

CT Body Composition Reading Center Methodology

CT Scan Reading Center Purpose

The CTSRC at the University of Colorado Health Sciences Center (UCHSC) was responsible for reading and analyzing the CT body composition scans obtained for the Health ABC protocol. Functions of the CTSRC included:

- Train the CT technologists at each site on CT scan collection, storage and transmittal protocols and provide continuous technical support for each site.
- Provide quality control and clinical review of the CT scans for each site.
- Perform quantitative analysis on each Body Composition CT image obtained.

CT Body Composition Scan Protocol

Axial CT scans at the L4-L5 and mid-thigh level were obtained on each participant during their first examination of the Health ABC protocol. The CT body composition scans consist of a lateral abdominal scout, a single axial image at L4-L5, an AP thigh scout and a single axial image at mid-thigh.

All CT images were acquired on the scanners listed for each site below.

- GE 9800 Advantage - Pittsburgh Computerized Tomography Associates.
- Siemens Somatom Plus - U of Tennessee, Memphis, TN
- Picker PQ 2000S – St. Joseph’s Hospital, Memphis, TN

In this population, the only exclusion criterion was severe debilitation such that the participant was unable to lie supine. Pregnancy as an exclusion criteria was not an issue in this population. If a participant’s size was such that not all of the skin and subcutaneous fat could be captured in the CT image, the site was requested to perform the imaging anyway, using the largest display field of view available. Although a subcutaneous fat calculation could not be made for such a participant, all other parameters were measured.

A summary of approximate radiation doses for the body composition protocol follows. Note that exact doses are scanner- and protocol- dependent.

Scan	Effective Whole Body Dose (microSv)
Abdomen from lateral scout:	100
Abdomen, L4-L5 axial slice:	100
Thigh from AP scout:	15
Mid-thigh from axial slice:	30

For imaging, participants were placed in the supine position with the arms above the head and toes directed toward the top of the gantry, as routine for a body CT. For the thigh CT, the participant's legs were flat on the table. For the abdominal CT, the participant's legs were elevated with a cushion, to reduce the lordotic curve in the back.

To locate the mid-thigh scan position, an AP scout including the entire femur was obtained. The femoral length was measured in cranial-caudal dimension, and the scan position determined as the midpoint of the distance between the medial edge of the greater trochanter and the intercondyloid fossa. This measurement was done using the right leg, unless otherwise indicated on the exam referral sheet from the HABC clinic. A single, 10mm thick, axial image was obtained at the femoral midpoint, making sure that the entire circumference of both thighs were included in the field of view. The recommended scanning parameters for this image were 120kVp and 200-250mAs. Actual values used for each image are included in the dataset reported to the coordinating center.

To locate the abdominal L4/L5 scan position, a lateral scout covering T4 through the upper sacrum was obtained. The L4-L5 disc space was located on this scout by counting the (non rib-bearing) lumbar vertebrae. In the unusual event that there were six non rib-bearing lumbar vertebrae, the interspace closest to the iliac crest was considered to be L4-L5. A single abdominal image at L4-L5, during suspended respiration, was obtained. The recommended scanning parameters for this image were 140kVp and 300-360mAs. Actual values used for each image are included in the dataset reported to the coordinating center.

CT image were then transfered to CTSRC via:

- 9-track magnetic tape - Pittsburgh Computerized Tomography Associates.
- 5.25 inch MOD - U of Tennessee.
- 8mm tape – St. Joseph's

CT Scan Quality Control and Clinical Review

Once images were received at the CTSRC, they were read onto an image review workstation. A quality review was performed on each participant's images to assure that all images were present, that the proper scan techniques were used and that the image was of appropriate quality for analysis. In addition, a clinical review of all images was done

to determine if any pathology was demonstrated. Any such pathology was reported to the clinical imaging center. Parameters that were recorded during this review process are given in the attached Table 1.

CT Scan Image Analysis

Images were then network transferred (TCP/IP protocols) to a SUN Workstation (SPARCstation II, Sun Microsystems, Mountain View, CA) for review. Muscle and fat content of the abdomen and thigh was calculated from the axial, body composition CT images. The analysis software was written in-house using IDL development software (RSI Systems, Boulder, CO). This software is capable of reading the image header from these various scanners allowing automated determination of the image and pixel sizing. Areas were calculated by multiplying the number of pixels of a given tissue type by the pixel area. Density values were determined by averaging the CT number (pixel intensity) values of the regions outlined on the images. CT numbers are defined on a Hounsfield Unit (HU) scale where 0 equals the HU of water and -1000 equals the HU of air.

For adipose tissue area determination, the determination of tissue type basically relies on a bimodal image histogram resulting from the distribution of CT numbers in fat tissues and muscle (Seidell, 1993). These peaks are readily separable and the area of fat in the image is determined by the area under the fat peak of the histogram. The histogram is determined from sampling of the entire image. Thus we use each participant's image as its own control in determining the range of CT values that determine the fat intensity. This eliminates errors that may result if a drift in CT numbers has occurred in the calibration of the CT scanner.

In the abdominal image, visceral fat is separated from subcutaneous fat by manually drawing a line through the abdominal muscles or the fascial plane which separates the two fat compartments. For the thigh image, the intermuscular fat is separated from the subcutaneous fat by drawing a line along the deep fascial plane surrounding the thigh muscles. When the plane is not evident, the fat-muscle border is used.

Once the adipose tissue is segmented from the images, the individual muscles are identified. In the abdominal image, muscles are well outlined by adipose tissue and the adipose tissue border is used to identify the muscle border. The primary exceptions to this rule are separation of the anterior extent of the lateral abdominal muscles from the lateral extent of the rectus muscles, separation of the posterior extent of the lateral abdominal muscles from the iliac crest and separation of the inferior margin of the psoas muscle from the L4/L5 disk. These borders are outlined manually, with internal controls in place to assure that no bone density pixels are included in the muscle area.

The same procedure is used in outlining the muscle groups of the thigh. In addition the inferior portion of the muscle groups border the femur which is defined as any pixel with an intensity greater than 150HU. Muscle-muscle borders are manually drawn.

Calculated and reported values obtained from the image analysis of the abdominal and thigh images are listed in Tables 2 and 3. Reproducibility was assessed by reanalysis of a 5% convenience sample of the images (both thigh and abdomen). These results are presently at the coordinating center for analysis. Our preliminary analysis indicates that all areas are reproducible within 5%.

Table 1. Fields related to Image Quality and Data Acquisition

Participant ID

Health ABC Participant Id (ie.,HA1234)

Acrostic

Health ABC acrostic from the participants name.

Study

Always “HABC”

EXAM Date

Date the CT Exam was performed.

Operator ID

Code for the CT technologist who performed the exam.

HABC EXAM

Exam sequence, 1=first exam, 2=2nd exam, etc.

Date Read

Date that QC was performed on images.

ABD level

This is the vertebral level at which the image was acquired. Protocol dictates this to be at the L4/L5 disk space.

ABD Slice thick (mm)

This the thickness of the acquired CT image. According to protocol, it should be 10mm. Thinner slices will have more noise. Units of millimeters.

ABD kVp

This is the energy at which the abdominal CT image is acquired (kVp = peak kilovolts). Normally it should be 120 or 140. A much lower energy (less than 100) would affect the quality of the image, introducing more noise, and decrease the accuracy of the calculation.

ABD maS

This is the Xray tube current (in milliamps) times the exposure time (in seconds) for the acquisition of the abdominal study. This will vary, dependent on the size of the participant. A larger value is required to get a good quality image for larger participants. Units of milliamp-sec.

ABD pathology

This is coded 0 or 1.

0 = No reported pathology

1 = Reported pathology, some calculated variables may not be available.

QC-metal problem

This is coded 0,1 or 2 for image quality problems in the abdominal image.

0 = No metal artifact in image;

1 = minimal metal artifact;

2 = artifact affecting the calculation, some calculated variables may not be available.

QC-FOV problem

This is coded 0,1 or 2 for image quality problems in the abdominal image.

0 = Appropriate FOV;

1 = small amount of Subcutaneous Fat (SF) cut off on image;

2 = large amount of SF fat cut off - SF result will not be calculated.

QC-breathing

This is coded 0,1 or 2 for image quality problems in the abdominal image.

0 = No breathing artifact in image;

1 = minimal breathing artifact;

2 = breathing artifact affecting the calculation, some calculated values may not be available.

QC-quality problems

This is coded 0,1 or 2 for image quality problems in the abdominal image.

0 = Image quality is acceptable;

1 = minimal quality degradation;

2 = poor quality affecting the calculation, some calculated variables may not be available.

TH-femur length (mm)

Length of the femur as measured on the CT scout image. Femur length is measured as the distance between the medial edge of the greater trochanter and the intercondyloid fossa. A missing value indicates that the scout did not cover the entire femur and the femur length could not be measured. Units of millimeters.

TH-scan location (mm)

Location of the thigh image plane, measured from the medial edge of the greater trochanter on the CT scout image. According to protocol, the thigh image plane should be at the center of the femur using the femur length measurement above. Therefore, according to protocol, this value should be one-half of the measured femur length above. If the femur length value is missing and this value is present, then the CT scout did not cover the entire femur but did include the medial edge

of the greater trochanter and the scan location could be determined. A missing value in this field indicates that the scout did not include the medial edge of the greater trochanter. Units of millimeters.

TH-slice thick (mm)

Thickness of the acquired CT thigh images. According to protocol, it should be 10mm. Thinner slices will have more noise. Units of millimeters.

TH- kVp

This is the energy at which the CT thigh image is acquired (kVp = peak kilovolts). Normally it should be 120 or 140. A much lower energy (less than 100) would affect the quality of the image, introducing more noise, and decrease the accuracy of the calculation.

TH - maS

This is the Xray tube current (in milliamps) times the exposure time (in seconds) for the acquisition of the thigh study. This will vary, dependent on the size of the participant. A larger value is required to get a good quality image for larger participants. Units of milliamp-sec.

TH - pathology

This is coded 0 or 1.

0 = No reported pathology

1 = Reported pathology, some calculated variables may not be available.

QC TH Artifacts

This is coded 0,1 or 2 for image quality problems in the thigh image.

0 = No artifact in image;

1 = minimal artifact;

2 = artifact affecting the calculation, some calculated variables may not be available.

LEG

Value is L or R to indicate the leg on which the scan plane determination was made.

Table 2. Fields Related to Abdominal Calculations

Date Read

Date that the following analyses were performed.

ABD FOV (mm)

Field of view of the abdominal image. Units of millimeters.

Abdomen Sag Diam (mm)

Maximum sagittal diameter as measured from the abdominal CT image. This is a midline measurement from the posterior skin line, anteriorly to the maximum extension of the anterior skin line. Units of millimeters.

Abdomen Total Area

Area of entire region defined as abdomen in the abdominal CT image. Includes all tissue types (muscle, fat, vascular, skin, bowel...) and air in abdomen. Units of cm-sq.

Abdomen VF Area1

Area of region defined as visceral fat in the abdominal image. First measurement. Units of cm-sq.

Abdomen VF Area2

Area of region defined as visceral fat in the abdominal image. Second measurement for participants involved in reproducibility study. Units of cm-sq.

Abdomen SF Area1

Area of region defined as subcutaneous fat in the abdominal image. First measurement. Units of cm-sq.

Abdomen SF Area2

Area of region defined as subcutaneous fat in the abdominal image. Second measurement for participants involved in reproducibility study. Units of cm-sq.

Area- R rectus

Area of region defined as right rectus muscle in the abdominal image. Units of cm-sq.

Area- L rectus

Area of region defined as left rectus muscle in the abdominal image. Units of cm-sq.

Area-R lat abdominal

Area of region defined as right lateral abdominal muscles in the abdominal image. Units of cm-sq.

Area-L lat abdominal

Area of region defined as left lateral abdominal muscles muscle in the abdominal image. Units of cm-sq.

Area-R psoas

Area of region defined as right psoas muscle in the abdominal image. Units of cm-sq.

Area-L psoas

Area of region defined as left psoas muscle in the abdominal image. Units of cm-sq.

Abdomen VF Density

Average CT density of region defined as visceral fat in the abdominal image. Units of HU where water is set to 0 as a standard.

Abdomen VF Density SD

Standard deviation of average CT density of region defined as visceral fat in the abdominal image. Units of HU where water is set to 0 as a standard.

Abdomen SF Density

Average CT density of region defined as subcutaneous fat in the abdominal image. Units of HU where water is set to 0 as a standard.

Abdomen SF Density SD

Standard deviation of Average CT density of region defined as subcutaneous fat in the abdominal image. Units of HU where water is set to 0 as a standard.

R rectus Density

Average CT density of region defined as R rectus muscle in the abdominal image. Units of HU where water is set to 0 as a standard. Decrease in any muscle density over normal muscle is usually an indication of a fatty muscle.

R rectus Density SD

Standard deviation of Average CT density of region defined as R rectus muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

L rectus Density

Average CT density of region defined as L rectus muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

L rectus Density SD

Standard deviation of Average CT density of region defined as L rectus muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

R lat abdominal Density

Average CT density of region defined as R lateral abdominal muscles in the abdominal image. Units of HU where water is set to 0 as a standard.

R lat abdominal Density SD

Standard deviation of Average CT density of region defined as R lateral abdominal muscles in the abdominal image. Units of HU where water is set to 0 as a standard.

L lat abdominal Density

Average CT density of region defined as L lateral abdominal muscles in the abdominal image. Units of HU where water is set to 0 as a standard.

L lat abdominal Density SD

Standard deviation of Average CT density of region defined as L lateral abdominal muscles in the abdominal image. Units of HU where water is set to 0 as a standard.

R psoas Density

Average CT density of region defined as R psoas muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

R psoas Density SD

Standard deviation of Average CT density of region defined as R psoas muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

L psoas Density

Average CT density of region defined as L psoas muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

L psoas Density SD

Standard deviation of Average CT density of region defined as L psoas muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

Table 3. Fields Related to Thigh Calculations

Date Read

Date that the following analyses were performed.

TH-FOV (mm)

Field of view of the thigh image. Units of millimeters.

R Thigh Total Area

Area of entire region defined as right thigh in the thigh image. Includes all tissue types (bone, muscle, fat, vascular, skin...) Units of cm-sq.

R Thigh Bone Area

Area of entire region defined as bone and bone marrow in the right thigh on the thigh image. Units of cm-sq.

R Thigh SF Area

Area of entire region defined as subcutaneous fat in the right thigh on the thigh image. This is the fat lying between the skin and the deep fascial plane surrounding the muscles. Units of cm-sq.

R Thigh IMF Area

Area of entire region defined as intermuscular fat in the right thigh on the thigh image. Intermuscular fat is that tissue, with a density of fat, lying interior to the deep fascial plane surrounding the muscles. Units of cm-sq.

R Thigh Quadriceps Area

Area of entire region defined as the quadricep muscles in the right thigh on the thigh image. The quadricep muscles include the Vastus Lateralis, Vastus Intermedius, Vastus Medialis and the Rectus Femoris. Units of cm-sq.

R Thigh Hamstrings Area

Area of entire region defined as hamstring muscles in the right thigh on the thigh image. The hamstrings include the Biceps Femoris, Short Head; Biceps Femoris, Long Head; Semitendinosus and Semimembranosus muscles. Units of cm-sq.

R Thigh Total Muscle Area

Area of all muscle regions in the right thigh on the thigh image. Units of cm-sq.

L Thigh Total Area

Area of entire region defined as left thigh in the thigh image. Includes all tissue types (bone, muscle, fat, vascular, skin...) Units of cm-sq.

L Thigh Bone Area

Area of entire region defined as bone and bone marrow in the left thigh on the thigh image. Units of cm-sq.

L Thigh SF Area

Area of entire region defined as subcutaneous fat in the left thigh on the thigh image. This is the fat lying between the skin and the deep fascial plane surrounding the muscles. Units of cm-sq.

L Thigh IMF Area

Area of entire region defined as intermuscular fat in the left thigh on the thigh image. Intermuscular fat is that tissue, with a density of fat, lying interior to the deep fascial plane surrounding the muscles. Units of cm-sq.

L Thigh Area Quadriceps Area

Area of entire region defined as the quadricep muscles in the left thigh on the thigh image. The quadricep muscles include the Vastus Lateralis, Vastus Intermedius, Vastus Medialis and the Rectus Femoris. Units of cm-sq.

L Thigh Area Hamstrings Area

Area of entire region defined as hamstring muscles in the left thigh on the thigh image. The hamstrings include the Biceps Femoris, Short Head; Biceps Femoris, Long Head; Semitendinosus and Semimembranosus muscles. Units of cm-sq.

L Thigh Total Muscle Area

Area of all muscle regions in the left thigh on the thigh image. Units of cm-sq.

R Thigh SF Density

Average CT density of region defined as subcutaneous fat in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh SF Density SD

Standard deviation of average CT density of region defined as subcutaneous fat in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh IMF Density

Average CT density of region defined as intermuscular fat in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh IMF Density SD

Standard deviation of average CT density of region defined as intermuscular fat in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh Quadriceps Density

Average CT density of region defined as the quadricep muscles in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh Quadriceps Density SD

Standard deviation of average CT density of region defined as the quadricep muscles in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh Hamstrings Density

Average CT density of region defined as the hamstring muscles in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh Hamstrings Density SD

Standard deviation of average CT density of region defined as the hamstring muscles in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh Total Muscle Density

Average CT density of all regions defined as muscle in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

R Thigh Total Muscle Density SD

Standard deviation of average CT density of all regions defined as muscle in the right thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh SF Density

Average CT density of region defined as subcutaneous fat in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh SF Density SD

Standard deviation of average CT density of region defined as subcutaneous fat in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh IMF Density

Average CT density of region defined as intermuscular fat in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh IMF Density SD

Standard deviation of average CT density of region defined as intermuscular fat in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh Quadriceps Density

Average CT density of region defined as the quadricep muscles in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh Quadriceps Density SD

Standard deviation of average CT density of region defined as the quadricep muscles in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh Hamstrings Density

Average CT density of region defined as the hamstring muscles in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh Hamstrings Density SD

Standard deviation of average CT density of region defined as the hamstring muscles in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh Total Muscle Density

Average CT density of all regions defined as muscle in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

L Thigh Total Muscle Density SD

Standard deviation of average CT density of all regions defined as muscle in the left thigh on the thigh image. Units of HU where water is set to 0 as a standard.

Table 4. Fields Related to Paraspinous Muscle Calculations

Area- R paraspinous

Area of region defined as right paraspinous muscle in the abdominal image. Units of cm-sq.

Area- L paraspinous

Area of region defined as left paraspinous muscle in the abdominal image. Units of cm-sq.

R paraspinous Density

Average CT density of region defined as R paraspinous muscle in the abdominal image. Units of HU where water is set to 0 as a standard. Decrease in any muscle density over normal muscle is usually an indication of a fatty muscle.

R paraspinous Density SD

Standard deviation of Average CT density of region defined as R paraspinous muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

L paraspinous Density

Average CT density of region defined as L paraspinous muscle in the abdominal image. Units of HU where water is set to 0 as a standard.

L paraspinous Density SD

Standard deviation of Average CT density of region defined as L paraspinous muscle in the abdominal image. Units of HU where water is set to 0 as a standard.