nine locations:

Royal New Zealand Air Force

- Whenuapai Airforce Base (Sioux Block)
- Ohakea Airforce Base (Squadron 3 Hangar)
- Woodbourne Airforce Base (Conference Centre)

New Zealand Army

- Papakura Military Camp (Conference Centre)
- Waiouru Military Camp (Workwear Clothing Store)
- Linton Military Camp (Conference Centre)
- Trentham Military Camp (Band Room)
- Burnham Military Camp (Gymnasium)

Royal New Zealand Navy

- Devonport Naval Base (Navy Amenities A Building)

3.4.2 Survey layout and equipment

Where available, each survey site consisted of a briefing area, two measurement rooms and a body scanning room or area. The briefing desk consisted of a laptop equipped with an Anthroscan demographic questionnaire (digital), participant information sheets and informed consent forms.

Each measurement room contained two tables: one for the measurement equipment and one for the data collection laptop. See Appendix A for detailed information about the layout and placement of items and Appendix B for a detailed list of measuring equipment.

3.5 Body scanner

As per the advice provided by Massey University to procure a 3-D body scanner for survey purposes, the NZDFAS acquired a Human Solutions Vitus XXL whole body laser scanner (Human Solutions GmbH, Kaiserslautern, Germany). This 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) with Cartesian coordinates. Accuracy of the Vitus XXL is ±1 mm with a resolution of 27 points/cm^3. The scanner is comprised of four scan heads/sensor assemblies, one in each of the scanner columns. Scan images are collected from each assembly using optical triangulation and are merged to create a single 'digital statue'. Total scan volume is 2100 mm x 1200 mm x 1,000 mm. The scanner uses eye-safe Class 1 visible red laser light and was manufactured and developed in compliance with the regulations of the U.S. Food and Drug Administration pertaining to laser safety (21CFR1040.10 and 21CDR1040.11).

As the external dimensions of the scanner are 2950 mm x 2200 mm x 2200 mm, survey locations were required to have a ceiling height of at least 3.1 m and a floor area more than 4 m^2. An ability to darken the room was also required to optimise the scan quality. Additional space was also required to accommodate a small desk for the computer. The measurement rooms were required to be in close vicinity to the body scanner and were set up in accordance with the requirements provided in Appendix A.

3.6 Data collection procedure

Data collection and analysis was based on manufacturer instructions and standards followed by other large-scale military anthropometry surveys (e.g. the Australian Warfighter Anthropometry Survey (AWAS) [7, [11]2[13]3], the Anthropometric Survey of the Royal Australian Navy (ASRAN) [14], and the Anthropometric Surveys of U.S. Army Personnel (ANSUR II) [15, 16] and U.S. Marine Corps Personnel [17]. Defence Research and Development Canada (DRDC) also provided video resources and a batch file conversion tool to facilitate converting scan images from their native body scan raw .bsf file format to the more common .obj file format.

A typical data collection day consisted of the following six key activities:

1. Vitus XXL calibration
    - As per manufacturer's instructions
2. Participant registration
    - Overview of the study provided
    - Informed consent obtained
    - Unique participant ID assigned
    - Demographic data collected
    - Feedback on issues of equipment fit and uniform fit collected
3. Landmarking
    - Body landmarks identified via palpation (Appendix F)
4. Manual measurements
    - Manual anthropometric measurements obtained in accordance with Appendix G
5. Body scan
    - 3-D body scans obtained in each of the standing (2) and seated (1) postures
6. Data backup
    - All data incrementally saved to three external hard drives at the end of each day

Each of these steps are discussed in greater detail in the following sub-sections.

3.6.1 Calibration

All survey equipment was calibrated regularly. Manual measurement equipment, e.g. callipers, was calibrated using a ruler or tape measure. The body scanner platform scale and manual (SECA) scales were calibrated using a 20 kg weight. The body scanner was calibrated daily as per manufacturer's instructions, by scanning the Human Solutions calibration column in five predefined locations centred on the body scan volume. The Anthroscan 'register' function uses the position and dimensional data from these scans to

calculate the appropriate calibration matrix. Full details of the calibration procedure are provided in the Vitus XXL instruction manual [16].

3.6.2 Brief

Participants were briefed individually before participating in the survey (Figure 1). The brief consisted of a short introduction to the study covering the aim, purpose, application of data and testing procedure. Each participant was requested to read and sign an informed consent form (Appendix C) and informed of their right to withdraw from the study at any time without consequence. An electronic demographic questionnaire (Appendix D) was then administered, consisting of age, gender, posting location, handedness, ethnicity, job/role, uniform shirt and trouser size, and uniform shirt and trouser perceived fit (rated on a Likert scale from 1 = Very good to 5 = Very poor).

On completion of the demographic questionnaire, each participant was invited to provide additional open-ended comments regarding issues of fit associated with the equipment they use and wear when carrying out their work.

Figure 1. Example briefing area.

3.6.3 Landmarking

To facilitate ease and consistency of measuring, key anatomical landmarks were identified and marked on each participant. After the briefing and signing of the informed consent form, each participant was directed to a private booth where they disrobed to their undergarments. Participants were informed to wear form-fitting shorts (and bras for women).

They were then landmarked by a trained anthropometrist. Male and female anthropometrists were available, to accommodate participant preference. Landmarks were identified by palpation or visual identification and indicated with a mark from a felt tip pen or whiteboard marker (Figure 2).

Figure 2. Examples of physical (manual) landmarking.

To obtain the body dimension measures, a total of 22 surface landmarks were required to be marked, which took an average of 10 minutes to complete. Landmarks were taken from the facial midline or the right side of the body, as appropriate. In certain instances, such as the tragion and acromion, bilateral landmarks were marked to facilitate breadth measures. If a right-side landmark could not be identified due to injury or physical deformity, then the left side of the body was landmarked. Certain physical landmarks were used for both manual and digital measures (indicated by the underlined text in Table 2) – these 16 landmarks were later marked with a black ring sticker prior to body scanning for easy visual identification on the 3-D scan. A further 20 landmarks were identified digitally on each 3-D scan, using CySize software. A visual guide to each landmark is provided in Appendix F.

Table 2. Marked NZDFAS physical and digital landmarks. Underlined landmarks were used for both physical and digital measures.

Physical landmarks (via palpation)	Digital landmarks (via CySize©)
Acromion, Left	Acromion, Left
Acromion, Right	Acromion, Right
Anterior Scye/Axilla	Anterior Scye/Axilla
Cervicale (C7 Vertebra)	Buttock Point
Iliocristale	Buttock Point, Sitting
Midpatella	Centre Wrist
Midshoulder	Cervicale (C7 Vertebra)
Midstylion	Cervicale, Sitting
Radiale	Crotch Point
Second Thoracic Vertebra (T2)	Dactylion III
Stylion	Ectocanthus
Submandibular	Ectocanthus, Sitting
Suprapatella	Hallux
Tenth Rib	Iliocristale
Tibiale Laterale	Medial Malleolus
Tragion, Left	Midpatella
Tragion, Right	Midshoulder
Trapezius Point, Left	Olecranon, Bottom
Trapezius Point, Right	Olecranon, Rear
Trochanterion	Popliteal Point
Waist Preferred, Anterior	Radiale
Waist Preferred, Posterior	Seat Pan Height Marker
	Second Thoracic Vertebra (T2)
	Stylion
	Suprapatella
	Tenth Rib
	Thelion/Bustpoint
	Thelion/Bustpoint, Projected
	Thelion/Bustpoint, Sitting
	Thigh Point, Top
	Tibiale Laterale
	Trochanterion
	Waist Breadth, Left
	Waist Breadth, Right
	Waist Preferred, Anterior
	Waist Preferred, Posterior

3.6.4 Manual measurements

For each participant, a trained anthropometrist took 25 manual measurements (Table 1). Due to technical [4] and scan volume limitations, these measurements could not be accurately captured by the body scanner and hence were collected manually. Various tools such as a stadiometer, anthropometry box, measuring tapes, rulers, anthropometer and callipers were used (see Figure 3 for an example of these tools in use). All manual measurement equipment was borrowed from the Auckland University of Technology (AUT) Sports Performance Research Institute of New Zealand (SPRINZ).

All measurements were taken on the right side of the body unless there was an injury or deformity present (in which case they were taken on the left side). See Appendix H for a complete description of each measure definition and measurement procedure. The measuring process took, on average, approximately 30 minutes to complete.

Figure 3. Examples of manual measurement.

[4] In cases where the measurement is small (e.g. index finger breadth, distal) or where the measurement relates to the foot, artefacts are common.

On completion of all manual measures, the participant re-dressed and was escorted to the body scanner waiting area.

3.6.5 Body scan

Once at the body scanner location, the participant was required to undress to their undergarments. Participants were instructed to wear form-fitting underwear, as loose-fitting boxer-type briefs are not suitable for obtaining an accurate scan of the pelvis, crotch and upper thighs.

The body scan operator placed a landmark sticker over landmarked locations, to enhance detection of the landmark in the scan image. The stickers were black or white rings (14 mm diameter with 6 mm hole), as appropriate, to achieve maximum contrast to the participant's skin tone and accurate positioning of the sticker in relation to the marked landmark. Participants were then positioned (by the operator) on the body scanner podium in each of three scan postures (two standing and one sitting), as depicted in Figure 4. These postures are based on those used in AWAS [11]. Note that Posture 2 deviated from the equivalent Human Solutions posture, which indicates the hands being held in a loose fist (Figure 5).

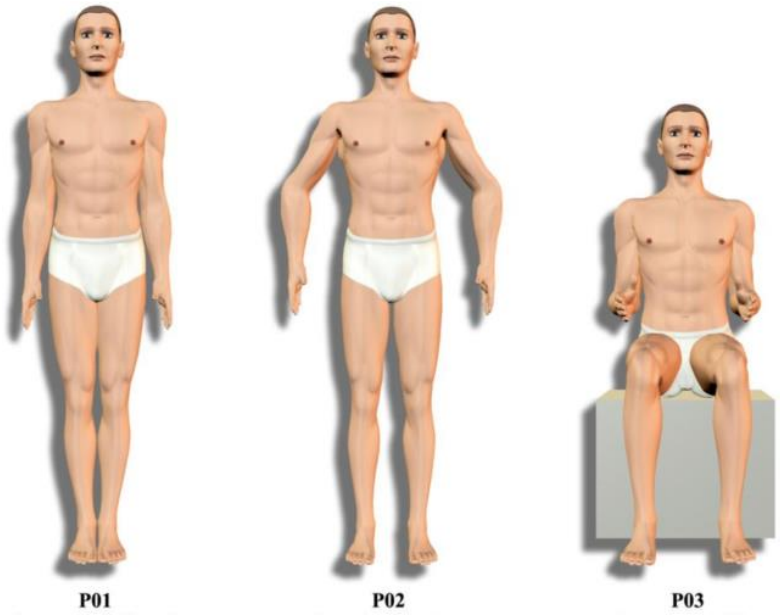

Figure 4. Body scanner postures. Illustration used with permission [9, 12].

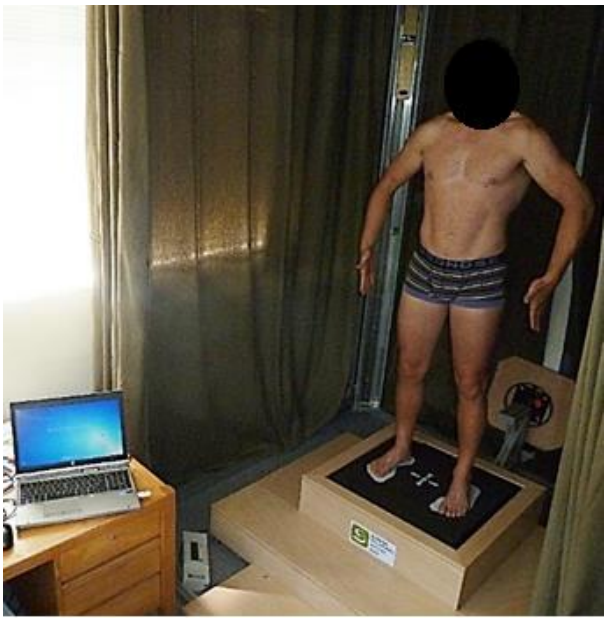

Figure 5. Preparing participant for body scan (Posture 2).

Immediately after each scan, the body scan operator checked to ensure a) that the 16 physical-digital landmarks were present and clearly visible, b) that participant posture and positioning was correct (a strict requirement for the 3-D analysis process), and c) that the scan image was of good quality. If any scans were deemed inadequate, the scanning process was repeated. Once scans of each of the three postures had been successfully captured, the data collection was considered complete, and the participant was able to re-dress and leave. Stickers were removed by the scan operator and marked landmarks cleaned with alcohol swabs.

3.6.6 Data backup

At the end of each data collection day, all .bsf files, PErsonal DAta (PEDA) files (containing demographic information) and manual measures (.xls) files were copied on to three external hard drives. PEDA files were then copied from the briefing laptop to the participants' respective scan folders on the body scanner computer.

3.7 Analysis

3.7.1 Automated measurements

All body scan images were uploaded to a Human Solutions Anthroscan database. Anthroscan uses a special automated landmarking and measurement algorithm and measurement definitions derived from ISO 7250 to automatically derive a number of body measurements (Figure 6). Seventeen measurements in this survey were obtained using these automated algorithms and are listed in Table 3.

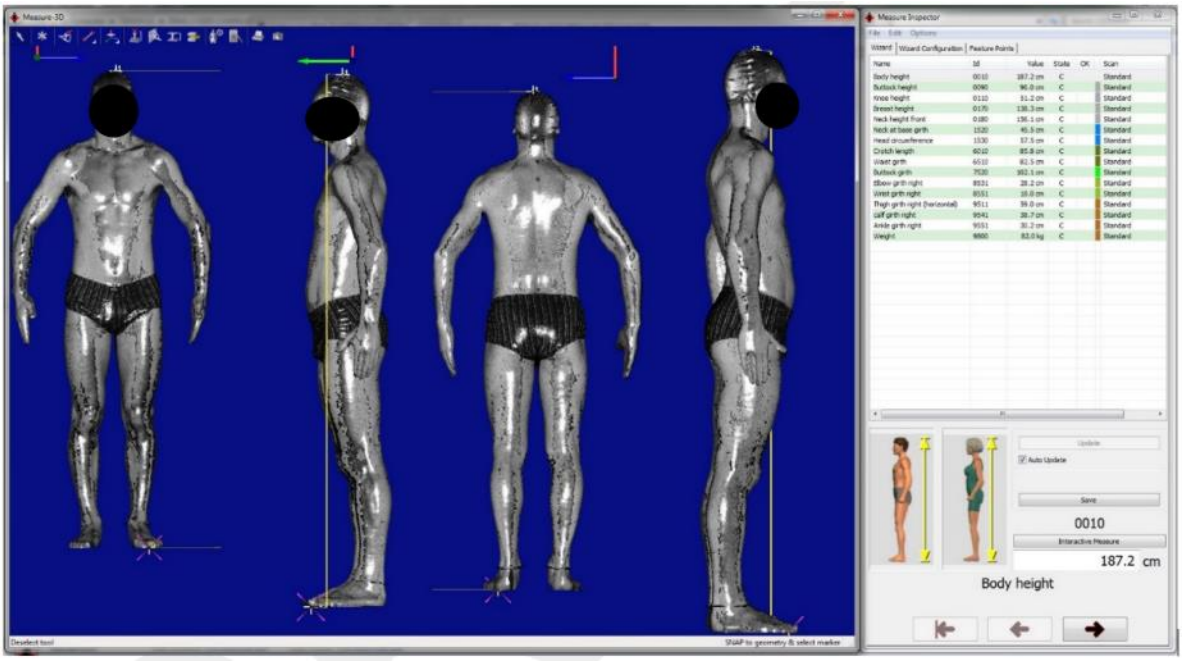

Figure 6. Example of Anthroscan automated measurement. Body Height (Stature) measurement is indicated in this example.

Table 3. List of NZDFAS scan measures obtained by Anthroscan automated software.

Anthroscan automated measures
Ankle Circumference
Buttock Circumference
Buttock Height
Calf Circumference
Chest/Bust Circumference
Chest/Bust Height
Crotch Length
Elbow Circumference
Head Circumference
Knee Height
Neck Circumference, Base
Stature
Suprasternale Height
Thigh Circumference
Waist Circumference, Natural Indentation
Weight
Wrist Circumference

All three scan posture files were uploaded to the NZDF Anthroscan online database, along with the associated demographic information for each participant. Automated measurements were derived from Posture 2 (Figure 4), the 'Standard' scan posture, as per Anthroscan software guidelines. To extract the automated measurements, the operator followed the procedures outlined in the Anthroscan User Manual entitled 'Running an Automated Measurement' [16]. Anthroscan automatically identifies landmarks and measurement locations and extracts user-selected, pre-defined

measurements from each scan. A quality control check was performed by inspecting for errors such as improper posture or clothing or hair artefact, and to verify that the measurement indicators (i.e. landmarks and measurement line) were correctly located on the body. Examples of these errors and recommended remedial actions are provided in Table 4. Visual examples of errors are provided in Figure 7.

Table 4. Automated measures analysis challenges and recommended actions.

Issue	Recommended Action
Head Circumference – for many female participants, the circumference line was drawn around the hair bun which exaggerated the head circumference results. The measurement line may also follow an incorrect path.	• If the line does not follow the appropriate path, adjust it by moving the front or back feature points (landmarks) of the measurement line until it passes through the appropriate landmarks (Figure 7a). • If the hair bun is located over the Opisthocranion landmark, skip this measure as an accurate measure is not possible (Figure 7b). • For future data collection, ensure the hair bun is removed or is passed through an aperture in the scan cap as per ISO 20685. • Future data collection should use the manual technique.
Neck Circumference, Base – the line drawn by the software does not follow the natural curvature of the base of the neck. This creates an error in the results.	• Adjust by moving the measurement line feature points until they conform to the shape of the neck. The software re-adjusts the curvature of the measurement line accordingly (Figure 7c).
Crotch Length – the wearing of loose-fitting shorts affects the accuracy of this measurement. Close-fitting undergarments were recommended but not all participants wore these during the assessment.	• If the shorts are not form-fitting, skip this measure (Figure 7d). • For future data collection, ensure participants are wearing the appropriate undergarment or provide form-fitting shorts for participants to wear.

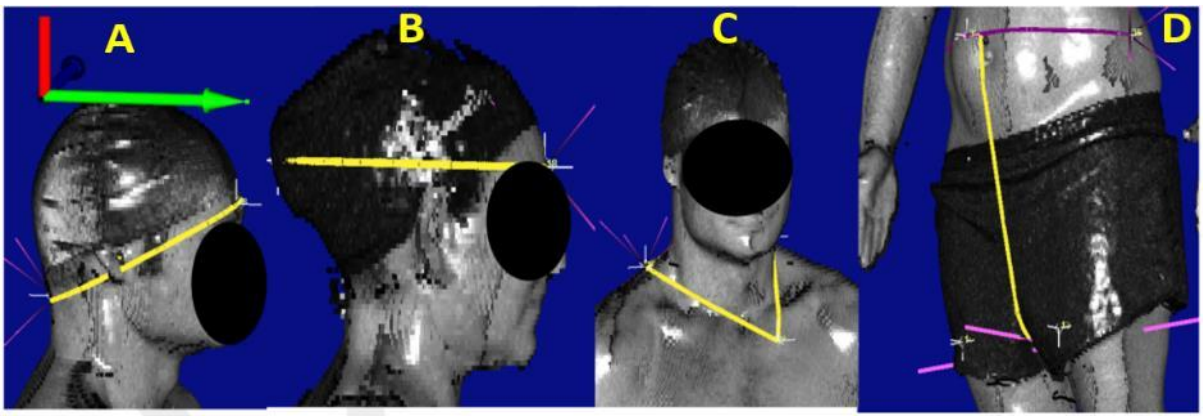

Figure 7. Examples of measures which require checking, adjustment, or removal – Head Circumference (A & B), Neck Circumference (C) and Crotch Length (D).

3.7.2 Manual measurements

Participants' individual manual measures were recorded in a Microsoft Excel spreadsheet (Figure 10). The spreadsheet was based on a modified ISAK Level 2 data collection sheet, with NZDFAS-specific measures and known correction factors specific to measuring equipment added. For example, Grip Reach required 0.35 cm to be added to the original measurement. This is to account for the radius of the rod held in the participant's hand as the true measure is to the centre axis of the rod. Correction factors used for manual measures are as follows:

- Index Finger Reach – add 1.1 cm to account for width of anthropometer blade;
- Thumbtip Reach – add 1.1 cm to account for width of anthropometer blade;
- Grip Reach – add 0.35 cm (+1.1 cm to account for the width of anthropometer blade and -0.75 cm to account for the radius of the grip rod);
- Elbow-Grip Length – subtract 0.75 cm to account for the radius of the grip rod;
- Elbow Rest Height, Standing – add 40.3 cm to account for the height of the anthropometry box.

Each measurement was taken twice to obtain an average. If the first and second measurements differed by a specified tolerance, then a third measure was taken and the median of the three measures was used. The allowable error was 1% between the two measurements, except for Seated Height, Index Finger Reach, Thumbtip Reach, Grip Reach, Elbow Grip Length, Elbow Rest Height Standing, Bicep Circumference Flexed, and Arm Span, which all had a tolerance of 5%. Allowable errors and correction factors were reviewed and approved by a Level 3 anthropometrist from AUT University.

									CORRECTED
	ID Code	10716003				% Difference	3rd measure required?	Mean or	Mean or
	Measurer initials	SK	1	2	3			Median	Median
1	Head Length		20.6	20.6		0.0%	No	20.6	20.6
2	Head Breadth		16.0	15.8	15.9	-1.3%	Yes	15.9	15.9
3	Bizygomatic Breadth		15.0	15.0		0.0%	No	15.0	15.0
4	Bitragion mandibular Arc		29.6	31.6	31.5	6.8%	Yes	31.5	31.5
5	Interpapillary Breadth		6.2	6.2		0.0%	No	6.2	6.2
6	Seated Height		94.5	94.5		0.0%	No	94.5	94.5
7	Index finger reach		81.9	80.7		-1.5%	No	81.3	82.4
8	Thumb tip reach		81.3	78.0		-4.1%	No	79.7	80.8
9	Grip reach		74.0	74.8		1.1%	No	74.4	74.8
10	Elbow-grip length		35.5	35.8		0.8%	No	35.7	34.9
11	Elbow rest height standing		64.4	64.6		0.3%	No	64.5	104.8
12	Forearm - forearm breadth		61.8	60.0	61.3	-2.9%	Yes	61.3	61.3
13	Bicep Circumference, flexed		41.5	41.8		0.7%	No	41.7	41.7
14	Arm span		182.8	183.5		0.4%	No	183.2	183.2
15	Buttock-Heel length		106.5	106.2		-0.3%	No	106.4	106.4
16	Index finger breadth distal		1.5	1.5		0.0%	No	1.5	1.5
17	Index finger breadth proximal		1.8	1.8		0.0%	No	1.8	1.8
18	Hand breadth		8.2	8.4	8.3	2.4%	Yes	8.3	8.3
19	Palm length		11.7	11.7		0.0%	No	11.7	11.7
20	Hand length		19.5	19.8	19.8	1.5%	Yes	19.8	19.8
21	Hand circumference		19.4	20.1	20.1	3.6%	Yes	20.1	20.1
22	Foot length		25.2	25.2		0.0%	No	25.2	25.2
23	Ball of foot length		18.6	18.8	18.8	1.1%	Yes	18.8	18.8
24	Foot breadth		9.6	9.4	9.4	-2.1%	Yes	9.4	9.4
25	Ball of foot circumference		24.5	24.4		-0.4%	No	24.5	24.5

Figure 8. Example manual measures data collection sheet.

3.7.3 Digital measurements using CySize

Digital measurements were obtained using CySize, a third-party software used by military research organisations such as DRDC Canada and DST-G Australia. CySize is a powerful and accurate visual measuring tape tool for analysing 3-D body scan data.

CySize software training was provided to the Lead Researcher by the University of South Australia. Three DTA scientists were then trained in the use of CySize by the Lead Researcher to provide additional capacity for scan data analysis.

The NZDFAS CySize measurement process was primarily based on the AWAS Landmarking and Measurement process [11]. The AWAS manual was a valuable source of information for file preparation, defining the basic measurement tools and processes in CySize, and troubleshooting issues.

CySize outputs measurement data in three-element arrays. For landmark locations, each location was represented by an x, y and z coordinate. When imported into Microsoft Excel, locations appear as a single string with each coordinate delimited by a space. Using the Excel 'Split' function, the z value was extracted from this array and used to calculate height measures such as Stature, Acromial Height, and Crotch Height. Measures such as Seated Height were calculated by subtracting the height of the seat pan from the seated height of the vertex. Linear and circumferential measures were also provided as three-element arrays, with the elements representing – 1) linear distance between points, 2) surface (geodesic) distance and 3) a virtual tape measure distance. The appropriate element was extracted depending on the measure of interest. Finally, a new calliper tool was developed to provide maximum depth or breadth measures located within a specified region. For example, this tool was used to determine measures such as waist and buttock depth.

3.7.4 Data outlier and logic checks

All automated, semi-automated and manual measurements were exported to a Microsoft Excel spreadsheet and merged with the corresponding demographic information (PEDA files) and service numbers (obtained through the NZDF profile database) to provide a complete data record for each participant. Measurements were then visually inspected for gross outliers or potentially erroneously input data. If the suspect data was collected by either the automated or semi-automated processes, then the original scan was inspected and reprocessed if warranted. If the reprocessed data were plausible then new values replaced the suspect data. Data that could not be reconciled were deleted from the database and treated as null.

The working dataset was then imported into JASP version 0.14.1.0 statistical software (JASP Team, 2020; [19]) for further analysis. As per ISO 15535 recommendations [6], data points greater than ±3 SD from the mean of each measure were inspected for outliers. Additionally, regression residual analysis was performed, and scatterplots were created for measures that were highly correlated. This additional step was useful in identifying measurements that appeared sound, however, their relationship to other correlated measures was suspect. For example, Figure 9 illustrates the use of a regression/scatterplot approach to outlier analysis. The data point circled in red falls within the distribution of both hand breadth and circumference, however, it is evident that the relationship between these two measures is not consistent with other data points. Each measure was then assessed to determine which of the pair is suspect. As with the first pass of data checks using Excel, suspect data were assessed against scan data and adjusted or deleted accordingly.

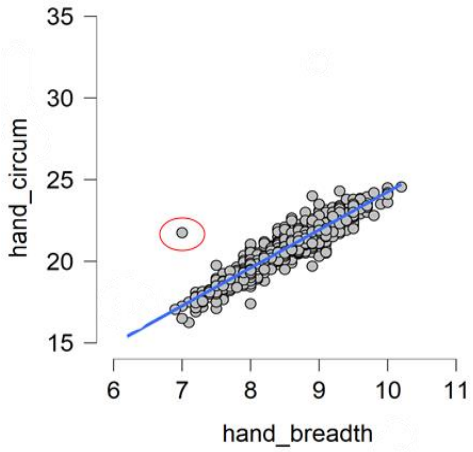

Figure 9. Example of outlier analysis using the regression/scatterplot approach showing a possible outlier (circled in red) that was not identified via the traditional univariate outlier analysis.

4 Results

Demographic information and manual, automated and semi-automated measurement data for all 85 measures were collated in a single Microsoft Excel worksheet for subsequent analysis. These data comprise the master NZDFAS database that will form the NZDF standard for future anthropometric analysis and decision making. Summary statistics for all measures are provided in Appendix I.

4.1 Survey results and measuring locations

A total of 1,000 NZDF personnel participated in the survey, representing approximately 11% of the Regular Force at the time of the survey and 75% of the preliminary target of 1,333 participants (set as 15% of the NZDF Regular Force). As only 1,096 of the targeted 1,333 personnel could be contacted for survey recruitment, the target was adjusted to this value. Total participants represented 91% of the adjusted target of 1,096 personnel.

In terms of measuring locations, Linton (Army), Burnham (Army), Philomel (Navy) and Whenuapai (Air Force) surveys had the most participants at 25%, 15%, 13% and 12% respectively (Table 5).

Table 5. Total NZDFAS participants by survey location.

Location	Male	Female	% of Total
Linton	217	34	25
Burnham	121	33	15
Philomel	85	41	13
Whenuapai	88	36	12
Ohakea	85	22	11
Trentham	72	12	8
Waiouru	46	15	6
Woodbourne	40	9	5
Papakura	35	9	4
Total	**789**	**211**	**100**

4.2 Survey demographics

To provide an indication of sub-group representation, the following section provides a breakdown of the survey sample by various demographic attributes. A comparison of the Actual NZDFAS sample and the Target sample is included for attributes where sampling targets were set to ensure population representativeness (sex, service, ethnicity, trade).

4.2.1 Sex

A total of 789 males and 211 females were measured, accounting for 79% and 21% of the overall survey respectively. While the male sampling target was not achieved (86% success rate), the female target was exceeded by 17% (Table 6). As the overall survey sample was not met, it is meaningful to express the subgroups within the actual survey sample as a proportion of the total survey to evaluate if it is representative of the NZDF.

When compared to the proportion of females in the NZDF, females in the NZDFAS data set were oversampled (Table 6). However, the absolute number of females sampled did not meet the ISO sampling requirements for many measures. The implications of this are discussed in Subsections 5.1 and 5.4.

Table 6. Target and Actual samples by Sex, with percentage of Target Total and Actual Total displayed in brackets.

Sex	Target	Actual
Female	180 (16%)	211 (21%)
Male	916 (84%)	789 (79%)
Total	1,096	1,000

4.2.2 Service

The NZDFAS was a tri-service survey, sampling from the Air Force, Army and Navy. Compared to the sampling targets, the actual Air Force and Army samples exceeded the target by 9%. Due to recruitment constraints, only 44% of the Navy target sample was achieved. When the proportion of each of the three services were evaluated, it is evident that the Army sample comprises 58% of all NZDFAS participants, while only 13% of participants represent the Navy (Table 7).

Table 7. Target and Actual samples by Service, with percentage of Target Total and Actual Total displayed in brackets.

Service	Target	Actual
Air Force	264 (24%)	288 (29%)
Army	535 (49%)	580 (58%)
Navy	297 (27%)	132 (13%)
Total	**1,096**	**1,000**

Breaking each service down by sex, both male and female sampling targets were achieved for Air Force and Navy personnel. Sampling targets were not met for male and female Navy personnel, with only 38% of the Navy male and 67% of the Navy female sampling targets achieved (Table 8).

Table 8. Target and Actual sample by Service and Sex.

Service	Sex	Target	Actual
Air Force	Male	215	215
	Female	49	73
Army	Male	470	486
	Female	65	94
Navy	Male	231	88
	Female	66	44
Total		**1,096**	**1,000**

When considered as a proportion of the actual sample for each service (Table 9), women were oversampled compared to the proportions of women in the Air Force (19.2%), Army (13.6%) and Navy (23.8%) [20].

Table 9. Male and Female representation in the NZDFAS sample by Service.

Service	Male (%)	Female (%)	% of Total
Air Force	75	25	29
Army	84	16	58
Navy	67	33	13
Total	**79**	**21**	**100**

4.2.3 Ethnicity

In terms of ethnicity, the largest group represented was European, accounting for 41% of respondents, followed by Māori/Pacific at 20%. Composition of the 'Other' category (33%) revealed that the majority represented in this category (n=306 of 334) identified as 'New Zealander'.

Target numbers for Europeans were exceeded, while all other ethnicities were under-represented (Table 10). This trend is further illustrated when ethnicity is expressed as a proportion of the Target and Actual survey sample (see percentages in Table 10).

Table 10. Target and Actual samples by Ethnicity, with percentage of Target Total and Actual Total displayed in brackets.

Ethnicity	Target	Actual
European	381 (35%)	407 (41%)
Māori/Pacific Peoples	282 (26%)	199 (20%)
Asian	41 (4%)	22 (2%)
Middle East/Latin American	7 (1%)	3 (0.3%)
African	8 (1%)	0 (0%)
Other	377 (34%)	334 (33%)
Not disclosed	-	35 (4%)
Total	**1,096**	**1,000**

4.2.4 Trade

In terms of trades, targets were only met for the less populated trades, including Specialist, Medical and Health, Aviation and Apprentice (Table 11). Other trades were sampled to around 90% of their target, except for Hospitality (47%) and Combat (74%). As Combat is considered an operational trade that utilises specialised protective and personal equipment, platforms and vehicles, it is desirable that this trade be sampled as completely as possible. When proportionality within the total sample is considered, the Actual sample matched well with the Target sample composition (see percentages in Table 11). Slightly less than half (44%) of the total survey sample is represented by two Army trades – Engineering/Technical and Combat (which is slightly short of the 48% in the Target sample), however, the proportional representation across trades is consistent with the Target sampling proportions.

Table 11. Target vs Actual sampling by Trade, with percentage of Target Total and Actual Total displayed in brackets.

Trade	Target	Actual
Engineering/Technical	276 (25%)	249 (25%)
Combat	257 (23%)	191 (19%)
Logistics and Admin	128 (12%)	112 (11%)
Intelligence IT COMS	100 (9%)	92 (9%)
Other	83 (8%)	73 (7%)
Hospitality	73 (7%)	34 (3%)
Specialist	63 (6%)	96 (10%)
Medical Health	55 (5%)	60 (6%)
Aviation	33 (3%)	46 (5%)
Apprentice	28 (3%)	47 (5%)
Total	**1,096**	**1,000**

4.2.5 Age

Age groups were not sampled according to specific targets, however, Table 12 highlights that the 20-to-29-year age group was the largest group (54%), followed by the 30-to-39 age group (20%). This was consistent for both males and females with the 20-to-29-year age group representing 53% of males and 55% of female respondents (Table 12).

Comparison of the male and female groups was performed to assess if there was any difference in mean age between the two groups. A Shapiro-Wilk test of normality confirmed that both male and female age distributions were normally distributed, however, a Levene's test to evaluate equality of variances revealed a significant difference ($p<0.01$). Based on this information, a Welch's t-test was performed to compare the two groups. Results indicate a significant difference ($t = 1.362$, $df = 369.628$, $p = 0.174$) with males (M = 31.6, SD = ± 10.7, Range = 18-69 years) being older than females (M = 30.5, SD = ± 9.4, Range = 18-59 years). The effect size (Cohen's $d = -0.1$) was small suggesting the average differences in age between the two groups is negligible, despite the statistical significance.

Table 12. Age of NZDFAS participants, with percentage of Female Total, Male Total and overall NZDFAS Sample Total displayed in brackets.

Age Group	Female	Male	Total
<20	10 (5%)	44 (6%)	54 (5%)
20 to 29	117 (55%)	418 (53%)	535 (54%)
30 to 39	44 (21%)	155 (20%)	199 (20%)
40 to 49	30 (14%)	114 (15%)	144 (14%)
50 to 59	10 (5%)	49 (6%)	59 (6%)
60 to 69	-	8 (1%)	8 (1%)
Not disclosed	-	1 (0%)	1 (0%)
Total	**211**	**789**	**1,000**

4.2.6 Rank

Ranks were collated into four groups representing:

- Junior Non-Commissioned Officers and Enlisted (JNCO/E)
- Junior Officers and Officer Cadets (JO/Cadet)
- Senior Non-Commissioned Officers (SNCO)
- Senior Officers (SO)

Sampling targets were not applied to Rank Groups during data collection. Distributions of Rank Groups are provided in Table 13 and Table 14. The NZDFAS survey comprised 85% Non-Commissioned Officers (NCO) and 16% Officers. Within each of these groups, Junior and Senior NCOs represented most participants. Note that Table 14 percentages were calculated based on available data.

Comparing across Services and Sex, the Air Force sample comprised the most Officers, with 30% of female and 24% of male participants being Junior Officer and Officer Cadet or Senior Officers. The Army sample predominantly comprised Junior NCO and Enlisted and Senior NCOs, with 90% of male and 84% of female participants in these Rank Groups. This closely matched the Navy sample where Junior NCO and Enlisted and Senior NCOs comprised 88% of male and 89% of female participants. Conversely, the Navy NCO Rank Groups represent the greatest proportion of women across the three Services at 89%, followed closely by Army women at 84%.

Table 13. Rank Group by Service and Sex.

Rank Group	Air Force		Army		Navy		Total
	Female	Male	Female	Male	Female	Male	
JNCO/E	33	106	58	327	35	57	616
JO/Cadet	16	41	3	13	2	7	82
SNCO	17	58	14	75	4	20	188
SO	6	10	11	31	3	4	65
Missing	1	0	8	40	0	0	49
Total	**73**	**216**	**94**	**486**	**44**	**89**	**1,000**

Table 14. Rank Group as a percentage of valid data by Service and Sex.

Rank Group	Air Force		Army		Navy		Total
	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	(%)
JNCO/E	46	49	67	73	80	65	65
JO/Cadet	22	19	3	3	5	8	9
SNCO	24	27	17	17	9	23	20
SO	8	5	7	7	7	5	7
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

4.2.7 Length of service

Length of service of survey participants was heavily weighted towards recent recruits, with 52% of male and 54% of female respondents having 5 or less years of service (Table

15). Interestingly, 5% of participants did not provide a response to this question. When both age and years of service are considered, it is apparent that the NZDFAS is representative of the average age of NZDF personnel (32 years) but with the majority of participants (69%) having less years of service than the NZDF average of 10.3 years [21].

Table 15. Years of Service of NZDFAS participants, with percentage of Female Total and Male Total displayed in brackets.

Years of Service	Females	Males	% of Total
0 to 5	108 (54%)	386 (52%)	52
6 to 10	43 (21%)	162 (22%)	22
11 to 15	17 (8%)	60 (8%)	8
16 to 20	10 (5%)	47 (6%)	6
21 to 25	11 (5%)	29 (4%)	4
26 to 30	9 (4%)	40 (5%)	5
31 to 35	3 (1%)	14 (2%)	2
36 to 40	0 (0%)	7 (1%)	1
40+	0 (0%)	0 (0%)	0
Not disclosed	10	44	
Total	**211**	**791**	**1,000**

Note: All percentages exclude those that did not disclose years of service

4.2.8 Handedness

A total of 945 participants (95%) provided their handedness information. Of these, the majority indicated right hand dominance (88%), while 1% of respondents indicated being ambidextrous (Table 16).

Table 16. NZDFAS participant handedness. % of Total excludes those that did not disclose handedness.

Handedness	Frequency	% of Total
Right	833	88
Left	96	10
Ambidextrous	14	1
Not disclosed	57	-
Total	**1,000**	**100**

4.3 Comparison of subgroups within the NZDFAS

NZDFAS was a stratified, randomised survey, sampling across services, trades, age groups and ethnicities according to one strata – sex. As age, trade, sex and ethnicity are key determinants of anthropometric differences between groups [22], it is helpful to examine the data to understand if there are any inherent differences between subgroups.

To provide a high-level comparison of anthropometry across these groups, a one-way ANOVA was performed on select anthropometric measures that represent gross body size in standing and seated postures. A Bonferroni correction ($p = 0.0125$) was used to compare mean values across the following measures:

- Stature
- Weight
- Sitting Height
- Buttock-Knee Length

A direct comparison between males and females is appropriate, but it is not recommended to perform statistical analysis between female subgroups (e.g. across services), as the available dataset is too small to allow for valid statistical inferences. As such, the comparison results presented in this section are based on male NZDFAS data only. Caution must be extended to the male dataset as well; when subdivided across various age, ethnicity or occupation groups, the actual sample size is well below the minimum required ISO 15535 sample size for many measures (Appendix J). Thus, the sample size of these groups may not ensure true population variability is represented.

4.3.1 Across sex

Anthropometric differences between men and women are an important factor due to sexual dimorphism resulting in women being, on average, smaller than men for most measures. Dimorphism is characterised by males and females exhibiting different size and body shape characteristics, as illustrated by differences in distribution of stature in Figure 10. Combining male and female data would result in a bimodal distribution (i.e. a distribution with two peaks) which is not suitable for statistical analysis. For this reason, men and women are typically compared separately.

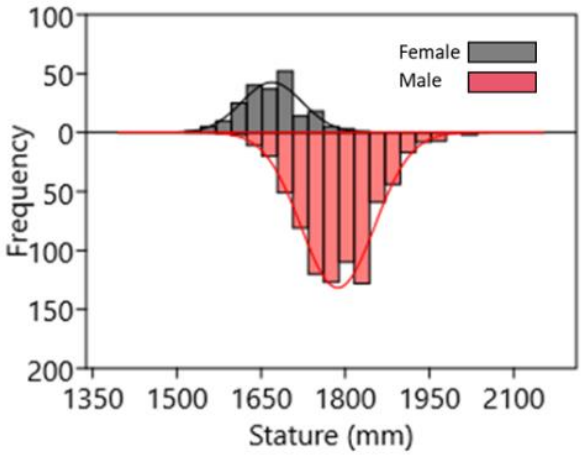

Figure 10. Bimodal distribution of stature between men and women.

Anthropometric differences between men and women are exemplified by significant differences for the following measures: Stature ($F(1,574)$, $p<.001$, $\eta_p^2=0.125$), Weight ($F(1,254)$, $p<.001$, $\eta_p^2=0.211$), Sitting Height ($F(1,347)$, $p<.001$, $\eta_p^2=0.292$) and Buttock-Knee Length ($F(1,136)$, $p<.001$, $\eta_p^2=0.125$) (Table 17).

Table 17. Summary statistics for males and females across key body measures. Significance between groups is denoted at p<.001([a],[b]).

Measure	Female	Male
Stature (mm)	1669 ± 65[a]	1786 ± 54[b]
Weight (kg)	70.2 ± 11.3[a]	85.9 ± 12.8[b]
Sitting Height (mm)	890 ± 30[a]	942 ± 33[b]
Buttock-Knee Length (mm)	599 ± 26[a]	627 ± 30[b]

A bivariate representation of the standing and seated measures of NZDFAS males and female is provided in Figure 11. This figure clearly illustrates the bimodal relationship between these data.

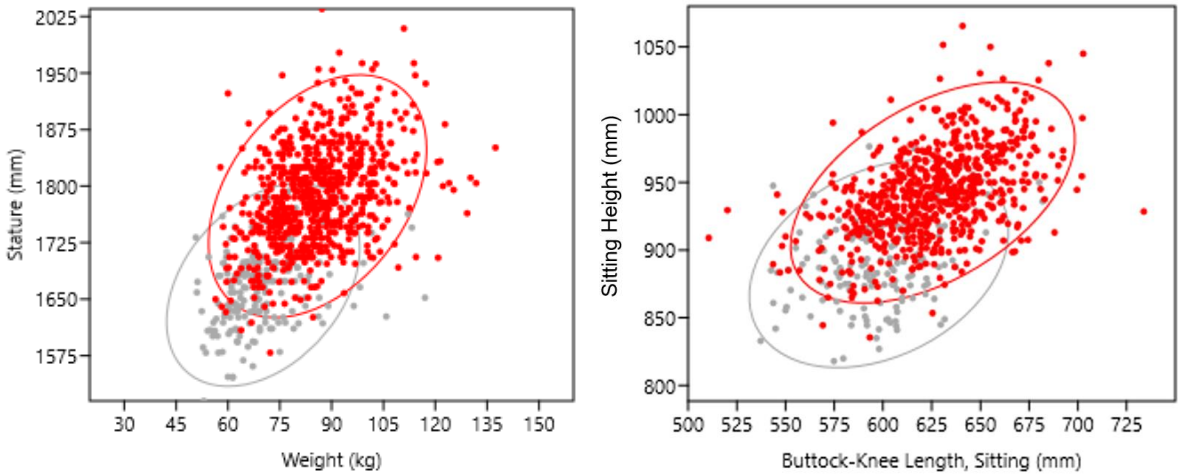

Figure 11. Bivariate plots of standing (left) and seated (right) measures, comparing males (red) and females (grey). Accommodation ellipse is defined at 95%.

It is important to note that not all measures are larger for males. In particular, the mean values for measures such as Buttock Girth, Chest Depth, Crotch-Waist Length Preferred Posterior, Hip Breadth (Standing), Hip Girth Maximum, Sitting Elbow Rest Height and Thigh Girth are similar between the sexes. However, mean values are not typically useful for anthropometric analysis as it is the distribution that is typically more important. For univariate design problems where only one body measure is of concern, it is often assumed that the 5th percentile female is the smallest and the 95th percentile male is the largest person. However, for measures such as Hip Breadth the 5th percentile values belong to males and 95th percentile belong to females (Figure 12). This highlights the importance of consulting the summary statistics in Appendix I when developing system specifics.

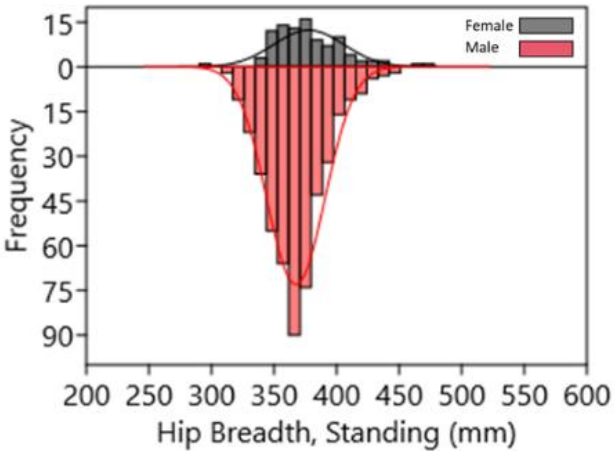

Figure 12. Hip Breadth (Standing) values demonstrating females being larger than males at each end of the distribution.

4.3.2 Across service

While the NZDFAS sampled personnel from across the Air Force, Army and Navy, with only 88 male observations, it is not recommended that the Navy sample be considered as a standalone data set.

Summary statistics for the four select measures are provided in Table 18 and bivariate visualisations of the distribution of these data are provided in Figure 13 and Figure 14. Inspection of these data suggest minor differences, such as the mean height for Air Force personnel being 1.0 cm greater than Army and Navy and Navy being approximately 2.5 kg heavier than the other services. However, results of the ANOVA revealed no main effects of service across all four measures, indicating that the male data of the three services may be pooled into a single NZDFAS dataset.

Table 18. Comparison of four key measures across services (males).

Measure	Air Force	Army	Navy
Stature (mm)	1794 ± 67	1784 ± 66	1784 ± 56
Weight (kg)	85.4 ± 14.1	85.8 ± 12.2	88.0 ± 13.5
Sitting Height (mm)	943 ± 33	943 ± 34	941 ± 27
Buttock-Knee Length (mm)	629 ± 33	624 ± 29	632 ± 28

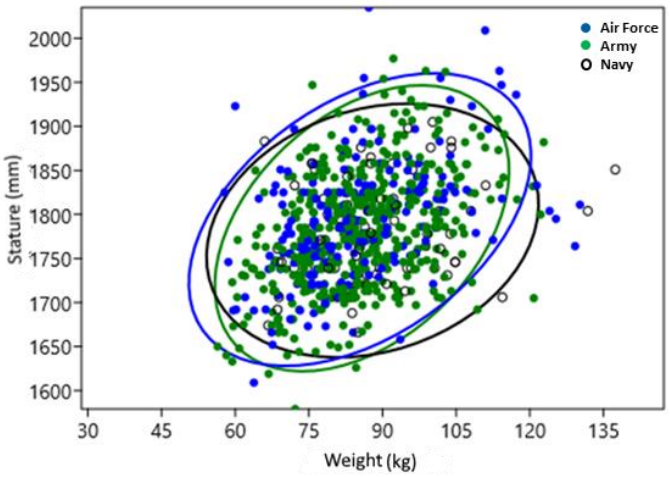

Figure 13. Visualisation of male Stature and Weight across all three services represented in the NZDFAS.

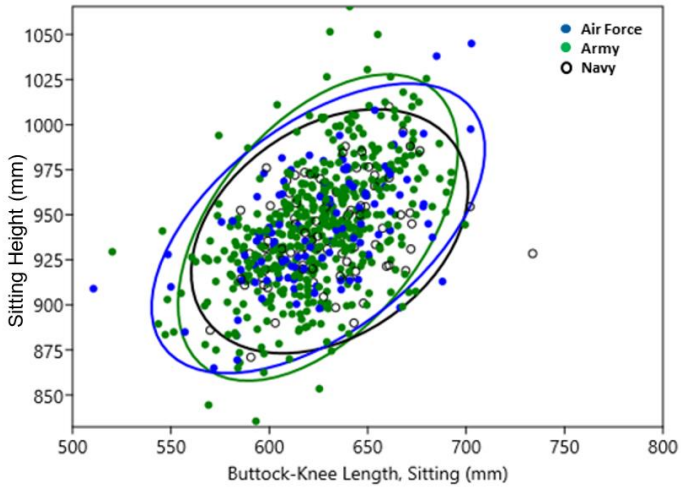

Figure 14. Visualisation of male Sitting Height and Buttock-Knee Length across all three services represented in the NZDFAS.

4.3.3 Across ethnicity

For ethnicity, the majority (94%) of male participants were clustered in three main groups – European, Māori/Pacific and Other. While the Other ethnic group primarily identified as 'New Zealanders', it is likely comprised of European and Māori/Pacific ethnicities. However, as this group comprises a substantial portion of the NZDFAS it warrants further investigation as to possible differences between ethnic groups. As there were few participants in the African, Asian and Middle East/Latin American groups, these were excluded from this analysis.

A one-way Analysis of Variance (ANOVA) was performed, investigating the effect of Ethnicity Group on Stature, Weight, and Seated Height. This ANOVA revealed a statistical difference in Ethnicity Group between at least two groups for stature ($F(2,731) = 5.141$, $p = .006$, $\eta_p^2 = .014$) and weight ($F(2, 693)$, $p < .001$, $\eta_p^2 = 0.033$). However, the partial eta

squared values of 0.014 and 0.033 indicate the effect size as being small for both measures. Thus, the differences between groups likely have little operational significance.

Table 19 provides the results of a Tukey's HSD post hoc test for the one-way ANOVAs performed on each of the four dependent variables with Ethnicity Group as the predictor. Significant differences between Ethnicity Groups are indicated by different symbols while same symbols indicate no difference. For example, Stature is significantly different between European ([a]) and Māori/Pacific ([b]) groups but there are no differences between these groups and the Other ([ab]) group. The same notation is used in the plots below (i.e. different letter superscripts indicate significant differences between groups).

Table 19. Summary statistics for Weight across the three main Ethnicity Groups. Significance between groups is denoted at p < .001 ([a],[b]) and p < .005 (*, [†]) respectively.

Measure	European	Māori/Pacific	Other
Stature (mm)	1796 ± 67[b]	1777 ± 61[a]	1787 ± 61[ab]
Weight (kg)	85.7 ± 13.5*	90.6 ± 12.6[†]	84.2 ± 11.6[†]
Sitting Height (mm)	946 ± 33	943 ± 33	941 ± 33
Buttock-Knee Length (mm)	630 ± 31	626 ± 29	625 ± 28

In terms of Weight, a post hoc Tukey test indicates significant differences between European and Māori/Pacific (adjusted p<.001) and Other and Māori/Pacific (adjusted p<.001), with the Māori/Pacific group being approximately 5-6 kg heavier on average than the other two groups (Figure 15).

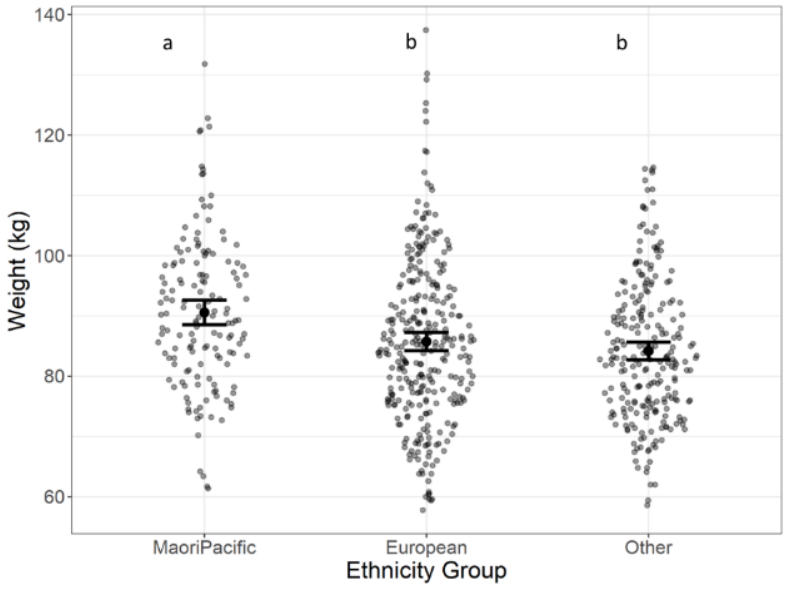

Figure 15. Weight distributions across three Ethnicity Groups. [a,b] denotes significance between groups at p<.001.

With regards to Stature, post hoc Tukey tests revealed a significant difference between the European and Māori/Pacific groups (adjusted p=.005) with European males being, on average, 20 mm taller (Figure 16).

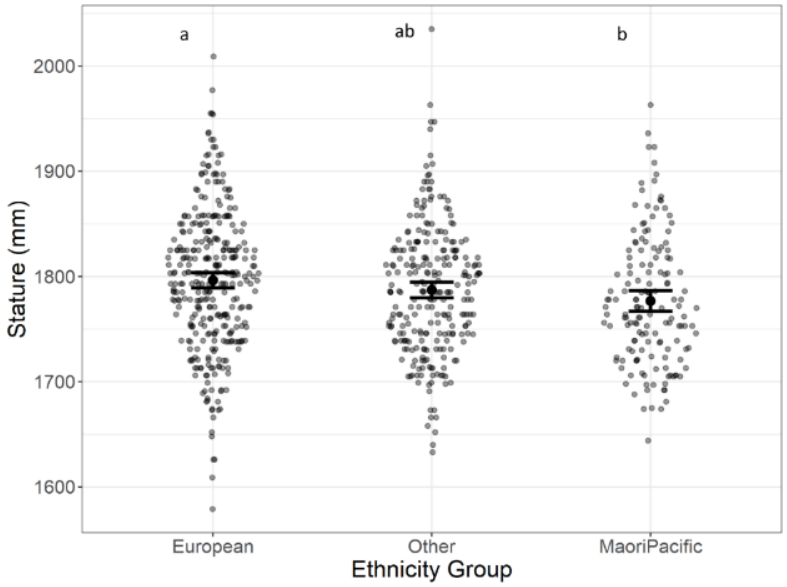

Figure 16. Stature distribution across three Ethnicity Groups. [a,b] denotes significance between groups at p<.005.

Based on the results of the Ethnicity Group analysis, it is evident that there are significant differences in Stature and Weight between key groups. While the effect size is small, it is possible that other measures related to Weight (i.e. circumferences) or Stature (i.e. length measures) may further discriminate between the groups and should be examined in a dedicated analysis.

4.3.4 Across age

It has been previously established that there was no difference between males and females when comparing age (Subsection 4.2.5. Additionally, as the majority (> 70%) of data is represented by the 20-29 and 30-39 age groups, the available data is unsuitable for analysis across a broader age range and there is little utility in comparing across age groups.

4.4 Missing data

Missing data was noted across both sexes for all but two measures – Ankle Circumference and Stature (reasons for missing data are discussed in Section 5.5). While the amount of missing data was low for many measures, 30% of male and 29% of female measures were missing at least 10% of data, and many important measures were missing 20% or more of their data. Table 20 provides a summary of the measures for males and females with an incidence of missing data of at least 20%. From this table, the worst cases of missing data were for Trochanterion Height (50%) and Hip Circumference, Maximum (59%). This is of particular concern for the female dataset as it reduces an already statistically small sample to only 86 valid observations.

Table 20. Measures missing more than 20% of data for male and female NZDFAS participants.

Males		Females	
Measure	**Missing Data (%)**	**Measure**	**Missing Data (%)**
Trochanterion Height	50	Hip Circumference, Maximum	59
Hip Circumference, Maximum	40	Hip Breadth, Standing	54
Hip Breadth, Standing	38	Crotch Height	42
Crotch-Waist Length Preferred, Posterior	35	Trochanterion Height	39
Vertical Trunk Circumference	33	Crotch-Waist Length Preferred, Posterior	39
Malleolus-Hallux Length	31	Head Circumference	38
Thigh Clearance	27	Vertical Trunk Circumference	36
Waist Breadth	24	Waist Circumference, Preferred	31
Abdominal Extension Depth, Sitting	23	Malleolus-Hallux Length	30
Crotch-Waist Length Preferred, Anterior	23	Crotch-Waist Length Preferred, Anterior	24
Buttock Depth	21	Buttock-Popliteal Length	23
Crotch Height	21	Thigh Clearance	22
		Iliocristale Height	22
		Abdominal Extension Depth, Sitting	21

Counts of valid observations and missing data for each measure in the NZDFAS are provided within the summary statistics tables in Appendix I. When applying these data, users must evaluate it in the context of minimum sampling requirements (Appendix J) and against demographic data to determine if there is any bias due to the missing data and establish if there is sufficient data to provide a representative sample.

4.5 Participant comments relating to clothing and equipment fit

Comments from surveyed personnel emphasised issues of fit with uniform and equipment at the time of the survey. Although the average personnel rating of shirt and trouser fit was between ‘acceptable’ and ‘good’, individual feedback from personnel highlighted issues with the fit and sizing of uniform.

Comments relating to packs highlighted two main themes – a dislike of the Terminator pack and a preference for the Alice pack. Comments about webbing, body armour, footwear, and helmets generally focussed on issues of fit, sizing, comfort and equipment

integration. Comments about vehicles suggested that the space within Pinzgauers is too cramped for some individuals, particularly those of a larger stature.

Comparison of the top comments for male and female personnel revealed greater fit and sizing issues for female personnel, for various pieces of kit including uniform, body armour, and webbing. Although a reflection of the fact that the 'male' standard is used in equipment design and supply, particularly in the case of body armour, this finding accentuates the need for such items to consider female body dimensions.

It should be noted that the survey likely did not capture all issues from personnel. Had personnel been asked specific questions around each item, different feedback may have been received. This means that although the comments analysis captures a snapshot of issues at the time (most of which would likely be enduring due to minimal change in clothing and equipment since the survey), it may not represent a true reflection of the magnitude of all issues.

5 Discussion

5.1 Body dimensions

The study produced 85 anonymised body dimensions (including body weight). Summary statistics for these can be found in Appendix I. The study also produced an anonymised body scan and measurement database (three postures – two standing and one seated).

5.2 Sample size

As discussed in Section 4.1, the overall sample size of 1,000 participants (789 men and 211 women) achieved 91% of the revised target of 1,096 participants and represents 11% of the 2018 NZDF Regular Force population (Table 21). A key explanation for the difference between target and actual samples was the difficulty in meeting the Royal New Zealand Navy target, with only 131 personnel or 44% of the target being measured. Even with the reduced sample size, the NZDFAS survey represents approximately 13% of women and 10% of men in the NZDF, according to 2019 statistics [23].

Table 21. Comparison of Anthropometry surveys from the FVEYs community [[7],8,14,16,17,24]. The percentage of the total Regular Force sampled is included in brackets where data was available.

	New Zealand 2018	Canadian Forces 2012 [8]	Australian Army 2012 [7]	Australian Navy 2015 [14]	US Army Personnel 2012 [16]	US Marine Corps 2010 [17]	UK Armed Forces 2007 [24]
Total measured	**1,000 (11%)**	2,205 (3.2%)	2,138 (7.1%)	1,322	5,178 (0.5%)	1,921	2,470 (1.2%)
Males	**791**	1,890	1,861	1,322	4,082	1,301	2,160
Females	**211**	315	277	232	1,986	620	311
No. of measures	**85**	52	85	87	93	94	120

Sampling targets in anthropometric surveys can be determined according to two criteria – 1) ISO 15535 minimum sampling requirements and 2) proportional representation of subgroups. While the achieved sample size in the NZDFAS is reasonable from the perspective of proportionality, the absolute sample size is limited for those measures that demonstrate a large coefficient of variation. Based on this knowledge, a small sample size may introduce bias or fail to adequately represent the true variability of the population distribution. The degree to how a small sample size affects measurement relative accuracy is illustrated in Appendix J, which provides a listing of minimum sample size requirements for each measure in the NZDFAS calculated in accordance with ISO 15535 guidelines.

Based on ISO sampling requirements of 5^{th} to 95^{th} percentiles at 95% confidence and 1% relative accuracy, the current NZDFAS sample meets 67 of 85 (79%) requirements for male data and 17 of 85 (20%) for female measures. Thus, despite NZDFAS females being proportionally oversampled, the absolute sample size is insufficient to adequately represent most measures at 1% relative accuracy. Due to missing data, the adequacy of the sample size is likely even lower than this calculation.

The ISO sample size requirement is based on sampling from a large population. As a result, some of the required minimum sample sizes are greater than the number of women in the NZDF. For example, a minimum of 2,375 women are required to adequately sample body weight with 95% confidence and 1% relative accuracy. This compares to the 2019 reported total of 1,651 women in the NZDF Regular Force. Reducing the relative accuracy to 2% reduces the required sample size to 594 women, which is still a substantial proportion (36%) of the total population of NZDF women.

When a required sample size is greater than 5% of the target population, a modified version of Cochran's (1977) finite population correction formula can be used to adjust the sample size to reflect the smaller target population [25].

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$ (2) Finite population sampling correction formula.

Where:

n_0 = Sample size derived from the ISO 15535 equation;

N = Size of the target population.

Using the example of body weight for the reported 1,651 women in the NZDF Regular Force [23], the adjusted sample size would be:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} = \frac{2{,}375}{1 + \frac{(2{,}375 - 1)}{1{,}651}} = 974$$

Thus, the required minimum sample size at 1% relative accuracy is reduced from 2,375 to 974 women, while still retaining the confidence and precision of the ISO 15535 calculation. Note that at 2% relative accuracy, the required sample size is reduced from 594 to 437 individuals.

As mentioned above, 79% (67) of male and 20% (17) of female measures (not accounting for missing data) satisfy ISO sampling requirements. No determination can be made for eight of the NZDFAS measures as suitable data to calculate sample size could not be found in other surveys. Applying the Cochran correction formula increases the acceptable sample rate to 80% of measures for males and 34% for females. This increases to 91% for males and 80% for females at 2% relative accuracy. As each measure has a unique recommended sample size, it is important to consult Appendix J to determine the sampling quality of any measure of interest. In general, measures that require greater sample sizes and are thus most affected by insufficient sample size involve circumferential and depth measures in the hip, abdominal and chest regions. Table 22. provides a summary of the NZDFAS measures requiring the largest sample size for men and women. Due to the limited sample size of the NZDFAS, these measures are under-sampled at the 1% relative accuracy level, and in some cases under-sampled at 2% relative accuracy. Use of these data for design or system specification will require an understanding of the limitations of under sampling data, as they may not accurately represent the true mean and variability of the target population.

Table 22. NZDFAS measures requiring largest sample size at 95% confidence and 1% relative accuracy. Cochran's correction has been applied to required sample size.

Males		Females	
Measures	**Required Sample Size**	**Measures**	**Required Sample Size**
Weight	1,885	Weight	974
Abdominal Extension Depth, Sitting	1,550	Waist Depth	896
Waist Depth	1,541	Abdominal Extension Depth, Sitting	837
Waist Circumference, Natural	1,094	Waist Circumference, Natural and Preferred	701
Elbow Rest Height	1,065	Elbow Rest Height	679
Elbow Rest Height, Sitting	1,003	Chest Depth	661
Buttock Depth	921	Waist Breadth	657
Waist Breadth	903	Buttock Depth	618
Chest Depth	858	Elbow Rest Height, Sitting	614
Biceps Circumference, Flexed	760	Biceps Circumference, Flexed	589

5.3 Demographics

The demographic results show that the target numbers were achieved and indeed exceeded for Air Force and Army. Unfortunately, the low success rate of the Navy survey meant that the overall 1,096 target was not achieved. Several uncontrollable factors, such as absence due to leave or training, posting cycles and operational deployments, affected participation. If the Navy target had been met then the final count would be in the vicinity of 1,169 personnel, translating to 106% of the target.

Plans for a second Navy survey have been discussed but have not been implemented due to personnel availability. It is hoped that a second survey will be approved in the near future.

The NZDFAS female participant rate is particularly positive. However, only 86% of the male target was achieved.

The largest proportion of the sample was between 20 and 29 years of age with most being relatively new to the organisation (52% had 0 to 10 years of experience). Whether these proportions are reflected in the main population (n = 8,885 Regular Force) requires further investigation, however, a younger demographic is arguably preferable considering

operational procurement decisions will generally be targeted at users within the 20-40 years age range.

Although the original target numbers for trade and ethnicity were not met for all sub-groups, the final sample still reflected the proportional differences of both categories across the NZDF. 44% of the participants came from the Engineering/Technical and Combat trades, which is important as these trades often wear specialised protective equipment. Having sufficient anthropometric data is beneficial for determining clothing, equipment and vehicles specifications.

Analysis of ethnicity reveals that the Māori/Pacific group tends to be shorter than the European group and heavier than both European and Other groups. Differences between Māori and other groups are exemplified by Baxter and Baxter [11] who found significant differences in foot dimensions of Māori in the New Zealand Army, resulting in a high proportion of these soldiers being unable to find a suitable boot size. Given that Māori comprise approximately 14.6% of the NZDF Regular Force [26], and a portion of the 'Other' group are likely also of Māori descent, it is important to further explore the anthropometric differences of these groups to determine the potential implications for system specification and design.

5.4 Sample weightings

As the NZDFAS is based on a proportional sampling, it is important to adjust sample observations by weighting factors to ensure that the survey is representative of the target population. As a minimum, sampling weightings need to be calculated for the primary strata of sex, if male and female data are to be combined when calculating summary statistics for future project use. However, age and ethnicity may also be reasonable candidates for calculating weighting factors if comparison of these factors are important. A sample weighting compensates for biases (i.e., under/over representation) of sample proportions. Weightings are then applied to measurement values in the corresponding strata to provide statistics such as a weighted mean or median.

Sample weightings are simply the reciprocal of the probability of the likelihood of being sampled. For the NZDFAS, sample weightings for males and females are calculated as follows:

$$w_{sex} = \frac{Population\ Proportion_{Sex}}{Sample\ Proportion_{Sex}}$$

(3) Formula for calculation of simple sample weightings.

Where w_{sex} represents the sample weighting for males or females.

Based on the NZDFAS target and actual sample for sex (Table 6), males were under-sampled (79%) and females oversampled (21%) compared to their proportion in the NZDF of 84% and 16% respectively. To adjust for this, the sample weightings for males and females are as follows:

$$w_{males} = \frac{84\%}{79\%} = 1.06$$

And

$$w_{females} = \frac{16\%}{21\%} = 0.76$$

To use these weightings to calculate the combined average Stature of men and women, one would use the following formula:

$$Mean\ Stature_{NZDFAS} = \frac{\sum_{i=1}^{m} 1.06(men_i) + \sum_{i=1}^{n} 0.76(women_i)}{m+n}$$

Where i = the Stature for i^{th} men or women;

m = the total number of observations of Stature for males;

n = the total number of observations of Stature for women.

5.5 Missing data

Data loss is often the result of technical issues affecting equipment function or calibration, administrative errors such as failure to review, save or backup data, or procedural errors during data collection.

Technical issues were the main contributor to data loss, due to poor scan quality because of arm/torso interference and poor foot scan quality. As these were identified as concerns during the NZDFAS validation study [5], a stricter protocol would have avoided or mitigated these issues. Missing data affects the quality of many measures, for example, 59% of missing Hip Circumference, Maximum data reduced the available female data to only 86 valid observations. When all measures are considered, 30% of all male and female measures are missing at least 10% of data. Missing data is considered a violation of data integrity that affects not only the measure in question, but also has an adverse effect on multivariate analysis, as the relationship between missing and non-missing variables is affected. For example, when designing gloves, hand length and width may be measures of concern. If a hand breadth value is missing, then the associated hand length datum is of less value since these measures must be considered concurrently. Additionally, when considering the minimum required sample, missing values can result in a decreased representativeness of the data due to under sampling. Additionally, if there are systematic reasons for the missing data (e.g. taller individuals disproportionally affected), bias will be introduced into the dataset.

Inspection of the measurements demonstrating high levels of missing data reveals that most measures have two distinct features in common. These measures were primarily scan-derived from Posture 1. Second, except for women's Head Circumference, they were dependent on landmarks identified in the region extending from the hips to the abdomen.

Two key factors account for the loss of data in the hip to abdomen region. In the case of males, many participants wore baggy boxer shorts which adversely affected the ability to identify key landmarks, such as the crotch, and interfered with the ability to make accurate surface measurements due to the looseness of fabric or folds (addressed further in Subsection 5.5.1). For both male and female participants, the arm was often held too close to the body during scanning in Posture 1 (see Subsection 3.7.3). This occluded landmarks such as the Trochanterion, Iliocristale and others around the hip, making it impossible to take measures based on these landmarks. Second, as the arm could not be distinguished from the hip or torso, circumferential measures could not be obtained in this region. These scan posture artefacts have been previously identified and are illustrated in Appendix E.

Missing data for Head Circumference is primarily due to the influence of hair affecting the quality of the scan. Women's long hair was gathered in a bun under the scan cap. As the Opisthocranion (the most posterior point on the head) was obscured by the bun, Head Circumference measures were impossible to extract on these individuals. Ideally, Head Circumference should be taken using the manual method, with the hair not gathered in a bun and the bulk of hair compressed by the measuring tape. If Head Circumference is taken by scan, then the modified scan cap recommended in ISO 20685 should be used. This cap has a hole in the superior-posterior portion of the cap to allow the hair to be drawn through and the hair bun can be formed externally.

Another measure adversely affected by missing data is Malleolus-Hallux Length. As the Vitus scan is based on the view of two laser heads, the lower head is obscured by the scan podium when taking measures near ground level. This introduces interference, resulting in scan anomalies. In future studies, it is not recommended to use the Vitus scanning system for foot measures. Alternatively, a small standing block could be used to raise the participant above the podium by several centimetres.

Seated measures, such as Buttock-Popliteal Length, Thigh Clearance and Abdominal Extension Depth, were affected by voids in the scan mesh and surface reconstruction errors caused by the CySize software. These issues could be avoided in future by slight changes in posture to reduce shadowing (e.g. seated posture with arms straight at side, sit forward to create gap between seat and popliteal fossa). Scan voids on the top of the thigh could be prevented by placing a small dome marker on the top of the thigh to provide better scan reflectance.

In addition to scan pose and scan technical considerations, an administrative error resulted in no Seated Height data being collected for the 125 RNZAF participants (41 women, 117 men) at Whenuapai. This accounts for most of the total of 144 missing cases of Seated Height, resulting in the loss of one half of RNZAF sitting height data. Such a loss is of particular concern as sitting height is an important consideration for cockpit accommodation.

5.5.1 Quality control and improving scan quality

As most measures were extracted from Posture 1, in future, scan quality control checks should be performed to quickly verify proper arm separation from the hips and torso and thigh separation to facilitate circumferential and crotch measures. This may involve posture verification by the scanner operator or the use of aids such as spacers to assist in setting the posture and ensuring a minimum distance is maintained between the arm and torso. A study by Kouchi and Mochimaru [26] indicates that accurate shoulder height and breadth measures could be achieved from 3-D scans as long as arm abduction was less than 5° and leg abduction less than 20°, suggesting that arm and leg separation could be greater than what was typically adopted during data collection.

Some scan issues were the result of artefacts caused by the CySize auto body fill process. These could be mitigated in future by processing the scans as soon as possible after scanning, to identify any potential issues in scan and measurement extraction quality. Although this is a time-consuming process and is likely not feasible after each scan is obtained, daily or even weekly incremental processing of scans would allow early detection of postural concerns and facilitate adjustments to the scanning process as issues are identified.

As many male participants wore boxer shorts, a stronger emphasis on wearing proper undergarments could have been made during the survey recruitment process to mitigate this issue. Additionally, low-cost disposable medical/travel briefs could have been available for any participants that did not bring suitable undergarments. Again, continuous processing of all or randomly sampled scan data would have identified issues in scan and measurement extraction quality early so mitigating procedures could be implemented to minimise further data loss.

As the bulk of hair under the scan cap was a major contributor for women's Head Circumference data loss, a second scan could be taken with the hair hanging loosely below the scan cap. This would reduce the scan error greatly; however, this measure is best obtained using manual methods and should be captured accordingly in future surveys.

5.5.2 Remediation of missing data

It may be possible to recover missing anthropometric data through three possible techniques – imputation (and other associated numerical techniques), reprocessing of existing scan data, and collection of new data. It must be emphasised, however, that these methods will not provide as accurate and valid data as would have been achieved with direct measuring techniques.

5.5.2.1 Imputation

Imputation of anthropometric data can be achieved through many techniques, such as replacement with mean, regression techniques, or matching techniques. Additionally, there are several machine learning statistical concepts, such as random forest [28] and

Support Vector Machines [29], that have emerged recently which show promise for imputing anthropometric data. Due to the large amount of missing data in the NZDFAS database across many related variables, the use of such techniques must be carefully examined to establish if they are valid methods to impute missing data.

Nearest Neighbour Matching is a form of imputation whereby an anthropometric 'twin' of a survey participant located within the current or similar database is identified. Assuming this twin has a complete data profile, the missing data of the survey participant is then populated with the relevant twin's data. One particular method cited in anthropometric studies is hot-deck swapping [30]. This involves finding the nearest neighbour of a survey participant based on the minimal Cartesian distance of several measures. The measurement(s) of the nearest neighbour, or twin, is then used to complete the missing data of the survey participant.

Ideally, the data from which potential source twins are derived should be matched to the target twin based on demographics such as sex, age, race and occupation. The selection of matching measurements should also be meaningfully related to the measure that is to be imputed. For example, when imputing a measure such as Waist Circumference, matching based on arm and leg length may not provide an accurate match compared to matching on Torso Circumference measures.

A practical example of matching is an evaluation of the quality of NZDFAS Head Circumference data. As these data were obtained from scan data, there is a concern that the resulting data overestimated true Head Circumference. A matching evaluation was completed by comparing scan derived Head Circumferences of NZDFAS males and females with those manually measured in the most recent U.S. Army Survey (ANSUR II) [15, 16]. As Head Breadth and Head Length were measured manually in both ANSUR II and NZDFAS, using the same method, these measures could be used to calculate nearest neighbour head sizes between the two surveys.

To perform this comparison, only NZDFAS participants where all Head Breadth, Head Length and Head Circumference were available were evaluated. This resulted in a reduced database of 757 men and 120 women. The Cartesian distance between each NZDFAS and ANSUR II participant's Head Length (HL) and Head Breadth (HB), for participants of the same sex, was computed using the following formula:

$$\text{Distance} = \sqrt{(\text{HL}_{\text{NZDFAS}} - \text{HL}_{\text{ANSUR II}})^2 + (\text{HB}_{\text{NZDFAS}} - HB)^2} \quad (4)$$

(4) Distance calculation for head nearest neighbours.

For each NZDFAS participant, distance values were computed to each ANSUR II participant and then sorted from smallest to largest. The Head Circumferences of the five closest ANSUR II matches were then averaged to provide a predicted Head Circumference for each NZDFAS participant. In general, minimum nearest neighbour distances were in the order of 1 to 5 mm indicating a good match was found between surveys.

To compare the Anthroscan measured NZDFAS Head Girths (circumferences) and those predicted from ANSUR II data, a simple delta measure was calculated by subtracting the Anthroscan measure from the predicted measure. Figure 17 provides a visualisation of these results. In general, the ANSUR II-predicted Head Girths for each NZDFAS participant are smaller than Anthroscan measures for both males ($t(756) = 46.96$, $P < .001$, Cohen's $d = 1.71$) and females ($t(119) = 8.81$m, $p < .001$, Cohen's $d = 0.80$). The mean difference in Head Circumference between Anthroscan and predicted measures is -18.0 mm and -10.3 mm, for males and females respectively. This is expected as this method compensates for the hair bulk that is included in the NZDFAS measure. Interestingly, a greater difference is found in males which is unexpected as women tend to have longer hair which may result in increased bulk. When the difference is normalised to absolute head size, male head size is reduced by 3.0%, while female head size is reduced 1.7%, thus differences in head size do not account for the observed difference between males and females. In lieu of head size effects, it is possible that initial differences between NZDFAS and ANSUR male and female sample size, head size distribution and scan extraction methodological issues may account for differences in predicted head size.

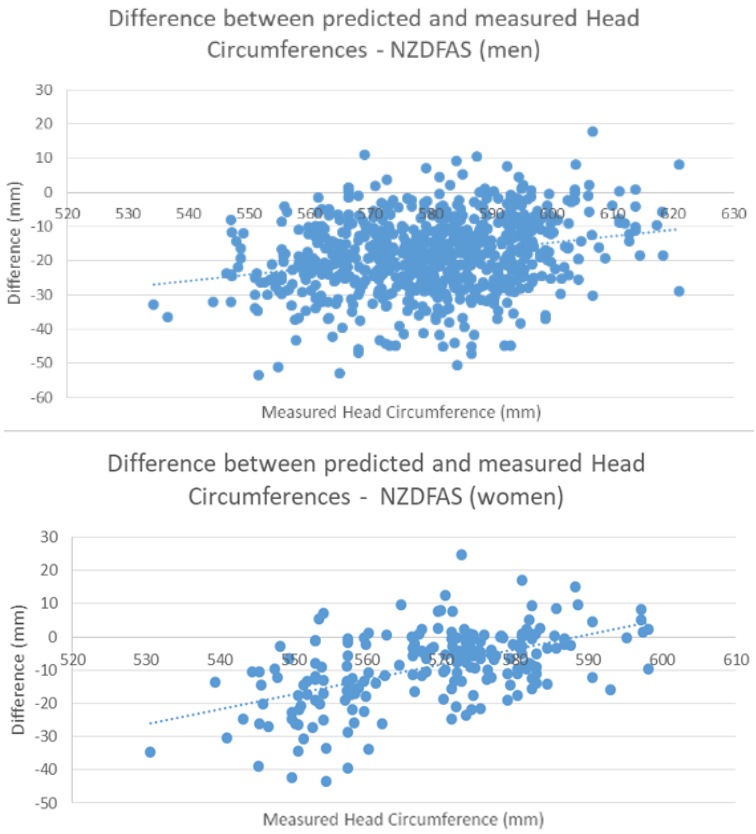

Figure 17. Comparison of difference between ANSUR-predicted and measured Head Circumferences for NZDFAS males and females.

Inspection of NZDFAS data before the matching study indicated that the Head Girths of males and females tended to be larger than ANSUR II for any given Head Breadth (Figure 18). While this could be due to demographic differences between the two populations, it is likely that a large portion of this is due to systematic methodological differences between manual and scan derived measures.

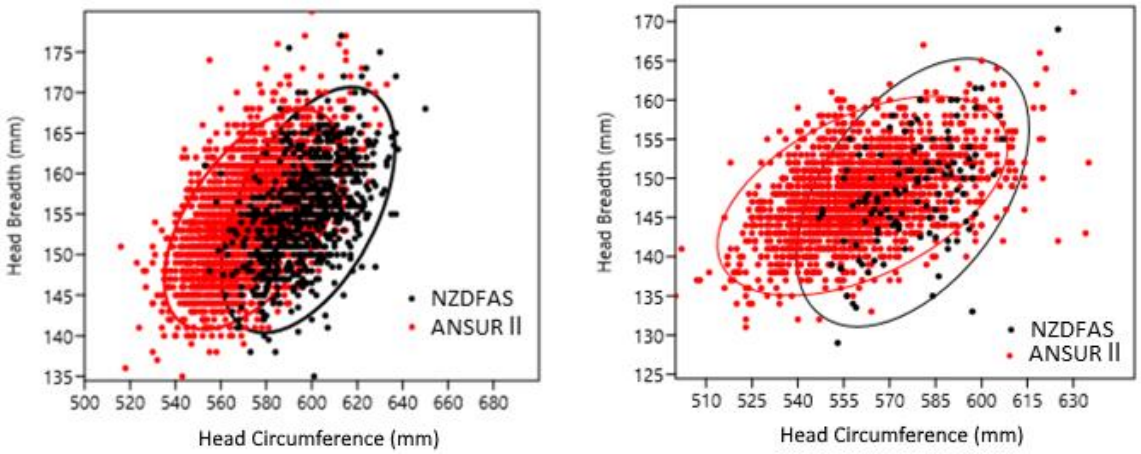

Figure 18. NZDFAS with ANSUR II Head Breadth and Head Circumference distributions for males (left) and females (right).

When NZDFAS head circumference is adjusted by substituting the average of the five nearest ANSUR II Head Breadth and Head Length neighbours to the data, it is apparent that the NZDFAS Head Circumference data is in much greater correspondence with the ANSUR II data (Figure 19). While it appears that this realignment of data is indicative of a bias in the NZDFAS Head Circumference data, a thorough analysis that includes matching databases on age, ethnicity and possibly occupation should be completed.

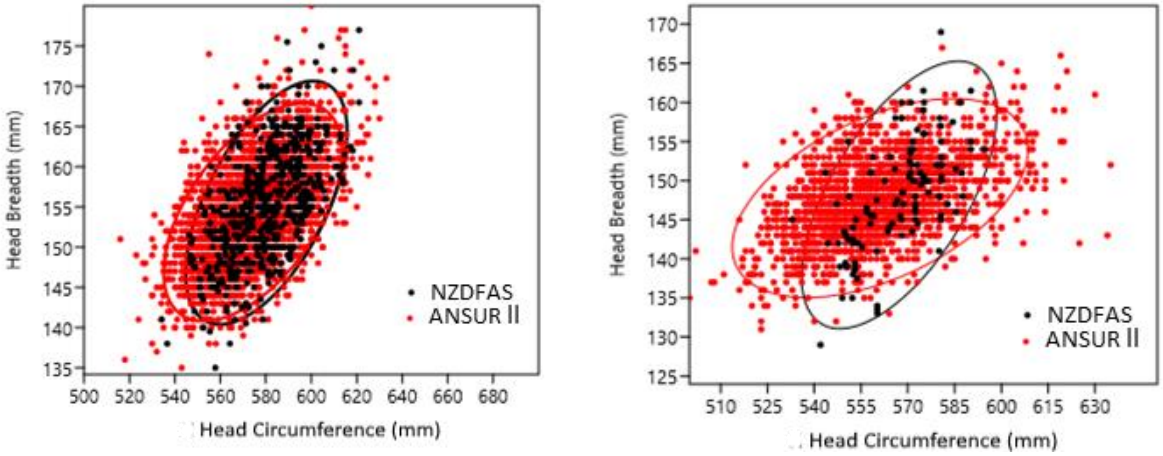

Figure 19. Nearest neighbour adjustment of NZDFAS Head Circumference for males (left) and females (right).

In addition to ensuring demographic similarities between the matching and target databases, it is also important to ensure that the two databases are comparable in body size and shape variability and that the matching database is large enough to provide a sufficient number of potential matches. Ideally, the matching database would represent a wider distribution of body sizes and overlap the extreme regions of the target database. For instance, in the Head Circumference example above, the average distances between the 10 best matches were 1.3±1.6 mm for men and 3.0±2.7 mm for women. However, the maximum distances were 21.8 mm for men and 17.2 mm for women indicating that there were several head sizes that were not well matched between surveys. Mismatches are

likely to occur at the extremes of the distribution if the matching database does not adequately represent those regions.

5.5.2.2 Regression

Regression is a common approach used to predict measures based on other measures that are highly correlated. For example, Sitting Height is highly correlated with Eye Height, Sitting (r = 0.893 for males and 0.909 for females), therefore a reasonable prediction of Sitting Heights may be achieved through the following linear regression formulas:

$$\text{Sitting Height (mm)} = 0.89\ \text{Eye Height, Sitting} + 206.05\ \text{(males)}$$

$$\text{Sitting Height (mm)} = 0.94\ \text{Eye Height, Sitting} + 158.24\ \text{(females)}$$

In all cases of regression, it is recommended that separate analyses be performed for men and women, as the proportionality between measures may vary between the sexes. Suitability of the regression may be evaluated by inspection of the regression residuals to understand the variability of the prediction and identify any outliers. A Q-Q plot will also be helpful in ensuring that the data are normally distributed and that the regression is sufficiently robust to accurately predict measures at the small and large end of the distribution.

5.5.2.3 Derived measures

A second method that may be applied in certain circumstances involves the derivation of new measures from existing measures. Derivation of measures is a method that has been extensively used in surveys such as ANSUR II, where 41 derived measures were obtained by adding or subtracting directly measured dimensions to create new ones. It must be emphasised that this technique is generally not as accurate as obtaining the measurement directly, but if the underlying measurements were obtained with sufficient precision, then the derived measure is valid for design use.

As an example, and as an alternative to using regression, Sitting Height may be derived using several measures that were collected as part of the NZDFAS. For example, the distance from the Ectocanthus to the Vertex can be calculated as the difference between Stature and Eye Height, Standing. This measure should be fixed within each participant, as both measurement landmarks are located on the head and are not susceptible to postural variability as other measures that cross joints would be. Thus, Sitting Height may be represented by the following formula:

$$\text{Sitting Height} = (\text{Stature} - \text{Eye Height, Standing}) + \text{Eye Height, Sitting}$$

There is sufficient data in the NZDFAS to reclaim almost all missing Sitting Height data using this method.

Although derived measures were not used in the NZDFAS, there are sufficient measures and landmarks to identify additional measures that may be of use for specific clothing and equipment design projects. For example, front and back ballistic plates are often sized

based on an individual's front and/or back length. As C7 and Suprasternale heights are provided in the NZDFAS, along with 10th Rib, Iliocristale and Waist Height, sufficient data is available for defining sizing for this personal equipment based on torso lengths defined by these measures. Examples of other useful, common measures that can be derived from NZDFAS measures include:

- Body Mass Index $= \frac{\text{Stature}}{\text{Weight}^2}$
- Suprasternale Height, Sitting $=$ Sitting Height $-$ (Stature $-$ Suprasterale Height)
- Ectocanthus to Vertex Height $=$ Sitting Height $-$ Eye Height, Sitting

Considering the number of measures available, as well as the landmark coordinates extracted using CySize, there are likely many more derived measures that can be computed from existing data.

5.5.2.4 Reassessment of alternate scan posture

As mentioned in Section 5.5, many missing values were a result of arm and torso/hip occlusion, as well as thigh interference caused by too narrow a stance when adopting Posture 1. This results in two issues that adversely affect accurate body measurements. First, large occlusions in the scan mesh may occur as the laser light is not able to penetrate small gaps between the arm and torso, or between the thighs. Filling large occlusions often results in geometric errors as the missing scan regions have to be estimated. Second, the measuring software may be unable to differentiate between close body segments, resulting in the formation of a scan 'webbing' that bridges the gap between segments.

It is possible that many missing data values may be completed by analysing the Posture 2 scan data that was collected for each participant. As illustrated in Figure 20, Posture 2 is an open stance with arms and legs held apart providing unobtrusive views of the side of the abdomen, hip and thigh regions. In fact, this posture is very similar to the 'Standard' posture (Figure 4) that is prescribed by Human Solutions for extraction of most scan measures and by the AWAS survey for measures that are difficult to obtain in Posture 1 (e.g. Thigh Circumference).

Figure 20. Examples of Posture 1 (right) and Posture 2 (left) collected as part of the NZDFAS.

Analysis of Posture 2 can allow recovery of missing circumferential and breadth data about the central region of the body, and many missing heights can also be extracted, providing the leg separation angle is less than 20° in accordance with the guidance provided by Kouchi, as described in Subsection 5.5.1. As an example, Axilla Height (18% missing from females) and Crotch Height (21% missing from males) may be better identified in this posture than Posture 1, providing valid measures of these measures.

Finally, Posture 2 provides an alternate scan model that may be free from any scanning artefact that may have affected Posture 1. This provides an opportunity to review measures obtained from Posture 1 that may have been based on a poor-quality scan and recover missing measures such as Malleolus-Hallux Length.

Inspection of the NZDFAS list of measures suggests that many of the standing measures could be satisfied by Posture 2 except for those requiring unique postures such as reaches, hand and face measures and certain arm measures. Shoulder measures are not recommended in this posture as excessive arm abduction affects the location of the deltoid and acromion landmarks. Fortunately, measures depending on these landmarks are not substantially affected by missing data. The wearing of boxer shorts, primarily by male participants, remains an issue of concern and it is likely that measures about the hip and crotch will remain unresolved for these participants.

When considering Posture 2 for completing missing data, it is important to carefully review each scan to verify that the posture is relaxed and neutral without any exaggerated separation of the legs (waist/hip measures) or raised arms (axilla/chest height measures), which may affect measurements in these regions. If there is concern regarding the reliability of any measure between Postures 1 and 2, a simple reliability study could be conducted comparing valid measures from Posture 1 to those obtained from Posture 2.

5.5.2.5 Correction of mesh errors

Extracting measurements from Posture 2 is a reasonable alternative to obtain measures affected by scanning artefacts in Posture 1. Figure E-1 in Appendix E provides an example of these artefacts created during the body autofill process employed by both CySize and Anthroscan software. As discussed previously, the body autofill process removes any voids in the scan surface to provide a complete surface mesh and facilitate measurements. However, this process is easily confused when two body segments are in proximity. The small gap between the segments is a void in the scan surface and the autofill algorithms create a bridging mesh to complete this void. While CySize software provides a rudimentary tool to manually identify the separation of body segments, Human Solutions Anthroscan software provides two comprehensive tools called the Slits Wizard and Bridge Cut Wizard which allow the user to identify areas to be separated, such as segments at the axilla and crotch, and repair any mesh bridges that are created during the surface reconstruction (autofill) process. For example, Figure 21 demonstrates the identification and repair of a bridge artefact created between the arm and the hip.

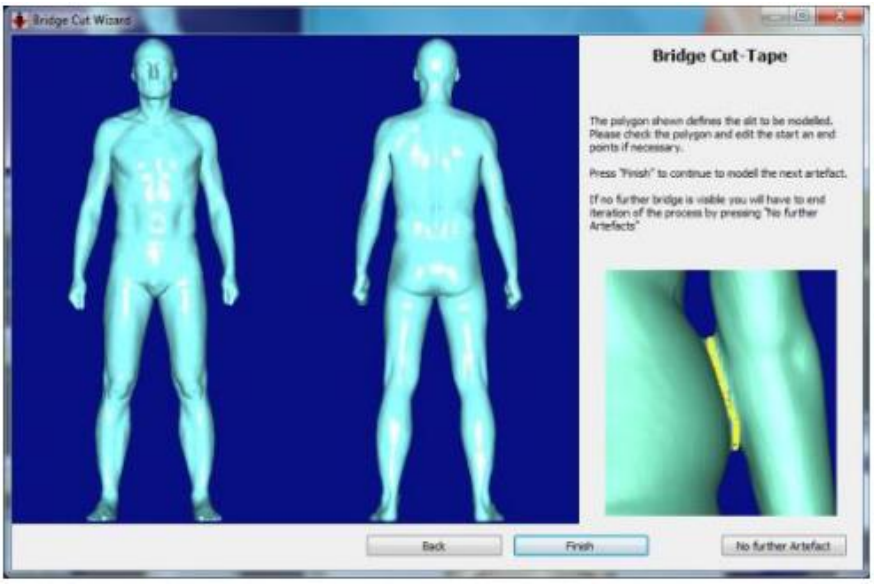

Figure 21. Screenshot of Anthroscan's Bridge Cut Wizard.

As Anthroscan provides superior scan editing capabilities, including interactive measurement tools like CySize, it is feasible that many missing data values can be completed by reprocessing and measuring the problematic scans using Anthroscan software. In certain cases, it may be desirable to use the mesh deletion tools to remove the arms from the scan before mesh reconstruction, to provide less ambiguity between the arm and torso and improve waist and hip measures.

5.5.2.6 Correction to existing data

The NZDFAS validation study identified the following measures as not being of sufficient quality to be extracted by automated measurement, however, a decision was made by the Project Lead at the time to retain them as automated measurements:

- Head Circumference
- Ankle Circumference
- Chest/Bust Circumference
- Elbow Circumference
- Waist Circumference, Natural Indentation

As a result of this decision, the quality of these measures is suspect. An alternate method of obtaining these measures is the further processing of the 3-D scans using CySize software. Evidence to support the collection of anthropometric measures in the NZDFAS using CySize was provided by a validation trial report prepared by the University of South Australia [13], in support of the Australian Warfighter Anthropometric Survey (AWAS). Unfortunately, the measures listed above were not included in this report, however, the AWAS landmarking and measurement guide [11] indicates Ankle Circumference being obtained using CySize. This suggests that CySize is a valid tool to obtain this measure, however, it is recommended that the authors of the AWAS report be contacted to verify its validity. As for the other measures, Head Circumference, Chest/Bust Circumference and Waist Circumference (Omphalion) were all obtained using manual methods,

suggesting CySize is not a valid measurement extraction method for these measures. Unfortunately, Elbow Circumference was not included in the AWAS so a separate validation effort would need to be conducted to confirm if this measure can be obtained using CySize.

A reassessment of the NZDFAS validation trial data revealed that the automated scan extraction validity of all the above measures was acceptable. Unfortunately, Ankle Circumference was evaluated on only three participants so the validation data for this measure is inconclusive. Reassessment of validation data involved the removal of outliers and adjusting the validation data to correct for systematic bias between the scan extracted and manual measure. As scan measures were consistently larger than the manual measures, each scan measure was adjusted by subtracting the mean difference of the manual and scan measures. To improve the accuracy of the existing NZDFAS database, it is recommended that automated scan measures be adjusted by their associated correction factor, where applicable.

Finally, as Interpupillary (IP) Breadth was measured using a transparent Perspex ruler, there is a possibility of parallax error during measuring. During pre-processing of the NZDFAS data, measurements as low as 40 mm were noted. IP distances this small are more representative of those found in children and were removed from the NZDFAS dataset as probable outliers. The resulting male NZDFAS IP distances (61.1±3.8 mm) are slightly smaller than what is found in other surveys, such as ANSUR II (64.0±3.4 mm) and CFAS (63.0±3.0 mm), which should be treated with caution. A similar trend exists for female data suggesting bias in the NZDFAS data. Figure 22 provides a visual comparison of the distribution of male IP distances in NZDFAS and ANSUR II. In future data collection efforts, it is recommended that IP Breadth be collected using a pupilometer rather than Perspex ruler, to ensure data accuracy and integrity.

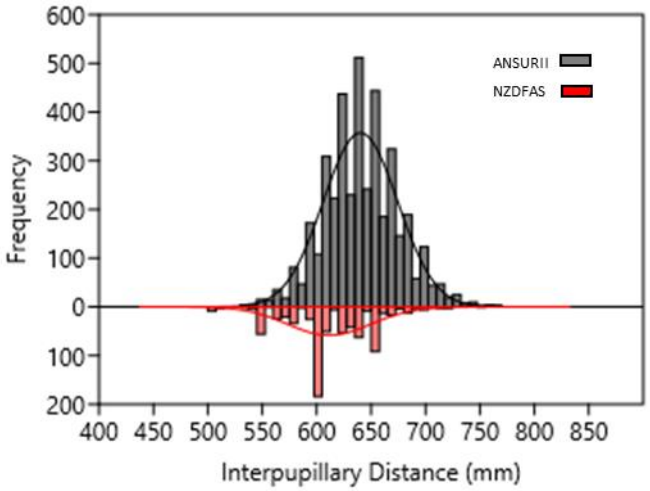

Figure 22. Interpupillary Breadth of NZDFAS and ANSUR II males.

5.6 Limitations of existing data

5.6.1 Comprehensiveness of NZDFAS measures

While the NZDFAS provides a comprehensive set of anthropometric measures, it is difficult to forecast and meet the requirements of all potential applications of these data. Therefore, future project requirements may specify additional body measures that were not part of this survey. Fortunately, the library of seated and standing 3-D scans can be continuously analysed to provide additional measures as required, assuming that the current poses and identifiable landmarks are available.

Unfortunately, there are certain measures which cannot be extracted from 3-D scans with acceptable reliability and accuracy, due to technical limitations of the Vitus XXL scanner. Measures of the head, hands and feet do not scan well due to the resolution of the scanner and complex surface of these body segments. Additionally, collection of certain measures is not feasible from 3-D body scans due to their requirement for specialised postures. If, after review of available scan postures, predicting or deriving new measures is not feasible, a dedicated effort to supplement the NZDFAS by measuring additional personnel may be warranted.

Despite the relative comprehensiveness of the NZDFAS, there are several measures that were not collected that would be of value to clothing and individual equipment projects. For specifying torso borne gear, such as load carriage systems, fragmentation protection vests and ballistic plates, the following measures can readily be extracted from scan data:

- Waist-Back Length (contour)
- Waist-Back Length (vector)
- Waist-Front Length (contour)
- Waist-Front Length (vector)

Under Bust Circumference is an additional measure that is important for sizing and fitting clothing and protective equipment for women. While it is feasible to extract this measure from 3-D scans for many women, it is difficult to extract for those women who present with breast ptosis (sagging) due to larger breasts.

In addition to these torso measures, there are several head measures of value. Menton-Sellion Length is of particular importance for respirator sizing and fitting. These measures should be able to be extracted from 3-D scans with reasonable accuracy, with Tragion to Vertex being susceptible to hair artefact:

- Menton-Sellion Length (face length)
- Tragion to Vertex
- Bitragion-Chin Arc

Time will be the true assessment of the comprehensiveness of the NZDFAS, as projects related to workspace accommodation and habitability, biomechanics, clothing and

individual equipment procurement, and physical fitness leverage the current anthropometric data and introduce new measures and analysis requirements.

5.6.2 Collection of supplemental data

It is ideal to recover missing measurements where possible, however, there remains a strong possibility that factors such as improper scan attire (i.e. boxer shorts) and other postural or scan issues will preclude certain measurement extraction. While it may be possible to recover some manual measures using the aforementioned techniques, many measures are impacted by sufficiently large amounts of missing data that imputation may not provide reliable data. In these cases, it is advised to implement supplementary data collection to complete these missing data.

One of the key measures of concern is Head Circumference, where both missing and existing data are of concern. Missing Head Circumference almost exclusively affected female participants (38%) and was due to the bulk of hair under the scan cap affecting accurate measurement of the skull. This error was noted in the NZDFAS validation report where it was acknowledged that Head Circumference demonstrated poor reliability when measured by automated scan extraction. As measuring error is due to hair artefact rather than landmarking, the scans would not be of sufficient quality to attempt recovering these data using CySize software. In retrospect, this measure should have been obtained using manual methods to obtain an accurate measurement for both female and male participants.

While it is tempting to focus additional data collection on replacing only missing data, it is important to remember that multivariate analysis of anthropometric data is concerned with relationships between various body measures within an individual, as well as across a population. Therefore, it is important to have a complete set of data for each participant. If supplementary data collection is proposed, demographic and occupation criteria must be assessed to maintain the proportionality defined by the sampling targets and not create biases to the overall dataset.

Apart from missing body measures, additional data collection should focus on sampling additional Royal New Zealand Navy personnel to augment the current sample size to achieve proportional representation. Second, while the female cohort of the NZDFAS was proportional to the representation of women in the NZDF, the statistical power of the current sample size of 211 women would be strengthened by additional observations.

5.7 Application of NZDFAS data

Data presented in Appendix I should be used with care. These data provide an overview and basic statistical reference for individual measures for NZDF males and females. These data are also useful for answering requests that require univariate data, where only one measure is required and its relationship to other measures is not considered. For example, stature to define maximum cabin height in airframes. These data cannot, however, provide answers to questions of a multivariate nature (a combination of

measures) without the assistance of a qualified and experienced Anthropometrist. For example, workstation design is dependent on multiple measures which must be considered simultaneously. To answer multivariate questions, advanced statistical analysis of raw anthropometric data is required. All requests for data should be directed to the current DST Human Sciences Programme.

Survey protocol/procedures, data collection, and analysis techniques have been developed specifically for this survey. The process can be modified, simplified and reduced to support various activities for the NZDF, such as conducting a targeted survey of a specific group within the NZDF, e.g. Navy divers, Special Forces, Army drivers, etc. With CySize, new measurements can be created provided the body scan images are free of artefacts and obstructions.

5.8 Limitations

Various measurements were affected by missing data due to digital artefacts, such as webbing, when processed in CySize. Improvements to initial posturing and provision of appropriate scan clothing can aid in reducing this data loss. The use of scan extraction for Head Circumference is invalid due to hair artefact and manual measuring methods should be used for this measure in the future. Mitigation strategies for addressing missing or biased data are provided in Section 5.5.2.

As the sample size for the NZDFAS is small, particularly for women, missing data has a negative consequence that reduces the validity of certain measures being representative of the NZDFAS male or female population. Appendix J provides guidance on the minimum required sample size for each measure and can be used to assess the adequacy of each measure's sample size. It is recommended that steps be taken to address limited data and representation of demographic groups by pursuing missing data mitigation strategies or conducting a focused anthropometric data collection effort to augment the current NZDFAS. In particular, deficiencies in the representation of Navy and of women should be addressed.

A short measurement time for each participant was one of the most critical requirements for this survey, to ensure a high volume of participants could be measured whilst capturing as many measures as possible. Some of the more traditional measurements (e.g. Stature, Hip Breadth, Bideltoid Breadth etc.) were obtained using semi-automated or fully automated digital methods (CySize or Anthroscan) to save time during the survey. Validation of Anthroscan measures was based on a limited population (as little as three participants) and may not represent the true validity of these measures. Additionally, certain measures that did not pass the validation study were included in the automated scan extraction analysis (e.g. Head, Ankle, and Chest Circumferences). Although no validation study was performed on CySize measures, the AWAS validation report provided guidance on the suitability of semi-automated measurement extraction. It has been determined that not all NZDFAS CySize measures can be accounted for by the AWAS report. It is recommended that additional review of the validity of each measure be conducted to identify measures that have not been validated. Furthermore, review of the

NZDFAS validation study found a constant bias between scan measures and certain automated extracted measures using Anthroscan. Consideration of adjusting the pertinent measures in the NZDFAS database to correct for this bias is recommended.

Being the first study of its kind in the NZDF and indeed New Zealand, many of the processes developed by the survey team were based on a mixture of innovation (resource limitations) and trial and error. For example, the sampling strategy calculations, logistics planning, measurement identification procedures, measurement definition protocols, landmark identification protocols, post-survey data sorting and analysis protocols were all trialled and refined. As a result of this time, effort, and lessons learned, future surveys will be able to be conducted more effectively and efficiently.

5.9 Future work

The comprehensive NZDFAS body scan and measurement database is now complete. The following related activities are underway:

- Development of an NZDF Anthropometric data request template. This will help streamline requests for anthropometric data and aid the client/NZDF personnel in identifying the best data for their requirements.

- The development of a clothing sizing prediction application. The purpose of this application is to predict accurate clothing (uniform) sizes for the NZDF based on an individual's body scan.

- Identification of how NZDFAS data can support research on optimising military clothing (e.g. combat and standard dress uniform) and equipment (e.g. helmet, armour, PT equipment, weapon systems or "bomb suit") sizing and fit.

It is envisaged that future applications of the survey data will be as follows:

- Development or acquisition of visualisation and analysis tools to support the anthropometric expert and decision makers in the use and analysis of multivariate anthropometric data. This may be facilitated through international collaboration with FVEY colleagues.

- Identification of software that can facilitate multivariate analysis or define test manikins that represent the anthropometric diversity of the NZDF based on discrete measures or 3-D body scans. These can then be used to assess:

    - Work activities in 3-D, e.g. potential muscular-skeletal disorders associated with maintenance tasks.

    - Operator issues within confined platforms, such as vehicles, aircraft, and common work areas.

    - Specification of clothing, equipment and personal protective equipment (PPE) for design, fit and logistics.

- Comparison of NZ data with anthropometric data of allied nations to determine a level of interoperability for items such as clothing, equipment, platforms, or weapon systems.

6 Conclusions

DTA has conducted the largest tri-service anthropometry study in the NZDF to date, surveying 1,000 Regular Force personnel. The survey was also the first anthropometry study in New Zealand to utilise a 3-D whole body laser scanner.

A robust baseline tri-service anthropometric dataset of the NZDF has been created which can now be used to inform design, health, human performance and human systems integration applications. The study has laid a strong foundation for future short-term (i.e. targeted) and longer-term (i.e. longitudinal; 5 or 10 years) surveys.

The methodology utilised in this report was based on those of the Australian Defence Force, and the Canadian and US Armed forces anthropometry surveys, though DTA has introduced new techniques not seen in previous surveys, e.g. the introduction of a 3-D calliper tool for measuring maximum breadths and depths directly from a 3-D mesh in CySize.

It should be noted that some measures in the database are missing data, particularly the scan-derived measures. While some gaps can be addressed using mathematical modelling techniques, to avoid these issues and improve scan quality, future surveys should ensure that participants wear form-fitting underwear and adopt the correct posture during scans. The use of an alternate scan posture or a different measurement technique may be more appropriate in some cases.

The dataset represents the current make-up of the NZDF (as at 2016) with respect to trade and ethnicities. However, trades that represent the “front line”, such as Combat trades, were under-represented and may form the focus for future immediate surveys. Personnel from the Navy were also under-represented. Therefore, a second survey of Navy personnel is recommended at the earliest opportunity.

The NZDFAS has a high percentage of female participants compared to overseas surveys. It is apparent from both the number of females participating and the comments provided, that female members of the NZDF want their say in decisions regarding the procurement of clothing and equipment and seek solutions/options that consider their body form.

The NZDFAS data are now part of an anonymised NZDF body scan database. Requests for specific information from this database can be made by contacting the current DST Human Sciences Programme.

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Appendix A Measurement Room Layout

This appendix describes the measurement room layout and setup (as shown in Figure A-1). The enclosed measurement space (at least 3 m x 3 m) was constructed using room divider boards if a room of the required size was not available, and was situated near the body scanner. Two separate measurement cubicles/rooms were often used.

Each measurement room contained the following:

- two measurement boards (to create a flat and level surface)
- one anthropometry box (for seated measurements and landmarks)
- one stadiometer (for Seated Height measurements)
- one Brannock device (for foot measurements)
- one large table (to lay out measuring tools)
- one belt (for preferred waist landmarking)
- one hand measurements board (for hand measurements)
- one clear Perspex ruler (for Interpupillary Breadth measurement)
- one small bone calliper (for small breadths like Hand Breadth)
- tapes – one steel anthropometric tape measure (for general landmarking) and one standard builders tape (for Buttock-Heel Length measurement)
- head-square plates (adapted use for Buttock-Heel Measurement)
- one anthropometer (for measurements such as Index Finger Reach)
- one segmometer (for Hand Length and Palm Length measurements)
- one large calliper (for Head Length and Head Breadth measurements)
- consumables (marker pens for landmarking, alcohol wipes for cleaning equipment, hand sanitiser to maintain hygiene, black stickers for landmarking for the scan)
- one laptop (to record measurements)
- one chair (for the measurement scribe)

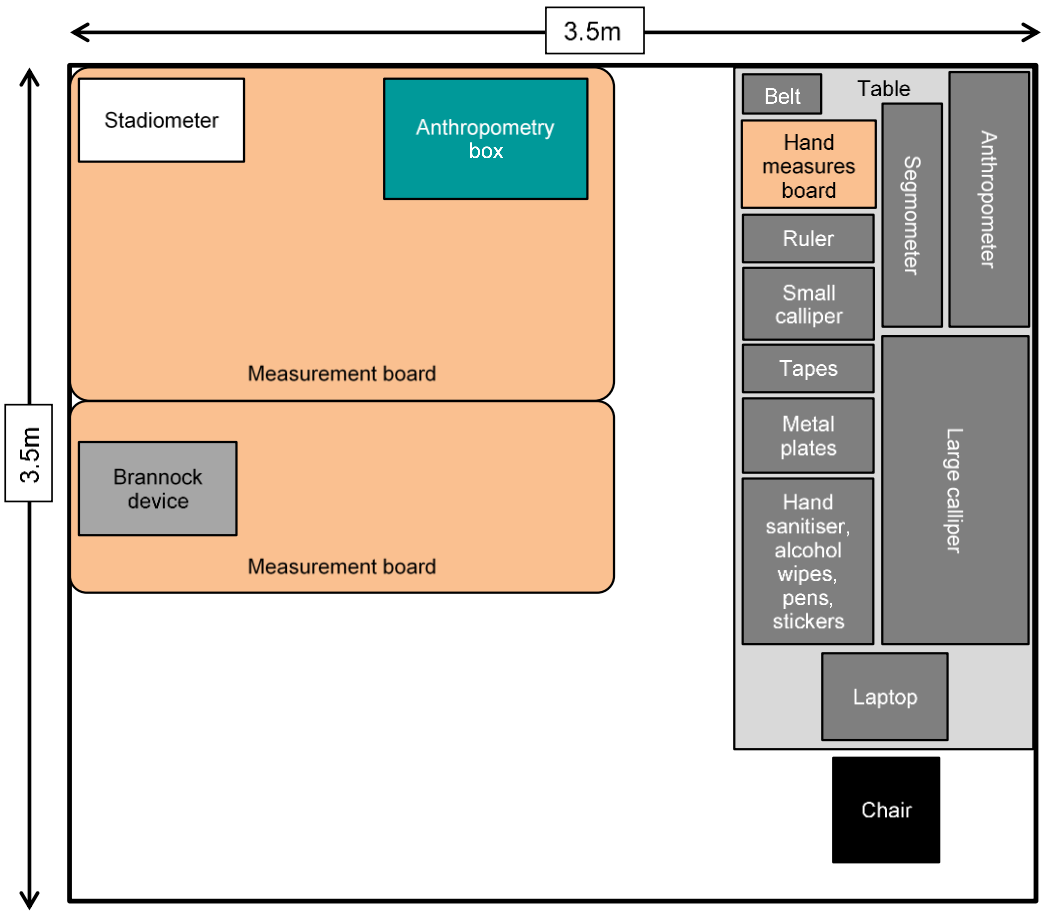


Figure A-1. Schematic of the measuring room layout.

To accommodate the 3-D body scanner, survey sites were required to have:

- a ceiling height of at least 3 metres
- a floor area in excess of 2.2 x 2.2 m
- the capacity to darken the room for the best scanning results (e.g. drawn curtains), with no direct sunlight entering the room, and no major swings in temperature and humidity
- A vibration-free and level floor

A schematic of the scan booth and platform location is provided in Figure A-2.

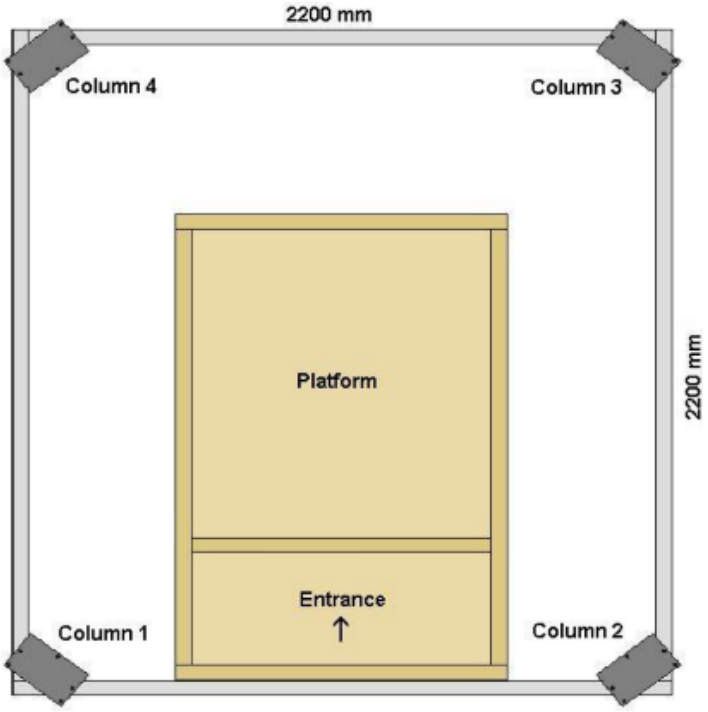
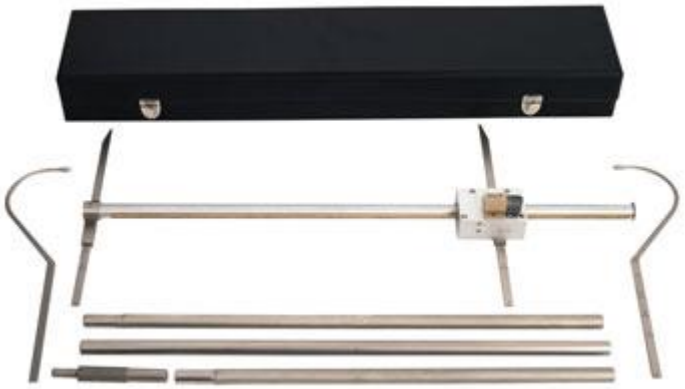


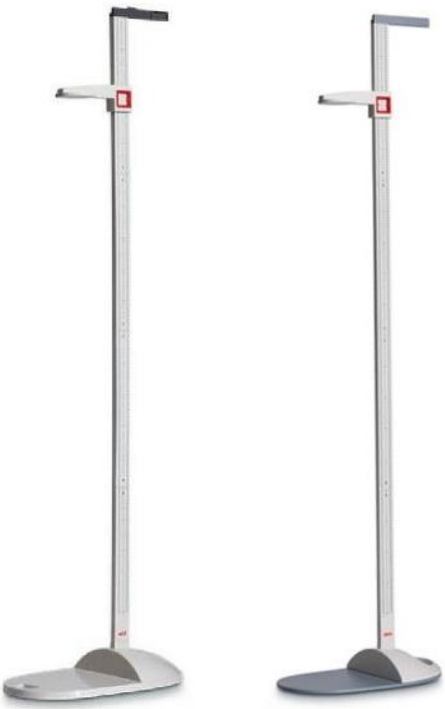
Figure A-2. Scanner floor layout.

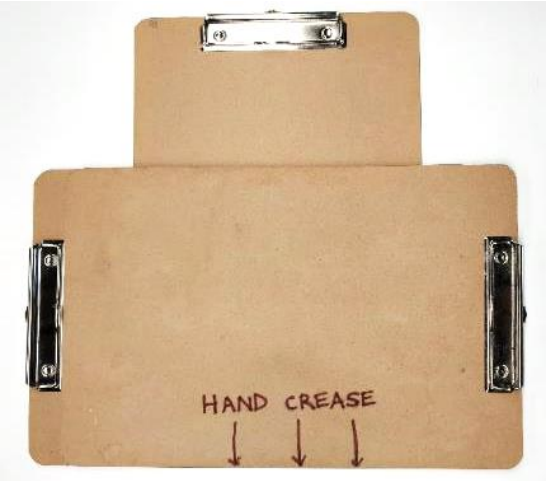
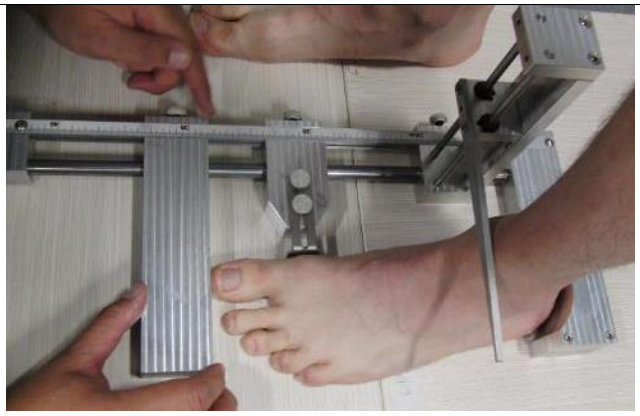
Appendix B Equipment and Instrumentation

The following appendix contains a comprehensive list of the measuring equipment, tools and consumables used to collect body measurements for the NZDF Anthropometry Survey. Manufacturer or supplier details are included where necessary.

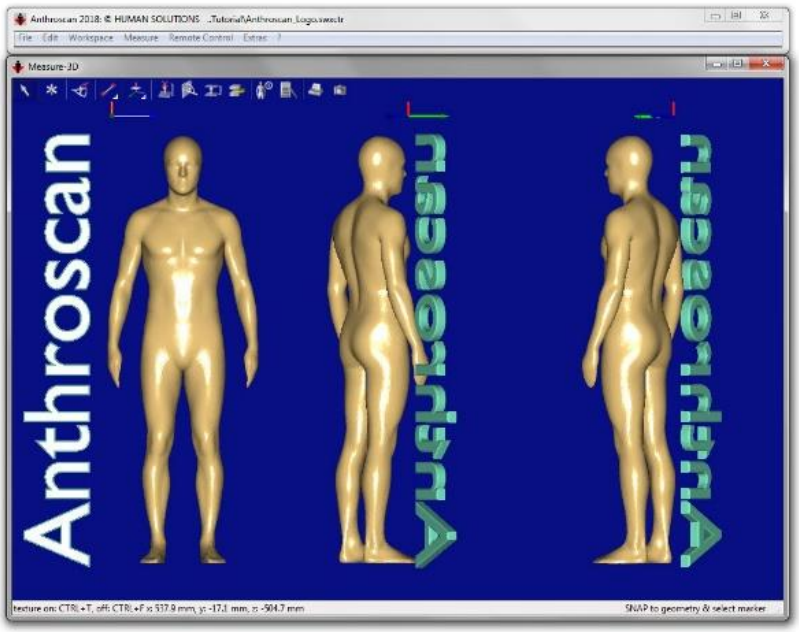
Table B-1. NZDFAS measuring equipment.

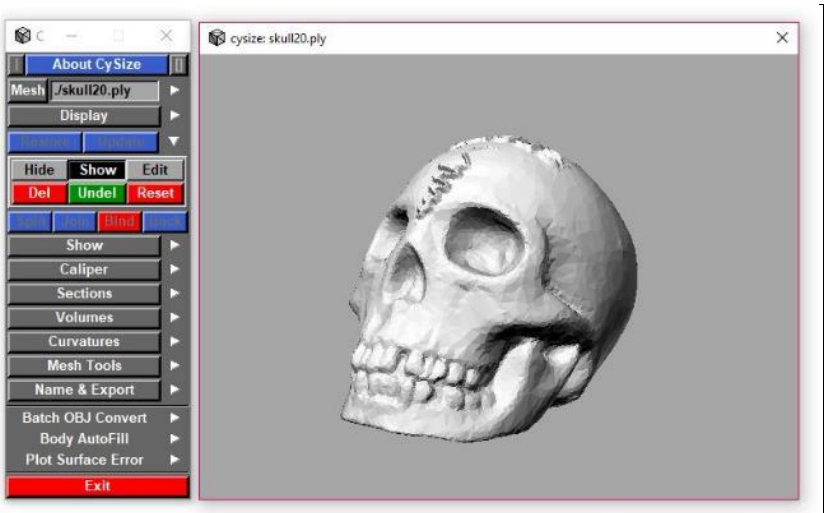
Harpenden anthropometer (*Holtain Limited*, loaned from AUT SPRINZ Clinic)	
Large calliper (*Rosscraft Innovations* Campbell 20 (54 cm) with AP branches)	
Small bone calliper (*Rosscraft Innovations* Campbell 10 (18 cm))	
Segmometer (*Rosscraft Innovations* Segmometer 4)	

Steel anthropometric tape (*Cescorf* 6 mm wide x 2 m long)	
Standard builders tape	
Standard clear Perspex ruler	
Stadiometer (*Seca* 213 and 217)	

Hand measurement boards (Total 8 mm thickness, constructed from three clipboards)	
Measurement boards to provide flat surface (Large MDF boards)	
Grip rod (Standard whiteboard marker, 1.5 cm diameter)	
Brannock device, left foot (Custom AUT SPRINZ Clinic)	

Anthropometry box (Custom DTA built to standard anthropometry box dimensions 30 cm x 40 cm x 50 cm)	
Non-elastic belt (Polyurethane or leather)	
Head-square plates (*Rosscraft Innovations* Centurion kit, adapted use for Buttock-Heel Length measurement)	
Consumables Fine-tip markers for manual landmarking 14 mm adhesive black dots with 6 mm hole for scanner landmarking Alcohol prep pads and wipes Hand sanitiser	   
3-D body scanner (*Human Solutions* VITUS Smart XXL with associated	

Anthroscan software versions 3.4.0 and 3.6.1)	 

CySize software (*Headus* CySize software version 3.7, used for semi-automated measurements from 3-D body scans)	

Appendix C Briefing Procedure and Informed Consent

All NZDFAS participants received a brief upon arrival to explain the purpose of the survey, address any questions, and collect informed consent. The brief was delivered by one of the trained survey staff and included two parts: (i) an initial brief and (ii) informed consent.

Initial brief

Participants were briefed either individually or in small groups if multiple participants arrived together. Although a standardised script was not used, the brief generally covered:

- the aims and objectives of the anthropometry survey
- the data to be collected (demographic data, manual measurement data and digital 3-D scan data)
- the privacy and security of the collected data (only approved DTA scientists and researchers would have access to the full data and scans, data was de-identified with a participant ID code and saved on password-protected devices)
- the measurement and scanning procedure (sequence of manual measurements and scanning, number of measurements, etc.)
- what was required of participants during measurement and scanning (clothing requirements, posture requirements during the scan, etc.)

Participants were given an opportunity to have any questions or concerns addressed at the end of this initial introduction.

Informed consent

Following the initial brief, individuals who were willing to participate were asked to complete an informed consent form and assigned a unique participant ID code. It was emphasised that:

- the study had received ethics approval from the Auckland University of Technology Ethics Committee (AUTEC)
- the study was safe and all data collected was confidential
- participation was voluntary and individuals were free to withdraw consent and leave at any point

A copy of the informed consent form is included below.

New Zealand DEFENCE FORCE
Te Ope Kātua O Aotearoa
NAVY NZ ARMY AIR FORCE

Defence Technology Agency
New Zealand Defence Force
Naval Base
Private Bag 32901
Auckland 0744, New Zealand

T +64 (0)9 445 5914
F +64 (0)9 445 5890
E s.kolose@dta.mil.nz

Participant File Number: _____

6 May 2016

NZDF ANTHROPOMETRY SURVEY AND DATABASE: INFORMED CONSENT FOR USE OF DATA FOR RESEARCH

Name: _____ Service Number: _____

Work Address: _____

_____

Work Phone: _____ Work E-mail: _____

Emergency contact:

Name: _____ Relationship: _____

Phone #1: _____ Phone #2: _____

1. The details of the NZDF anthropometry survey/test and on-going anthropometry database have been explained to me. I am clear about what will be involved (test protocol and measures) and I am aware of the purpose of the test(s), the potential benefits and the potential risks. Any questions I have about the test session have been answered.	Yes ☐ No ☐
2. I have disclosed any injury or illness that will affect my ability to complete the test(s).	Yes ☐ No ☐
3. My permission to perform this test(s) is voluntary; I am free to stop the test(s) at any time, if I so desire.	Yes ☐ No ☐
4. I acknowledge that there are risks and dangers inherent in any testing and declare that I know of no reason why I should not complete the test(s) described.	Yes ☐ No ☐
5. I agree that my data may be stored indefinitely in the NZDF anthropometry database. I agree that my de-identified scan can be used for future research projects, and shared with other NZDF approved researchers without me providing any additional consent beyond this consent. The kind of projects my de-identified data might be used for include AUT University approved student research for degree completions and international collaborative research. The de-identified database is accessible to an approved list of researchers and may also be shared with other researchers overseas for approved projects. My data is linked to my name only on the subject identifier section of the database which is separate from the de-identified data on the NZDF anthropometry database. I may request withdrawal of my data from the database at any time.	Yes ☐ No ☐
6. I agree to my contact details being stored indefinitely in the subject identifier section of NZDF anthropometry database in case I need to be contacted for possible follow-up research (e.g. long term follow-up studies).	Yes ☐ No ☐

7 I have read the Participant Information Sheet and I agree in advance, individual test results are confidential and only approved personnel, namely Mr. Stephven Kolose – Project Lead; and Mr. Andy Richardson – Director Human Systems, DTA), will have access to the raw data and the database will also be used for Mr. Stephven Kolose PhD with AUT University.	Yes ☐ No ☐

Participant name: _____ Signed: _____ Date: _____

Signature of parent/guardian if under 18:_____

Tester/Briefed by:

Name: _____ Signed: _____ Date:_____

Defence Technology Agency

Stephven Kolose
Human Factors Scientist
Defence Technology Agency

Appendix D NZDFAS Demographics Questionnaire

Following completion of the initial brief and informed consent upon arrival, all NZDFAS participants were then asked to provide demographic data. The PEDA (PErsonal DAta) file feature within the scanner associated Anthroscan software was used to record this demographic information. PEDA files were completed by one of the trained survey staff during a face-to-face interview with each participant. Figure D-1 and Table D-1 detail the information collected and options presented.

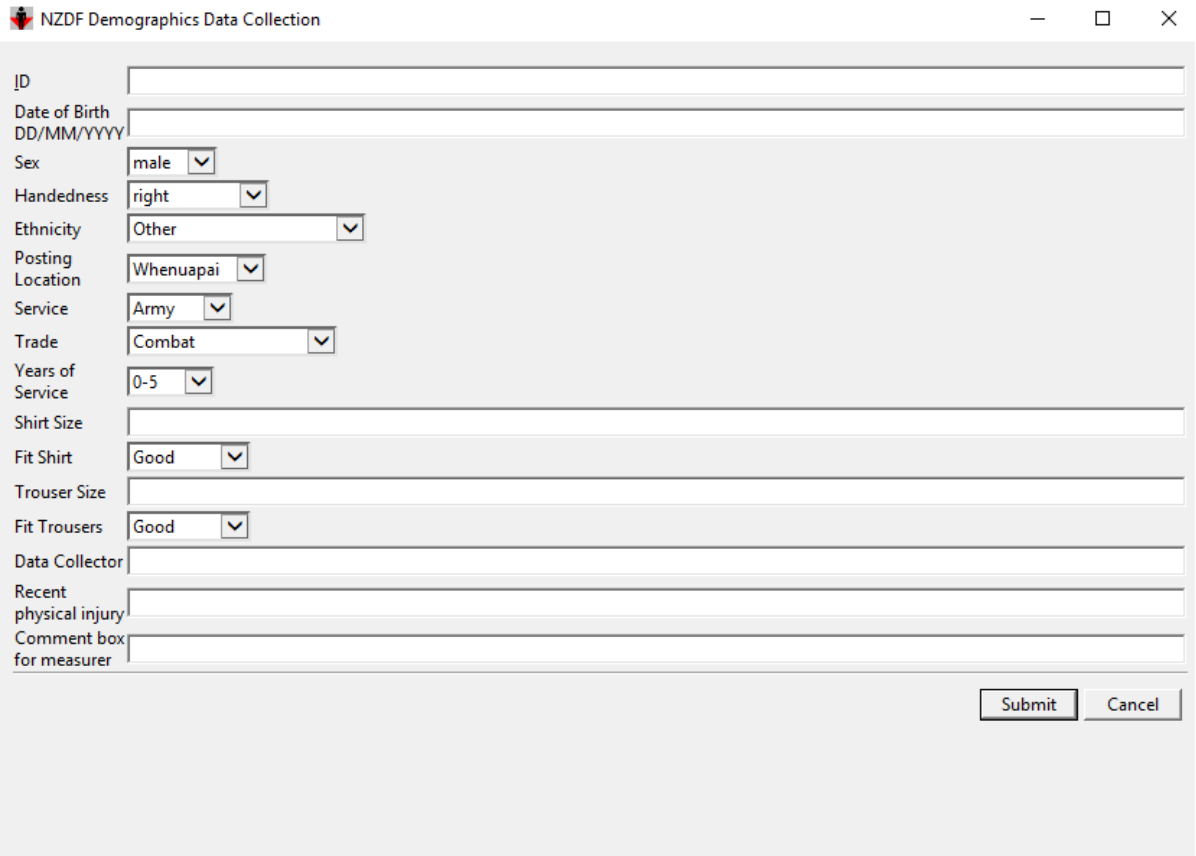


Figure D-1. Example of NZDFAS demographics and clothing fit satisfaction questionnaire.

Table D-1. Description of NZDFAS demographics questionnaire fields.

Field	Description
ID	9-digit ID assigned to the participant (6-digits representing the measurement date (DD/MM/YY) followed by 3-digits representing the count for that day e.g. 110618001).
Date of birth	The participant's date of birth, collected in the DD/MM/YYYY format.
Sex	The sex of the participant. Two options were provided: male or female.
Handedness	The handedness of the participant describing their dominant or preferred hand. Three options were provided: left, right, or ambidextrous.

Ethnicity	The main ethnicity that the participant identified with. Six options were provided: European, Māori/Pacific Island, Asia, Middle East/Latin America, Africa, or Other.
Posting location	The posting location of the participant. Nine options were provided (corresponding to the nine major NZDF camps): Whenuapai, Philomel, Papakura, Waiouru, Linton, Ohakea, Trentham, Woodbourne, or Burnham.
Service	The service that the participant belonged to. Three options were provided: Army, Navy, or Air Force.
Trade	The trade that the participant belonged to. Nine options were provided (based on the main trade categories on the NZDF website at the time of the survey): Combat, Specialist, Medical/Health, Apprentice, Engineering/Technical, Hospitality, Intelligence/IT/COMs, Logistics/Admin, Aviation, or Other.
Years of service	The completed years of service for the participant. Nine options were provided: 0-5, 6-10, 11-15, 16-20, 21-25, 26-30, 31-35, 36-40, or 40 plus.
Shirt size	The participant's shirt size of their everyday working uniform (i.e. the "General Working Dress" or GWD for Navy, the "Multi-terrain Combat Uniform" or MCU for Army, and the "General Purpose Uniform" or GPU for Air Force).
Fit shirt	The self-rated fit of participant's shirt, referring to their everyday working uniform. Five options were provided (based on a five-point Likert scale): Very good, Good, Acceptable, Poor, or Very Poor.
Trouser size	The participant's trouser size of their everyday working uniform.
Fit trousers	The self-rated fit of participant's trousers, referring to their everyday working uniform. Five options were provided (based on a five-point Likert scale): Very good, Good, Acceptable, Poor, or Very Poor.
Data collector	The name of the survey staff member collecting the demographic information.
Recent physical injury	A brief list of recent physical injuries for the participant (important for landmarking and measurement procedure).
Comment box for measurer	A field for the survey staff member to record any issues of clothing and/or equipment fit reported by the participant. This was posed as an open-ended question where participants were simply asked to describe any issues with their clothing/uniform fit and/or the equipment they used on a day-to-day basis.

Appendix E Methods to Address Scan Anomalies

Artefacts were found in the digital 3D body scans during post-scan processing and the CySize analysis. Figure E-1 and Table E-1 depict typical scan anomalies observed in the NZDFAS dataset, and the recommended actions to address these.

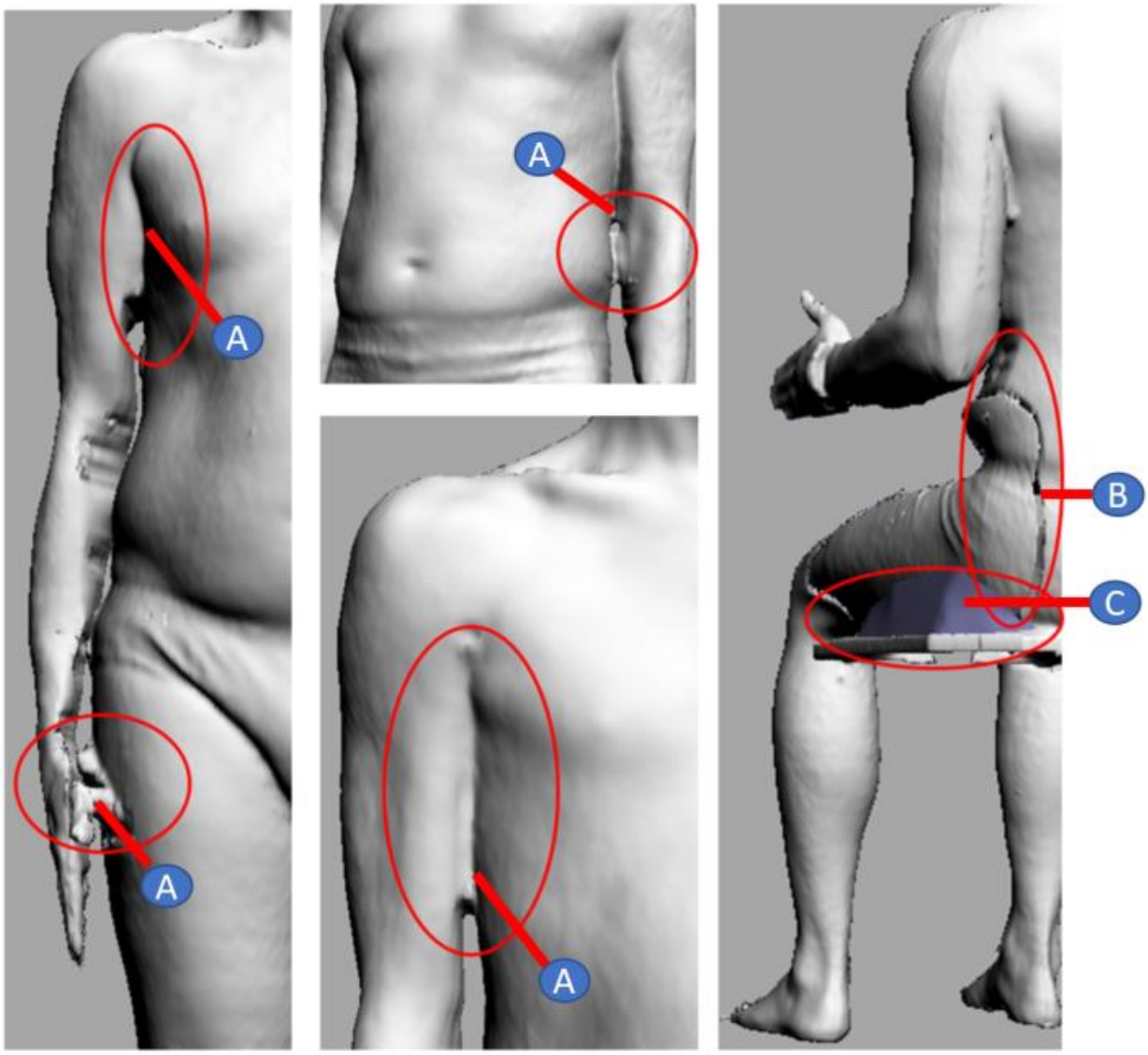


Figure E-1. Common artefacts with CySize analysis - webbed skin (A), holes on the surface (B) or unknown artefacts (C - artefact below the left thigh).

Table E-1. CySize analysis challenges and recommended actions.

Issue	Recommended Action
Difficulty in seeing landmarks clearly. Some landmarks were obstructed from view due to a digital phenomenon or artefact known as "webbing". Webbing occurs when two surfaces of the body are too close together and the software connects them during post processing (see items labelled A in Figure E-1).	• Recalculate the automatic body auto-fill function and modify the cut lines for the arms and the crotch. • Zoom in on the webbing, sometimes there are "holes" where the digital tape can still pass through unimpeded, providing it is still in the approximate vicinity. • Alternatively, take the measure just above or below the webbing, providing it still meets requirements in the measurement protocol definition. • If the webbing is too extensive or there is clear doubt, skip this measure.
Measurements can be obscured by other body parts. For example, the upper bicep being too close to (or touching) the chest, thus affecting clear Chest Circumference or Chest Breadth measurements.	• Reinspect the scan using the "segmentation" tool within CySize. This tool allows the user to manually specify cut lines to separate close body segments. • If the issue persists, skip this measure.
The surface mesh can appear to have a "void" in the scan surface (see item labelled B in Figure E-1).	• The void may be due to a misalignment of one of the eight scan patches that comprise each body scan model. Anthroscan provides an "adjust patches" utility which can be used to address these misalignments. • Recalculate auto body fill. • If this problem persists, skip this measure.
Unknown artefact or objects in the scan. For example, see item labelled C in Figure E-1.	• Adjust body cut points and recalculate auto body fill. • In the example of the purple patch in Figure E-1, the auto hole filling function used during scan post process was unable to differentiate between the body and the seat pan, hindering the placement of the seat pan height landmark. Searching for a suitable surface on the opposite side of the seat pan may be an acceptable alternative as only the Y coordinate of the landmark is required in this case, regardless of the horizontal location on the seat pan. • If in doubt, skip this measure.
Inter-operator differences in how each landmark location is interpreted.	• Schedule regular meetings (weekly or fortnightly) to communicate concerns or discrepancies. • Develop an "issues" register for unclear landmarks that the Lead Researcher checks and provides feedback on. • Lead Researcher should conduct regular checks of the CySize measurer's landmark positioning and measurement positions.
Participant body scan images off-axis (i.e. not in an x, y, z compatible position). This can be due to participant's incorrect body posturing within the scanner. For example, a participant may be facing slightly to the right, or body "hunched" forward, left or right.	• This issue was communicated to the CySize developer who 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 the scan may need to be deleted/ignored.

Appendix F Landmarks

To accurately obtain anthropometric measurements in the survey, a series of anatomical landmarks were identified on the body. These can be divided into “marked” (physically or digitally labelled) and “unmarked” (not labelled) landmarks. For each landmark, a definition, visual image, description of the identification method and landmark source are detailed below. Note that for “source”, secondary sources or other surveys with similar definitions are included in brackets.

The Frankfurt plane is frequently referred to in the landmarking procedures and describes the head position where the orbitale (the inferior point on the anterior border of the bony eye socket, identified by gentle palpation) and tragion (the superior point on the juncture of the cartilaginous flap (tragus) of the ear with the head) are horizontally aligned when viewed from the side (Figure F-1).

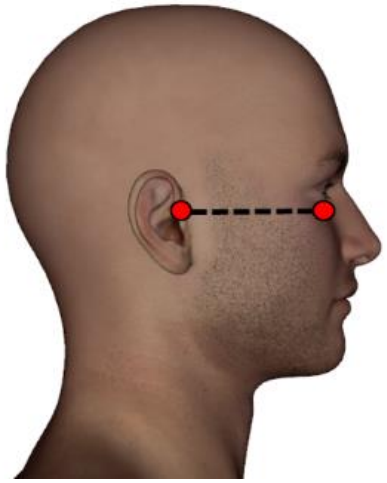


Figure F-1. Frankfurt plane.

Landmarks and body measurements are typically aligned to anatomical reference planes. For example, circumferential measures are typically measured at an angle perpendicular to the long axis of the limbs. Vertical Trunk Circumference and Waist Circumference Preferred are examples of exceptions to this rule as they follow physical landmarks that are not aligned to body axes. For the legs, head and torso, the long axis is congruent with the horizontal (transverse) plane. Depth measures are typically made along, or parallel to, the sagittal (anterior-posterior) plane, and breadth measurements are aligned with the frontal (coronal) plane. Figure F-2 provides a visualisation of the three anatomical planes, as well as the X, Y, Z coordinate system that is applied to each 3-D body scan by CySize.

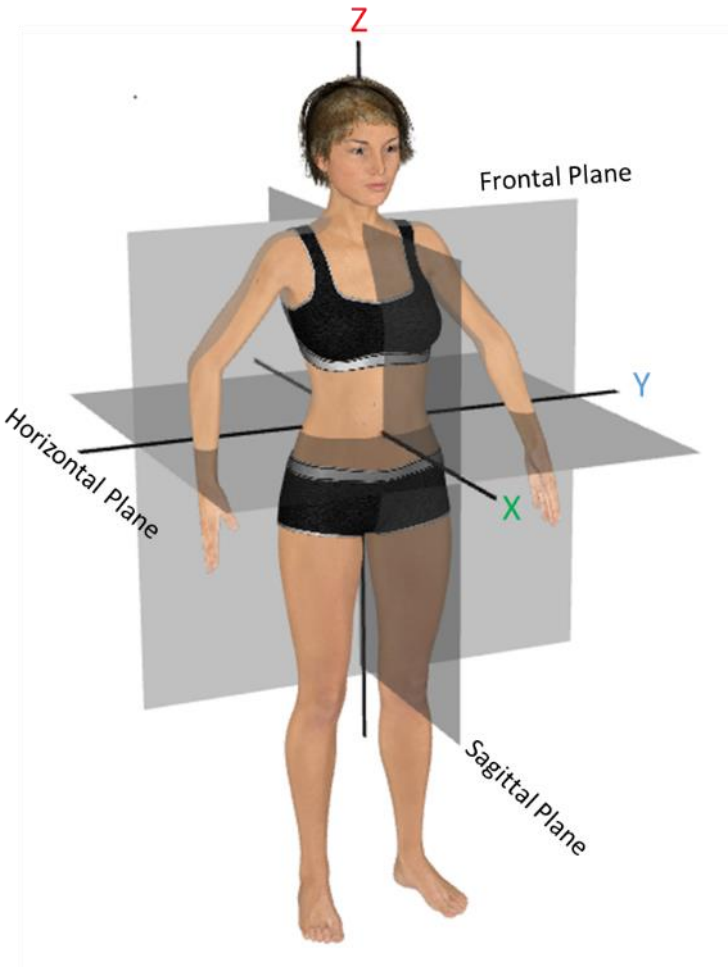
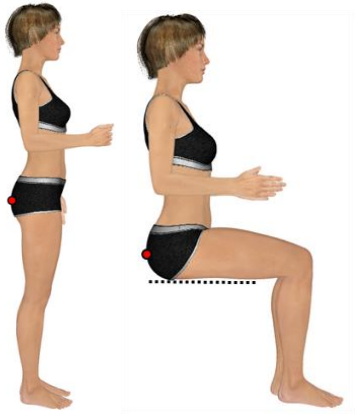


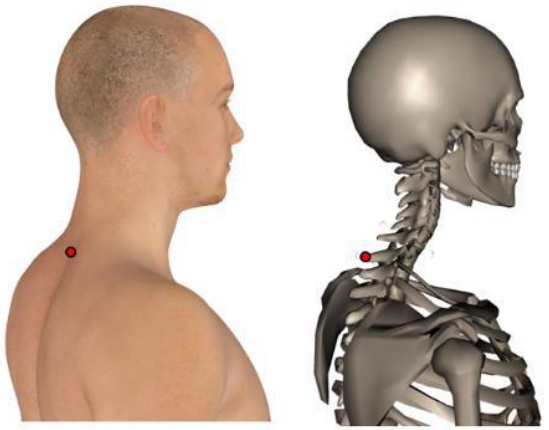
Figure F-2. Anatomical planes and coordinate system used for taking manual and CySize-based measurements.

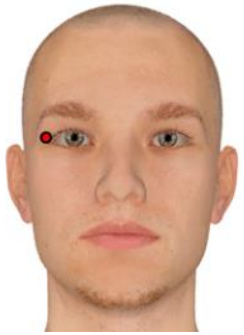
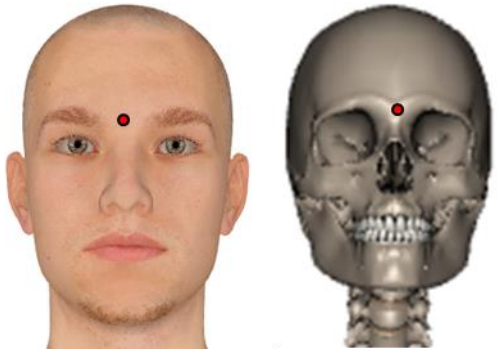
The following tables provide an index and descriptions of all marked and unmarked (i.e. visually identified) landmarks used in the NZDFAS.

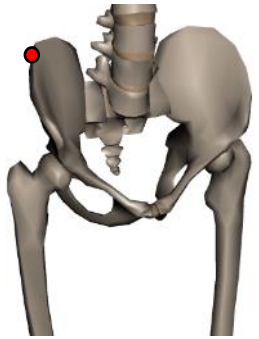
Table F-1. Descriptions and images of marked landmarks.

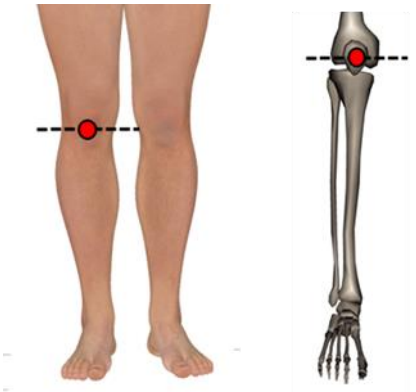
MARKED LANDMARKS		
Landmark	**Description**	**Image**
Acromion, Right and Left	**Definition:** The point on the superior aspect of the lateral part of the acromion border. **Source:** ISAK (ANSUR I/II, AWAS, CLFS, CFAS) **Identification method:** The participant stands in the anthropometric position. Standing behind the participant, palpate the spine of the scapula towards the corner of the acromion (this represents the start of the lateral border which usually runs anteriorly, slightly superiorly and medially). The acromion has an associated bone thickness; palpate superiorly to the top margin of the acromion border in line with the lateral aspect. Apply the straight edge of a pen to the lateral and superior margin of the acromion to confirm the location of the lateral part of the border, and then mark this point. The same procedure is used for both left and right shoulders. The landmarks are also digitally marked on the P01 standing scan (both right and left) and the P03 sitting scan (only Acromion Right).	 

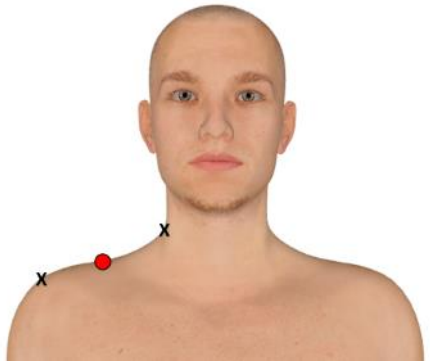
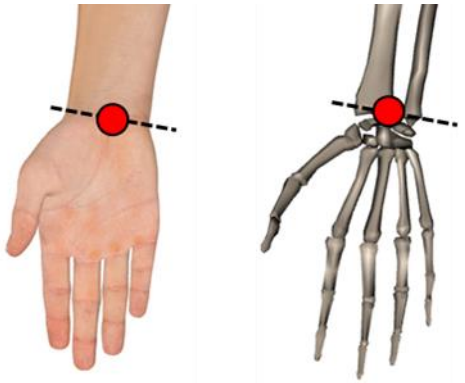
Anterior Scye/Axilla	**Definition:** The apex of the anterior axillary fold on the torso. **Source:** ANSUR I/II (AWAS, CFAS, CFLS) **Identification method**: The participant stands in the anthropometric position, with both hands on the hips. Firmly place the edge of a plastic ruler into the right armpit, in a horizontal position, and then prompt the participant to carefully lower the arm to rest against their side, clamping the ruler in place. Ensure that the ruler is level, then prompt the participant to relax the shoulders and mark the top of the ruler on the anterior side of the torso. This landmark is also digitally marked on the P01 standing scan.	
Buttock Point Posterior	**Definition:** The point of maximum protrusion of the right buttock. **Source:** ANSUR I/II (AWAS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on the P02 standard scan and the P03 sitting scan. Use CySize section tools (X axis) to locate the most protruding point on the right buttock.	

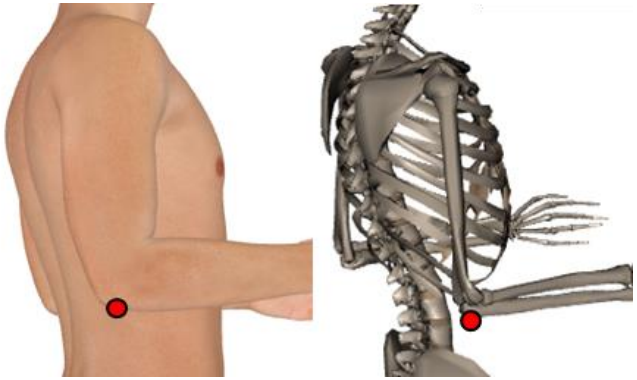
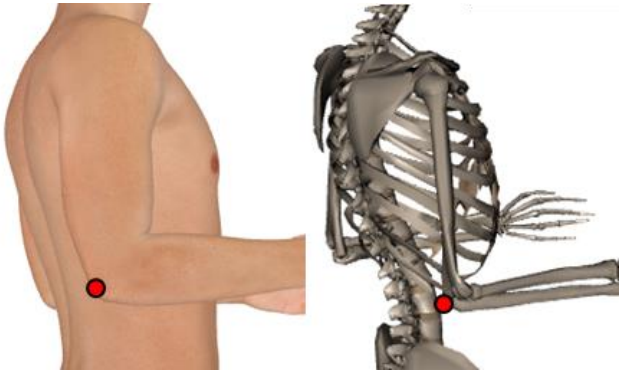
Cervicale (C7, Nape)	**Definition:** The superior palpable point of the spine of the seventh cervical vertebra. **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant stands in the anthropometric position. The spine of the seventh cervical vertebra is generally the most prominent bony process on the back of the neck. Prompt the participant to bend the head downwards and palpate the most prominent spinous process with the pad of the index finger. Ask the participant to slowly bring the head up to the Frankfurt plane, while physically tracking the seventh vertebra during this movement. Once the head is in place, mark the most prominent point of the seventh cervical vertebra spine. This landmark is also digitally marked on the P01 standing scan and the P03 sitting scan.	
Crotch Point	**Definition:** The underside of the groin on the right of the genitalia. **Source:** CFAS (ANSUR II, AWAS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on both standing scans (P01 and P02). Use CySize section tools (Y and Z axes) to locate the lowest point of the groin area, on the right of male genitalia.	

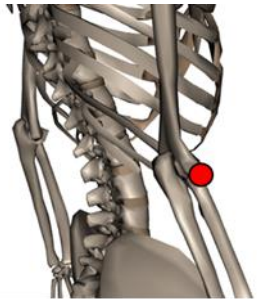
Dactylion III	**Definition:** The tip of the middle finger. **Source:** ANSUR I/II (AWAS, CFAS, CLFS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on the P03 sitting scan. Use CySize section tools (X axis) to locate the most protruding point on the tip of the middle finger of the right hand (excluding the fingernail).	
Ectocanthus	**Definition:** The outside corner of the right eye formed by the meeting of the upper and lower eyelids. **Source:** ANSUR I/II (AWAS, CFAS, CLFS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on the P01 standing scan and the P03 sitting scan by visual inspection.	
Glabella	**Definition:** The anterior point on the frontal bone midway between the bony brow ridges. **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant stands with the head in a neutral position and looks straight ahead with brows relaxed. Visually identify the location of the glabella as the anterior point on the brow ridge and	

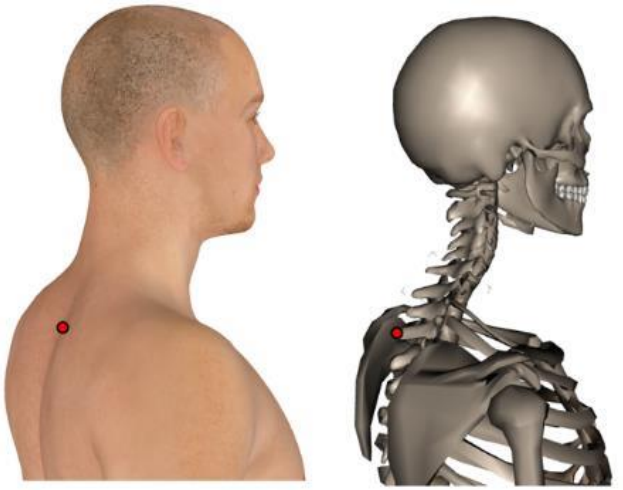
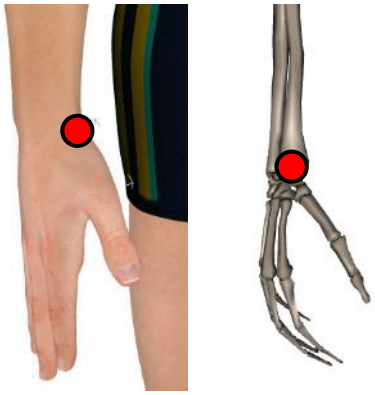
	confirm by palpation. Mark the site in line with the midsagittal plane. Note: On some participants there is no distinctly anterior point; in such circumstances, use judgement to establish its location.	
Hallux	**Definition:** The tip of the first or innermost toe (big toe). **Identification method:** This landmark is digitally identified on the P03 sitting scan. Use CySize section tools (X axis) to locate the most protruding point on the tip of the big toe on the right foot (excluding the toenail).	
Iliocristale	**Definition:** The point on the most lateral aspect of the iliac tubercle, which is on the iliac crest. **Source:** ISAK (CFAS, CLFS) **Identification method:** The participant stands in a relaxed position with the right arm folded across the chest. Standing behind the participant, firmly press the right hip bone with the right hand to locate the top of the iliac crest, using the left hand to provide resistance on the left side of the pelvis and stabilise the body. Once identified, palpate horizontally to locate the most lateral aspect of the crest and mark this site. This landmark is also digitally marked on the P01 standing scan.	 

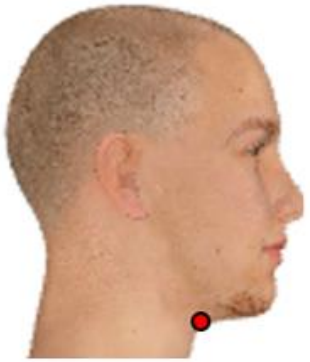
Medial malleolus	**Definition:** The medial point of the medial malleolus (inside ankle bone). **Source:** ANSUR I/II (CFAS, CLFS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on the P03 sitting scan. Use CySize section tools (Y axis) to locate the most medially protruding point on the inside ankle bone.	
Midpatella	**Definition**: The anterior point halfway between the top and bottom of the right patella (the kneecap). **Source:** ANSUR I/II (AWAS, CLFS) **Identification method:** The participant stands erect on the anthropometry box with the knee relaxed. Locate the kneecap with the forefinger on the superior edge of the patella and the thumb on the inferior edge of the patella. Visually identify the midpoint between both edges and mark this site. Caution: Participants commonly lock their knees during the identification of this landmark. If the participant is experiencing difficulty in relaxing the knee, firmly hold the participant's thigh a few inches above the knee and then let go to relax the patella. This landmark is also digitally marked in the P01 standing scan.	

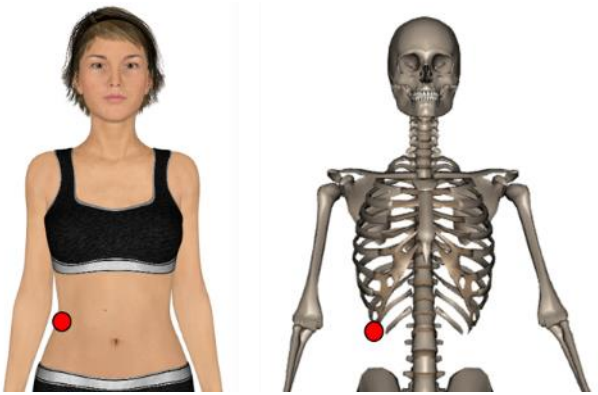
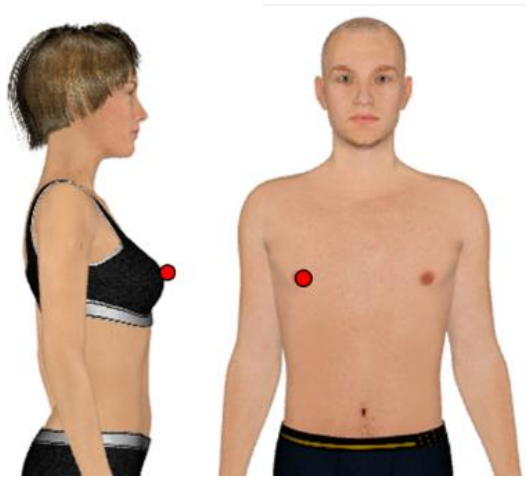
Midshoulder	**Definition:** The point on the top of the right shoulder midway between the neck (Trapezius Point, Right) and the tip of the right shoulder (Acromion, Right). **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant stands in the anthropometric position. Standing behind the participant, lay the anthropometric tape along the top of the shoulder from the Trapezius Point (at the juncture of the neck and shoulder) to the Acromion Landmark at the tip of the right shoulder. Mark the site at one-half of the measured distance, ensuring that this point crosses over the top of the trapezius muscle. This landmark is also digitally labelled in the P02 standard scan.	
Midstylion	**Definition:** The midpoint, on the anterior surface of the wrist, of the horizontal line at the level of the stylion. **Source:** ISAK **Identification method:** The participant stands with their right hand extended in front of them. Align the anthropometric tape around the participant's wrist (palm facing up) in line with the Stylion Landmark and perpendicular to the long axis of the forearm. Estimate the mid-point between the medial and lateral edges of the wrist and mark this site in line with the tape.	

Olecranon Bottom	**Definition:** The inferior aspect of the olecranon (tip of the ulna bone) with the elbow flexed at 90°. **Source:** ANSUR I/II (AWAS, CLFS), adapted for digital landmarking **Identification method:** This landmark is visually identified on the digital P03 sitting scan. CySize section tools (Y and Z axes) can be used to confirm the location of the most inferior point on the surface of the flexed right elbow joint.	
Olecranon Rear	**Definition:** The posterior point of the olecranon (tip of the ulna bone) with the elbow flexed 90°. **Source:** ANSUR I/II (CLFS), adapted for digital landmarking **Identification method:** This landmark is visually located on the digital P03 sitting scan. CySize section tools (X and Y axes) can be used to confirm the location of the most posterior point on the surface of the flexed right elbow joint.	

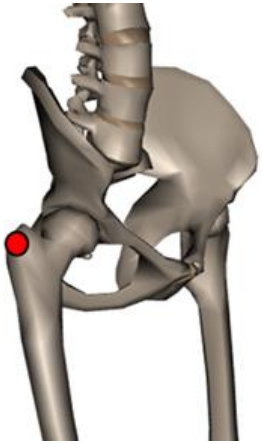
Popliteal Point	**Definition:** The juncture between the right calf and thigh behind the knee, with the knee flexed 90°. **Source:** AWAS (ANSUR I/II), adapted for digital landmarking **Identification method:** This landmark is visually located on the digital P03 sitting scan. CySize section tools (X and Y axes) can be used to confirm the location of the innermost point of the thigh-calf junction at the back of the right knee, along the mid-sagittal plane of the right leg.	
Radiale	**Definition:** The superior point on the lateral border of the head of the radius. **Source:** ISAK (ANSUR I/II, AWAS, CFAS, CLFS) **Identification method:** The participant stands relaxed with arms hanging by the sides. Palpate the hollow dimple on the lateral side of the right elbow and locate the articular space between the humerus and the radius. Palpate the site downwards to locate the superior point on the lateral edge of the head of the radius, and mark this site without pulling the skin up or down. In difficult cases, hold the participant's wrist and slightly rotate the forearm to aid identification of the radius head during palpation. This landmark is also digitally marked on the P01 standing scan.	 

Second Thoracic Vertebra (T2)	**Definition:** The superior point of the spine of the second thoracic vertebra. **Source:** AWAS **Identification method:** The participant can sit or stand for this landmark. Palpate the bony protrusions on the back of the neck down the spine using the index finger and thumb to track the length of each vertebra. Identify the bony protrusion two segments down from the Cervicale or C7 landmark (the most prominent spinous process at the back of the neck) and mark this site. This landmark is also digitally marked on the P01 standing scan.	
Stylion	**Definition:** The inferior point on the lateral margin of the styloid process of the radius. **Source:** ISAK (ANSUR I/II, AWAS, CFAS, CLFS) **Identification method:** The participant stands with their right hand forward and wrist lifted in front of them. Palpate the thumb side of wrist toward the wrist to locate the end of the radius and mark this site. This landmark is also digitally marked on the P01 standing scan.	

Submandibular	**Definition:** The juncture, in the midsagittal plane, of the lower jaw and the neck. **Source:** ANSUR I/II (AWAS, CLFS) **Identification method:** The participant sits with the head positioned in the Frankfurt plane. Place a pen on the underside of the jaw and lightly roll back toward the neck until it stops. Ensure that this landmark is above the infrathyroid before marking the site. On participants with a sloping anterior neck, use judgement about the likely position of a helmet strap.	
Suprapatella	**Definition:** The superior point of the patella (kneecap). **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant sits with the right leg extended forward. Palpate the patella from the lateral and medial sides, working up to the superior border through the patellar tendon. Once identified, re-position the participant's knee to form a 90° bend and track the superior border of the patella during the movement. Mark the site once in position. This landmark is also digitally marked in the P03 sitting scan.	

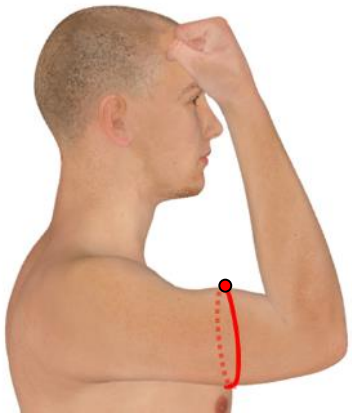
Tenth Rib	**Definition:** The inferior point of the tenth rib bone. **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant stands erect. Palpate the bottom of the rib cage on the right side of the body, toward the front until the bottom of the tenth rib is located. Mark this site. On heavier participants, palpate horizontally from the lateral side, being careful not to move flesh from above or below the area. Apply firm pressure to locate the deep bony structure but avoid prolonged palpation of this area as participants may be sensitive in this region. This landmark is also digitally marked on the P01 standing scan.	
Thelion/Bustpoint	**Definition:** The anterior point of the right bra cup for females (Bustpoint) or the centre of the nipple for males (Thelion). **Source:** ANSUR I/II (AWAS, CLFS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on all three posture scans (P01, P02 and P03). Use CySize section tools (X axis) to locate the most protruding point on the right bra cup in females (Bustpoint), or visually identify the centre of the right nipple in males (Thelion).	

Thigh Point Top	**Definition:** The highest point of the top of the right thigh of a seated individual. **Source:** ANSUR I/II (AWAS, CFAS), adapted for digital landmarking **Identification method:** This landmark is digitally identified on the P03 sitting posture scan. Use CySize section tools (Z axis) to locate the highest point on the top of the right thigh.	
Tibiale Laterale	**Definition:** The superior point on the lateral border of the tibial plateau of the knee. **Source:** ISAK **Identification method:** The participant stands on the anthropometry box. Palpate the knee area using firm pressure to locate the joint space bounded by the lateral condyle of the femur and the antero-lateral part of the lateral tibial condyle (perpendicular to the axis of the leg). Locate the superior point on the lateral border of the tibial head by pressing firmly inwards. Mark the site roughly one-third of the distance along the border moving posteriorly. This landmark is also digitally marked on the P01 standing scan. Note: This landmark can be difficult to identify due to thick lateral ligaments and tendons that run across the knee joint. It is often useful to have participants flex and	

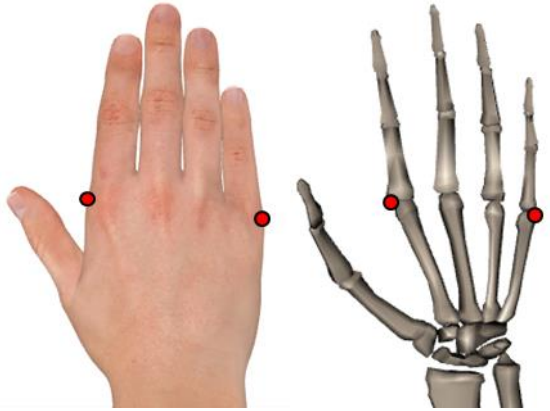
	extend the knee several times to ensure that the correct site has been marked.	
Trapezius Point, Right and Left	**Definition:** The point at which the anterior border of the trapezius muscle crosses the lateral point at the base of the neck. **Source:** ANSUR I/II (AWAS, CLFS) **Identification method:** The participant stands and looks straight ahead with their right hand placed on the left shoulder (to help outline the trapezius muscle on the right shoulder). Moving from the shoulder to the neck, palpate the mass of the trapezius muscle to locate its anterior border. Mark the point where the anterior border of the muscle crosses the lateral sides of the neck. Repeat this procedure for the other side.	
Trochanterion	**Definition:** The superior point of the greater trochanter of the femur (not the lateral point). **Source:** ISAK (ANSUR I/II, AWAS, CLFS) **Identification method:** The participant stands in a relaxed position with the right arm across the chest. Palpate the lateral aspect of the gluteal muscle with the heel of the right hand to locate the greater trochanter, while supporting the left side of the participant's hip with the left hand. Locate the lowest point on the thigh where the superior surface of the trochanter can be felt when	 

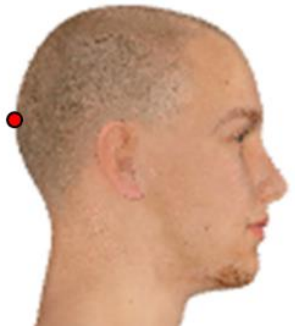
	strong downward and medial pressure is applied. Mark this site. This landmark is also digitally marked on the P01 standing scan. Note: This landmark can be difficult to locate, particularly in individuals with thick adipose tissue at the hip joint. It is often helpful to have participants flex at the hip and knee to assist location, or extend the right leg forward and pivot on the heel. Once located, track this point whilst returning the participant's leg to the vertical. On heavier participants, ensure that palpation is applied directly horizontal and the flesh either above or below the landmark is not moved.	
Waist Preferred, Anterior and Posterior	**Definition:** The height at which a participant would comfortably wear a belt or the waistband of their trousers. **Source:** AWAS **Identification method:** The participant stands in a relaxed position. Ask the participant to wear a belt, placing it at their preferred position. Mark the anterior landmark just above the belt in line with the Omphalion (Waist Preferred Anterior), and the posterior landmark just above the belt in line with the spine (Waist Preferred Posterior). These landmarks are also digitally marked on the P01 standing scan (only Waist Preferred Posterior) and the P02 standard scan (both landmarks).	

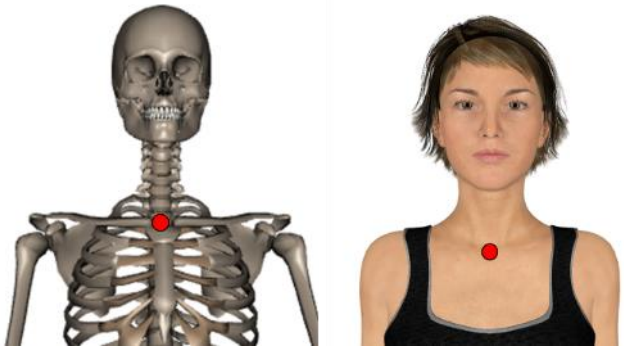
Table F-2. Descriptions and images of unmarked landmarks.

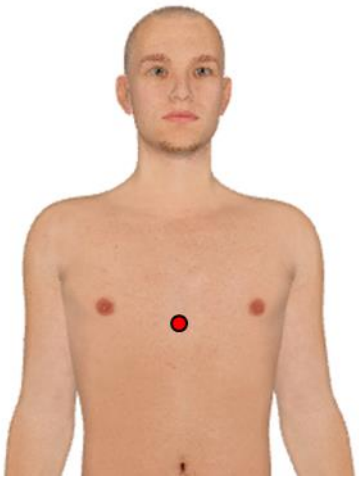
UNMARKED LANDMARKS		
Landmark	**Description**	**Image**
Acropodion	**Definition:** The tip of the first (Hallux) or second toe, whichever is longer. **Source:** ANSUR I/II (AWAS, CFAS, CFLS) **Identification method:** This landmark is located visually during manual measurement as the most anterior point on the longest toe, excluding the toenail.	
Biceps Point	**Definition:** The highest point of the right flexed biceps brachii muscle as viewed from the participant's right side. **Source:** ANSUR I/II (AWAS, CLFS) **Identification method:** The participant stands with the right upper arm extended forward and the elbow flexed at 90°, with the fist tightly clenched and held facing the head. Prompt the participant to flex the biceps brachii muscle and locate the highest point on this muscle via visual inspection.	

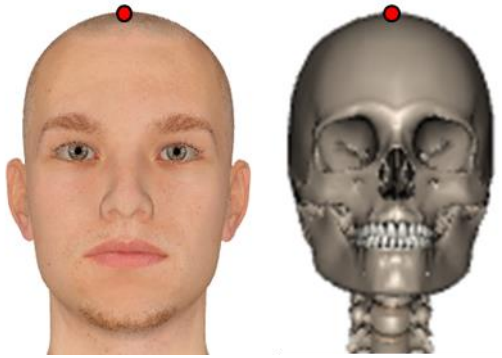
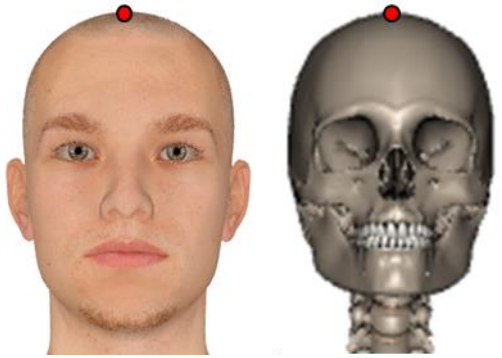
Deltoid Muscle	**Definition:** The large muscle on the lateral border of the shoulder. **Source:** ISO 7250-1:2008(E) **Identification method:** This landmark is located on the digital P03 sitting scan via visual inspection.	
Inguinal Point	**Definition:** The crease at the angle of the trunk and the anterior thigh with the participant in the seated position. **Source:** ISAK **Identification method:** This landmark is located on the digital P03 sitting scan via visual inspection.	

Metacarpali II and V	**Definition:** Metacarpale II - The lateral point of the right metacarpophalangeal joint II (at the base of the index finger on the outer edge of the hand). Metacarpale V - The medial point of the right metacarpophalangeal joint V (at the base of the little finger on the outer edge of the hand). **Source:** ANSUR I/II (CFAS, CLFS) **Identification method:** The participant sits with their right hand placed palm down on a table. Palpate the joint at the base of the index finger and the little finger to locate the most laterally protruding points.	
Metatarsophalangeal Protrusion I and V	**Definition:** The medial protrusion of the right foot in the region of the first metatarsophalangeal joint (I), and the lateral protrusion of the right foot in the region of the fifth metatarsophalangeal joint (V). **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant stands on a flat surface with weight equally distributed on both feet. Position the foot so that the inner side is parallel to a line on the surface. Visually locate the maximum protrusion on the inside and outside of the foot near the first and fifth metatarsophalangeal joints. If the protrusions are	

	not clearly defined, palpate the joints to locate the most laterally protruding bony points.	
Omphalion	**Definition:** The centre of the navel or belly button on the waist. **Source:** CFAS (ANSUR I/II, AWAS, CLFS) **Identification method:** This landmark is located visually during manual measurement and on the digital P02 standing scan, and is used as a guide for other markers (e.g. Waist Breadth markers).	
Opisthocranion	**Definition:** The posterior point on the back of the head. **Source:** ANSUR II (AWAS, CFAS) **Identification method:** This landmark is located visually during manual measurement.	

Pternion	**Definition:** The posterior point on the heel of the foot. **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** This landmark is located visually during manual measurement.	
Suprasternale	**Description:** The inferior point of the jugular notch of the sternum (top of the breastbone). **Source**: ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** This landmark is located visually on the digital P02 standing posture scan.	

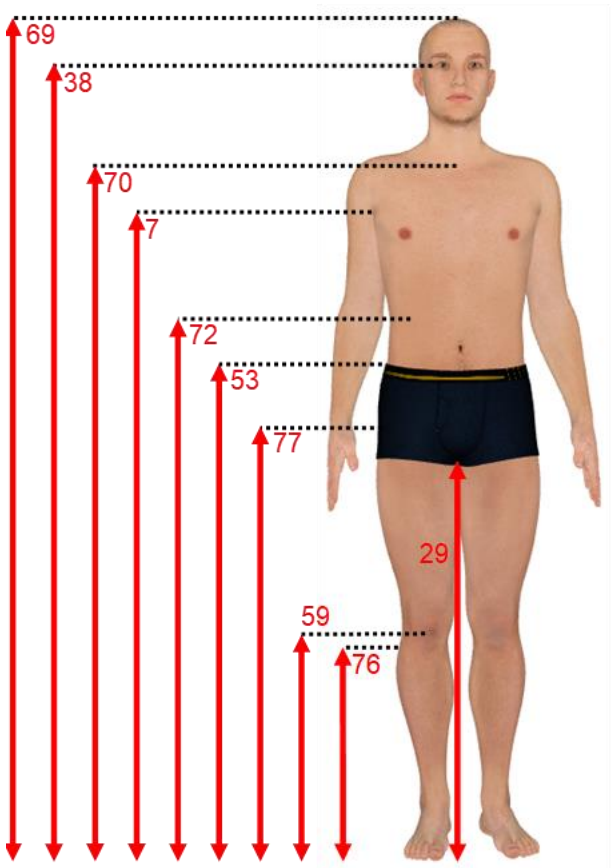
Substernale	**Definition:** The inferior palpable point on the sternum. **Source:** AWAS **Identification method:** This landmark is located visually on the digital P03 sitting scan.	
Tragion, Right and Left	**Definition:** The superior point on the juncture of the cartilaginous flap (tragus) of the ear with the head. **Source:** ANSUR I/II (AWAS, CFAS, CFLS) **Identification method:** This landmark is located visually during manual measurement.	

Vertex	**Definition:** The highest point on the head when the head is in the Frankfurt plane. **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** This landmark is located visually during manual measurement.	
Zygion, Right and Left	**Description:** The lateral points on the zygomatic arch. **Source:** ANSUR I/II (AWAS, CFAS, CLFS) **Identification method:** The participant stands and looks straight ahead with the facial muscles relaxed. Visually identify the most lateral point on each zygomatic arch and confirm by palpation.	

Appendix G Measurement Guide

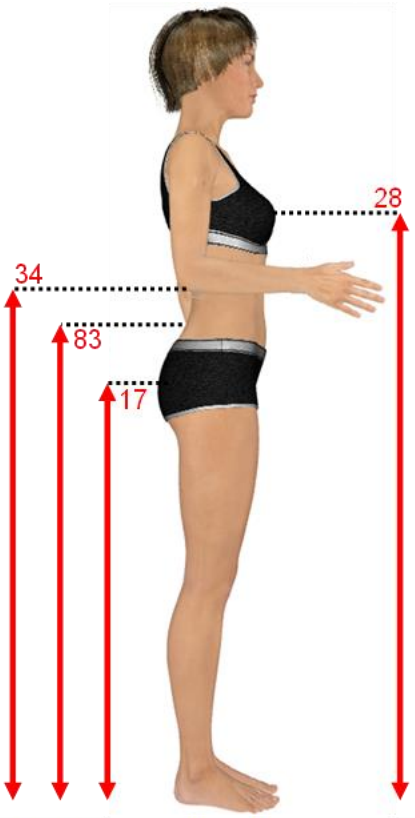
This section presents a simple visual guide of all measurements taken in the NZDF Anthropometry Survey except for body weight. These can be classified into heights, lengths, breadths, depths, circumferences, reaches, hand measurements and foot measurements. All human models were created using DAZ3D (www.daz3D.com) software and published in accordance with the regulations indicated by the DAZ3D end user license agreement.

G.1 Heights & Clearances

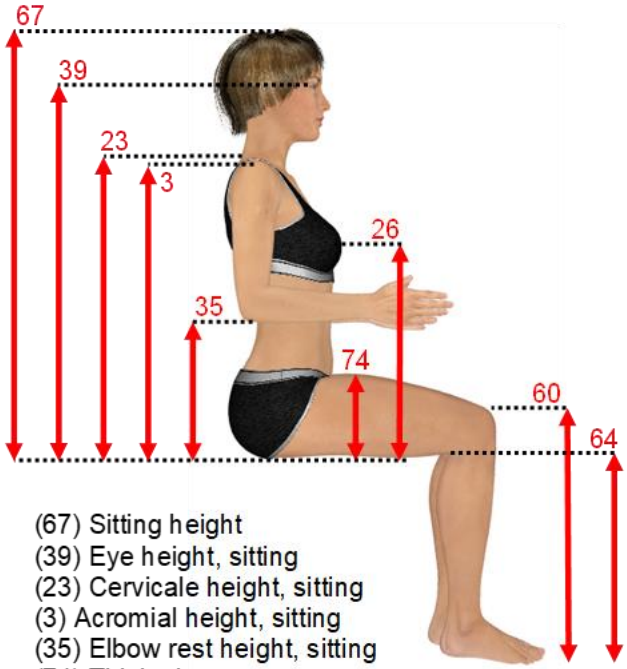


(69) Stature
(38) Eye height
(70) Suprasternale height
(7) Axilla height
(72) Tenth rib height
(53) Iliocristale height
(77) Trochanterion height
(59) Knee height
(76) Tibiale-laterale height
(29) Crotch height

(2) Acromial height
(71) T2 height
(22) Cervicale height

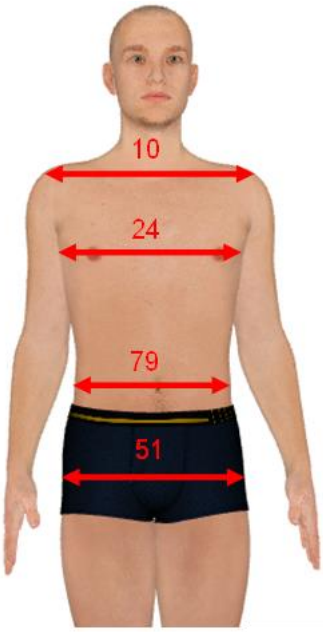


(34) Elbow rest height
(83) Waist height preferred, posterior
(17) Buttock height
(28) Chest/bust height

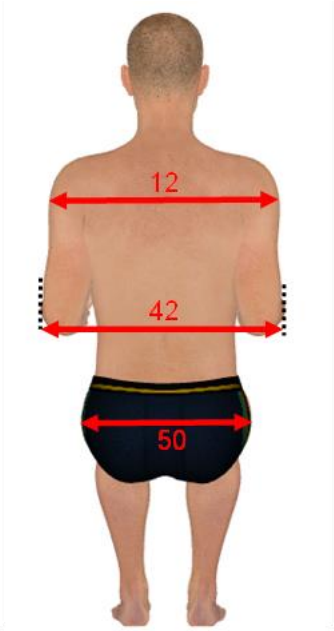


(67) Sitting height
(39) Eye height, sitting
(23) Cervicale height, sitting
(3) Acromial height, sitting
(35) Elbow rest height, sitting
(74) Thigh clearance
(26) Chest height, sitting
(60) Knee height, sitting
(64) Popliteal height

G.2 Breadths



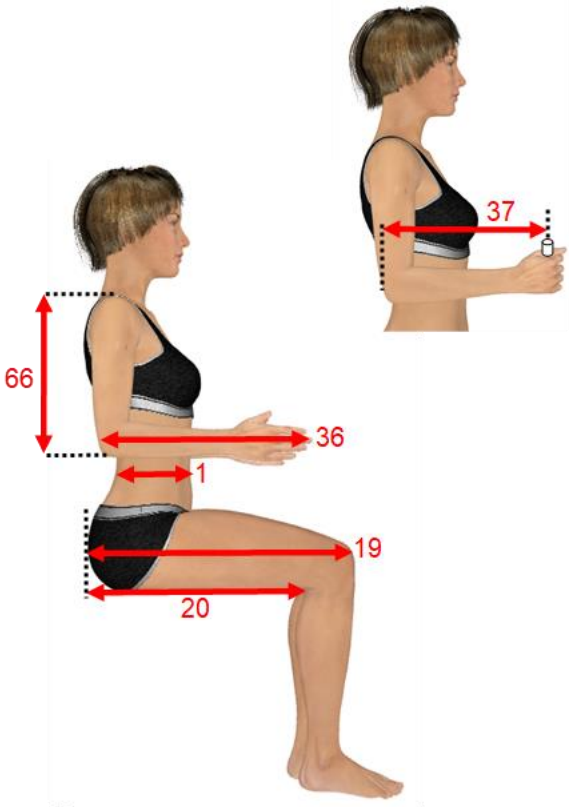
(10) Biacromial breadth
(24) Chest breadth
(79) Waist breadth
(51) Hip breadth, standing



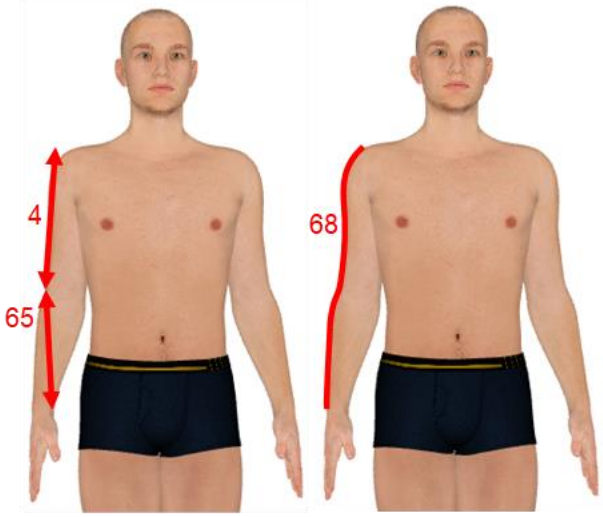
(12) Bideltoid breadth
(42) Forearm-forearm breadth
(50) Hip breadth, sitting

G.3 Lengths & Depths

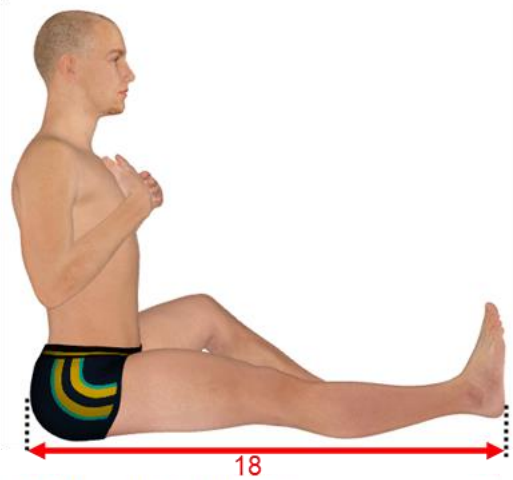
(25) Chest depth
(82) Waist depth
(16) Buttock depth
(30) Crotch length
(31) Crotch-waist length preferred, anterior
(32) Crotch-waist length preferred, posterior



(66) Shoulder-elbow length
(36) Elbow-fingertip length
(1) Abdominal extension depth, sitting
(19) Buttock-knee length
(20) Buttock-popliteal length
(37) Elbow-grip length

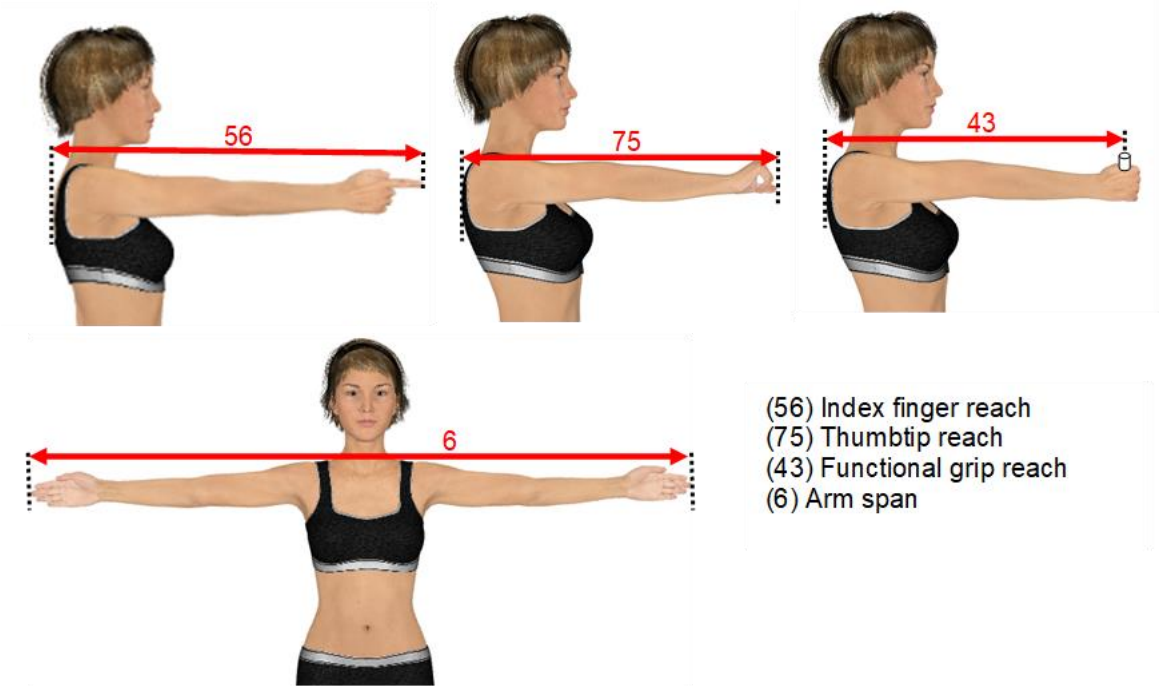


(4) Acromion-radiale length
(65) Radiale-stylion length
(68) Sleeve outseam



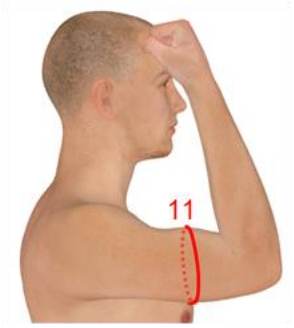
(18) Buttock-heel length

G.4 Reaches



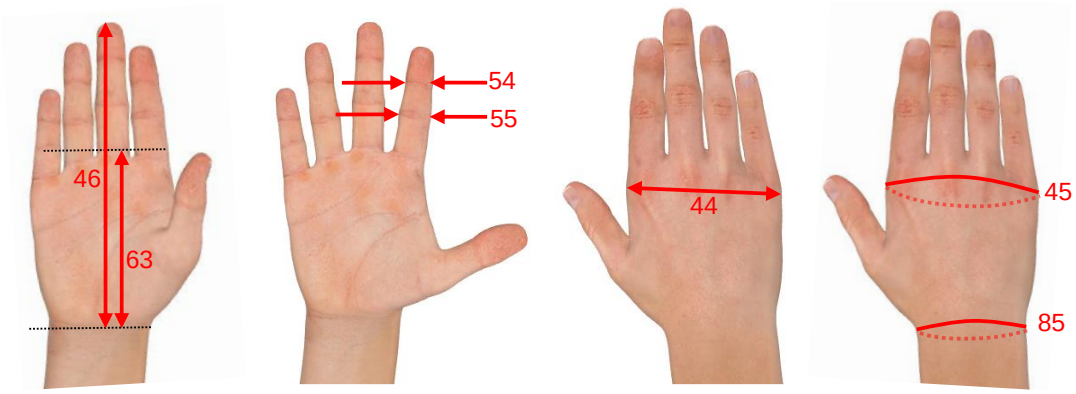
(56) Index finger reach
(75) Thumbtip reach
(43) Functional grip reach
(6) Arm span

G.5 Circumferences



(62) Neck circumference, base
(27) Chest/bust circumference
(33) Elbow circumference
(80) Waist circumference, natural indentation
(81) Waist circumference, preferred
(15) Buttock circumference
(52) Hip circumference, maximum
(85) Wrist circumference
(73) Thigh circumference
(58) Knee circumference
(21) Calf circumference
(5) Ankle circumference
(78) Vertical trunk circumference
(11) Biceps circumference, flexed

G.6 Hand Measures



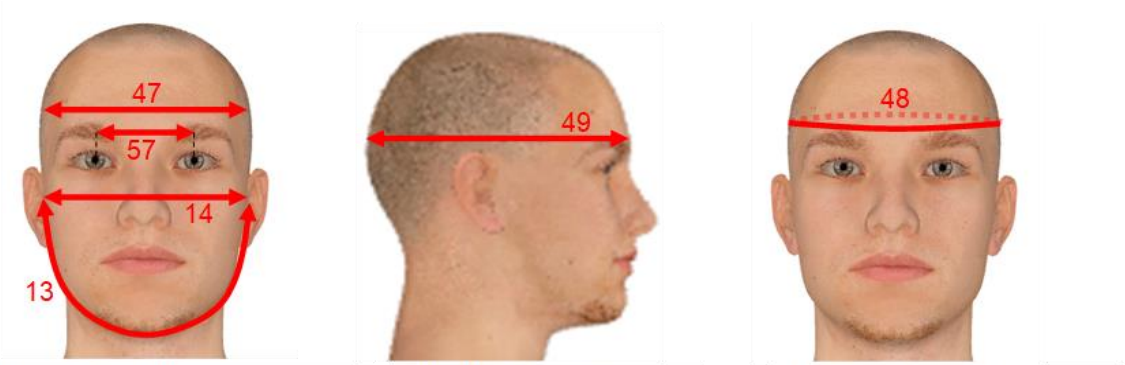
(46) Hand length
(63) Palm length
(54) Index finger breadth, distal
(55) Index finger breadth, proximal

(44) Hand breadth
(45) Hand circumference

G.7 Foot Measures

(40) Foot breadth
(41) Foot length
(9) Ball of foot length
(61) Malleolus-hallux length
(8) Ball of foot circumference

G.8 Head & Face Measures



(47) Head breadth
(57) Interpupillary breadth
(14) Bizygomatic breadth
(13) Bitragion submandibular arc

(49) Head length

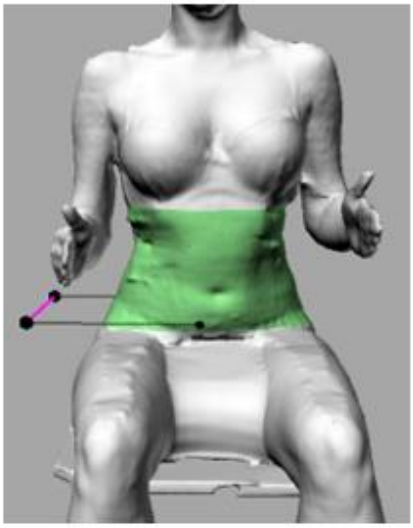
(48) Head circumference

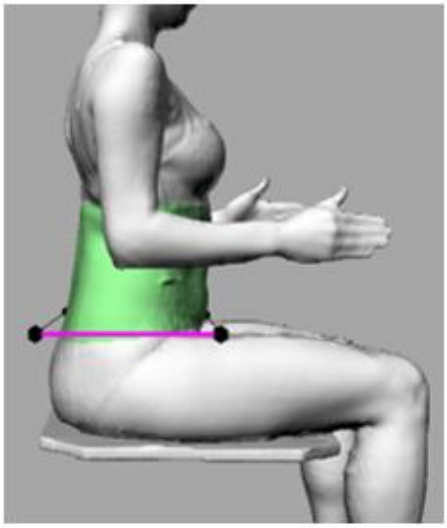
Appendix H Measurement Description

This section provides a detailed description of each measurement taken in the NZDF Anthropometry Survey using manual, automated or semi-automated measuring techniques. The purpose of this section is to document the measurement methods of the NZDFAS and provide a reference for future studies where anthropometric data is collected. Each measure is accompanied by its definition, a reference to the measurement definition source (e.g., previous military survey or international standard), the required measuring tools, and details regarding the measurement protocol.

H.1 Abdominal Extension Depth, Sitting

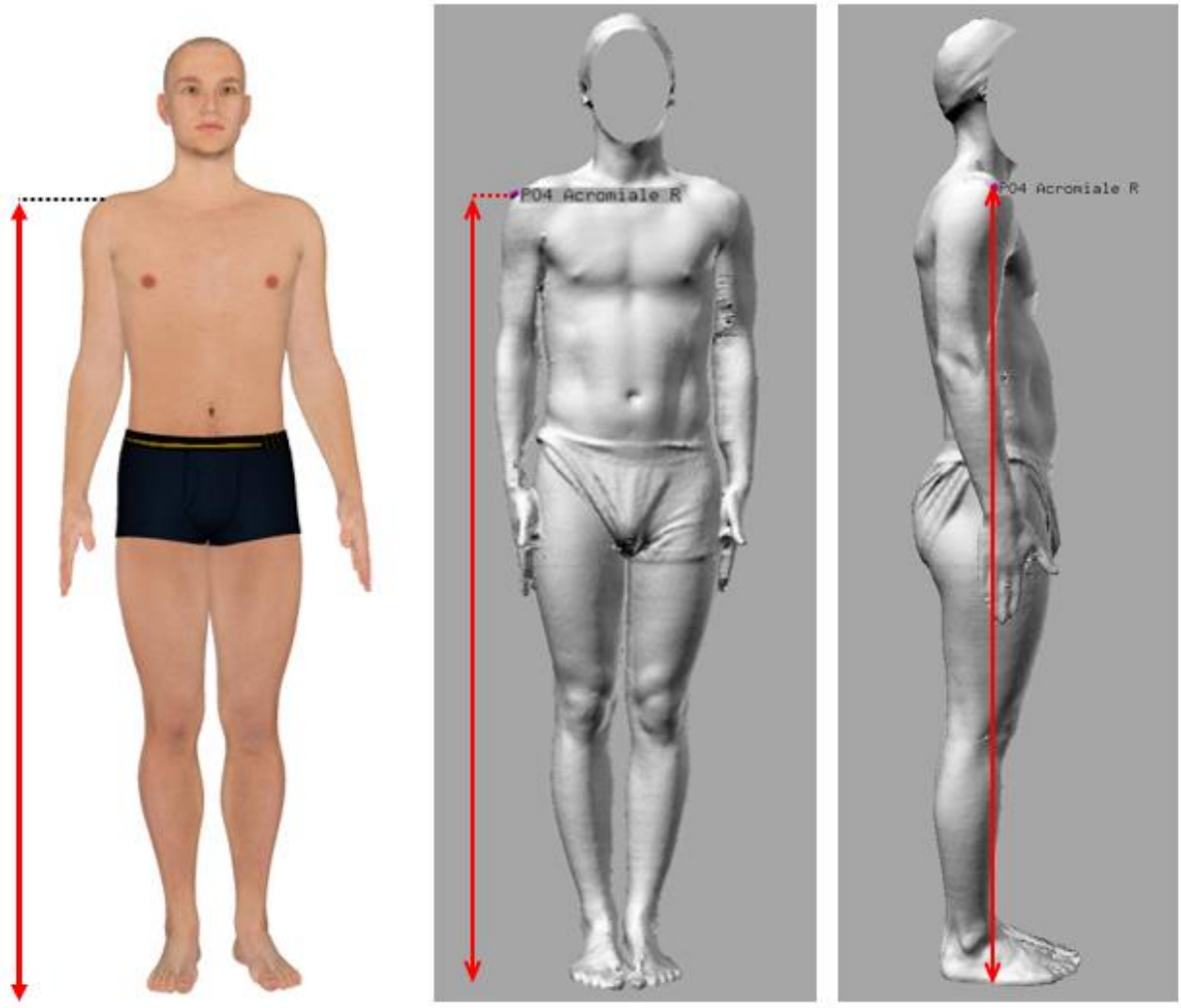
Definition	The largest horizontal depth of the abdomen region between the Substernale Landmark and the Inguinal Point in the seated posture.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Substernale and Inguinal Point
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan. Highlight the torso region between the Substernale Landmark and the Inguinal Point and use the calliper tool to find the largest depth (X function) within the highlighted region. Note that the scan is captured at end tidal expiration. Note: This measure cannot be obtained from scans containing artefacts in the abdomen region (often caused by shadowing from the hands). Future surveys should investigate a different technique to obtain this measure given the high frequency of these scan artefacts.





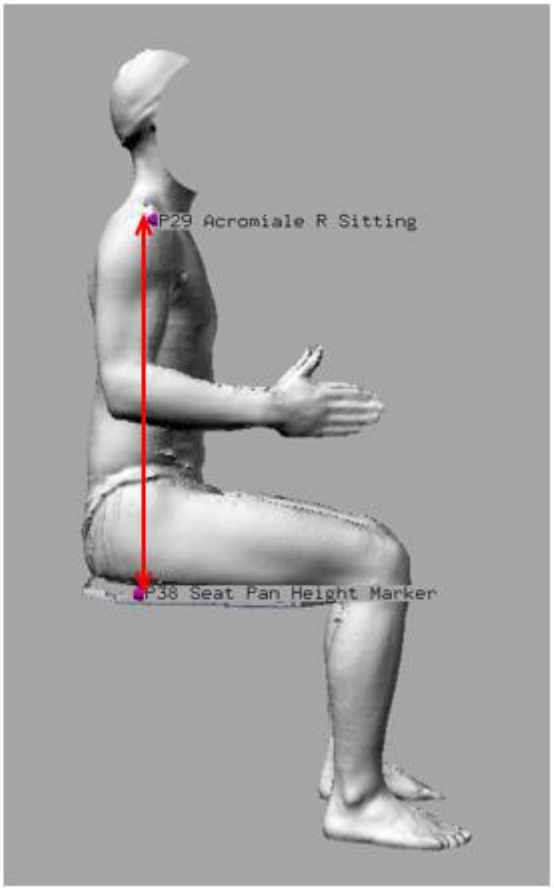
H.2 Acromial Height, Standing

Definition	The vertical distance between the standing surface and the Acromion Right Landmark on the tip of the right shoulder.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Acromion Right
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Acromion Right Landmark. Note that the scan is captured at end tidal expiration.



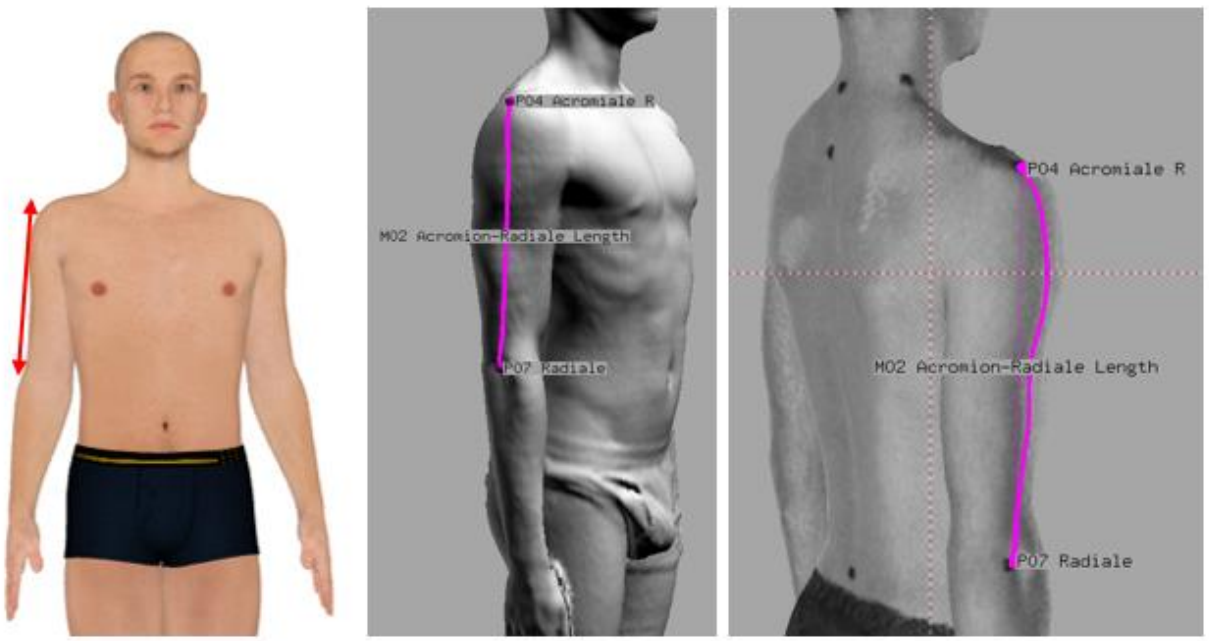
H.3 Acromial Height, Sitting

Definition	The vertical distance between the sitting surface and the Acromion Right Landmark on the tip of the right shoulder.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Acromion Right and Seat Pan Height Marker
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the difference between the Y coordinate of the Acromion Right Landmark and the Y coordinate of the Seat Pan Height Marker (which marks the top edge of the seat pan). The calculation is performed in an Excel spreadsheet. Note that the scan is captured at end tidal expiration.



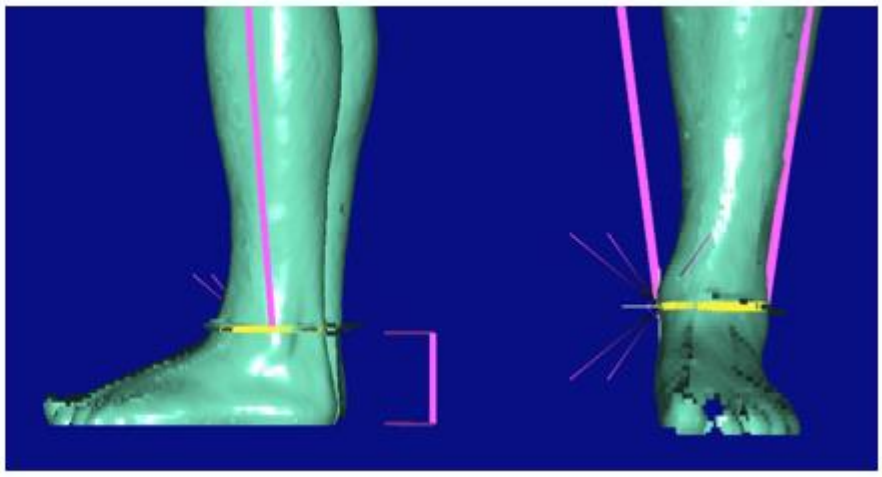
H.4 Acromion-Radiale Length

Definition	The distance between the Acromion Right Landmark on the tip of the right shoulder and the Radiale Landmark on the right elbow.
Source	AWAS
Landmark(s)	Acromion Right and Radiale
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the point-to-point distance between the Acromion Right and Radiale landmarks. Note: Despite the appearance of a contoured surface line in the figure, this measurement is extracted from CySize as a point-to-point linear distance.



H.5 Ankle Circumference

Definition	The horizontal perimeter of the lower leg measured at the height of the left anklebone (Lateral Malleolus), measured parallel to the standing surface.
Source	Anthroscan [Measurement ID 9550]
Landmark(s)	Lateral Malleolus
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. Ensure that the tape (represented by the yellow line) is horizontal. 2. Future surveys should obtain this measurement from the right foot instead of the left foot, as is standard anthropometry practice. 3. Future surveys should investigate a more accurate technique of obtaining this measure (e.g. manual measurement).

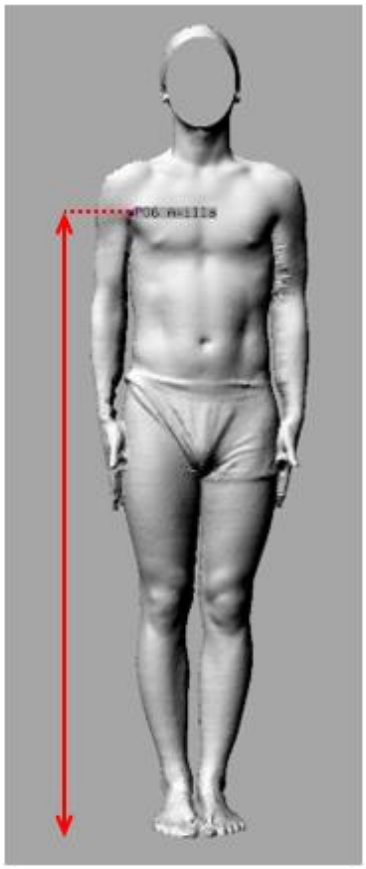


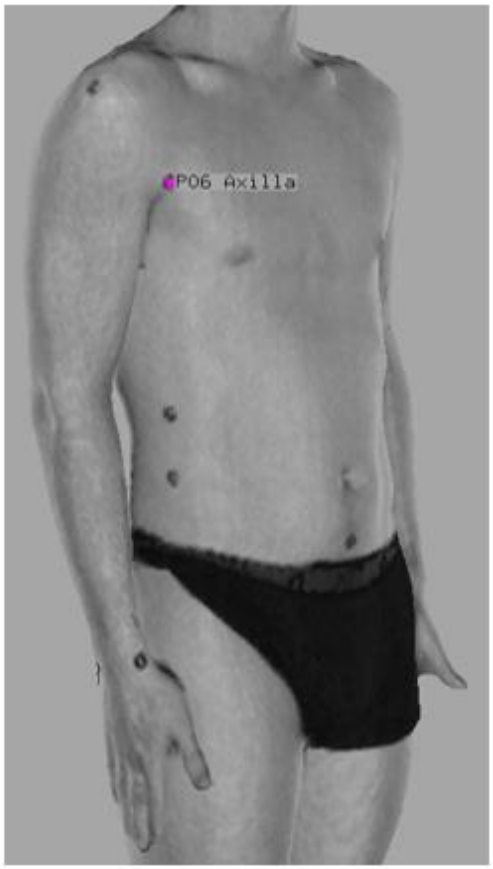
H.6 Arm Span

Definition	The distance between the tips of the middle fingers (Dactylion III) of the arms, both stretched maximally horizontally.
Source	ISAK
Landmark(s)	Dactylion III (left and right hand)
Instrument(s)	– A clear section of wall (flat, at least 2.5 m wide and with a clear corner or edge), with a blank sheet of paper temporarily fixed to the wall surface roughly 1.5 m from the edge or corner – Standard builders tape
Procedure	The participant stands erect against a wall with the feet together and arms spread out laterally at 90° to the body. Align the fingertip of the right hand with the edge of the wall. Prompt the participant to take a deep breath in and extend both arms laterally as far as possible. Ensure that the Dactyllion III (middle finger) fingertip remains in contact with the edge of the wall, and the heels, buttocks, upper back and back surfaces of the arms remain in contact with the wall surface. Mark the tip of the Left Dactylion III on the sheet of paper. Measure the distance from the right edge of the wall to this line with the builders tape to the nearest 0.1 cm, ensuring the tape is horizontal. Note: Future surveys should consider using a wall-mounted scale for ease and faster measurements.

H.7 Axilla Height

Definition	The vertical distance between the standing surface and the right axillary fold designated by the Anterior Scye Landmark on the front of the torso.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Anterior Scye
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Anterior Scye Landmark. Note that the scan is captured at end tidal expiration. Note: The Anterior Scye Landmark can be hidden in the P01 scan if there is insufficient clearance at the armpit. Future surveys should investigate obtaining this measure from the P02 scan where the hands are abducted further away from the body, or use a different measurement technique.



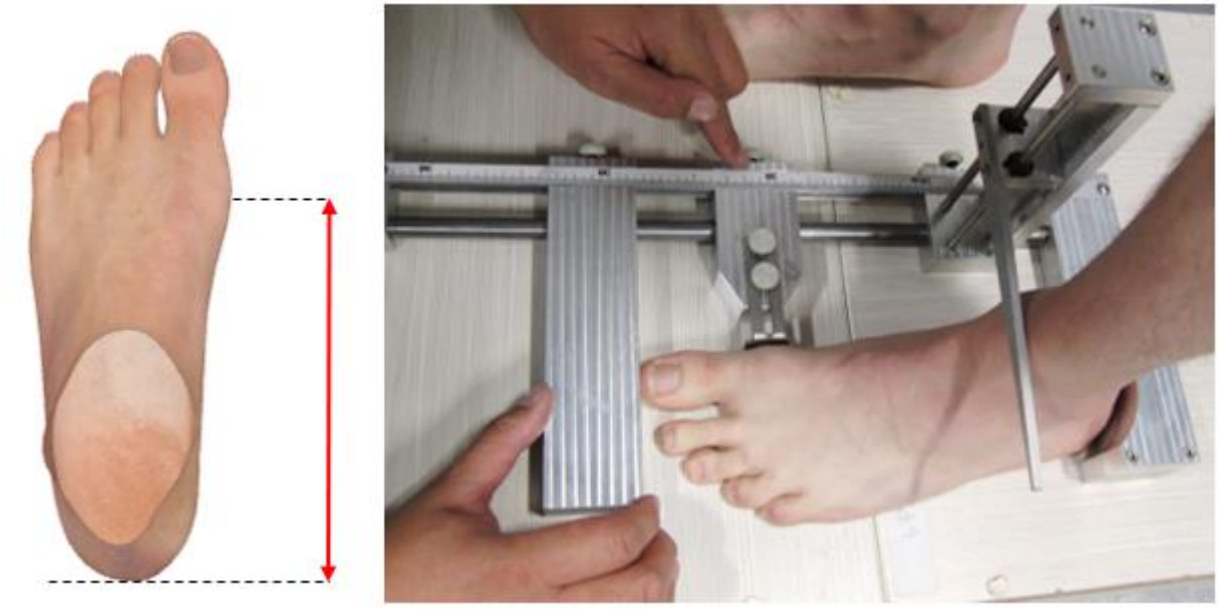


H.8 Ball of Foot Circumference

Definition	The circumference of the foot at the first and fifth metatarsophalangeal protrusions on the ball of the left foot.
Source	ANSUR
Landmark(s)	Metatarsophalangeal Protrusion I and V
Instrument(s)	Anthropometric tape
Procedure	The participant stands in a relaxed position with feet comfortably apart and weight evenly distributed. Visually inspect the left foot and palpate to identify the first and fifth metatarsophalangeal bony protrusions. Place the tape around these sites and take the circumference reading to the nearest 0.1 cm. Note: 1. 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. 2. To ensure correct tape positioning, adjust the tape and prompt the participant to raise and lower their foot as required. 3. Future surveys should obtain this measurement from the right foot instead of the left foot, as is standard anthropometry practice.

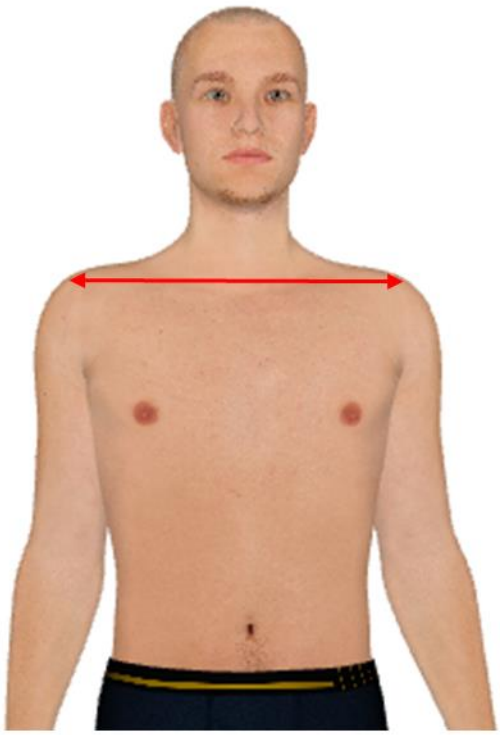
H.9 Ball of Foot Length

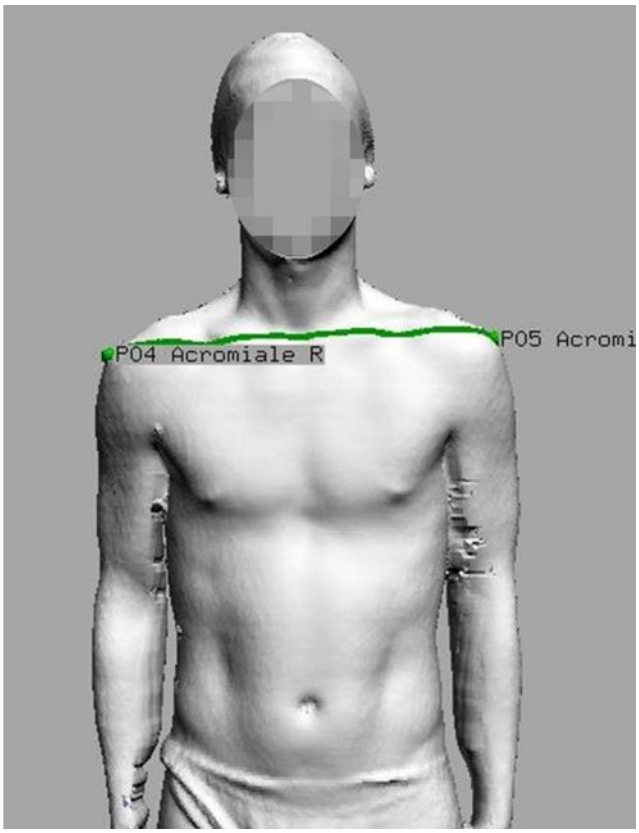
Definition	The distance from the back of the heel (Pternion) to the first metatarsophalangeal protrusion on the ball of the left foot.
Source	ANSUR II
Landmark(s)	Metatarsophalangeal Protrusion I and Pternion
Instrument(s)	Brannock device
Procedure	The participant stands in a relaxed position with the left foot placed in the Brannock device and the right foot comfortably apart with weight distributed evenly. Press the heel (Pternion) lightly against the rear curved plate, with the long-axis of the foot aligned with the long-axis of the device. Position the side-sliding plate to lightly press against the Metatarsophalangeal Protrusion I Landmark, using the extension latch of the device for increased accuracy. Take the reading to the nearest 0.1 cm. Note: Future surveys should obtain this measurement from the right foot instead of the left foot, as is standard anthropometry practice.



H.10 Biacromial Breadth

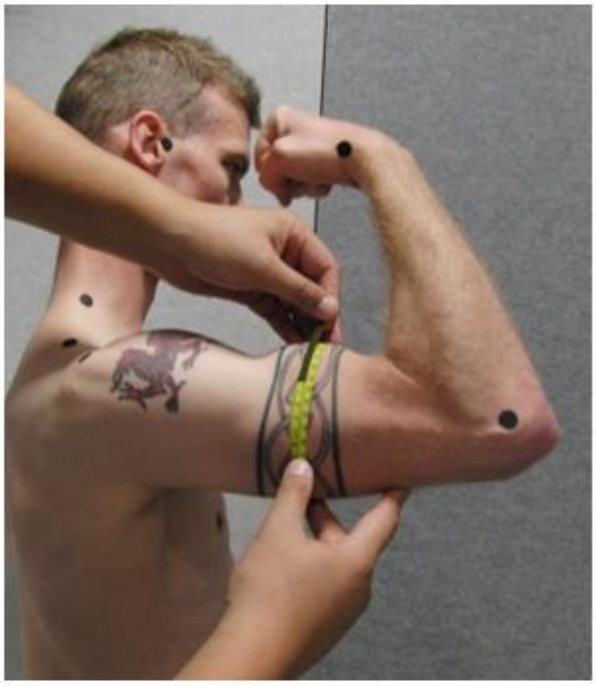
Definition	The distance between the Acromion Landmarks on the tips of the shoulders.
Source	AWAS
Landmark(s)	Acromion Right and Acromion Left
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the point-to-point distance between the Acromion Right and Acromion Left landmarks. Note: Despite the appearance of a contoured surface line in the figure, this measurement is extracted from CySize as a point-to-point linear distance.





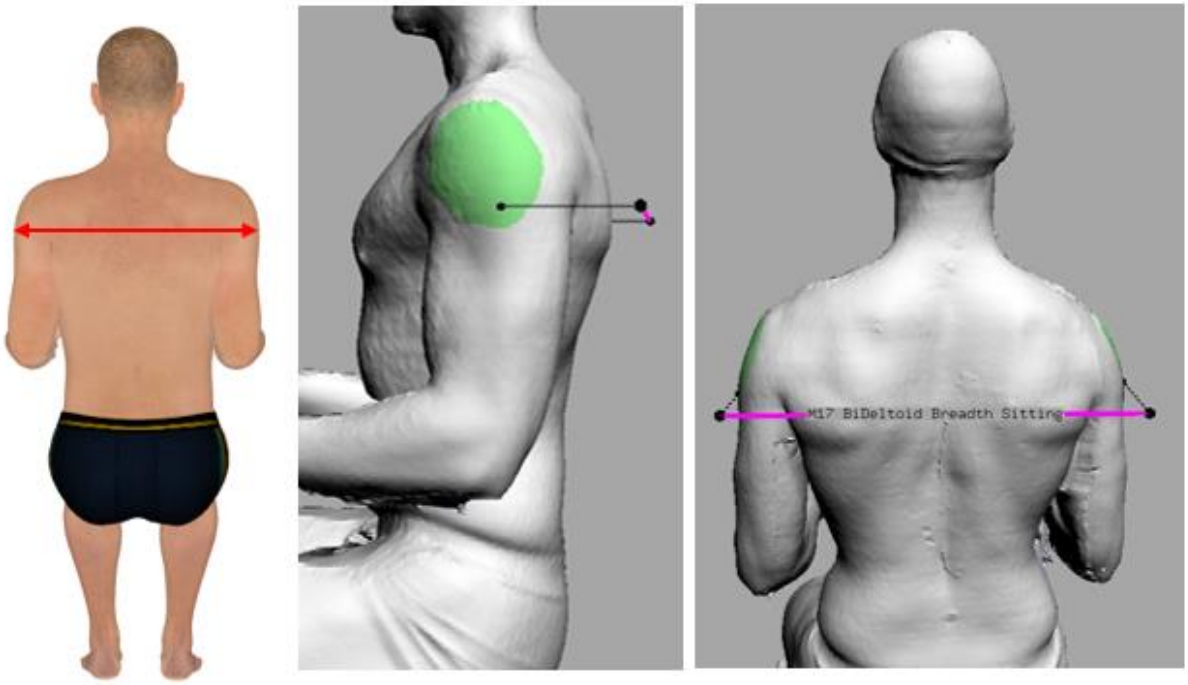
H.11 Biceps Circumference, Flexed

Definition	The circumference of the right upper arm around the flexed biceps muscle perpendicular to the long axis of the arm at the peak of the contracted Biceps Brachii (Biceps Point Landmark).
Source	AWAS/ANSUR
Landmark(s)	Biceps Point
Instrument(s)	Anthropometric tape
Procedure	The participant sits or stands with the right upper arm extended horizontally forward, the elbow flexed at 90° and the fist clenched and held facing the head. Prompt the participant to contract or flex the right biceps muscle. Position the tape at the peak of the bicep perpendicular to the long-axis of the arm. Apply light tension to the tape to eliminate gaps and ensure minimal skin indentation. Take the reading to the nearest 0.1 cm with the muscle maximally contracted.



H.12 Bideltoid Breadth

Definition	The largest horizontal distance between the lateral margins of the upper arms on the Deltoid Muscles.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Deltoid Muscles
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan. Highlight the Deltoid Muscles (region of the upper arm between the Acromion and the Axilla landmarks) on both shoulders and use the calliper tool to find the largest horizontal breadth (Y function) within this highlighted region. Note that the scan is captured at end tidal expiration.

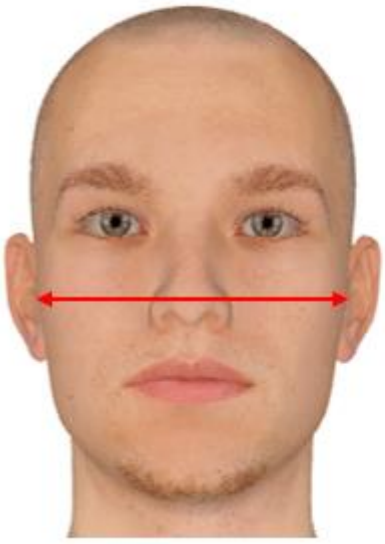


H.13 Bitragion Submandibular Arc

Definition	The distance from the Tragion Right Landmark over the Submandibular Landmark at the juncture of the jaw and neck, to the Tragion Left Landmark, with the head positioned in the Frankfurt plane.
Source	ANSUR
Landmark(s)	Tragion Right, Tragion Left and Submandibular
Instrument(s)	Anthropometric tape
Procedure	The participant sits or stands erect and looks straight ahead with the head positioned in the Frankfurt plane and the teeth lightly occluded. Position the tape with the zero mark aligned with the Left Tragion, passing over the Submandibular Landmark to the Right Tragion. Apply light tension to the tape to eliminate gaps and ensure minimal skin indentation. Take the reading the nearest 0.1 cm.

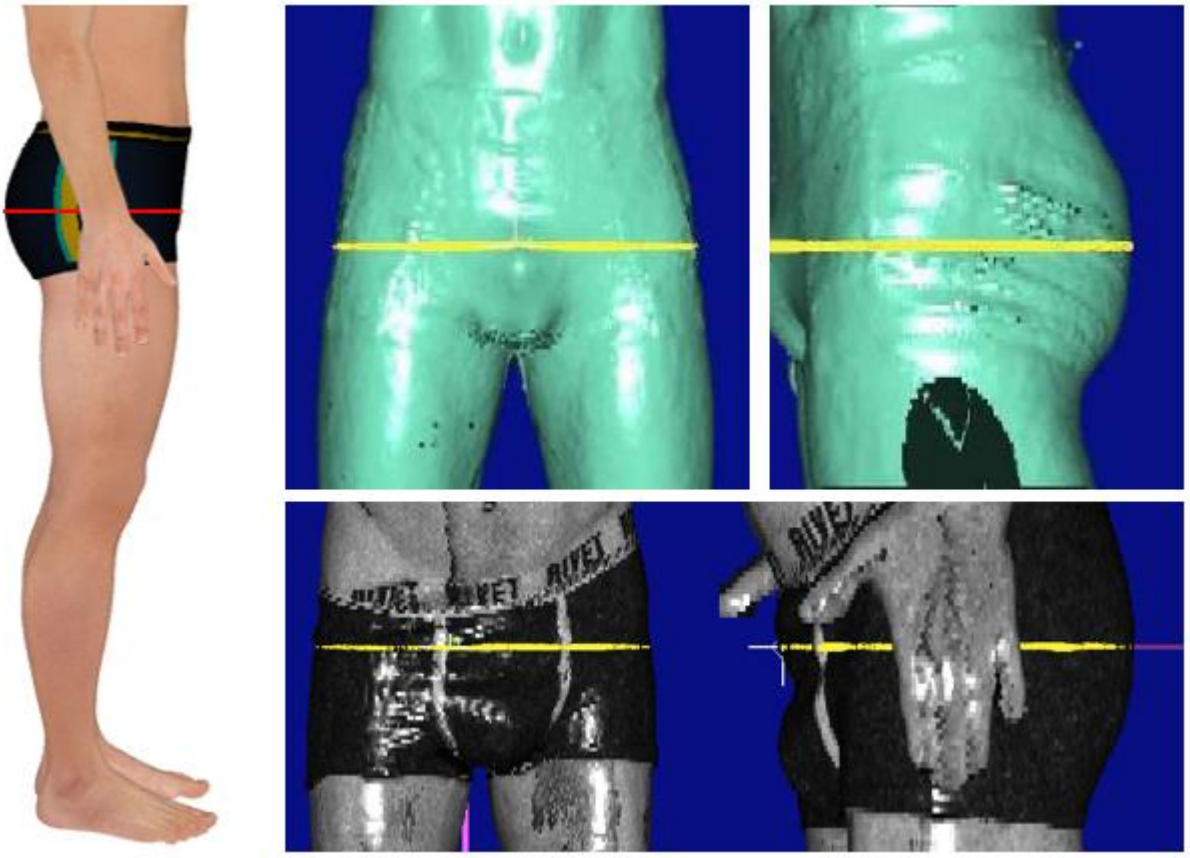
H.14 Bizygomatic Breadth

Definition	The maximum horizontal breadth of the face between the left and right Zygion.
Source	ANSUR (adapted to use small bone calliper instead of spreading calliper)
Landmark(s)	Zygion Left and Zygion Right
Instrument(s)	Small bone calliper
Procedure	The participant sits or stands erect and looks straight ahead with glasses removed (if wearing). Palpate the cheekbones to locate the most lateral aspects of the zygomatic arches and place the calliper plates at these points at a 45° angle. Apply light pressure to the calliper branches to maintain contact with the skin but not indent the skin. Take the reading to the nearest 0.1 cm. Note: 1. The head is in a neutral position for this measurement. The Frankfurt position is not required. 2. The small bone calliper is used instead of the large sliding calliper (more traditional tool for this measurement) as it provides a greater level of control. The large sliding calliper may be required for larger individuals with a breadth beyond 18 cm.



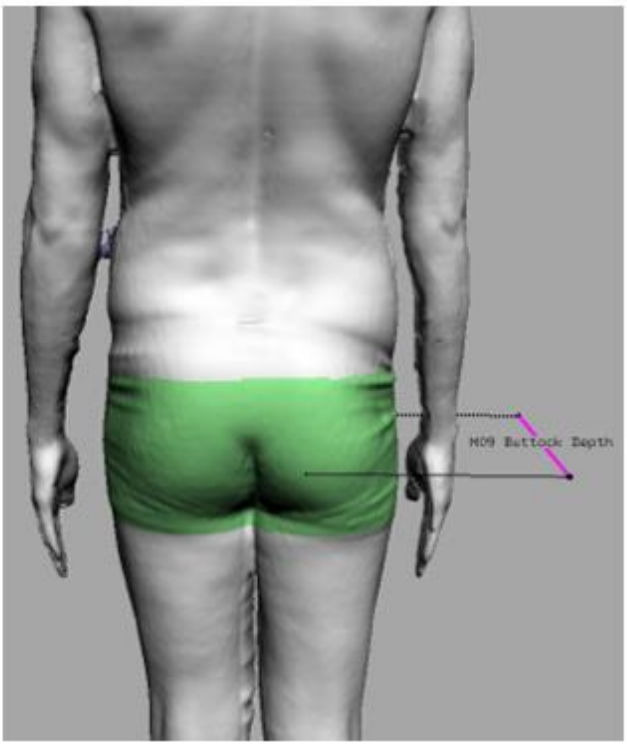
H.15 Buttock Circumference

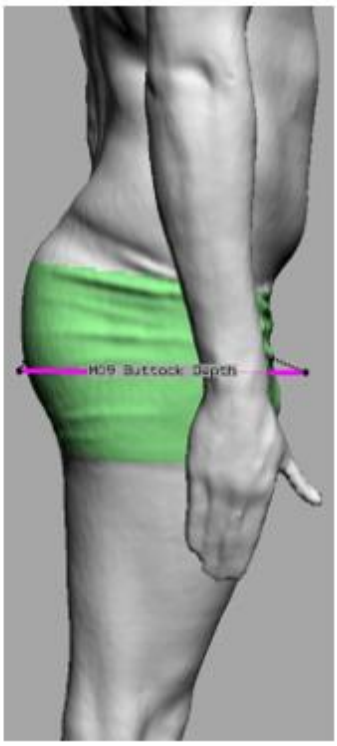
Definition	The circumference of the buttock measured with the tape passing just above the most protruding point of the buttock, parallel to the standing surface.
Source	Anthroscan [Measurement ID 7520]
Landmark(s)	Buttock Point Posterior
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. This measure cannot be accurately obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans. 2. Ensure that the tape (represented by the yellow line) is horizontal and does not pass around the hands.



H.16 Buttock Depth

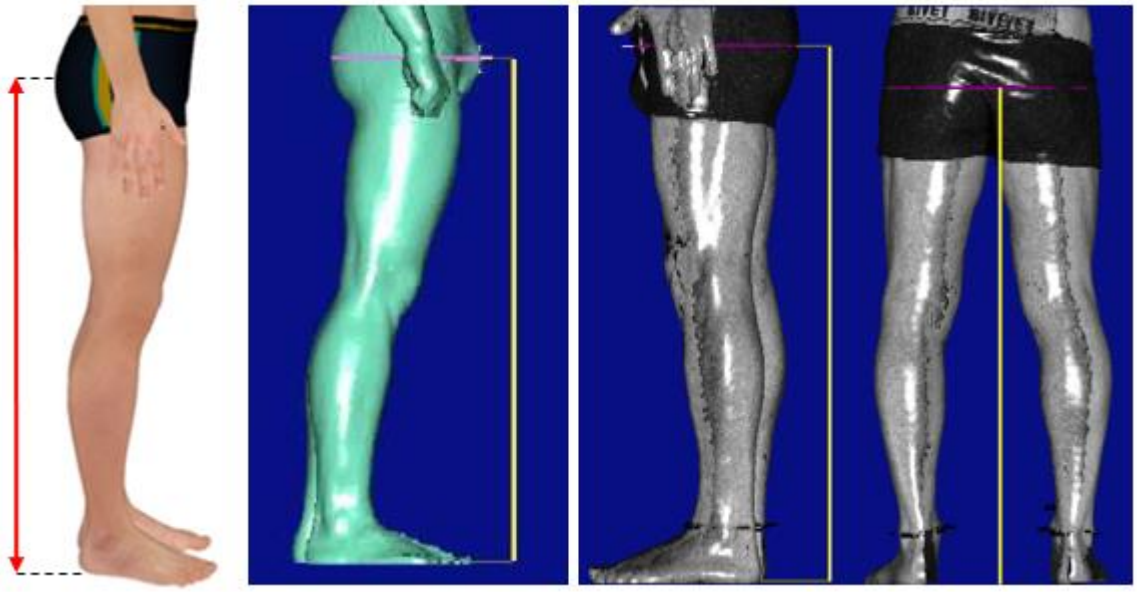
Definition	The largest horizontal depth of the right buttock and crotch region measured with the participant in the standing posture.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Iliocristale and Crotch
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan. Highlight the area below the Iliocristale Landmark and above the Crotch Landmark on the main body, avoiding any webbing scan artefacts between the hip and hands (occurs if the hands are too close to the body). Use the calliper tool to find the largest horizontal depth (X function) within the highlighted region. Note: This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.





H.17 Buttock Height

Definition	The vertical height of the Buttock Circumference measurement (just above the most protruding point of the buttock) to the standing surface.
Source	Anthroscan [Measurement ID 0090]
Landmark(s)	Buttock Point Posterior
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: This measure cannot be accurately obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.

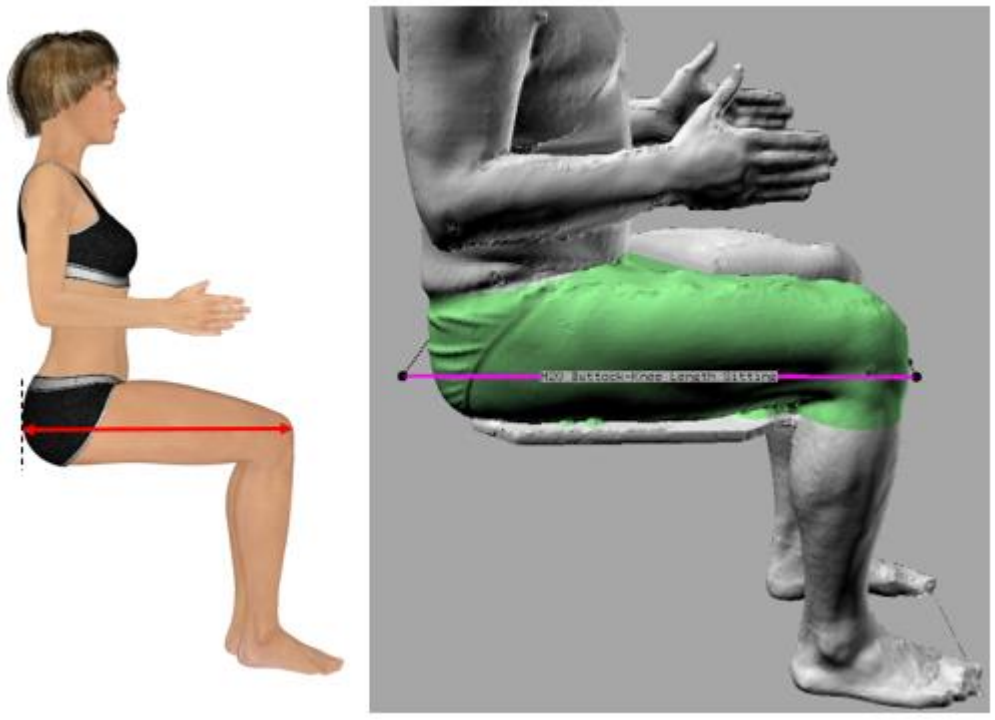


H.18 Buttock-Heel Length

Definition	The distance between the back of the right buttock and the plane of the bottom of the right foot, with the participant seated on the floor and the right leg extended.
Source	RNZAF (unpublished)
Landmark(s)	Right Buttock and Heel Pad
Instrument(s)	Standard builders tape and two measurement plates (or Rosscraft headboard plates)
Procedure	The participant sits on the floor with the right leg fully extended forward (toes pointing up) and hands placed on the thighs. The buttock is shifted back as close to the wall as possible, with the left leg folded for increased comfort if necessary. Place one plate flat against the most posterior aspect of the buttock (not the wall), and the second plate flat against the heel of the outstretched foot (with the scribe's assistance). Ensure that both measurement plates are held vertically upright and perpendicular to the tape to avoid error. Following a line parallel to the leg, measure the distance between the inner surfaces of the two plates to the nearest 0.1 cm. Take the measurement immediately to avoid participant discomfort.

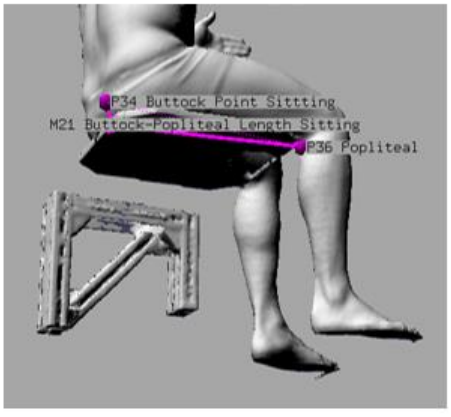
H.19 Buttock-Knee Length

Definition	The largest horizontal depth from the back of the right buttock to the front of the right knee flexed at 90°.
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Right Buttock and Right Knee
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan. Highlight the region from the posterior aspect of the right buttock to the anterior aspect of right knee. Use the calliper tool to find the maximum horizontal depth (X function) within this highlighted region. Note: This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.



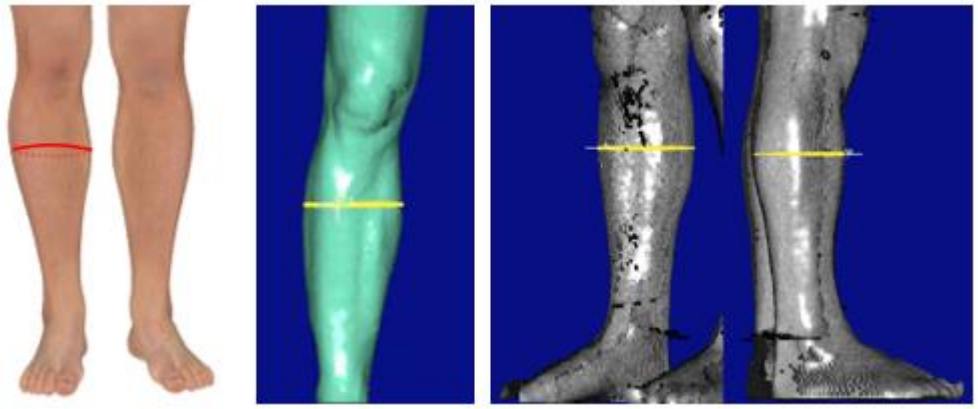
H.20 Buttock-Popliteal Length

Definition	The horizontal distance between the Buttock Point Posterior (most protruding point on the right buttock) and the Popliteal Landmark, in the seated posture.
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Buttock Point Sitting and Popliteal
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the point-to-point distance between the Buttock Point Sitting (the most posterior aspect of the right buttock in the seated position) and the Popliteal Landmark (on the back of the right knee at the juncture of the calf and thigh). Note: 1. Despite the appearance of a contour line in the figure, this measurement is extracted from CySize as a point-to-point linear distance. 2. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans. 3. Other military surveys used a footrest or foot plates to ensure a 90° bend in the knees. In the NZDFAS, the height of the scanner seat platform was adjusted for each participant to ensure 90° knee flexion, with both feet and heels flat on the scanner platform. 4. The measure cannot be obtained if webbing scan artefacts are present behind the back of the knee, close to the seat pan. Future surveys should ensure that when participants are positioned for the sitting scan, there is sufficient space between the back of the knee and the forward edge of the seat pan (i.e. the participant sits slightly forward if necessary).



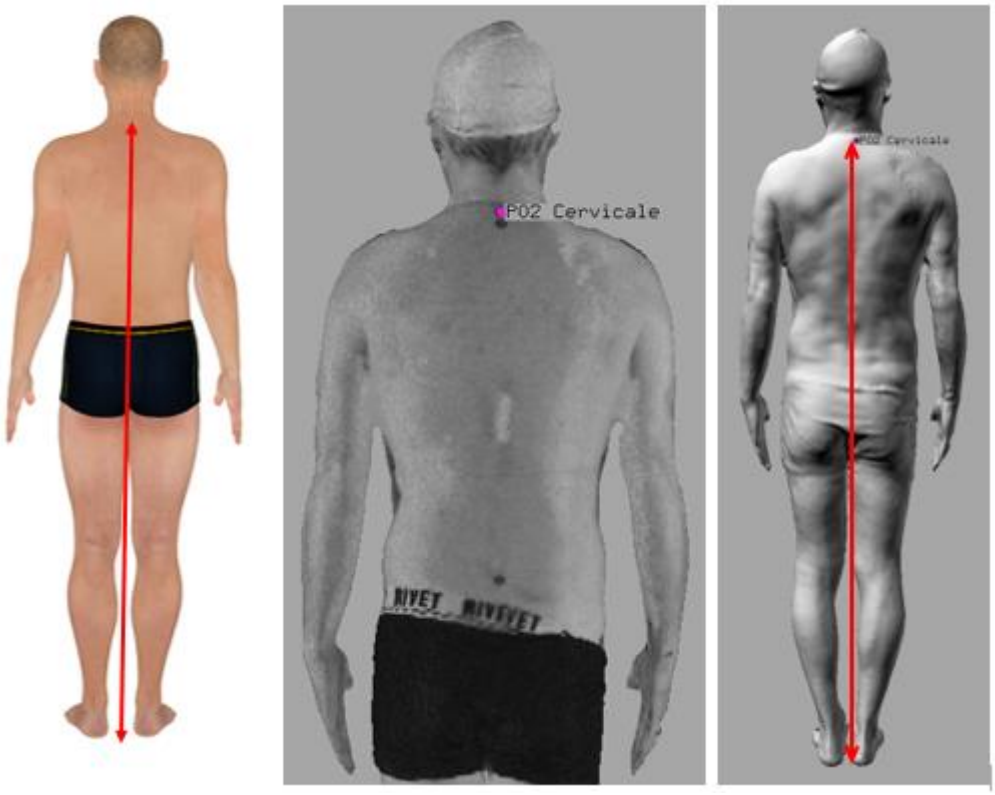
H.21 Calf Circumference

Definition	The maximal horizontal perimeter over the calf muscle of the right lower leg, parallel to the standing surface.
Source	Anthroscan [Measurement ID 9541]
Landmark(s)	Calf Muscle
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: Ensure that the tape (represented by the yellow line) is horizontal and passes around the widest point of the calf.



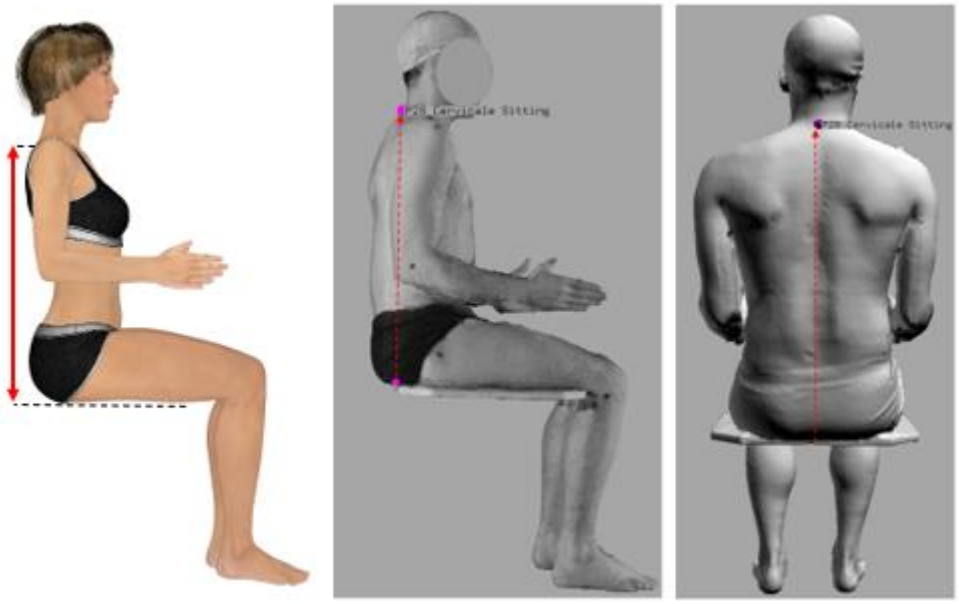
H.22 Cervicale Height

Definition	The vertical distance between the standing surface and the Cervicale (C7) Landmark on the spine at the base of the neck.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Cervicale (C7)
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Cervicale Landmark. Note that the scan is captured at end tidal expiration.



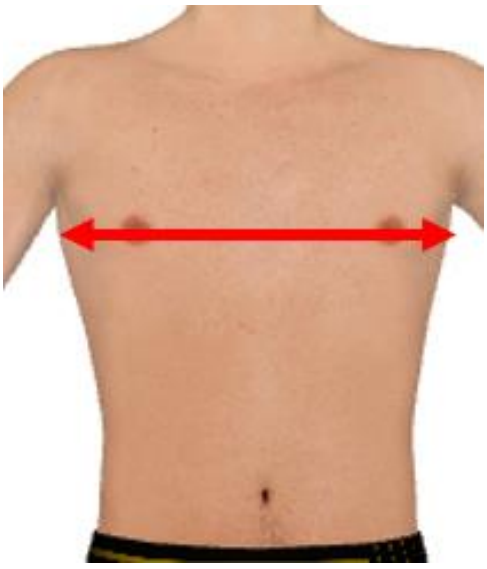
H.23 Cervicale Height, Sitting

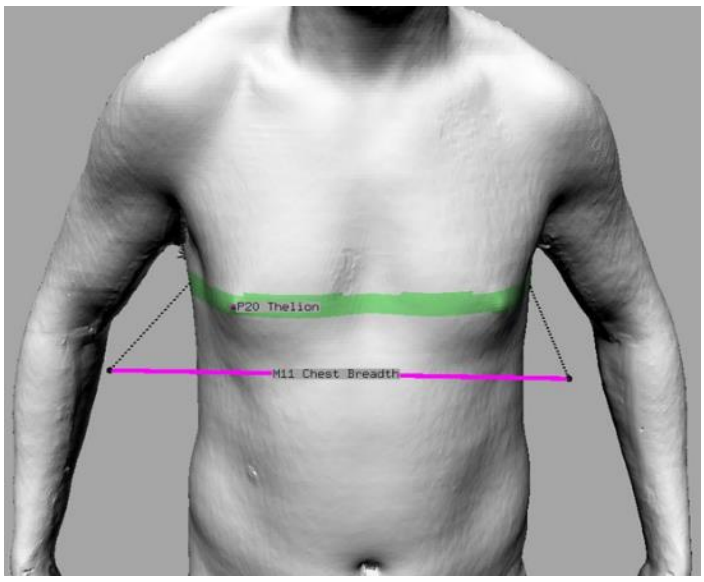
Definition	The vertical distance between the sitting surface and the Cervicale (C7) Landmark on the spine at the base of the neck.
Source	ANSUR I (adapted for digital measurement, and captured at end tidal expiration instead of at the point of maximum respiration)
Landmark(s)	Cervicale (C7) and Seat Pan Height Marker
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the difference between the Y coordinate of the Cervicale (C7) Landmark and the Y coordinate of the Seat Pan Height Marker (which marks the top edge of the seat pan). The calculation is performed in an Excel spreadsheet. Note that the scan is captured at end tidal expiration.



H.24 Chest Breadth

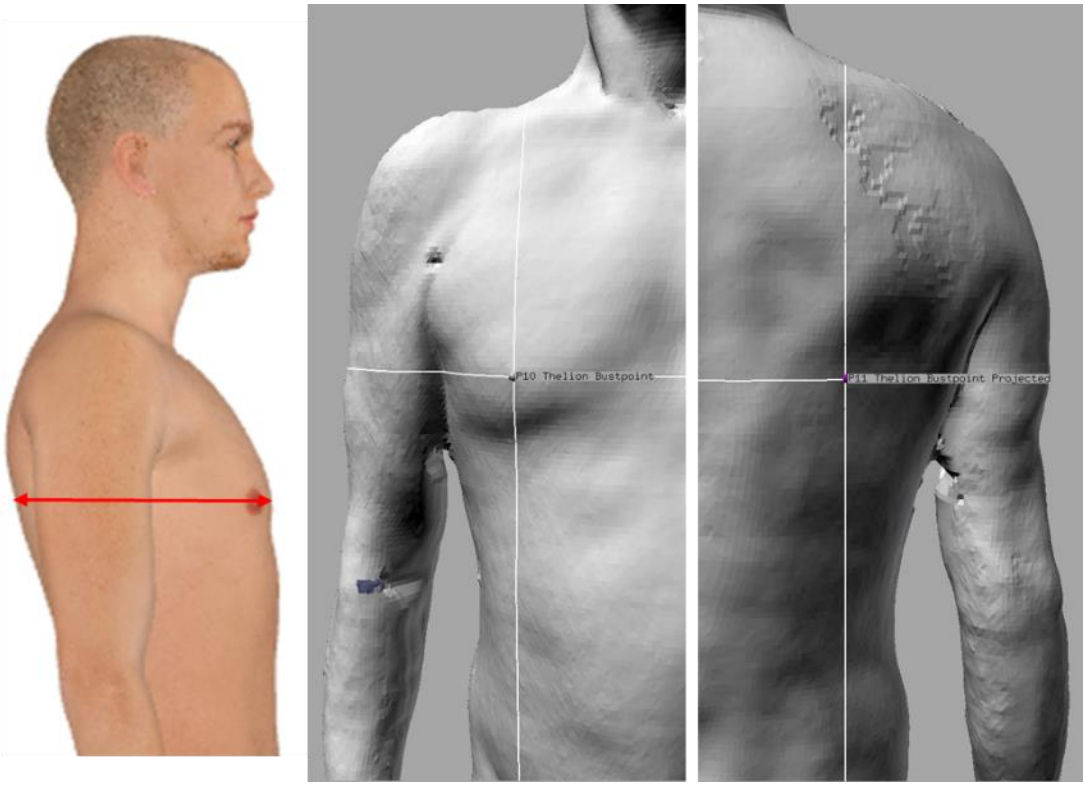
Definition	The maximum horizontal breadth of the chest at the level of the Thelion (right nipple) in males or the Bustpoint (most protruding point on the right bra cup) in females.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Thelion/Bustpoint
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P02 standard scan. Highlight a thin horizontal region encompassing the centre of the Thelion/Bustpoint Landmark, avoiding any webbing scan artefacts between the arms and upper body at the armpits. Use the calliper tool to find the maximum horizontal breadth (Y function) within the highlighted region. Note that the scan is captured at end tidal expiration. Note: This measure cannot be obtained in scans where significant webbing scan artefacts are present at the armpits (from the arms being too close to the body). Future surveys should ensure that the hands are adequately abducted from the torso at the armpits to provide sufficient clearance and avoid webbing artefacts.





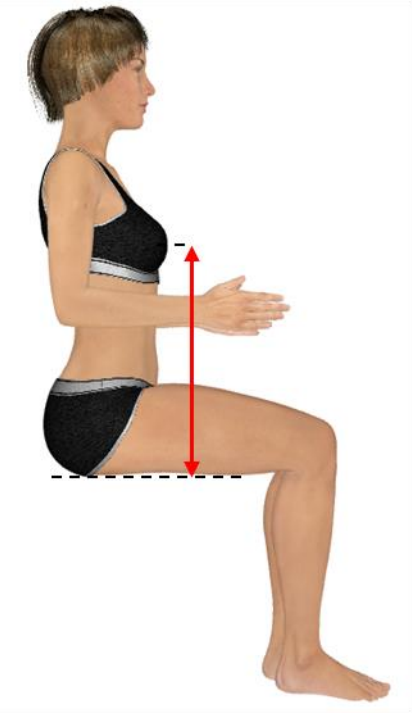
H.25 Chest Depth

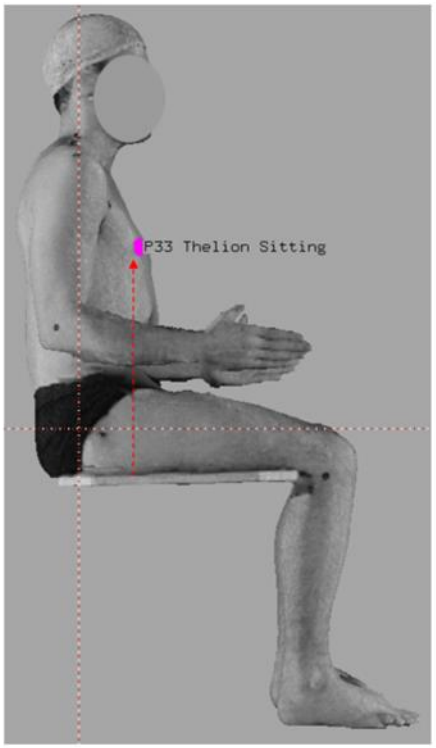
Definition	The horizontal distance between the Thelion (right nipple) in males or the Bustpoint (most protruding point on the right bra cup) in females, and point on the back at the same level.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Thelion/Bustpoint and Thelion/Bustpoint Projected
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing as the point-to-point distance between the Thelion/Bustpoint and the Thelion/Bustpoint Projected Landmarks by adding their X coordinates together (calculation performed in an Excel spreadsheet). Note that the scan is captured at end tidal expiration. Note: 1. Locate the Thelion/Bustpoint Projected Landmark in CySize by adding Y and Z sections to the Thelion/Bustpoint Landmark and placing a new marker at the intersection of these lines on the posterior surface of the torso. 2. Future survey should consider using the calliper tool (X function) for chest depth measurements.



H.26 Chest Height, Sitting

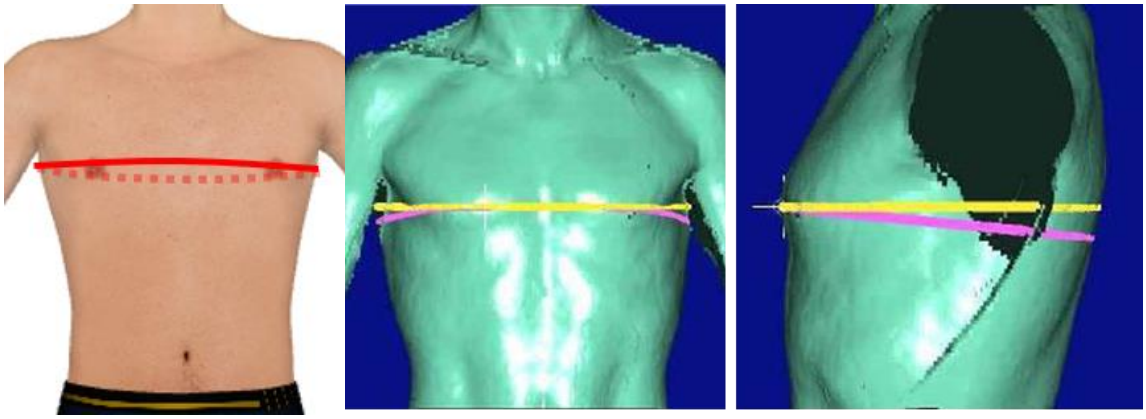
Definition	The vertical distance between the sitting surface and the Thelion (right nipple) in males or the Bustpoint (most protruding point on the right bra cup) in females.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Thelion/Bustpoint and Seat Pan Height Marker
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the difference between the Y coordinate of the Thelion/Bustpoint Landmark and the Y coordinate of the Seat Pan Height Marker (which marks the top edge of the seat pan). This calculation is performed in an Excel spreadsheet. Note that the scan is captured at end tidal expiration.





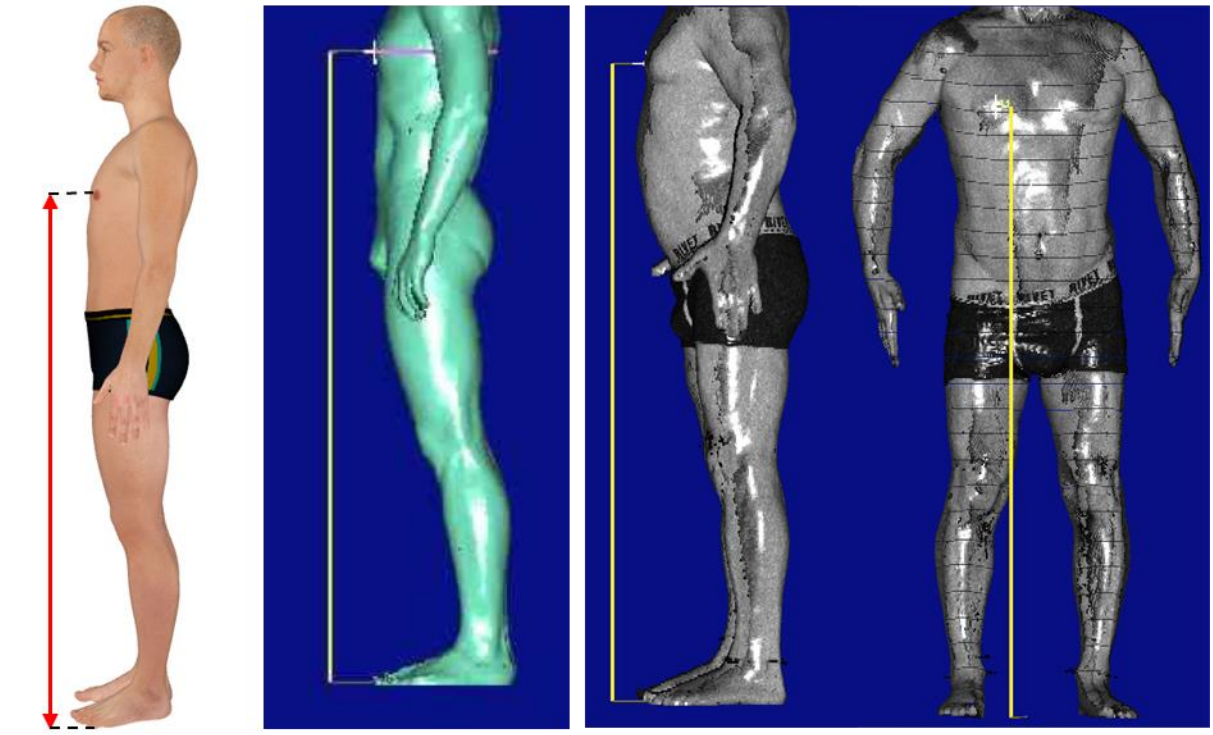
H.27 Chest/Bust Circumference

Definition	The circumference of the chest at the level of the Thelion (right nipple) in males or the Bustpoint (the most protruding point on the right bra/breast) in females, measured parallel to the standing surface.
Source	Anthroscan [Measurement ID 4510]
Landmark(s)	Thelion/Bustpoint
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note that the scan is captured at end tidal expiration. Note: 1. Ensure that the tape (represented by the yellow line) is horizontal and does not pass around the arms. 2. Future surveys should investigate other measurement techniques to more accurately obtain this measure.



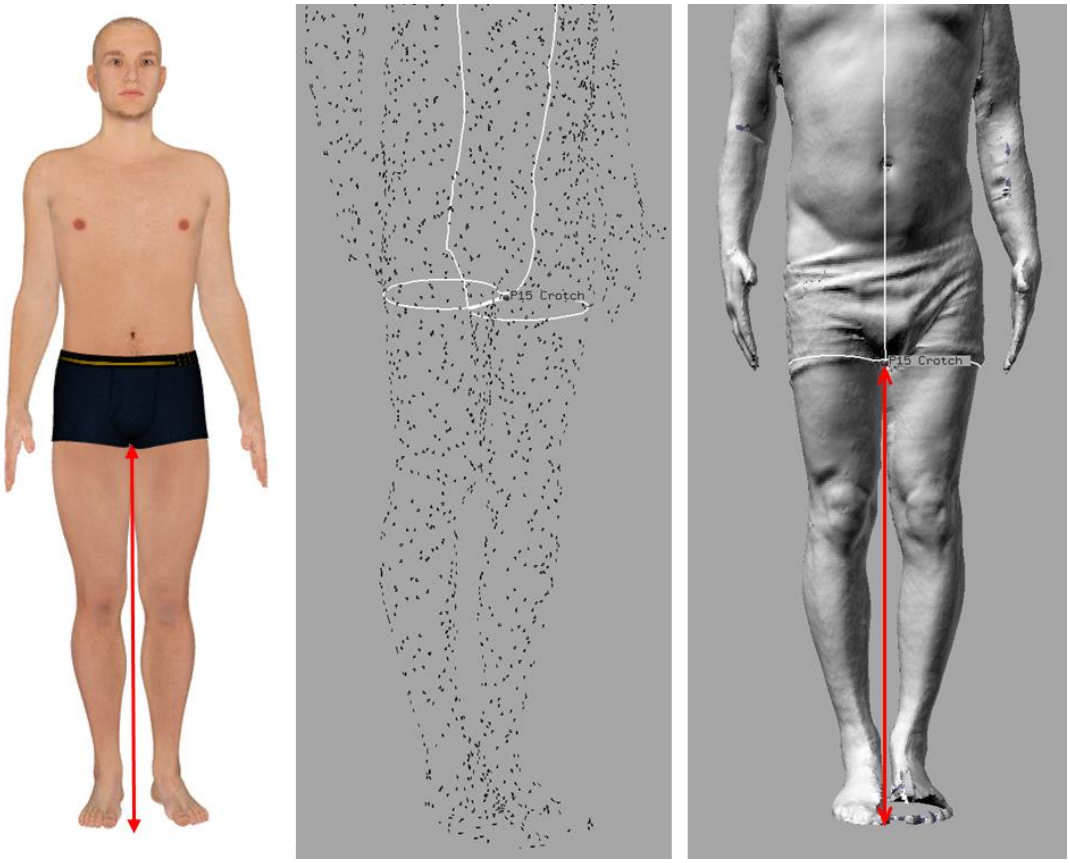
H.28 Chest/Bust Height

Definition	The vertical height of the front breast circumference level at the Thelion (right nipple) in males or the Bustpoint (the most protruding point on the right bra/breast) in females, to the standing surface.
Source	Anthroscan [Measurement ID 0170]
Landmark(s)	Thelion/Bustpoint
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note that the scan is captured at end tidal expiration.



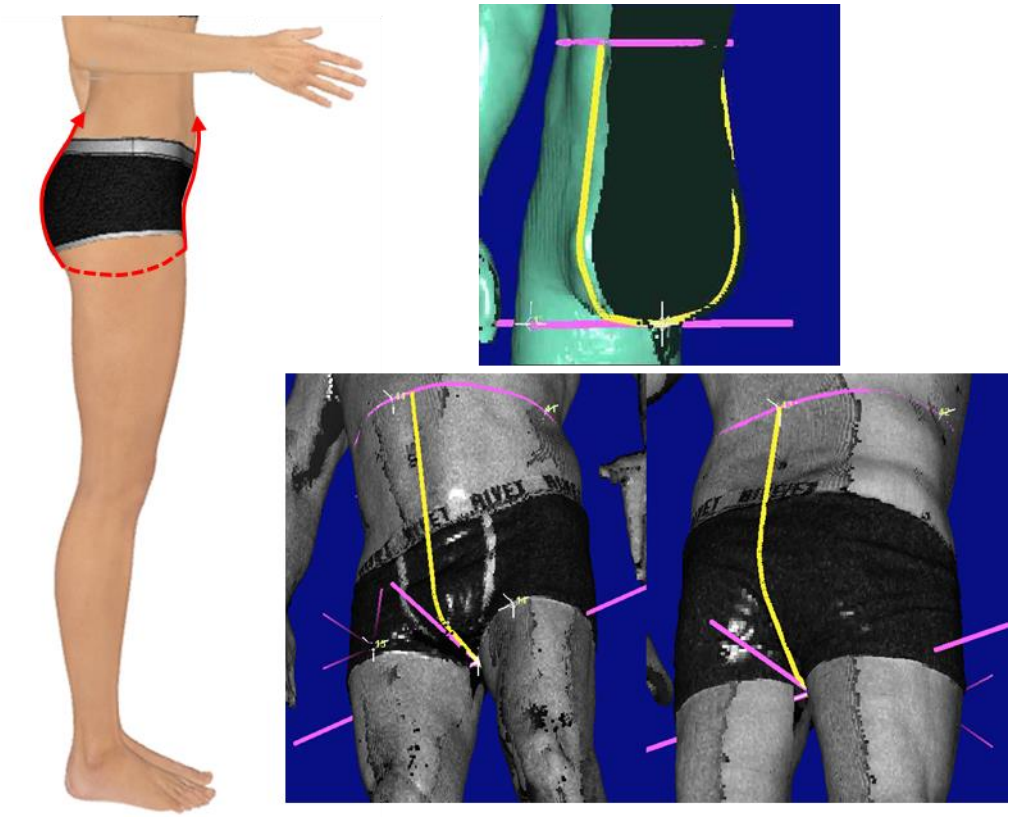
H.29 Crotch Height

Definition	The vertical distance between the standing surface and the crotch.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Crotch
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Crotch Landmark. Note that the scan is captured at end tidal expiration. Note: 1. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans. 2. The Crotch Landmark can be difficult to locate if the legs are too close together and there is insufficient clearance between the thighs in the P01 scan. Future surveys should investigate obtaining this measure from the P02 scan where the legs are further apart, or use a different measurement technique.



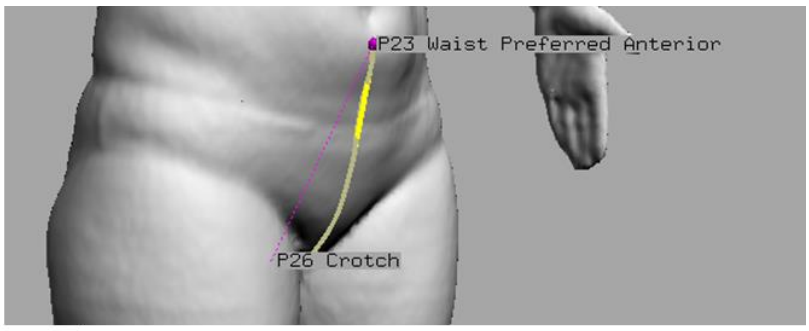
H.30 Crotch Length

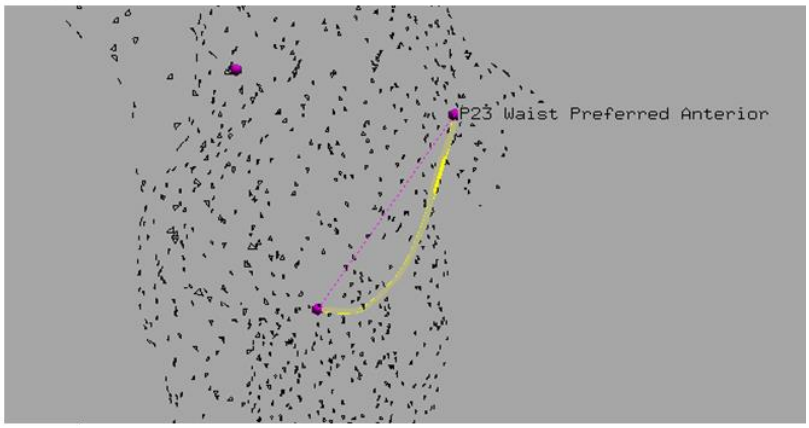
Definition	The distance from the front waist to the back waist (at the height of the natural waist or the natural contraction points of the waist), passing through the crotch.
Source	Anthroscan [Measurement ID 6010]
Landmark(s)	Natural Waist Contraction Points and Crotch
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. The natural waist points are located by identifying the natural points of waist narrowing at the torso. 2. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.



H.31 Crotch-Waist Length Preferred, Anterior

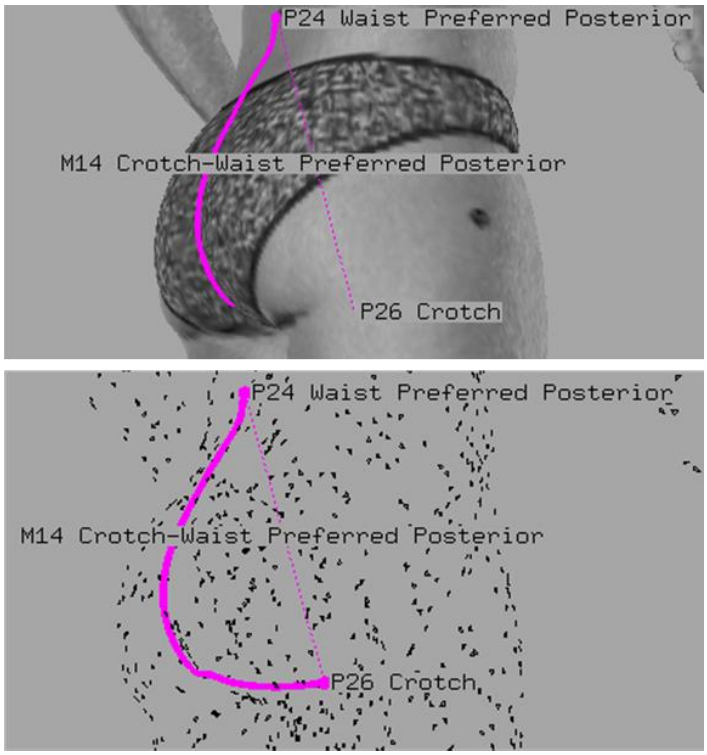
Definition	The distance between the Waist Preferred Anterior Landmark (at the level of the participant's preferred belt height on the front waist in line with the Omphalion) and the Crotch Landmark.
Source	Nil
Landmark(s)	Crotch and Waist Preferred Anterior
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P02 standard scan as the "tape" length (a CySize function that mimics an anthropometric tape) between the Crotch and Waist Preferred Anterior landmarks. Note: 1. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans. 2. The Crotch Landmark can be difficult to locate if the legs are too close together and there is insufficient clearance between the thighs in the P01 scan. Future surveys should investigate obtaining this measure from the P02 scan where the legs are further apart, or use a different measurement technique.





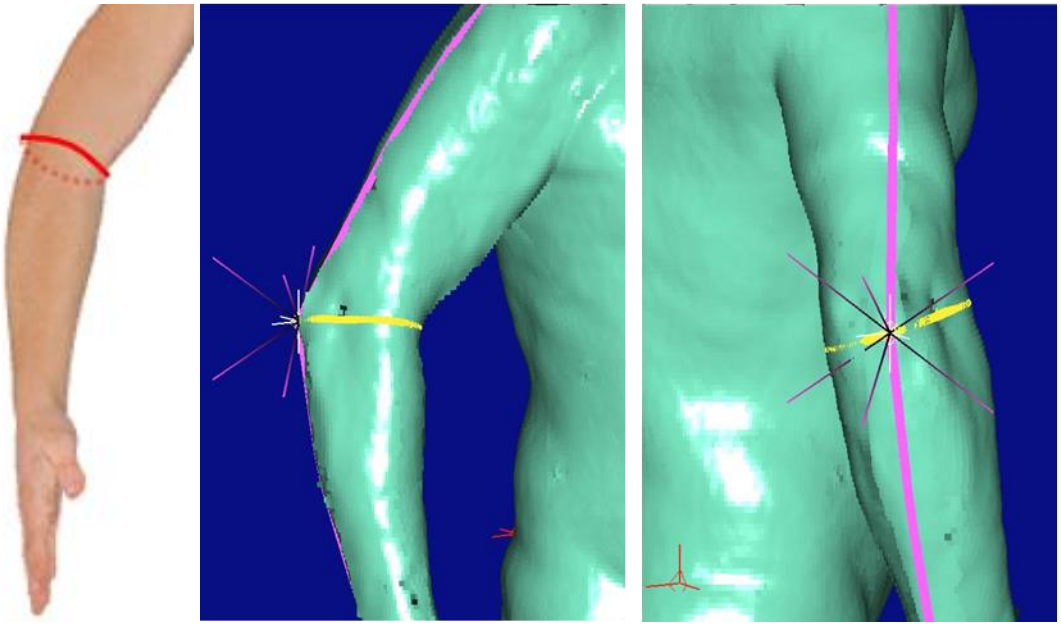
H.32 Crotch-Waist Length Preferred, Posterior

Definition	The distance between the Waist Preferred Posterior Landmark (at the level of the participant's preferred belt height on the back waist in line with the spine) and the Crotch Landmark.
Source	Nil
Landmark(s)	Crotch and Waist Preferred Posterior
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P02 standard scan as the "tape" length (a CySize function that mimics an anthropometric tape) between the Crotch and Waist Preferred Posterior landmarks. Note: 1. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans. 2. The Crotch Landmark can be difficult to locate if the legs are too close together and there is insufficient clearance between the thighs in the P01 scan. Future surveys should investigate obtaining this measure from the P02 scan where the legs are further apart, or use a different measurement technique.



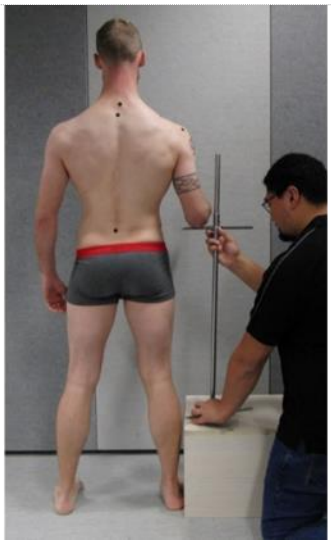
H.33 Elbow Circumference

Definition	The elbow perimeter measured with a line passing over the right elbow backbone and the arm front hollow.
Source	Anthroscan [Measurement ID 8531]
Landmark(s)	Elbow
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. Ensure that the tape (represented by the yellow line) is horizontal and passes over the inner crease of the elbow and the olecranon process (tip of the elbow). 2. Elbow position and posture can vary significantly in scans and affect the accuracy of this measurement. Future surveys should use a different measurement technique to more accurately obtain this measure.



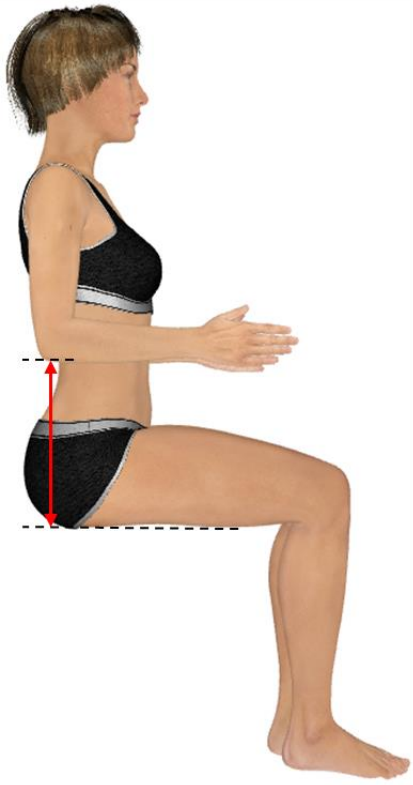
H.34 Elbow Rest Height

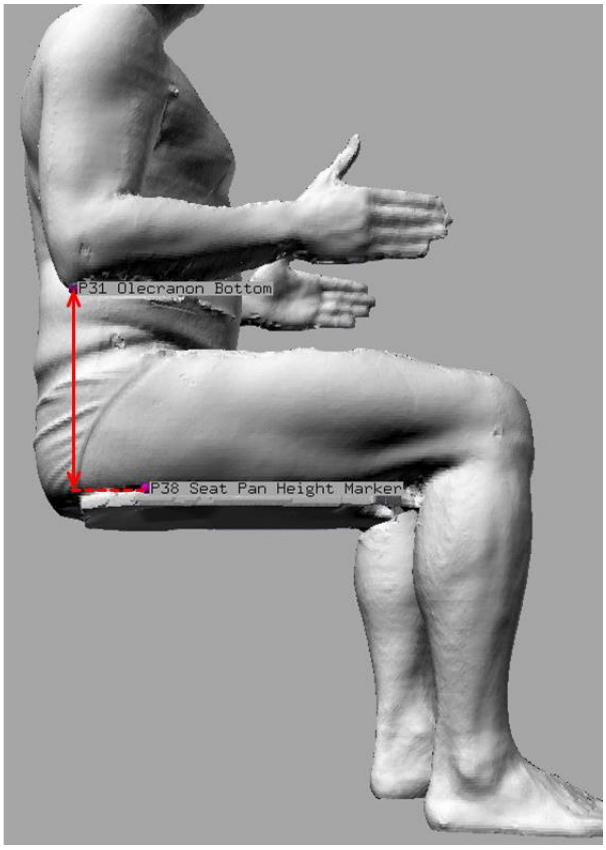
Definition	The vertical distance between the standing surface and the Olecranon Bottom Landmark (lowest point) on the flexed right elbow.
Source	ISO 7250-1:2008
Landmark(s)	Olecranon Bottom
Instrument(s)	Anthropometer and Anthropometry box
Procedure	The participant stands erect on the left side of the anthropometry box (lateral surface of the right leg touching the box) with the right elbow flexed at 90°. Measure the distance from the inferior point of the bony elbow process (Olecranon Bottom) to the top surface of the anthropometry box with the anthropometer. At end tidal expiration, take the reading at the distal edge of the sliding branch to the nearest 0.1 cm, maintaining contact with the elbow. A correction factor of +40.3 cm is added post-measurement to account for the height of the box. Note: 1. Use a sturdy table if the anthropometry box is too low. 2. Hold the fixed anthropometer branch flat against the top of the anthropometry box, and ensure the anthropometer is vertical. 3. Keep the long axis of the right arm perpendicular to the anthropometry box top surface. For participants with a wider Lattisimus Dorsi, prompt the participant to slightly abduct the elbow away from the body. 4. Take the reading at end tidal expiration to avoid fluctuations and movement due to breathing. 5. Take the reading at the distal (outside) edge of the measuring window to include the width of both anthropometer branches.



H.35 Elbow Rest Height, Sitting

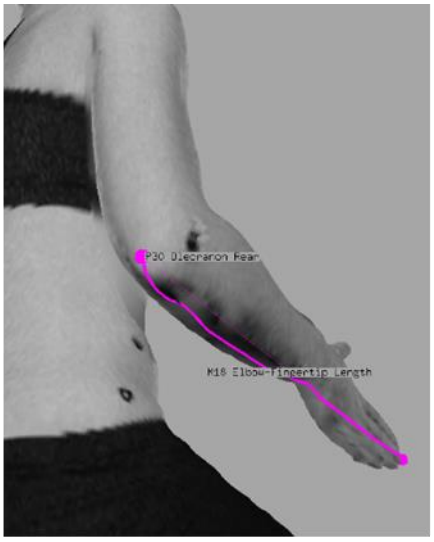
Definition	The vertical distance between the sitting surface and the Olecranon Bottom Landmark (lowest point) on the flexed right elbow.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Olecranon Bottom and Seat Pan Height Marker
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the difference between the Y coordinate of the Olecranon Bottom Landmark and the Y coordinate of the Seat Pan Height Marker (which marks the top edge of the seat pan). The calculation is performed in an Excel spreadsheet. Note that the scan is captured at end tidal expiration. Note: 1. Ensure that the forearm is horizontal and parallel to the sitting surface. 2. The bottom surface of the elbow can often contain scan artefacts, affecting the accuracy of this measure. Future surveys should investigate a different technique to obtain this measure.

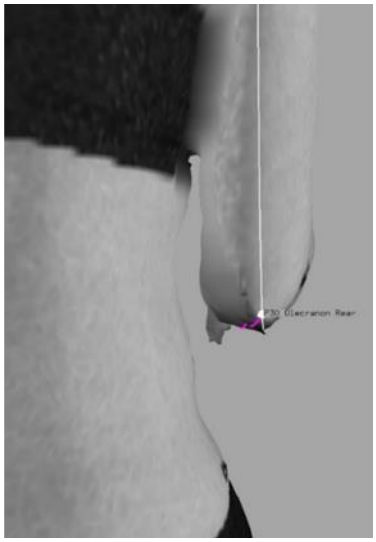




H.36 Elbow-Fingertip Length

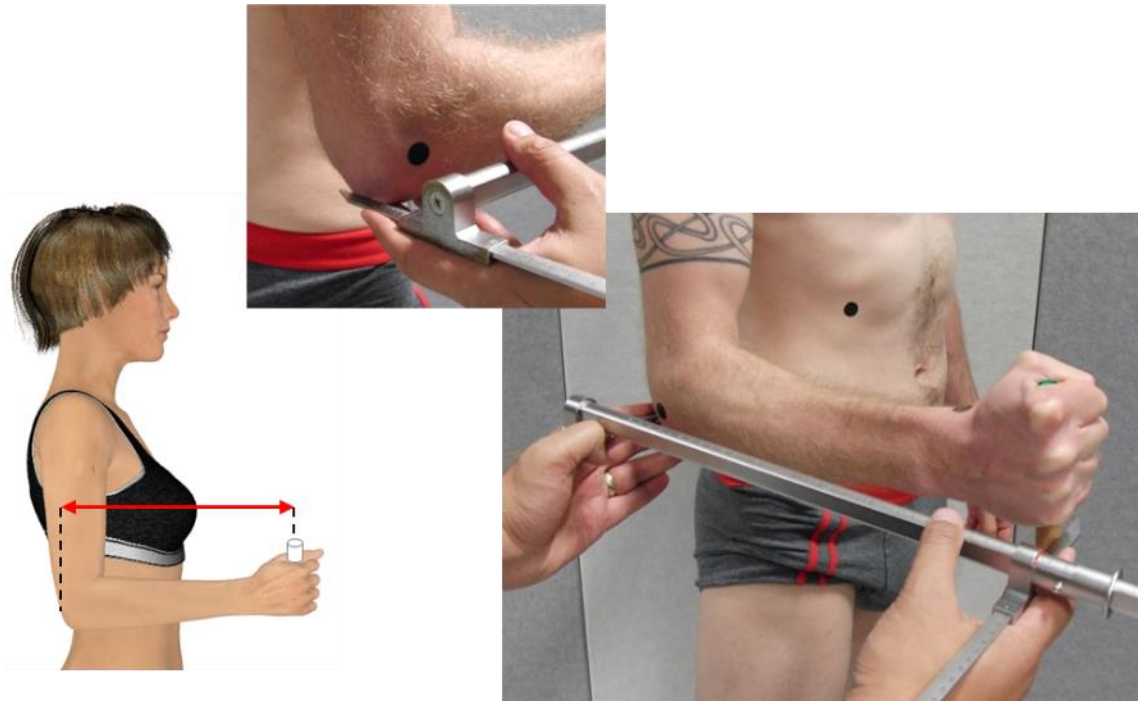
Definition	The horizontal distance from the Olecranon Rear Landmark on the back tip of the flexed right elbow to the tip of the middle finger (Dactylion III), with the hand held out straight and the palm facing inward.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Olecranon Rear and Dactylion III
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the point-to-point distance between the Olecranon Rear and the Dactylion III landmarks. Note: 1. The Olecranon Rear Landmark is located as a point on the posterior surface of the olecranon process in line with the "belly" or midline of the triceps. Note that this is somewhat subjective. Future surveys should investigate other techniques to obtain this measurement more reliably. 2. Despite the appearance of a contour line in the figure, this measurement is extracted from CySize as a point-to-point linear distance.





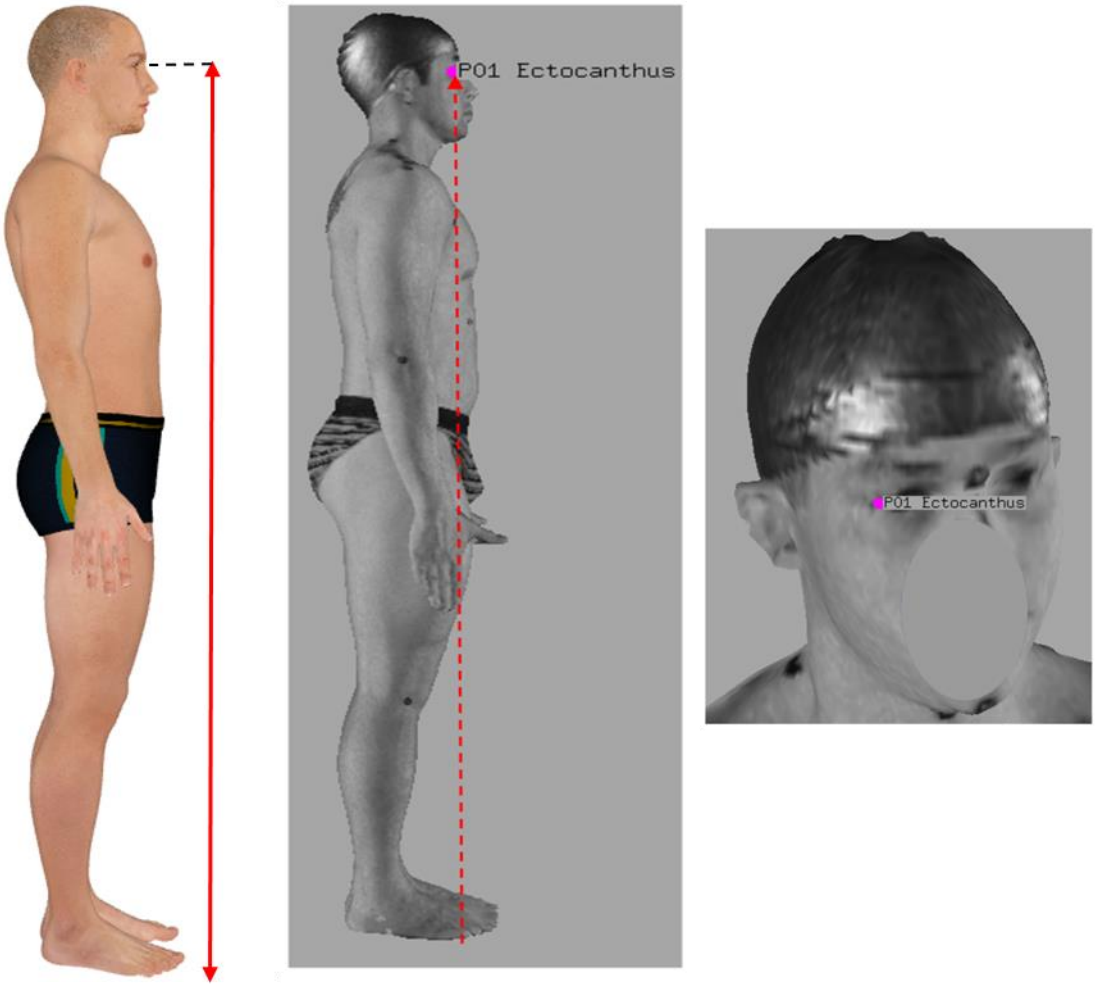
H.37 Elbow-Grip Length

Definition	The horizontal distance from the back tip of the flexed right elbow to the centre of a 1.5 cm diameter marker gripped vertically in the right hand.
Source	ISO 7250-1:2008
Landmark(s)	Olecranon and Grip Rod
Instrument(s)	Anthropometer and Grip rod
Procedure	The participant stands erect and holds a grip rod (marker pen) in their right hand (palm facing medially). The elbow is flexed at 90°. Palpate the posterior surface of the elbow joint and place the inside edge of the fixed anthropometer branch on the posterior aspect of the olecranon process. Position the inside edge of the sliding branch to lightly touch the anterior surface of the marker. Take the reading to the nearest 0.1 cm with the arm and anthropometer both horizontally level. A correction factor of –0.75 cm is applied post-measurement to account for the additional radius of the 1.5 cm diameter marker. Note: 1. Ensure that the grip rod (marker pen) is held firmly and in a vertical position to avoid error. 2. Take the reading at the red line edge of the measuring window to exclude the width of both anthropometer branches.



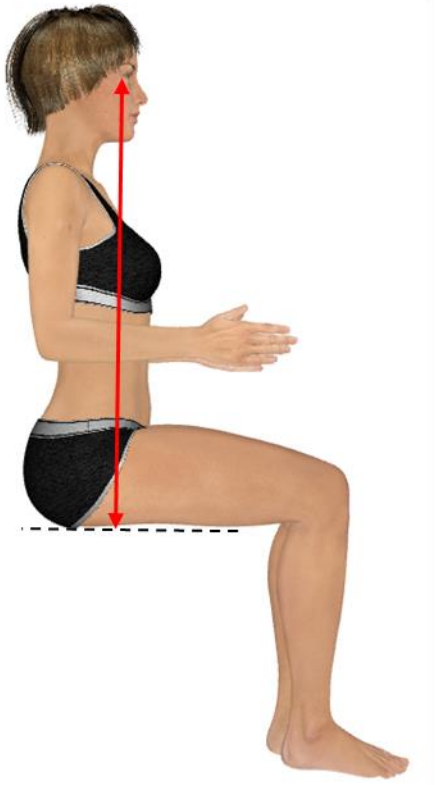
H.38 Eye Height

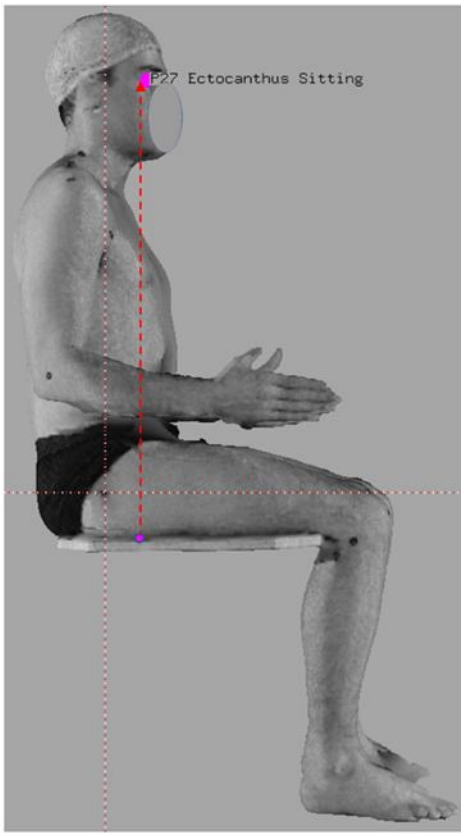
Definition	The vertical distance between the standing surface and the Ectocanthus Landmark on the outer corner of the right eye.
Source	ISO 7250-1:2008 (adapted for digital measurement)
Landmark(s)	Ectocanthus
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Ectocanthus Landmark. Note that the scan is captured at end tidal expiration.



H.39 Eye Height, Sitting

Definition	The vertical distance between the sitting surface and the Ectocanthus Landmark on the outer corner of the right eye.
Source	ISO 7250-1:2008 (adapted for digital measurement)
Landmark(s)	Ectocanthus Sitting
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the difference Y coordinate of the Ectocanthus Landmark and the Y coordinate of the Seat Pan Height Marker (which marks the top edge of the seat pan). This calculation is performed in an Excel spreadsheet. Note that the scan is captured at end tidal expiration.



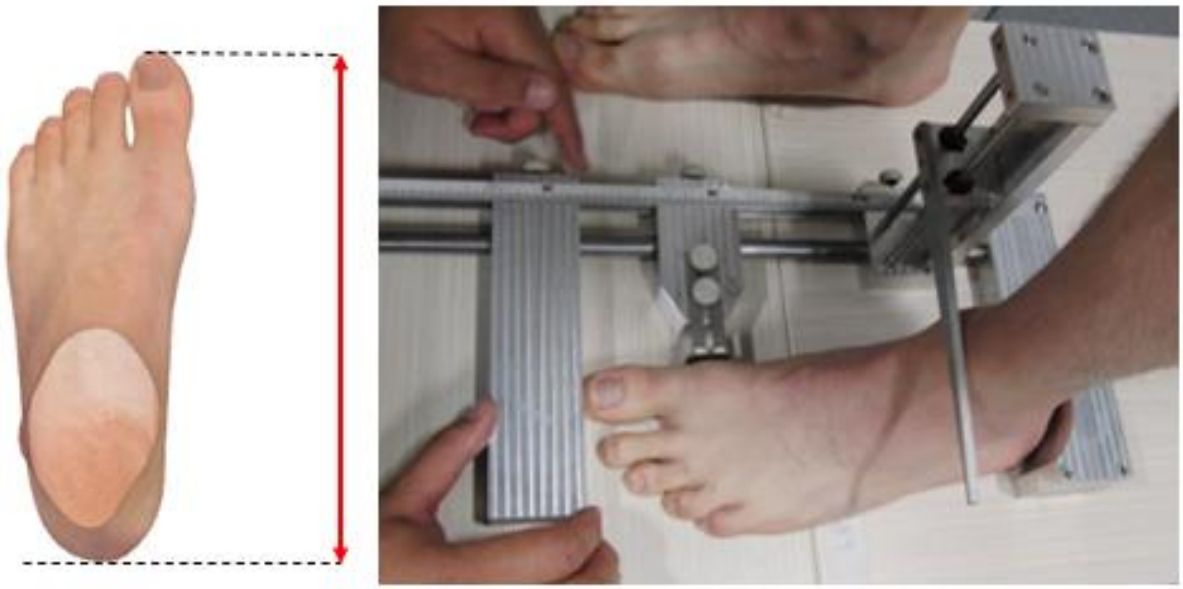


H.40 Foot Breadth

Definition	The maximum horizontal distance of the left foot at the metatarsophalangeal joints (between Metatarsophalangeal Protrusions I and V).
Source	ANSUR (adapted by using small bone calliper)
Landmark(s)	Metatarsophalangeal Protrusions I and V
Instrument(s)	Small bone calliper
Procedure	The participant stands in a relaxed position with the feet comfortably apart and weight evenly distributed. Palpate the left foot to locate the first and fifth bony metatarsophalangeal protrusions. Firmly place the calliper plates on these sites and take the reading to the nearest 0.1 cm. Note: 1. The first and fifth metatarsophalangeal protrusions are not necessarily horizontal in position, hence the callipers may be at an angle offset to the long axis of the foot. 2. Apply firm pressure to the calliper plates at the bony sites for greater accuracy. 3. Future surveys should obtain this measurement for the right foot instead of the left foot, as is standard anthropometry practice.

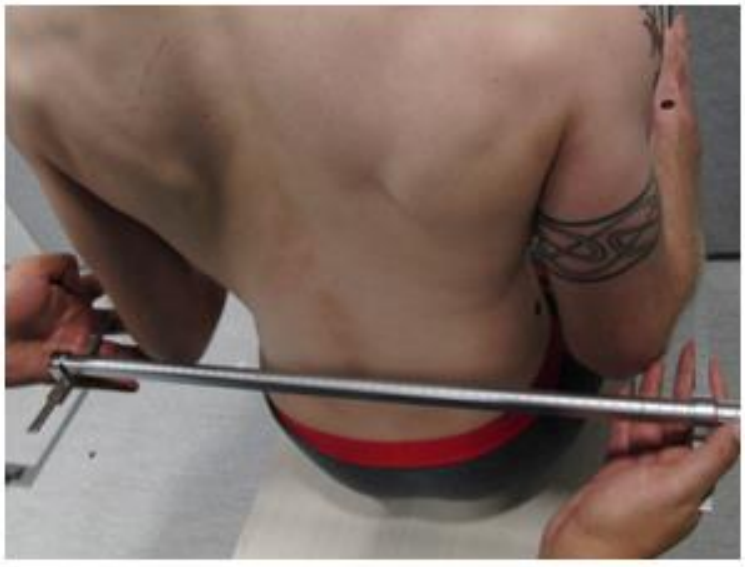
H.41 Foot Length

Definition	The length of the left foot from the Acropodian (the tip of the first or second toe, whichever is longer) to the Pternion (most posterior point on the heel).
Source	ANSUR II
Landmark(s)	Acropodian and Pternion
Instrument(s)	Brannock device
Procedure	The participant stands in a relaxed position with the feet comfortably apart and weight evenly distributed. The left foot is placed in the Brannock device with the heel lightly pressed against the rear, curved plate of the device. Move the sliding plate to make contact with the tip of the longest toe (the first or second toe), maintaining light pressure, and take the reading to the nearest 0.1 cm. Note: Future surveys should obtain this measurement for the right foot instead of the left foot, as is standard anthropometry practice.



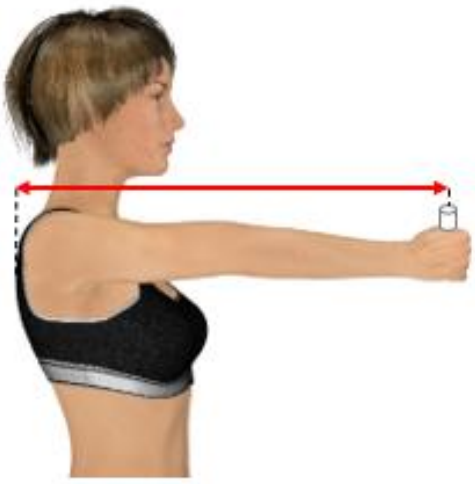
H.42 Forearm-Forearm Breadth

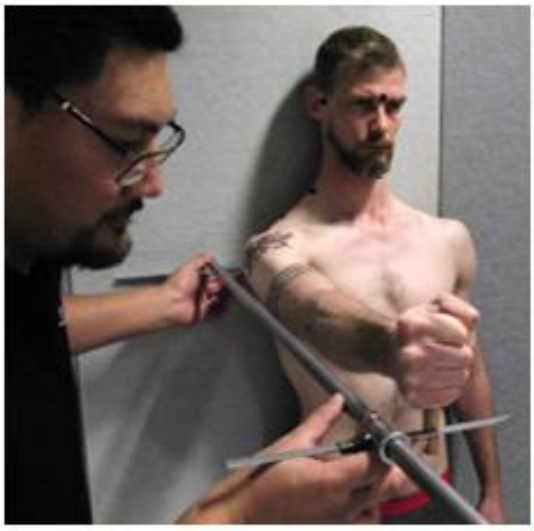
Definition	The maximum horizontal distance between the outer sides of the left and right forearms.
Source	AWAS
Landmark(s)	Forearm
Instrument(s)	Anthropometer or Large sliding calliper, and Anthropometry box
Procedure	The participant sits erect on the anthropometry box, looking straight ahead with the shoulders and upper arms relaxed and both elbows bent at 90°. The forearms and hands are extended forward horizontally with the palms facing each other. Use either the large sliding calliper (for smaller individuals with a breadth less than 56 cm) or the anthropometer (for larger individuals) to obtain the measurement. Place the inner edge of the branches on the lateral points of each forearm. Take the reading at end tidal expiration to the nearest 0.1 cm. Note: 1. For participants with a wider Lattisimus Dorsi, prompt the participant to slighly abduct the elbows away from the body. 2. Take the reading at end tidal expiration to avoid fluctuations and movement due to breathing. 3. If using the anthropometer, take the reading at the red line edge of the measuring window to exclude the width of both branches.



H.43 Functional Grip Reach

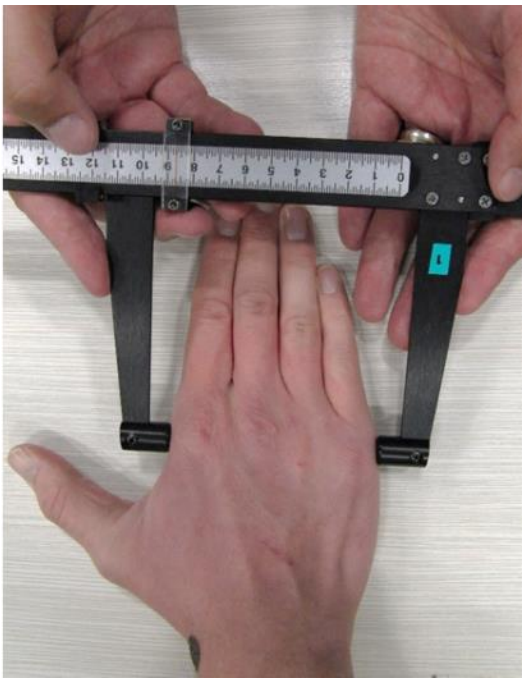
Definition	The horizontal distance from the back wall to the centre of a rod gripped in the hand of the outstretched right arm, with the right shoulder pressed against the wall.
Source	ISO 7250-1:2008
Landmark(s)	Posterior surface of shoulder blade and Grip rod
Instrument(s)	Anthropometer and Grip rod (marker pen)
Procedure	The participant stands erect with both shoulder blades against a wall. The right arm is extended horizontally forward at 90° to the body, and the grip rod (marker pen) is held in the right hand with the palm facing medially. Place the fixed anthropometer branch firmly against the wall and position the inner edge of the sliding branch to lightly touch the anterior surface of the grip rod. Take the reading to the nearest 0.1 cm with the arm and the anthropometer horizontally level. A correction factor of +0.35 cm is added post-measurement (+1.1 cm to account for the width of the fixed anthropometer branch, and -0.75 cm to account for the additional radius of the 1.5 cm diameter grip rod). Note: 1. Adjust the length of the anthropometer to suit the arm length of the participant by adding/removing sections. 2. Hold the grip rod firmly in a vertical position to avoid error. 3. Take the reading at the red line edge of the measuring window to exclude the width of both anthropometer branches. 4. Ensure that the shoulder blades and buttocks remain in contact with the wall during the measurement, and hold the fixed branch securely against the wall for stability.





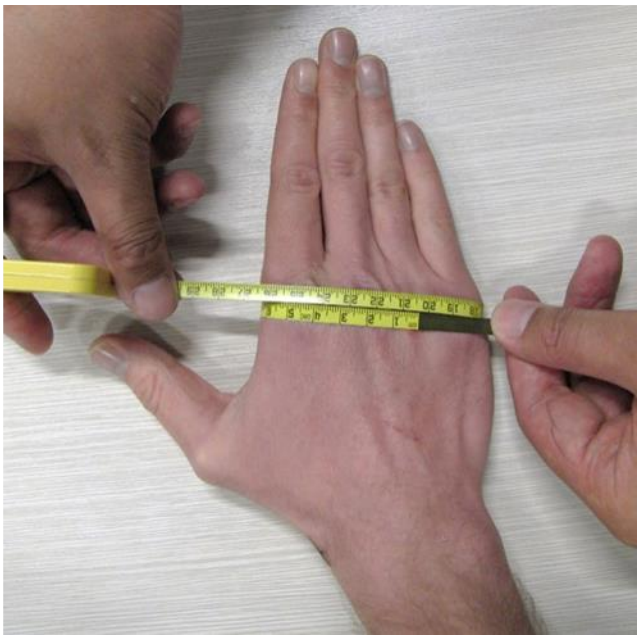
H.44 Hand Breadth

Definition	The breadth of the right hand between the protrusions at Metacarpali II and V.
Source	ANSUR (adapted to use small bone calliper instead of sliding calliper)
Landmark(s)	Metacarpali II and V
Instrument(s)	Small bone calliper and Hand measurement board (8 mm thickness)
Procedure	The participant sits at a table with the right hand palm down on the table surface, the fingers together and the thumb abducted. The middle finger is aligned parallel to the long axis of the forearm. The two distal phalanges of the fingers rest on the hand measurement board (or a flat surface 8 mm higher than the table). Place the calliper plates on the Metacarpale II and Metacarpale V bony protrusions. Apply firm pressure to the calliper plates and take the reading to the nearest 0.1 cm. Note: The hand measurement board is used to reduce the "cupping" propensity of the hand and to ensure the hand is flat during measurement (palm resting on the table surface with the fingers resting on the hand measurement board).



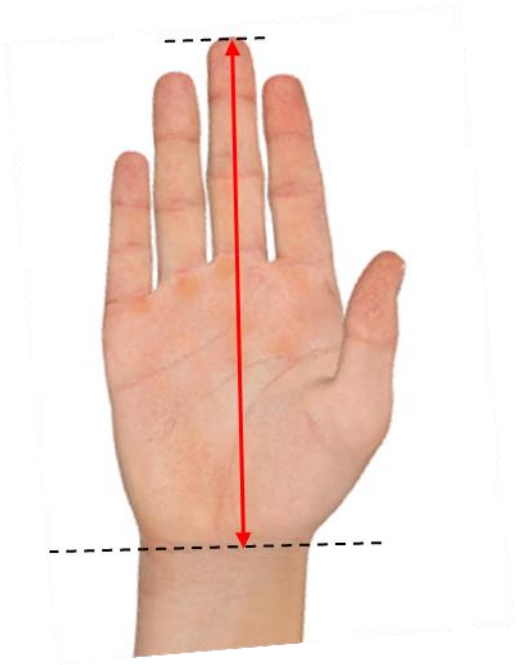
H.45 Hand Circumference

Definition	The circumference of the right hand encompassing the protrusions at Metacarpali II and V.
Source	ANSUR
Landmark(s)	Metacarpali II and V
Instrument(s)	Anthropometric tape and Hand measurement board
Procedure	The participant sits at a table with the right hand palm down on the table, the fingers together and the thumb abducted. The middle finger is aligned parallel to the long axis of the forearm. The two distal phalanges of the fingers rest on the hand measurement board (or a flat surface 8 mm higher than the table). Position the tape around the palm, passing over the Metacarpali II and V bony protrusions. Apply light tension to the tape to eliminate gaps and ensure minimal skin indentation. Take the reading to the nearest 0.1 cm. Note: The hand measurement board is used to reduce the "cupping" propensity of the hand and to ensure the hand is flat during measurement (palm resting on the table surface with the fingers resting on the hand measurement board).



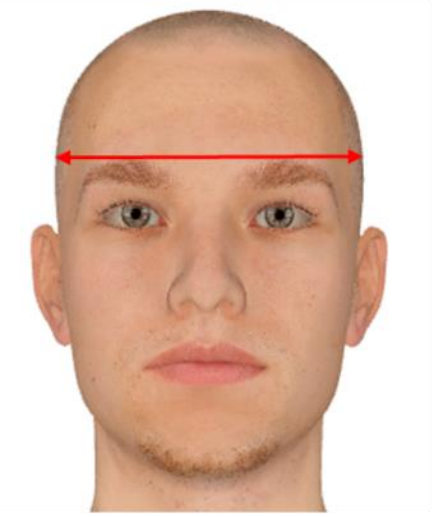
H.46 Hand Length

Definition	The distance from the tip of the middle finger (Dactylion III), along its axis, to the Midstylion Landmark at the centre of the right wrist, measured with the hand stretched out flat, palm up.
Source	ANSUR (adapted to use segmometer instead of Poech sliding calliper, and measured palm up).
Landmark(s)	Dactylion III and MidStylion
Instrument(s)	Segmometer
Procedure	The participant sits at a table with the right forearm and hand flat on the table surface. The palm is open and facing up, with the fingers and thumb together and fully extended. Place the fixed branch of the segmometer on the Midstylion Landmark and position the sliding branch to lightly press against the tip of the middle finger (Dactylion III). Take the reading to the nearest 0.1 cm. Note: 1. Ensure that the back of the hand and fingers are flat against the table surface (without cupping) during measurement. 2. Take the measure to the tip of the middle finger, not the tip of the fingernail.



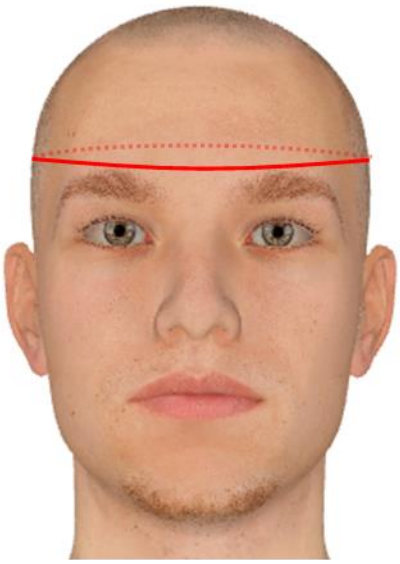
H.47 Head Breadth

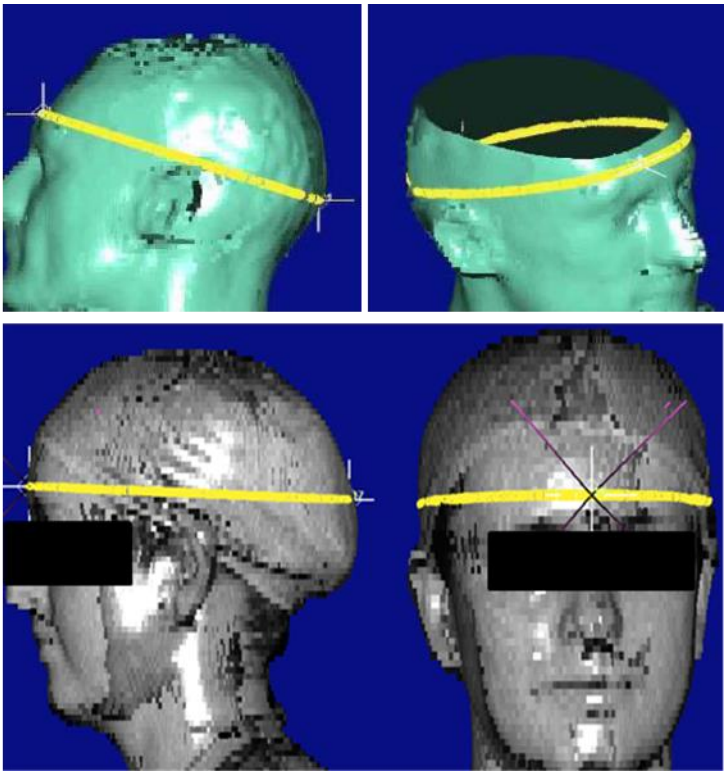
Definition	The maximum horizontal breadth of the head above the ears.
Source	ANSUR (adapted to use large sliding calliper instead of spreading calliper)
Landmark(s)	Lateral aspects of the head
Instrument(s)	Large sliding calliper
Procedure	The participant sits erect and looks straight ahead with glasses removed (if wearing). Visually identify the lateral aspects of the head (above the ears) and place the branches of the large sliding calliper at these points. Take the reading to the nearest 0.1 cm. Note: 1. Ensure that the calliper branches rests on the skin surface without indenting the skin. 2. Hold the calliper above the participant's head and perpendicular to the mid-sagittal plane (with the scale facing the rear). 3. The head is in a neutral position for this measurement. The Frankfurt position is not required.



H.48 Head Circumference

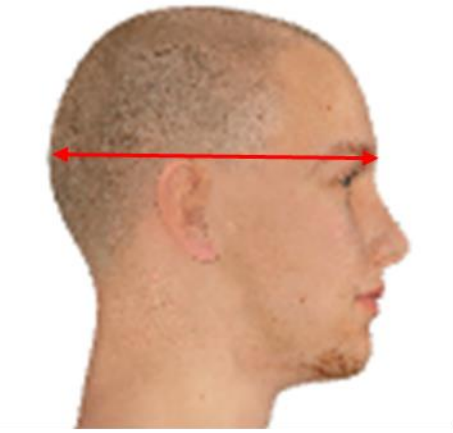
Definition	The circumference around the forehead just above the bony brow ridges and across the most protruding point of the back of the head.
Source	Anthroscan [Measurement ID 1530]
Landmark(s)	Glabella and Opisthocranion
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. Ensure that the tape (represented by the yellow line) is horizontal at the bony brow ridge. 2. For females, ensure that the position of the hair bun does not interfere with the measurement (ideally, the hair bun should be below the top of the ear). In cases where there is interference, the measure is unobtainable. 3. If the head is not in the Frankfurt plane (i.e. too high or low, looking up or down), manually adjust the tape within the software so that it is parallel to this plane. 4. Future surveys should obtain this measurement manually using the anthropometric tape.

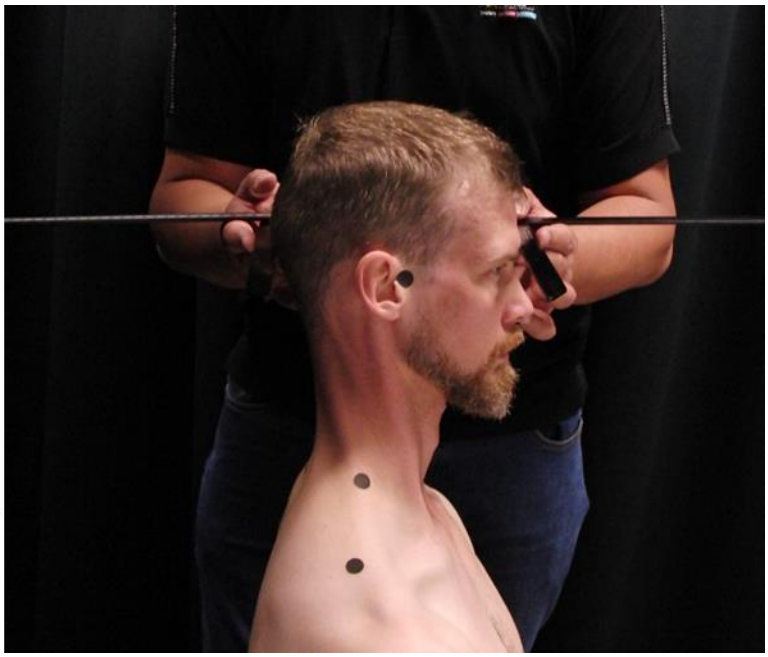




H.49 Head Length

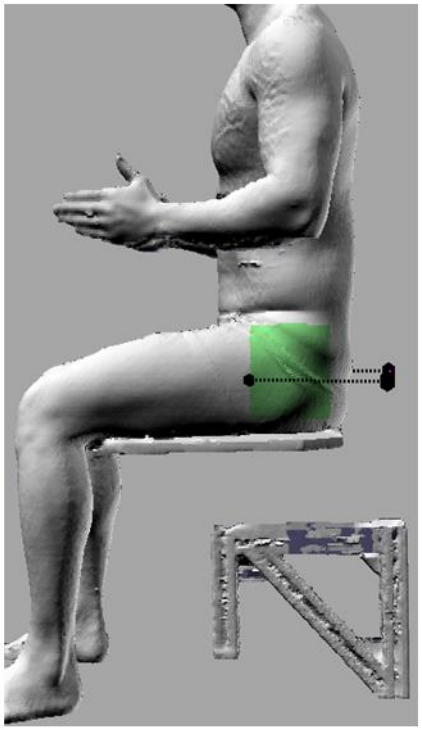
Definition	The straight line distance between the Glabella (located between the brow ridges) and the Opisthocranion on the back of the head.
Source	ANSUR (adapted to use large sliding calliper instead of spreading calliper)
Landmark(s)	Glabella and Opisthocranion
Instrument(s)	Large sliding calliper
Procedure	The participant sits erect and looks straight ahead with glasses removed (if wearing). Place the branches of the large sliding calliper on the Glabella, located between the brow ridges, and the Opisthrocanion (posterior point on the back of the head). Take the reading to the nearest 0.1 cm. Note: 1. Ensure that the calliper branches rest on the skin surface without indenting the skin. 2. The head is in a neutral position for this measurement. The Frankfurt position is not required. 3. For females, ensure that the measurement excludes the hair bun (should be tied low to avoid interference).





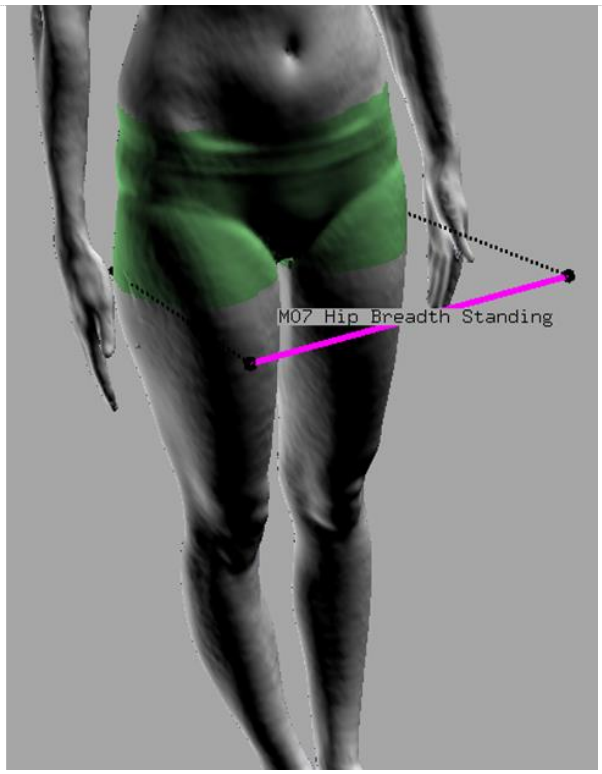
H.50 Hip Breadth, Sitting

Definition	The maximum horizontal breadth of the seated participant at the hips or thighs, whichever is larger.
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Inguinal Fold
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan. Highlight the hip and upper thigh region (from the posterior aspect of the buttock to the Inguinal Fold at the junction between the torso and thigh), and use the calliper tool to find the largest horizontal breadth (Y function) within this highlighted region. Note: 1. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans. 2. The accuracy of this measurement is strongly affected by the sitting posture of the participant. Individuals seated in a wide stance (with the knees extended laterally out instead of straight forward) are likely to record a greater breadth. Future surveys should investigate other techniques to obtain this measure more reliably.



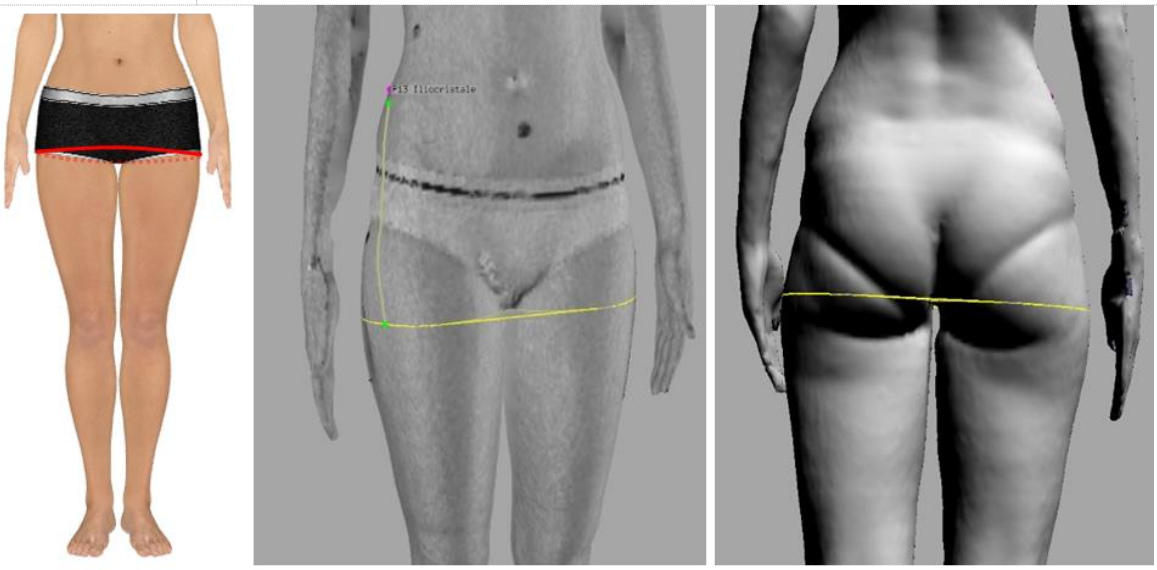
H.51 Hip Breadth, Standing

Definition	The largest horizontal breadth of the hip region between the Iliocristale and Crotch landmarks.
Source	ISO 7250-1:2008 (adapted for digital measurement)
Landmark(s)	Iliocristale and Crotch
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan. Highlight the hip region from the Iliocristale Landmark to the Crotch Landmark and use the calliper tool to find the largest horizontal breadth (Y function) within this highlighted region. Note: 1. When highlighting the hip region, exclude any webbing scan artefacts between the hands and hip/thighs (occurs when the hands were too close to the body) and large creases and folds in the underwear. If this is not possible, the measure cannot be obtained. Future surveys should investigate obtaining this measure from the P02 scans where the hands are further away from the body. 2. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.



H.52 Hip Circumference, Maximum

Definition	The maximum circumference of the body (excluding the appendages) at or about the height of the hip but below the height of the iliac crest.
Source	AWAS
Landmark(s)	Iliocristale and Crotch
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan. Place two markers on the hip region, one just below the top of the Iliocristale Landmark and one just below the Crotch Landmark. Add a guideline between the two markers, and use the software to identify the maximum circumference of the hip region. Extract the measurement as the "tape" length (a CySize function that mimics an anthropometric tape). Note: 1. When highlighting the hip region, exclude any webbing scan artefacts between the hands and hips/thighs (occurs when the hands were too close to the body) and large creases and folds in the underwear. If this is not possible, the measure cannot be obtained. Future surveys should investigate obtaining this measure from the P02 scans where the hands are further away from the body. 2. This measure cannot be obtained for participants wearing baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.

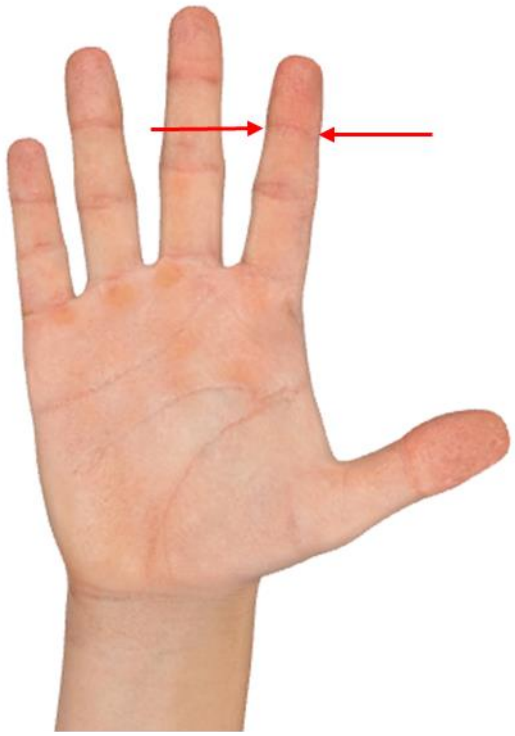


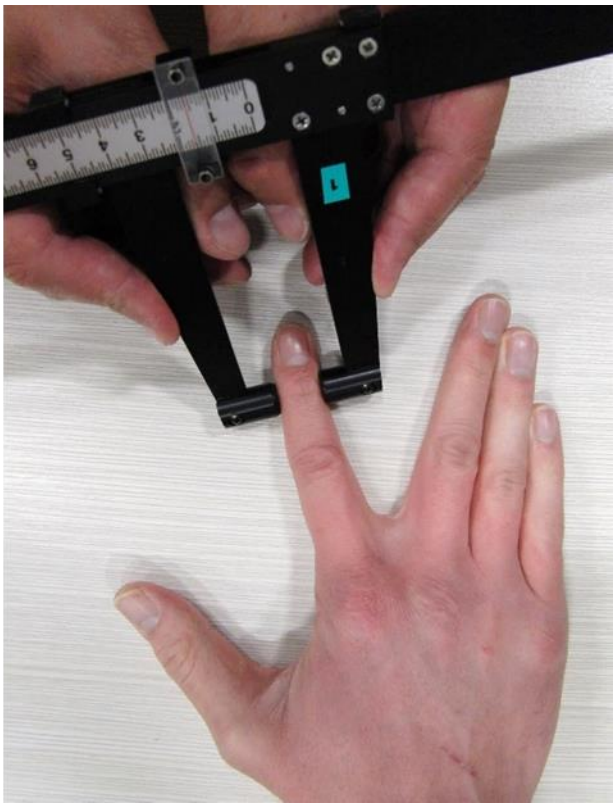
H.53 Iliocristale Height

Definition	The vertical distance between the standing surface and the Iliocristale Landmark on the top right side of the pelvis.
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Iliocristale
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Iliocristale Landmark. Note: The Iliocristale Landmark can be difficult to see on scans if the right arm and hand is positioned too close to the body. The scanner operator must ensure that there is sufficient space between the right upper limb and torso, and that the sticker identifying this landmark is clearly visible. Future surveys should investigate obtaining this measure from the P02 scan where the hands are further away from the body.

H.54 Index Finger Breadth, Distal

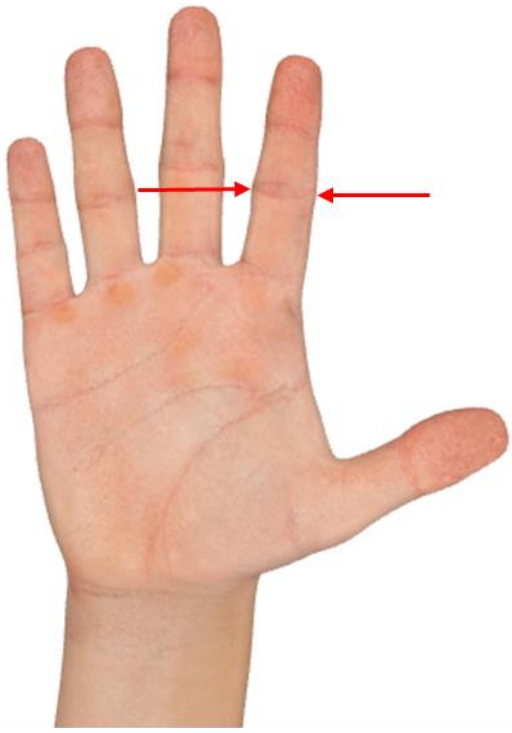
Definition	The maximum breadth of the index finger in the region of the joint between middle and distal phalanges, measured with the hand stretched out flat and fingers spread, palm down.
Source	ISO 7250-1:2008 (adapted to measure palm down)
Landmark(s)	Distal interphalangeal joint of the right index finger
Instrument(s)	Small bone calliper
Procedure	The participant sits at a table with the right hand placed palm down on the hand measurement board. The centre wrist and medial side of the forearm rest flat on the table, with the index finger abducted from the rest. Firmly place the plates of the small bone calliper on the medial and lateral aspects of the distal interphalangeal joint of the index finger, and take the reading to the nearest 0.1 cm. Note: 1. Apply firm pressure to the calliper plates at the bony sites for greater accuracy. 2. Ensure that the palm and fingers rest flat on the table surface.

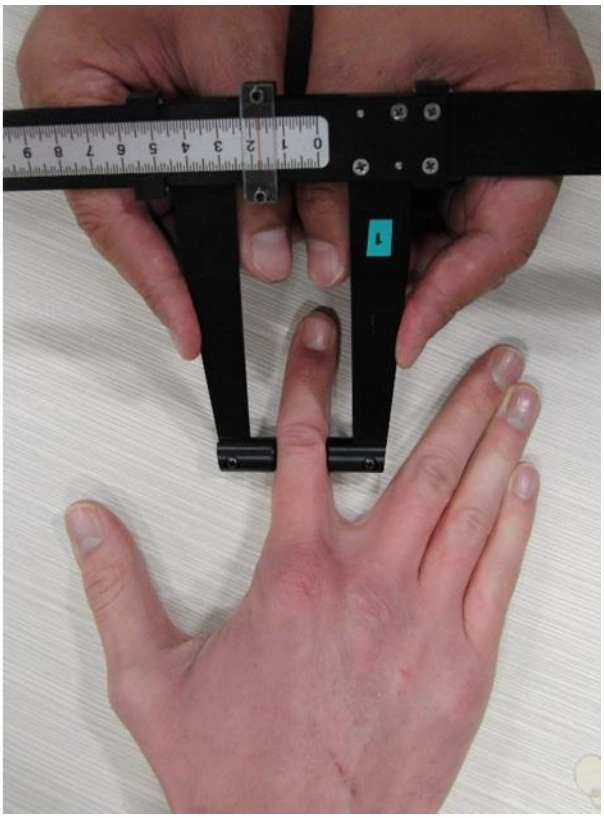




H.55 Index Finger Breadth, Proximal

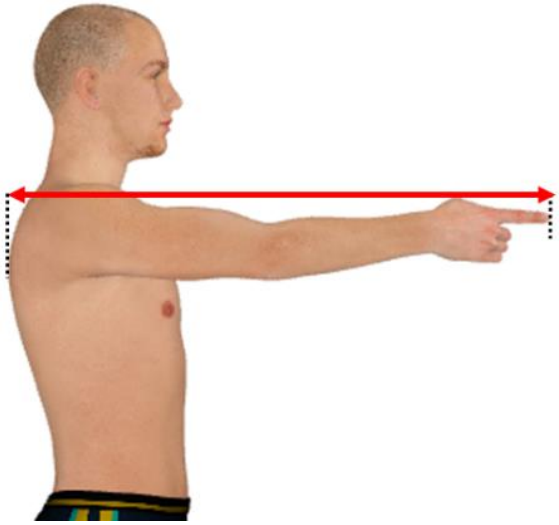
Definition	The maximum breadth of the index finger in the region of the joint between middle and proximal phalanges measured with the hand stretched out flat and fingers spread, palm down.
Source	ISO 7250-1:2008 (adapted to measure palm down)
Landmark(s)	Proximal interphalangeal joint of the right index finger
Instrument(s)	Small bone calliper
Procedure	The participant sits at a table with the right hand placed palm down on the hand measurement board. The centre wrist and medial side of the forearm rests flat on the table, with the index finger abducted from the rest. Firmly place the plates of the small bone calliper on the medial and lateral aspects of the proximal interphalangeal joint of the index finger, and take the reading to the nearest 0.1 cm. Note: 1. Apply firm pressure to the calliper plates at the bony sites for greater accuracy. 2. Ensure that the palm and fingers rest flat on the table surface.

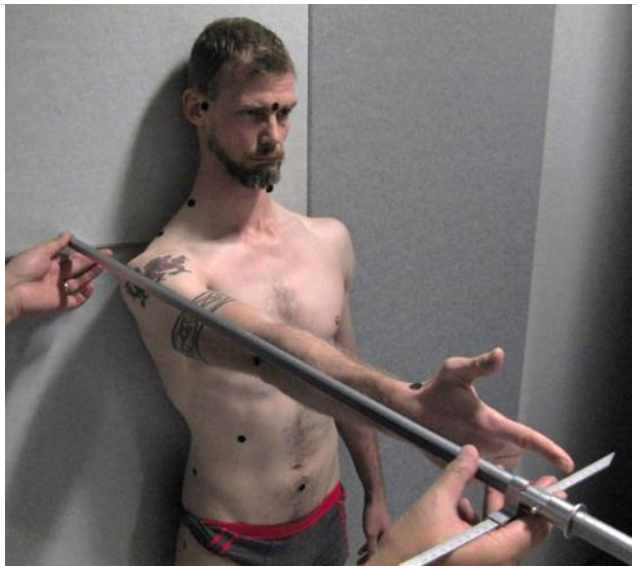




H.56 Index Finger Reach

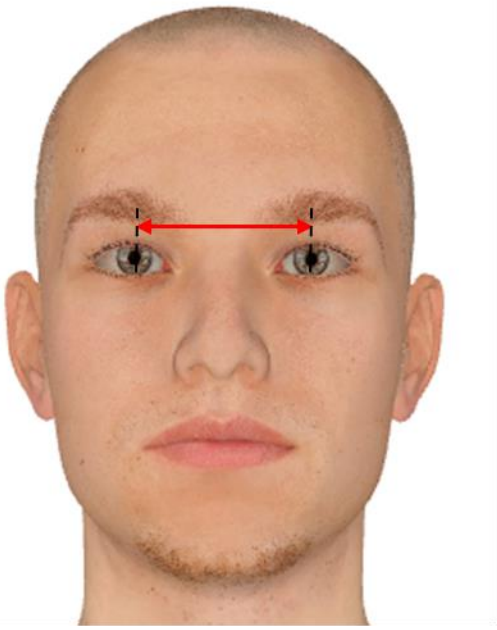
Definition	The horizontal distance from the back wall to the tip of the right index finger of the outstretched right arm, with the right shoulder pressed against the wall.
Source	ANSUR (adapted for manual measurement)
Landmark(s)	Posterior surface of shoulder blade and Index finger
Instrument(s)	Anthropometer
Procedure	The participant stands erect with both shoulder blades against a wall. The right arm is extended horizontally forward at 90° to the body. The index finger is fully extended with all other fingers folded in (palm facing medially). Firmly hold the fixed anthropometer branch against the wall and move the inner edge of the sliding branch to lightly touch the tip of the index finger (excluding the fingernail). Take the reading to the nearest 0.1 cm with the arm and anthropometer both horizontally level. A correction factor of +1.1 cm is added post-measurement to add on the width of the fixed anthropometer branch. Note: 1. Adjust the length of the anthropometer to suit the arm length of the participant by adding/removing sections. 2. Take the reading at the red line edge of the measuring window to exclude the width of both anthropometer branches. 3. Ensure that the shoulder blades and buttocks remain in contact with the wall during the measurement, and hold the fixed branch securely against the wall for stability.





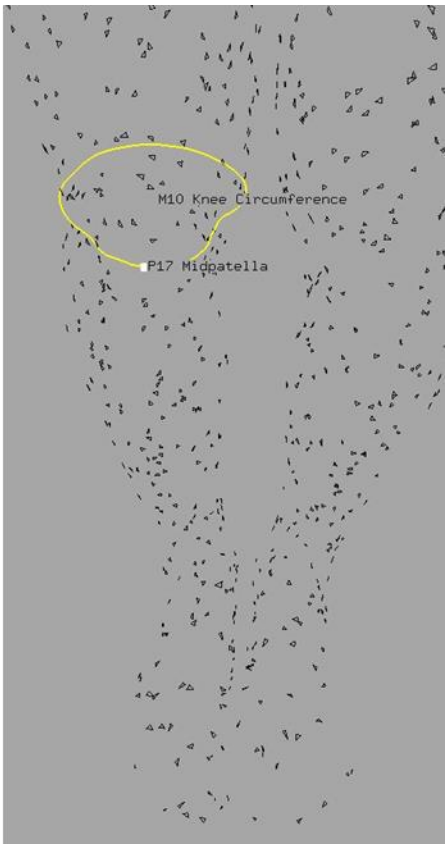
H.57 Interpupillary Breadth

Definition	The distance between the centres of the left and right pupils.
Source	AWAS
Landmark(s)	Pupils
Instrument(s)	A standard transparent ruler
Procedure	The participant looks straight ahead with glasses removed (if wearing) and eyes focussed on a distant object straight ahead. Hold the transparent ruler in front of the nose and align the zero mark with the centre of the left pupil. For stability, hold the ruler between the thumb and index finger, and the use the remaining fingers to hold the face. Take the reading at the centre of the right pupil to the nearest 0.1 cm. Note: 1. Ask participants to keep eye movement to a minimum during measurement. 2. Future surveys should use a pupilometer to obtain this measurement.



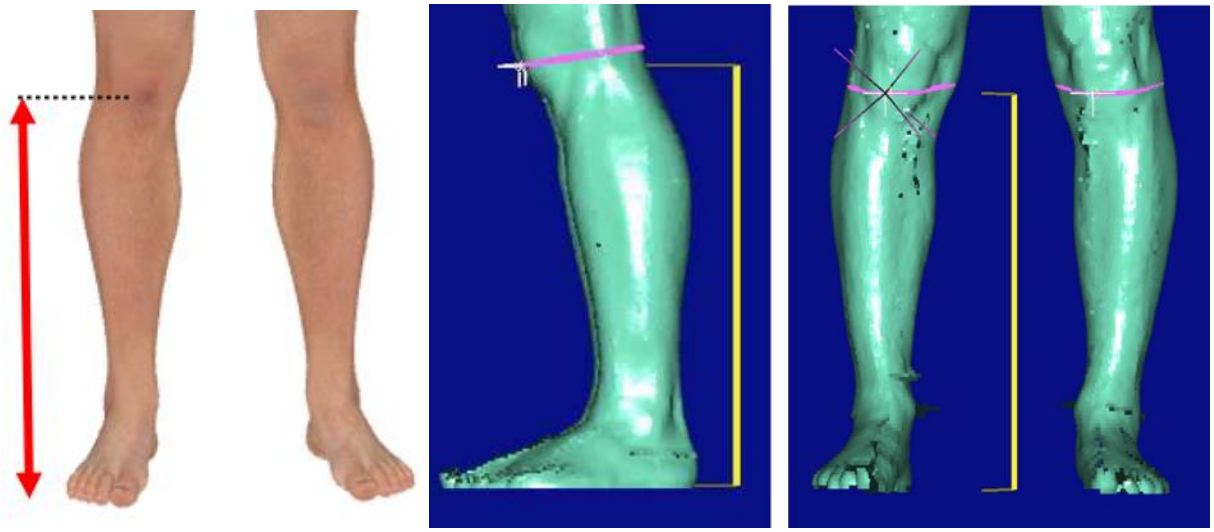
H.58 Knee Circumference

Definition	The horizontal circumference of the knee at the height of the Midpatella Landmark at the centre of the right kneecap.
Source	AWAS
Landmark(s)	Midpatella
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the "tape" length (a CySize function that mimics an anthropometric tape) of a Z section around the Midpatella Landmark on the right knee. Note: Ensure that no webbing scan artefacts are present between the left and right knee (occurs when the knees were too close to each other). If webbing is present, this measure cannot be obtained. Future surveys must ensure that there is sufficient clearance between the knees in the P01 scan, or investigate obtaining this measure from the P02 scan where the legs are further apart.



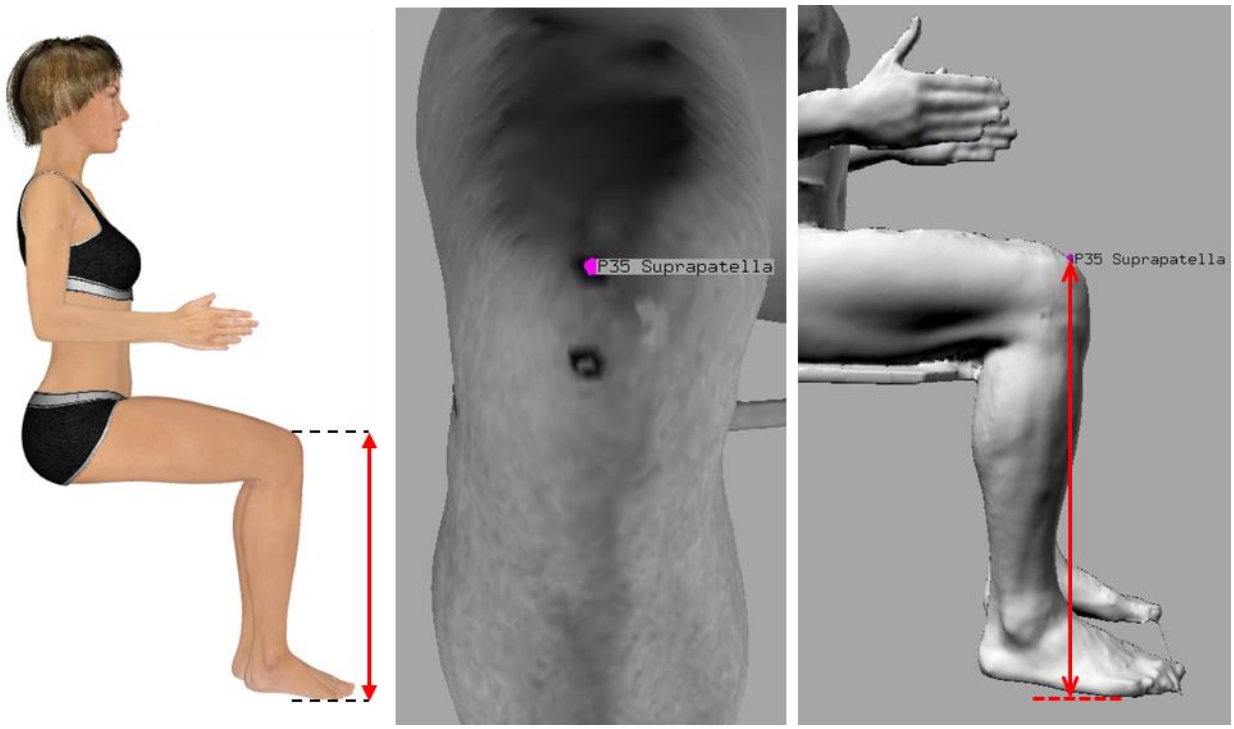
H.59 Knee Height

Definition	The vertical height of the front of the knee circumference level (over the right kneecap perpendicular to the leg-axis) to the standing surface.
Source	Anthroscan [Measurement ID 0110]
Landmark(s)	Midpatella
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: Ensure that the measurement line (represented by the pink line) is aligned with the level of the Midpatella Landmark.



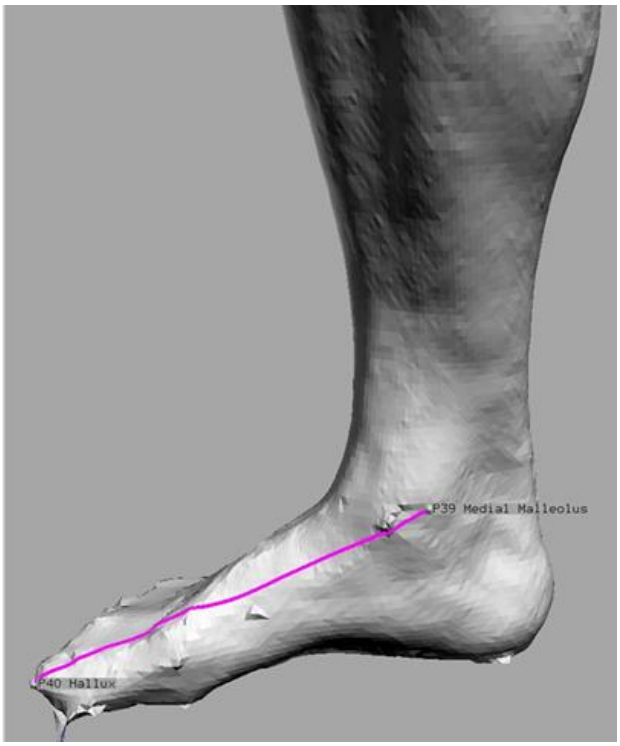
H.60 Knee Height, Sitting

Definition	The vertical distance between a footrest surface and the Suprapatella Landmark at the top of the right kneecap.
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Suprapatella
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the Y coordinate of the Suprapatella Landmark. Note: Other military surveys used a footrest or foot plates to ensure a 90° bend in the knees. In the NZDFAS, the height of the scanner seat platform was adjusted for each participant to ensure 90° knee flexion, with both feet and heels flat on the scanner platform.



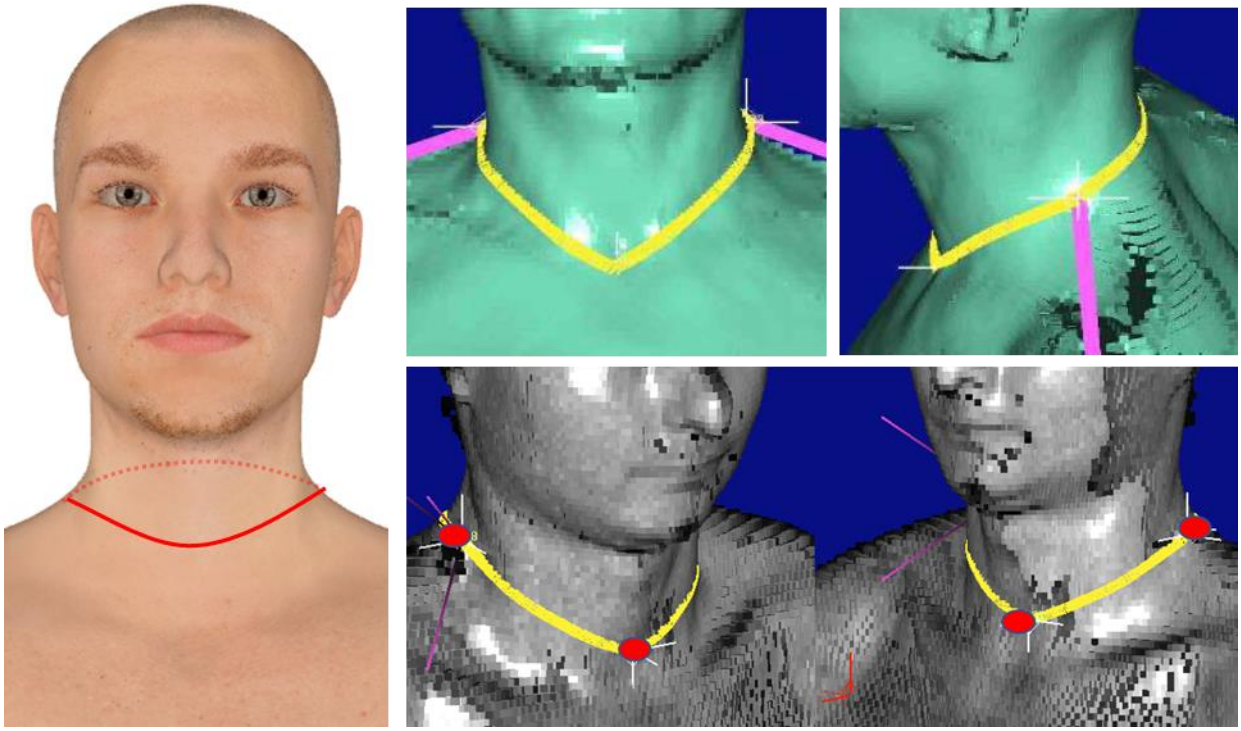
H.61 Malleolus-Hallux Length

Definition	The distance between the inner anklebone protusion (Medial Malleolus) and the tip of the big toe (Hallux).
Source	Nil
Landmark(s)	Medial Malleolus and Hallux
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the point-to-point distance between the Medial Malleolus and Hallux landmarks on the right foot. Note: 1. Scan quality is often poor for the feet. If scan artefacts are present, this measure is often obtainable. Future surveys should obtain this measure via manual measurement. 2. The Medial Malleolus Landmark is located using CySize section tools (Y section) to find the most medially protruding point on the inner anklebone protrusion. 3. The Hallux Landmark is located using CySize section tools (X section) to find the most anteriorly protruding point on the big toe.



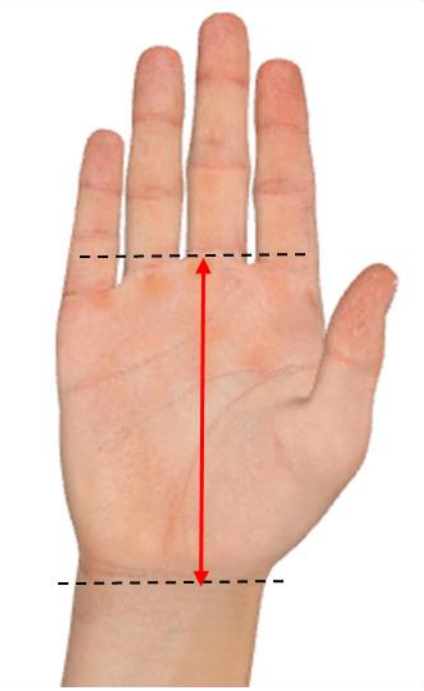
H.62 Neck Circumference, Base

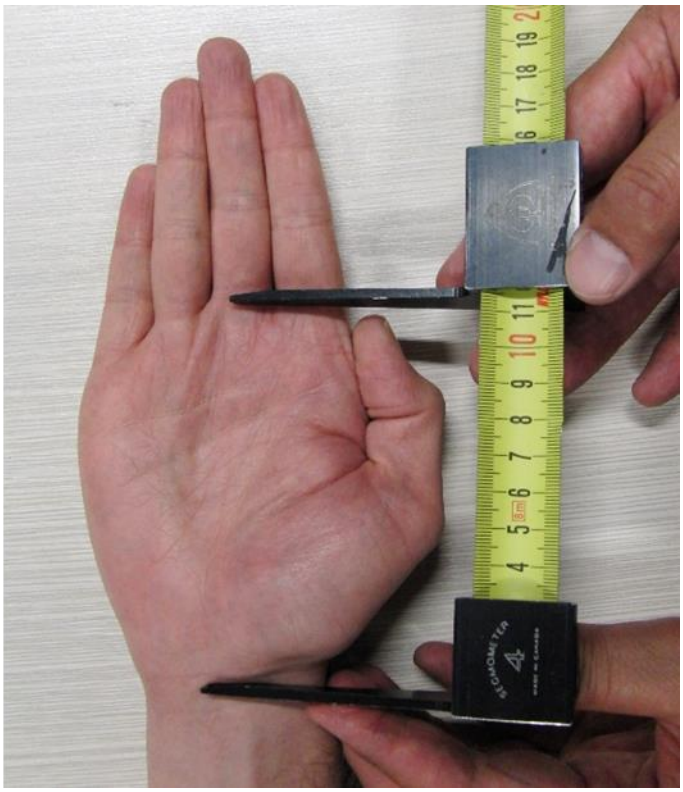
Definition	The circumference at the base of the neck, just on the transition between torso and neck.
Source	Anthroscan [Measurement ID 1520]
Landmark(s)	Base of the neck
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: This measure sometimes requires manual modification of the measurement points as Anthroscan often produces sharp points at the base of the throat. In such cases, adjust the measurement points to create a more rounded profile that mimics an anthropometric tape.



H.63 Palm Length

Definition	The distance from the proximal finger crease of the middle finger on the palm of the hand to the Midstylion Landmark at the centre of the wrist, measured with the hand stretched out flat, palm up.
Source	ISO 7250-1:2008 (adapted to use a segmometer instead of a sliding calliper)
Landmark(s)	Midstylion
Instrument(s)	Segmometer
Procedure	The participant sits at a table with their right forearm and hand flat against a table (palm open and facing up). The fingers and thumb are kept together. Place the fixed branch of the segmometer on the Midstylion Landmark and the sliding branch at the proximal crease of the middle finger. Take the reading to the nearest 0.1 cm. Note: Ensure that the back of the hand and fingers is flat against the table surface (without cupping) during measurement.



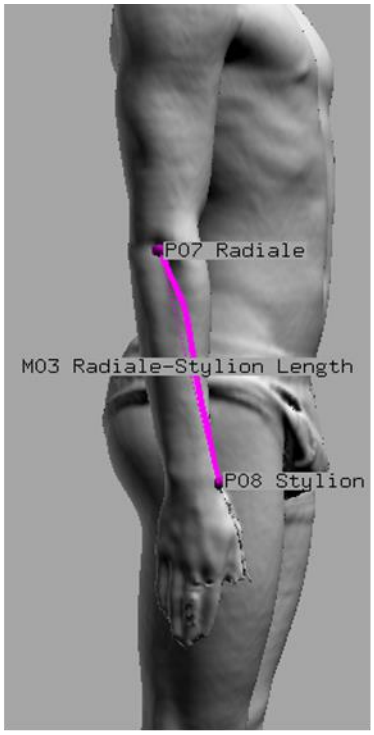


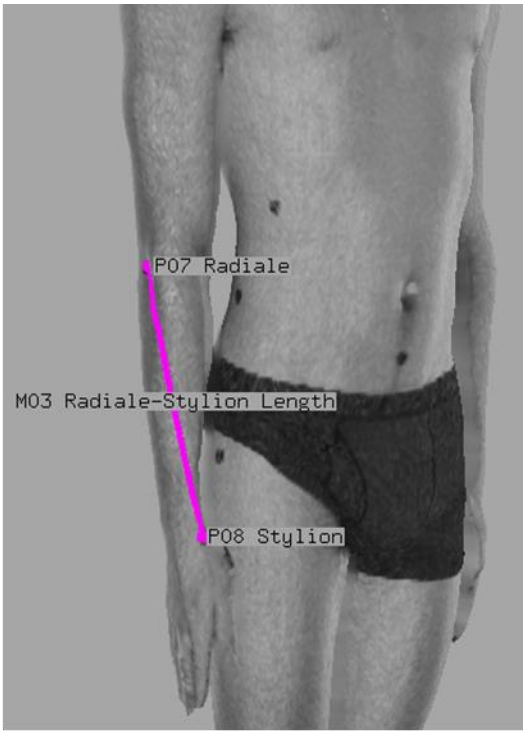
H.64 Popliteal Height

Definition	The vertical distance from the floor to the back of the right knee (the popliteal fossa at the dorsal juncture of the right calf and thigh).
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Popliteal
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the Y coordinate of the Popliteal Landmark. Note: 1. Other military surveys used a footrest or foot plates to ensure a 90° bend in the knees. In the NZDFAS, the height of the scanner seat platform was adjusted for each participant to ensure 90° knee flexion, with both feet and heels flat on the scanner platform. 2. The measure cannot be obtained in cases where webbing scan artefacts are present behind the back of the knee to the seat pan. Future surveys should ensure that when participants are positioned for the sitting scan, there is sufficient space between the back of the knee and the forward edge of the seat pan (i.e. the participant sits slightly forward if necessary).

H.65 Radiale-Stylion Length

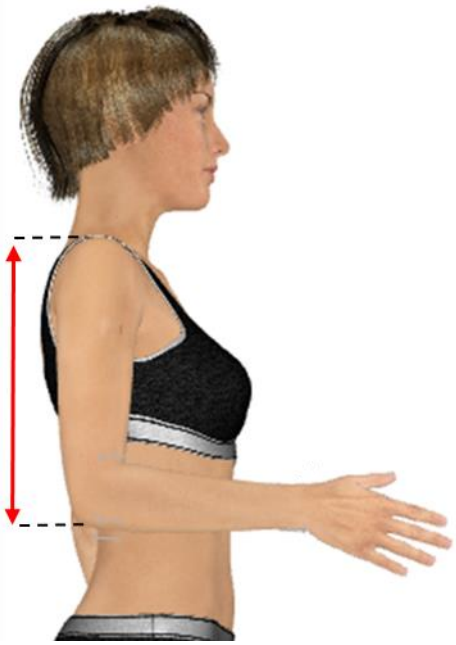
Definition	The distance between the Radiale Landmark on the right elbow and the Stylion Landmark on the right wrist.
Source	AWAS
Landmark(s)	Radiale and Stylion
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the point-to-point distance between the Radiale and Stylion landmarks. Note: Despite the appearance of a contoured surface line in the figure, this measurement is extracted from CySize as a point-to-point linear distance.

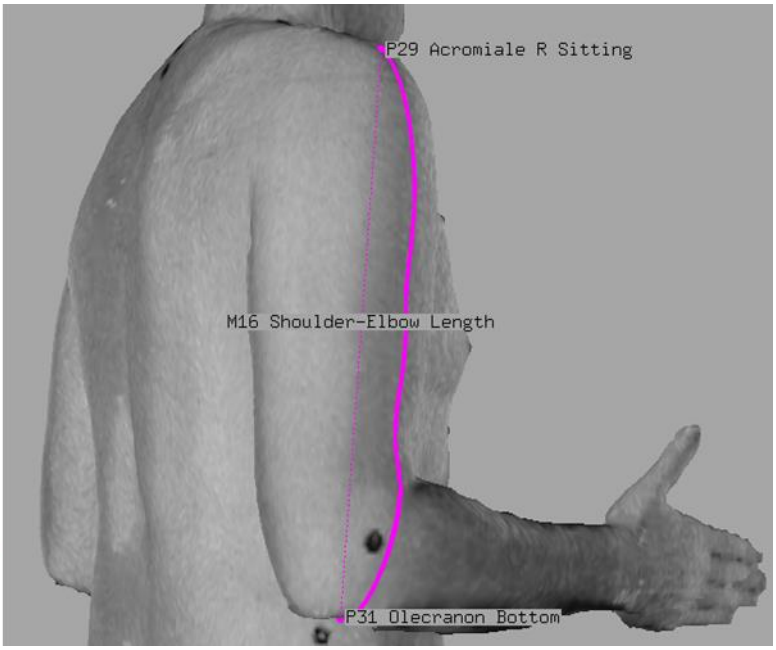




H.66 Shoulder-Elbow Length

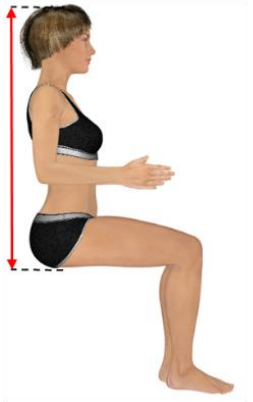
Definition	The distance between the Acromion Right Landmark on the tip of the right shoulder and the Olecranon Bottom Landmark on the tip of the right elbow.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Acromion Right and Olecranon Bottom
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the point-to-point distance between the Acromion Right and Olecranon Bottom landmarks. Note: Despite the appearance of a contoured surface line in the figure, this measurement is extracted from CySize as a point-to-point linear distance.





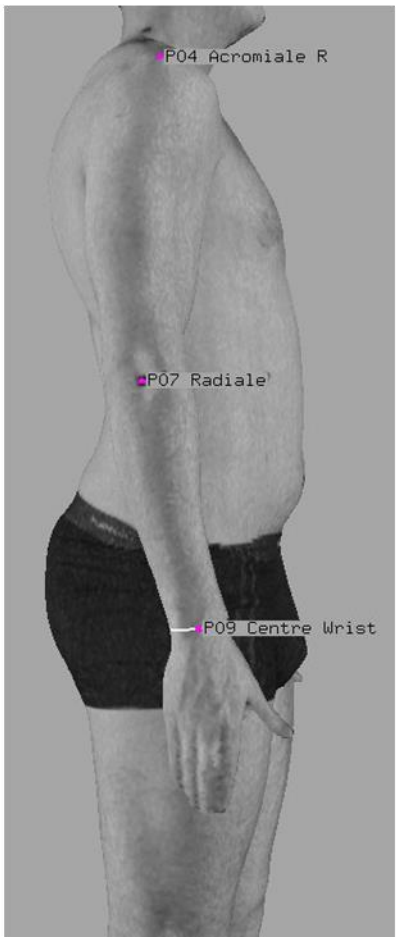
H.67 Sitting Height

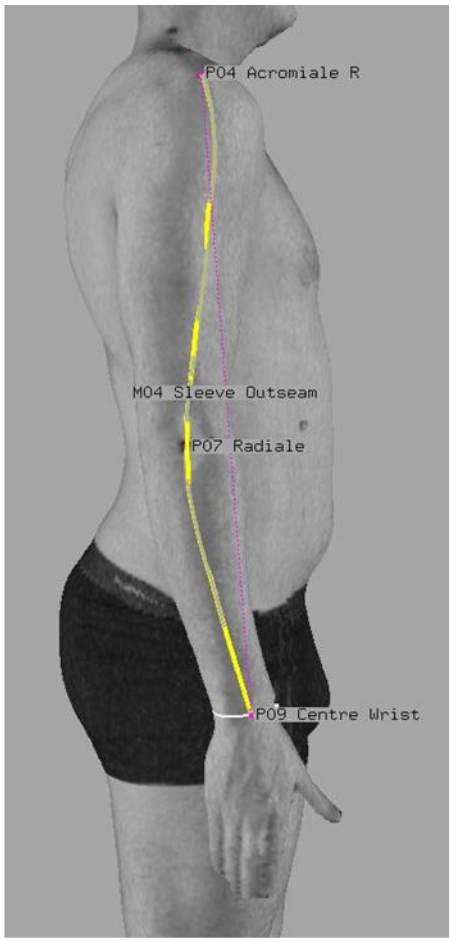
Definition	The vertical distance between the sitting surface and the top of the head.
Source	ISAK
Landmark(s)	Vertex
Instrument(s)	Stadiometer, placed on the Anthropometry box
Procedure	The participant sits erect on the stadiometer platform with their hands resting on their thighs or by their side, and the head positioned in the Frankfurt plane. The knees are flexed approximately 90° with the thighs parallel and the feet flat and in line with the thighs. Place your thumbs below each orbitale on the participant's face and the remaining fingers at the mastoid process at the base of the skull. Prompt the participant to take a deep breath in and hold. Apply a gentle upward lift through the mastoid process while keeping the head in the Frankfurt plane. Firmly push the stadiometer headboard down on the Vertex or the top of the head (with the scribe's assistance), compressing the hair as much as possible, and take the reading to the nearest 0.1 cm. Note: 1. A stretched stature method is used to account for diurnal spinal changes, as per ISAK protocol. Care must be taken to only lift the head upwards and not forwards or at an angle. 2. Ensure that the participant does not contract the gluteal muscles nor push up with the legs. 3. If the anthropometry box is too short to achieve parallel thighs and 90° knee flexion, a sturdy table can be used instead. 4. Future surveys should investigate deriving this measure using Stature, Eye Height (Standing) and Eye Height (Sitting): *Sitting Height = (Stature – Eye Height, Standing) + Eye Height, Sitting*



H.68 Sleeve Outseam

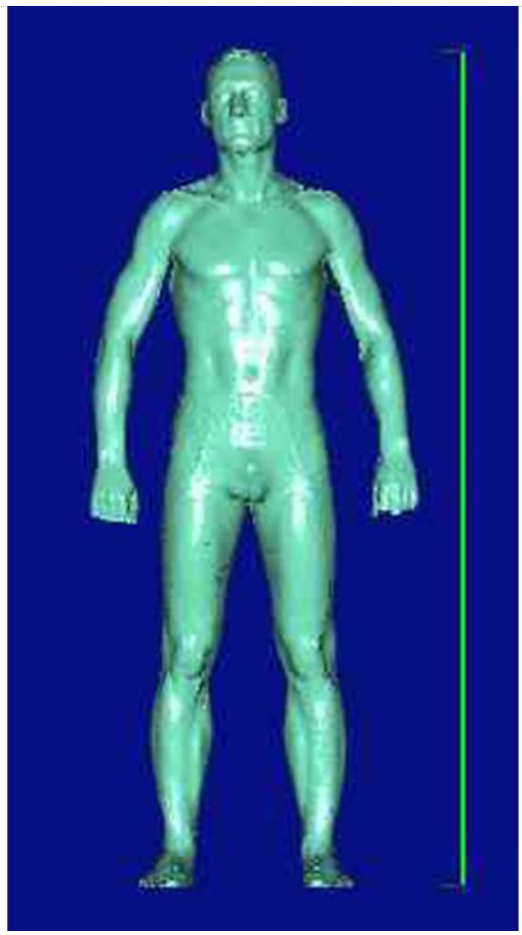
Definition	The surface distance between the Acromion Right Landmark on the tip of the right shoulder and the Centre Wrist Landmark, passing over the Radiale Landmark.
Source	AWAS (adapted to use tape length instead of contour length)
Landmark(s)	Acromion Right, Radiale and Centre Wrist
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the "tape" length (a CySize function that mimics an anthropometric tape) of a measurement line connecting the Acromion Right, Radiale and Centre Wrist landmarks. Note: The Centre Wrist Landmark is located in CySize by adding a Z section to the Stylion Landmark and then adding a marker on this loop at the mid-point between the lateral edges of the wrist when viewed straight on from the right side (parallel to the long axis of the arm).

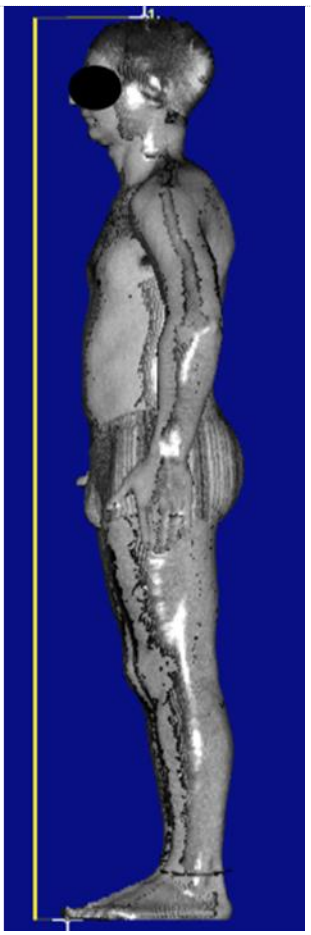




H.69 Stature

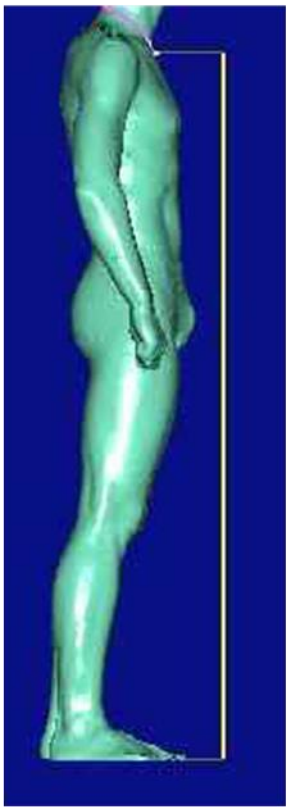
Definition	The vertical height from the standing surface to the top of the head.
Source	Anthroscan [Measurement ID 0010]
Landmark(s)	Vertex
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. Ensure that the participant is standing erect with the head in the Frankfurt position for the scan. 2. Although traditional height protocols require legs and feet together, Anthroscan measures body height with the legs shoulder-width apart to represent a more “natural” standing position.

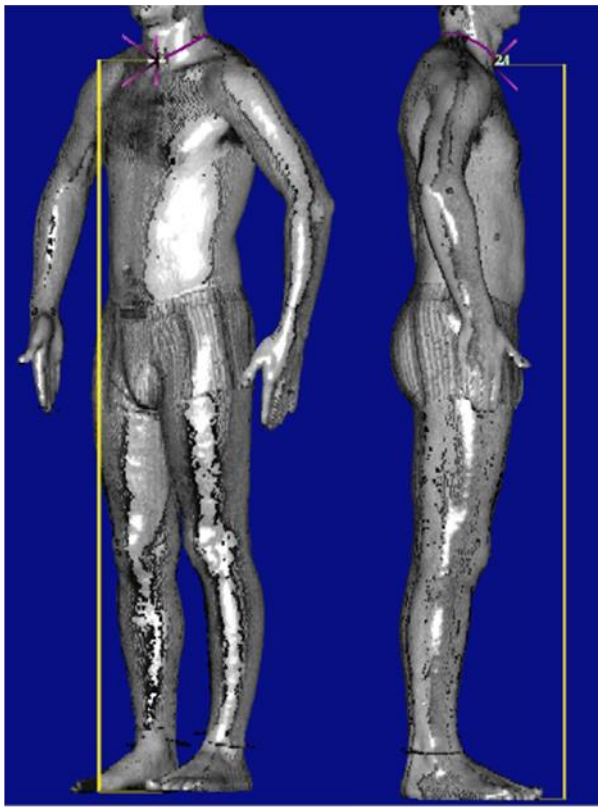




H.70 Suprasternale Height

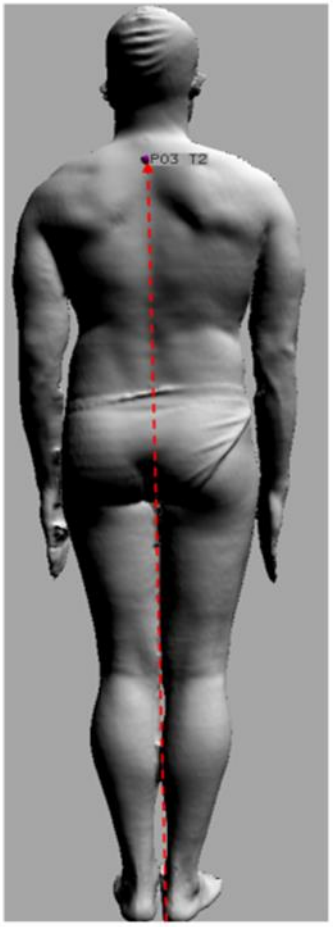
Definition	The vertical height of the base of the neck (front/lowest point of neck at base measurement, just on the transition between torso and neck) to the standing surface.
Source	Anthroscan [Measurement ID 0180]
Landmark(s)	Suprasternale
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: Ensure that the participant is standing erect with the head in the Frankfurt position for the scan.

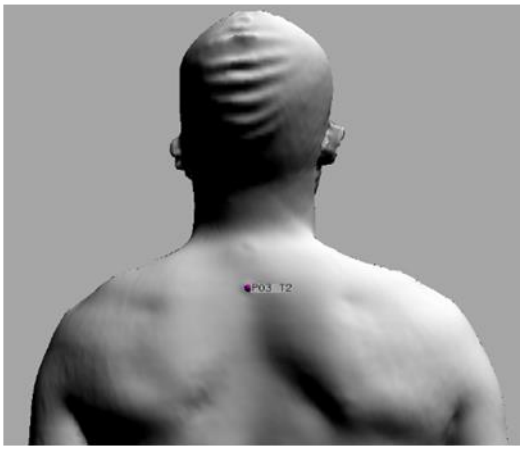




H.71 T2 Height

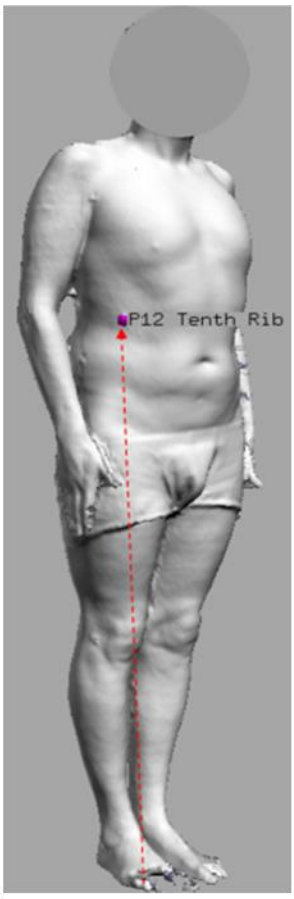
Definition	The vertical distance between the standing surface and the Second Thoracic Vertebra (T2) Landmark.
Source	AWAS (adapted for digital measurement)
Landmark(s)	T2
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the T2 Landmark. Note that the scan is captured at end tidal expiration.





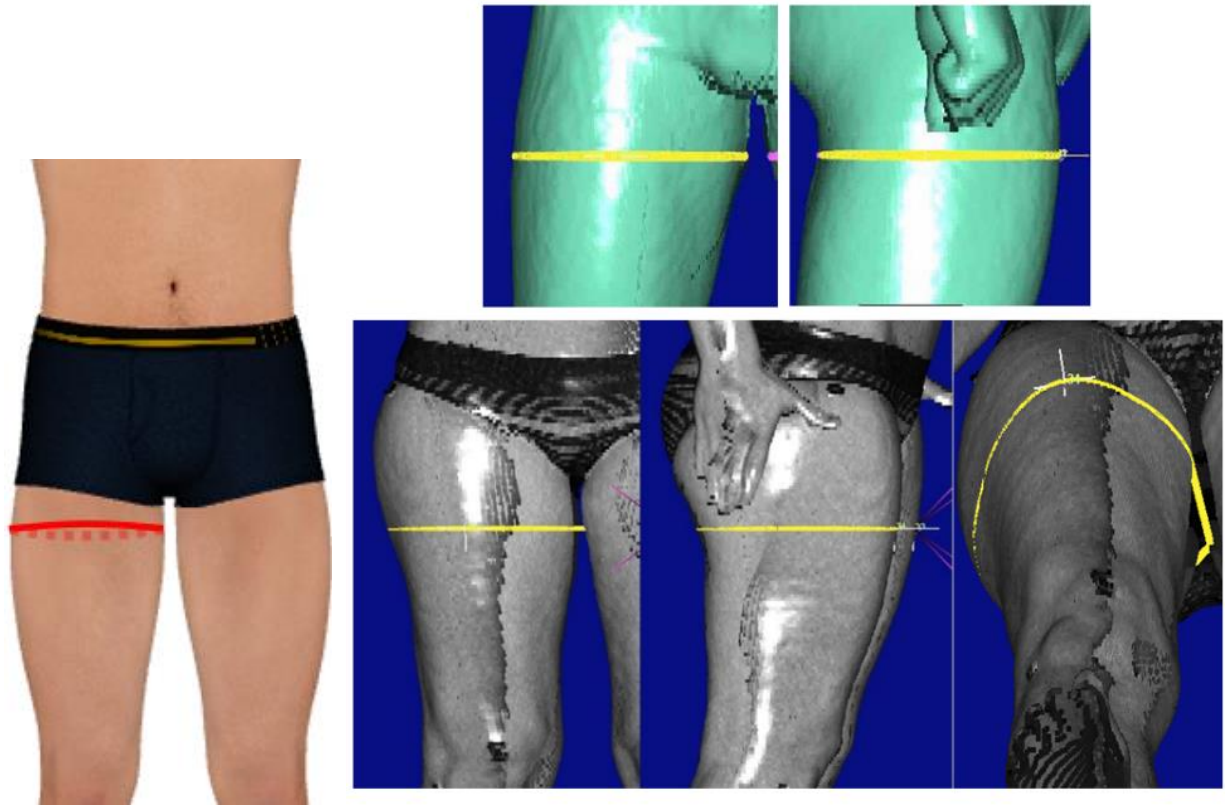
H.72 Tenth Rib Height

Definition	The vertical distance between the standing surface and the Tenth Rib Landmark located at the bottom of the right side of the ribcage.
Source	AWAS (adapted for digital measurement)
Landmark(s)	Tenth Rib
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Tenth Rib Landmark. Note that the scan is captured at end tidal expiration.



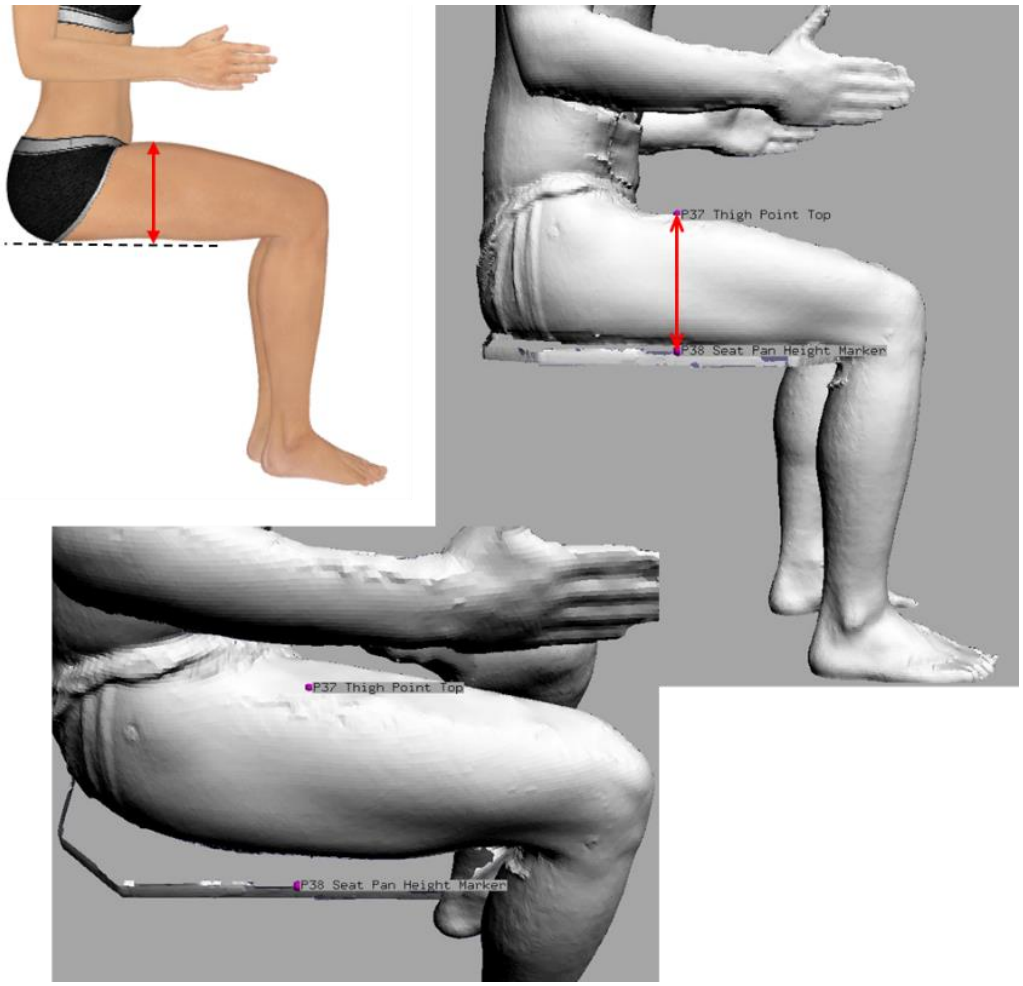
H.73 Thigh Circumference

Definition	The horizontal circumference around the right leg slightly underneath the crotch, measured parallel to the standing surface.
Source	Anthroscan [Measurement ID 9511]
Landmark(s)	Crotch
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. Ensure that the tape (represented by the yellow line) is horizontal and only includes the right thigh, especially in cases where both thighs are close together. If the thighs are too close, the measurement cannot be obtained. 2. The tape can sometimes include artefacts (for example, see image on bottom right). Ensure that the tape closely follows the curvature of the thigh.



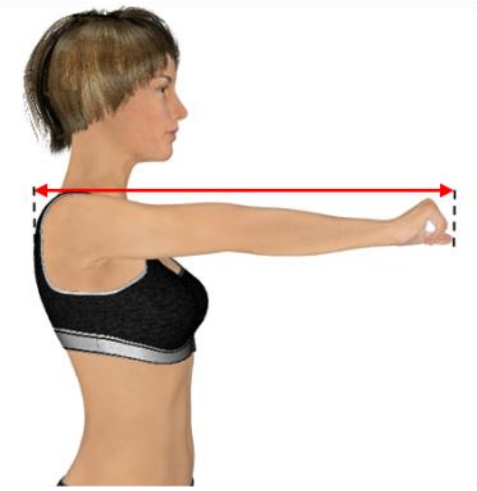
H.74 Thigh Clearance

Definition	The vertical distance between the sitting surface and the Thigh Point Top Landmark (the highest point on the right thigh).
Source	ANSUR/AWAS (adapted for digital measurement)
Landmark(s)	Thigh Point Top and Seat Pan Height Marker
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P03 sitting scan as the difference between the Y coordinate of the Thigh Point Top Landmark and the Y coordinate of the Seat Pan Height Landmark (which marks the top edge of the seat pan). This calculation is performed in an Excel spreadsheet. Note that the scan is taken at end tidal expiration. Note: This measure cannot be obtained from scans containing artefacts on the thigh surface (often caused by shadowing from the hands). Future surveys should investigate a different technique to obtain this measure given the high frequency of scan artefacts.



H.75 Thumbtip Reach

Definition	The horizontal distance from the back wall to the tip of the thumb of the outstretched right arm, with the right shoulder pressed against the wall.
Source	AWAS (adapted to use anthropometer instead of wall mounted arm span ruler)
Landmark(s)	Posterior surface of shoulder blade and Thumb
Instrument(s)	Anthropometer
Procedure	The participant stands erect with both shoulder blades against a wall. The right arm is extended forward at 90° to the body. The thumb is extended straight along the horizontal line of the arm, and the index finger curved around to touch the pad at the end of the thumb (palm facing down). Hold the fixed anthropometer branch firmly against the wall and position the inner edge of the sliding branch to lightly touch the tip of the thumb (excluding the fingernail). Take the reading to the nearest 0.1 cm with the arm and anthropometer both horizontally level. A correction factor of +1.1 cm is added post-measurement to add the width of the fixed anthropometer branch. Note: 1. Adjust the length of the anthropometer to suit the arm length of the participant by adding/removing sections. 2. Take the reading at the red line edge of the measuring window to exclude the width of both anthropometer branches. 3. Ensure that the shoulder blades and buttocks remain in contact with the wall, and hold the fixed branch securely against the wall for stability.

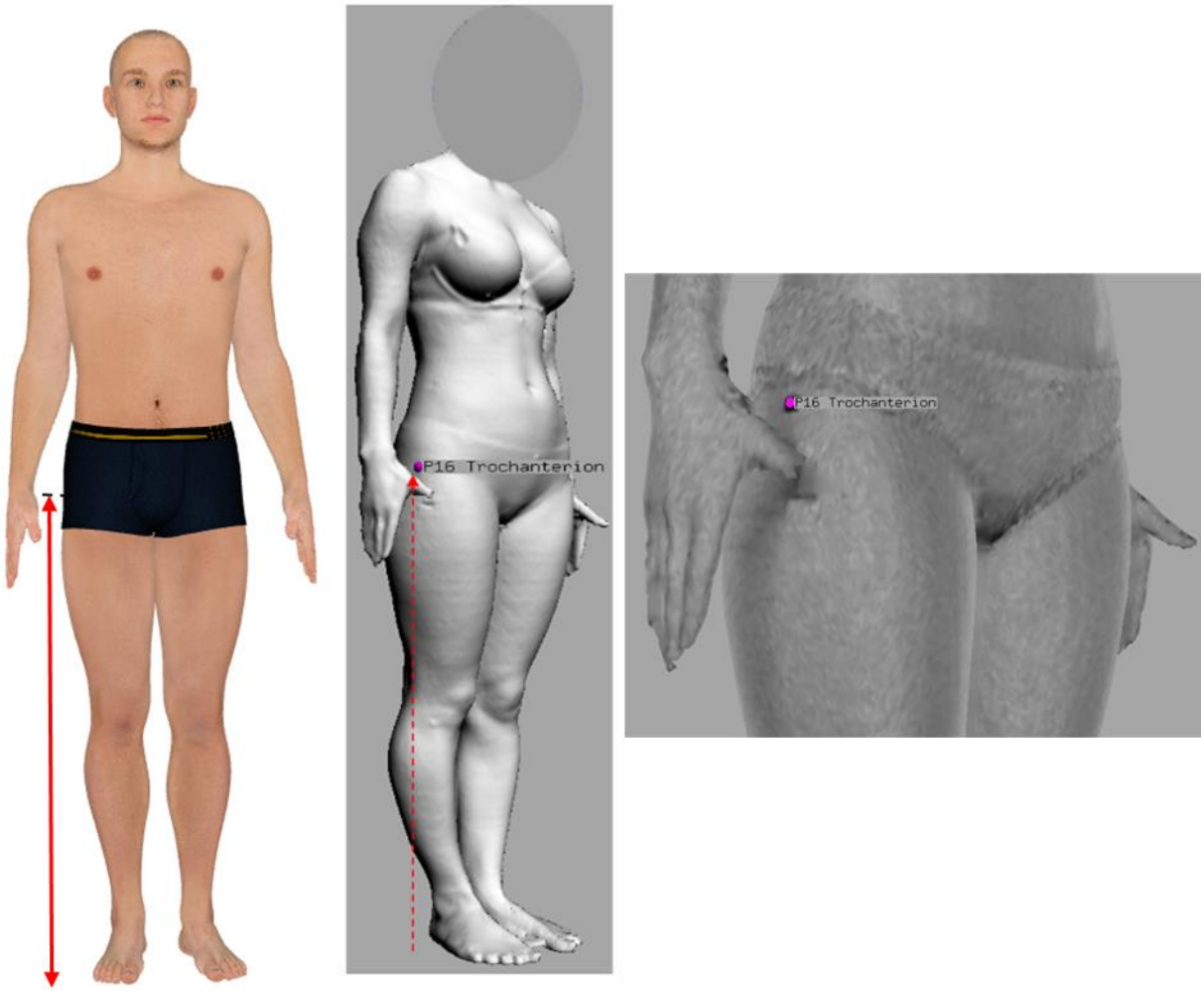


H.76 Tibiale-Laterale Height

Definition	The vertical distance between the standing surface and the Tibiale-Laterale Landmark on the right knee.
Source	Nil
Landmark(s)	Tibiale-Laterale
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Tibiale-Laterale Landmark.

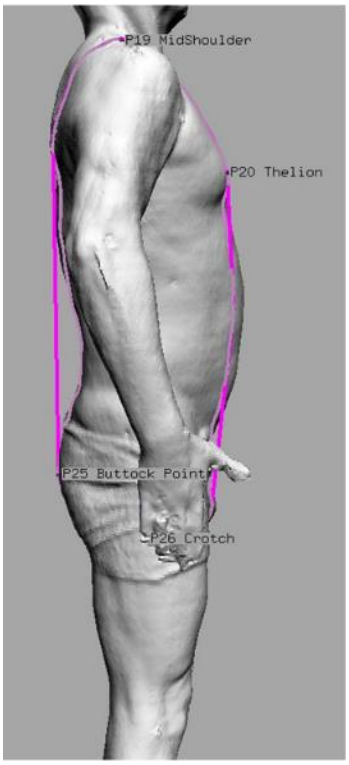
H.77 Trochanterion Height

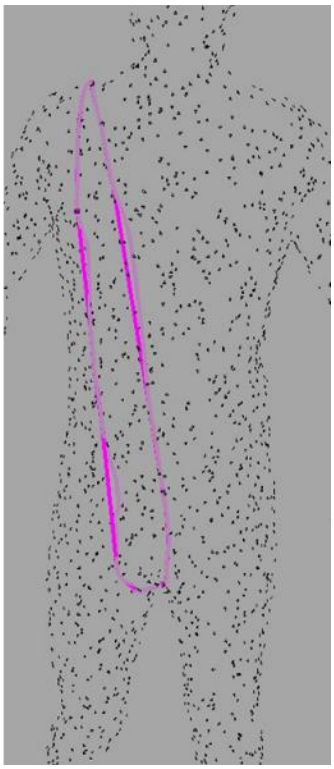
Definition	The vertical distance between the standing surface and the Trochanterion Landmark on the upper side of the right thigh.
Source	AWAS
Landmark(s)	Trochanterion
Instrument(s)	CySize
Procedure	This measure is digitally extracted as the Y coordinate of the Trochanterion Landmark in the P01 standing scan. Note: The Trochanterion Landmark can often be hidden due to the position of the hands in the P01 scan, therefore, this measure may be frequently unobtainable. Future surveys should investigate obtaining this measure from the P02 scan where the hands are further apart from the body, or use another measurement technique.



H.78 Vertical Trunk Circumference

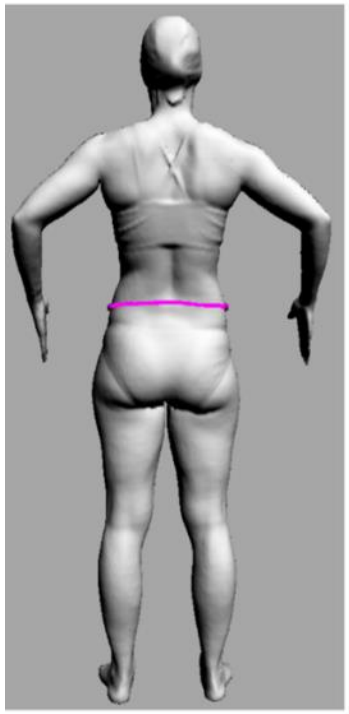
Definition	The vertical circumference of the trunk on a line passing through the crotch and over the landmarks at Bustpoint (females) or Thelion (males), Midshoulder, and Buttock Point Posterior.
Source	AWAS
Landmark(s)	Crotch, Thelion (males) or Bustpoint (females), Midshoulder, and Buttock Point Posterior.
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P02 standard scan as the "tape" length (a CySize function that mimics an anthropometric tape) of a measurement loop connecting the Midshoulder, Thelion/Bustpoint, Crotch and Buttock Point Posterior landmarks. Note: This measure cannot be obtained for participants with baggy or loose-fitting underwear (e.g. boxers or shorts). Future surveys should ensure that participants wear form-fitting underwear for the scans.





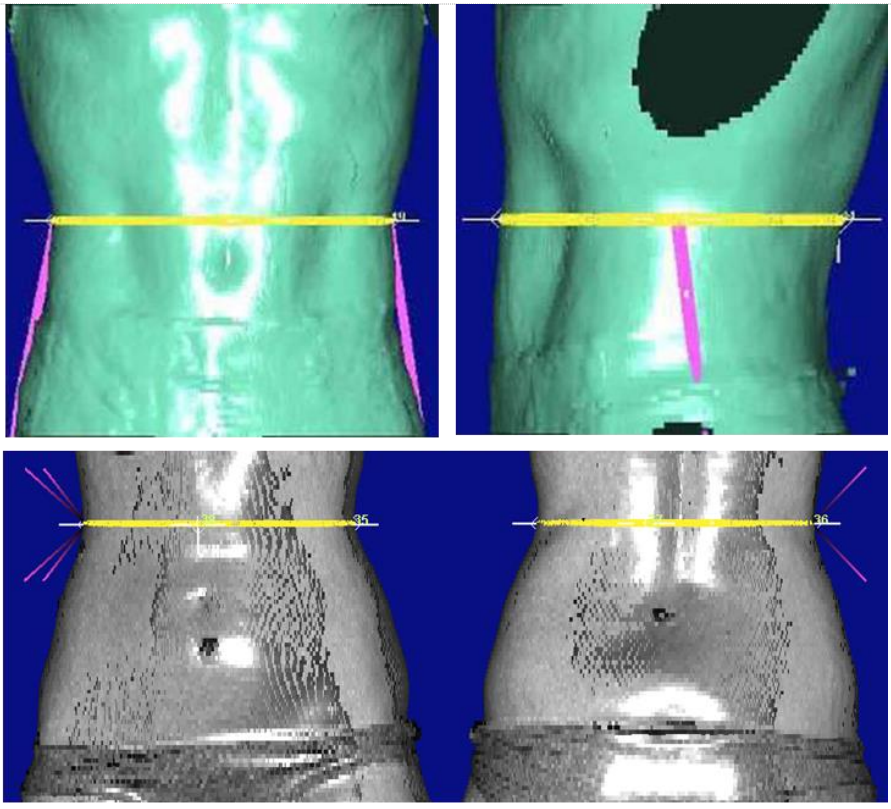
H.79 Waist Breadth

Definition	The horizontal breadth of the waist at the level of the Omphalion.
Source	ANSUR (adapted for digital measurement)
Landmark(s)	Waist Breadth Left and Waist Breadth Right
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P02 standard scan as the point-to-point distance between the Waist Breadth Right and Waist Breadth Left Landmarks at the level of the Omphalion. Note: 1. The Waist Breadth markers are located in CySize by adding a Z section to the Omphalion marker, and then placing new markers with Y sections along this line to find the most laterally protruding points. 2. Despite the appearance of a contoured surface line in the figure, this measurement is extracted from CySize as a point-to-point linear distance. 3. Future surveys should consider using the CySize calliper tool to obtain this measure from the P02 scan.



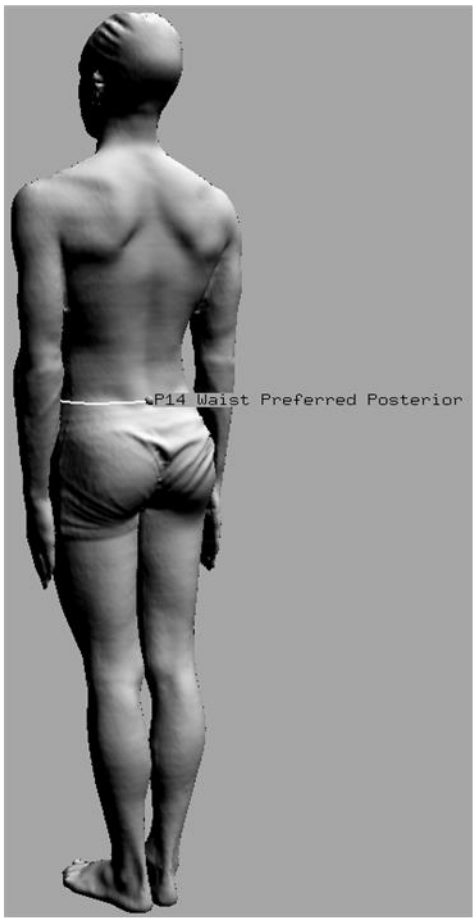
H.80 Waist Circumference, Natural Indentation

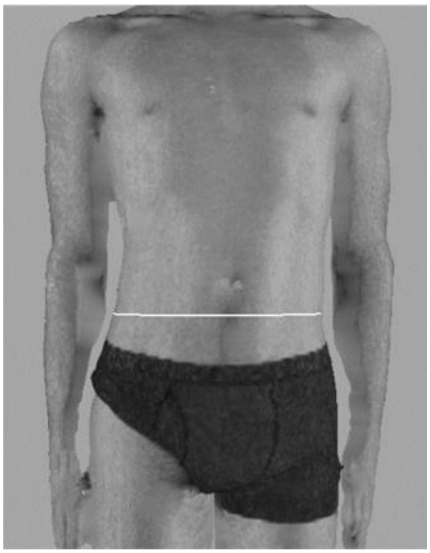
Definition	The horizontal circumference of the waist measured at the height of the natural waist, determined by the point of contraction on the side.
Source	Anthroscan [Measurement ID 6510]
Landmark(s)	Natural waist contraction points
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: 1. Ensure that the tape (represented by the yellow line) is horizontal. 2. Adjust the measurement points to align with the natural waist contraction points (i.e. the point where the waist naturally narrows) if necessary. 3. Future surveys should investigate other techniques to more accurately obtain this measure.



H.81 Waist Circumference, Preferred

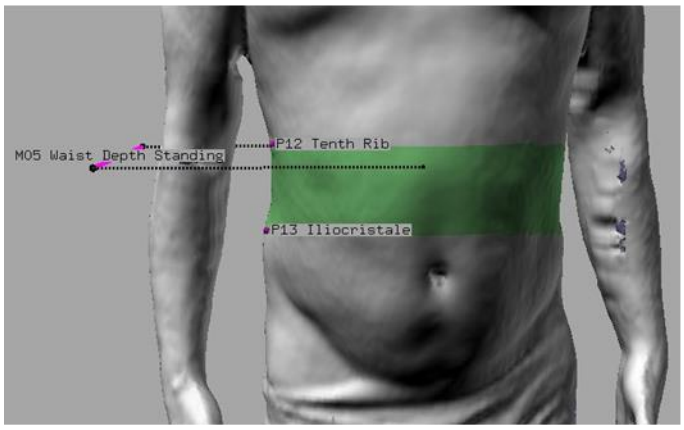
Definition	The horizontal circumference of the torso at the height of the Waist Preferred Posterior Landmark (representing the preferred belt height on the back).
Source	AWAS
Landmark(s)	Waist Preferred Posterior
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the "tape" length (a CySize function that mimics an anthropometric tape) of a Z section around the Waist Preferred Posterior Landmark. Note: This measure cannot be obtained in cases where the hands are too close to the body and webbing scan artefacts are present between the hands and torso. Future surveys should investigate obtaining this measure from the P02 scan where the hands are further away from the body, or use a different measurement technique.

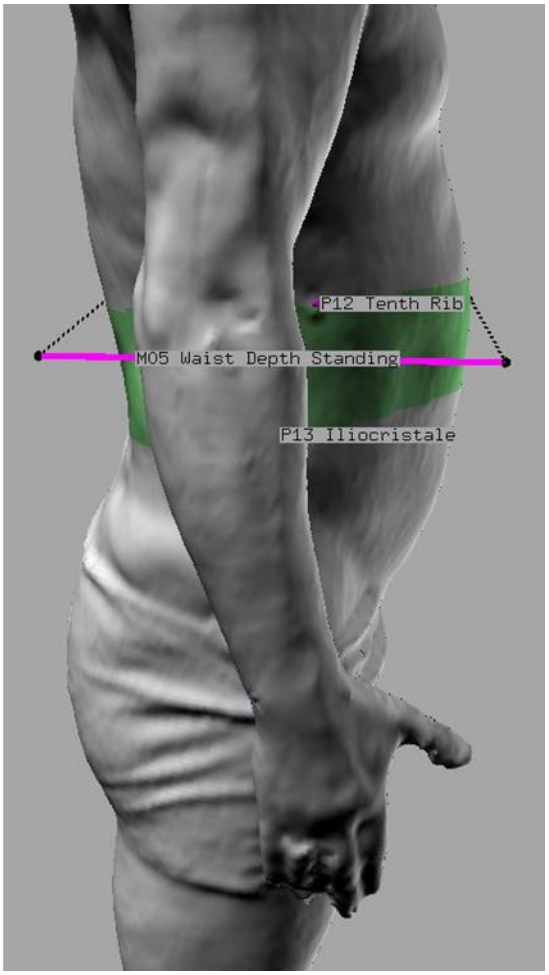




H.82 Waist Depth

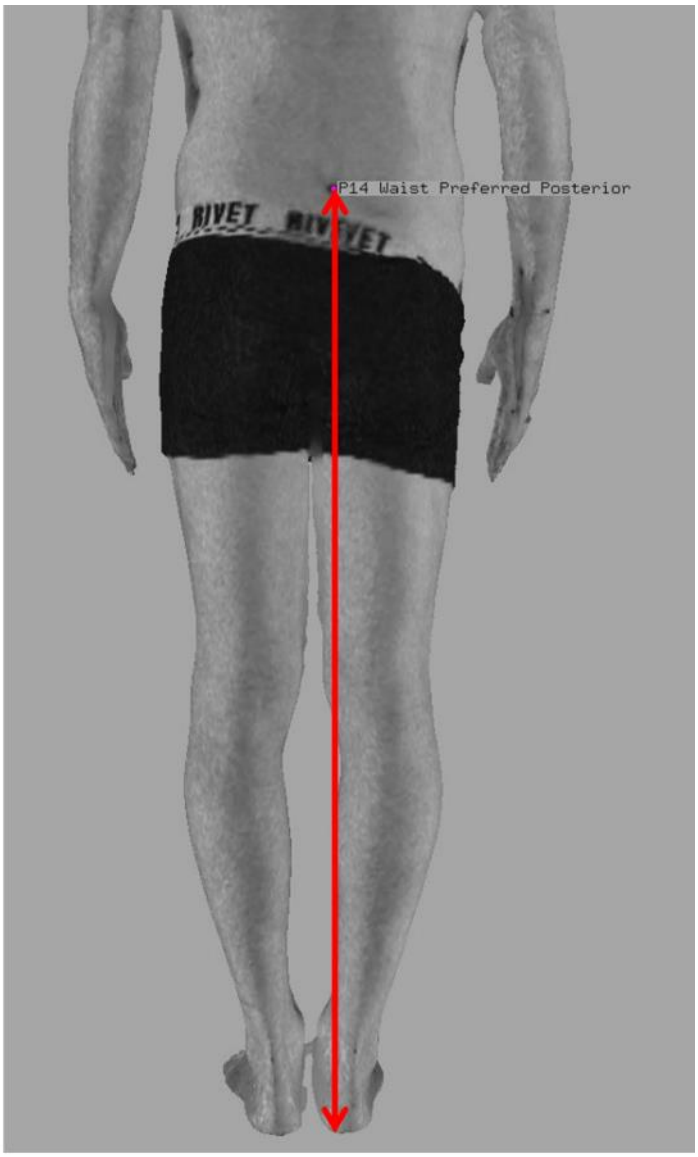
Definition	The largest horizontal depth of the torso between the Iliocristale and the Tenth Rib landmarks.
Source	ANSUR (adapted for digital extraction)
Landmark(s)	Iliocristale and Tenth Rib
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan. Highlight the region of the torso between the Iliocristale and Tenth Rib landmarks, taking care to avoid the hands, and use the calliper tool (X function) to find the largest depth within the highlighted region. Note: Unlike the ANSUR protocol, the scan is captured at end tidal expiration rather than at the maximum point of quiet respiration, and measurement is not limited to the height of the Omphalion (as it is in the ANSUR protocol).





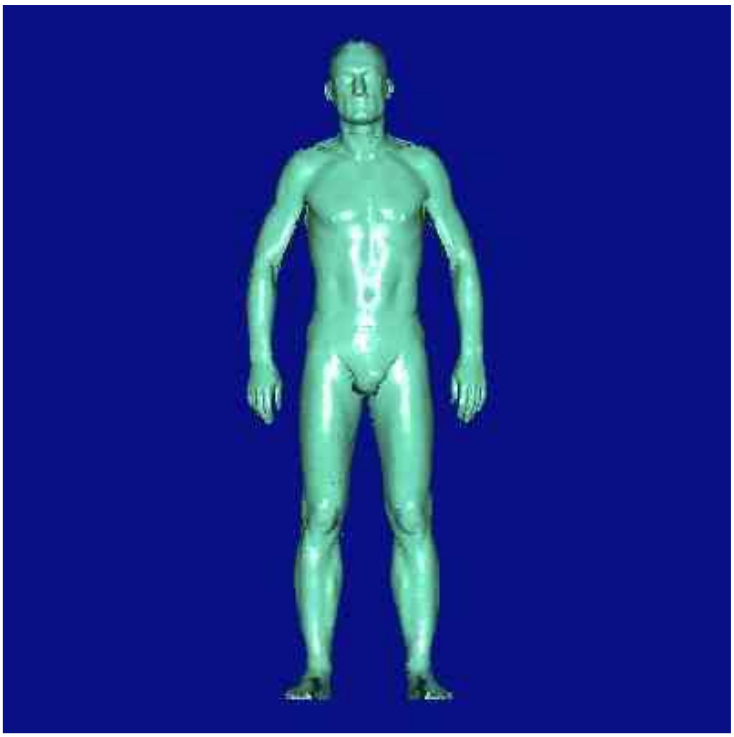
H.83 Waist Height Preferred, Posterior

Definition	The vertical distance between the standing surface and the Waist Preferred Posterior Landmark (representing the preferred belt height on the back).
Source	AWAS
Landmark(s)	Waist Preferred Posterior
Instrument(s)	CySize
Procedure	This measure is digitally extracted from the P01 standing scan as the Y coordinate of the Waist Preferred Posterior Landmark. Note that the scan is captured at end tidal expiration.



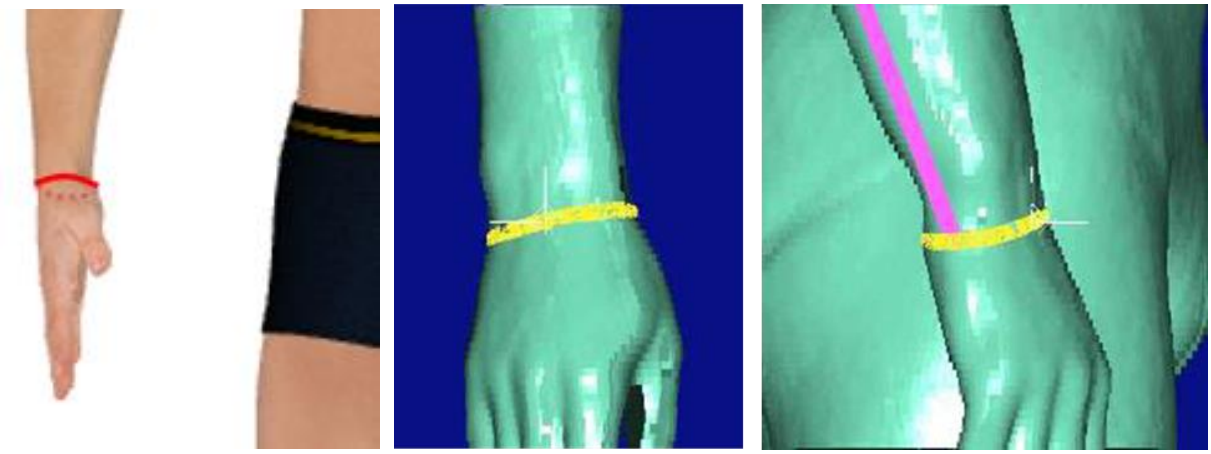
H.84 Weight

Definition	Body weight (in kilograms) measured with the scale integrated into the scanner platform.
Source	Anthroscan [Measurement ID 9800]
Landmark(s)	Nil
Instrument(s)	Anthroscan
Procedure	The body weight measure is recorded with the P02 standard scan and saved using the Automated Measurement wizard in Anthroscan. Note: 1. Tare the scale at the beginning of each scan measurement session, and check calibration with a known weight (generally the calibration pole). 2. The 3-D scanner frequently experiences weight errors. Check the scan folder immediately after each scan to ensure that a weight raw file is present. If not, rescan the participant or manually record the weight and enter this into the Anthroscan file post-scan.



H.85 Wrist Circumference

Definition	The circumference of the right wrist measured at the arm extremity just before the transition to the hand.
Source	Anthroscan [Measurement ID 8551]
Landmark(s)	Wrist
Instrument(s)	Anthroscan
Procedure	This measure is digitally extracted from the P02 standard scan via the Automated Measurement wizard in Anthroscan. Note: Ensure that the tape (represented by the yellow line) is perpendicular to the long axis of the arm across the wrist.



Appendix I Summary Statistics

This appendix provides a summary of the results for each measure available in the NZDFAS. For each measure a definition, visual representation, summary statistics and percentiles are provided for both men and women.

The statistics presented are defined as follows:

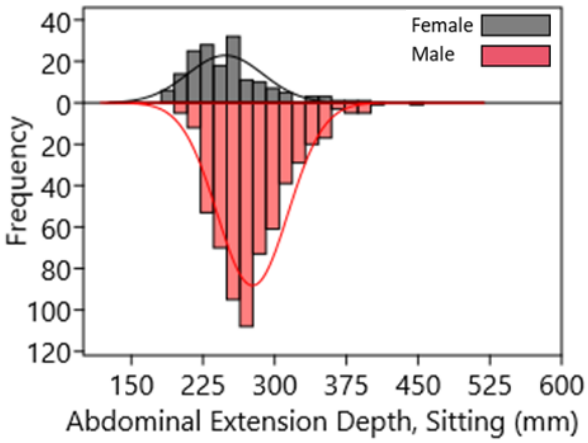
- **Valid** – Number of cases containing valid measurements
- **Missing** – Number of missing measurements
- **Mean (mm)** – Mean value
- **SE (mm)** – Standard Error
- **SD (mm)** – Standard Deviation
- **Min (mm)** – Minimum measurement
- **Max (mm)** – Maximum measurement
- **Skew** – Skewness. A measure of symmetry of the data compared to a normal distribution. A positive value indicates a longer tail to the right.
- **Kur** – Kurtosis. A measure of the tails of the data compared to a normal distribution. A negative kurtosis indicates a flat distribution with greater presence of outliers while a positive kurtosis indicates a peaked distribution.
- **Norm (p)** – Normality. Results of a Shapiro-Wilkes test to evaluate if the data is normally distributed. A value >.05 indicates the data is not normally distributed.
- **CV (%)** – Coefficient of Variation. A measure to describe the dispersion of the data. Equal to the standard deviation divided by the mean, multiplied by 100.

I.1 ABDOMINAL EXTENSION DEPTH, SITTING

Definition: The largest horizontal depth of the abdomen region between the Substernale Landmark and the Inguinal Point, measured in the seated posture.

Abdominal Extension Depth, Sitting		
Female		**Male**
165	**Valid**	597
46	**Missing**	192
248	**Mean (mm)**	277
3	**SE (mm)**	2
39	**SD (mm)**	37
181	**Min (mm)**	203
399	**Max (mm)**	456
1.2	**Skew**	0.9
1.9	**Kur**	1.2
< .001	**Norm (p)**	< .001
16%	**CV (%)**	13%

Percentiles		
Female	**%**	**Male**
186	**1**	210
194	**3**	222
200	**5**	228
208	**10**	233
210	**15**	239
216	**20**	246
218	**25**	251
226	**30**	255
230	**35**	259
234	**40**	264
237	**45**	267
241	**50**	271
249	**55**	275
253	**60**	280
257	**65**	285
260	**70**	291
264	**75**	297
272	**80**	305
280	**85**	314
298	**90**	327
332	**95**	347
351	**98**	359
371	**99**	390

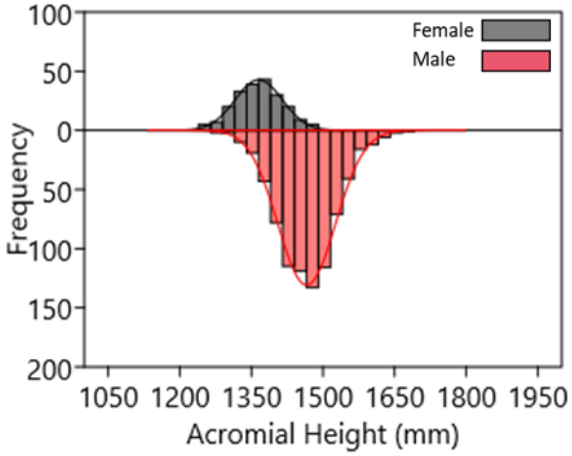


I.2 ACROMIAL HEIGHT

Definition: The vertical distance between the standing surface and the Acromion Right Landmark on the tip of the right shoulder.

Acromial Height		
Female		**Male**
211	**Valid**	786
0	**Missing**	3
1365	**Mean (mm)**	1466
3	**SE (mm)**	2
49	**SD (mm)**	60
1240	**Min (mm)**	1276
1489	**Max (mm)**	1691
0.0	**Skew**	0.1
-0.2	**Kur**	0.3
0.928	**Norm (p)**	0.278
4%	**CV (%)**	4%

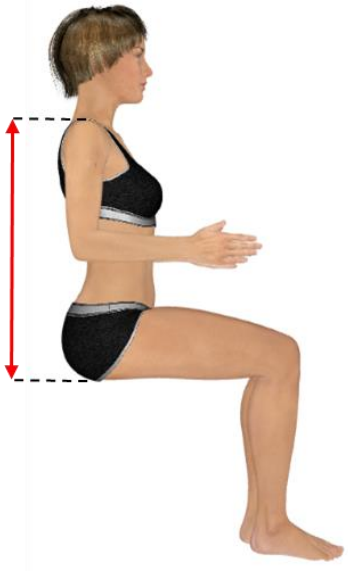
Percentiles		
Female	**%**	**Male**
1261	**1**	1327
1267	**3**	1347
1287	**5**	1369
1301	**10**	1391
1313	**15**	1406
1326	**20**	1416
1330	**25**	1425
1337	**30**	1432
1347	**35**	1442
1355	**40**	1450
1359	**45**	1459
1366	**50**	1466
1373	**55**	1472
1379	**60**	1481
1383	**65**	1487
1390	**70**	1495
1398	**75**	1505
1405	**80**	1515
1418	**85**	1527
1432	**90**	1540
1445	**95**	1564
1461	**98**	1592
1482	**99**	1618



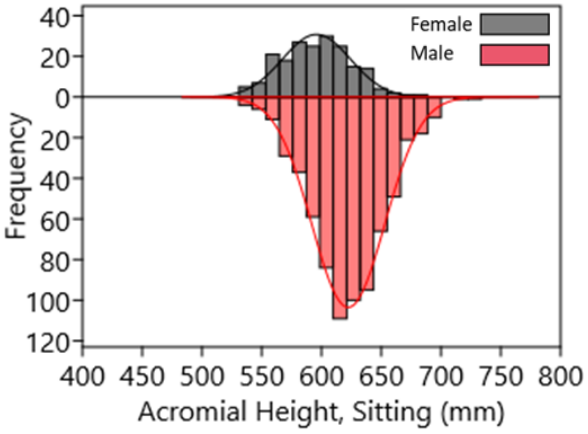
I.3 ACROMIAL HEIGHT, SITTING

Definition: The vertical distance between the sitting surface and the Acromion Right Landmark on the tip of the right shoulder.

Acromial Height, Sitting		
Female		**Male**
195	**Valid**	700
16	**Missing**	89
596	**Mean (mm)**	622
2	**SE (mm)**	1
28	**SD (mm)**	30
531	**Min (mm)**	532
683	**Max (mm)**	734
0.2	**Skew**	0.0
-0.2	**Kur**	0.1
0.513	**Norm (p)**	0.922
5%	**CV (%)**	5%



Percentiles		
Female	**%**	**Male**
535	**1**	551
547	**3**	562
552	**5**	572
558	**10**	583
564	**15**	592
570	**20**	598
576	**25**	603
579	**30**	608
585	**35**	612
588	**40**	615
593	**45**	618
596	**50**	622
601	**55**	625
603	**60**	629
606	**65**	634
612	**70**	638
615	**75**	642
619	**80**	648
625	**85**	654
633	**90**	660
640	**95**	673
650	**98**	681
665	**99**	694

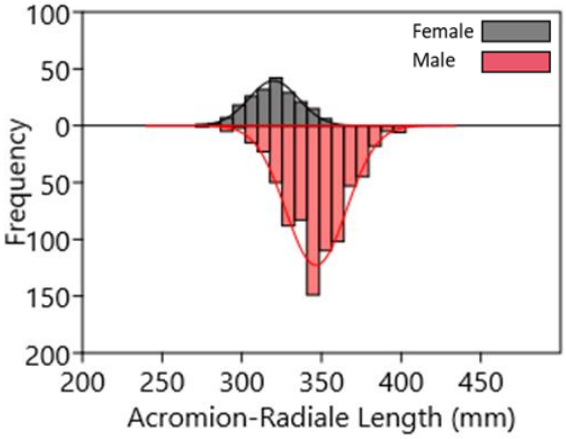


I.4 ACROMION-RADIALE LENGTH

Definition: The distance between the Acromion Right Landmark on the tip of the right shoulder and the Radiale Landmark on the right elbow.

Acromion-Radiale Length		
Female		**Male**
199	**Valid**	755
12	**Missing**	34
320	**Mean (mm)**	347
1	**SE (mm)**	1
16	**SD (mm)**	19
271	**Min (mm)**	278
353	**Max (mm)**	403
-0.1	**Skew**	-0.1
-0.3	**Kur**	0.2
0.358	**Norm (p)**	0.623
5%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
286	**1**	302
290	**3**	307
295	**5**	315
299	**10**	323
304	**15**	328
307	**20**	330
309	**25**	334
311	**30**	338
313	**35**	341
316	**40**	342
318	**45**	345
320	**50**	347
323	**55**	349
324	**60**	351
326	**65**	354
329	**70**	356
330	**75**	359
334	**80**	362
337	**85**	366
341	**90**	371
347	**95**	377
349	**98**	384
351	**99**	392

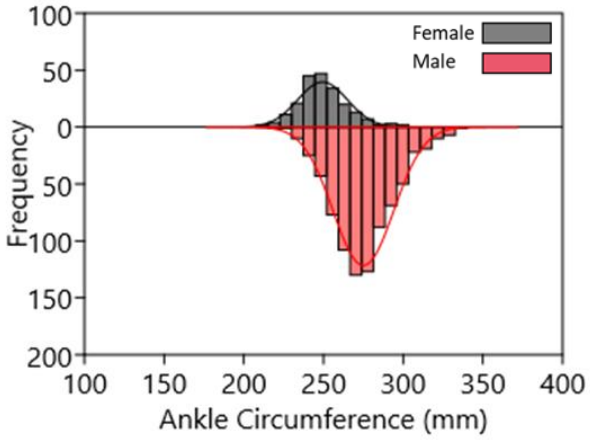


I.5 ANKLE CIRCUMFERENCE

Definition: The horizontal perimeter of the lower leg measured at the height of the left anklebone (Lateral Malleolus), measured parallel to the standing surface.

Ankle Circumference		
Female		**Male**
211	**Valid**	788
0	**Missing**	1
249	**Mean (mm)**	275
1	**SE (mm)**	1
16	**SD (mm)**	19
208	**Min (mm)**	218
298	**Max (mm)**	340
0.4	**Skew**	0.3
0.7	**Kur**	0.3
0.011	**Norm (p)**	< .001
6%	**CV (%)**	7%

Percentiles		
Female	**%**	**Male**
217	**1**	234
222	**3**	241
226	**5**	246
232	**10**	251
235	**15**	256
238	**20**	260
240	**25**	263
241	**30**	265
242	**35**	267
245	**40**	269
247	**45**	271
248	**50**	273
250	**55**	276
251	**60**	279
254	**65**	281
256	**70**	283
258	**75**	286
262	**80**	290
265	**85**	294
270	**90**	299
276	**95**	310
287	**98**	316
291	**99**	325

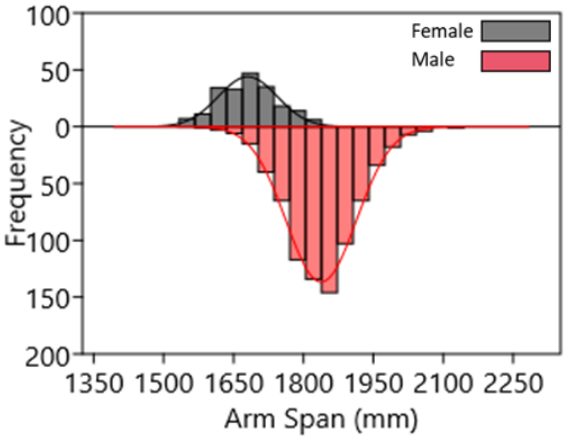


I.6 ARM SPAN

Definition: The distance between the tips of the middle fingers (Dactylion III) of the arms, both stretched maximally horizontally.

Arm Span		
Female		**Male**
205	**Valid**	759
6	**Missing**	30
1681	**Mean (mm)**	1838
4	**SE (mm)**	3
63	**SD (mm)**	75
1534	**Min (mm)**	1593
1821	**Max (mm)**	2144
0.0	**Skew**	0.1
-0.3	**Kur**	0.5
0.256	**Norm (p)**	0.172
4%	**CV (%)**	4%

Percentiles		
Female	**%**	**Male**
1543	**1**	1663
1547	**3**	1689
1575	**5**	1719
1607	**10**	1743
1619	**15**	1764
1628	**20**	1776
1634	**25**	1788
1647	**30**	1799
1656	**35**	1811
1666	**40**	1821
1673	**45**	1831
1682	**50**	1839
1685	**55**	1845
1694	**60**	1854
1706	**65**	1863
1710	**70**	1875
1719	**75**	1886
1732	**80**	1898
1749	**85**	1910
1767	**90**	1931
1793	**95**	1965
1811	**98**	1992
1818	**99**	2023

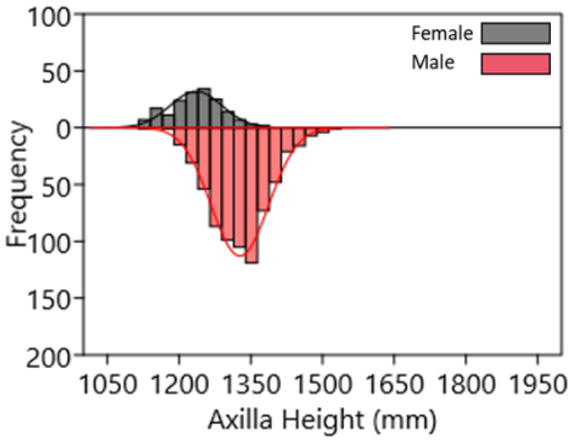


I.7 AXILLA HEIGHT

Definition: The vertical distance between the standing surface and the right axillary fold designated by the Anterior Scye Landmark on the front of the torso.

Axilla Height		
Female		**Male**
174	**Valid**	683
37	**Missing**	106
1235	**Mean (mm)**	1327
4	**SE (mm)**	2
54	**SD (mm)**	60
1115	**Min (mm)**	1126
1376	**Max (mm)**	1538
0.0	**Skew**	0.2
-0.3	**Kur**	0.1
0.38	**Norm (p)**	0.103
4%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
1124	**1**	1201
1129	**3**	1216
1145	**5**	1233
1160	**10**	1248
1172	**15**	1265
1190	**20**	1276
1201	**25**	1285
1208	**30**	1295
1216	**35**	1303
1224	**40**	1311
1231	**45**	1319
1238	**50**	1329
1247	**55**	1335
1250	**60**	1342
1254	**65**	1350
1264	**70**	1358
1270	**75**	1364
1279	**80**	1373
1288	**85**	1386
1308	**90**	1401
1319	**95**	1432
1339	**98**	1454
1363	**99**	1476

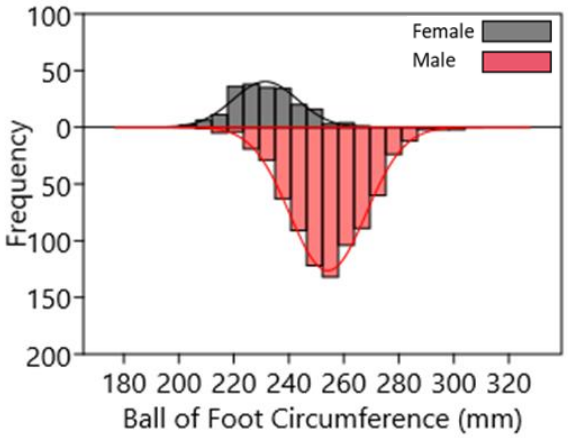


I.8 BALL OF FOOT CIRCUMFERENCE

Definition: The circumference of the foot at the first and fifth metatarsophalangeal protrusions on the ball of the left foot.

Ball of Foot Circumference		
Female		**Male**
206	**Valid**	761
5	**Missing**	28
231	**Mean (mm)**	254
1	**SE (mm)**	1
12	**SD (mm)**	14
201	**Min (mm)**	210
265	**Max (mm)**	304
0.2	**Skew**	0.0
-0.1	**Kur**	0.3
0.482	**Norm (p)**	0.251
5%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
207	**1**	220
210	**3**	227
213	**5**	231
219	**10**	236
220	**15**	240
222	**20**	244
223	**25**	245
224	**30**	247
226	**35**	250
227	**40**	251
229	**45**	253
232	**50**	254
233	**55**	255
234	**60**	257
235	**65**	259
238	**70**	261
239	**75**	264
241	**80**	265
244	**85**	269
247	**90**	272
251	**95**	276
255	**98**	280
260	**99**	285

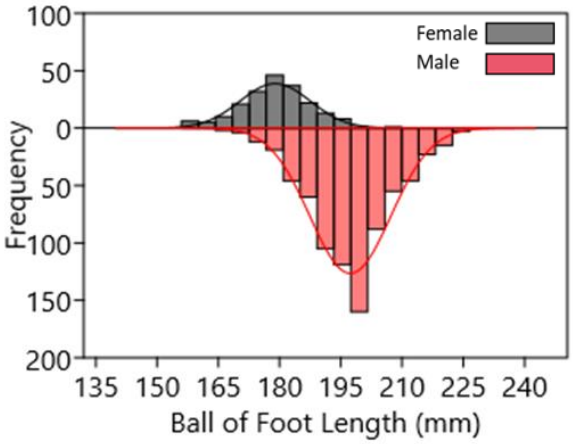


I.9 BALL OF FOOT LENGTH

Definition: The distance from the back of the heel (Pternion) to the first metatarsophalangeal protrusion on the ball of the left foot.

Ball of Foot Length		
Female		**Male**
202	**Valid**	757
9	**Missing**	32
179	**Mean (mm)**	197
1	**SE (mm)**	0
9	**SD (mm)**	10
156	**Min (mm)**	165
206	**Max (mm)**	227
-0.2	**Skew**	0.0
0.3	**Kur**	0.2
0.298	**Norm (p)**	0.088
5%	**CV (%)**	5%

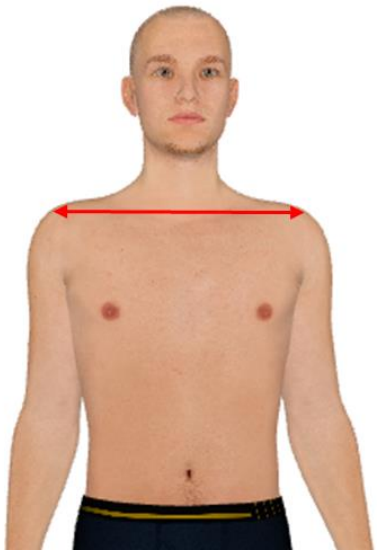
Percentiles		
Female	**%**	**Male**
158	**1**	175
160	**3**	178
164	**5**	181
168	**10**	185
171	**15**	187
173	**20**	190
174	**25**	191
175	**30**	192
176	**35**	194
177	**40**	195
179	**45**	197
179	**50**	198
180	**55**	199
181	**60**	200
182	**65**	201
183	**70**	202
185	**75**	203
186	**80**	205
188	**85**	207
190	**90**	210
191	**95**	215
195	**98**	218
196	**99**	221



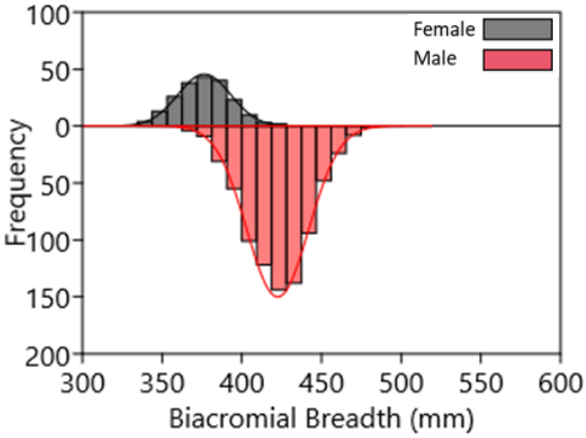
I.10 BIACROMIAL BREADTH

Definition: The distance between the Acromion Landmarks on the tips of the shoulders.

Biacromial Breadth		
Female		**Male**
202	**Valid**	779
9	**Missing**	10
376	**Mean (mm)**	423
1	**SE (mm)**	1
17	**SD (mm)**	19
334	**Min (mm)**	370
425	**Max (mm)**	484
0.1	**Skew**	-0.1
-0.1	**Kur**	-0.2
0.949	**Norm (p)**	0.694
4%	**CV (%)**	5%



Percentiles		
Female	**%**	**Male**
342	**1**	378
345	**3**	384
349	**5**	390
356	**10**	397
360	**15**	403
362	**20**	406
365	**25**	409
368	**30**	412
370	**35**	416
372	**40**	418
374	**45**	420
376	**50**	423
379	**55**	425
380	**60**	428
383	**65**	430
384	**70**	433
387	**75**	436
390	**80**	439
394	**85**	442
397	**90**	447
404	**95**	455
409	**98**	460
415	**99**	466

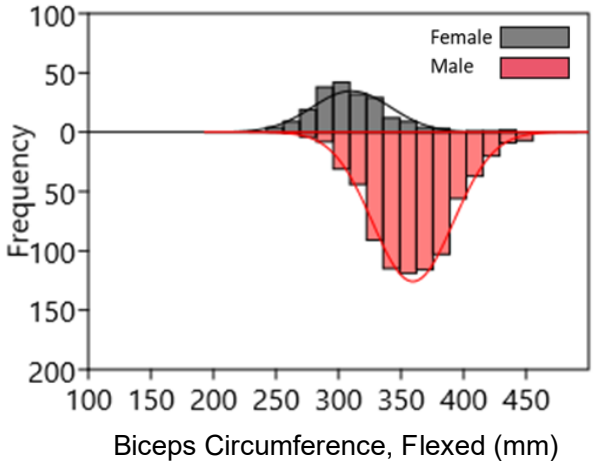


I.11 BICEPS CIRCUMFERENCE, FLEXED

Definition: The circumference of the right upper arm around the flexed biceps muscle perpendicular to the long axis of the arm at the peak of the contracted Biceps Brachii (Biceps Point Landmark).

Biceps Circumference, Flexed		
Female		**Male**
205	**Valid**	761
6	**Missing**	28
310	**Mean (mm)**	359
2	**SE (mm)**	1
31	**SD (mm)**	32
243	**Min (mm)**	264
441	**Max (mm)**	456
1.1	**Skew**	0.2
2.9	**Kur**	0.0
< .001	**Norm (p)**	0.224
10%	**CV (%)**	9%

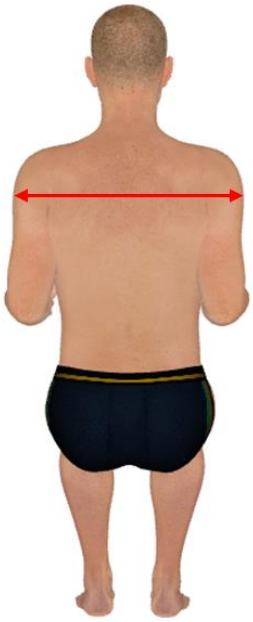
Percentiles		
Female	**%**	**Male**
251	**1**	290
261	**3**	302
268	**5**	307
275	**10**	320
281	**15**	327
287	**20**	332
291	**25**	337
295	**30**	342
296	**35**	346
301	**40**	350
304	**45**	355
308	**50**	358
310	**55**	364
313	**60**	367
315	**65**	371
322	**70**	376
326	**75**	381
332	**80**	386
336	**85**	392
345	**90**	402
363	**95**	415
380	**98**	426
423	**99**	439



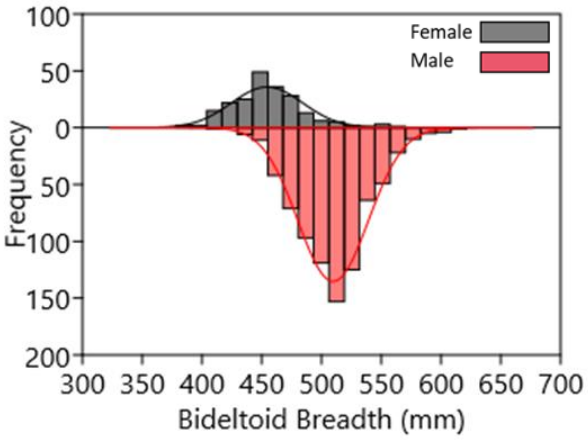
I.12 BIDELTOID BREADTH

Definition: The largest horizontal distance between the lateral margins of the upper arms on the Deltoid Muscles.

Bideltoid Breadth		
Female		**Male**
210	**Valid**	780
1	**Missing**	9
454	**Mean (mm)**	510
2	**SE (mm)**	1
30	**SD (mm)**	29
378	**Min (mm)**	414
565	**Max (mm)**	621
0.7	**Skew**	0.2
1.6	**Kur**	0.4
< .001	**Norm (p)**	0.014
7%	**CV (%)**	6%



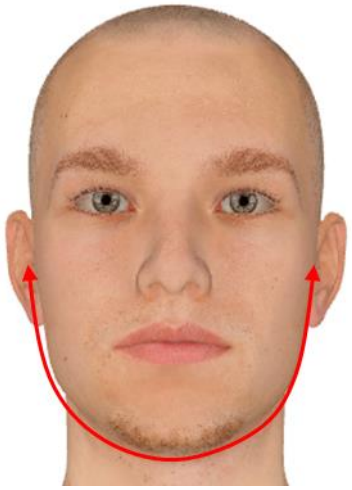
Percentiles		
Female	**%**	**Male**
395	**1**	447
406	**3**	457
411	**5**	463
419	**10**	472
427	**15**	478
430	**20**	485
436	**25**	490
440	**30**	494
444	**35**	498
447	**40**	503
449	**45**	507
452	**50**	511
455	**55**	514
458	**60**	517
462	**65**	520
466	**70**	524
470	**75**	527
475	**80**	532
480	**85**	538
491	**90**	547
507	**95**	558
529	**98**	572
551	**99**	588



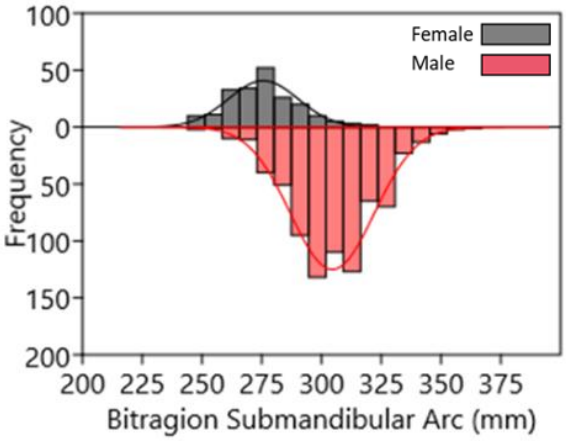
I.13 BITRAGION SUBMANDIBULAR ARC

Definition: The distance from the Tragion Right Landmark over the Submandibular Landmark at the juncture of the jaw and neck, to the Tragion Left Landmark, with the head positioned in the Frankfurt plane.

Bitragion Submandibular Arc		
Female		**Male**
206	**Valid**	759
5	**Missing**	30
276	**Mean (mm)**	305
1	**SE (mm)**	1
15	**SD (mm)**	18
244	**Min (mm)**	246
319	**Max (mm)**	367
0.3	**Skew**	0.1
0.1	**Kur**	0.2
0.087	**Norm (p)**	0.229
5%	**CV (%)**	6%



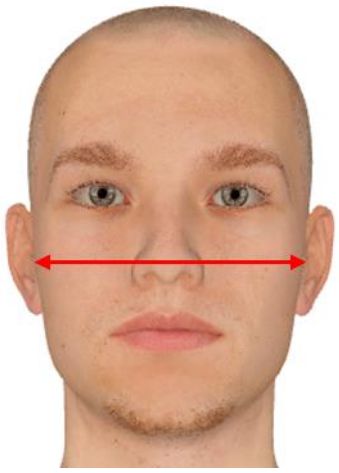
Percentiles		
Female	**%**	**Male**
246	**1**	265
248	**3**	270
253	**5**	275
258	**10**	284
260	**15**	287
265	**20**	290
265	**25**	293
268	**30**	295
270	**35**	296
270	**40**	300
274	**45**	302
275	**50**	305
277	**55**	305
280	**60**	310
280	**65**	311
282	**70**	315
284	**75**	316
285	**80**	320
291	**85**	324
294	**90**	326
301	**95**	334
307	**98**	340
312	**99**	346



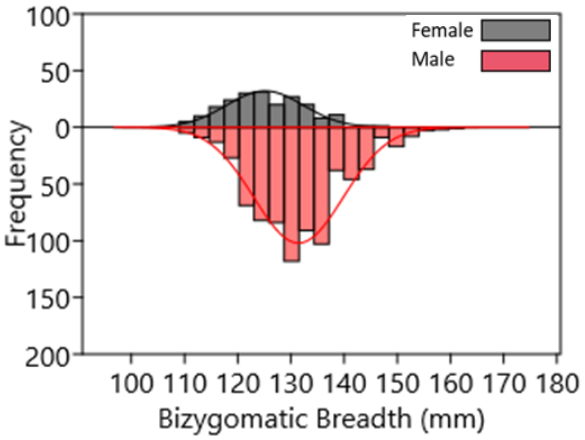
I.14 BIZYGOMATIC BREADTH

Definition: The maximum horizontal breadth of the face between the left and right Zygion.

Bizygomatic Breadth		
Female		**Male**
206	**Valid**	762
5	**Missing**	27
125	**Mean (mm)**	131
1	**SE (mm)**	0
7	**SD (mm)**	8
110	**Min (mm)**	109
146	**Max (mm)**	163
0.1	**Skew**	0.4
-0.4	**Kur**	0.4
0.18	**Norm (p)**	< .001
6%	**CV (%)**	6%



Percentiles		
Female	**%**	**Male**
110	**1**	112
112	**3**	116
114	**5**	119
115	**10**	122
117	**15**	123
120	**20**	125
120	**25**	125
122	**30**	127
122	**35**	128
123	**40**	129
124	**45**	130
125	**50**	131
126	**55**	132
126	**60**	133
128	**65**	134
130	**70**	135
130	**75**	136
132	**80**	138
132	**85**	140
134	**90**	143
138	**95**	147
139	**98**	150
140	**99**	154

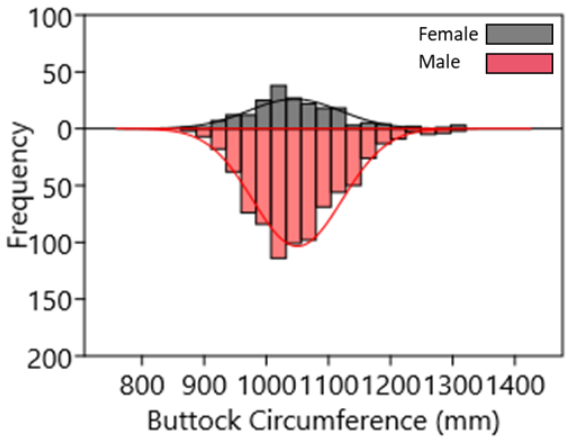


I.15 BUTTOCK CIRCUMFERENCE

Definition: The circumference of the buttock measured with the tape passing just above the most protruding point of the buttock, parallel to the standing surface.

Buttock Circumference		
Female		**Male**
200	**Valid**	773
11	**Missing**	16
1045	**Mean (mm)**	1050
5	**SE (mm)**	3
74	**SD (mm)**	72
870	**Min (mm)**	863
1310	**Max (mm)**	1321
0.9	**Skew**	0.5
1.8	**Kur**	0.4
< .001	**Norm (p)**	< .001
7%	**CV (%)**	7%

Percentiles		
Female	**%**	**Male**
919	**1**	903
927	**3**	922
945	**5**	949
958	**10**	966
976	**15**	977
989	**20**	987
999	**25**	1000
1009	**30**	1009
1016	**35**	1017
1020	**40**	1024
1024	**45**	1034
1035	**50**	1044
1040	**55**	1051
1052	**60**	1061
1064	**65**	1070
1072	**70**	1081
1084	**75**	1094
1097	**80**	1109
1115	**85**	1126
1124	**90**	1143
1177	**95**	1173
1228	**98**	1204
1301	**99**	1256

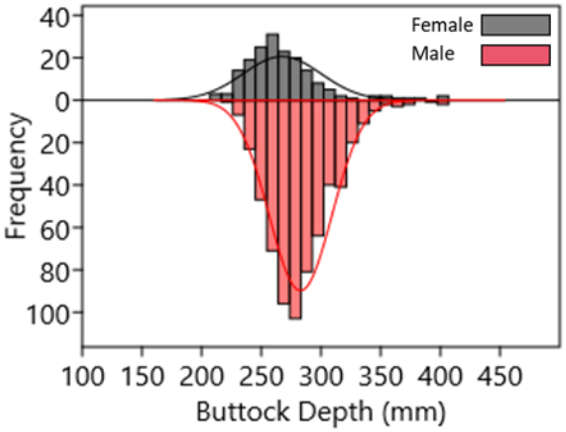


I.16 BUTTOCK DEPTH

Definition: The largest horizontal depth of the right buttock and crotch region measured with the participant in the standing posture.

Buttock Depth		
Female		**Male**
177	**Valid**	620
34	**Missing**	169
267	**Mean (mm)**	283
2	**SE (mm)**	1
33	**SD (mm)**	26
207	**Min (mm)**	223
405	**Max (mm)**	407
1.6	**Skew**	0.8
4.1	**Kur**	1.7
< .001	**Norm (p)**	< .001
12%	**CV (%)**	9%

Percentiles		
Female	**%**	**Male**
214	**1**	232
225	**3**	241
230	**5**	245
233	**10**	252
239	**15**	257
243	**20**	262
247	**25**	265
249	**30**	268
253	**35**	271
256	**40**	274
259	**45**	277
263	**50**	280
265	**55**	282
268	**60**	286
271	**65**	290
275	**70**	294
279	**75**	298
288	**80**	303
292	**85**	310
301	**90**	316
330	**95**	327
359	**98**	340
388	**99**	363

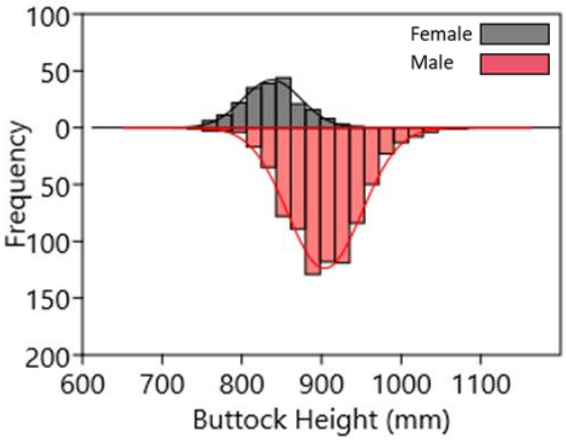


I.17 BUTTOCK HEIGHT

Definition: The vertical height of the buttock circumference measurement (just above the most protruding point of the buttock) to the standing surface.

Buttock Height		
Female		**Male**
206	**Valid**	780
5	**Missing**	9
838	**Mean (mm)**	904
3	**SE (mm)**	2
36	**SD (mm)**	46
751	**Min (mm)**	732
940	**Max (mm)**	1083
0.2	**Skew**	0.1
-0.1	**Kur**	0.6
0.718	**Norm (p)**	0.019
4%	**CV (%)**	5%

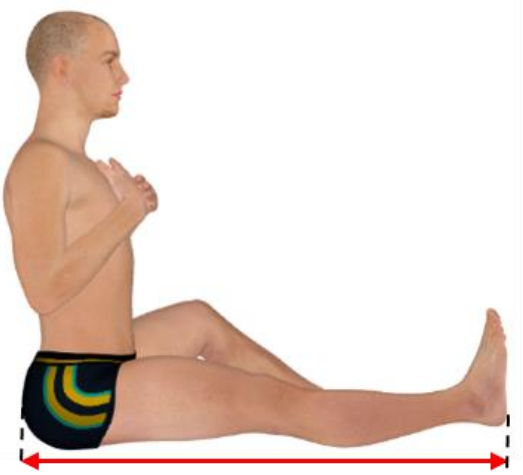
Percentiles		
Female	**%**	**Male**
759	**1**	796
769	**3**	816
780	**5**	833
792	**10**	848
797	**15**	858
807	**20**	864
814	**25**	873
817	**30**	880
824	**35**	887
828	**40**	892
834	**45**	898
838	**50**	905
843	**55**	909
846	**60**	916
851	**65**	921
856	**70**	927
860	**75**	933
863	**80**	940
877	**85**	949
886	**90**	960
759	**1**	796
769	**3**	816
780	**5**	833



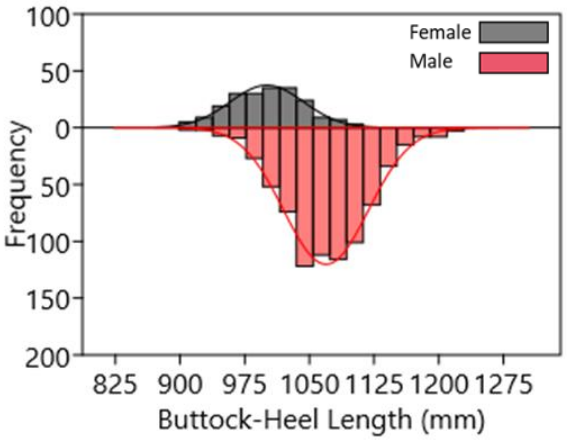
I.18 BUTTOCK-HEEL LENGTH

Definition: The distance between the back of the right buttock and the plane of the bottom of the right foot, with the participant seated on the floor and the right leg extended.

Buttock-Heel Length		
Female		**Male**
206	**Valid**	760
5	**Missing**	29
1001	**Mean (mm)**	1069
3	**SE (mm)**	2
43	**SD (mm)**	49
899	**Min (mm)**	909
1109	**Max (mm)**	1229
0.0	**Skew**	0.1
-0.2	**Kur**	0.3
0.72	**Norm (p)**	0.208
4%	**CV (%)**	5%



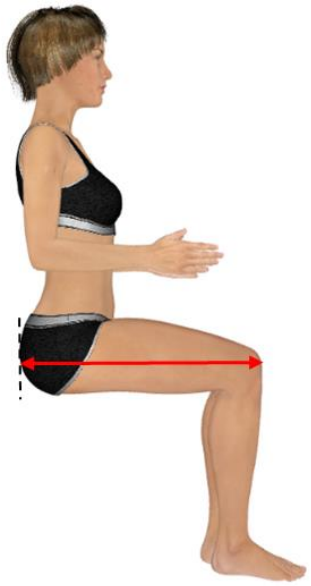
Percentiles		
Female	**%**	**Male**
900	**1**	954
919	**3**	976
926	**5**	991
946	**10**	1008
956	**15**	1020
966	**20**	1029
973	**25**	1037
977	**30**	1043
983	**35**	1049
990	**40**	1056
996	**45**	1062
1001	**50**	1070
1008	**55**	1076
1013	**60**	1081
1018	**65**	1089
1023	**70**	1095
1031	**75**	1102
1035	**80**	1110
1043	**85**	1117
1051	**90**	1128
1073	**95**	1147
1088	**98**	1170
1100	**99**	1197



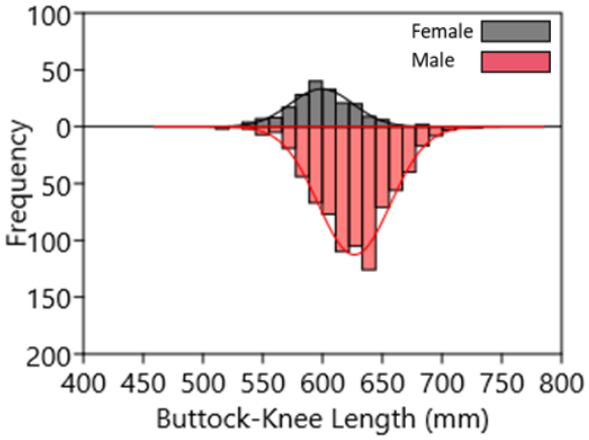
I.19 BUTTOCK-KNEE LENGTH

Definition: The largest horizontal depth from the back of the right buttock to the front of the right knee flexed at 90°.

Buttock-Knee Length		
Female		**Male**
196	**Valid**	761
15	**Missing**	28
599	**Mean (mm)**	627
2	**SE (mm)**	1
26	**SD (mm)**	30
537	**Min (mm)**	511
682	**Max (mm)**	734
0.2	**Skew**	-0.1
0.2	**Kur**	0.4
0.517	**Norm (p)**	0.282
4%	**CV (%)**	5%



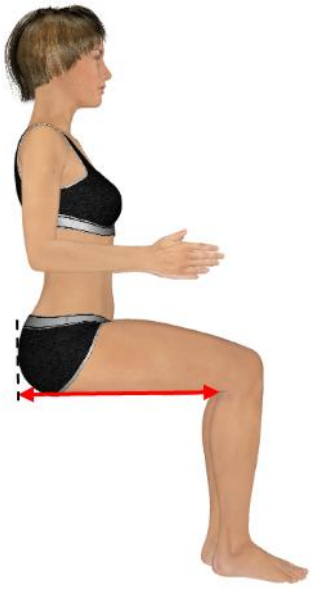
Percentiles		
Female	**%**	**Male**
544	**1**	549
546	**3**	568
555	**5**	579
567	**10**	588
575	**15**	596
578	**20**	601
583	**25**	607
586	**30**	612
590	**35**	616
592	**40**	620
595	**45**	623
599	**50**	628
602	**55**	631
606	**60**	635
607	**65**	638
611	**70**	642
615	**75**	646
622	**80**	651
628	**85**	659
632	**90**	665
641	**95**	675
648	**98**	685
659	**99**	692



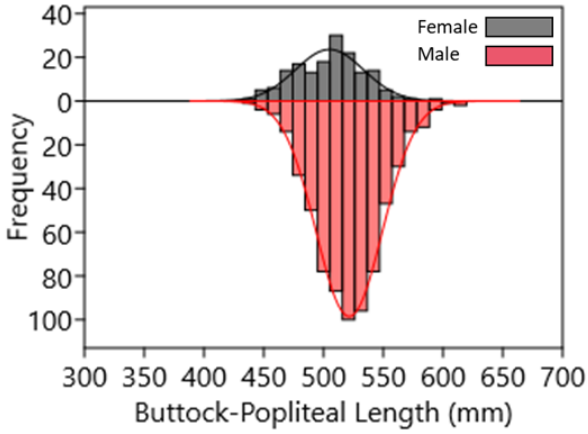
I.20 BUTTOCK-POPLITEAL LENGTH

Definition: The horizontal distance between the Buttock Point Posterior (most protruding point on the right buttock) and the Popliteal Landmark, in the seated posture.

Buttock-Popliteal Length		
Female		**Male**
162	**Valid**	658
49	**Missing**	131
505	**Mean (mm)**	521
2	**SE (mm)**	1
28	**SD (mm)**	28
433	**Min (mm)**	438
595	**Max (mm)**	620
0.0	**Skew**	0.1
-0.1	**Kur**	0.2
0.803	**Norm (p)**	0.736
6%	**CV (%)**	5%



Percentiles		
Female	**%**	**Male**
446	**1**	456
449	**3**	470
459	**5**	479
468	**10**	487
473	**15**	494
479	**20**	498
483	**25**	503
491	**30**	506
496	**35**	510
499	**40**	515
504	**45**	518
507	**50**	522
510	**55**	525
513	**60**	528
516	**65**	531
518	**70**	536
523	**75**	539
529	**80**	543
533	**85**	549
541	**90**	557
548	**95**	568
556	**98**	579
567	**99**	587

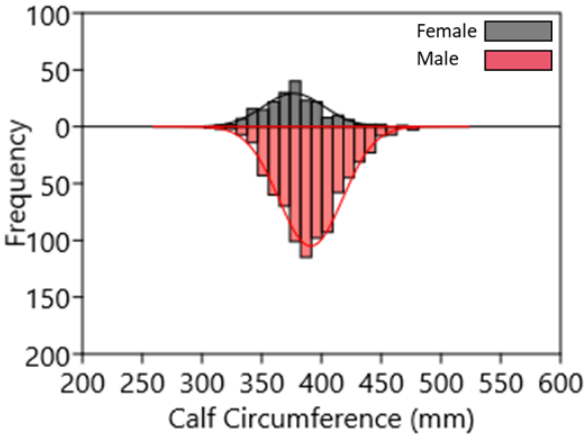


I.21 CALF CIRCUMFERENCE

Definition: The maximal horizontal perimeter over the calf muscle of the right lower leg, parallel to the standing surface.

Calf Circumference		
Female		**Male**
209	**Valid**	782
2	**Missing**	7
377	**Mean (mm)**	391
2	**SE (mm)**	1
26	**SD (mm)**	27
314	**Min (mm)**	302
471	**Max (mm)**	481
0.5	**Skew**	0.2
0.6	**Kur**	0.2
0.022	**Norm (p)**	0.025
7%	**CV (%)**	7%

Percentiles		
Female	**%**	**Male**
325	**1**	335
334	**3**	345
338	**5**	350
345	**10**	358
350	**15**	363
356	**20**	369
361	**25**	373
364	**30**	376
369	**35**	381
371	**40**	384
374	**45**	387
375	**50**	390
377	**55**	393
380	**60**	397
383	**65**	400
387	**70**	403
393	**75**	407
396	**80**	413
400	**85**	419
411	**90**	426
422	**95**	437
430	**98**	444
446	**99**	457

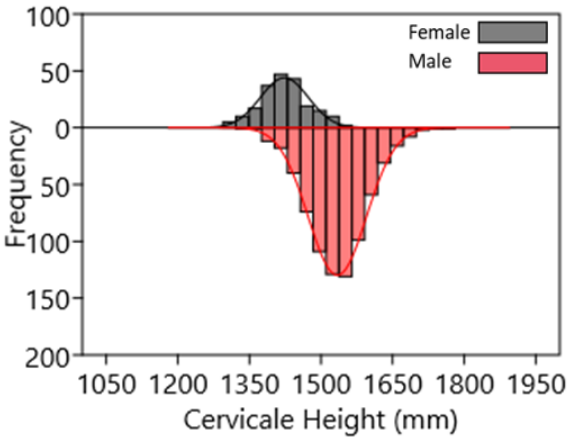


I.22 CERVICALE HEIGHT

Definition: The vertical distance between the standing surface and the Cervicale (C7) Landmark on the spine at the base of the neck.

Cervicale Height		
Female		**Male**
205	**Valid**	732
6	**Missing**	57
1423	**Mean (mm)**	1534
4	**SE (mm)**	2
50	**SD (mm)**	61
1295	**Min (mm)**	1323
1555	**Max (mm)**	1781
0.1	**Skew**	0.1
0.1	**Kur**	0.4
0.176	**Norm (p)**	0.504
4%	**CV (%)**	4%

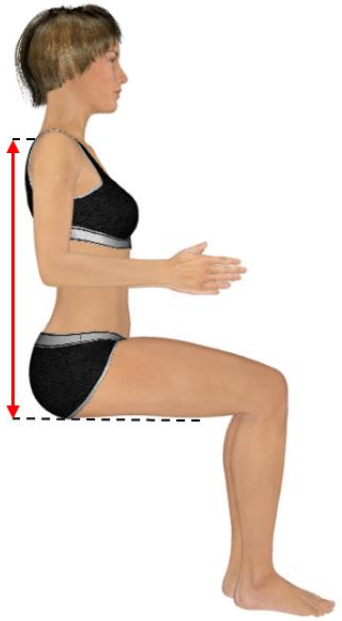
Percentiles		
Female	**%**	**Male**
1302	**1**	1396
1327	**3**	1420
1344	**5**	1436
1362	**10**	1457
1375	**15**	1473
1384	**20**	1484
1390	**25**	1494
1398	**30**	1502
1406	**35**	1511
1412	**40**	1520
1418	**45**	1526
1423	**50**	1533
1428	**55**	1542
1432	**60**	1550
1436	**65**	1557
1440	**70**	1564
1450	**75**	1575
1460	**80**	1582
1473	**85**	1593
1494	**90**	1611
1516	**95**	1636
1533	**98**	1654
1537	**99**	1680



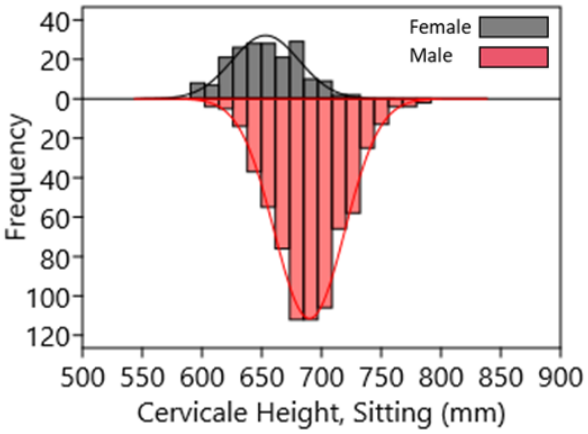
I.23 CERVICALE HEIGHT, SITTING

Definition: The vertical distance between the sitting surface and the Cervicale (C7) Landmark on the spine at the base of the neck.

Cervicale Height, Sitting		
Female		**Male**
191	**Valid**	693
20	**Missing**	96
653	**Mean (mm)**	690
2	**SE (mm)**	1
28	**SD (mm)**	29
591	**Min (mm)**	605
732	**Max (mm)**	792
0.1	**Skew**	0.1
-0.4	**Kur**	0.2
0.425	**Norm (p)**	0.475
4%	**CV (%)**	4%



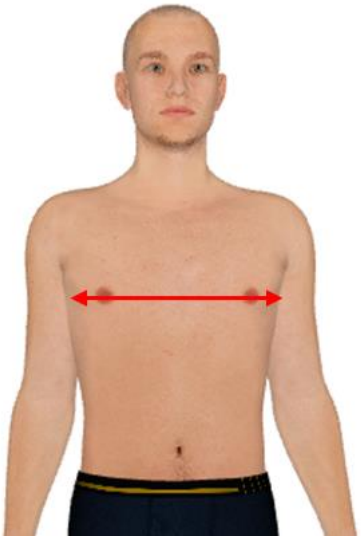
Percentiles		
Female	**%**	**Male**
597	**1**	624
599	**3**	634
609	**5**	643
617	**10**	654
624	**15**	659
627	**20**	665
633	**25**	671
636	**30**	675
641	**35**	678
645	**40**	682
649	**45**	686
653	**50**	690
658	**55**	694
660	**60**	697
666	**65**	701
671	**70**	704
675	**75**	709
678	**80**	714
681	**85**	721
687	**90**	726
698	**95**	738
707	**98**	748
712	**99**	763



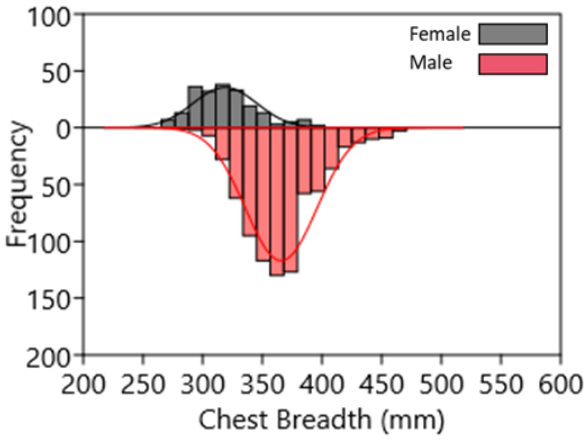
I.24 CHEST BREADTH

Definition: The maximum horizontal breadth of the chest at the level of the Thelion (right nipple) in males or the Bustpoint (most protruding point on the right bra cup) in females.

Chest Breadth		
Female		**Male**
208	**Valid**	771
3	**Missing**	18
319	**Mean (mm)**	366
2	**SE (mm)**	1
27	**SD (mm)**	30
265	**Min (mm)**	287
401	**Max (mm)**	471
0.7	**Skew**	0.6
0.4	**Kur**	0.6
< .001	**Norm (p)**	< .001
8%	**CV (%)**	8%



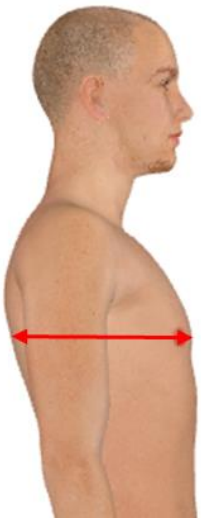
Percentiles		
Female	**%**	**Male**
268	**1**	308
274	**3**	316
280	**5**	322
288	**10**	331
294	**15**	336
297	**20**	341
299	**25**	345
301	**30**	349
306	**35**	353
309	**40**	356
313	**45**	360
317	**50**	363
320	**55**	366
322	**60**	370
326	**65**	374
329	**70**	377
333	**75**	381
339	**80**	389
343	**85**	396
353	**90**	405
372	**95**	421
384	**98**	440
388	**99**	450



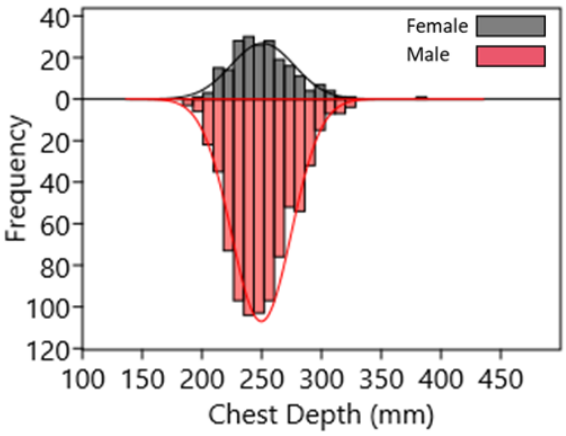
I.25 CHEST DEPTH

Definition: The horizontal distance between the Thelion (right nipple) in males or the Bustpoint (most protruding point on the right bra cup) in females, and point on the back at the same level.

Chest Depth		
Female		**Male**
209	**Valid**	787
2	**Missing**	2
251	**Mean (mm)**	250
2	**SE (mm)**	1
26	**SD (mm)**	25
195	**Min (mm)**	184
388	**Max (mm)**	326
1.0	**Skew**	0.3
2.8	**Kur**	-0.1
< .001	**Norm (p)**	< .001
11%	**CV (%)**	10%



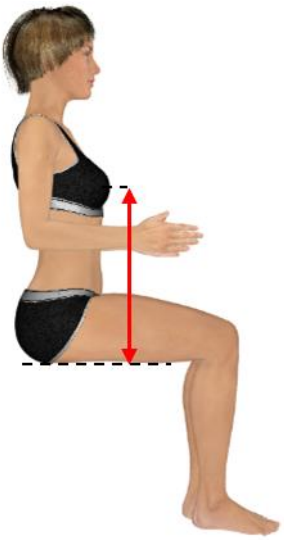
Percentiles		
Female	**%**	**Male**
205	**1**	199
211	**3**	205
213	**5**	212
220	**10**	220
224	**15**	225
230	**20**	228
233	**25**	232
235	**30**	235
238	**35**	238
240	**40**	241
244	**45**	245
248	**50**	248
251	**55**	251
256	**60**	254
258	**65**	258
261	**70**	262
265	**75**	265
272	**80**	272
275	**85**	278
284	**90**	283
297	**95**	292
306	**98**	301
317	**99**	315



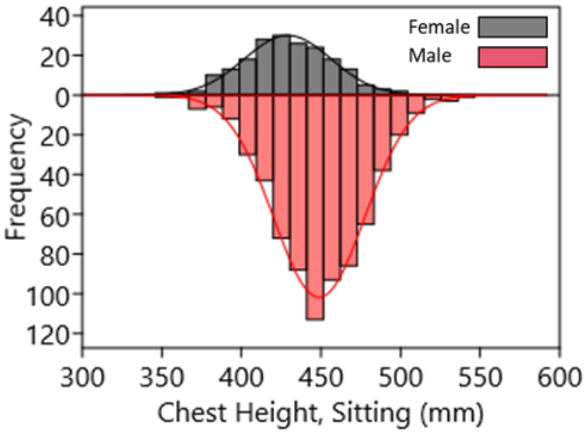
I.26 CHEST HEIGHT, SITTING

Definition: The vertical distance between the sitting surface and the Thelion (right nipple) in males or the Bustpoint (most protruding point on the right bra cup) in females.

Chest Height, Sitting		
Female		**Male**
194	**Valid**	690
17	**Missing**	99
429	**Mean (mm)**	449
2	**SE (mm)**	1
27	**SD (mm)**	29
355	**Min (mm)**	346
500	**Max (mm)**	547
0.1	**Skew**	-0.1
-0.2	**Kur**	0.3
0.979	**Norm (p)**	0.404
6%	**CV (%)**	6%



Percentiles		
Female	**%**	**Male**
367	**1**	372
380	**3**	390
387	**5**	403
394	**10**	412
400	**15**	420
407	**20**	425
411	**25**	431
413	**30**	435
419	**35**	438
423	**40**	442
425	**45**	446
428	**50**	449
431	**55**	452
435	**60**	457
441	**65**	460
445	**70**	464
448	**75**	467
452	**80**	473
457	**85**	479
463	**90**	484
473	**95**	494
484	**98**	500
493	**99**	513

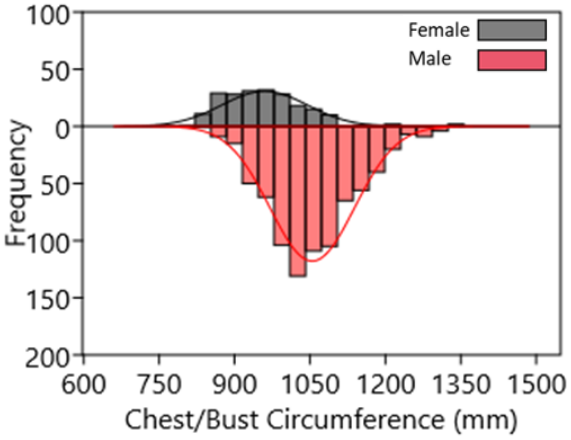


I.27 CHEST/BUST CIRCUMFERENCE

Definition: The circumference of the chest at the level of the Thelion (right nipple) in males or the Bustpoint (the most protruding point on the right bra/breast) in females, measured parallel to the standing surface.

Chest/Bust Circumference		
Female		Male
209	Valid	787
2	Missing	2
960	Mean (mm)	1055
6	SE (mm)	3
85	SD (mm)	84
790	Min (mm)	824
1356	Max (mm)	1321
1.2	Skew	0.3
3.3	Kur	0.0
< .001	Norm (p)	< .001
9%	CV (%)	8%

Percentiles		
Female	%	Male
830	1	883
845	3	910
850	5	925
864	10	950
874	15	967
886	20	987
896	25	998
904	30	1008
920	35	1019
929	40	1026
940	45	1037
954	50	1049
963	55	1061
973	60	1070
982	65	1081
991	70	1095
1007	75	1105
1020	80	1124
1041	85	1145
1067	90	1168
1085	95	1200
1129	98	1228
1230	99	1281

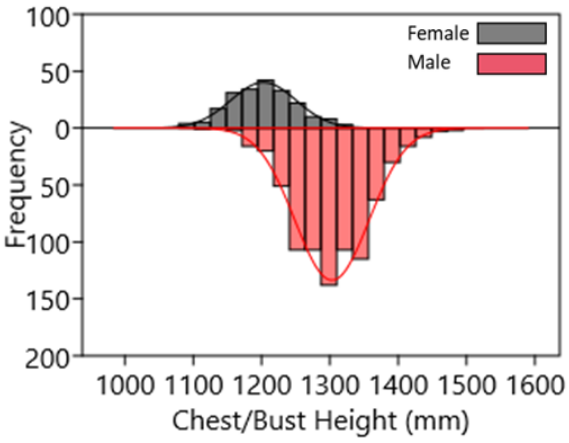


I.28 CHEST/BUST HEIGHT

Definition: The vertical height of the front breast circumference level at the Thelion (right nipple) in males or the Bustpoint (the most protruding point on the right bra/breast) in females, to the standing surface.

Chest/Bust Height		
Female		**Male**
209	**Valid**	786
2	**Missing**	3
1203	**Mean (mm)**	1303
3	**SE (mm)**	2
48	**SD (mm)**	54
1079	**Min (mm)**	1121
1327	**Max (mm)**	1495
0.1	**Skew**	0.1
-0.2	**Kur**	0.1
0.78	**Norm (p)**	0.618
4%	**CV (%)**	4%

Percentiles		
Female	**%**	**Male**
1100	**1**	1183
1110	**3**	1197
1130	**5**	1218
1144	**10**	1235
1153	**15**	1247
1158	**20**	1256
1169	**25**	1263
1174	**30**	1274
1181	**35**	1281
1190	**40**	1289
1198	**45**	1296
1202	**50**	1303
1209	**55**	1310
1214	**60**	1317
1220	**65**	1325
1227	**70**	1334
1231	**75**	1339
1241	**80**	1345
1256	**85**	1357
1264	**90**	1371
1287	**95**	1393
1298	**98**	1410
1313	**99**	1435

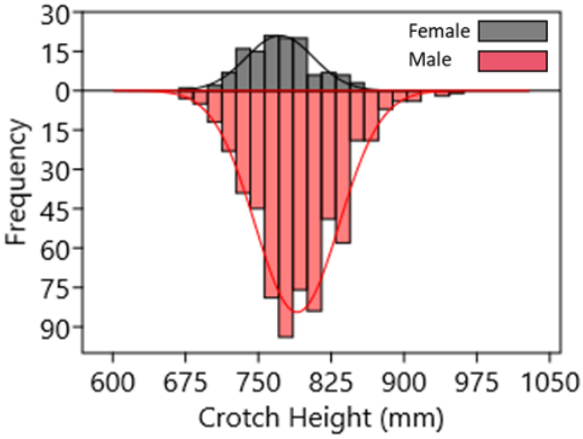


I.29 CROTCH HEIGHT

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

Crotch Height		
Female		**Male**
123	**Valid**	624
88	**Missing**	165
772	**Mean (mm)**	790
3	**SE (mm)**	2
35	**SD (mm)**	43
673	**Min (mm)**	669
852	**Max (mm)**	962
0.1	**Skew**	0.3
-0.1	**Kur**	0.6
0.552	**Norm (p)**	0.01
4%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
703	**1**	697
714	**3**	709
726	**5**	719
728	**10**	736
735	**15**	747
738	**20**	756
748	**25**	763
751	**30**	768
759	**35**	773
763	**40**	779
767	**45**	783
773	**50**	787
778	**55**	792
781	**60**	800
785	**65**	805
791	**70**	809
793	**75**	816
798	**80**	826
805	**85**	834
819	**90**	841
832	**95**	862
842	**98**	878
851	**99**	903

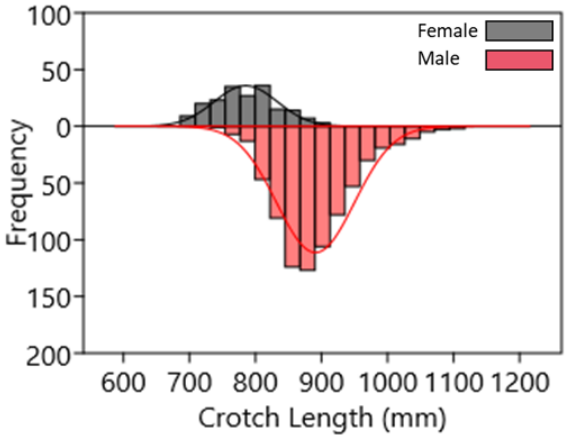


I.30 CROTCH LENGTH

Definition: The distance from the front waist to the back waist (at the height of the natural waist or the natural contraction points of the waist), passing through the crotch.

Crotch Length		
Female		**Male**
189	**Valid**	723
22	**Missing**	66
785	**Mean (mm)**	891
3	**SE (mm)**	2
48	**SD (mm)**	59
686	**Min (mm)**	747
897	**Max (mm)**	1117
0.2	**Skew**	0.8
-0.6	**Kur**	0.9
0.052	**Norm (p)**	< .001
6%	**CV (%)**	7%

Percentiles		
Female	**%**	**Male**
698	**1**	776
704	**3**	797
710	**5**	808
722	**10**	825
731	**15**	836
742	**20**	844
749	**25**	851
758	**30**	857
764	**35**	863
769	**40**	870
776	**45**	876
782	**50**	883
791	**55**	890
797	**60**	898
803	**65**	905
811	**70**	912
817	**75**	922
825	**80**	934
838	**85**	947
849	**90**	969
868	**95**	1005
884	**98**	1040
893	**99**	1064

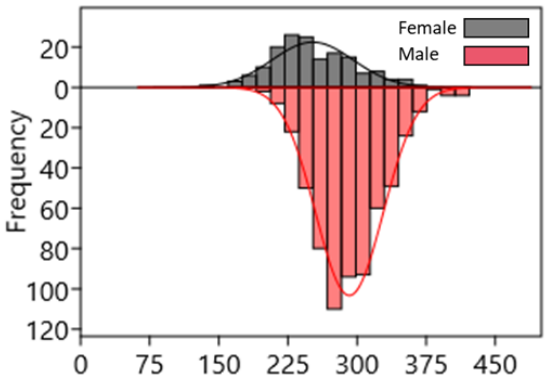


I.31 CROTCH-WAIST LENGTH PREFERRED, ANTERIOR

Definition: The distance between the Waist Preferred Anterior Landmark (at the level of the participant's preferred belt height on the front waist in line with the Omphalion) and the Crotch Landmark.

Crotch-Waist Length Preferred, Anterior		
Female		**Male**
161	**Valid**	613
50	**Missing**	176
252	**Mean (mm)**	292
3	**SE (mm)**	1
44	**SD (mm)**	36
129	**Min (mm)**	198
363	**Max (mm)**	422
0.3	**Skew**	0.4
-0.2	**Kur**	0.3
0.05	**Norm (p)**	< .001
17%	**CV (%)**	13%

Percentiles		
Female	**%**	**Male**
166	**1**	218
177	**3**	224
189	**5**	237
204	**10**	247
210	**15**	255
217	**20**	261
222	**25**	266
225	**30**	271
232	**35**	275
236	**40**	279
239	**45**	284
243	**50**	290
250	**55**	294
257	**60**	299
268	**65**	305
275	**70**	310
282	**75**	314
287	**80**	321
296	**85**	330
320	**90**	339
330	**95**	353
345	**98**	367
352	**99**	396



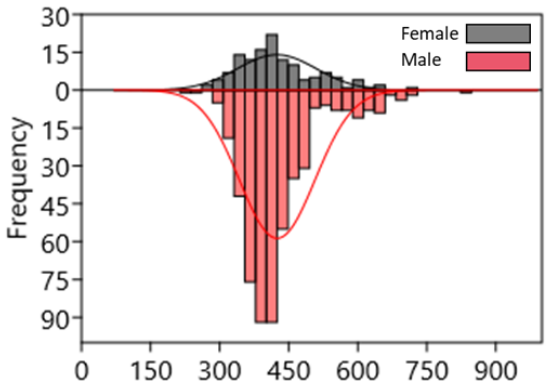
Crotch-Waist Length Preferred, Anterior (mm)

I.32 CROTCH-WAIST LENGTH PREFERRED, POSTERIOR

Definition: The distance between the Waist Preferred Posterior Landmark (at the level of the participant's preferred belt height on the back waist in line with the spine) and the Crotch Landmark.

Crotch-Waist Length Preferred, Posterior		
Female		**Male**
129	**Valid**	515
82	**Missing**	274
424	**Mean (mm)**	425
8	**SE (mm)**	4
86	**SD (mm)**	82
269	**Min (mm)**	214
710	**Max (mm)**	847
0.8	**Skew**	1.5
0.5	**Kur**	2.9
< .001	**Norm (p)**	< .001
20%	**CV (%)**	19%

Percentiles		
Female	**%**	**Male**
277	**1**	304
298	**3**	317
310	**5**	332
331	**10**	347
340	**15**	358
352	**20**	366
366	**25**	375
378	**30**	379
383	**35**	387
393	**40**	393
402	**45**	401
406	**50**	406
414	**55**	413
425	**60**	420
434	**65**	428
452	**70**	440
464	**75**	449
495	**80**	465
525	**85**	489
543	**90**	549
600	**95**	613
615	**98**	640
649	**99**	693



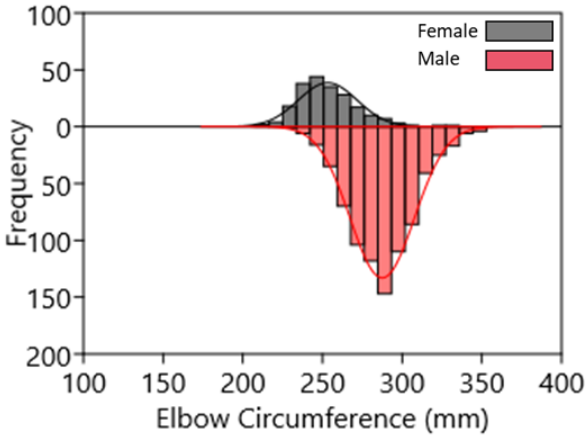
Crotch-Waist Length Preferred, Posterior (mm)

I.33 ELBOW CIRCUMFERENCE

Definition: The elbow perimeter measured with a line passing over the right elbow backbone and the arm front hollow.

Elbow Circumference		
Female		**Male**
209	**Valid**	786
2	**Missing**	3
253	**Mean (mm)**	287
1	**SE (mm)**	1
18	**SD (mm)**	20
208	**Min (mm)**	232
333	**Max (mm)**	353
1.0	**Skew**	0.2
2.1	**Kur**	0.1
< .001	**Norm (p)**	0.032
7%	**CV (%)**	7%

Percentiles		
Female	**%**	**Male**
222	**1**	243
225	**3**	249
229	**5**	256
233	**10**	262
236	**15**	266
239	**20**	271
241	**25**	274
243	**30**	277
245	**35**	279
247	**40**	282
248	**45**	285
250	**50**	287
252	**55**	290
255	**60**	292
257	**65**	294
261	**70**	297
263	**75**	300
266	**80**	304
270	**85**	308
277	**90**	313
286	**95**	324
295	**98**	330
304	**99**	338

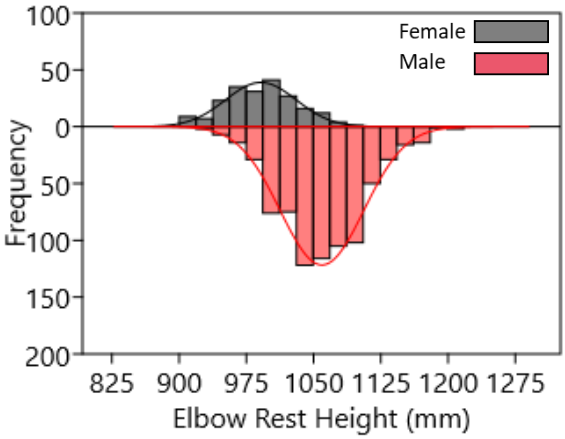


I.34 ELBOW REST HEIGHT

Definition: The vertical distance between the standing surface and the Olecranon Bottom Landmark (lowest point) on the flexed right elbow.

Elbow Rest Height		
Female		**Male**
206	**Valid**	760
5	**Missing**	29
991	**Mean (mm)**	1059
3	**SE (mm)**	2
39	**SD (mm)**	47
900	**Min (mm)**	934
1087	**Max (mm)**	1218
0.0	**Skew**	0.1
-0.4	**Kur**	0.0
0.616	**Norm (p)**	0.235
4%	**CV (%)**	4%

Percentiles		
Female	**%**	**Male**
905	**1**	955
913	**3**	968
924	**5**	985
942	**10**	999
949	**15**	1010
959	**20**	1021
963	**25**	1029
970	**30**	1034
975	**35**	1040
981	**40**	1046
987	**45**	1051
992	**50**	1057
997	**55**	1064
1002	**60**	1072
1008	**65**	1079
1011	**70**	1085
1018	**75**	1090
1024	**80**	1097
1031	**85**	1105
1044	**90**	1116
1055	**95**	1138
1064	**98**	1151
1072	**99**	1173

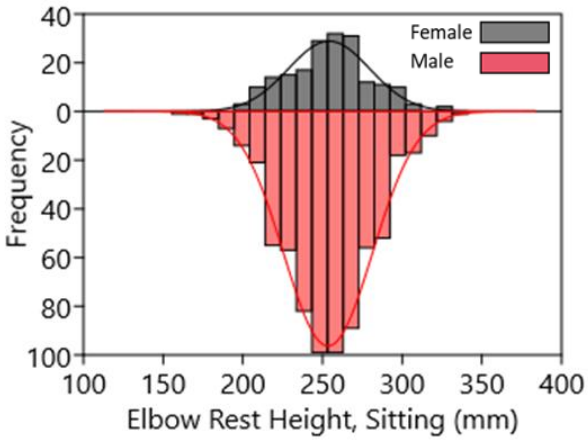


I.35 ELBOW REST HEIGHT, SITTING

Definition: The vertical distance between the sitting surface and the Olecranon Bottom Landmark (lowest point) on the flexed right elbow.

Elbow Rest Height, Sitting		
Female		**Male**
189	**Valid**	686
22	**Missing**	103
254	**Mean (mm)**	253
2	**SE (mm)**	1
26	**SD (mm)**	28
201	**Min (mm)**	155
327	**Max (mm)**	341
0.1	**Skew**	0.0
-0.2	**Kur**	0.2
0.111	**Norm (p)**	0.725
10%	**CV (%)**	11%

Percentiles		
Female	**%**	**Male**
203	**1**	192
207	**3**	198
210	**5**	208
218	**10**	218
225	**15**	224
232	**20**	231
236	**25**	235
243	**30**	239
247	**35**	243
250	**40**	247
253	**45**	250
257	**50**	253
258	**55**	257
261	**60**	260
264	**65**	264
266	**70**	266
268	**75**	271
273	**80**	276
278	**85**	282
288	**90**	287
299	**95**	300
302	**98**	309
310	**99**	321

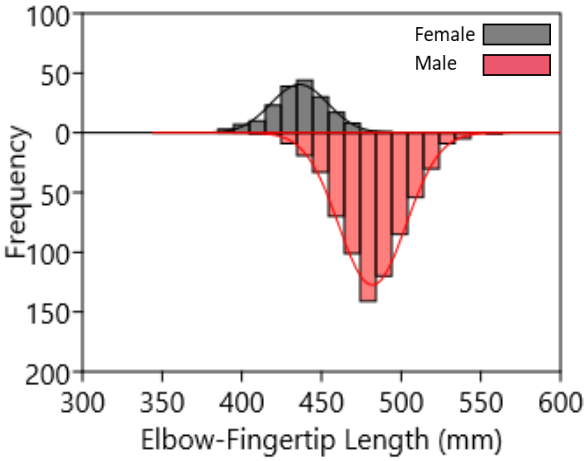


I.36 ELBOW-FINGERTIP LENGTH

Definition: The horizontal distance from the Olecranon Rear Landmark on the back tip of the flexed right elbow to the tip of the middle finger (Dactylion III), with the hand held out straight and the palm facing inward.

Elbow-Fingertip Length		
Female		Male
183	Valid	679
28	Missing	110
436	Mean (mm)	482
1	SE (mm)	1
18	SD (mm)	21
385	Min (mm)	412
486	Max (mm)	564
-0.1	Skew	0.0
0.1	Kur	0.3
0.803	Norm (p)	0.526
4%	CV (%)	4%

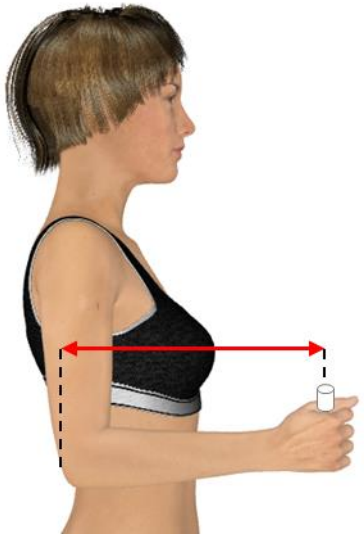
Percentiles		
Female	%	Male
393	1	432
401	3	439
404	5	447
413	10	455
418	15	460
421	20	465
425	25	469
427	30	472
432	35	475
433	40	477
435	45	479
436	50	481
438	55	484
440	60	487
442	65	489
445	70	492
448	75	495
450	80	499
453	85	504
461	90	509
465	95	518
470	98	522
474	99	533



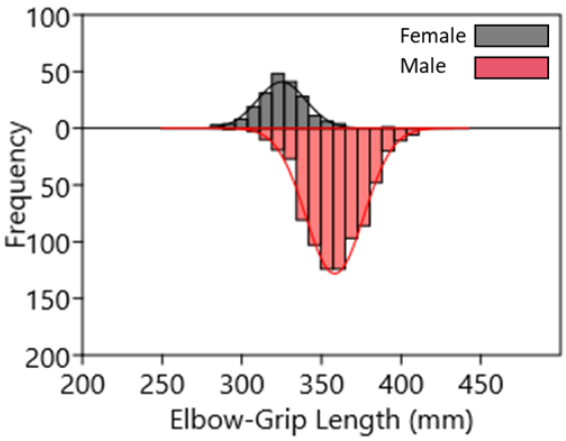
I.37 ELBOW-GRIP LENGTH

Definition: The horizontal distance from the back tip of the flexed right elbow to the centre of a 1.5 cm diameter marker gripped vertically in the right hand.

Elbow-Grip Length		
Female		**Male**
204	**Valid**	760
7	**Missing**	29
325	**Mean (mm)**	358
1	**SE (mm)**	1
15	**SD (mm)**	18
281	**Min (mm)**	293
393	**Max (mm)**	411
0.2	**Skew**	0.0
1.7	**Kur**	0.1
0.013	**Norm (p)**	0.503
5%	**CV (%)**	5%



Percentiles		
Female	**%**	**Male**
288	**1**	315
294	**3**	321
302	**5**	328
306	**10**	337
310	**15**	340
313	**20**	343
316	**25**	346
318	**30**	349
321	**35**	351
323	**40**	354
324	**45**	356
325	**50**	358
327	**55**	360
328	**60**	363
329	**65**	365
331	**70**	367
334	**75**	371
337	**80**	375
339	**85**	378
343	**90**	382
350	**95**	388
354	**98**	395
359	**99**	401

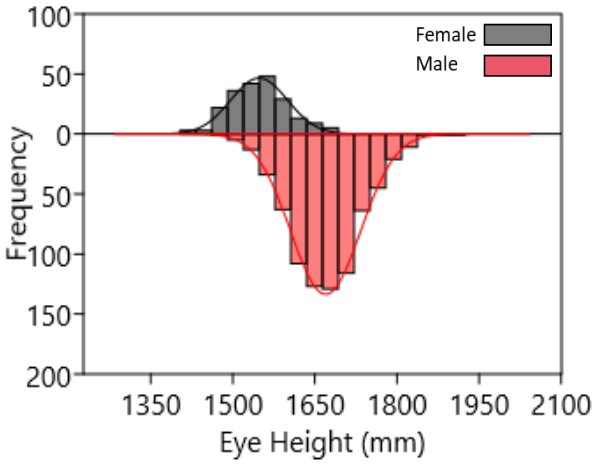


I.38 EYE HEIGHT

Definition: The vertical distance between the standing surface and the Ectocanthus Landmark on the outer corner of the right eye.

Eye Height		
Female		**Male**
210	**Valid**	740
1	**Missing**	49
1548	**Mean (mm)**	1670
4	**SE (mm)**	2
52	**SD (mm)**	64
1404	**Min (mm)**	1476
1684	**Max (mm)**	1924
0.1	**Skew**	0.2
0.1	**Kur**	0.3
0.43	**Norm (p)**	0.164
3%	**CV (%)**	4%

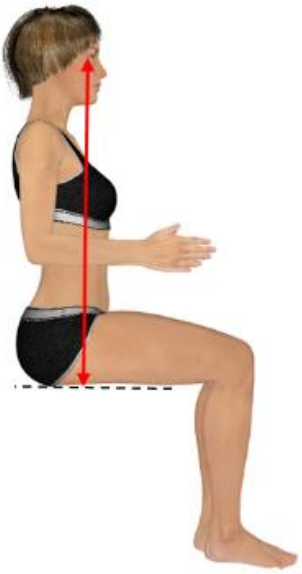
Percentiles		
Female	**%**	**Male**
1428	**1**	1522
1455	**3**	1549
1471	**5**	1569
1482	**10**	1595
1495	**15**	1605
1504	**20**	1615
1513	**25**	1626
1519	**30**	1635
1529	**35**	1644
1536	**40**	1651
1543	**45**	1660
1548	**50**	1668
1553	**55**	1678
1561	**60**	1685
1565	**65**	1693
1571	**70**	1701
1580	**75**	1709
1586	**80**	1720
1594	**85**	1732
1619	**90**	1753
1640	**95**	1776
1660	**98**	1802
1676	**99**	1824



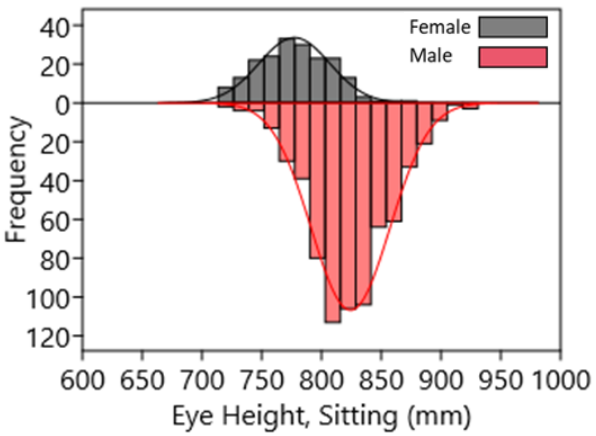
I.39 EYE HEIGHT, SITTING

Definition: The vertical distance between the sitting surface and the Ectocanthus Landmark on the outer corner of the right eye.

Eye Height, Sitting		
Female		**Male**
195	**Valid**	687
16	**Missing**	102
777	**Mean (mm)**	824
2	**SE (mm)**	1
30	**SD (mm)**	33
714	**Min (mm)**	720
868	**Max (mm)**	931
0.2	**Skew**	0.1
-0.2	**Kur**	0.2
0.217	**Norm (p)**	0.474
4%	**CV (%)**	4%



Percentiles		
Female	**%**	**Male**
722	**1**	747
724	**3**	762
729	**5**	772
738	**10**	783
745	**15**	793
749	**20**	798
756	**25**	803
761	**30**	807
766	**35**	812
769	**40**	815
774	**45**	819
776	**50**	823
782	**55**	828
786	**60**	831
789	**65**	836
793	**70**	840
797	**75**	845
804	**80**	853
808	**85**	861
812	**90**	866
824	**95**	879
830	**98**	889
847	**99**	900

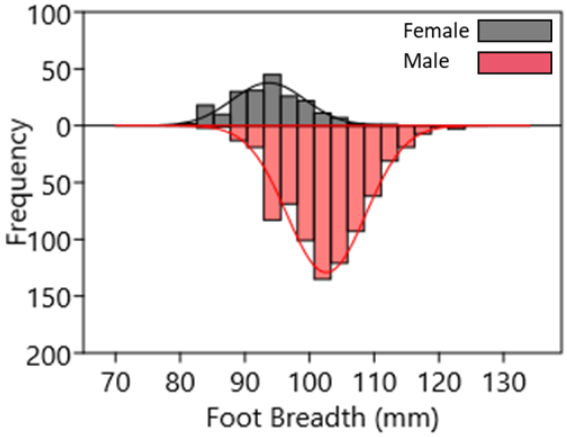


I.40 FOOT BREADTH

Definition: The maximum horizontal distance of the left foot at the metatarsophalangeal joints (between Metatarsophalangeal Protrusions I and V).

Foot Breadth		
Female		**Male**
206	**Valid**	760
5	**Missing**	29
94	**Mean (mm)**	103
0	**SE (mm)**	0
6	**SD (mm)**	6
81	**Min (mm)**	85
113	**Max (mm)**	124
0.3	**Skew**	0.1
0.0	**Kur**	0.0
0.131	**Norm (p)**	0.009
6%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
83	**1**	90
84	**3**	91
85	**5**	93
86	**10**	95
88	**15**	95
89	**20**	97
90	**25**	99
91	**30**	100
92	**35**	100
92	**40**	101
93	**45**	102
94	**50**	103
94	**55**	103
95	**60**	104
95	**65**	105
97	**70**	106
98	**75**	106
99	**80**	108
100	**85**	109
101	**90**	111
103	**95**	113
104	**98**	115
107	**99**	117

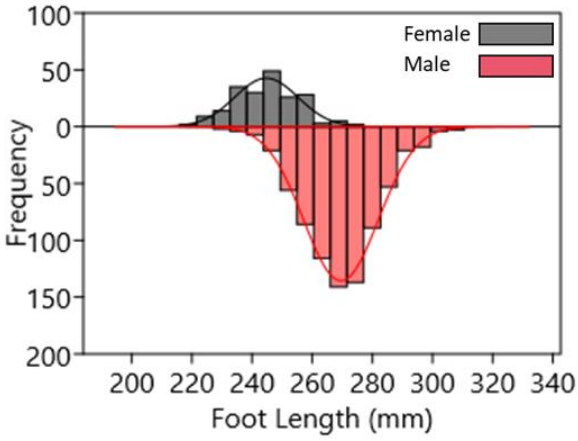


I.41 FOOT LENGTH

Definition: The length of the left foot from the Acropodian (the tip of the first or second toe, whichever is longer) to the Pternion (most posterior point on the heel).

Foot Length		
Female		**Male**
203	**Valid**	758
8	**Missing**	31
245	**Mean (mm)**	270
1	**SE (mm)**	0
11	**SD (mm)**	12
216	**Min (mm)**	229
276	**Max (mm)**	311
0.1	**Skew**	0.0
0.1	**Kur**	0.3
0.513	**Norm (p)**	0.163
4%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
223	**1**	241
226	**3**	246
227	**5**	250
231	**10**	254
234	**15**	256
236	**20**	259
238	**25**	262
239	**30**	264
241	**35**	265
242	**40**	267
244	**45**	269
245	**50**	270
246	**55**	271
247	**60**	273
249	**65**	275
250	**70**	276
252	**75**	277
254	**80**	280
256	**85**	281
257	**90**	285
260	**95**	290
268	**98**	295
271	**99**	299

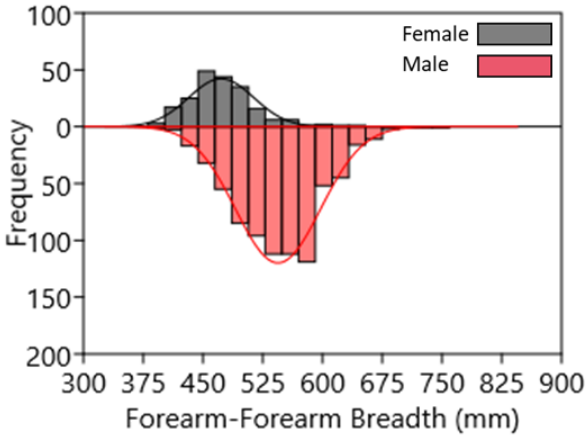


I.42 FOREARM-FOREARM BREADTH

Definition: The maximum horizontal distance between the outer sides of the left and right forearms.

Forearm-Forearm Breadth		
Female		**Male**
206	**Valid**	761
5	**Missing**	28
473	**Mean (mm)**	544
3	**SE (mm)**	2
41	**SD (mm)**	53
381	**Min (mm)**	396
633	**Max (mm)**	759
0.9	**Skew**	0.1
1.7	**Kur**	0.1
< .001	**Norm (p)**	0.121
9%	**CV (%)**	10%

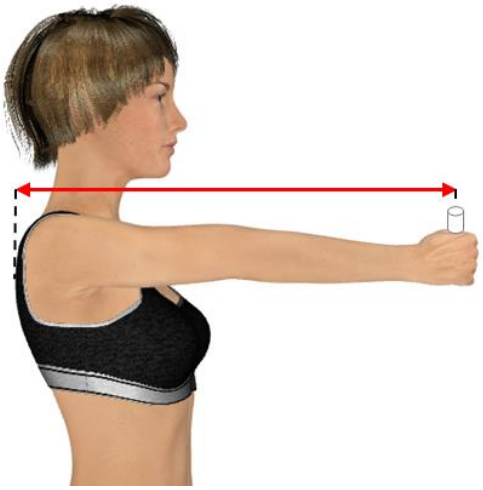
Percentiles		
Female	**%**	**Male**
399	**1**	430
410	**3**	443
413	**5**	455
425	**10**	477
434	**15**	489
443	**20**	497
447	**25**	506
450	**30**	515
455	**35**	524
459	**40**	531
464	**45**	539
470	**50**	545
474	**55**	552
478	**60**	559
484	**65**	566
488	**70**	574
495	**75**	581
501	**80**	586
509	**85**	596
515	**90**	612
551	**95**	630
565	**98**	649
602	**99**	669



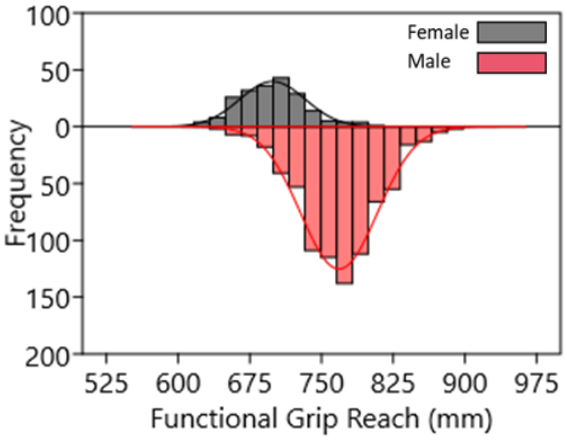
I.43 FUNCTIONAL GRIP REACH

Definition: The horizontal distance from the back wall to the centre of a rod gripped in the hand of the outstretched right arm, with the right shoulder pressed against the wall.

Functional Grip Reach		
Female		Male
206	Valid	760
5	Missing	29
699	Mean (mm)	768
2	SE (mm)	1
34	SD (mm)	40
617	Min (mm)	646
816	Max (mm)	899
0.4	Skew	-0.1
0.5	Kur	0.3
0.03	Norm (p)	0.273
5%	CV (%)	5%



Percentiles		
Female	%	Male
622	1	663
644	3	685
649	5	702
658	10	716
665	15	730
668	20	737
674	25	742
680	30	748
684	35	754
689	40	759
693	45	765
698	50	769
702	55	773
708	60	778
712	65	783
715	70	787
718	75	793
724	80	801
730	85	810
742	90	821
755	95	831
780	98	850
788	99	862

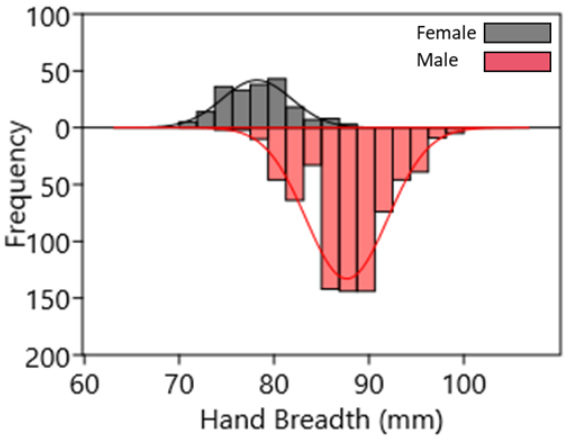


I.44 HAND BREADTH

Definition: The breadth of the right hand between the protrusions at Metacarpali II and V.

Hand Breadth		
Female		**Male**
205	**Valid**	761
6	**Missing**	28
78	**Mean (mm)**	88
0	**SE (mm)**	0
4	**SD (mm)**	4
69	**Min (mm)**	75
87	**Max (mm)**	102
0.1	**Skew**	0.1
-0.3	**Kur**	0.0
0.035	**Norm (p)**	< .001
5%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
70	**1**	79
72	**3**	80
72	**5**	80
74	**10**	82
75	**15**	83
75	**20**	84
75	**25**	85
76	**30**	85
76	**35**	86
77	**40**	87
78	**45**	87
78	**50**	88
79	**55**	88
79	**60**	89
80	**65**	89
80	**70**	90
80	**75**	90
81	**80**	91
82	**85**	92
83	**90**	93
85	**95**	95
86	**98**	96
87	**99**	97

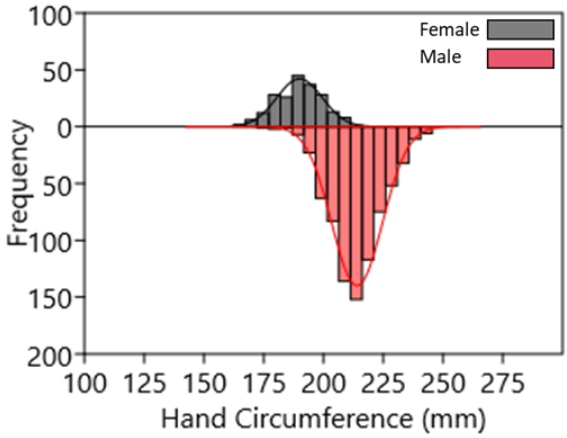


I.45 HAND CIRCUMFERENCE

Definition: The circumference of the right hand encompassing the protrusions at Metacarpali II and V.

Hand Circumference		
Female		**Male**
206	**Valid**	761
5	**Missing**	28
190	**Mean (mm)**	214
1	**SE (mm)**	0
10	**SD (mm)**	11
163	**Min (mm)**	174
215	**Max (mm)**	246
-0.1	**Skew**	0.1
-0.2	**Kur**	0.2
0.965	**Norm (p)**	0.096
5%	**CV (%)**	5%

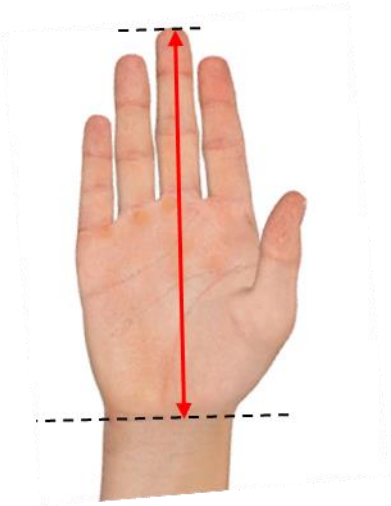
Percentiles		
Female	**%**	**Male**
169	**1**	190
172	**3**	195
175	**5**	197
178	**10**	201
181	**15**	204
182	**20**	206
183	**25**	207
185	**30**	209
186	**35**	210
188	**40**	211
189	**45**	212
190	**50**	214
190	**55**	215
193	**60**	216
194	**65**	218
195	**70**	220
196	**75**	221
198	**80**	223
200	**85**	225
202	**90**	228
206	**95**	233
208	**98**	235
210	**99**	239



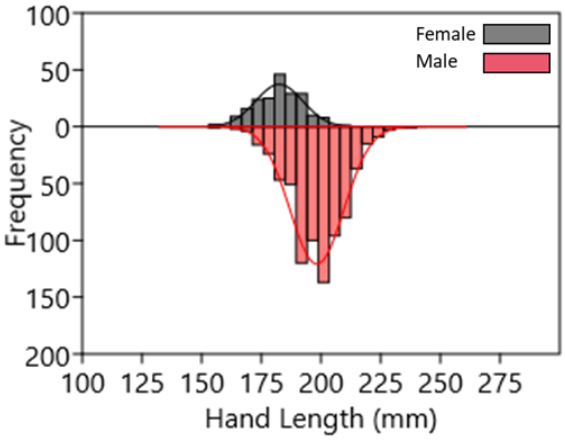
I.46 HAND LENGTH

Definition: The distance from the tip of the middle finger (Dactylion III), along its axis, to the Midstylion Landmark at the centre of the right wrist, measured with the hand stretched out flat, palm up.

Hand Length		
Female		**Male**
201	**Valid**	744
10	**Missing**	45
182	**Mean (mm)**	198
1	**SE (mm)**	0
10	**SD (mm)**	11
153	**Min (mm)**	158
211	**Max (mm)**	240
-0.1	**Skew**	-0.1
0.0	**Kur**	0.3
0.975	**Norm (p)**	0.139
5%	**CV (%)**	6%



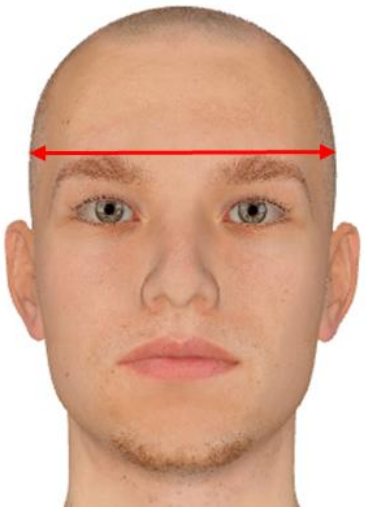
Percentiles		
Female	**%**	**Male**
161	**1**	172
164	**3**	175
166	**5**	180
169	**10**	184
173	**15**	187
175	**20**	190
175	**25**	191
178	**30**	193
180	**35**	194
181	**40**	195
182	**45**	197
183	**50**	199
184	**55**	200
185	**60**	201
186	**65**	203
187	**70**	204
189	**75**	206
191	**80**	208
193	**85**	210
194	**90**	211
199	**95**	216
201	**98**	220
203	**99**	224



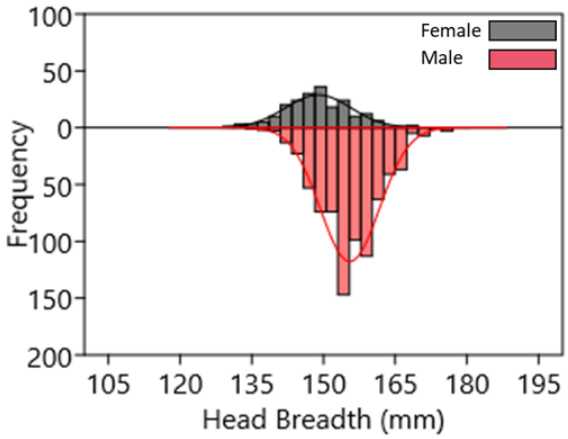
I.47 HEAD BREADTH

Definition: The maximum horizontal breadth of the head above the ears.

Head Breadth		
Female		**Male**
206	**Valid**	759
5	**Missing**	30
149	**Mean (mm)**	156
0	**SE (mm)**	0
7	**SD (mm)**	6
129	**Min (mm)**	135
169	**Max (mm)**	177
0.1	**Skew**	0.0
0.2	**Kur**	0.2
0.857	**Norm (p)**	0.058
5%	**CV (%)**	4%



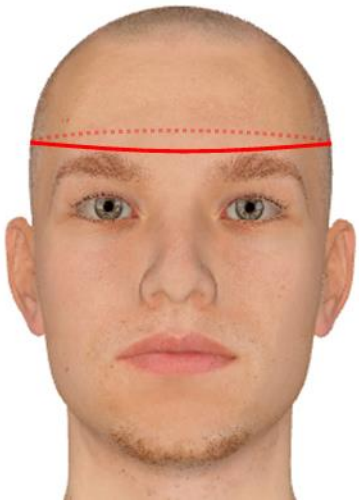
Percentiles		
Female	**%**	**Male**
133	**1**	141
135	**3**	143
139	**5**	145
141	**10**	148
142	**15**	149
143	**20**	150
145	**25**	151
146	**30**	152
146	**35**	154
147	**40**	155
148	**45**	155
149	**50**	155
150	**55**	156
151	**60**	157
151	**65**	158
152	**70**	159
153	**75**	160
155	**80**	161
156	**85**	162
158	**90**	164
160	**95**	165
162	**98**	166
165	**99**	170



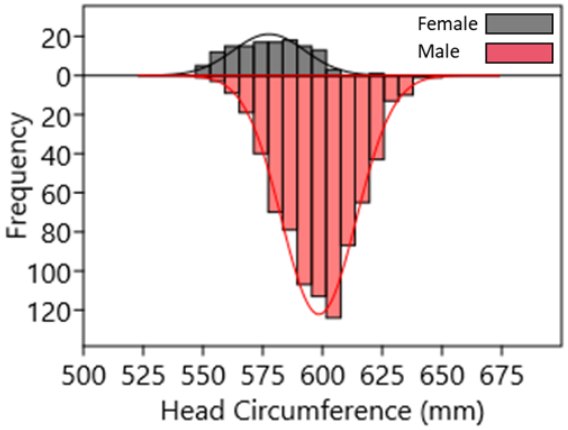
I.48 HEAD CIRCUMFERENCE

Definition: The circumference around the forehead just above the bony brow ridges and across the most protruding point of the back of the head.

Head Circumference		
Female		**Male**
131	**Valid**	785
80	**Missing**	4
578	**Mean (mm)**	598
1	**SE (mm)**	1
15	**SD (mm)**	16
547	**Min (mm)**	553
625	**Max (mm)**	650
0.1	**Skew**	0.0
-0.4	**Kur**	-0.2
0.068	**Norm (p)**	0.397
3%	**CV (%)**	3%



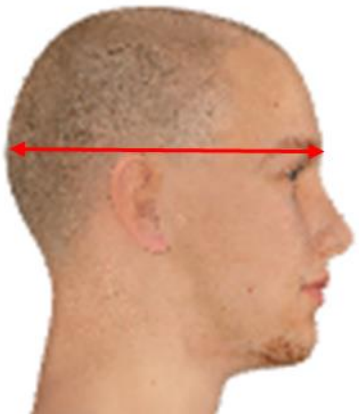
Percentiles		
Female	**%**	**Male**
548	**1**	563
552	**3**	569
555	**5**	573
558	**10**	578
561	**15**	581
563	**20**	585
566	**25**	588
568	**30**	590
571	**35**	593
573	**40**	595
575	**45**	597
579	**50**	599
580	**55**	601
583	**60**	603
585	**65**	605
588	**70**	607
589	**75**	609
592	**80**	612
594	**85**	614
596	**90**	619
598	**95**	623
603	**98**	627
607	**99**	634



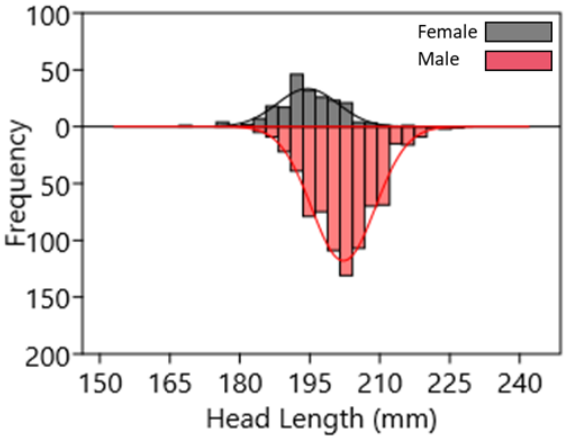
I.49 HEAD LENGTH

Definition: The straight line distance between the Glabella (located between the brow ridges) and the Opisthocranion on the back of the head.

Head Length		
Female		**Male**
206	**Valid**	759
5	**Missing**	30
194	**Mean (mm)**	202
0	**SE (mm)**	0
7	**SD (mm)**	7
167	**Min (mm)**	183
215	**Max (mm)**	228
-0.4	**Skew**	0.1
1.7	**Kur**	0.1
0.002	**Norm (p)**	0.159
3%	**CV (%)**	3%



Percentiles		
Female	**%**	**Male**
176	**1**	186
182	**3**	189
185	**5**	191
187	**10**	194
188	**15**	195
190	**20**	196
191	**25**	197
192	**30**	199
192	**35**	200
193	**40**	200
194	**45**	202
194	**50**	202
195	**55**	203
196	**60**	204
197	**65**	205
198	**70**	206
199	**75**	207
200	**80**	208
201	**85**	209
202	**90**	211
204	**95**	213
207	**98**	216
208	**99**	219

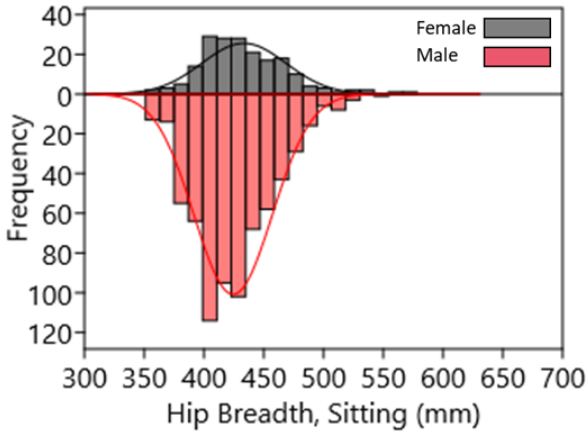


I.50 HIP BREADTH, SITTING

Definition: The maximum horizontal breadth of the seated participant at the hips or thighs, whichever is larger.

Hip Breadth, Sitting		
Female		**Male**
189	**Valid**	689
22	**Missing**	100
433	**Mean (mm)**	424
3	**SE (mm)**	1
35	**SD (mm)**	33
354	**Min (mm)**	351
578	**Max (mm)**	552
0.9	**Skew**	0.5
1.7	**Kur**	0.2
< .001	**Norm (p)**	< .001
8%	**CV (%)**	8%

Percentiles		
Female	**%**	**Male**
368	**1**	359
377	**3**	368
386	**5**	377
395	**10**	384
400	**15**	391
405	**20**	398
410	**25**	402
412	**30**	406
418	**35**	409
419	**40**	413
424	**45**	418
428	**50**	422
432	**55**	426
437	**60**	429
444	**65**	433
448	**70**	439
455	**75**	445
461	**80**	451
466	**85**	459
474	**90**	468
495	**95**	483
520	**98**	495
536	**99**	513

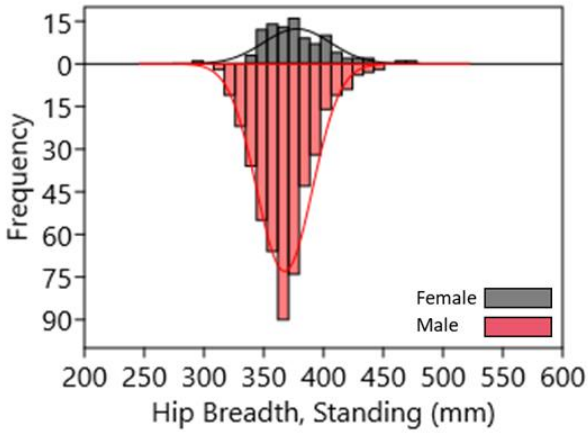


I.51 HIP BREADTH, STANDING

Definition: The largest horizontal breadth of the hip region between the Iliocristale and Crotch landmarks.

Hip Breadth, Standing		
Female		**Male**
97	**Valid**	476
114	**Missing**	313
378	**Mean (mm)**	367
3	**SE (mm)**	1
28	**SD (mm)**	23
290	**Min (mm)**	314
478	**Max (mm)**	449
0.7	**Skew**	0.5
2.0	**Kur**	0.6
< .001	**Norm (p)**	< .001
7%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
336	**1**	322
341	**3**	326
345	**5**	332
349	**10**	339
352	**15**	344
356	**20**	349
359	**25**	351
361	**30**	356
366	**35**	358
367	**40**	362
371	**45**	364
373	**50**	366
378	**55**	368
379	**60**	371
382	**65**	373
386	**70**	377
395	**75**	380
400	**80**	385
403	**85**	390
410	**90**	396
426	**95**	410
440	**98**	422
464	**99**	433

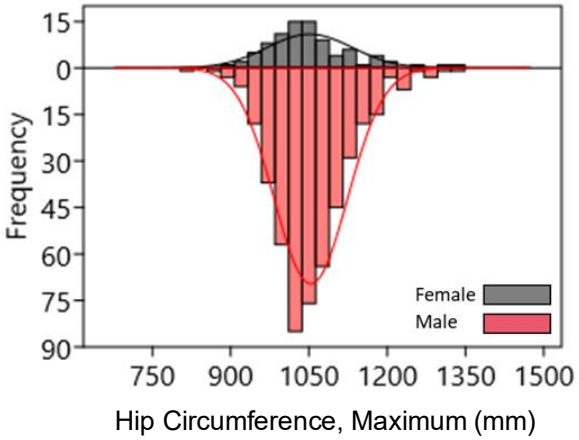


I.52 HIP CIRCUMFERENCE, MAXIMUM

Definition: The maximum circumference of the body (excluding the appendages) at or about the height of the hip but below the height of the iliac crest.

Hip Circumference, Maximum		
Female		**Male**
86	**Valid**	471
125	**Missing**	318
1051	**Mean (mm)**	1054
9	**SE (mm)**	3
82	**SD (mm)**	70
903	**Min (mm)**	803
1324	**Max (mm)**	1349
1.1	**Skew**	0.6
1.5	**Kur**	1.5
< .001	**Norm (p)**	< .001
8%	**CV (%)**	7%

Percentiles		
Female	**%**	**Male**
917	**1**	909
923	**3**	935
946	**5**	953
965	**10**	976
975	**15**	987
991	**20**	1001
1005	**25**	1010
1008	**30**	1017
1018	**35**	1024
1024	**40**	1032
1029	**45**	1038
1040	**50**	1046
1047	**55**	1053
1050	**60**	1062
1058	**65**	1070
1073	**70**	1079
1085	**75**	1092
1107	**80**	1105
1130	**85**	1120
1163	**90**	1144
1193	**95**	1182
1260	**98**	1221
1306	**99**	1267

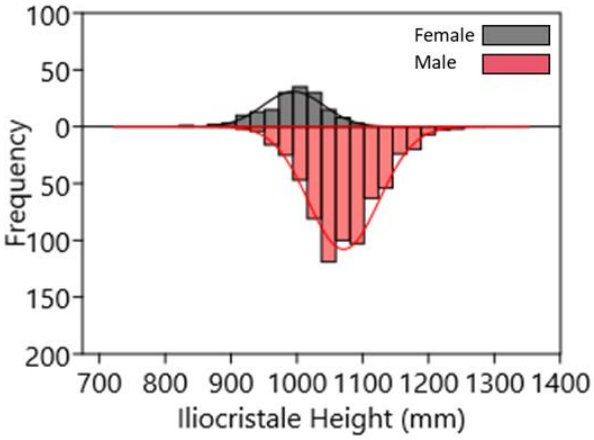


I.53 ILIOCRISTALE HEIGHT

Definition: The vertical distance between the standing surface and the Iliocristale Landmark on the top right side of the pelvis.

Iliocristale Height		
Female		**Male**
165	**Valid**	670
46	**Missing**	119
995	**Mean (mm)**	1071
4	**SE (mm)**	2
46	**SD (mm)**	54
821	**Min (mm)**	909
1093	**Max (mm)**	1254
-0.5	**Skew**	0.2
0.7	**Kur**	0.1
0.03	**Norm (p)**	0.409
5%	**CV (%)**	5%

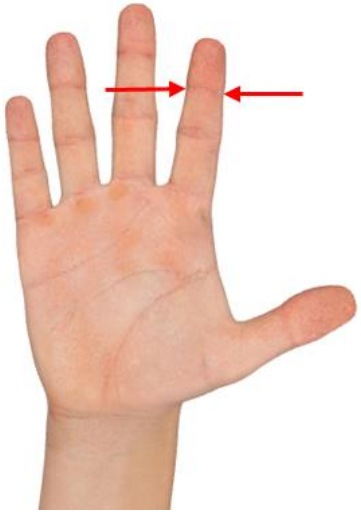
Percentiles		
Female	**%**	**Male**
875	**1**	952
902	**3**	966
917	**5**	986
933	**10**	1006
946	**15**	1018
958	**20**	1028
969	**25**	1035
975	**30**	1044
982	**35**	1050
989	**40**	1055
994	**45**	1061
998	**50**	1069
1003	**55**	1076
1008	**60**	1082
1014	**65**	1090
1021	**70**	1096
1025	**75**	1107
1031	**80**	1117
1038	**85**	1126
1052	**90**	1140
1066	**95**	1164
1078	**98**	1178
1083	**99**	1198



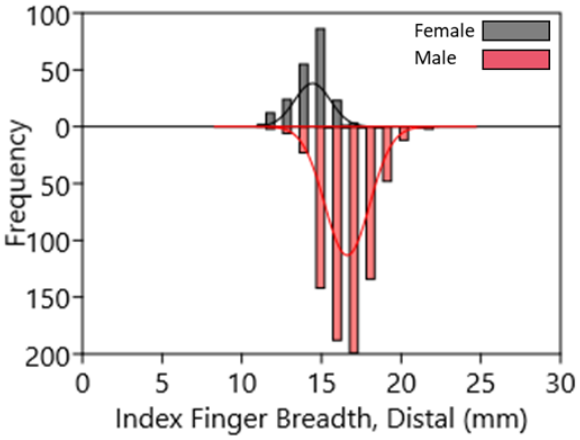
I.54 INDEX FINGER BREADTH, DISTAL

Definition: The maximum breadth of the index finger in the region of the joint between middle and distal phalanges, measured with the hand stretched out flat and fingers spread, palm down.

Index Finger Breadth, Distal		
Female		**Male**
206	**Valid**	761
5	**Missing**	28
14	**Mean (mm)**	17
0	**SE (mm)**	0
1	**SD (mm)**	1
11	**Min (mm)**	12
17	**Max (mm)**	22
-0.6	**Skew**	0.2
0.3	**Kur**	0.3
< .001	**Norm (p)**	< .001
8%	**CV (%)**	8%



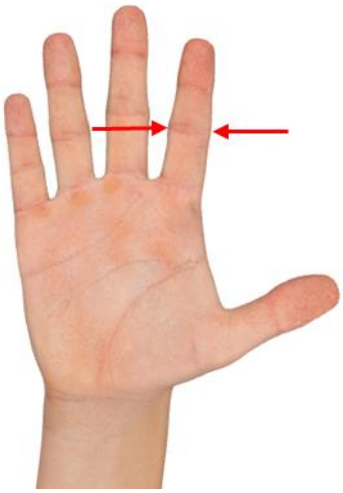
Percentiles		
Female	**%**	**Male**
12	1	14
12	3	14
12	5	15
13	10	15
13	15	15
14	20	15
14	25	16
14	30	16
14	35	16
14	40	16
14	45	16
15	50	17
15	55	17
15	60	17
15	65	17
15	70	17
15	75	18
15	80	18
15	85	18
16	90	18
16	95	19
16	98	19
17	99	20



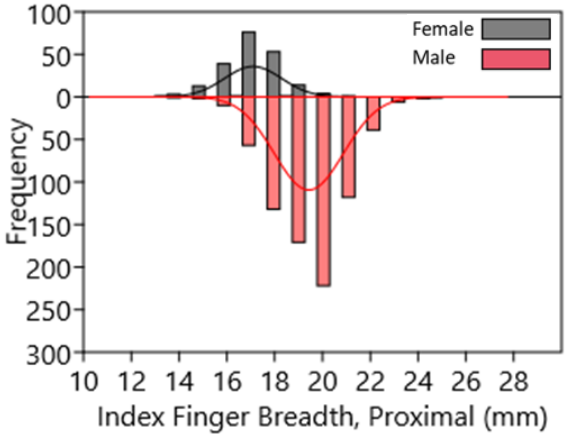
I.55 INDEX FINGER BREADTH, PROXIMAL

Definition: The maximum breadth of the index finger in the region of the joint between middle and proximal phalanges measured with the hand stretched out flat and fingers spread, palm down.

Index Finger Breadth, Proximal		
Female		**Male**
206	**Valid**	761
5	**Missing**	28
17	**Mean (mm)**	19
0	**SE (mm)**	0
1	**SD (mm)**	1
13	**Min (mm)**	14
21	**Max (mm)**	25
-0.1	**Skew**	-0.1
0.8	**Kur**	0.2
< .001	**Norm (p)**	< .001
7%	**CV (%)**	7%



Percentiles		
Female	**%**	**Male**
14	1	16
15	2.5	17
15	5	17
16	10	18
16	15	18
16	20	18
16	25	18
17	30	19
17	35	19
17	40	19
17	45	19
17	50	20
17	55	20
17	60	20
18	65	20
18	70	20
18	75	20
18	80	21
18	85	21
18	90	21
19	95	22
19	97.5	22
20	99	23

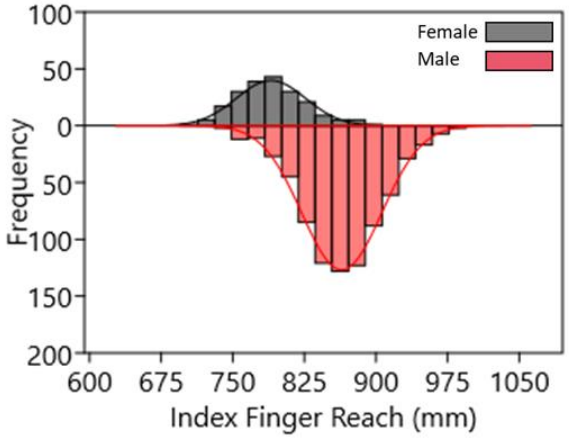


I.56 INDEX FINGER REACH

Definition: The horizontal distance from the back wall to the tip of the right index finger of the outstretched right arm, with the right shoulder pressed against the wall.

Index Finger Reach		
Female		**Male**
206	**Valid**	758
5	**Missing**	31
790	**Mean (mm)**	864
3	**SE (mm)**	2
36	**SD (mm)**	42
696	**Min (mm)**	744
899	**Max (mm)**	994
0.3	**Skew**	-0.1
0.1	**Kur**	0.1
0.324	**Norm (p)**	0.293
5%	**CV (%)**	5%

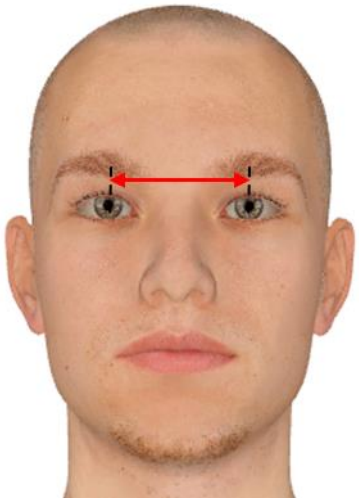
Percentiles		
Female	**%**	**Male**
717	**1**	756
725	**3**	776
733	**5**	794
747	**10**	812
753	**15**	823
759	**20**	830
765	**25**	838
770	**30**	844
774	**35**	850
780	**40**	854
784	**45**	860
789	**50**	865
793	**55**	870
798	**60**	875
801	**65**	880
806	**70**	885
814	**75**	892
819	**80**	899
827	**85**	907
834	**90**	914
853	**95**	934
871	**98**	947
879	**99**	963



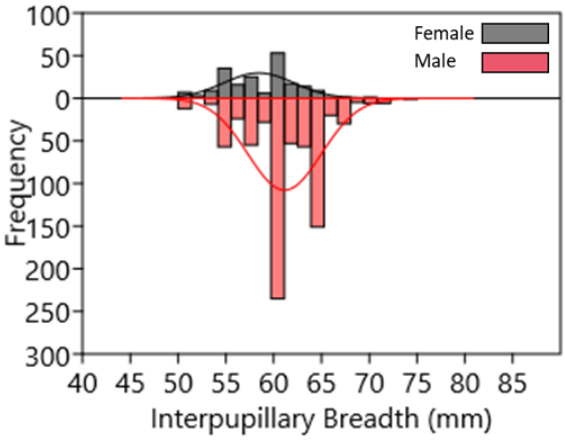
I.57 INTERPUPILLARY BREADTH

Definition: The distance between the centres of the left and right pupils.

Interpupillary Breadth		
Female		**Male**
197	**Valid**	747
14	**Missing**	42
58	**Mean (mm)**	61
0	**SE (mm)**	0
4	**SD (mm)**	4
50	**Min (mm)**	50
70	**Max (mm)**	75
0.0	**Skew**	-0.1
-0.2	**Kur**	0.4
< .001	**Norm (p)**	< .001
6%	**CV (%)**	6%



Percentiles		
Female	**%**	**Male**
50	**1**	50
50	**3**	54
53	**5**	55
55	**10**	55
55	**15**	57
55	**20**	58
55	**25**	60
56	**30**	60
57	**35**	60
57	**40**	60
58	**45**	60
59	**50**	61
60	**55**	61
60	**60**	62
60	**65**	63
60	**70**	64
61	**75**	64
62	**80**	65
62	**85**	65
63	**90**	65
64	**95**	67
65	**98**	68
67	**99**	70

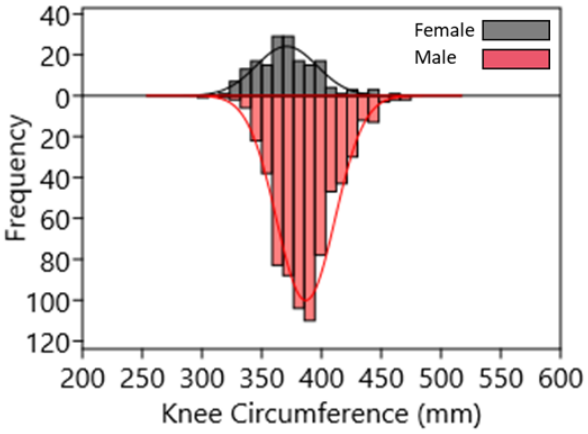


I.58 KNEE CIRCUMFERENCE

Definition: The horizontal circumference of the knee at the height of the Midpatella Landmark at the centre of the right kneecap.

Knee Circumference		
Female		**Male**
173	**Valid**	685
38	**Missing**	104
371	**Mean (mm)**	387
2	**SE (mm)**	1
26	**SD (mm)**	24
320	**Min (mm)**	296
462	**Max (mm)**	475
0.7	**Skew**	0.4
0.9	**Kur**	0.5
< .001	**Norm (p)**	< .001
7%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
326	**1**	336
330	**3**	345
333	**5**	350
338	**10**	359
345	**15**	363
349	**20**	366
352	**25**	370
359	**30**	373
363	**35**	377
365	**40**	379
367	**45**	382
369	**50**	385
372	**55**	388
373	**60**	391
377	**65**	394
381	**70**	397
387	**75**	402
390	**80**	406
396	**85**	413
401	**90**	419
411	**95**	430
431	**98**	440
446	**99**	447

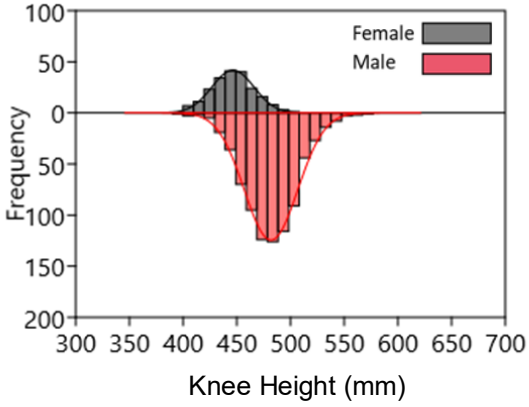


I.59 KNEE HEIGHT

Definition: The vertical height of the front of the knee circumference level (over the right kneecap perpendicular to the leg-axis) to the standing surface.

Knee Height		
Female		**Male**
208	**Valid**	787
3	**Missing**	2
446	**Mean (mm)**	482
1	**SE (mm)**	1
20	**SD (mm)**	25
400	**Min (mm)**	390
501	**Max (mm)**	577
0.1	**Skew**	0.1
-0.1	**Kur**	0.6
0.753	**Norm (p)**	0.03
4%	**CV (%)**	5%

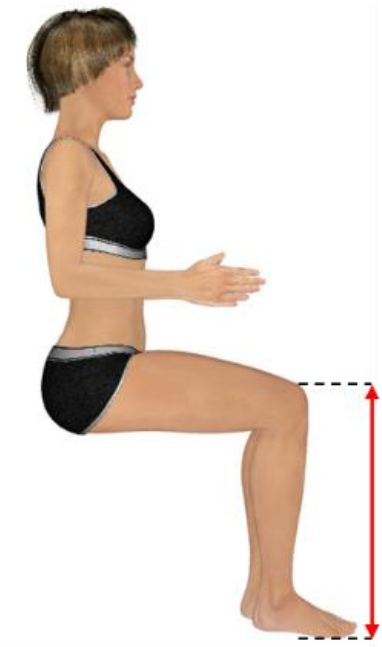
Percentiles		
Female	**%**	**Male**
404	**1**	424
407	**3**	435
415	**5**	443
422	**10**	452
425	**15**	457
430	**20**	461
434	**25**	465
436	**30**	469
439	**35**	473
441	**40**	475
444	**45**	478
447	**50**	482
449	**55**	485
451	**60**	488
454	**65**	491
456	**70**	494
458	**75**	497
460	**80**	501
467	**85**	506
472	**90**	512
481	**95**	524
487	**98**	534
490	**99**	545



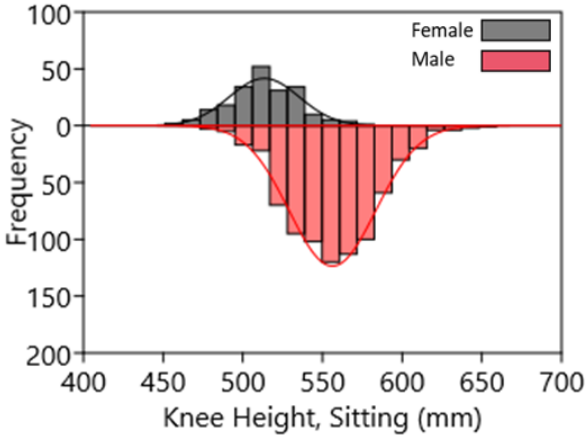
I.60 KNEE HEIGHT, SITTING

Definition: The vertical distance between a footrest surface and the Suprapatella Landmark at the top of the right kneecap.

Knee Height, Sitting		
Female		**Male**
210	**Valid**	767
1	**Missing**	22
513	**Mean (mm)**	556
2	**SE (mm)**	1
22	**SD (mm)**	27
451	**Min (mm)**	478
581	**Max (mm)**	659
0.0	**Skew**	0.1
0.2	**Kur**	0.2
0.982	**Norm (p)**	0.417
4%	**CV (%)**	5%



Percentiles		
Female	**%**	**Male**
465	**1**	494
471	**3**	505
476	**5**	512
484	**10**	523
491	**15**	528
496	**20**	533
500	**25**	537
502	**30**	542
506	**35**	546
508	**40**	549
510	**45**	552
514	**50**	557
515	**55**	560
518	**60**	563
522	**65**	567
525	**70**	570
528	**75**	574
532	**80**	578
536	**85**	583
539	**90**	591
549	**95**	599
559	**98**	609
565	**99**	623

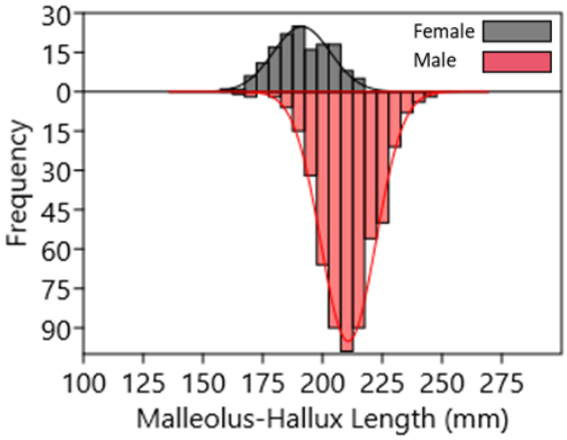


I.61 MALLEOLUS-HALLUX LENGTH

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

Malleolus-Hallux Length		
Female		**Male**
148	**Valid**	544
63	**Missing**	245
191	**Mean (mm)**	211
1	**SE (mm)**	0
12	**SD (mm)**	11
157	**Min (mm)**	167
217	**Max (mm)**	248
0.0	**Skew**	-0.1
-0.5	**Kur**	0.7
0.426	**Norm (p)**	0.02
6%	**CV (%)**	5%

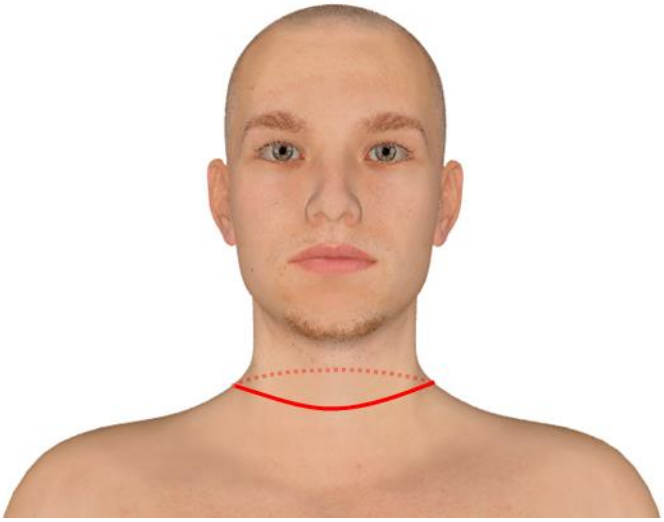
Percentiles		
Female	**%**	**Male**
167	**1**	184
170	**3**	189
173	**5**	193
177	**10**	197
178	**15**	200
181	**20**	202
183	**25**	203
184	**30**	205
186	**35**	207
188	**40**	208
189	**45**	209
191	**50**	211
192	**55**	212
194	**60**	213
197	**65**	215
199	**70**	216
201	**75**	218
203	**80**	221
204	**85**	223
207	**90**	225
210	**95**	229
214	**98**	233
216	**99**	237



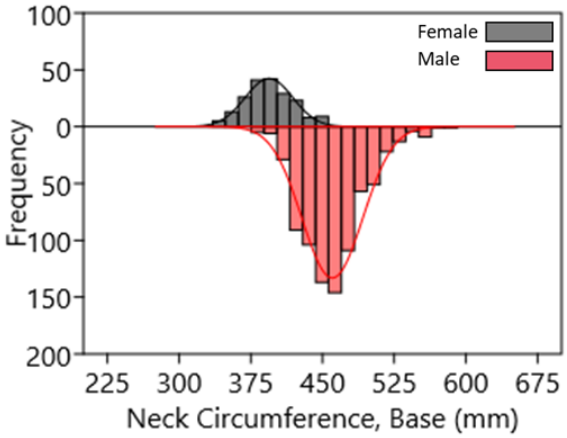
I.62 NECK CIRCUMFERENCE, BASE

Definition: The circumference at the base of the neck, just on the transition between torso and neck.

Neck Circumference, Base		
Female		**Male**
196	**Valid**	785
15	**Missing**	4
394	**Mean (mm)**	460
2	**SE (mm)**	1
25	**SD (mm)**	32
335	**Min (mm)**	378
456	**Max (mm)**	591
0.2	**Skew**	0.6
-0.2	**Kur**	0.8
0.251	**Norm (p)**	< .001
6%	**CV (%)**	7%



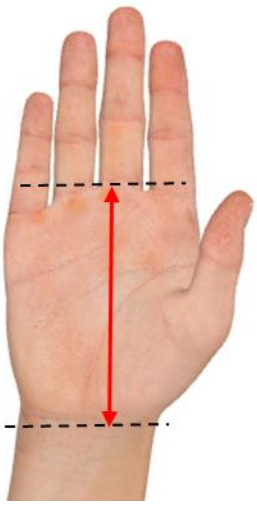
Percentiles		
Female	**%**	**Male**
342	**1**	398
351	**3**	407
354	**5**	415
364	**10**	422
368	**15**	428
372	**20**	434
376	**25**	438
382	**30**	443
384	**35**	446
387	**40**	450
390	**45**	454
393	**50**	458
395	**55**	462
399	**60**	465
403	**65**	469
405	**70**	474
408	**75**	478
416	**80**	484
420	**85**	491
426	**90**	502
441	**95**	518
446	**98**	529
450	**99**	557



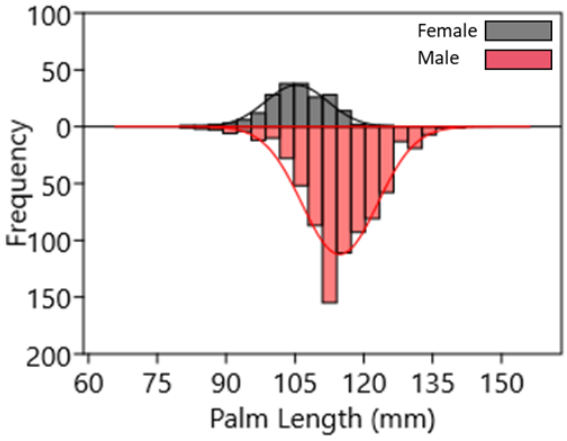
I.63 PALM LENGTH

Definition: The distance from the proximal finger crease of the middle finger on the palm of the hand to the Midstylion Landmark at the centre of the wrist, measured with the hand stretched out flat, palm up.

Palm Length		
Female		**Male**
201	**Valid**	744
10	**Missing**	45
105	**Mean (mm)**	115
0	**SE (mm)**	0
7	**SD (mm)**	8
80	**Min (mm)**	81
124	**Max (mm)**	142
-0.4	**Skew**	-0.4
0.9	**Kur**	1.1
0.013	**Norm (p)**	< .001
6%	**CV (%)**	7%



Percentiles		
Female	**%**	**Male**
87	**1**	90
90	**3**	96
94	**5**	102
98	**10**	105
100	**15**	107
101	**20**	109
102	**25**	110
103	**30**	111
103	**35**	112
104	**40**	113
105	**45**	114
105	**50**	115
106	**55**	116
106	**60**	117
108	**65**	118
110	**70**	119
110	**75**	120
111	**80**	122
112	**85**	123
114	**90**	125
116	**95**	127
117	**98**	130
119	**99**	133

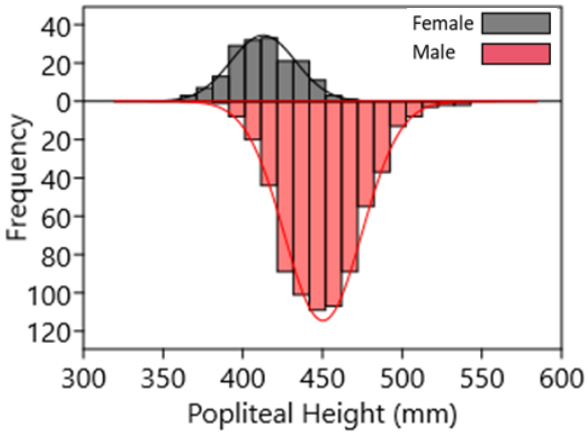


I.64 POPLITEAL HEIGHT

Definition: The vertical distance from the floor to the back of the right knee (the popliteal fossa at the dorsal juncture of the right calf and thigh).

Popliteal Height		
Female		**Male**
174	**Valid**	688
37	**Missing**	101
413	**Mean (mm)**	450
2	**SE (mm)**	1
20	**SD (mm)**	24
361	**Min (mm)**	388
463	**Max (mm)**	543
0.0	**Skew**	0.3
-0.3	**Kur**	0.3
0.63	**Norm (p)**	0.002
5%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
368	**1**	398
373	**3**	406
378	**5**	413
388	**10**	421
392	**15**	425
395	**20**	429
397	**25**	433
401	**30**	437
407	**35**	440
409	**40**	443
411	**45**	446
412	**50**	449
414	**55**	452
416	**60**	456
419	**65**	460
423	**70**	462
427	**75**	466
432	**80**	470
435	**85**	475
438	**90**	482
446	**95**	491
450	**98**	499
460	**99**	511

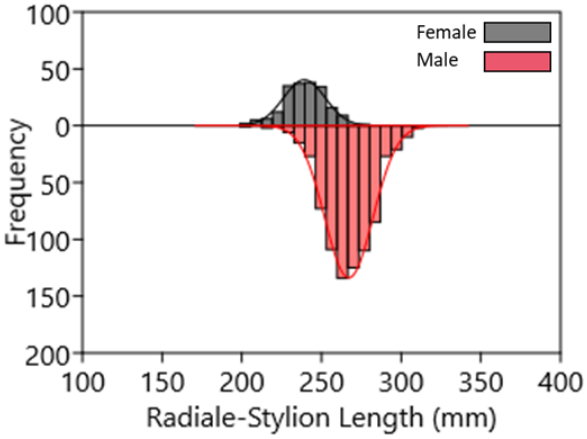


I.65 RADIALE-STYLION LENGTH

Definition: The distance between the Radiale Landmark on the right elbow and the Stylion Landmark on the right wrist.

Radiale-Stylion Length		
Female		**Male**
196	**Valid**	748
15	**Missing**	41
239	**Mean (mm)**	267
1	**SE (mm)**	1
13	**SD (mm)**	15
199	**Min (mm)**	204
279	**Max (mm)**	314
-0.2	**Skew**	-0.1
0.5	**Kur**	0.5
0.419	**Norm (p)**	0.067
5%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
208	**1**	229
211	**3**	237
218	**5**	243
223	**10**	249
227	**15**	252
229	**20**	255
230	**25**	257
233	**30**	259
234	**35**	261
236	**40**	263
237	**45**	265
240	**50**	267
241	**55**	269
243	**60**	270
245	**65**	273
247	**70**	275
248	**75**	277
250	**80**	280
252	**85**	283
256	**90**	285
260	**95**	292
261	**98**	298
265	**99**	303

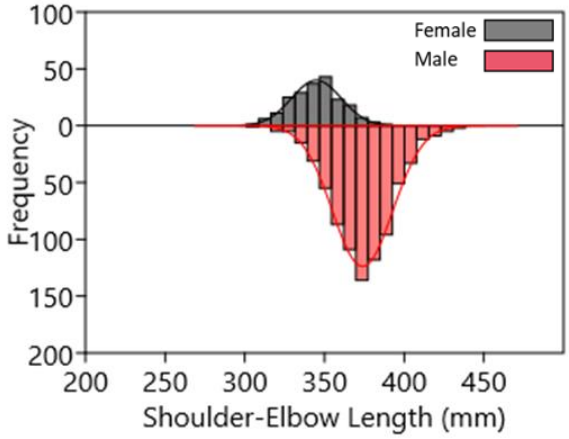


I.66 SHOULDER-ELBOW LENGTH

Definition: The distance between the Acromion Right Landmark on the tip of the right shoulder and the Olecranon Bottom Landmark on the tip of the right elbow.

Shoulder-Elbow Length		
Female		**Male**
204	**Valid**	770
7	**Missing**	19
345	**Mean (mm)**	374
1	**SE (mm)**	1
16	**SD (mm)**	19
307	**Min (mm)**	301
385	**Max (mm)**	438
0.1	**Skew**	0.0
-0.3	**Kur**	0.5
0.609	**Norm (p)**	0.155
5%	**CV (%)**	5%

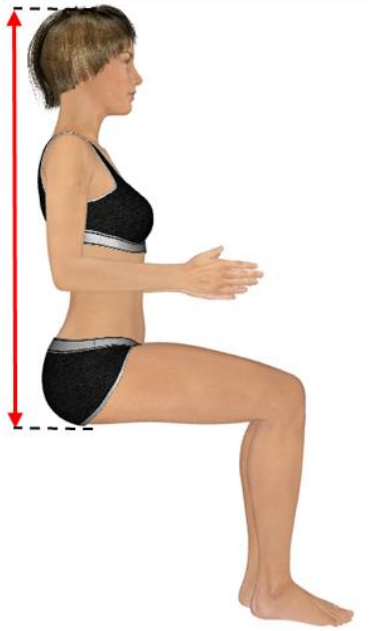
Percentiles		
Female	**%**	**Male**
314	**1**	328
316	**3**	336
320	**5**	344
324	**10**	350
328	**15**	355
331	**20**	358
334	**25**	361
336	**30**	365
339	**35**	368
341	**40**	370
343	**45**	372
345	**50**	374
347	**55**	376
349	**60**	378
351	**65**	381
352	**70**	383
355	**75**	386
357	**80**	389
361	**85**	392
367	**90**	397
370	**95**	404
376	**98**	414
380	**99**	422



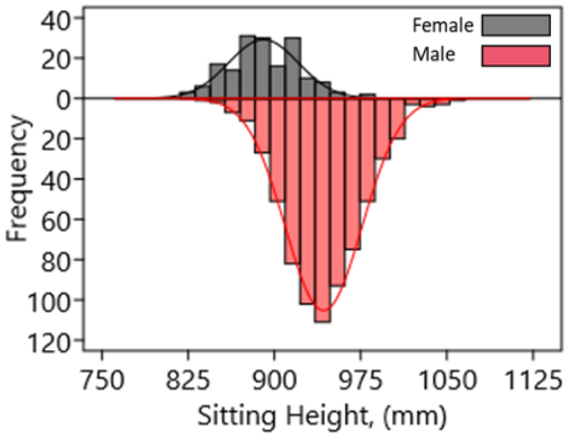
I.67 SITTING HEIGHT

Definition: The vertical distance between the sitting surface and the top of the head.

Sitting Height		
Female		**Male**
170	**Valid**	674
41	**Missing**	115
890	**Mean (mm)**	943
2	**SE (mm)**	1
30	**SD (mm)**	33
818	**Min (mm)**	836
977	**Max (mm)**	1066
0.1	**Skew**	0.2
-0.2	**Kur**	0.4
0.606	**Norm (p)**	0.142
3%	**CV (%)**	4%



Percentiles		
Female	**%**	**Male**
825	**1**	868
836	**3**	878
844	**5**	889
849	**10**	901
857	**15**	910
864	**20**	915
872	**25**	921
875	**30**	926
878	**35**	930
881	**40**	933
885	**45**	939
889	**50**	942
892	**55**	945
898	**60**	950
905	**65**	954
910	**70**	959
911	**75**	964
915	**80**	970
920	**85**	976
929	**90**	985
940	**95**	999
949	**98**	1008
959	**99**	1027

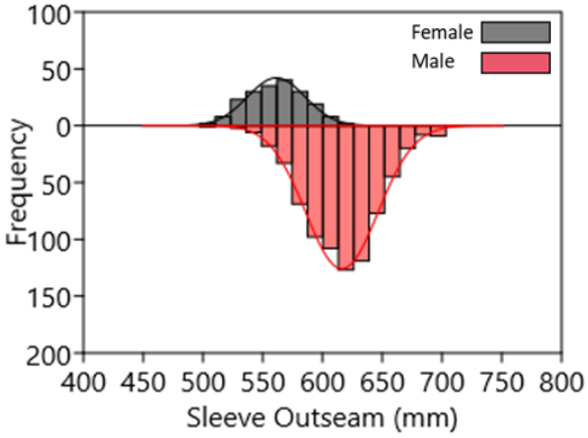


I.68 SLEEVE OUTSEAM

Definition: The distance between the Acromion Right Landmark on the tip of the right shoulder and the Centre Wrist Landmark, passing over the Radiale Landmark.

Sleeve Outseam		
Female		**Male**
197	**Valid**	740
14	**Missing**	49
561	**Mean (mm)**	616
2	**SE (mm)**	1
24	**SD (mm)**	30
498	**Min (mm)**	498
619	**Max (mm)**	703
0.0	**Skew**	0.0
-0.5	**Kur**	0.2
0.575	**Norm (p)**	0.487
4%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
512	**1**	545
518	**3**	557
524	**5**	569
529	**10**	577
534	**15**	584
540	**20**	591
543	**25**	596
547	**30**	600
552	**35**	604
557	**40**	609
560	**45**	613
562	**50**	617
564	**55**	620
567	**60**	624
571	**65**	628
575	**70**	632
578	**75**	635
584	**80**	642
587	**85**	647
593	**90**	653
600	**95**	665
604	**98**	677
611	**99**	693

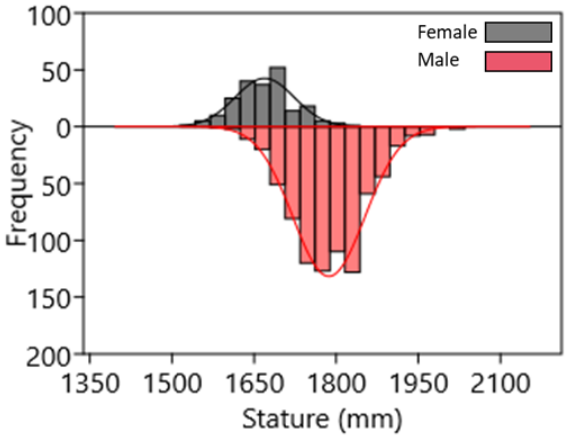


I.69 STATURE

Definition: The vertical height from the standing surface to the top of the head.

Stature		
Female		**Male**
211	**Valid**	788
0	**Missing**	1
1669	**Mean (mm)**	1787
4	**SE (mm)**	2
54	**SD (mm)**	65
1515	**Min (mm)**	1579
1832	**Max (mm)**	2035
0.2	**Skew**	0.2
0.0	**Kur**	0.2
0.305	**Norm (p)**	0.1
3%	**CV (%)**	4%

Percentiles		
Female	**%**	**Male**
1547	**1**	1640
1572	**3**	1666
1587	**5**	1683
1608	**10**	1706
1615	**15**	1720
1626	**20**	1731
1633	**25**	1739
1636	**30**	1752
1644	**35**	1760
1652	**40**	1768
1666	**45**	1778
1673	**50**	1785
1674	**55**	1793
1681	**60**	1803
1688	**65**	1811
1698	**70**	1818
1699	**75**	1825
1706	**80**	1836
1731	**85**	1851
1746	**90**	1868
1761	**95**	1897
1782	**98**	1923
1793	**99**	1954

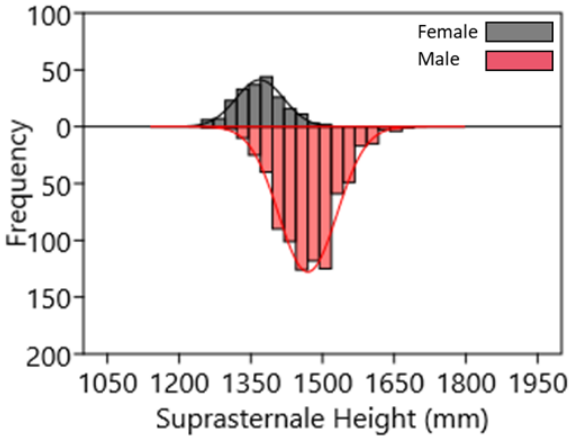


I.70 SUPRASTERNALE HEIGHT

Definition: The vertical height of the base of the neck (front/lowest point of neck at base measurement, just on the transition between torso and neck) to the standing surface.

Suprasternale Height		
Female		Male
208	Valid	787
3	Missing	2
1369	Mean (mm)	1469
3	SE (mm)	2
50	SD (mm)	61
1247	Min (mm)	1268
1511	Max (mm)	1691
0.1	Skew	0.2
0.0	Kur	0.2
0.606	Norm (p)	0.189
4%	CV (%)	4%

Percentiles		
Female	%	Male
1254	1	1336
1270	3	1353
1289	5	1373
1311	10	1395
1318	15	1409
1326	20	1417
1334	25	1427
1341	30	1438
1349	35	1445
1356	40	1452
1363	45	1460
1370	50	1468
1376	55	1475
1381	60	1482
1386	65	1493
1391	70	1503
1398	75	1511
1403	80	1518
1423	85	1528
1435	90	1547
1455	95	1567
1467	98	1595
1487	99	1616

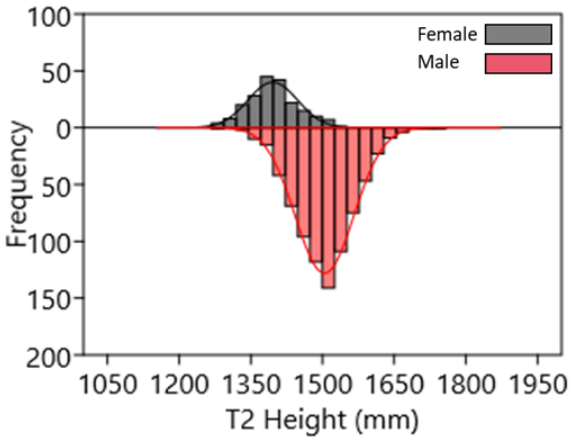


I.71 T2 HEIGHT

Definition: The vertical distance between the standing surface and the Second Thoracic Vertebra (T2) Landmark.

T2 Height		
Female		**Male**
202	**Valid**	764
9	**Missing**	25
1396	**Mean (mm)**	1504
4	**SE (mm)**	2
52	**SD (mm)**	61
1275	**Min (mm)**	1268
1539	**Max (mm)**	1757
0.2	**Skew**	0.1
-0.1	**Kur**	0.4
0.188	**Norm (p)**	0.329
4%	**CV (%)**	4%

Percentiles		
Female	**%**	**Male**
1289	**1**	1360
1301	**3**	1383
1306	**5**	1406
1330	**10**	1428
1342	**15**	1442
1356	**20**	1453
1362	**25**	1463
1372	**30**	1473
1377	**35**	1480
1381	**40**	1489
1387	**45**	1498
1393	**50**	1506
1400	**55**	1511
1404	**60**	1520
1409	**65**	1526
1416	**70**	1534
1428	**75**	1543
1438	**80**	1554
1451	**85**	1567
1471	**90**	1580
1491	**95**	1603
1509	**98**	1625
1510	**99**	1653

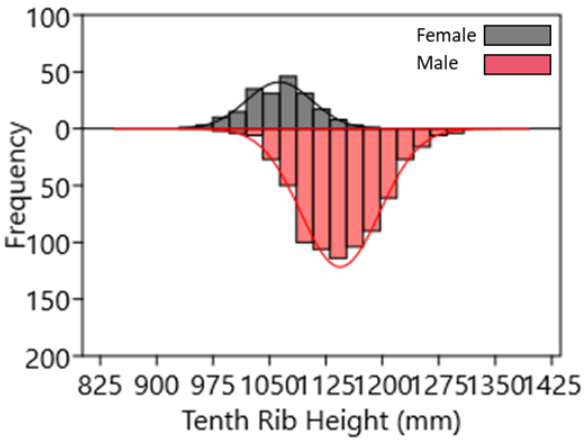


I.72 TENTH RIB HEIGHT

Definition: The vertical distance between the standing surface and the Tenth Rib Landmark located at the bottom of the right side of the ribcage.

Tenth Rib Height		
Female		**Male**
201	**Valid**	717
10	**Missing**	72
1063	**Mean (mm)**	1144
3	**SE (mm)**	2
44	**SD (mm)**	52
930	**Min (mm)**	976
1185	**Max (mm)**	1308
-0.1	**Skew**	0.1
-0.1	**Kur**	0.0
0.989	**Norm (p)**	0.338
4%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
963	**1**	1028
981	**3**	1048
990	**5**	1060
1007	**10**	1079
1022	**15**	1091
1026	**20**	1098
1035	**25**	1105
1039	**30**	1114
1044	**35**	1120
1053	**40**	1129
1058	**45**	1136
1065	**50**	1144
1071	**55**	1150
1077	**60**	1156
1082	**65**	1162
1085	**70**	1172
1093	**75**	1181
1100	**80**	1190
1106	**85**	1198
1118	**90**	1208
1132	**95**	1232
1140	**98**	1253
1157	**99**	1273

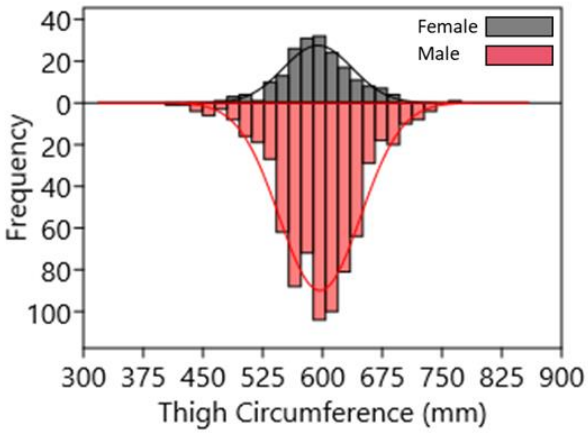


I.73 THIGH CIRCUMFERENCE

Definition: The horizontal circumference around the right leg slightly underneath the crotch, measured parallel to the standing surface.

Thigh Circumference		
Female		**Male**
193	**Valid**	745
18	**Missing**	44
594	**Mean (mm)**	597
3	**SE (mm)**	2
43	**SD (mm)**	51
478	**Min (mm)**	403
774	**Max (mm)**	734
0.3	**Skew**	-0.2
1.3	**Kur**	0.7
0.021	**Norm (p)**	< .001
7%	**CV (%)**	9%

Percentiles		
Female	**%**	**Male**
492	**1**	454
504	**3**	486
531	**5**	511
543	**10**	538
555	**15**	549
563	**20**	560
568	**25**	567
574	**30**	571
579	**35**	578
583	**40**	586
588	**45**	592
595	**50**	599
598	**55**	603
601	**60**	609
607	**65**	615
610	**70**	622
618	**75**	628
626	**80**	635
637	**85**	644
650	**90**	658
670	**95**	685
680	**98**	699
688	**99**	717

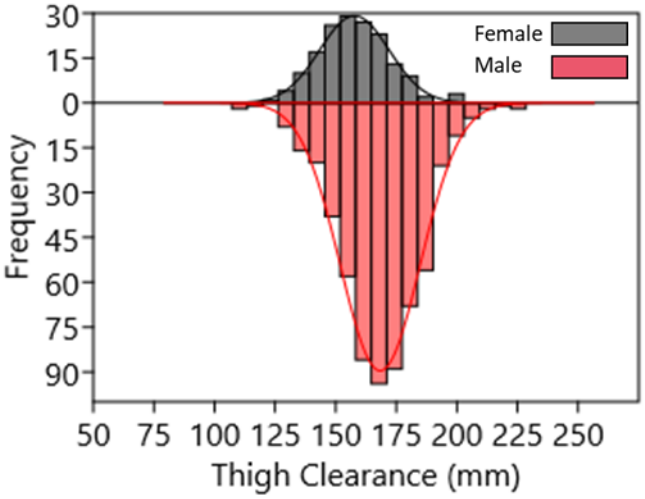


I.74 THIGH CLEARANCE

Definition: The vertical distance between the sitting surface and the Thigh Point Top Landmark (the highest point on the right thigh).

Thigh Clearance		
Female		**Male**
164	**Valid**	578
47	**Missing**	211
158	**Mean (mm)**	168
1	**SE (mm)**	1
14	**SD (mm)**	16
123	**Min (mm)**	107
203	**Max (mm)**	229
0.3	**Skew**	-0.1
0.2	**Kur**	0.8
0.382	**Norm (p)**	0.019
9%	**CV (%)**	10%

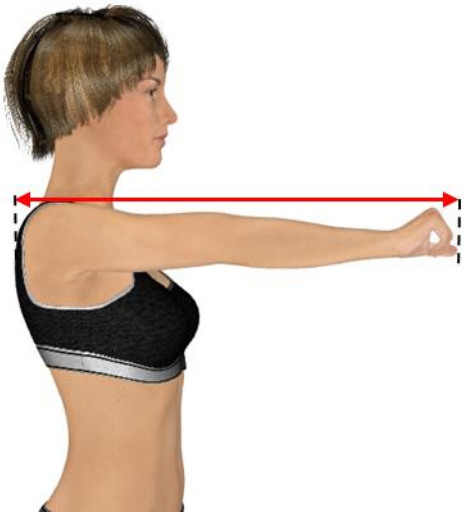
Percentiles		
Female	**%**	**Male**
127	**1**	130
131	**3**	134
136	**5**	140
140	**10**	148
144	**15**	152
146	**20**	155
147	**25**	158
149	**30**	161
152	**35**	162
154	**40**	165
155	**45**	167
157	**50**	169
159	**55**	171
161	**60**	173
163	**65**	174
165	**70**	177
168	**75**	179
170	**80**	182
171	**85**	185
175	**90**	188
182	**95**	193
184	**98**	198
197	**99**	206



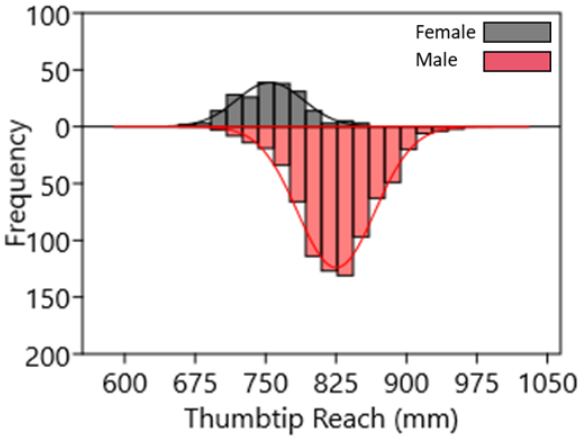
I.75 THUMBTIP REACH

Definition: The horizontal distance from the back wall to the tip of the thumb of the outstretched right arm, with the right shoulder pressed against the wall.

Thumbtip Reach		
Female		**Male**
206	**Valid**	757
5	**Missing**	32
755	**Mean (mm)**	825
2	**SE (mm)**	1
36	**SD (mm)**	41
658	**Min (mm)**	700
857	**Max (mm)**	961
0.3	**Skew**	-0.1
0.2	**Kur**	0.3
0.195	**Norm (p)**	0.073
5%	**CV (%)**	5%



Percentiles		
Female	**%**	**Male**
684	**1**	723
693	**3**	738
699	**5**	754
710	**10**	775
717	**15**	787
723	**20**	794
731	**25**	800
736	**30**	805
741	**35**	810
747	**40**	815
751	**45**	821
755	**50**	826
759	**55**	831
763	**60**	836
767	**65**	840
772	**70**	845
778	**75**	851
782	**80**	859
788	**85**	867
797	**90**	878
816	**95**	891
837	**98**	903
847	**99**	925

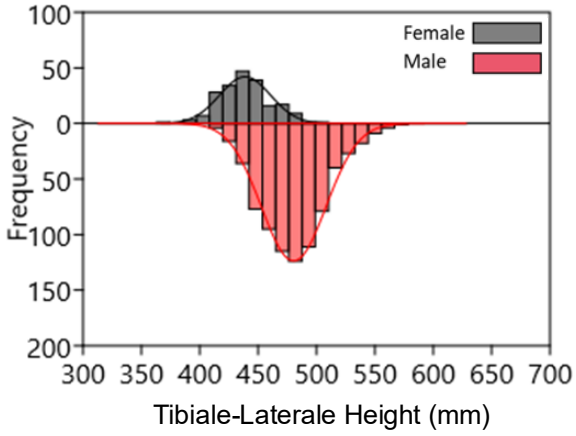


I.76 TIBIALE-LATERALE HEIGHT

Definition: The vertical distance between the standing surface and the Tibiale-Laterale Landmark on the right knee.

Tibiale-Laterale Height		
Female		**Male**
203	**Valid**	756
8	**Missing**	33
439	**Mean (mm)**	480
2	**SE (mm)**	1
22	**SD (mm)**	28
363	**Min (mm)**	409
506	**Max (mm)**	578
0.1	**Skew**	0.3
0.5	**Kur**	0.1
0.224	**Norm (p)**	0.002
5%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
388	**1**	422
402	**3**	430
407	**5**	437
414	**10**	446
417	**15**	451
420	**20**	457
424	**25**	461
428	**30**	465
430	**35**	469
432	**40**	473
435	**45**	476
438	**50**	480
440	**55**	483
444	**60**	487
446	**65**	490
448	**70**	494
450	**75**	498
456	**80**	502
463	**85**	507
471	**90**	516
477	**95**	530
479	**98**	541
486	**99**	549

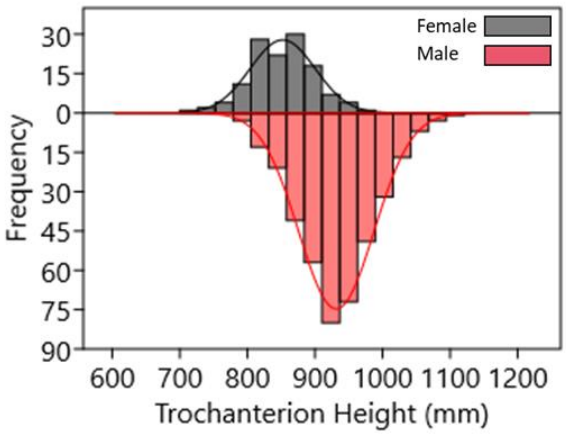


I.77 TROCHANTERION HEIGHT

Definition: The vertical distance between the standing surface and the Trochanterion Landmark on the upper side of the right thigh.

Trochanterion Height		
Female		**Male**
128	**Valid**	396
83	**Missing**	393
852	**Mean (mm)**	932
4	**SE (mm)**	3
48	**SD (mm)**	56
700	**Min (mm)**	783
975	**Max (mm)**	1121
-0.2	**Skew**	0.1
0.3	**Kur**	0.1
0.873	**Norm (p)**	0.807
6%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
736	**1**	813
755	**3**	823
778	**5**	840
793	**10**	860
808	**15**	875
813	**20**	885
821	**25**	897
827	**30**	902
830	**35**	912
835	**40**	917
847	**45**	924
855	**50**	930
861	**55**	937
864	**60**	944
873	**65**	951
878	**70**	959
882	**75**	966
894	**80**	977
901	**85**	989
908	**90**	1001
930	**95**	1025
942	**98**	1044
958	**99**	1064

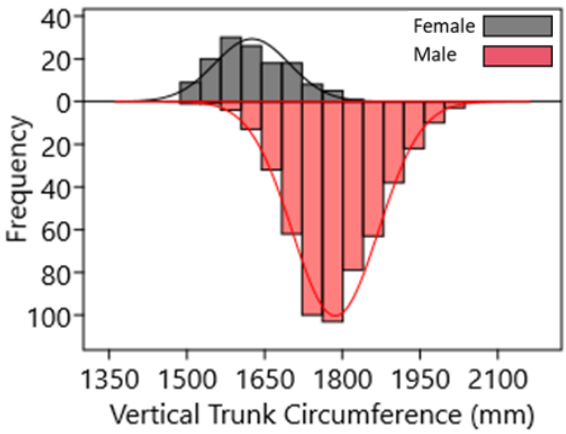


I.78 VERTICAL TRUNK CIRCUMFERENCE

Definition: The vertical circumference of the trunk on a line passing through the crotch and over the landmarks at Bustpoint (females) or Thelion (males), MidShoulder, and Buttock Point Posterior.

Vertical Trunk Circumference		
Female		Male
135	Valid	531
76	Missing	258
1626	Mean (mm)	1786
6	SE (mm)	4
72	SD (mm)	83
1487	Min (mm)	1524
1812	Max (mm)	2036
0.4	Skew	0.1
-0.4	Kur	0.0
0.048	Norm (p)	0.267
4%	CV (%)	5%

Percentiles		
Female	%	Male
1499	1	1597
1506	3	1629
1518	5	1660
1534	10	1685
1546	15	1706
1563	20	1720
1577	25	1732
1584	30	1742
1590	35	1752
1597	40	1762
1613	45	1769
1621	50	1778
1624	55	1792
1638	60	1802
1648	65	1814
1664	70	1829
1679	75	1842
1691	80	1859
1699	85	1874
1722	90	1899
1757	95	1931
1787	98	1953
1798	99	1972

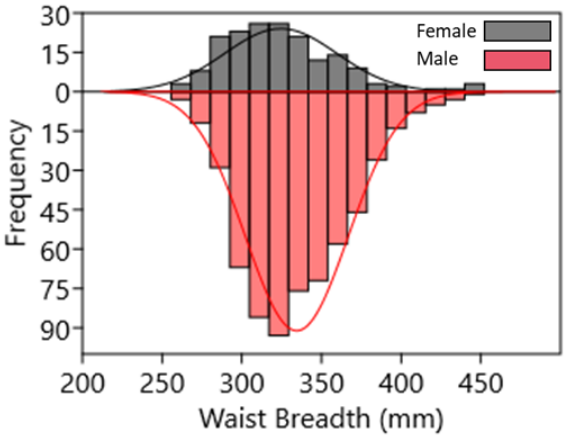


I.79 WAIST BREADTH

Definition: The horizontal breadth of the waist at the level of the Omphalion.

Waist Breadth		
Female		**Male**
173	**Valid**	599
38	**Missing**	190
324	**Mean (mm)**	334
3	**SE (mm)**	1
35	**SD (mm)**	32
259	**Min (mm)**	256
446	**Max (mm)**	452
1.0	**Skew**	0.5
1.4	**Kur**	0.1
< .001	**Norm (p)**	< .001
11%	**CV (%)**	10%

Percentiles		
Female	**%**	**Male**
266	**1**	272
273	**3**	282
279	**5**	289
285	**10**	296
289	**15**	303
295	**20**	306
299	**25**	311
301	**30**	315
308	**35**	319
312	**40**	323
316	**45**	326
320	**50**	331
324	**55**	336
328	**60**	340
332	**65**	344
339	**70**	350
344	**75**	355
352	**80**	363
358	**85**	369
367	**90**	377
382	**95**	392
417	**98**	403
441	**99**	420

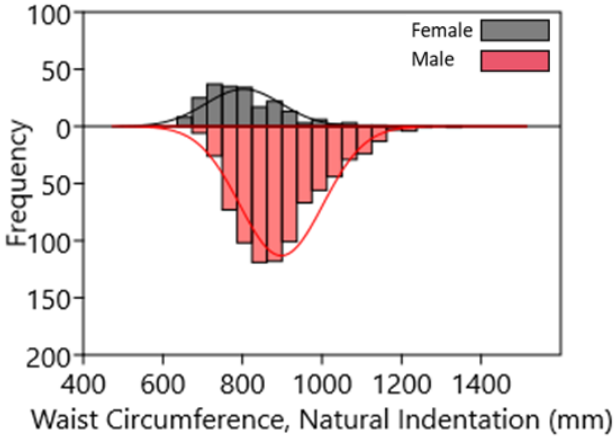


I.80 WAIST CIRCUMFERENCE, NATURAL INDENTATION

Definition: The horizontal circumference of the waist measured at the height of the natural waist, determined by the point of contraction on the side.

Waist Circumference, Natural Indentation		
Female		**Male**
207	**Valid**	787
4	**Missing**	2
803	**Mean (mm)**	898
7	**SE (mm)**	4
95	**SD (mm)**	104
636	**Min (mm)**	689
1148	**Max (mm)**	1351
1.0	**Skew**	0.7
1.2	**Kur**	0.4
< .001	**Norm (p)**	< .001
12%	**CV (%)**	12%

Percentiles		
Female	**%**	**Male**
661	**1**	718
664	**3**	741
682	**5**	755
701	**10**	777
709	**15**	790
726	**20**	805
737	**25**	820
743	**30**	836
753	**35**	846
764	**40**	858
776	**45**	870
783	**50**	883
796	**55**	896
810	**60**	907
819	**65**	921
829	**70**	940
858	**75**	959
877	**80**	982
895	**85**	1013
921	**90**	1046
1000	**95**	1093
1047	**98**	1128
1085	**99**	1169

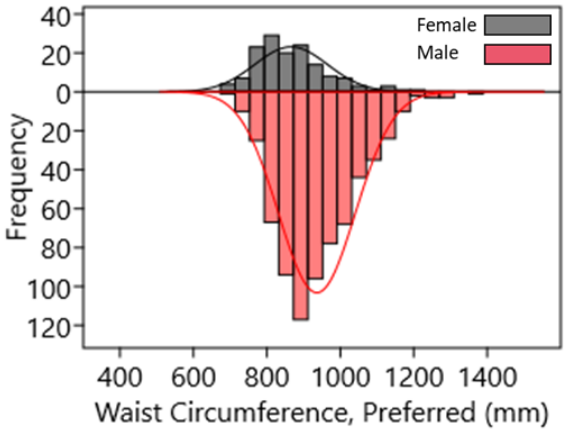


I.81 WAIST CIRCUMFERENCE, PREFERRED

Definition: The horizontal circumference of the torso at the height of the Waist Preferred Posterior Landmark (representing the preferred belt height on the back).

Waist Circumference, Preferred		
Female		**Male**
145	**Valid**	678
66	**Missing**	111
866	**Mean (mm)**	936
8	**SE (mm)**	4
99	**SD (mm)**	104
673	**Min (mm)**	709
1219	**Max (mm)**	1389
0.9	**Skew**	0.6
1.1	**Kur**	0.5
< .001	**Norm (p)**	< .001
11%	**CV (%)**	11%

Percentiles		
Female	**%**	**Male**
661	**1**	718
664	**3**	741
682	**5**	755
701	**10**	777
709	**15**	790
726	**20**	805
737	**25**	820
743	**30**	836
753	**35**	846
764	**40**	858
776	**45**	870
783	**50**	883
796	**55**	896
810	**60**	907
819	**65**	921
829	**70**	940
858	**75**	959
877	**80**	982
895	**85**	1013
921	**90**	1046
1000	**95**	1093
1047	**98**	1128
1085	**99**	1169

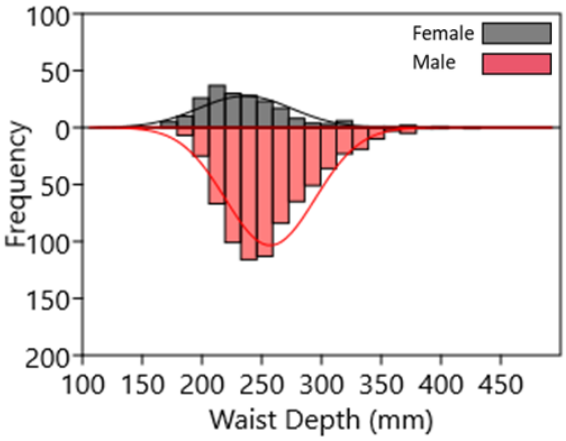


I.82 WAIST DEPTH

Definition: The largest horizontal depth of the torso between the Iliocristale and the Tenth Rib landmarks.

Waist Depth		
Female		**Male**
203	**Valid**	728
8	**Missing**	61
236	**Mean (mm)**	257
3	**SE (mm)**	1
39	**SD (mm)**	37
166	**Min (mm)**	185
400	**Max (mm)**	433
1.3	**Skew**	0.8
2.6	**Kur**	0.9
< .001	**Norm (p)**	< .001
17%	**CV (%)**	15%

Percentiles		
Female	**%**	**Male**
173	**1**	193
184	**3**	200
188	**5**	208
196	**10**	214
200	**15**	221
206	**20**	224
210	**25**	229
213	**30**	235
217	**35**	239
221	**40**	243
225	**45**	247
230	**50**	251
235	**55**	255
239	**60**	260
241	**65**	266
248	**70**	272
253	**75**	279
261	**80**	287
265	**85**	295
281	**90**	307
316	**95**	330
336	**98**	343
371	**99**	366

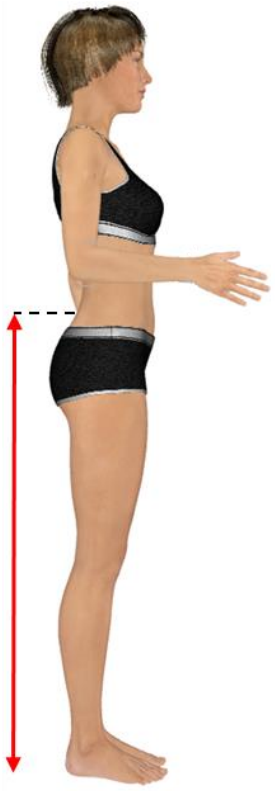


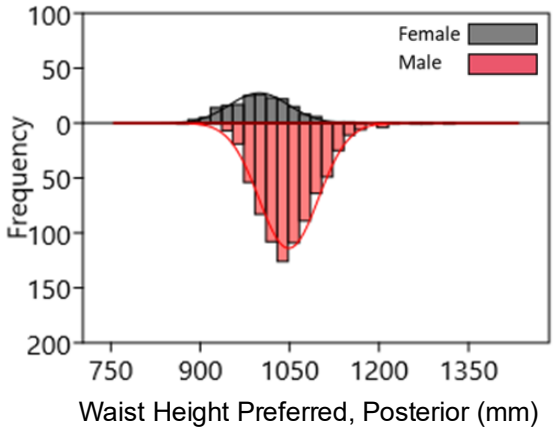
I.83 WAIST HEIGHT PREFERRED, POSTERIOR

Definition: The vertical distance between the standing surface and the Waist Preferred Posterior Landmark (representing the preferred belt height on the back).

Waist Height Preferred, Posterior		
Female		**Male**
182	**Valid**	761
29	**Missing**	28
999	**Mean (mm)**	1048
4	**SE (mm)**	2
49	**SD (mm)**	50
892	**Min (mm)**	861
1141	**Max (mm)**	1327
0.1	**Skew**	0.7
-0.3	**Kur**	2.2
0.592	**Norm (p)**	< .001
5%	**CV (%)**	5%

Percentiles		
Female	**%**	**Male**
894	**1**	951
905	**3**	964
918	**5**	976
932	**10**	990
941	**15**	999
952	**20**	1007
966	**25**	1015
973	**30**	1020
980	**35**	1027
987	**40**	1033
993	**45**	1038
998	**50**	1044
1006	**55**	1051
1012	**60**	1058
1020	**65**	1063
1028	**70**	1072
1032	**75**	1079
1039	**80**	1086
1051	**85**	1098
1058	**90**	1110
1077	**95**	1130
1090	**98**	1146
1108	**99**	1183



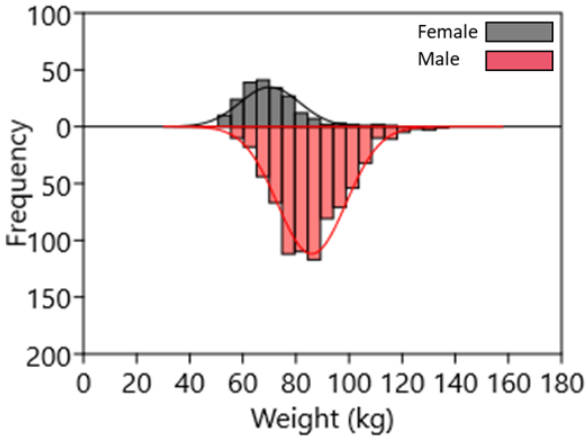


I.84 WEIGHT

Definition: Body weight (in kilograms) measured with the scale integrated into the scanner platform.

Weight		
Female		**Male**
205	**Valid**	748
6	**Missing**	41
70	**Mean (mm)**	86
1	**SE (mm)**	0
11	**SD (mm)**	13
51	**Min (mm)**	56
117	**Max (mm)**	137
1.3	**Skew**	0.5
2.8	**Kur**	0.5
< .001	**Norm (p)**	< .001
16%	**CV (%)**	15%

Percentiles		
Female	**%**	**Male**
51	**1**	60
53	**3**	63
56	**5**	67
58	**10**	70
60	**15**	73
61	**20**	75
62	**25**	76
64	**30**	78
65	**35**	80
66	**40**	82
68	**45**	83
69	**50**	85
70	**55**	86
71	**60**	88
72	**65**	90
74	**70**	92
76	**75**	94
77	**80**	97
79	**85**	99
83	**90**	102
89	**95**	108
51	**1**	60
53	**3**	63

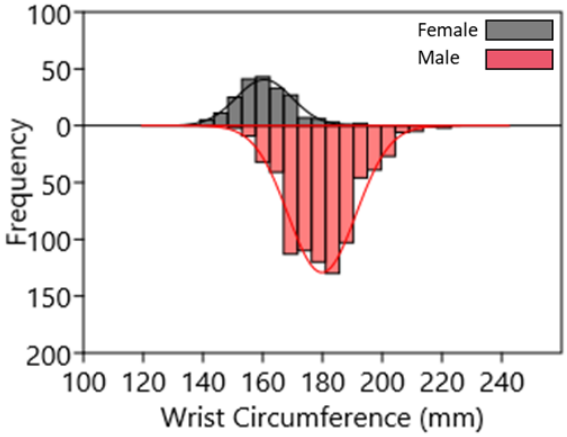


I.85 WRIST CIRCUMFERENCE

Definition: The circumference of the right wrist measured at the arm extremity just before the transition to the hand.

Wrist Circumference		
Female		**Male**
204	**Valid**	786
7	**Missing**	3
160	**Mean (mm)**	180
1	**SE (mm)**	0
9	**SD (mm)**	11
139	**Min (mm)**	150
192	**Max (mm)**	223
0.6	**Skew**	0.3
0.9	**Kur**	0.2
< .001	**Norm (p)**	< .001
6%	**CV (%)**	6%

Percentiles		
Female	**%**	**Male**
142	**1**	157
144	**3**	160
146	**5**	162
149	**10**	166
151	**15**	168
153	**20**	170
154	**25**	171
155	**30**	173
156	**35**	175
157	**40**	177
159	**45**	178
161	**50**	179
162	**55**	181
162	**60**	182
163	**65**	184
164	**70**	185
166	**75**	186
167	**80**	189
169	**85**	191
170	**90**	195
179	**95**	200
182	**98**	203
189	**99**	208



Appendix J Minimum Sampling Requirments

This appendix provides the minimum sampling size requirements for NZDFAS measures for both men and women. Note that these sample sizes are unique for each measure and are based on the calculation recommended by ISO 15535:2008 and provided in Equation 4 where CV is the coefficient of variation of the measure and a is the percent relative accuracy required or the acceptable tolerance (typically 1% or 2%).

$$n \geq \left(1.96 \times \frac{CV}{a}\right)^2 \times 1.534^2 \qquad \text{(5) ISO 15535 sample size}$$

In Table H-1, the CV was primarily derived from the ANSUR II summary statistics. For measures not available in ANSUR II, summary statistics from ANSUR I (*) and the Australian Warfighter Anthropometric Survey (†) were substituted. Summary statistics were not available for several measures as they were not measured in other military and civilian surveys reviewed. Recommended sample size could not be calculated for these measures. These measures are indicated by “NA” in Table J-1.

As the NZDF represents a finite sample of approximately 8900 individuals, the ISO sampling strategy tends to overestimate the true sampling requirements, particularly for measures requiring larger sample sizes. However, it does provide a reasonable metric to evaluate the quality of the sample achieved in the NZDFAS. Table J-1 also provides Cochran’s corrected sample size for finite populations for the ISO 1% relative accuracy sample size. As per Cochran’s recommendation, this correction is used when the estimated sample size is greater than 5% of the population or a sample size of 83 for women and 384 for men, based on 2019 NZDF populations estimates of 1,631 women and 7,677 men.

Table J-1. Minimum sampling rates for each measure in the NZDFAS according to ISO 15535:2008 guidance at relative accuracy (a) equal to 1% and 2%. Calculations are based on ANSUR II summary statistics, ANSUR I (*) and the Australian Warfighter Anthropometric Survey (†). Cochran's corrected sample size is provided for the ISO 1% relative accuracy sample. The Actual sample size is colour-coded to indicate where minimum sampling requirements have been met: green = the ISO 2% and the Cochran's corrected ISO 1% requirements are met; amber = the ISO 2% requirement is met but the Cochran's corrected 1% is not met; and red = none of the minimum sample size requirements are met.

NZDFAS Measure	Males				Females			
	Actual	1%	2%	Cochran (ISO 1%)	Actual	1%	2%	Cochran (ISO 1%)
Abdominal Extension Depth, Sitting	597	1492	485	1249	165	1696	424	1389
Acromial Height	786	174	44	170	211	171	43	167
Acromial Height, Sitting	700	226	56	220	195	217	54	211
Acromion-Radiale Length	755	246	61	238	199	275	69	266
Ankle Circumference	788	369	92	352	211	431	108	408
Arm Span	759	197	49	192	205	226	56	220
Axilla Height	683	181	45	177	174	183	46	179
Ball of Foot Circumference	761	238	60	231	206	241	60	234
Ball of Foot Length	757	245	61	237	202	253	63	245
Biacromial Breadth	779	192	48	187	202	227	57	221
Biceps Circumference, Flexed	761	844	211	760	205	915	229	818
Bideltoid Breadth, Sitting	780	366	92	349	210	367	92	350
Bitragion Submandibular Arc	759	251	63	243	206	255	64	247
Bizygomatic Breadth	762	172	43	168	206	156	39	153
Buttock Circumference	773	511	128	479	200	499	125	469
Buttock Depth	620	1047	262	921	177	986	246	874
Buttock Height	780	286	71	276	206	272	68	263
Buttock-Heel Length	760	223	56	217	206	242	60	235
Buttock-Knee Length, Sitting	761	221	55	215	196	275	69	266
Buttock-Popliteal Length	658	269	67	260	162	317	79	304
Calf Circumference	782	518	130	485	209	527	132	493
Cervicale Height	732	157	39	154	205	164	41	161

NZDFAS Measure	Males				Females			
	Actual	1%	2%	Cochran (ISO 1%)	Actual	1%	2%	Cochran (ISO 1%)
Cervicale Height, Sitting*	693	183	46	179	191	200	50	195
Chest Breadth	778	360	90	344	208	430	108	407
Chest/Bust Circumference	787	616	154	570	209	689	172	632
Chest Depth	787	966	242	858	209	1103	276	965
Chest/Bust Height, Sitting*	786	283	71	273	209	430	108	407
Chest/Bust Height	690	176	44	172	194	203	51	198
Crotch Height	624	273	68	264	123	294	74	283
Crotch Length	723	40	10	40	189	40	10	40
Crotch-Waist Length Preferred, Anterior	613	508	127	477	161	422	106	400
Crotch-Waist Length Preferred, Posterior	515	621	155	575	129	633	158	585
Elbow Circumference	786	NA	NA		209	NA	NA	
Elbow Rest Height	760	1236	309	1065	206	1153	288	1003
Elbow Rest Height, Sitting	686	1154	288	1003	189	977	244	867
Elbow-Fingertip Length	679	212	53	206	183	255	64	247
Elbow-Grip Length	760	241	60	234	204	291	73	280
Eye Height	740	NA	NA		210	NA	NA	
Eye Height, Sitting	687	154	38	151	195	149	37	146
Foot Breadth	760	239	60	232	206	240	60	233
Foot Length	758	211	53	205	203	230	58	223
Forearm-Forearm Breadth	761	697	174	639	206	621	155	575
Functional Grip Reach	760	NA	NA		206	NA	NA	
Hand Breadth	761	223	56	217	205	218	55	212
Hand Circumference	761	210	53	204	206	202	50	197
Hand Length	744	239	60	232	201	279	70	269
Head Breadth	759	116	29	114	206	112	28	110
Head Circumference	785	71	18	70	131	108	27	107
Head Length	759	112	28	110	206	139	35	137

NZDFAS Measure	Males				Females			
	Actual	1%	2%	Cochran (ISO 1%)	Actual	1%	2%	Cochran (ISO 1%)
Hip Breadth, Sitting	689	573	143	533	189	609	152	564
Hip Breadth, Standing	476	441	110	417	97	513	128	481
Hip Circumference, Maximum	471	382	95	364	86	394	98	375
Iliocristale Height	670	217	54	211	165	225	56	219
Index Finger Breadth, Distal	761	NA	NA		206	NA	NA	
Index Finger Breadth, Proximal	761	NA	NA		206	NA	NA	
Index Finger Reach	758	NA	NA		206	NA	NA	
Interpupillary Breadth	747	258	64	250	197	311	78	299
Knee Circumference	685	359	90	343	173	456	114	430
Knee Height	787	300	75	289	208	303	76	292
Knee Height, Sitting	767	230	57	223	210	253	63	245
Malleolus-Hallux Length	544	NA	NA		148	NA	NA	
Neck Circumference, Base	785	315	79	303	196	253	63	245
Palm Length	744	259	65	251	201	270	67	261
Popliteal Height	688	301	75	290	174	334	83	320
Radiale-Stylion Length	748	299	75	288	196	360	90	344
Shoulder-Elbow Length	770	226	57	220	204	241	60	234
Sitting Height	674	137	34	135	170	135	34	133
Sleeve Outseam	741	244	61	237	197	265	66	256
Stature	788	138	34	136	211	140	35	138
Suprasternale Height	787	164	41	161	208	167	42	163
T2 Height†	764	167	42	163	202	159	40	156
Tenth Rib Height	717	207	52	202	201	203	51	198
Thigh Circumference	745	790	197	716	193	741	185	676
Thigh Clearance	578	674	169	620	164	634	158	586
Thumbtip Reach	757	261	65	252	206	298	75	287
Tibiale-Laterale Height	756	292	73	281	203	296	74	285

NZDFAS Measure	Males				Females			
	Actual	1%	2%	Cochran (ISO 1%)	Actual	1%	2%	Cochran (ISO 1%)
Trochanterion Height	396	269	67	260	128	252	63	244
Vertical Trunk Circumference	531	261	65	252	135	215	54	209
Waist Breadth	599	1023	256	903	173	1091	273	955
Waist Circumference, Natural	787	1275	319	1094	207	1218	304	1051
Waist Circumference, Preferred	678	NA	NA		145	NA	NA	
Waist Depth	728	1928	482	1541	203	1960	490	1562
Waist Height Preferred, Natural and Posterior	761	220	55	214	182	235	59	228
Weight	748	2498	625	1885	205	2375	594	1814
Wrist Circumference	786	234	59	227	204	231	58	224

Symbols and Abbreviations

3-D	3-Dimension
AMU	Aviation Medical Unit
ANOVA	Analysis of Variance
ANSUR	Army Anthropometric Survey
AUT	Auckland University of Technology
AWAS	Australian Warfighter Anthropometric Survey
CFAS	Canadian Forces Anthropometric Survey
CFLS	Canadian Forces Land Survey
CV	Coefficient of Variation
DRDC	Defence Research and Development Canada
DST-Group	Defence Science and Technology Group
DTA	Defence Technology Agency
DST	Defence Science and Technology
DTSO	Defence Science and Technology Organisation
FVEY	Five Eyes
GPU	General Purpose Uniform
GWD	General Work Dress
IP	Interpupillary Distance
ISAK	International Society for the Advancement of Kinanthropometry
ISO	International Standards Organization
JNCO/E	Junior Non-Commissioned Officers and Enlisted
JO/Cadet	Junior Officers and Cadets
LINZ	Life in New Zealand
ISWRUP	In-Service Weapons Upgrade Program
MCU	Multi-terrain Combat Uniform
NCO	Non-Commissioned Officer
NZDF	New Zealand Defence Force
NZDFAS	New Zealand Defence Force Anthropometric Survey
OAHS	Operations Analysis and Human Systems
PEDA	Personal Data

PPE	Personal Protective Equipment
RNZAF	Royal New Zealand Air Force
SD	Standard Deviation
SE	Standard Error
SNCO	Senior Non-Commissioned Officers
SO	Senior Officers
SPRINZ	Sports Performance Research Institute of New Zealand
TTCP	The Technical Coordination Program