Natural Phenotypes of Fat, Lean, and Bone and Their Association to Metabolic Markers

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Summary

Fat, lean, and bone images created from a single DXA scan can be used to classify patients into meaningful phenotypes that relate to metabolic status. These phenotypes are unique for men and women.

Background

One in eleven people in the United States has diabetes, one of the many metabolic disorders. Even though diseases caused by malnutrition have become common, we lack accurate means to determine high risk phenotypes for these conditions. The two most widely used adiposity measurements are body mass index (BMI) and waist circumference. BMI only compares a person’s weight to their height and fails in muscular athletic populations. Waist circumference is used as a proxy for the amount of excess adiposity in the abdomen but it does not directly measure subcutaneous fat. Neither measurement captures information about the regional distribution of fat. Whole Body DXA reports fat and lean mass by body region, but these still reduce large areas of the body (arms, legs, trunk) to singular values. We asked if there was a better way to describe phenotypical fat distributions.

Our group have developed a method to deconvolve whole body DXA scans into three images, each consisting uniquely of fat, lean, and bone masses. See Figure 1. We asked if fat images can be used to define natural phenotypical groupings and if these groupings are related to common risk factors for metabolic disease.

Methods

Recruitment: 720 healthy adults from Shape Up! Adults Cohort, an observational study at UCSF and PBRC (IRB-approved). Measures: 3D whole body surface scans (Fit3D Proscanner), whole-body DXA (Hologic Horizon/A), metabolic blood panel. 3D whole-body surface scans (Fit3D Proscanner), whole-body DXA (Hologic Horizon/A), metabolic blood panel.

Figure 1. Example of DXA fat (left), lean (middle), and bone (right) images.

DXA Analysis: Standard analysis plus 52 fiducial points placed on the DXA fat mass images using random-forest automated model. See Figure 2. All imaged spatially registered. Principal Component Analysis (PCA) was used to describe the variance in the fat images in terms of shape and texture variances.

Figure 2. (a) 52-points with warping triangulation, alignment with (b) translation only, (c) affine only, (d) warping using triangles.

Sex-specific shape PCA modes were derived, then K-means cluster analysis was used to find natural groupings in the PCA space. An average optical scan was created using similar methods for each DXA fat cluster to visualize the phenotype. Lastly, phenotypes were further defined by testing for unique metabolic and demographic descriptors using 15 means.

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Methods (continued)

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Results

Table 2. R-values between the first 3 DXA fat PCs to anthropometric, blood, and DXA measurements.
P ≤ 0.05 shown P ≤ 0.001 bolded

Table 3. Present Recruitment Male Female

Table 4. Ethnicity

Table 5. Metabolic Syndrome

Discussion

We demonstrated a method using PCA to analyze fat distribution on whole body DXA independent of lean and bone.

Using the PCA modes, we found that men and women fall into unique phenotypes of body fat distribution.

The DXA fat phenotypes have unique body shape, demographics, metabolic profiles, and body composition.

These PCA phenotypes may be useful to identify individuals at risk for fracture, and poor metabolic conditions.

Further work includes expanding the concept to more individuals and genetic markers.

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Further Reading