AIS

AUSTRALIAN HIGH PERFORMANCE SPORT SYSTEM

DUAL-ENERGY X-RAY ABSORPTIOMETRY

Practitioner Best Practice Guidelines for DXA Assessment of Body Composition

CONTRIBUTORS

These Best Practice Guidelines are an initiative of the Australian High Performance (HP) Sport System. The Australian Institute of Sport (AIS) acknowledges the support of members of the National Institute Network (NIN) and National Sporting Organisations (NSO) and their staff.

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OBJECTIVE

These Best Practice Guidelines aim to support Performance Support Practitioners (the 'Practitioner') within the Australian High Performance (HP) Sport System who may be interested in acquiring estimates of body composition via dual-energy x-ray absorptiometry (DXA). They provide higher level information for Practitioners to aid decisions relating to body composition assessment and subsequent interpretation, particularly for athletes in the NIN and NSOs. Detailed information is also provided on the critical role played by Practitioners in facilitating the capture of the highest quality data, especially as it relates to athlete guidance in advance of a scan.

This document contains details on important considerations including pre-test athlete guidance, data capture and subsequent data interpretation and feedback as it relates to total body scans for the quantification of body composition, including regional and total body composition. This document does not provide details of site specific DXA scans used to assess bone mineral density (BMD). Details specific to the DXA Technician on acquisition and analysis of total body composition scans are contained within the **Australian HP Sport System Best Practice Protocols for DXA Assessment of Body Composition**.

It is important that the information within this document is interpreted within the confines of state-based radiation health guidelines which provide specific recommendations on accepted referral sources and scan frequency.

EXECUTIVE SUMMARY

The monitoring of body composition as one of an array of tests is common amongst athletes from a range of sports. It may be important for athletes to have an accurate measure of body composition, and to be able to monitor changes in response to growth and maturation, or specific training and nutrition programs. At present, the most common way for athletes to receive this information is via surface anthropometry; measures of skinfolds, girths and circumferences. However, skinfolds offer little insight into changes in muscle, and are unable to accurately quantify total body fat and muscle mass.

A DXA scan can be used periodically to complement surface anthropometry data, providing a fast and accurate estimate of whole body composition, while also providing insight into bone health. DXA also provides information on regional body composition; legs, arms and torso. This information may be useful to monitor changes due to targeted training programs or during the rehabilitation from injury. The physique assessment decision tree overpage provides a valuable means of helping Practitioners identify when assessment is justified, and if so, make a decision on the most appropriate method to use.

The DXA Best Practice Guidelines in this document focus on the information required to assist Practitioners to determine the appropriateness of a DXA total body scan to assess body composition, including bone mineral content (BMC), fat mass (FM), lean mass (LM), and relevant derivatives of these, at whole body and regional level. The guidelines also assist Practitioners to interpret subsequent reports and provide invaluable feedback to athletes associated with this.

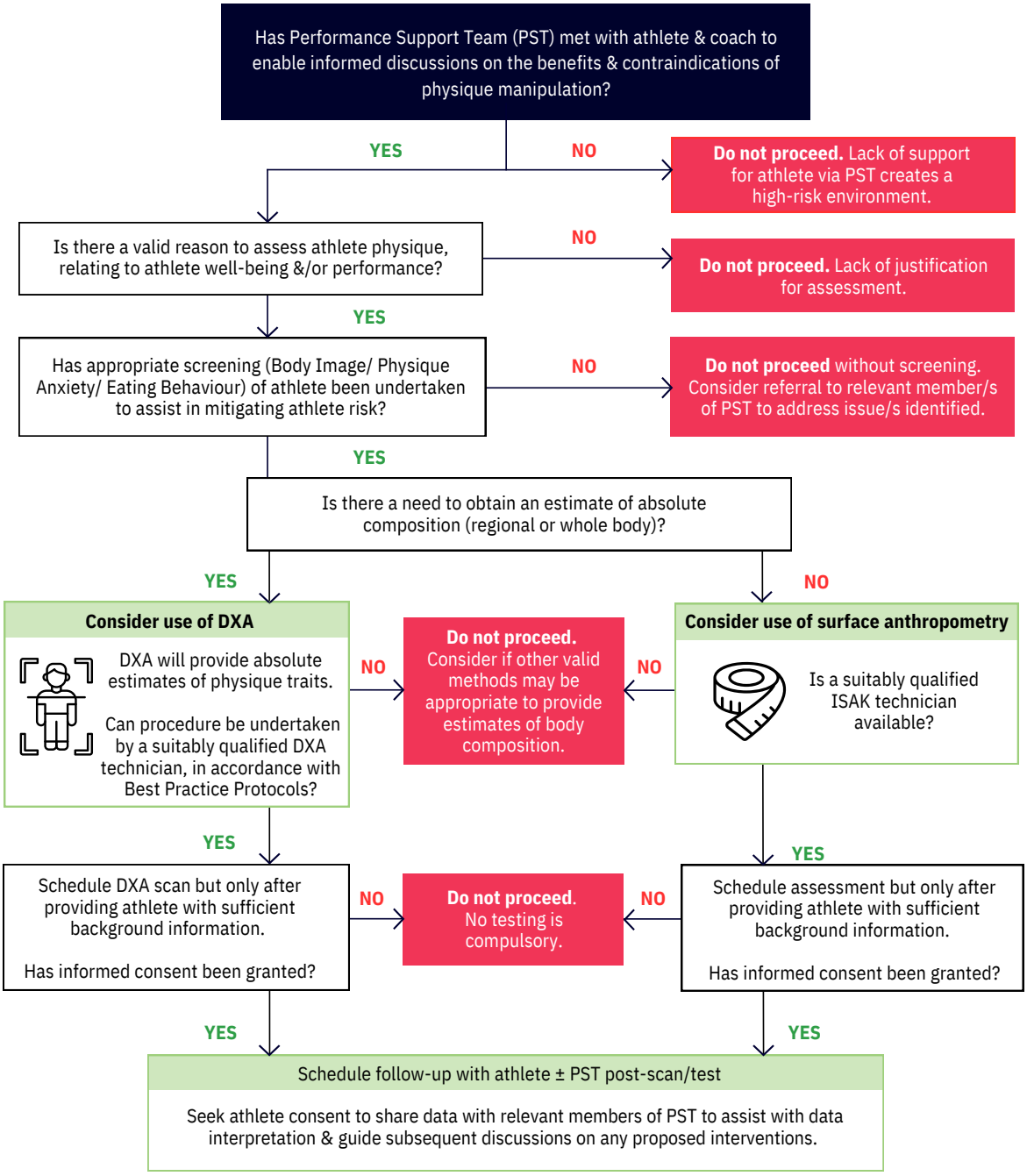
When undertaking DXA scans for the assessment of body composition, it is important to consider the appropriateness of the scan for each athlete, as well as understand and assess possible contraindications to acquiring a total body composition scan. Referring Practitioners should understand the best practice protocols relating to acquisition and analysis of DXA data. Compliance with these protocols will assist in the identification of small but potentially important changes in body composition, often observed among athletic populations.

It is important that the Practitioner:

- **Identifies a valid reason to assess physique** relating to athlete performance &/or well-being.
- **Recognises the contraindications to an athlete having a DXA scan, including...**
  - The athlete is < 18 years of age, except when parental/carer informed written consent is provided, and a case for clear justification for data collection is supported.
  - Past or current history of disordered eating (DE) or eating disorder (ED).
  - Body image concerns.
  - Lack of athlete support systems, including access to a Performance Support Team (PST).
  - Failure to provide a thorough explanation of the protocol to the athlete/ guardian, including pre-scan preparation and individual athlete feedback.
  - Where a scan(s) will result in radiation exposure in excess of annual limits.
  - Exposure to nuclear medicine examinations/ radiographic agents in the previous 48 hours (IV agents) to two weeks (oral agents).
  - Athlete weighs more than the machine's weight capacity.
  - Athlete is, or suspects they may be pregnant, or is breastfeeding.
  - Where body composition data cannot be treated as confidential health information.
  - Where precision error data specific to the Technician and DXA scanner are not available.
- **Understands the principal of ALARA as it relates to radiation exposure** i.e. As low as reasonably achievable. The ALARA radiation safety principal is based on the minimisation of radiation exposure. While radiation exposure from a DXA scan is very low relative to other imaging scans, it must still be considered. As such, the Practitioner must give consideration if the scan is deemed necessary. **As a rule, radiation safety guidelines advocate an athlete should not have more than 3-4 DXA scans per annum i.e., generally more often than every 12-18 weeks,** although there may be circumstances where repeat scans across 8 weeks may be justified, depending on anticipated change and Technician precision.

- **Understands the nuances associated with DXA to measure total body composition**, including the DXA machine used, experience of the DXA Technician, ability of the athlete to follow correct preparation and presentation guidelines, and appropriate data reporting and storage.
- **Appreciates their role in facilitating capture of high-quality data, by appropriately informing an athlete in advance of a scan the reason why the scan has been requested, the requirements and potential risks associated with a DXA scan**. The Practitioner also plays an essential role in moderate biological error by providing clear guidance on athlete requirements in advance of scans.
- **Is confident in the interpretation of data contained** within a report shared by the Technician, including the use of precision error data (specific to the Technician and DXA machine) to inform least significant change, and therefore understand longitudinal changes.
- **Recognises the sensitivity of the data, remaining vigilant in behaviours and language used in athlete engagement, and seeking athlete consent to share data with other relevant members of the PST, when deemed appropriate.**

Physique Assessment Decision Tree



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ABBREVIATIONS

AIS – Australian Institute of Sport

ALARA – As Low As Reasonably Achievable

AMS – Athlete Management System

ANZBMS – Australian and New Zealand Bone and Mineral Society

BMC – Bone Mineral Content

BMD – Bone Mineral Density

DE – Disordered Eating

DXA – Dual-energy X-ray Absorptiometry

ED – Eating Disorder

FFM – Fat Free Mass

FM – Fat Mass

HP – High Performance

ISCD – International Society for Clinical Densitometry

LEA – Low Energy Availability

LSC – Least Significant Change

LM – Lean Mass

NHANES – National Health and Nutrition Examination Survey

NIN – National Institute Network

NSO – National Sporting Organisations

PST – Performance Support Team

ROIs – Regions of Interest

TBLH – Total Body Less Head

BACKGROUND

Dual-energy X-ray Absorptiometry (DXA) is a medical imaging technology known as the reference technique to quantify bone mineral density (BMD) at specific sites to diagnose low bone mineral density and osteoporosis. However, as this technology has the capability to measure soft tissue, it has gained popularity for the assessment of body composition amongst athletes. DXA provides a measure of whole-body bone mineral content (BMC), fat mass (FM) and lean mass (LM), as well as information on regional composition (i.e., individual arms, legs, trunk). This makes DXA unique among body composition assessment techniques, thus appealing to sports nutrition Practitioners when assessing physique traits.

DXA technology is based on the differential attenuation of transmitted x-ray photons at two energy levels by bone, fat, and lean tissue. Attenuation of low energy photons are then expressed as a ratio to attenuation observed for the high-energy photons, the outcome of which is specific to different components, including fatty acids, protein, and bone. In theory, assessment of all three components would require measurement at three different photon energies. The DXA system can thus only be used to estimate the fractional masses of two components in any one pixel, which is a minute area of illumination on a display screen, with literally thousands of pixels identified in a whole-body scan. Therefore, in bone containing pixels, bone mineral and soft tissue can be measured while in non-bone containing pixels, a subdivision of fat and lean tissue can be quantified.

A total body scan measures the whole body from head to toe in just several minutes providing estimates of FM and LM, plus BMD and BMC. The DXA software also automatically sums LM and BMC together to provide a value commonly known as fat free mass (FFM). Overall soft tissue is calculated as LM and FM together, with the remainder BMC. Contemporary DXA machines typically have an active scan area equivalent to 195 x 66cm, accommodating most athletic populations. However, for particularly tall or broad athletes falling outside of these limits, an adjusted subject positioning protocol may be needed which should not impact on the validity of body composition estimates.

The ability of DXA to capture and quantify regional tissue allows comparison of left and right sections of the body, usually the trunk, arms, or legs. A total body scan will generate the data that allows regional body composition analysis. This information is useful for the assessment of regional mass for symmetrical analysis in bilaterally dominant sports, biomechanical analysis, or for monitoring the impact of injury on site-specific body composition. In some circumstances, a closer examination of a specific region of the body may be appropriate. For example, to track disuse atrophy and subsequent restoration following injury. When this is deemed appropriate, please discuss the use of custom regions of interest with your preferred DXA provider.

Standardised subject preparation and scanning technique are critical for accurate and reliable measurements and as such, it is important that DXA Technicians are appropriately trained, and athletes are well informed on the importance of standardised preparation in the lead up to a scan. Additionally, as each DXA scan exposes the athlete to a small amount of radiation, it is important that individual state and territory health and safety regulations are followed to limit athlete radiation exposure. This radiation exposure ensures DXA scans cannot be undertaken any more than 3-4 times per annum. This is typically not more often that every 12-18 weeks, however there may be circumstances where repeat scans across 8 weeks may be justified, depending on anticipated change and Technician precision. The duration between scans may limit the practicality to track longitudinal changes in body composition of athletes, at least over more acute periods of time across an annual schedule.

DXA INDICATIONS AND CONTRAINDICATIONS

Given DXA scans can quickly generate estimates of regional and whole-body composition, as well as provide insight into athlete bone health, it has become increasingly popular for use amongst athletic populations. However, the safety and well-being of the athlete should always be a priority. In particular athletes, body composition assessment has the potential to cause harm and it is impossible to understand which athletes may be vulnerable to this simply by looking at them. As such, consideration must be given to athlete informed consent, mandatory pre-scan checks and guidance on athlete presentation for a scan. Protocols should be established and implemented before, during and after assessments of body composition to reduce this risk. As such, both the Practitioner and DXA Technician need to undertake due diligence in creating a safe environment for any athlete they scan. Where it is deemed appropriate by the Practitioner based on their insights of the athlete, a screening of body image and eating behaviour concerns may be appropriate. It is also crucial that appropriate support systems within the daily training environment are in place and known to the athlete, if required before, during or after an assessment of body composition.

With the principal of 'As Low As Reasonably Achievable' (ALARA) in mind, due consideration must be given prior to referral for any DXA scan. As such, it's important to reflect on both the indications and contraindications for DXA whole body scans.

Possible indications for body composition assessment via DXA:

- Monitoring the impact of dietary and/or training interventions, especially when an absolute measure of FM and/or LM (absolute or change) is necessary.
- Monitoring the impact of detraining following injury/illness and subsequent rehabilitation, especially when an absolute measure of FM and/or LM (absolute or change) is necessary.
- Contribute to the diagnosis and management of Low Energy Availability (LEA).
- Characterisation of athletes for the determination of suitability for weight categories.
- Regional mass assessment for biomechanical analysis.
- Applied research activities.

Although the DXA Technician should confirm contraindications prior to any scan via the Mandatory Athlete DXA Screening Questionnaire **(Appendix 1)**, it is important that the referring Practitioner considers the following information prior to booking an athlete for a total body composition DXA scan.

A DXA scan should NOT be undertaken under the following circumstances:

- **The athlete is < 18 years of age**, except when parental/carer informed written consent is provided, and a case for clear justification for data collection is supported.
- **Failure to identify a valid reason for the assessment of body composition** with the support of the PST.
  - The data gained from the assessment should be used to assess or inform training and/or nutrition interventions. The data gained from this assessment is integrated into a management plan for the athlete with input from the athlete's PST.
- **Past or current history of disordered eating (DE) or eating disorder (ED)** – The appropriateness of testing an individual athlete should be discussed with the athlete and relevant members of their PST.
- **Body image concerns** – An evaluation should be made of the risk that the assessment may exacerbate body image concerns, with consideration of processes and support that are in place to safeguard the athlete.
  - Where there is concern regarding potential negative implications to athlete wellbeing from an assessment of physique traits, athlete safety should always be prioritised. In making such decisions amongst the PST, validated screening tools relating to athlete eating behaviour and body image are available.
- **Lack of athlete support systems, including access to a PST** – Consideration should be given to the PST available to the athlete in the daily training environment. If a change in body composition is justified because of the assessment, adequate expertise and support for the athlete must be provided. Where there is no access to relevant support and expertise, body composition assessment should be avoided.
- **Failure to provide a thorough explanation of the protocol to the athlete**, and where appropriate (i.e., <18 years.), their guardian, including rationale to why the scan has been requested, the requirements and risks of the scan, and subsequent informed consent.

- **Inability to provide athlete with guidelines on appropriate scan preparation** and/or athlete fails to comply with best practice guidelines for data capture.
- **Inability to schedule feedback to individual athletes** following scans on the interpretation of DXA results with an appropriate member of the athlete's PST. Typically, this would be the referring Practitioner.
- **Where a scan(s) will result in radiation exposure exceeding annual limits**, considering all other sources of radiation.
  - As a general guide, radiation safety plans of preferred DXA providers typically limit an athlete to no more than 3-4 scans annually i.e., not more often that every 12-18 weeks. Given the precision error of DXA and relatively small changes in body composition observed by most athletes, it would be difficult to justify scans more frequently than this.
  - DXA may be contraindicated amongst athletes who have had multiple other imaging investigations resulting in radiation exposure exceeding annual limits in the past 12 months e.g., more than 3 x-rays, CT scans, PET scans of the abdomen, head, chest, or spine.
- **Athlete has been exposed to nuclear medicine examinations or radiographic agents in the previous 48 hours (IV agents) to two weeks (oral agents).**
- **Athlete weighs more than the machine's weight capacity** (159-204 kg, depending on the specific DXA machine).
- **Athlete is, or suspects they may be pregnant, or is breastfeeding.**
- **Where all data related to body composition assessment (assessment, feedback, storage of data) cannot be treated as confidential health information with appropriate data security.**
- **Absence of appropriately trained and credentialed Technicians** to acquire and analyse the scan.
- **Lack of availability of appropriate equipment.** Equipment used in the assessment of body composition should be calibrated and maintained as per manufacturer's specifications and according to industry quality assurance standards. For longitudinal assessment, the same scanner should be used each time
- **Where precision error data (generated via between day repeat scans) specific to the Technician and DXA scanner are not available**, making interpretation of change impossible.
- Para athletes – **According to the type of impairment, some modification of the assessment protocol and interpretation of results may be needed.** If these cannot be accommodated, then the assessment should not proceed. For an athlete with an intellectual disability, considerations around the level of understanding of the entire process needs to be considered.

SOURCING DXA SCANS

As DXA is routinely used in the general population for the diagnosis of bone health issues, there are several options available to source DXA scans including commercial medical imaging centres, DXA specific assessment centres, and tertiary research institutes. In general, referring Practitioners will need to outsource scans. Considerations when deciding who to engage for DXA assessment include:

- **Specific DXA machine** – DXA machines from different manufacturers have individual nuances such as the size of scanning areas as well as differences in hardware and software, plus reference databases available; even different DXA machines of the same manufacturer and model may provide different results. The same machine (and software) should be used for all longitudinal monitoring. Preference should be given to larger scanning beds when dealing with athletic populations. Where a scanner is replaced (or hardware upgraded) during the longitudinal monitoring of an athlete, cross-calibration procedures in line with recommendations of the International Society for Clinical Densitometry (ISCD) should be undertaken to facilitate consistency of data capture. Likewise, if software is upgraded, it is important that prior scans are appropriately reanalyzed.
- **Technician qualifications and experience** – Total body composition scans should only be undertaken by Technicians who have completed the Australian and New Zealand Bone Mineral Society (ANZBMS) Clinical Densitometry course (or equivalent) and have completed further training with an experienced Technician in the acquisition and analysis of body composition assessment. Where possible, the same Technician should undertake scans for all longitudinal monitoring of athletes. Positioning aids should be used at each scan to ensure the athlete is positioned correctly and consistently at subsequent scans.

There are two primary commercial manufacturers of DXA machines available in Australia – GE Lunar Medical Systems Inc. (Madison, Wisconsin) and Hologic Inc. (Waltham. Massachusetts). Both provide bone density and body composition measurements, and additional features such as visceral fat assessment, advanced hip structural analysis and paediatric applications. Data should never be compared between DXA machines, even between different machines from the same manufacturer. Thus, when using DXA to assess longitudinal change, the same specific DXA machine (important for imaging centres with multiple scanners) should be used throughout, and preferably captured by the same Technician each time. More recently, Norland manufacturers have added a densitometer with larger scanning bed dimensions, that may have future application for athletic populations.

While referring Practitioners are not required to have a detailed knowledge of data acquisition and analysis, the **Best Practice Protocols for DXA Assessment of Body Composition**, specific to GE Lunar are available. Despite there being two common manufacturers of DXA machines, GE Lunar is the predominant machine used by preferred providers within the Australian HP System.

All referring Practitioners should have confirmation that the location of their outsourced total body composition DXA scans follows best practice protocols as outlined in the Best Practice Protocols for DXA Assessment of Body Composition. This includes radiation safety protocols, qualifications, and training of DXA Technicians, precision assessment data, quality assurance and quality control protocols and management of drift, servicing information, scan acquisition and scan analysis protocols.

PRE-SCAN PROCEDURES

Athletes (and their parent/guardian if <18 yrs.) must be fully informed of the procedure and risks of DXA and must complete an informed consent form prior to a DXA scan **(Appendix 2)**. Before obtaining consent, it is important that athletes are provided with sufficient information about the procedure to make a truly informed decision on whether to proceed with a DXA scan. While specific content of the information may vary depending on the specific DXA machine being used, it should include information about the DXA procedure, the amount of radiation exposure, any other risks, and the athlete's rights including why the DXA scan has been requested and how their data will be managed. All athletes should have the opportunity to ask questions about DXA in advance of scheduling a scan and be made aware that they are able to withdraw their consent at anytime prior to the scan. **Appendix 2** provides an example informed consent form that can be used across the NIN to assist in enabling an athlete to make a truly informed consent.

Referring Practitioners must also confirm athletes are eligible for scanning, prior to scheduling a DXA scan. **Appendix 3** provides an example of a Practitioner referral form that addresses relevant issues, including prior radiation history, pregnancy etc.

Referring Practitioners play a critical role in facilitating capture of the highest quality data, given they will be responsible for providing guidance to athletes on requirements in advance of a scan. Heavy training loads undertaken by athletes result in large fluxes in total body water and muscle solute content, both of which can have a marked impact on reliability of data. Pre-test guidance made available to athletes will facilitate normalisation of hydration status and muscle solute content, moderating biological error, and thus enhancing the ability of DXA to identify small but potentially important changes in body composition. **Appendix 4** provides a checklist of athlete pre-test requirements that should be shared with athletes in advance of testing, so they are able to implement in the day prior to testing.

Athlete Preparation

- Athletes are to present in an overnight fasted state (no food or fluid for at least 8 hours). This means they must not eat or drink anything on the morning of their test. However, they should be glycogen replete, with dietary guidance to facilitate this process the day before their total body composition DXA scan;
- Athletes are to present in a rested state with no exercise on the morning of the scan, and no intense exercise undertaken since lunchtime the day prior;
- Athletes are to present in an euhydrated state (well hydrated). To help facilitate this, athletes should be advised to drink one to two glasses of water with each meal/snack the day before the scan. Confirmation of hydration status can be assessed by a waking mid-stream urine sample for the analysis of urinary specific gravity (USG), or where available, bioelectrical impedance.

Athlete Presentation

- Athletes are to wear lightweight clothing with no metal artefacts or residues such as chlorine, salt water or sweat. Examples include underwear or tight shorts, and crop tops or tight singlets without bra clips or underwire;
- Athletes must empty their bladder prior to scanning;
- Athletes must remove all jewellery and clothing that contains metal (e.g., hair clips, watches, zips, underwire);
- Athletes are required to untie hair if it is tied up.

SCAN ACQUISITION

The DXA Technician will acquire and analyse total body composition scans based on the guidance in the **Best Practice Protocols for DXA Assessment of Body Composition**. Standard regions of interest will allow interpretation of the differences in body composition between left and right sides of the trunk, arms, and legs **(Figure 1)**. There may be scenarios in which a closer examination of a specific region of the body may be required. The referring Practitioner must advise the DXA Technician at the time of referral if this is required, so custom regions of interest can be created.

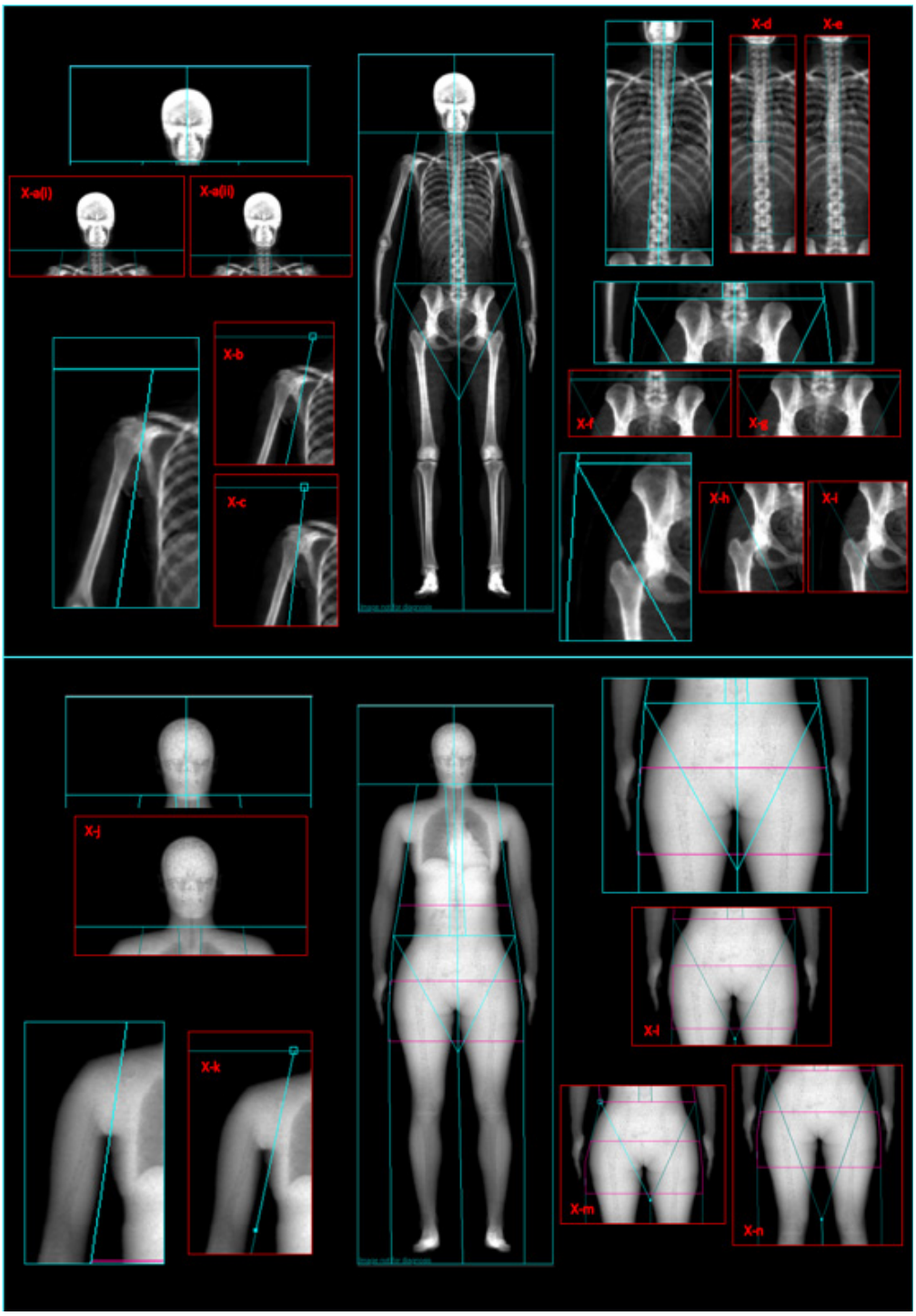


Figure 1. *Total body composition scan with markup of regions of interest (ROIs). Regions outlined in blue are correct placement of ROIs. Regions outlined in red are incorrect placement of ROIs. All ROIs are marked using bony landmarks for reference, and the soft tissue image should be used to ensure all tissue is captured in the correct ROI and symmetry is achieved.*

X-a, X-j: head line is too superior to the mandible; X-b: trunk like is too medial to the humeral-scapula joint; X-c: trunk line is too lateral to the humeral-scapula joint; X-d: spine lines are too lateral and include rib; X-e: spine lines are too medial and encroach on the spine; X-f: horizontal pelvis line is too superior; X-g: horizontal pelvis line is too inferior and encroaches on the iliac crest; X-h: diagonal pelvis line is too proximal to the pelvis and encroaches the ischium; X-i: diagonal pelvis line is too distal from the pelvis and encroaches the trochanter; X-k: trunk line is too medial and includes trunk tissue in the arm region; X-l: vertical leg lines are too medial, resulting in some leg tissue included in the arm regions; X-m: centre leg line is not centred, resulting in asymmetry of the left and right leg regions; X-n: point of the pelvis region is too superior.

Given the demands of sport, it may be common for athletes in some sports to be taller and/or broader than the scanning field.

Tall Athletes

If an athlete is too tall for the DXA machine (>195cm), they will be scanned as total body less head (TBLH) **(Figure 2)**. It is important to note that if making comparisons between longitudinal scans, or between athletes that include tall athletes, data would need to be interpreted as TBLH to make appropriate comparisons.

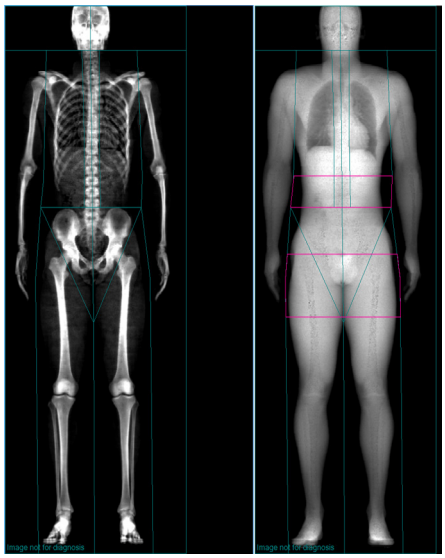


Figure 2. *Total body composition scan following AIS total body less head (TBLH) protocol.*

Broad Athletes

For broad athletes who exceed the width of the DXA bed, two different solutions are available.

Offset Scanning Procedure – Mirroring:

When a measurement of total body composition is required and symmetry is assumed, the mirroring option may be most appropriate **(Figure 3)**. This technique identifies tissue that is missing from the scan field (e.g., Left arm) and can 'mirror' this missing tissue from side of the body that is within the scan field (e.g., Right arm).

- **Note:** This technique results in body composition that is identical on each side, and may not be appropriate for injured athletes, or athletes from side-dominant sports.

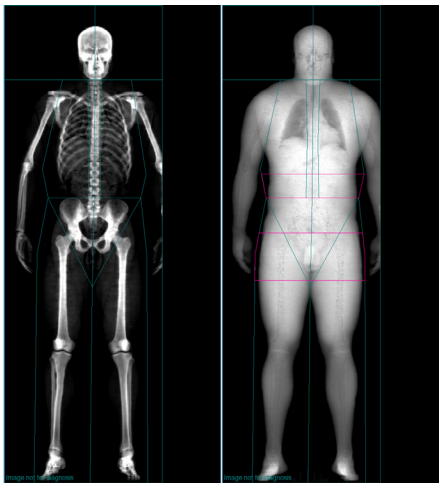


Figure 3. *Total body composition scan following AIS offset scanning protocol (mirroring)*

Combining Partial Scans:

When there is a need for accurate comparison between left and right sides, the acquisition of two body scans may be most appropriate, with results combined to obtain an estimate of total body composition [**Figure 4**].

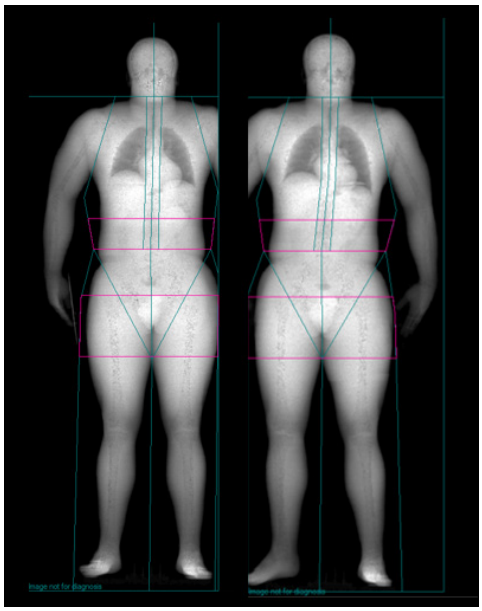


Figure 4. *Total body composition scan following AIS protocol of combining left and right-side partial scans of a broad athlete.*

Tall and Broad Athletes

For athletes who are both too tall and too broad for the scanning area, either of the protocols described for broad scans can be conducted as TBLH.

The referring Practitioner must provide detail of which technique is required at the time of referral, as amendments to the standard protocol may require additional time **(Appendix 3)**. Technical details relating to the assessment of tall and/ or broad athletes is addressed in **Appendix 5**. If this likely includes one or more of your athletes, please read through this documentation as it provides guidance on necessary steps to assist within interpretation of the data.

POST SCAN ANALYSIS

Regions of Interest (ROIs)

The enCORE software undertakes an automatic analysis of scans including ROIs based on anatomical landmarks. Because the software is not sensitive to the unique physique traits of athletes, the Technician should undertake a manual analysis to confirm, or adjust where appropriate, the ROIs (Figure 1). It is expected that the referring Practitioner has an appreciation of the correct placement of ROIs, particularly when regional body composition is of interest. Full details of the ten regions of interest can be found in the **Best Practice Protocols for DXA Assessment of Body Composition**.

Management of Artefacts (Point-Typing)

Point typing allows artefacts to be excluded from regions that are incorrectly identified as bone and tissue on the scan. Artefacts that cannot be removed prior to the scan acquisition should be considered for removal via point typing during scan analysis. These include:

- Internal or permanent artefacts (e.g., metal surgical implants following injury, silicone implants etc.)
  - In the case of longitudinal tracking of an individual with permanent artefacts, it is appropriate to retain the artifact since repeat point typing may introduce more error.
  - If the scan is to be compared to normative data, it is preferable to remove the artifact.
- External artefacts (e.g., jewellery or bra straps) that were forgotten or not able to be removed before the scan **(Figure 5)**
- Hair that has not been untied
- Clothing such as underwear with logos

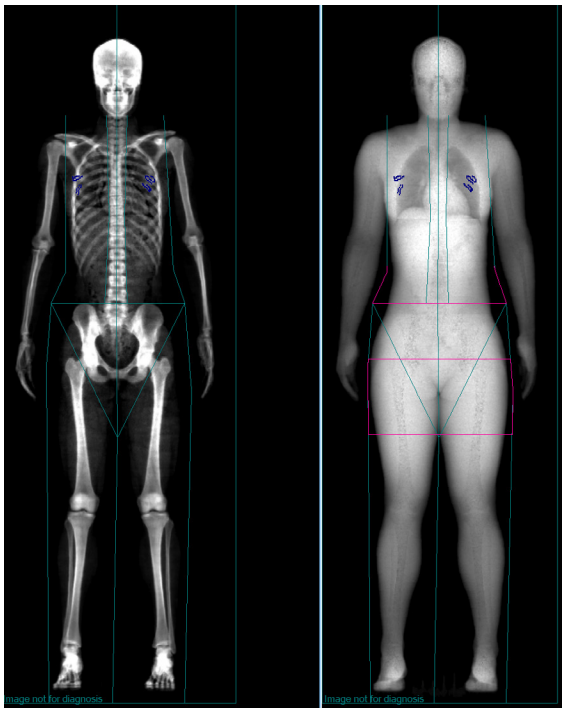


Figure 5. *Total body composition scan of an athlete wearing a bra with inappropriate clips. Bra clips are marked up as artefacts in point-typing.*

Note: if internal or permanent artefacts are present, it is important that the referring Practitioner considers how these should be managed, and notifies the DXA Technician of this.

DATA REPORTING AND INTERPRETATION

Referring Practitioners should be emailed an electronic DXA body composition report from the Technician within 24 hrs of a scan. Athletes will NOT be provided with verbal or written results from the Technician. As such, a follow up consultation should be scheduled with individual athletes to provide feedback on results, and any subsequent implications of the data. To assist with data interpretation, the expert guidance of other members of the athletes PST may be required. This may necessitate the sharing of data with relevant members. Prior to sharing an athlete's reports among other team members, consent must be obtained from the athlete. DXA scan reports must be treated as confidential health data, with the utmost care taken with data storage.

All DXA measured body composition data for athletes in the Australian HP Sports System, in particular athletes associated with a NIN or NSO, needs to be entered into the athlete management system (AMS). This will most likely be the responsibility of the referring Practitioner, however it is important to have this conversation with the DXA Technician. If reports are being sent for the Practitioner to enter into AMS, it is encouraged that reports are not emailed, and instead shared with the appropriate person(s) via secure online folders.

Contemporary DXA scanner software affords the creation of customisable total body composition reports. However, all reports should include both regional (head, trunk, including left and right trunk, arms, including left and right arm, plus legs, including left and right leg) and total body composition data across the following variables:

- Total mass
- Fat mass
- Lean mass
- Bone mineral content
- Fat free mass

A wide range of derived variables are also available, including fat mass (%), visceral adipose tissue (VAT), appendicular lean mass index (ALMI i.e., appendicular lean mass/Ht^2), lean mass index (LMI i.e. total lean mass/Ht^2) and fat mass index (FMI i.e. fat mass/Ht^2). While measures such as the ALMI, LMI and FMI have potential value in assisting to interpret data, this would require a normative database of elite athletes from a broad range of sports to contrast against. This information is not currently available.

The Technician may also include other relevant information into the report, including:

- An assessment of athlete hydration status, given hydration status can influence estimates of body composition.
- Modifications to DXA procedures specific to the athlete, including athlete positioning. As an example, broader athletes may be scanned without upper arm positioning aids, to ensure they remain within the scan area.
- Management of any artefacts. While adherence to best practice protocols will help to ensure scans are undertaken that avoid the presence of nuanced artefacts such as metal in clothing or jewellery, artefacts such as metal implants can only be managed post-scan.
  - In general, permanent artefacts such as metal screws or similar, are NOT excluded during post-scan analysis for athletes likely to undertake longitudinal assessment, despite artifacts having a small impact on estimates of body composition. This is because repeat removal of artefacts may introduce more error than the impact of the artefact itself.
  - Include when it is appropriate to mark up permanent artefacts (normative data)
- Reference database – No reference database has been verified as appropriate for highly trained athletes and their unique physique traits. As such, it is recommended the combined Geelong/Lunar database derived from an Australian population be selected, when using a GE Lunar DXA scanner.
- Precision error – specific to the DXA scanner, and preferably the Technician also. Given between day precision error calculations include both technical and biological error, this should be sourced, instead of within day estimates. The ISCD recommend the minimum acceptable precision for an individual technologist is 3% and 2% for FM and LM, respectively, however for interpreting longitudinal change, LSC for FM and LM should be quantified in grams. Once the precision error of a device is established, the least significant change (LSC) value for FM and LM (separately) can be calculated:

$$\text{LSC} = 2.77 \times \text{Precision Error}$$

Unless the change in estimates of body composition assessed longitudinally exceed the LSC, no change in composition can be confirmed. See **Appendix 6** for an example iDXA scan report, with guidance provided on the interpretation of the report.

APPENDIX 1.
DXA – MANDATORY ATHLETE SCREENING QUESTIONNAIRE

AUSTRALIAN HIGH PERFORMANCE SPORT SYSTEM
DXA - MANDATORY ATHLETE SCREENING QUESTIONNAIRE

Athlete Details

Title:	Name:
Date of birth:	Sport (category/position):
Measured stature:	Measured body mass:
Marker of hydration (USG / BIA):	

Have you had an X-Ray in the past 12-months? (eg. CT, PET, X-Ray, DXA, etc.) ☐ NO ☐ YES

If yes, please specify... type of investigation and date:

Do you have a current injury or one you are recovering from? (eg. Surgery, scoliosis, fractures, etc.)

Do you have orthopaedic pins, prosthesis, or implants? ☐ NO ☐ YES

Do you have a pacemaker? ☐ NO ☐ YES

Do you have any upcoming procedures you are preparing for? (eg. Colonoscopy, gastroscopy, etc.) ☐ NO ☐ YES

If yes, what is it?

Do you have any body piercings that can't be removed prior to scan? ☐ NO ☐ YES

Do you feel comfortable lying on your back for approximately 10-minutes? ☐ NO ☐ YES

FEMALES ONLY:

Are you currently or at risk of being pregnant? ☐ NO ☐ YES

Are you currently breastfeeding? ☐ NO ☐ YES

Total radiation exposure

Use the table below to estimate radiation exposure from imaging sources in the last 12 months. **Total exposure should NOT exceed 1000 µSv**. Furthermore, the number of DXA scans permitted in the radiation safety plan of the group in which scans are undertaken should not be exceeded, irrespective of the total annual exposure. Typically, this is 3-4 scans per annum.

RADIATION SOURCE	RADIATION EXPOSURE (µSv)	NUMBER (12 MTHS)	TOTAL EXPOSURE
DXA (total body)	1		
DXA (bone density)	4.4		
Dental x-ray	10		
Chest x-ray	20		
CT Scan	8000		
Total Exposure			

*DXA radiation exposure is based on iDXA standard scan mode. Bone density radiation exposure is based on spine + (1x) femur. Please see table below for radiation exposure from specific GE machines and different scan modes.

Indicative radiation dose to adult patients from common medical imaging procedures

REGION	PRODIGY (USV)			IDXA (USV)		
	Thin	Standard	Thick	Thin	Standard	Thick
AP Spine	0.1	0.3	0.6	0.3	1.0	2.3
Femur	0.2	0.9	1.9	0.9	3.4	7.6
Dual Femur	0.4	1.7	3.8	1.7	6.7	15.1
Forearm		0.002			0.01	
Total Body	0.1	0.1	0.3	1.0	1.0	2.0
BMD (Spine + Dual Femur)	0.5	1.8	4.1	2.7	7.7	17.1

APPENDIX 2.
DXA INFORMED CONSENT FORM

DXA INFORMED CONSENT FORM

The *[insert name of sporting organisation]*

is providing testing services to you.

The welfare of athletes is important to the

[insert name of sporting organisation]

and we only seek to undertake activities that minimises any potential harm to participants and respects their rights and integrity.

Your participation in this activity is voluntary and you may withdraw your consent freely at any time before, or during the assessment. If you become uncomfortable with any aspect of the assessment, please advise our staff who will cease all activities.

The *[insert name of sporting organisation]*

will respect your rights to restrict your information and provide you with the opportunity to ask questions and be fully informed about all aspects of the assessment.

If you are happy to continue, please read and sign the form below.

What is a DXA assessment?

DXA is a medical imaging technology that is the preferred method for assessing bone health, and more recently we've learned of its value in measuring body composition. That is the amount of lean tissue, including muscle but also internal organs, as well as bone mass and fat mass that make up your body. You may have been referred for an assessment of body composition, bone health, or both.

Trained DXA Technicians, in conjunction with radiographers and/or trained medical doctors, can use bone mineral density [BMD] scans acquired on an athlete to provide information on their bone health. BMD scans usually require a scan of an athlete's spine and one femur [hip], however in some scenarios a dual femur scan [both hips] or a forearm scan may be useful.

Among athletic populations, DXA for the assessment of body composition is best used when an estimate of absolute body composition is required, either at the whole-body level, or a specific body region. This helps monitor changes following injury and the subsequent rehab period, or to assist in assessing energy status of the body. This information can also assist in categorising athletes in weight category sports, into the most appropriate weight class to support their health and performance.

Monitoring body composition may be undertaken as it can influence your health but also performance in some sports. The impact on performance varies between sports, and it's important to recognise it's just one factor to be considered. Overemphasizing the impact of body composition on performance is inappropriate, detracting attention from far more important priorities.

What to expect?

The scan itself will only take several minutes, depending on whether you are having an assessment of bone health, body composition, or both. The DXA Technician will take their time in positioning you correctly on the scanner, helping to ensure the capture of high-quality data. To do this, they will ensure you are lying centred on the DXA scanner and will use positioning aids to ensure you are positioned the same time at every visit. There are a couple of techniques they may use to ensure your hips and spine are straight – please let your DXA Technician know if you have any current injuries.

You will be asked for your consent prior to the scan, given the sensitivities that may be associated with measurements related to your body. Females will be asked to confirm they are not pregnant prior to scanning.

How to prepare?

In order to achieve an accurate and reliable DXA scan, you will be asked to consider your diet, hydration, and exercise in the 24 hours prior to your scan. You will also be asked to undertake the DXA scan in minimal clothing and to remove jewellery. Your referring Practitioner will provide you with all necessary information in advance of your assessment.

Is a DXA scan safe?

A DXA scan does expose you to a very small amount of radiation. Everyone is exposed to naturally occurring background radiation in their everyday life. The amount of background radiation present depends on many factors, like the type of soil and rock present, altitude, latitude and an individual's diet. While this can make exposure highly variable, on average, Australians are exposed to 1700 millisievert (μSv) each year (4.7 μSv daily) from natural sources. The effective dose to an adult from a DXA scan will vary slightly depending on the manufacturer, model and scan mode used, plus type of scan, but the following provide general guidance:

- Bone mineral density DXA scan **- 4.4 μSv**
- Total body composition DXA scan **- 1 μSv**

At this dose, no harmful effects of radiation have been demonstrated as any effect is too small to measure. Thus, the risk is believed to be minimal.

All testing is undertaken in accordance with the radiation safety plan that has been approved under the confines of state-based radiation health guidelines which provide specific recommendations on accepted referral sources and scan frequency. DXA imaging comes under the regulation of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Your Technician has specialist training in the use of DXA. However, if this raises concerns for you, please discuss this with your referring Practitioner or the DXA Technician in advance of your scan.

A DXA scan should NOT be undertaken if...

Under certain circumstances, it may be inappropriate or unsafe to undergo a DXA assessment. Please check if any of the below relate to you and be sure to inform your referring Practitioner or Technician in advance of your DXA scan, preferably prior to scheduling a scan.

- ☐ **A clear rationale for testing has not been provided.** Data gained from the scan should be used to assess or inform training and/or nutrition interventions, and associated performance and/or wellbeing outcomes.
- ☐ **You (or your guardian if you are <18 yrs) are unable to provide informed consent.**
- ☐ **You are unable to lie still on your back for 5-10 minutes.**
- ☐ **You are pregnant or suspect that you may be pregnant, or are breast feeding.**
- ☐ **You have not been provided with, or are unable to comply with guidelines on appropriate preparation the day prior to, and morning of, a scheduled scan.**
- ☐ **You have had exposure to nuclear medicine examinations or radiographic agents in the previous 48 48 hours (IV agents) to two weeks (oral agents).**
- ☐ **A scan will result in an annual ionising radiation exposure that is in excess of annual limits** (>1000 μSv). Your referring Practitioner will assess this with your feedback in advance of scheduling a scan.
- ☐ **You are unable to schedule individual feedback in confidence** on the interpretation of DXA results with an appropriate member of your performance support team. Typically, this would be your referring Practitioner.
- ☐ **If there is a risk that undertaking a DXA scan may exacerbate body image concerns or your eating behaviours.**
- ☐ **Your body mass exceeds the maximum capacity of the scanner.** The weight capacity of most DXA models range between 160 and 204 kg.

When will I get the results?

Unless explicitly instructed otherwise by your referring Practitioner, the DXA Technician will not provide you with your results. Instead, follow up with your referring Practitioner for detailed feedback on your scan results and what it means for you. Results will be stored securely on the Athlete Management System (AMS). It may be appropriate to share some, or all of the results from your test with relevant members of your Performance Support Team, including your coach. However, your consent will be sought separately from your referring Practitioner before any data is shared with others. Unless explicitly specified otherwise, your data will only be made available to your referring Practitioner.

Retention of records

The *[insert name of sporting organisation]*

is required to apply the Archives Act 1983 (Cth) to maintain the security and retention of its records over time. This legally

requires the *[insert name of sporting organisation]*

to keep athlete health records (including DXA scans) and to manage them appropriately for periods up to 100 years.

Your rights

You have a right to physical privacy and respect. Please advise the DXA Technician conducting the testing of any considerations concerning bodily integrity, gender or the presence of other persons in the testing environment.

If you have questions or concerns, please feel free to reach out to your referring Practitioner to seek clarification. Remember, no testing is compulsory. If you are uncomfortable or encounter a negative experience before, during, or after your assessment, please raise this with someone you feel comfortable with. This may be the DXA Technician, your referring Practitioner, or another person in your Performance Support team. There are also independent avenues for you to seek support such as **AIS Be Heard** and the **AIS Mental Health Referral Network**.

If you are not satisfied that your rights have been upheld, you may make a confidential complaint to the Australian Sports Commission Complaints Team (**complaints@ausport.gov.au**) or through the complaints page of the ASC website.

Watch our brief video

Statement of Consent

1. I *[print name]* acknowledge and agree that:

   b. I have been provided with information relating to the use of DXA as a tool for assessing bone health and/ or body composition, which clearly describes what is involved, the potential benefits but also associated risks associated with a DXA scan. I have read and understood the contents of that document ± associated video;

   c. Relevant staff have explained to me in detail the nature, safety procedures, risks and discomforts associated with a DXA scan, and I understood their explanation; and

   d. I have been given an opportunity to ask questions, and have received a satisfactory response, about the nature, safety procedures and associated risks and discomforts of a scan, including pre- and post-scan procedures.

2. I agree that I will:

   a. present myself for the DXA scan in an appropriate condition, having abided by pre-test requirements, including diet and physical activity guidance, plus appropriate clothing clearly described to me for me by relevant staff; and

   b. advise relevant staff conducting the scan of any reasons why I should NOT undertake a DXA scan (see checkboxes under **'A DXA scan should NOT be undertaken if...'**)

3. I understand that my participation in the DXA scan is voluntary and that I may withdraw my consent freely and without prejudice (e.g. without limiting future assessment opportunities) at any time before or during the scan.

4. I understand that the information obtained during the DXA scan will be treated confidentially, respecting my rights of privacy. If it is deemed appropriate that the DXA scan results be shared with specific members of my broader performance health support team, my specific and separate consent must be sought before the data can be shared.

5. The *[insert name of sporting organisation]*

   may use broad themes, learnings and insights from DXA scans in research, education and publication to enhance our programs and practices and to improve athlete health and performance both internally and within Australian sport. Any insights created or released from DXA scans will not contain the personal information of any individual participants.

Signature of Athlete:	**Date:**
Parent/Guardian name (required if Athlete aged under 18):	
Parent/Guardian signature:	**Date:**

I, the undersigned explained to the athlete the nature of the DXA scan and to my best knowledge and belief they understood the safety procedures, risks and discomforts associated with the procedure.

Technician name:	
Technician signature:	**Date:**

Referring Practitioner or Technician to complete

Use the table below to estimate radiation exposure from imaging sources in the last 12 months. **Total exposure should NOT exceed 1000 µSv**. Furthermore, the number of DXA scans permitted in the radiation safety plan of the group in which scans are undertaken should not be exceeded, irrespective of the total annual exposure. Typically, this is 3-4 scans per annum.

RADIATION SOURCE	RADIATION EXPOSURE (µSv)	NUMBER (12 MTHS)	TOTAL EXPOSURE
DXA (total body)	1		
DXA (bone density)	4.4		
Dental x-ray	10		
Chest x-ray	20		
CT Scan	8000		
Total Exposure			

*DXA radiation exposure is based on iDXA standard scan mode. Bone density radiation exposure is based on spine + (1x) femur. Please see table below for radiation exposure from specific GE machines and different scan modes.

Indicative radiation dose to adult patients from common medical imaging procedures

REGION	PRODIGY (USV)			IDXA (USV)		
	Thin	Standard	Thick	Thin	Standard	Thick
AP Spine	0.1	0.3	0.6	0.3	1.0	2.3
Femur	0.2	0.9	1.9	0.9	3.4	7.6
Dual Femur	0.4	1.7	3.8	1.7	6.7	15.1
Forearm		0.002			0.01	
Total Body	0.1	0.1	0.3	1.0	1.0	2.0
BMD (Spine + Dual Femur)	0.5	1.8	4.1	2.7	7.7	17.1

APPENDIX 3.
DXA - PRACTITIONER REFERRAL FORM

AUSTRALIAN HIGH PERFORMANCE SPORT SYSTEM
DXA - PRACTITIONER REFERRAL FORM

Reason for Referral...

Total body composition ☐

Bone mineral density ☐ AP Spine ☐ Left femur ☐ Right femur ☐ Forearm ☐ Dual femur

Please confirm with your state-based radiation health guidelines requirements for medical referral

Athlete Details

Name:	Date of birth:
Sport:	Category/position (eg. U23 lightweight rowing):
Stature:	*If <195cm scan should be acquired capturing total body, including head. *If >195cm please measure following total body less head (TBLH) positioning protocol.
Body mass:	*Please measure body mass immediately prior to scan. If this is not possible, use body mass provided here.

> If athlete is too broad for AIS standard positioning protocol:

☐ Offset scanning procedure (mirroring) – preferred method
*estimates missing side from complete side (assuming symmetry)

☐ Two partial scans (left + right)
*requires acquisition of two TBC scans, exposing athlete to double the radiation dose

> Is a blinded scale mass measurement required?

☐ YES
☐ NO

Checklist

☐ Athlete informed of testing

☐ Athlete consent obtained

☐ Athlete 18 years of age (or over)
*If <18y parent/guardian consent required

☐ Total radiation exposure (12 months) does not exceed 1000 µSv

☐ Athlete will not be exposed to nuclear medicine examinations or radiographic agents in the 48h prior to DXA

☐ Repeat scan: Same machine, software, reference database, scan mode, and technician

☐ Machine and technician precision error is available

☐ Female only: Currently or at risk of becoming pregnant, or breastfeeding

Performance Health Support Practitioner

Name:	Date:
Email:	Organisation:

Total radiation exposure

Use the table below to estimate radiation exposure from imaging sources in the last 12 months. **Total exposure should NOT exceed 1000 µSv**. Furthermore, the number of DXA scans permitted in the radiation safety plan of the group in which scans are undertaken should not be exceeded, irrespective of the total annual exposure. Typically, this is 3-4 scans per annum.

RADIATION SOURCE	RADIATION EXPOSURE (µSv)	NUMBER (12 MTHS)	TOTAL EXPOSURE
DXA (total body)	1		
DXA (bone density)	4.4		
Dental x-ray	10		
Chest x-ray	20		
CT Scan	8000		
Total Exposure			

*DXA radiation exposure is based on iDXA standard scan mode. Bone density radiation exposure is based on spine + (1x) femur. Please see table below for radiation exposure from specific GE machines and different scan modes.

Indicative radiation dose to adult patients from common medical imaging procedures

REGION	PRODIGY (USV)			IDXA (USV)		
	Thin	Standard	Thick	Thin	Standard	Thick
AP Spine	0.1	0.3	0.6	0.3	1.0	2.3
Femur	0.2	0.9	1.9	0.9	3.4	7.6
Dual Femur	0.4	1.7	3.8	1.7	6.7	15.1
Forearm		0.002			0.01	
Total Body	0.1	0.1	0.3	1.0	1.0	2.0
BMD (Spine + Dual Femur)	0.5	1.8	4.1	2.7	7.7	17.1

APPENDIX 4.
ATHLETE PRE-TEST REQUIREMENTS

ATHLETE DXA PRE-TEST REQUIREMENTS

How to prepare?

You play an important role to ensure accurate data is captured.

Follow these steps to ensure the most accurate results:

DAY BEFORE SCAN

Eat as normal.
Do not change what or how much you would normally eat.

Be well hydrated.
Drink 1-2 glasses of water with every meal and snack.
**Check hydration status by assessing the colour of your urine – aim for a light straw colour or lighter.*

No intense training
the afternoon before your scan.

DAY OF SCAN

REST
on the morning of your scan.

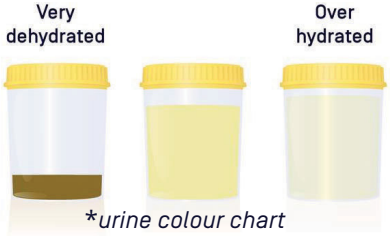
Do not eat or drink anything, including water. Your scan will be scheduled early in the morning and testing must be fasted.

Bring breakfast with you to consume afterwards, especially if you are going straight to training.

AT SCAN

Void your bladder
upon arrival.

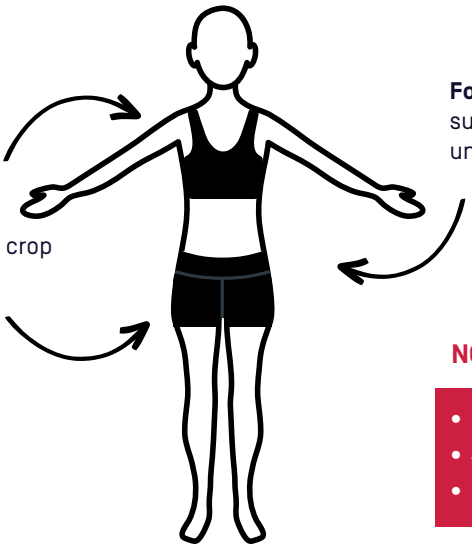
Collect a urine sample, if a specimen container was provided, so the DXA technician can assess your hydration status.



*urine colour chart

What to wear?

For females
suitable clothing will include underwear or tight shorts plus a crop top (no underwire or bra clips).



For males
suitable clothing will include underwear or tight shorts.

If possible, wear clothing without logos.

NO

- Clothing containing metal or plastics
- Jewellery, including piercings
- Hair ties/clips [remove prior to scan]

APPENDIX 5.
TEST PROCEDURES TO ACCOMMODATE TALL AND/ OR BROAD ATHLETES

TEST PROCEDURES TO ACCOMMODATE TALL AND/ OR BROAD ATHLETES

Technicians engaged by preferred providers of DXA across the NIN will have been trained in appropriate protocols for scan acquisition and subsequent analysis of particularly tall and/ or broad athletes. Each of these protocols have been validated to confirm their application in this unique population group, which can be more common in some sports. While much of the technical nuances of scanning tall and/ or broad athletes will be managed by the DXA Technician, the referring Practitioner may need to undertake some calculations from provided reports to summate total composition of the athlete. Details are provided below

Tall athletes

For athletes who exceed the length of the DXA scan bed (≥195cm on both iDXA and Prodigy), the accepted solution is to measure these athlete as 'total body less head' (TBLH). This affords athletes up to ~215cm to be scanned with confidence. Given composition of the head is unlikely to change over time, the impact of this technical adjustment is likely insignificant, even when undertaking longitudinal profiling. However, there will be marked differences between TBLH summed mass against scale mass in the report provided. This is to be expected given the head accounts for ~7% of total body mass.

Broad athletes

For broad athletes who exceed the width of the DXA scan bed (≥ 66cm on the iDXA and ≥60cm on the Prodigy), two different solutions are available:

1. Offset scanning procedure, known as mirroring (preferred method)
2. Acquisition of two partial scans

Offset Scanning Procedure - mirroring

Latest DXA software options allow the completion of a half body (right side) analysis while undertaking an estimate of left side (not totally imaged) by assuming symmetry of the body. **This procedure correlates well with whole-body measurements and is the preferred method given it is more time efficient and limits radiation exposure.** Automatic offset scanning will only mirror the part of the body that falls outside of the scan field (i.e. arm) as reflected in **Figure 1a**. Offset scanning can also be manually applied by the Technician after the scan has been completed. In this situation, software will mirror the entire left side, from the entire right side **(Figure 1b).**

Composition (Enhanced Analysis)									
Region	Tissue (%Fat)	Centile	Total Mass (kg)	Region (%Fat)	Tissue (g)	Fat (g)	Lean (g)	BMC (g)	Fat Free (g)
(e) Arms	12.3	-	11.3	11.7	10,703	1,314	9,389	560	9,950
(e) Arm Right	12.3	-	5.6	11.7	5,352	657	4,695	280	4,975
Arm Left	12.3	-	5.6	11.7	5,352	657	4,695	280	4,975
Legs	12.3	-	29.9	11.8	28,448	3,512	24,936	1,433	26,368
Leg Right	11.5	-	14.9	10.9	14,194	1,628	12,566	698	13,264
Leg Left	13.2	-	15.0	12.6	14,253	1,884	12,369	735	13,104
Trunk	13.7	-	44.0	13.4	43,016	5,910	37,107	950	38,057
Trunk Right	14.3	-	21.1	14.0	20,600	2,938	17,662	461	18,123
Trunk Left	13.3	-	22.9	13.0	22,416	2,971	19,445	489	19,934
Android	12.0	-	6.4	11.9	6,299	754	5,545	61	5,606
Gynoid	13.8	-	12.4	13.3	12,040	1,661	10,379	402	10,782

Figure 1a. *An example report generated via automatic offset scanning, where only parts of the body that fall outside the scan field are copied. In this example, only the arms fell outside the scan field, and thus data across left and right arms are exactly the same, but leg mass differs.*

Composition (Enhanced Analysis)									
Region	Tissue (%Fat)	Centile	Total Mass (kg)	Region (%Fat)	Tissue (g)	Fat (g)	Lean (g)	BMC (g)	Fat Free (g)
(e) Arms	12.3	-	11.3	11.7	10,703	1,314	9,389	560	9,950
(e) Arm Right	12.3	-	5.6	11.7	5,352	657	4,695	280	4,975
Arm Left	12.3	-	5.6	11.7	5,352	657	4,695	280	4,975
Legs	12.3	-	29.9	11.8	28,448	3,512	24,936	1,433	26,368
Leg Right	11.5	-	14.9	10.9	14,194	1,628	12,566	698	13,264
Leg Left	13.2	-	15.0	12.6	14,253	1,884	12,369	735	13,104
Trunk	13.7	-	44.0	13.4	43,016	5,910	37,107	950	38,057
Trunk Right	14.3	-	21.1	14.0	20,600	2,938	17,662	461	18,123
Trunk Left	13.3	-	22.9	13.0	22,416	2,971	19,445	489	19,934
Android	12.0	-	6.4	11.9	6,299	754	5,545	61	5,606
Gynoid	13.8	-	12.4	13.3	12,040	1,661	10,379	402	10,782

Figure 1b. *An example report generated via offset scanning applied by the Technician after the scan, where the entire left side is mirrored from data obtained from the right side.*

Combining Partial Scans

Where there is a need for accurate comparison between left and right sides (e.g., symmetry issues for a broad athlete), the acquisition of two partial body scans may be appropriate, with results combined to obtain an estimate of total body composition. As such, you may be required to collate data across two scans to obtain an estimate of whole-body composition. Analyse the scans by adding the values for total mass, total fat, total lean and total BMC for the right and left scans **(Figure 2)**.

Check that summed mass is within ~1% of scale mass captured prior to the DXA scan.

Note: This method requires the acquisition of 2x total body composition scans and therefore exposes athletes to double the radiation dose. Please inform the Technician in advance of a scan if combined partial scans are required.

If you have concerns relating to the integrity of any reports, always reach out to the relevant Technician for feedback.

Tall and broad athletes

For athletes who are both too tall and too broad for the scanning area, either of the protocols described for broad scans can be conducted as as total body less head (TBLH). Similar to a TBLH scan, scale mass of athletes measured in this way cannot be compared to DXA total mass, as tissue from the head will be missing. See **Figure 3** for guidance.

[e] – Estimated

Region	Tissue [%fat]	Region [%fat]	Tissue [g]	Fat[1] [g]	Lean[2] [g]	BMC[3] [g]	Total Mass[4] [kg]
[e] Left Arm	6.1	5.8	8,195	498	7,698	379	8.6
Left Leg	11.9	11.3	16,162	1,921	14,241	811	17.0
Left Trunk	10.4	10.1	22,949	2,384	20,565	748	23.7
[e] Left Total	10.1	9.7	48,987	4,935	44,052	2,119	51.1
Right Arm	6.1	5.8	8,195	498	7,698	379	8.6
Right Leg	11.9	11.3	16,329	1,940	14,389	819	17.1
Right Trunk	10.4	10.0	20,495	2,128	18,367	692	21.2
Right Total	10.0	9.5	48,697	4,852	43,845	2,314	51.0
[e] Arms	6.1	5.8	16,391	996	15,395	759	17.1
Legs	11.9	11.3	32,491	3,862	28,630	1,630	34.1
Trunk	10.4	10.1	43,444	4,512	38,932	1,439	44.9
Android	9.5	9.4	5,546	528	5,018	79	5.6
Gynoid	14.7	14.3	14,188	2,092	12,096	436	14.6
[e]	**10.0**	**9.6**	**97,684**	**9,787**	**87,897**	**4,433**	**102.1**

[e] – Estimated

Region	Tissue [%fat]	Region [%fat]	Tissue [g]	Fat[1] [g]	Lean[2] [g]	BMC[3] [g]	Total Mass[4] [kg]
Left Arm	5.9	5.6	7,818	462	7,356	369	8.2
Left Leg	11.7	11.1	16,007	1,873	14,134	792	16.8
Left Trunk	11.2	10.9	22,754	2,559	20,194	776	23.5
Left Total	10.4	9.9	49,013	5,086	43,927	2,209	51.2
[e] Right Arm	5.9	5.6	7,818	462	7,356	369	8.2
Right Leg	11.7	11.1	16,479	1,928	14,551	815	17.3
Right Trunk	11.3	10.9	21,742	2,440	19,293	742	22.5
[e] Right Total	10.3	9.9	49,069	5,078	44,018	2,255	51.4
[e] Arms	5.9	5.6	15,635	924	14,712	737	16.4
Legs	11.7	11.1	32,486	3,801	28,685	1,606	34.1
Trunk	11.3	10.9	44,495	5,008	39,487	1,517	46.0
Android	11.2	11.1	5,493	618	4,875	77	5.6
Gynoid	14.2	13.8	14,143	2,006	12,137	428	14.6
[e] Total	**10.4**	**9.9**	**98,109**	**10,164**	**87,945**	**4,463**	**102.6**

1. To manually calculate total fat mass, add right total fat + left total fat.
2. To manually calculate total lean mass, add right total lean + left total lean.
3. To manually calculate total BMC, add right total BMC + left total BMC.
4. To manually calculate total mass, add right total mass + left total mass.

Figure 2. *Manual calculation of body composition for broad athletes from the summation of two scans*

[e] – Estimated

Region	Tissue [%fat]	Region [%fat]	Tissue [g]	Fat[1] [g]	Lean[2] [g]	BMC[3] [g]	Total Mass[4] [kg]
[e] Left Arm	6.1	5.8	8,195	498	7,698	379	8.6
Left Leg	11.9	11.3	16,162	1,921	14,241	811	17.0
Left Trunk	10.4	10.1	22,949	2,384	20,565	748	23.7
[e] Left Total	10.1	9.7	48,987	4,935	44,052	2,119	51.1
Right Arm	6.1	5.8	8,195	498	7,698	379	8.6
Right Leg	11.9	11.3	16,329	1,940	14,389	819	17.1
Right Trunk	10.4	10.0	20,495	2,128	18,367	692	21.2
Right Total	10.0	9.5	48,697	4,852	43,845	2,314	51.0
[e] Arms	6.1	5.8	16,391	996	15,395	759	17.1
Legs	11.9	11.3	32,491	3,862	28,630	1,630	34.1
Trunk	10.4	10.1	43,444	4,512	38,932	1,439	44.9
Android	9.5	9.4	5,546	528	5,018	79	5.6
Gynoid	14.7	14.3	14,188	2,092	12,096	436	14.6
[e] **Total**	**10.0**	**9.6**	**97,684**	**9,787**	**87,897**	**4,433**	**102.1**

[e] – Estimated

Region	Tissue [%fat]	Region [%fat]	Tissue [g]	Fat[1] [g]	Lean[2] [g]	BMC[3] [g]	Total Mass[4] [kg]
Left Arm	5.9	5.6	7,818	462	7,356	369	8.2
Left Leg	11.7	11.1	16,007	1,873	14,134	792	16.8
Left Trunk	11.2	10.9	22,754	2,559	20,194	776	23.5
Left Total	10.4	9.9	49,013	5,086	43,927	2,209	51.2
[e] Right Arm	5.9	5.6	7,818	462	7,356	369	8.2
Right Leg	11.7	11.1	16,479	1,928	14,551	815	17.3
Right Trunk	11.3	10.9	21,742	2,449	19,293	742	22.5
[e] Right Total	10.3	9.9	49,096	5,078	44,018	2,255	51.4
[e] Arms	5.9	5.6	15,635	924	14,712	737	16.4
Legs	11.7	11.1	32,486	3,801	28,685	1,606	34.1
Trunk	11.3	10.9	44,495	5,008	39,487	1,517	46.0
Android	11.2	11.1	5,493	618	4,875	77	5.6
Gynoid	14.2	13.8	14,143	2,006	12,137	428	14.6
[e] **Total**	**10.4**	**9.9**	**98,109**	**10,164**	**87945**	**4,463**	**102.6**

1. To manually calculate "headless" fat, add right arm fat + right leg fat + right trunk fat + left arm fat + left leg fat + left trunk fat.
2. To manually calculate "headless" lean, add right arm lean + right leg lean + right trunk lean + left arm lean + left leg lean + left trunk lean.
3. To manually calculate "headless" BMC, add right arm BMC + right leg BMC + right trunk BMC + left arm BMC + left leg BMC + left trunk BMC.
4. To manually calculate "headless" mass, add right arm mass + right leg mass + right trunk mass + left arm mass + left leg mass + left trunk mass.

Figure 3. *Manual calculation of body composition for tall and broad athletes.*

APPENDIX 6.
EXAMPLE IDXA SCAN REPORT

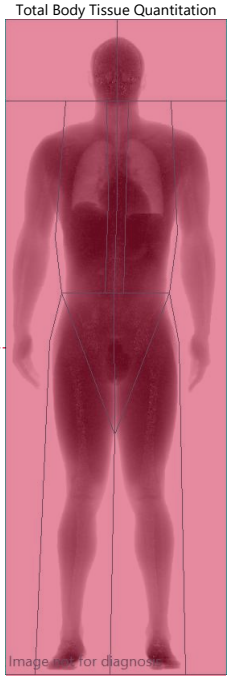
EXAMPLE IDXA SCAN REPORT

Physique & Fuel Centre

Australian Institute of Sport
Leverrier St, Bruce ACT 2617

Patient:	,			**Referring Physician:**	(not specified)
Birth Date:		**Age:**		**Attendant:**	
Height:	186.0 cm	**Weight:**	90.4 kg	**Measured:**	26/11/2019 6:38:21 AM (16 [SP 2])
Sex:	Male	**Ethnicity:**	White	**Analyzed:**	22/07/2022 2:04:33 PM (18 [SP 3])

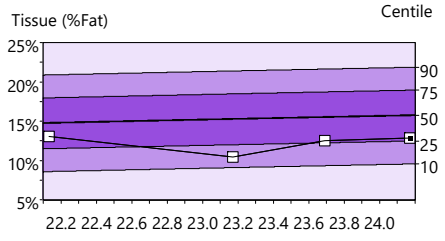
Total Body Tissue Quantitation



Composition (Enhanced Analysis)

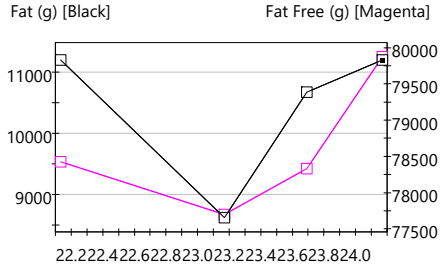
Region	Total (%Fat)	Centile	Total Mass (kg)	Fat (g)	Lean (g)	BMC (g)
Arms	9.3	-	11.5	1,065	9,822	571
Arm Right	9.1	-	5.7	524	4,932	287
Arm Left	9.5	-	5.7	541	4,890	285
Legs	12.4	-	31.4	3,874	26,010	1,468
Leg Right	13.2	-	15.8	2,092	12,961	746
Leg Left	11.5	-	15.6	1,782	13,048	721
Trunk	12.4	-	43.7	5,433	37,089	1,198
Total	12.3	28	91.1	11,190	76,016	3,859
Total Right	12.5	-	45.2	5,663	37,592	1,934
Total Left	12.0	-	45.9	5,527	38,423	1,925

Total Body: Total



Australia (Combined Geelong/Lunar)

Composition Trend: Total



Australia (Combined Geelong/Lunar) Trend: Total (Enhanced Analysis)

Measured Date	Age (years)	Total (%Fat)	Centile	Total Mass (kg)	Tissue (g)	Fat (g)	Lean (g)	BMC (g)	Fat Free (g)
26/11/2019	24.1	12.3	28	91.1	87,206	11,190	76,016	3,859	79,874
4/06/2019	23.6	12.0	27	89.0	85,194	10,665	74,529	3,802	78,331
26/11/2018	23.1	10.0	16	86.3	82,485	8,624	73,861	3,838	77,699
13/11/2017	22.1	12.5	36	89.6	85,682	11,194	74,488	3,935	78,423

COMMENTS: USG: 1.033

Statistically 68% of repeat scans fall within 1SD (± 0.4 % Fat, ±150 g Tissue Mass, ±280 g Fat Mass, ±310 g Lean Mass for Total Body Total); Australia (Combined Geelong/Lunar) Total Body Composition, Male Reference Population (v113); Composition Matched for Age, Sex
Date created: 20/09/2022 12:32:58 PM 18 [SP 3]; Filename: blackr_48ij1q4igh.meb; Total Body; 100,0.19:153.85:15.6 0.00:-1.00 2.40x3.04 12.8:%Fat=12.8%; 0.00:0.00 0.00:0.00; Scan Mode: Standard; 3.0 µGy; 3.88 cGy*cm²

GE Healthcare

Lunar iDXA
ME+210545

Footnotes

1. **Height & Weight data**: Captured immediately prior to every scan using a calibrated stadiometer and body mass scales. This scale mass should be within 1% of the DXA total mass, except for a TBLH scan for a tall athlete. When DXA total mass is >1% below scale mass, confirm all body regions have been captured in the scan.

   Note: Self-reported stature and body mass are not sufficient.

2. **Measured & Analyzed**: Timing of the measure will assist in confirming if the scan was undertaken early in the morning. A delay in analysis after measurement is not generally an issue, but scans measured later in the day are less likely to be overnight fasted (including nil fluid), violating best practice protocols.

3. **Total Body Tissue Quantification Image**: All body regions should appear within the rectangle. Areas falling outside of this may indicate failure of an athlete to be positioned within the scan region, potentially impacting the validity of the test. For tall or broad athletes, exceeding the scanning region, this cannot be avoided. However, the Technician can modify the test protocol to accommodate larger athletes without compromising validity of the scan.

   Note: Correct placement of regions of interest (ROIs) should be apparent, as well as markup of any artefacts.

4. **Composition (Enhanced Analysis):** Provides estimates of regional composition, including fat (grams, percentage and centile) lean and bone mineral content (BMC). Fat mass tends to be symmetrically distributed across left and right sides. However, asymmetries may exist for lean and bone mineral content, either because of nuances of the sport, left-right dominance or prior injury. As a guide, differences between left and right arms should be <200-300g for lean mass, often with the dominant arms carrying more lean mass. Between left and right legs, differences in lean mass are typically <500g.

5. **Total Body Composition:** Provides estimates of whole-body composition, including fat (grams, percentage and centile) lean, bone mineral content (BMC), and fat free (sum of lean and BMC) for current scan, as well as prior scans. The most recent data appears at the top of the table. Precision error data from the DXA Technician is required to interpret longitudinal changes in fat and lean tissue. Precision error data affords the calculation of least significant change values, which can be used to interpret longitudinal data.

- Interpreting composition change via % fat is discouraged, given this value is influenced just as much by changes in lean mass as it is fat mass.
- Body fat centile data indicates where a person sits relative to a reference population. For data captured on 26/11/2019, % fat sits on the 28th centile i.e. 28% of the specific population (matched for sex and ethnicity) are below that percentage fat, 72% are above it. Given the reference population represent the general population, and not an athletic population, it has limited application for athletes.
  - Centiles should not be used to monitor change in body composition over time. Absolute values (g) or delta values should only be used to assess changes in body composition.
- The table also confirm the use of the Combined Geelong/ Lunar reference database. While the International Society for Clinical Densitometry (ISCD) advocate use of the National Health and Nutrition Examination Survey (NHANES) reference database, a preferred database has NOT been confirmed for athletic populations. The Combined Geelong/ Lunar database has been chosen, given it is derived from an Australian population.
- For athletes <20 yrs, data will display TBLH data, however settings can be adjusted to reflect total data (including head).

6. **Comments: USG 1.033** Depending on the preferred DXA provider, an assessment of the pre-scan bladder void urine sample may have been undertaken. This is used to confirm on hydration status, given being hypohydrated (as is the case here) may result in an underestimate of lean mass. Unfortunately, there is currently no way of being able to correct lean mass based on presenting hydration status. Athletes should be reminder to increase fluid intake the day prior to testing to facilitate a state of euhydration.
   - Any modifications to the BPPs should also be noted here; for example acquisition of tall and/or broad athlete, amendments to positioning of athlete, and markup of artefacts as examples.
   - The Technician should also provide details of machine and Technician specific precision error to assist in the interpretation of longitudinal change.

APPENDIX 7.
COMMON DXA RELATED QUESTIONS AND ANSWERS

COMMON DXA RELATED QUESTIONS AND ANSWERS

Can total or regional bone mineral density captured from a total body scan, be used as a screening tool for the identification of athletes at risk of low bone mineral density or osteoporosis?

Bone mineral density data from a whole-body scan can NOT be used to diagnose bone health. Instead, only regional scans (anterior-posterior spine and/or femur) can be used diagnostically. There is interest in the use of whole-body bone mineral density data (either whole body or region specific) to triage those athletes requiring follow up regional scans. Watch this space.

Can a 'phantom head' be developed for the estimation of total body composition for tall athletes measured as total body less head (TBLH)?

Contemporary DXA scanners have a scan area equivalent to 195 x 66cm. The International Society for Clinical Densitometry (ISCD) recommend such individuals should have their body composition assessed as Total Body Less Head (TBLH). The latest iDXA software (V18.0) automates this and this output is available on scans. For older software versions, this must be manually calculated, by adding trunk, arms and legs data for lean, bone mineral content and fat. While this adjustment accommodates body composition assessment of individuals up to ~215cm, it does NOT allow a comparison of DXA summed mass against scale mass, measured immediately prior to a scan, a comparison that is encouraged when attempting to confirm on the integrity of a scan. As such, there is interest in establishing a phantom head, that could be added to trunk, arms and legs data to provide a whole body estimate of composition. Watch this space.

What is the impact of diet and physical activity standardisation the day prior to testing on precision error of DXA?

Preliminary research suggests that the standardisation of diet and physical activity in the day prior to DXA scans can markedly reduce biological error associated with longitudinal scans, improving precision error and enhancing the ability of DXA to identify small changes in physique traits. This needs to be confirmed in follow up investigations before it can be incorporated into DXA Best Practice Protocols. The practicality of replicating food and activity prior to all subsequent DXA scans also needs to be considered.

Can indices of hydration status be used to correct estimates of lean mass measured by DXA?

Analysis of pre-scan bladder void urine samples confirms athletes can present for DXA scans in a hypohydrated state, despite guidance to prevent this. Hypohydration results in an underestimation of lean mass, but it is not currently possible to 'correct' for this based on indices of hydration such as urinary specific gravity. There is interest in concurrently capturing estimates of total body water via impedance, but research to validate this remains to be undertaken. Until then, continue to encourage athletes to increase total daily fluid intake in the day prior to testing to assist in ensuring they present in a euhydrated state.

What is the most appropriate reference database for the comparison of athlete body composition?

The ISCD recommend the use of the NHANES reference database for estimates of body composition. However, this data comes from normative data on an American population, which unlikely reflects the unique physique traits of athletes populations, given their potential extremes in lean mass and fat mass. Until new information becomes available, Technicians have been encouraged to use the combined Geelong/Lunar database, given it is derived from an Australian population. Changing the reference database WILL influence estimates of body composition so changing the reference database is not something that should be considered lightly.

What impact do artefacts such as metal inserts have on estimates of body composition?

The specific impact of artefacts is likely impacted by the composition and size of the artefact, as well as the specific DXA scanner. Based on preliminary research on Hologic scanners, both metal artifacts and breast implants increase estimates of whole body bone mineral density and/or bone mineral content by upwards of 5-10%, but have little impact on estimates of fat and lean mass.

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