Automated segmentation of visceral adiposity in MRI in obese children

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Summary

- Children obesity is a growing concern in the healthcare system
  - dependence and cronic health problems results in the adult phase of life.
- Non-alcoholic liver fat and visceral adiposity are two biomarkers of the health status of the child.
- Some studies try to measure the impact of exercise and improved habits in the reduction of these biomarkers.
- fat enhancing magnetic resonance imaging sequence, but visceral fat is costly to segment manually.

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Introduction

- Overweight and childhood obesity in developed countries has become epidemic and constitute a huge problem in the public health system
- 5 times more likely to develop insulin resistance and type 2 diabetes mellitus
- at least one cardiovascular (CV) risk factor
- a clinical trial has been proposed aiming to measure the effects of controlled exercise sessions in several biomarkers, among then the volume of visceral addipose tissue (VAT).
- The study hypothesis is that exercise of moderate to high intensity (between ventilatory thresholds) will reduce liver fat, VAT and improve body composition and cardiovascular health in overweight children.

Objectives

- automated method to distinguish different type of adipose tissue: visceral (VAT) and subcutaneous (SAT)
  - accurate, reproducible
- before and after treatment tissue segmentation will serve to measure treatment impact by volume quantification

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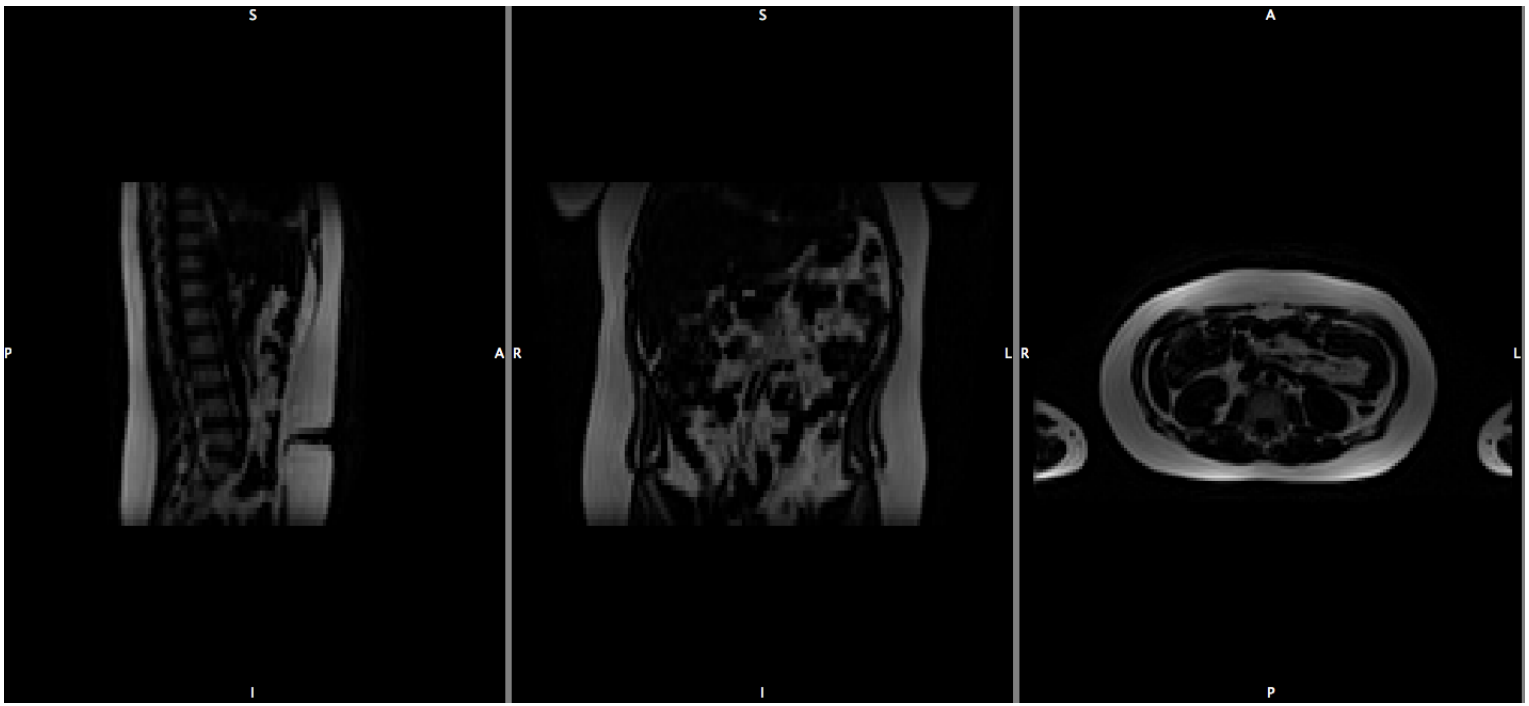
The fat signal

- Magnetom Avanto equipment, Siemens Healthcare, 1.5 Tesla, of 33mt m maximum gradient amplitude, minimum rise time of 264 microseconds, high sink rate of 125 T/m/s, version syngo MR B17, Numaris / 4 software.
- The sequences were performed in supine position, in apnea without intravenous contrast injection, using phased array matrix body antennas and spine matrix.
- The fat signal (proton density fat fraction) is acquired from multi-echo 3D gradient echo acquisition.
  - A Dixon decomposition provides initial guesses of the separation between fat and water using two echos.
  - The estimation is refined in a multistep adaptive fitting process.

The fat signal



VAT segmentation algorithm

1. Image intensity normalization by inhomogeneity correction
2. Removal of anatomical irregularities: the navel and the arms
3. Identification of the periferical and visceral regions
4. Extraction of the VAT applying the mask
5. Detection of the vertebrae and the intervertebral disks.
6. Computation of the VAT removing intervertebral disks.

Image intensity normalization

- strong smoothing of the volume with a large Gaussian kernel.
  - each voxel contains roughly the average value of a large neighborhood,
  - thus it is proportional to the value of the illumination field.
- We divide the original fat image by this smooth image obtaining intensity values around 1,
  - a threshold of a value near 1 to produce a mask of fat.
- Values near 0.8 of the threshold provide good results.

Removal of anatomical irregularities

- to remove the navel
  - We compute the 3D boundary of the body of one voxel of width by substracting from the fat mask an erosion with an structural element that is a square of 3x3 filled with ones.
  - We compute the derivatives of the boundary considered as a line in each slice
  - When we find two large derivatives coming from the two sides of the frontal boundary, we have found the navel boundaries,
  - We link these points with a line in the external boundary. Filling the corrected external boundary, we can fill the navel.

Removal of anatomical irregularities

- To remove the arms,
  - we start from the middle of the body where the arms are clearly separated from the body moving upwards.
  - We consider at each slide the external boundary of the central fat region in the image,
    - the separated external bondaries correspond to the arms, and can be removed.
  - at the axiles there is a fusion of the outer arm region with the body,
    - we proceed by assuming that the external boundary of the body remains the same

Identification of the VAT and SAT masks

- Boundary: substraction of the erosion with the square unit structural element as before.
  - external and internal boundaries are separated
  - we can use the internal boundary to delineate the boundary of the visceral region.
- In order to break some links between periferical fat and the visceral fat,
  - we carry out a strong opening of the image.
- internal mask: filling the internal boundary
- the diference between the whole volume filled and the internal mask is the mask of the subcutanous fat.

Detection of the vertebrae

- the vertebral column has a regular structure, with a regular succesion of local maxima and minima.
- detection: correlation in the saggital and coronal planes of a sliding window
  - a pattern that has a strip of minimum values in the center and maxima in the sides.
  - The dimensions of the pattern are different for the saggital and the coronal planes, to fit the vertebrae dimensions in these planes.
- The intervertebral disk are detected by similar procedure,

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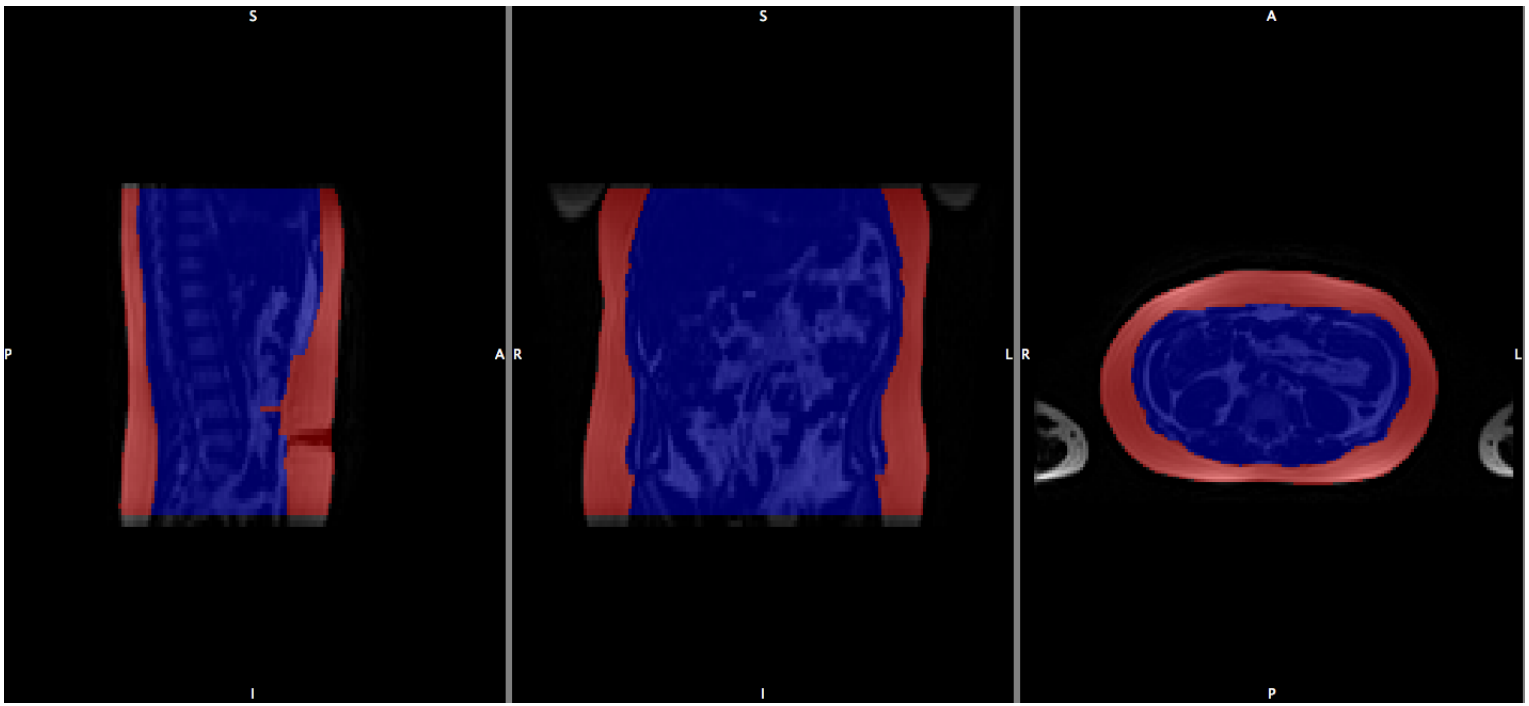
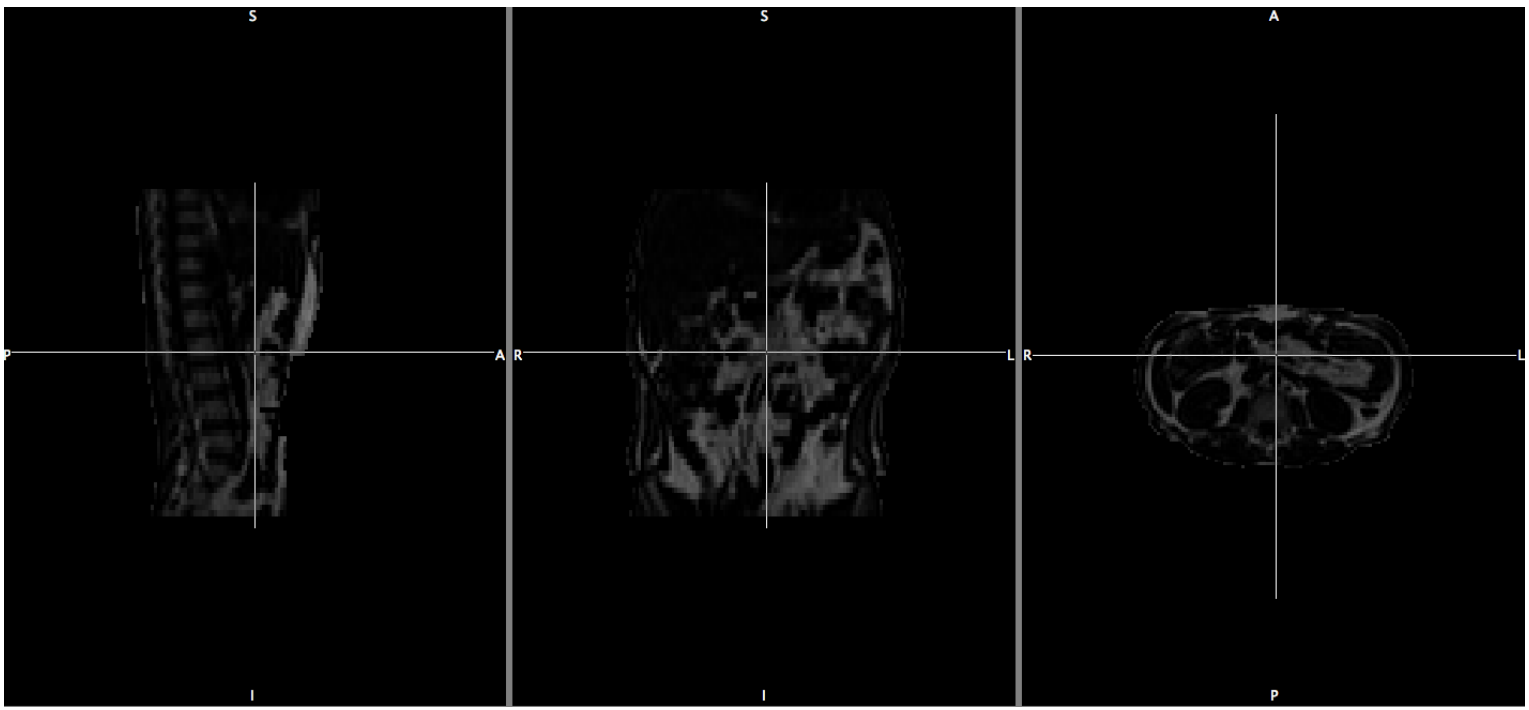
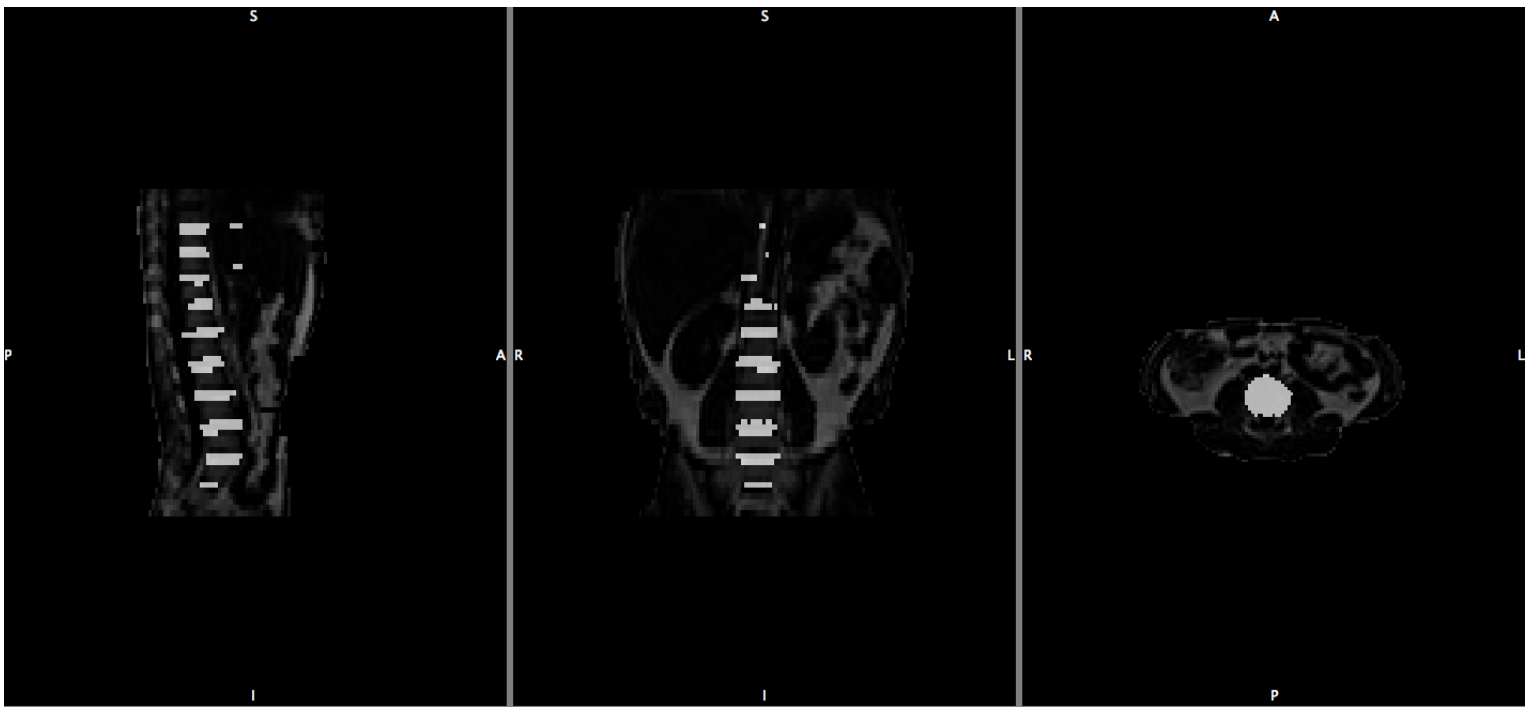
VAT and SAT masks



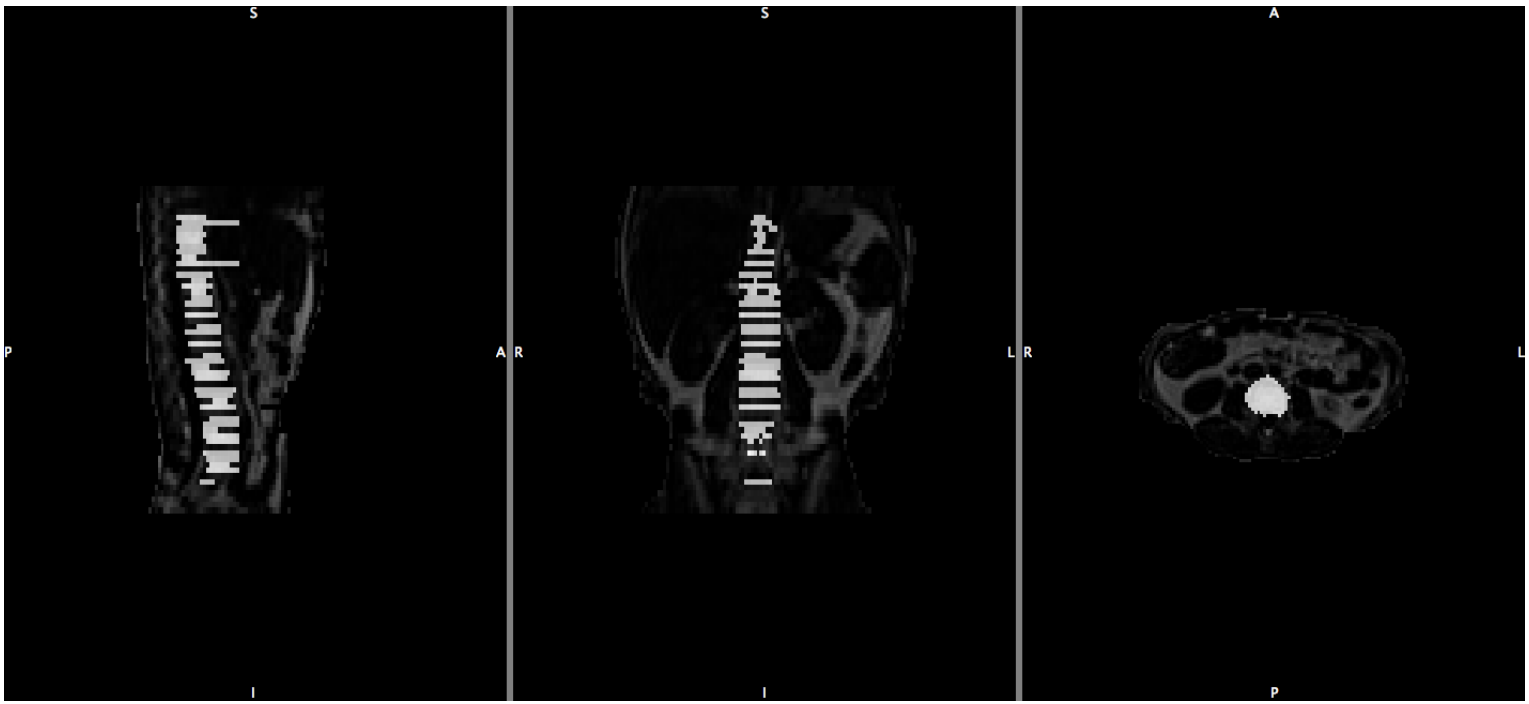
VAT extracted



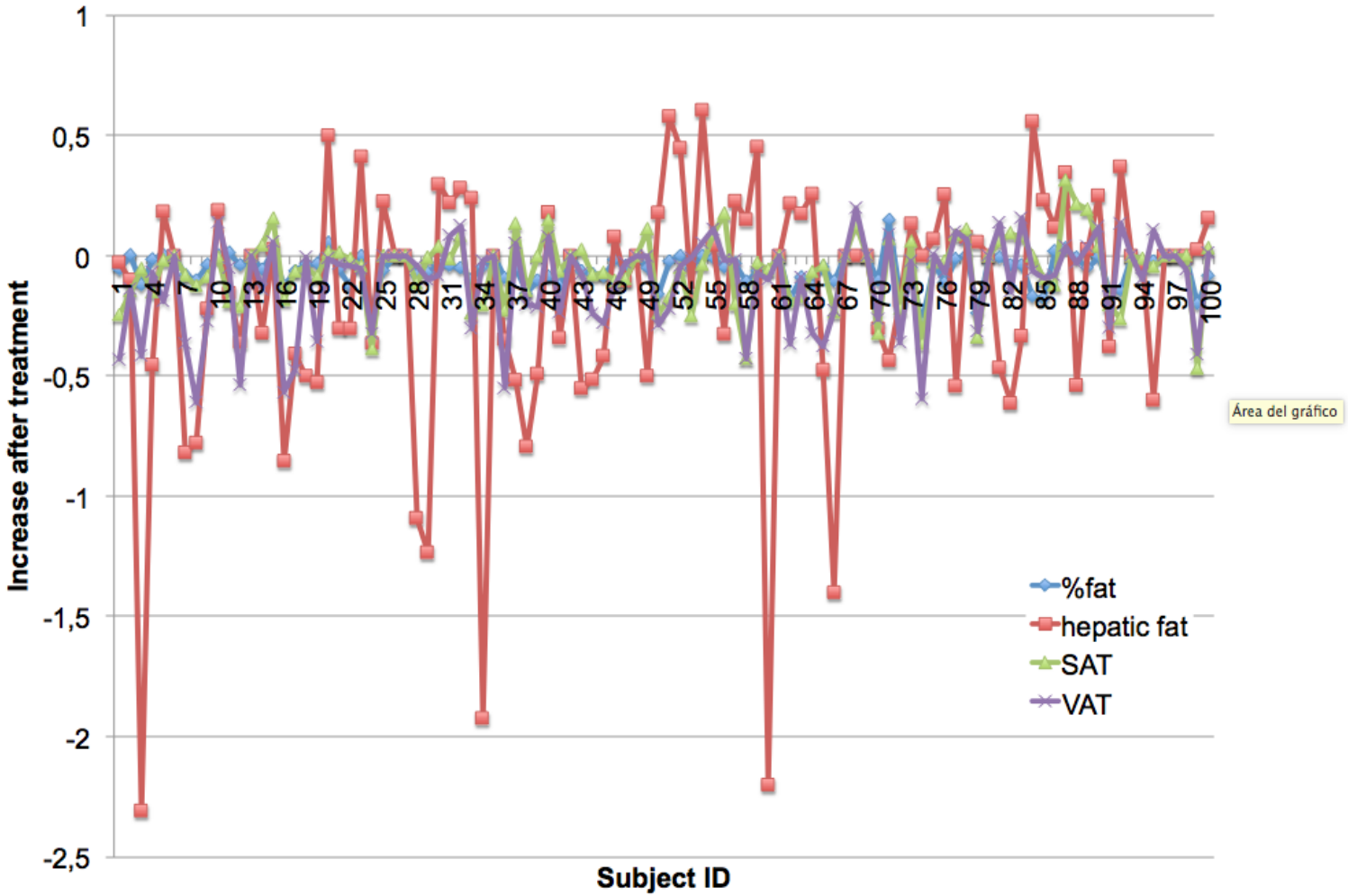
Vertebral disks



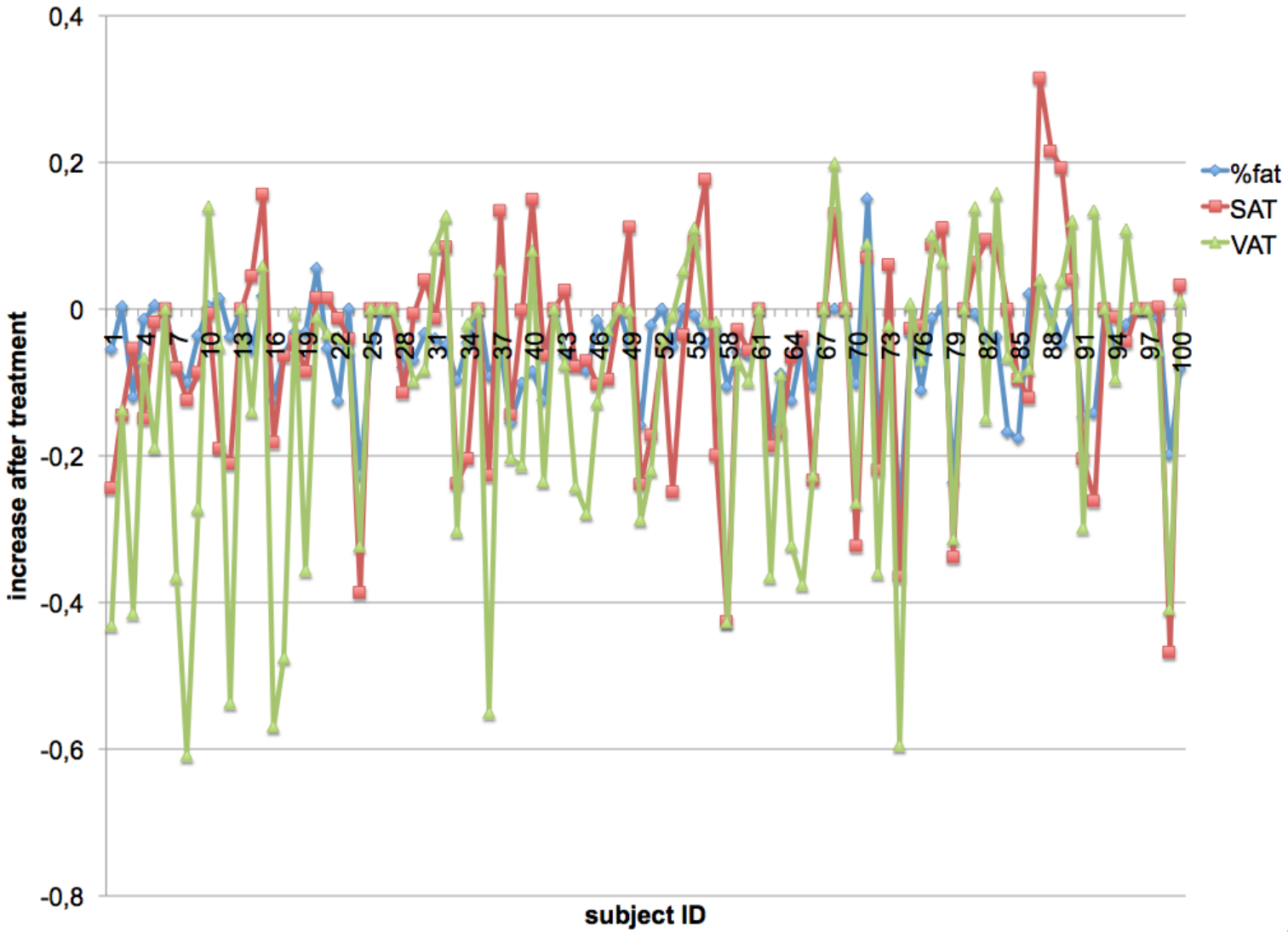
Estimation of the column



Results


1
0,5
0
-0,5
-1
-1,5
-2
-2,5
Increase after treatment
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100
Subject ID
%fat
hepatic fat
SAT
VAT
Área del gráfico

Results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0
-0,2
-0,4
-0,6
-0,8
increase after treatment
1
4
7
10
13
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22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
subject ID
%fat
SAT
VAT

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Conclusions

- We have developed a robust automatic segmentation algorithm for visceral (VAT) and subcutaneous (SAT) fat,
- that is currently applied to the date produced by a study on the effect of exercise in the VAT volume of obese children, among other biomarkers of obesity which are processed concurrently.