Alternative Methods To Estimate Body Fat

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Part 1: Introduction

Abstract

- Fat percentage of the human body may be of clinical importance
  - Influence in morbidity and mortality
  - Alter effectiveness of drugs
  - Affect body's ability to retain heat
- Current methods to estimate body fat percentage are expensive and technical
  - Electrical calipers
  - Bioelectrical impedance
  - Hydrostatic weighing

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A skin-fold test is done using a tool called calipers to pinch different areas of your body and measure body fat. There are a few ways to measure, but many people go with a three-site approach developed by researchers Jackson and Pollock in the 1980s. This method takes the least amount of time to complete. It's also cost-effective, as you can find calipers online for less than $7.

How to:

- If you're a man, measure fat at your chest, abdominals, and thigh.
- If you're a woman, measure fat at your triceps, suprailiac (about an inch above the hip bone), and the thigh.
- Calipers may come with instructions on how to convert these numbers to your body fat percentage.
- You can also consult an online skinfold calculator if you'd rather not do the math yourself.
- Measure on one side of your body, usually the right, for consistency.
- Mark the pinch site 1 centimeter above the skinfold.
- Consider asking a friend or family member to do the measurements for you.
- Take at least two measurements of the same area and average them for the most accurate data.

Tips

Accuracy

When performed correctly, there is around a +/– 3 percent error rate. You may also do a seven-site measurement. This approach is more time-consuming, but it may be slightly more accurate.

AIM: To estimate body fat percentage within a ~3% margin of error using multiple linear regression on common body measurements

The Data Set

Background

- Collected by the Human Performance Research Center at Brigham Young University
- Originally used to produce predictive equations for body composition (1974)
- Available at https://dasl.datadescription.com/datafile/bodyfat

Variables

Response

- `pct_bf`

General characteristics

- `age` (years)
- `weight` (kg)
- `height` (cm)

Circumference measurements (cm)

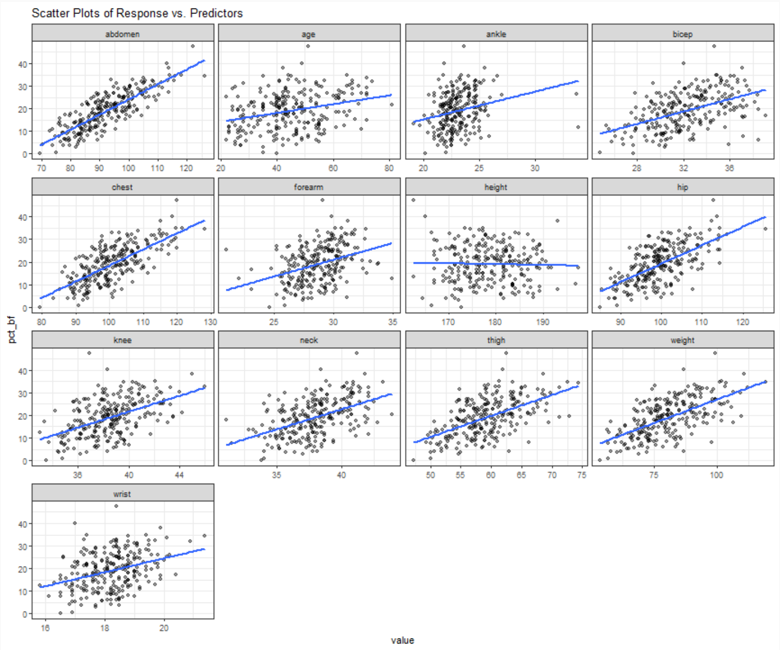
- `neck`, `chest`
- `abdomen`, `hip`
- `thigh`, `knee`
- `ankle`, `bicep`
- `forearm`, `wrist`

Part 2: Analysis

Analysis: Initial Assumptions

☑ Linearity

- Response of `pct_bf` against all predictor variables is linear
- ∴ Linearity assumption is satisfied after EDA



☑ Independence

- All observations independent measurements taken from 250 different males
- ∴ Independence assumption is satisfied

Analysis: Model Exploration

Step-wise search

- Search using AIC and then drop insignificant ($p < 0.05$) predictors

Backward Search

	pct bf	
Predictors	*Estimates*	*p*
(Intercept)	2.90	0.720
age	0.06	**0.020**
height	-0.13	**0.008**
abdomen	0.77	**<0.001**
wrist	-1.91	**<0.001**
Observations	250	
R^2 / R^2 adjusted	0.738 / 0.734	

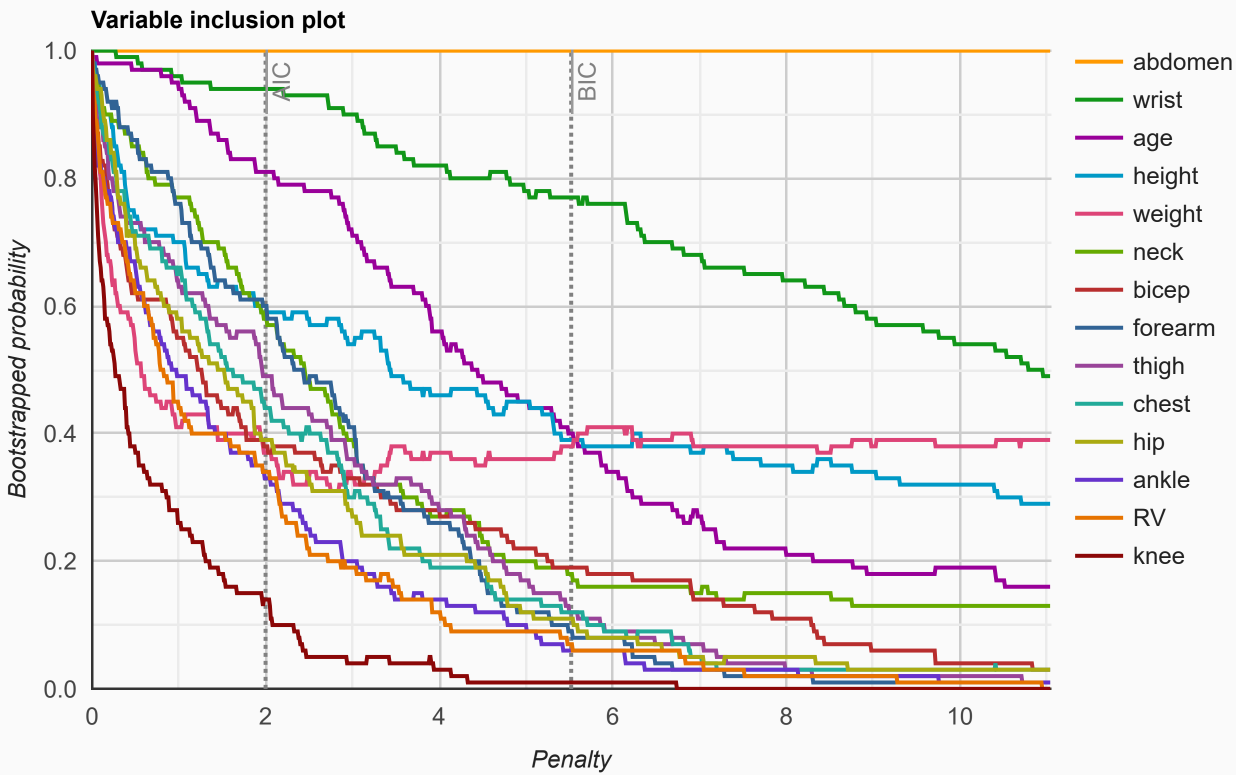
Forward Search

	pct bf	
Predictors	*Estimates*	*p*
(Intercept)	-27.89	**<0.001**
abdomen	0.96	**<0.001**
weight	-0.21	**<0.001**
wrist	-1.37	**0.002**
Observations	250	
R^2 / R^2 adjusted	0.734 / 0.730	

Analysis: Model Exploration

Stability analysis

- Is a certain variable or model consistently selected despite changes in the data set?



Stability analysis

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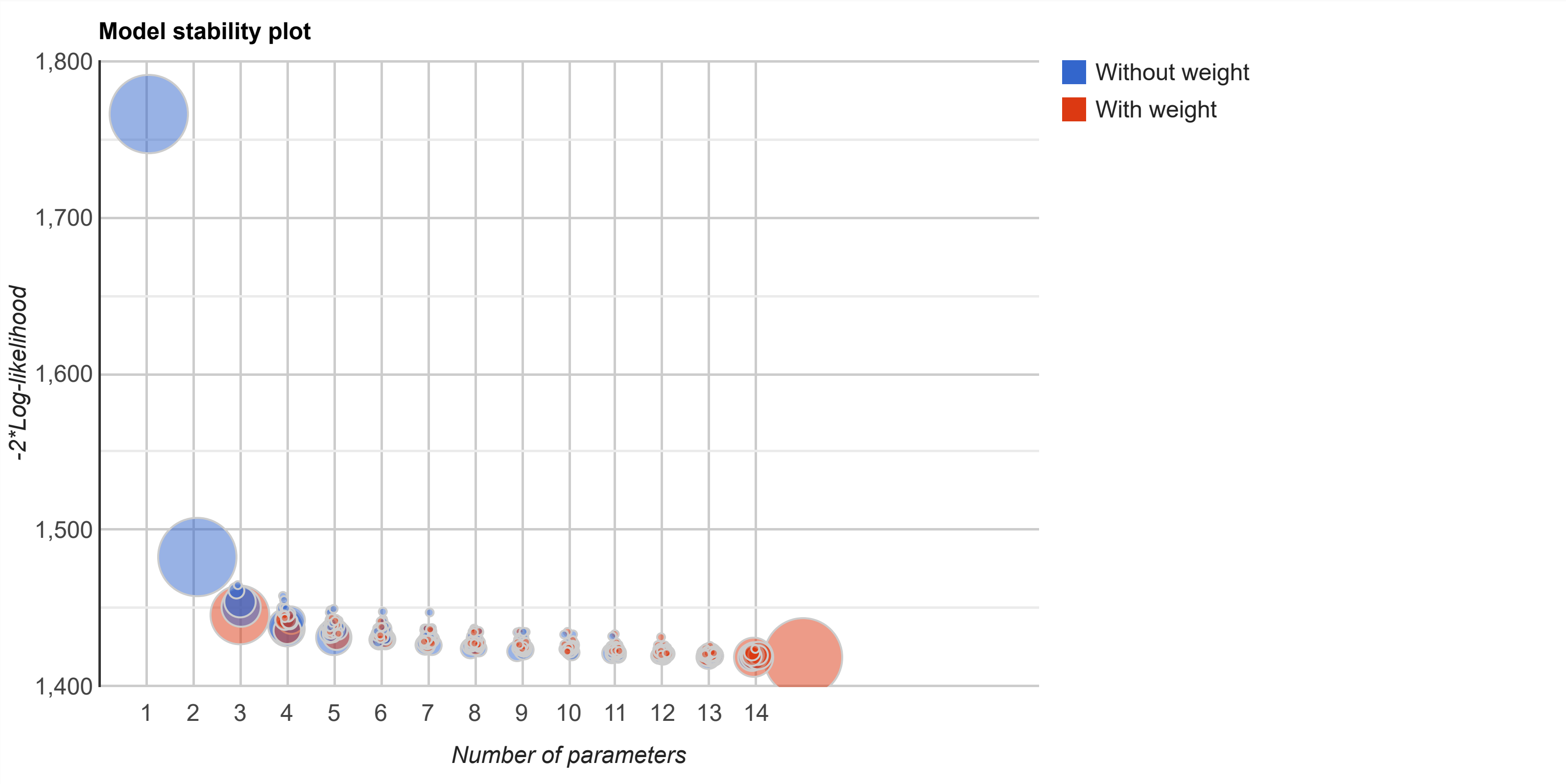


Analysis: Model Exploration

- Stability plots suggest that these two models are consistent performers:

Abdomen

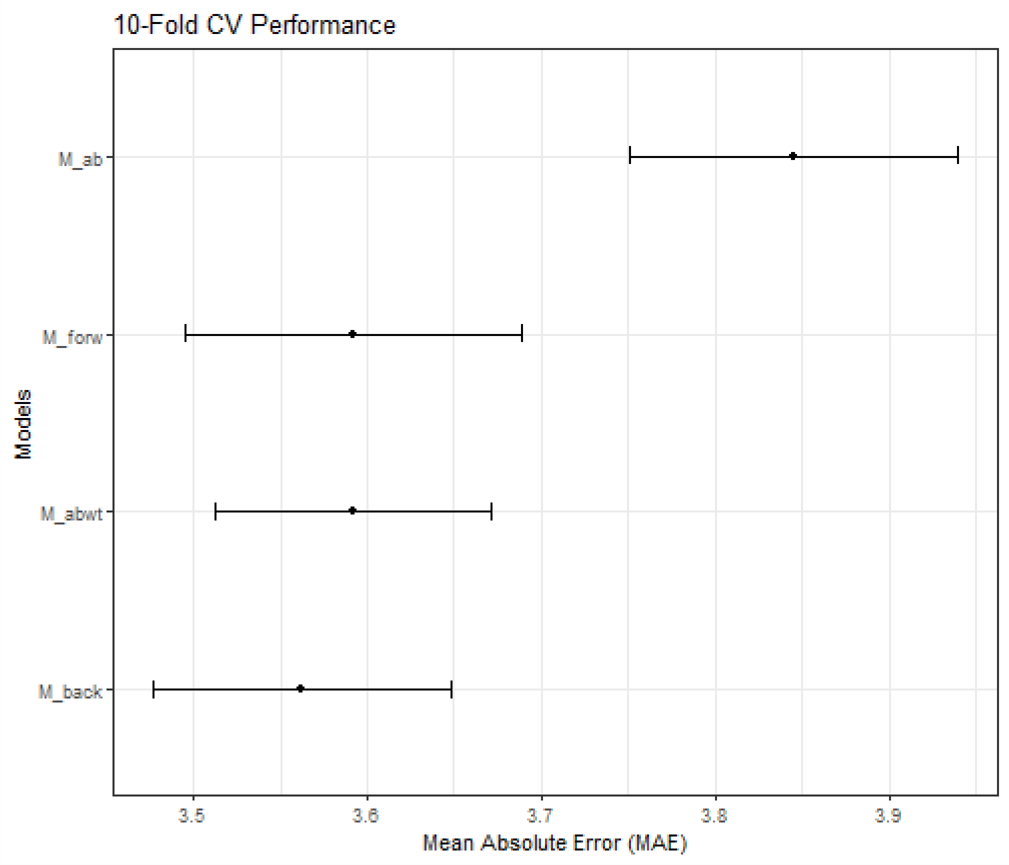
	pct bf	
Predictors	*Estimates*	*p*
(Intercept)	-42.73	**<0.001**
abdomen	0.67	**<0.001**
Observations	250	
R^2 / R^2 adjusted	0.678 / 0.677	

Abdomen + Weight

	pct bf	
Predictors	*Estimates*	*p*
(Intercept)	-47.45	**<0.001**
abdomen	0.98	**<0.001**
weight	-0.29	**<0.001**
Observations	250	
R^2 / R^2 adjusted	0.723 / 0.721	

Analysis: Cross-validation

- Our exploration has yielded 4 models that we would like to compare
- We use 10-fold cross-validation and compare MAEs



Analysis: Model Selection

- We choose `M_abwt`, which is specified as:

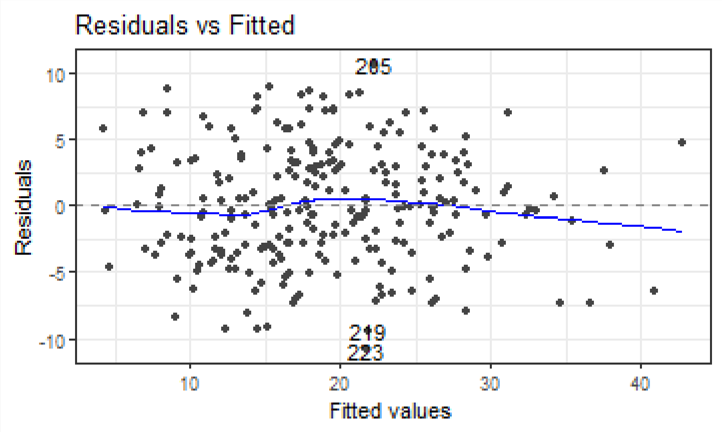
$$\widehat{\text{pct\_bf}} = -47.45 + 0.98 \text{ abdomen} - 0.29 \text{ weight}$$

- Good CV performance
- Parsimonious
- Highly significant coefficients
- Very stable

Analysis: Final Assumptions

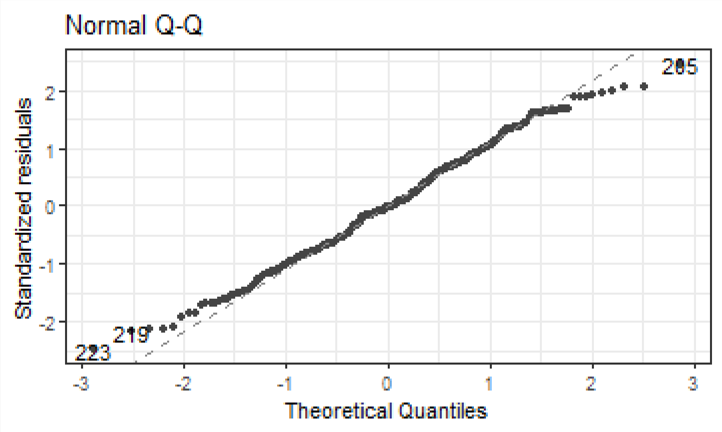
☑ Equal variance

- Residuals vs fitted plot shows no clear patterns
- Fairly equal distribution of points above and below zero line
- Homoskedasticity (equal variance) assumption satisfied



☑ Normality

- Residuals lie mostly along QQ line
- Large amount of observations, $n = 250$
- $\therefore$ CLT will apply
- Hence normality assumption satisfied



Part 3: Results

Results

$$\widehat{\text{pct\_bf}} = -47.45 + 0.98\ \text{abdomen} - 0.29\ \text{weight}$$

Abdomen + Weight

	pct bf	
Predictors	*Estimates*	*p*
(Intercept)	-47.45	**<0.001**
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Performance

- CV MAE of ~3.6
- R^2 of 0.723

Interpretations

- +1cm in abdomen circumference results in +0.98% in body fat on average, holding all else constant
- +1kg in weight results in -0.29% in body fat on average, holding all else constant

Inferences

- Abdomen circumference and weight are both highly significant predictors

Part 4: Conclusion

Conclusion

Link to abstract

- Cross-validation score shows that we were on average ~3.6% off the true body fat percentage
- Very similar accuracy to the calipers method
- Easier to measure abdomen circumference and weight

Assumptions and limitations

- Our model met the linearity and $\varepsilon \sim N(0, \sigma^2)$ assumptions
- The source of the data (1974 study) suggested that independence was satisfied

Future research

- Try other regression methods, e.g. kNN and LASSO
- Implement a train/validation/test workflow to select among these methods (may require more data)

References

Data set

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Code help

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