

Abdominal Fat Quantification from a Single Cross-Sectional CT Image Using Imagej Manual and Semiautomated Modules

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Abstract: *The aim of this study was to quantify abdominal fat from a single cross-sectional ct image using imageJ software with manual and semi automated modules and to evaluate if ImageJ method could be applied clinically in the future, to be one of the routine component of clinical nutrition assessment . This retrospective, cross-sectional study was carried out between October 2017 and February 2018 and included 30 patients aged 25-60 years who underwent CT scanning, of which, 15 were males and 15 females. The visceral fat as measured by our technique ranged from 24.29 to 65.35% with an average of 43.32%. There were statistical significant differences with $p < 0.01$ between males (average of 49.52, standard deviation 9.03) and females (average of 31.19, standard deviation 7.51). The mean BMI was 23.44 ± 2.74 kg/m², and the mean waist circumference was 79.53 ± 7.19 cm It was found that waist circumference showed high correlations with the SAT ($r = 0.502$, $p = 0.01$) and VAT ($r = 0.639$, $p = 0.01$) obtained using the manual measurements. Also, strong correlations were noted between waist circumference and the automatic measurement results, in SAT ($r = 0.465$, $p = 0.01$) and VAT ($r = 0.639$, $p = 0.01$). To evaluate the performance of the software proposed in this study, the running time of the software was measured, and it was found that the software's semi automated module required significantly reduced time to quantify compared to manual segmentation. We were able to demonstrate that quantification of abdominal fat from a single cross-sectional ct image using free imageJ software is feasible, yielding reproducible results. Measuring visceral fat, with all its compartments represents a useful tool in the obese patient's evaluation. We consider promoting the inclusion of VF measurements in the regular computed tomography report. Through development of a free novel software, which could automatically identify, and measure SAT and VAT from CT scan data we can overcome the laborious procedure in manual segmentation and provide the clinician with useful information leading to a better patient management.*

1. Objectives

- To quantify abdominal fat from a single cross-sectional ct image using imagej manual and semiautomated modules, a free versatile software for measuring signal intensity without dedicated specialized software or PACS.
- To evaluate and compare the manual and semiautomated modules
- To evaluate if the Image J method could be applied clinically in the future, to be one of the routine component of clinical nutrition assessment

2. Materials and Methods

- This retrospective, cross-sectional study was carried out between October 2017 and February 2018 and included 30 patients aged 25-60 years who underwent CT scanning. Of these, 15 were males and 15 females.
- Exclusion criteria were chronic diseases, hepatorenal disease, and use of hepatotoxic drugs, corticosteroids, or immune suppressants that could promote fat storage in the liver.

Abdominal CT

- All CT exams were performed at YMC, Derlakatte. Images were acquired in a 16 Brightspeed CT machine (General Electric, Milwaukee, USA) and radiological measurements were obtained with ImageJ software.

3. Radiological Measurements

- Visceral and subcutaneous adipose tissue (VAT and SAT) were measured by computer tomography (CT) scan

at 125kV with a 16 Brightspeed CT machine (General Electric, Milwaukee, USA), which scanned a single slice of 5mm thickness at the fourth lumbar (L4) vertebral level using manual method and semi automated AAST module ,their results were obtained and compared.

Images were taken with the participant supine, in fixed inspiration and with their arms extended overhead

Imaging Analysis

- The DICOM/JPEG images (matrix 512 x 512) were analyzed using ImageJ software (rsbweb.nih.gov/ij/) with auto threshold plugin which converts automatically grayscale pixels into binary images, based in a global histogram-derived method. Black pixels represent adipose tissue and white pixels the remaining soft tissue (muscle, solid organs, intestinal loops, and vessels).
- Adipose tissue was subsequently categorized into visceral and subcutaneous fat through manual division, which was accomplished by drawing a line following the abdominal wall to separate intra and extra abdominal compartments. Visceral and subcutaneous fat areas (cm²) were measured separately.
- VAT was measured on the CT image by circumscribing the visceral compartment manually (using Image-J software ,and using an attenuation range of -190 to -30 Hounsfield units to quantify adipose tissue within.
- Total abdominal adipose tissue was measured using an automated function that gave the adipose tissue in the whole cross-sectional slice.
- SAT was calculated by subtracting the area of adipose tissue within outer border of the abdominal wall musculature from the total adipose tissue, using the above attenuation range.

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- The reliability of VAT and SAT measurements was tested by comparing two sets of measurements from one observer on a sample of thirty participants.
- The selected image was saved in .DICOM/JPEG format.
- Open the NIH ImageJ software (click microscope icon) and left click on FILE tab, move the mouse cursor to OPEN and left click. A new window called OPEN will pop up which allows any NIH ImageJ compatible file to be opened such as a DICOM as previously discussed.
- Select the directory where DICOM L3 image files are stored on computer or storage device.
- Pick the desired L3 image DICOM file and click "OPEN" tab to open the image.
- Evaluate your image. Precise estimate of waist circumference requires image to include a complete abdominal perimeter. Additionally, the abdominal skeletal muscles, particularly the obliques and transversus abdominus, should be visible all the way around the abdominal cavity.
- **Technique for Assessment of WC and SM**—Once the L3 image is obtained and determined to be of good quality, the following CT imaging protocol can be used for assessment of WC and SM area at the L3 region. Attach the graphics tablet to the computer and launch NIH ImageJ (i.e., microscope icon). The NIH ImageJ tabs **FILE**, **IMAGE**, and **ANALYZE** will be employed for this tutorial.
- Open the DICOM image as previously described. Under the tab headings there are a series of boxes representing drawing tools to trace ROIs on medical and scientific images. Move the mouse over the different tools to see the types and names of these tools. The 'Freehand selections' and 'Wand (tracing) tool' will be used in the following CT body composition analysis protocol presented in this tutorial.

Step 1: Abdominal perimeter for WC

- Go to **Image>Adjust>Threshold**. A Threshold window opens.
- Click **SET** to change the **LOWER** and **UPPER** thresholds to -250 and 1000, respectively.
- Click OK to close this window.
- Select 'Wand Tracing Tool' icon on **IMAGEJ** control box. Click on the outer surface of the threshold-highlighted area. A yellow line should appear surrounding the entire abdominal perimeter.
- Go to **ANALYZE>SET MEASUREMENTS** and select **AREA** and **PERIMETER** from the list provided and unselect any other measurements.
- Click OK to close this window.

Go to **ANALYZE>MEASURE** for estimates of **AREA** and **PERIMETER**. A **RESULTS** window opens listing first measurement of area and perimeter (Measurement 1).

Step 2: Outer Musculature Perimeter

- Return to the **THRESHOLD** window again and adjust the **LOWER** and **UPPER** thresholds to -250.
- Select the 'Freehands selection,' tool then click on image to remove abdominal perimeter line and using the stylus, carefully trace the outer perimeter of the abdominal musculature. If hand slips or if tracing line is not directly

over the perimeter, click the pen over the line to make it disappear and repeat again. Repeat the trace around the outer musculature perimeter as many times as needed in order to get it as close as possible to the actual perimeter. Once the best line is drawn, be careful not to touch the image again or the line will be erased.

- Return to **THRESHOLD** window and adjust **LOWER** and **UPPER** thresholds to -29 and +150, respectively.
- Go to **ANALYZE>SET MEASUREMENTS** and select **AREA**, **PERIMETER** and **LIMIT TO THRESHOLD**.
- Click **OK** to close this window.

Go to **ANALYZE>MEASURE** for estimates of **AREA**, **PERIMETER** and **LIMIT TO THRESHOLD**. A **RESULTS** window opens listing these measurements (Measurement 2).

Step 3: Inner Musculature Perimeter

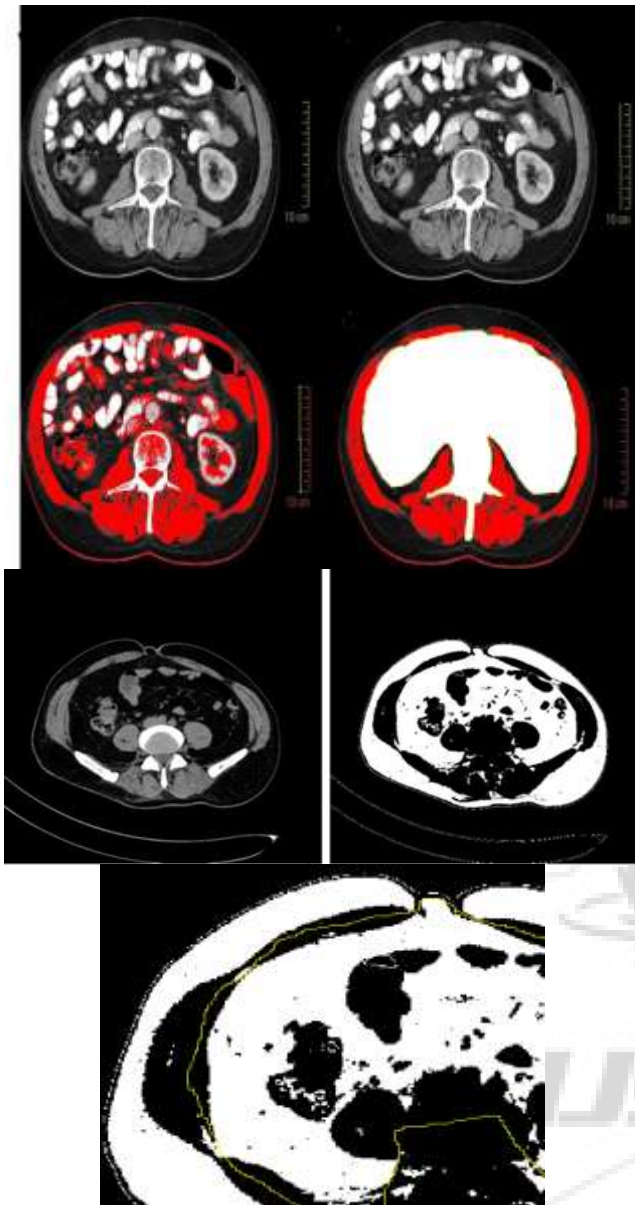
- Delineate the inner abdominal musculature perimeter (Figure 8). The inner abdominal musculature perimeter is also needed for calculation of SM.
- Return to **THRESHOLD** window and adjust **LOWER** and **UPPER** values to -250.
- Repeat tracing the inner abdominal musculature perimeter as many times as needed to get the delineation as accurate as possible.
- Once the inner perimeter muscle wall is outlined, return to the **THRESHOLD** window and set the **LOWER** and **UPPER** thresholds to -29 and +150, respectively.
- Go to **ANALYZE>MEASURE**. A third set of measurements (Measurement 3) will be added to the **RESULTS** box.
- Steps for outer and inner abdominal musculature perimeters can be repeated as many times as desired.

Step 4: Unit conversion process (cm and cm²)

- Copy and paste these measurements to a Microsoft EXCEL spreadsheet.
- To copy and paste the measurements, return to **RESULTS** window, highlight the measurements and then right click on mouse and select **COPY**.
- Open a Microsoft Excel spreadsheet and paste the measurements.

Step 5: Closing ImageJ

- To close ImageJ, simply click on in corner of the **ImageJ** window.
- All windows will close.
- **D) Calculating WC and SM estimates**—Insert the results copied to a Microsoft Excel spreadsheet into the following calculations to derive WC and SM area:
 - For WC, take Measurement 1 (**Perimeter**, mm) and divide by 10. For example, Measurement 1 equals 1058.832 mm, divide this number by 10 to get 105.832 cm. This is the WC measurement.
 - For SM area, take Measurement 3 (inner **area**, mm²) and subtract it from Measurement 2 (outer **area** mm²) and divide the result by 100. For example, subtract 7144.093 (Measurement 3) from 24280.911 (Measurement 2) and divide by 100 to get 171.37 cm². This is the SM area measurement.



4. Results

- Of the 30 subjects included in this study, aged 25-60 years who underwent CT scanning 15 were male and 15 female.
- The visceral fat as measured by our technique ranged from 24.29 to 65.35% with an average of 43.32%.
- There were statistical significant differences with $p < 0.01$ between males (average of 49.52, standard deviation 9.03) and females (average of 31.19, standard deviation 7.51). The mean BMI was 23.44 ± 2.74 kg/m², and the mean waist circumference was 79.53 ± 7.19 cm.
- Also, the first manual measurement's results were, TAT at 2521.43 ± 713.56 ml, SAT at 1641.22 ± 434.65 ml, and VAT at 896.71 ± 449.63 ml
- The second measurement's recorded TAT of 2530.27 ± 719.02 ml, SAT of 1619.51 ± 431.19 ml, and VAT of 889.76 ± 459.18 ml. This paper took the means of these values.
- The semi automatic measurement software produced the following results: TAT of 2787.17 ± 846.94 ml, SAT of 1799.84 ± 545.76 ml, and VAT of 991.33 ± 502.47 ml.

- Using Pearson's correlation coefficient the correlations between the automated measurements and manual measurements are as follows; TAT ($r = 0.995$, $p = 0.01$), SAT ($r = 0.987$, $p = 0.01$), VAT ($r = 0.993$, $p = 0.01$) all showed significant results.
- Further analysis was conducted using waist circumference measurement. It was found that waist circumference showed high correlations with the SAT ($r = 0.502$, $p = 0.01$) and VAT ($r = 0.639$, $p = 0.01$) obtained using the manual measurements.
- Also, strong correlations were noted between waist circumference and the automatic measurement results, in SAT ($r = 0.465$, $p = 0.01$) and VAT ($r = 0.639$, $p = 0.01$).
- Also, to further evaluate the performance of the software proposed in this study, the running time of the software was measured. Only the duration for separating and measuring AT were considered, and it was found that the software required the average of 3-4 seconds to process 24 CT slices whereas manual segmentation took an average of 3-5 mins.
- The coefficient of variation for VAT was 0.95% and for SAT 0.68%. thickness 5.0 mm, gap were obtained.
- These results indicate that the semiautomatic measurement method produces similar results to measurements taken by professionals, and that the software provides high reliability.
- By automating the identification and measurement processes for SAT and VAT using computer image processing methods, quick and simple measurements become possible, and objective quantitative measurements can offer reliable results
- Previous studies have proved, further analysis which includes different blood tests and clinical data are important for a better understanding of the computed tomography examinations in obesity related pathology diagnosis and treatment.
- MRI provides tissue cross-section images that can be used to measure VAT without exposure to radiation, but is expensive and time-consuming and has been reported to be less accurate in detecting adipose tissue (AT) than CT, thus decreasing the frequency of its actual use.
- CT images, much like MRI, are cross-section images of patient tissue, and can clearly discern adipose tissue from the surrounding tissue. CT scans provide the greatest accuracy and are widely used as a standard measurement method. However, they accompany the issue of radiation exposure. Furthermore, since all cross section images must be differentiated, it is difficult to use practically, and is costly and time consuming.

Due to these issues, despite its accuracy, CT scans are used little in practice. However, some of these issues can be resolved by taking measures such as the use of low-dose CT, or reusing CT scans from different examinations.

5. Conclusion

- We demonstrate that quantification of abdominal fat from a single cross-sectional ct image using imageJ manual and semi automated modules is feasible, yielding reproducible results.

- The free versatile software Image J (U.S. National Institutes of Health) can be used for measuring signal intensity without dedicated specialized software or PACS.
- Measuring visceral fat, with all its compartments represents a useful tool in the obese patient's evaluation. We consider promoting the inclusion of VF measurements in the regular computed tomography report.
- The laborious procedure in manual segmentation and less so in semi automated modules, can be a thing of past if we develop free novel software, which could automatically identify and measure SAT and VAT from CT scan data with similar accuracy as we can provide the clinician with useful information leading to a better patient management.

References

- [1] Klopfenstein BJ, Kim MS, Kriskey CM, Szumowski J, Rooney WD, Purnell JQ. Comparison of 3 T MRI and CT for the measurement of visceral and subcutaneous adipose tissue in humans. *The British journal of radiology*. 2012 Oct;85(1018):e826-30.
- [2] Manios GE, Mazonakis M, Voulgaris C, Karantanis A, Damilakis J. Model based quantification of visceral and subcutaneous abdominal adipose tissue volume on CT data. *Physica Medica: European Journal of Medical Physics*. 2016 Sep 1;32:326.
- [3] KISSEBAH, A.H., et al., *Relation of Body Fat Distribution to Metabolic Complications of Obesity*. *Journal of Clinical Endocrinology & Metabolism*, 1982. **54(2): p. 254-260.**
- [4] Jensen, M.D., et al., *Measurement of abdominal and visceral fat with computed tomography and dual-energy x-ray absorptiometry*. *The American Journal of Clinical Nutrition*, 1995. **61(2): p. 274-8.**
- [5] Kvist, H., L. Sjostrom, and U. Tylen, *Adipose tissue volume determinations in women by computed tomography: technical considerations*. *Int J Obes*, 1986. **10(1): p. 53-67.**
- [6] Seidell, J.C., C.J. Bakker, and K. van der Kooy, *Imaging techniques for measuring adipose-tissue distribution--a comparison between computed tomography and 1.5-T magnetic resonance*. *The American Journal of Clinical Nutrition*, 1990. **51(6): p. 953-7.**
- [7] Goodpaster, B.H., et al., *Subcutaneous Abdominal Fat and Thigh Muscle Composition Predict Insulin Sensitivity Independently of Visceral Fat*. *Diabetes*, 1997. **46(10): p. 1579-1585.**
- [8] Enzi, G., et al., *Subcutaneous and visceral fat distribution according to sex, age, and overweight, evaluated by computed tomography*. *The American Journal of Clinical Nutrition*, 1986. **44(6): p. 739-46.**
- [9] Doyle, S.L., et al., *Establishing computed tomography-defined visceral fat area thresholds for use in obesity-related cancer research*. *Nutrition Research*, 2013. **33(3): p. 171-179.**
- [10] Yoshizumi, T., et al., *Abdominal Fat: Standardized Technique for Measurement at CT1*. *Radiology*, 1999. **211(1): p. 283-286.**