Mānoa Horizons

Volume 3 | Issue 1 Article 29

11-15-2018

External Abdominal Measurements Predictive of Various Fat Distributions

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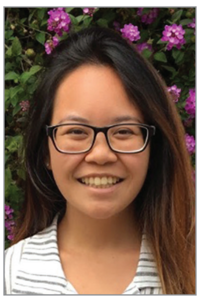
There are purported links between central obesity and incidence of various cancers. Visceral fat, which includes both pancreatic and liver fat, wraps around major organs, while subcutaneous fat is surface level "belly fat." The significance of this research is due to its potential to act as another method of measuring fat, as the only methods now are imaging by a CT scan, which is a cross-sectional X-ray of a body area, or an MRI scan, which is imaging done via magnetic resonance.

Cross-sectional analyses of scaled MRI images from 228 subjects of Black, Hawaiian, Japanese, Latino, and White ethnicity in the Multiethnic Cohort were performed. Statistical analysis software (SAS) 9.4 was used to perform analyses of measurements.

Although there was a significant correlation with subcutaneous fat, the measurements did not prove to be either significant or practical predictors of overall visceral fat ($r^2<0.00019, p>0.1403$)*. However, when analyses of measurements were done in both sexes, they were significant and practical predictors of overall visceral fat for women* ($p=0.0005$, <0.05) *and pancreatic fat for men* ($p=0.0559$)*. When compared to waist and hip circumference measurements, the geometric measurements of the MRI images were better predictors of liver fat* ($r^2=0.013795$, $r^2=0.116628$, *respectively) and pancreatic fat* ($r^2 = 0.113253$, $r^2=0.132597$, *respectively) in males.*

Our findings support the use of external, geometric measurements as a means of determining overall visceral fat distribution in females and pancreatic fat, a type of visceral fat, distribution in males; it also surpass the effectiveness of waist and hip circumference in predicting liver and pancreatic fat in men.



This research paper was produced during my time participating in the University of Hawaii Cancer Center Summer Internship Program, under the guidance and mentorship of Dr. Lynne Wilkens, DrPH, MS. I was born and raised in Honolulu, and this past May 2018, I completed my Bachelors in Science in Biology. My passion and appreciation for the field of science are what play a role in driving and motivating me to pursue my highest academic goal of obtaining my medical degree to serve the community of Hawaii.

Mānoa Horizons, Vol. 3, 2018, pp. 145–150

Introduction

Obesity is a major public health crisis both nationally and internationally [8]. There are purported links between central obesity and incidence and survival of other various cancers. Studies have shown that patients diagnosed with breast cancer (P=0.01), colorectal adenoma (P<0.001), and prostate cancer (P<0.001) have been shown to exhibit significantly greater visceral fat area [5, 6, 9, 10, 11]. Types of visceral fats include pancreatic fat and liver fat. It has also been shown that intra-abdominal fat plays a role in predicting overall survival in pancreatic cancer patients [3], and morbidly obese women with endometrial and/or epithelial cancer are more likely to die due to this factor [1, 2, 3, 4]. Additionally, abdominal obesity is also positively related to cardiovascular disease risks and cancer mortality [12, 13]. Greater abdominal adiposity has been found to be significantly and positively associated with all-cause cardiovascular diseases, even among normal-weight women [14].

Yet, despite the association between visceral fat accumulation and distribution, and chronic diseases and cancers, the only current technique for estimating fat distribution (e.g., visceral, subcutaneous, peripheral) is imaging by CT or MRI9. There also have been no recent studies investigating alternative methods for predicting visceral fat distribution.

Thus, the objective of this study is to examine the possibility of determining internal fat distribution based on external abdominal outlines, using MRI scans as a proxy for subjects. We hypothesize that simple geometric measures of the external shape of the individual's abdomens while lying down can be used to predict internal fat distribution.

Materials and Methods

Subjects and samples

Members of the Multiethnic Cohort were imaged by DXA—which can be used to measure body fat, lean mass, and bone health—and MRI for their fat distribution. Approximately 18,60 individuals were imaged, approximately evenly divided by sex and 5 ethnic groups: African American, Latino, White, Japanese and Native Hawaiian. Participants received MRI scans at the University of Hawai'i at Mānoa (UHM) and University of Southern California (USC) Research Centers. The MRI images were created on Siemens machines and are stored in DICOM format. Abdominal images from 228 individuals were systematically selected at random to be measured for analysis. As a simple means to get a sample across sexes, ethnic groups and time, individuals were selected using systematic sampling. This was done by arranging their ID numbers in descending chronological order and choosing every 9th participant's ID to include. The IDs are of the form 37nnnnn, where nnnnn is a number assigned consecutively from 00001.

Measurements

Cross-sectional analyses of scaled images were performed using simple geometric measurements of the MRI images of patients' abdominal sections. Measurements performed on the images were predicted to be the most mathematically practical technique to determine how greatly the shape differed from a perfect circle. This is because it was assumed that leaner subjects would have an abdominal section scan that was closer to the shape of a perfect circle. The tallest height (Fig 1) and widest width (Fig 2) of the image were measured. Two circles were drawn on the image at the same center point using a compass. The first circle was inscribed in the image, and the second circle was circumscribed around the image. The greatest distance from the circumference of the inscribed circle to the circumference of the MRI image were then measured. The same was done for the circumscribed circle, as well (Fig 3). These distances measured are referred to as Hausdorff distances, and they are used to determine and emphasize the degree of re-

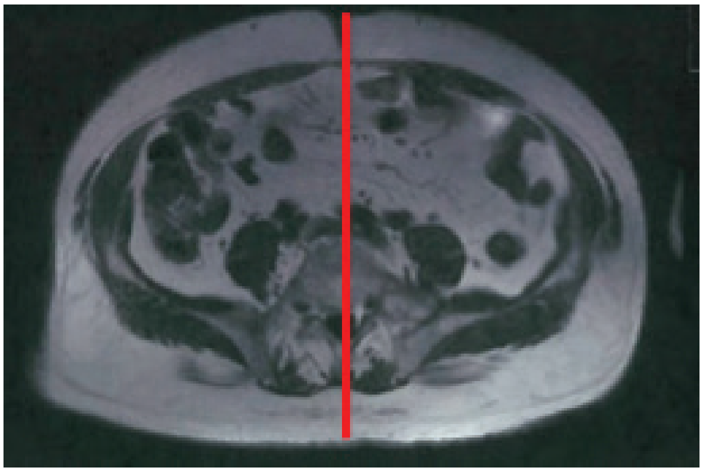


Figure 1 Greatest height measurement

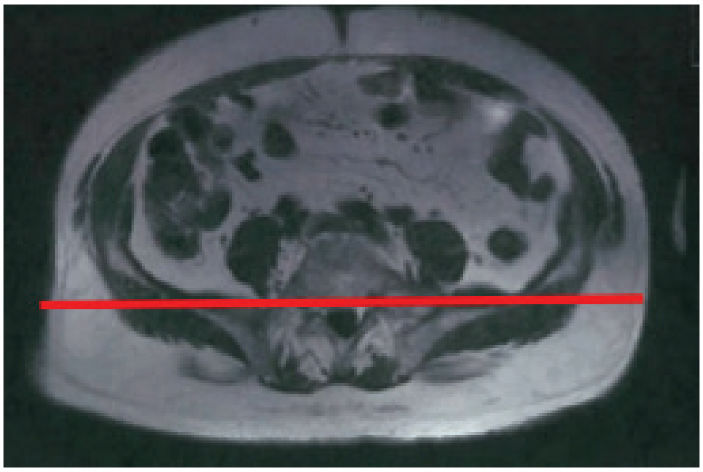


Figure 2 Greatest width measurement

semblance between two sets [7]. The images' circumference lengths were also obtained (Fig 4). Measurements were taken in centimeters.

All individual measurements were divided by circumference length as a way to normalize the data. Circumference, itself, was normalized for Hawaii (HI) and Los Angeles (LA) participants by dividing by the mean circumference of images taken at those geographic areas.

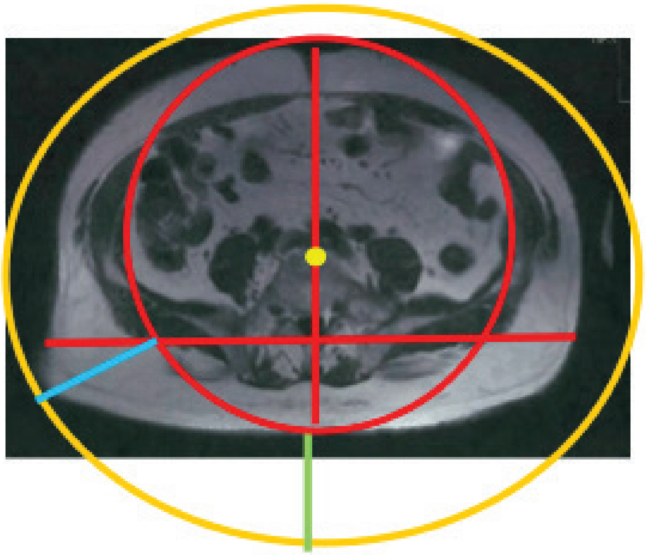


Figure 3 Hausdorff distances. The yellow point in the middle marks the center of the image. This is the point which all circles were drawn from. The green line is the maximum distance that we measured between the image's outline and the circumscribed circle, which is drawn in yellow. The blue line is the maximum distance that we measured between the image's outline and the inscribed circle, which is drawn in red.

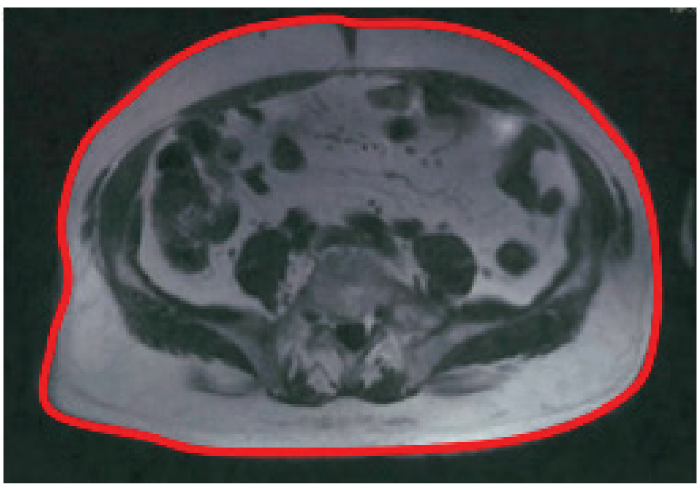


Figure 4 Circumference measurement

Data analyses

The SAS 9.4 software system was used to perform analyses of data measurements. Spearman correlations were computed between each measurement and MRI fat variables. Linear regression was performed on the MRI fat variables including all external measurements. The R-squared statistic measures the variability explained by the model. The data was also partitioned by sexes, and cluster analyses were run to determine the R-squared statistic between the MRI fat variables, and newly created cluster groups by sex and ethnicities within each sex. R-squared statistics were also determined for MRI fat variables, and waist and hip circumference. All R-squared values were transformed to fit a linear regression model, thus producing a more accurate and concise R-squared value.

Results

Systematic sampling proved to be an effective means of acquiring subject samples for the study. An equal amount of males and females were obtained, and a relatively equal distribution of Blacks, Hawaiians, Japanese, Latinos, and Whites were included, as well (Table 1).

When analyzing the various dependent variables to the entire grouping of independent variables, it was observed that holistically, the geometric measurements were significantly correlated with BMI, waist, weight, android fat (fat in the upper body), gynoid fat (fat in the lower body), leg fat, trunk fat, and subcutaneous fat; however, they were insignificantly correlated with liver, pancreatic, and overall visceral fat (Table 2).

An equal number of male and female subjects (n=114) were included in the study. Males and females were separated into individual groupings. Although each of the clusters included all five ethnic groups, each cluster showed higher numbers of certain ethnic groups. When separated from the female subgroup, in the male subgroup, the first cluster showed a higher number of Black males (n=13), the second cluster showed a higher number of Latino males (n=12), and the third and last

Table 1 Frequency of participants' sex and ethnicity in sample

Ethnicity	B	H	J	L	W	Total
Male	22	23	24	23	22	114
n=114	9.65	10.09	10.53	10.09	9.65	50
Female	21	21	32	21	19	114
n=114	9.21	9.21	14.04	9.21	8.33	50
Total	43	44	56	44	41	228
n=228	18.86	19.30	24.56	19.30	17.98	100

Table 2 Transformed R-squared values from regression model for fat variables and measurements

VARIABLE	R-SQUARED
OCL anthro BMI**	0.0784
OCL anthro waist**	0.0944
OCL anthro waist hip	0.0015
OCL anthro weight**	0.0346
ODXA BMD tot corr DXA	–0.005
ODXA fat android DXA**	0.0641
ODXA fat gynoid DXA**	0.1153
ODXA fat legs DXA**	0.091
ODXA fat tot corr**	0.0802
ODXA lean tot corr DXA	–0.004
ODXA fat trunk DXA**	0.08033
OMRI pct liver fat	0.0156
OMRI pct panc fat	0.0356
OMRI pct subc fat avg corr**	0.0574
OMRI pct visc fat avg corr	0.00019

**Results are significant

Table 3 Frequency of male participants' ethnicity in sample

CLUSTER	MB	MH	MJ	ML	MW	TOTAL
1 n=29	13	5	2	6	3	29
2 n=31	4	5	6	12	4	31
3 n=54	5	13	14	6	15	54
TOTAL n=114	22	23	22	25	22	114

Table 4 Frequency of female participants' ethnicity in sample

CLUSTER	FM	FG	FJ	FL	FW	TOTAL
1 n=64	9	14	21	6	14	64
2 n=31	8	5	12	11	3	31
3 n=11	4	2	1	2	2	11
TOTAL n=114	21	21	34	19	19	114

clusters showed higher numbers of Hawaiian (n=13), Japanese (n=14), and White males (n=15), relatively (Table 3). In the female subgroup, the first cluster showed a higher number of Japanese females (n=21), the second cluster showed higher numbers of Japanese (n=12) and Latino (n=11) females, and third cluster showed a higher number of black females (n=4), respectively (Table 4). This shows that the differences in fat distribution do vary by ethnicity.

When separated by sex, analysis of the various dependent variables to the entire grouping of independent variables revealed correlational differences between the measurement variables and fat variables for males versus females. One difference was regarding the correlation between the categories "waist:hip" and "waist" measurements, which were insignificant for males, but were significant for females (Table 5). The other major difference was regarding the significantly correlated liver and overall visceral fat measurements for females, but not for males; and the significantly correlated subcutaneous fat measurements for males, but not females (Table 5). The measurements are both significant and practical predictors of overall visceral fat for women ($p=0.0005, <0.05$) and pancreatic fat for men ($p=0.0559$).

An analysis was also conducted to see how the effectiveness of our measurement variables on predicting visceral fat would compare to standard measures of waist and hip circumference. All variables considered in this analysis were significantly correlated with measures of waist and hip circumference, with the exception of bone mass density in males (Table 6). In fact, the MRI images were better than standard measures of waist and hip circumference as predictors of liver fat ($r^2=0.013795$, $r^2=0.116628$, respectively) and pancreatic fat ($r^2 = 0.113253$, $r^2=0.132597$, respectively) in males.

Discussion

This analysis examined the potential for estimating and determining fat distribution using the external outline of abdominal cross sections from MRI scans within a diverse population consisting of five different ethnicities and an even sex distribution. The significance lies in the lack of diverse alternative methods for predicting visceral fat distribution and trends, despite high association between visceral fat and various cancers and diseases.

The results from this study reveal a significant correlation between visceral fat distribution with the measurement

Table 5 Transformed R-squared values from regression model for fat variables and measurements, separated by sex

VARIABLE	R-SQUARED MALES	R-SQUARED FEMALES
OCL anthro BMI	0.066663**	0.206958**
OCL anthro waist	0.103441**	0.229249**
OCL anthro waist hip	0.018810	0.076030**
OCL anthro weight	0.146432**	0.179869**
ODXA BMD tot corr DXA	0.012126	0.025192
ODXA fat android DXA	0.084779**	0.115033**
ODXA fat gynoid DXA	0.162158**	0.082564**
ODXA fat arms	0.098948**	0.128926**
ODXA fat legs DXA	0.201097**	0.058537**
ODXA fat tot corr	0.132160**	0.096911**
ODXA lean tot corr DXA	0.106531**	0.189572**
ODXA fat trunk DXA	0.085198**	0.115144**
OMRI pct liver fat	0.013795	0.017971**
OMRI pct panc fat	0.113253†	0.076925**
OMRI pct subc fat avg corr	0.082561**	0.119658
OMRI pct visc fat avg corr	0.011453	0.129968**

**Results are significant.
† P-values were similar enough to $p<0.05$ to be classified as significant.

Table 6 Transformed R-squared values from regression model for fat variables and waist and hip circumference, separated by sex

	R-SQUARED MALES	R-SQUARED FEMALES
OCL anthro BMI	0.759526**	0.839097**
OCL anthro weight	0.830789**	0.8151310**
ODXA BMD tot corr DXA	0.043588	0.117684**
ODXA fat android DXA	0.678654**	0.760678**
ODXA fat gynoid DXA	0.678857**	0.776336**
ODXA fat arms	0.621907**	0.697277**
ODXA fat legs DXA	0.676909**	0.694946**
ODXA fat tot corr	0.640493**	0.760075**
OMRI pct liver fat	0.116628**	0.230771**
OMRI pct panc fat	0.132597†	0.350390**
OMRI pct subc fat avg corr	0.542941**	0.765669**
OMRI pct visc fat avg corr	0.549959**	0.550620**

**Results are significant.
† P-values were similar enough to $p<0.05$ to be classified as significant.

variables for women, but not for men. They also reveal a significant correlation between pancreatic fat distribution with the measurement variables for men, but not for women. Despite insignificant values ($p>0.05$) for correlation between the measurements and pancreatic fat in males ($p=0.0559$), the p-value indicating significance for these fat variables was very close to the commonly acceptable p-value of $p<0.05$ indicating significance; thus, we considered this fat variable to be significantly correlated to the measurement variables, as well. Additionally, when results were adjusted for age, R-squared values for both regression model sets were very similar to one another, indicating that the association between the measurements and visceral fat distribution are not due to an age effect.

When compared to waist and hip circumference measurements, the simple geometric measurements of the MRI images were both better predictors of liver fat ($r^2=0.013795$, $r^2=116628$, respectively) and pancreatic fat ($r^2=0.113253$, $r^2=0.132597$, respectively) in males. It was unsurprising to find a significant correlation between subcutaneous fat in both men and women throughout all analyses done, as the external measurements are made in surface contact with the outer, subcutaneous fat.

This current research demonstrated that there are sex differences that must be taken into consideration upon conducting visceral fat predictions, particularly when using MRI images as a means of obtaining information for visceral fat distribution. Additionally, it has demonstrated that simple, geometric measurements of abdominal MRI scans are practical predictors of visceral fat in women, and pancreatic fat in men; furthermore, these measurements surpass the effectiveness of waist and hip circumference in predicting liver and pancreatic fat in men. Thus, this method serves as an alternative, practical means for determining distribution of various types of visceral fats in individuals—depending on the individual's biological sex. This not only creates a greater number of methods but also more diverse ways to gauge an individual's potential risk for cancer or cardiovascular diseases based on their visceral fat distribution.

A weakness of this study may be that MRI images were used as a proxy for measurements performed on actual subjects. Additionally, the sample that was used within the Multi-Ethnic Cohort included men and women within a limited age range (45–53 years). The data that was collected was also from individuals in two different geographic locations—Los Angeles, California and Honolulu, Hawaii; thus, there is potential for environmental differences to act as confounding factors. Some strengths of this study may be that despite our sample having been obtained through systematic, random selection, an even distribution among all ethnic groups and sexes was obtained for our study. Additionally, aside from MRI imaging, information from DEXA images was also obtained for the subjects, which provides more opportunity to consider and control for more aspects of variables that may be affecting differences in visceral fat distribution, aside from just sex.

Further analysis can be conducted using the results and information obtained from this project. Although the project goal focused on discovering whether other methods to predict visceral fat existed and were effective aside from imaging, MRI images were used in the project. Had this been the goal of the project at the very start of the study, external measurements on the subjects could have been made as they were lying down. Then, the external measurements would be completely divorced from the MRI imaging. However, these types of measurements were not made at the UHM and USC Research Centers. Thus, we measured these quantities off of the image as a proxy to test the hypothesis.

As the results obtained from this study indicated that the geometric measurements were significantly correlated to several fat variables in men and women, future research can be conducted to make clinical measurements to test against internal fat.

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