

# Abdominal circumference v.s body fat

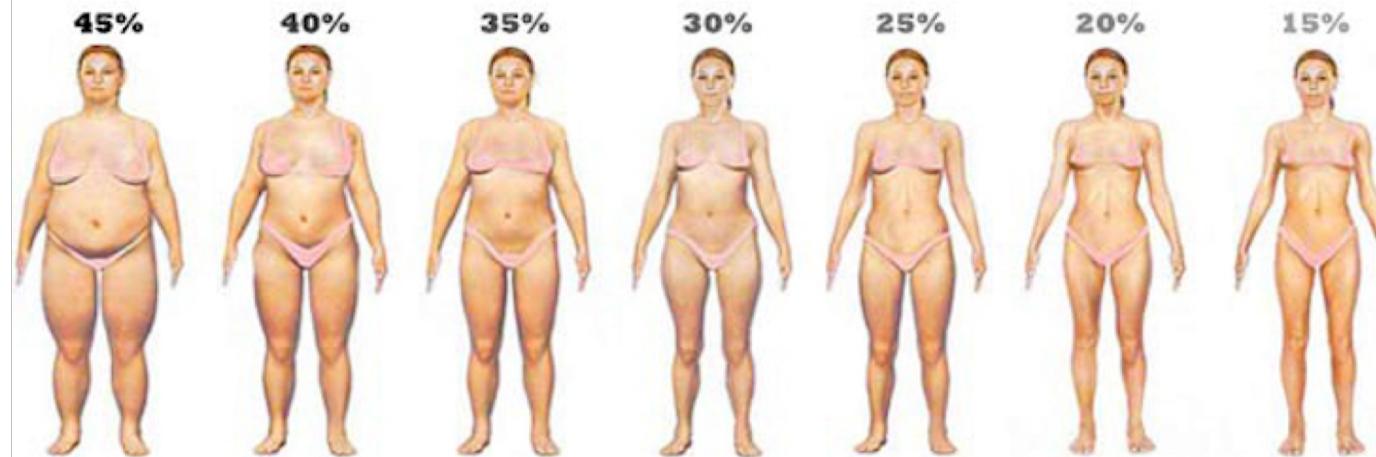
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## BODY FAT PERCENTAGE MEN



## BODY FAT PERCENTAGE WOMEN



The body fat percentage (BFP) of a human or other living being is the total mass of fat divided by total body mass, multiplied by 100.

# Dataset

The data set contains measurements from 252 men who had their body fat percentage accurately measured via underwater weighing.

17 Variable:

IDNO;

BodyFat(%) ----- Y (the outcome)

**Which one is the best predictor?**

Age (years) ; Weight (lbs) ; Height (inches) ; Adioposity (bmi) ; Neck circumference (cm)

Chest circumference (cm) ; Abdomen 2 circumference (cm) ; Hip circumference (cm)

Thigh circumference (cm) ; Knee circumference (cm) ; Ankle circumference (cm)

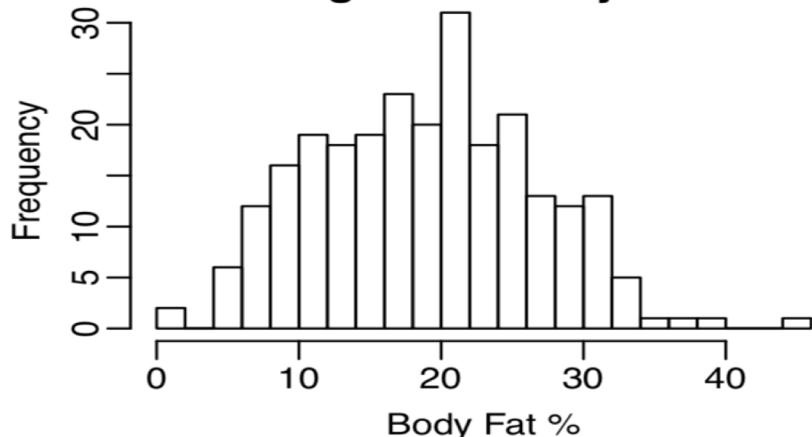
Biceps (extended) circumference (cm) ; Forearm circumference (cm) ; Wrist circumference (cm)

## Analyze Data

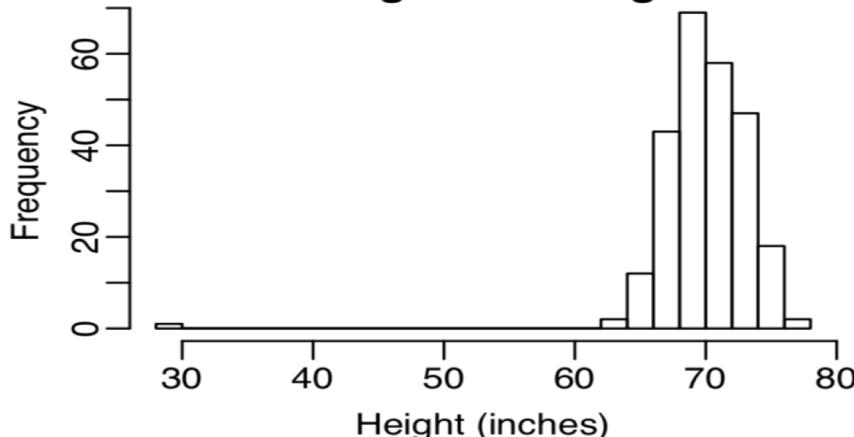
IDNO	BODYFAT	DENSITY	AGE	WEIGHT	HEIGHT
Min. : 1.00	Min. : 0.00	Min. :0.995	Min. :22.00	Min. :118.5	Min. :29.50
1st Qu.: 63.75	1st Qu.:12.80	1st Qu.:1.041	1st Qu.:35.75	1st Qu.:159.0	1st Qu.:68.25
Median :126.50	Median :19.00	Median :1.055	Median :43.00	Median :176.5	Median :70.00
Mean :126.50	Mean :18.94	Mean :1.056	Mean :44.88	Mean :178.9	Mean :70.15
3rd Qu.:189.25	3rd Qu.:24.60	3rd Qu.:1.070	3rd Qu.:54.00	3rd Qu.:197.0	3rd Qu.:72.25
Max. :252.00	Max. :45.10	Max. :1.109	Max. :81.00	Max. :363.1	Max. :77.75
ADIPOSITY	NECK	CHEST	ABDOMEN	HIP	THIGH
Min. :18.10	Min. :31.10	Min. : 79.30	Min. : 69.40	Min. : 85.0	Min. :47.20
1st Qu.:23.10	1st Qu.:36.40	1st Qu.: 94.35	1st Qu.: 84.58	1st Qu.: 95.5	1st Qu.:56.00
Median :25.05	Median :38.00	Median : 99.65	Median : 90.95	Median : 99.3	Median :59.00
Mean :25.44	Mean :37.99	Mean :100.82	Mean : 92.56	Mear	:59.41
3rd Qu.:27.32	3rd Qu.:39.42	3rd Qu.:105.38	3rd Qu.: 99.33	3rd	Qu.:62.35
Max. :48.90	Max. :51.20	Max. :136.20	Max. :148.10	Max.	:87.30
KNEE	ANKLE	BICEPS	FOREARM	WR	
Min. :33.00	Min. :19.1	Min. :24.80	Min. :21.00	Min.	
1st Qu.:36.98	1st Qu.:22.0	1st Qu.:30.20	1st Qu.:27.30	1st Qu.	
Median :38.50	Median :22.8	Median :32.05	Median :28.70	Median :18.30	
Mean :38.59	Mean :23.1	Mean :32.27	Mean :28.66	Mean :18.23	
3rd Qu.:39.92	3rd Qu.:24.0	3rd Qu.:34.33	3rd Qu.:30.00	3rd Qu.:18.80	
Max. :49.10	Max. :33.9	Max. :45.00	Max. :34.90	Max. :21.40	

SAME  
PERSON!

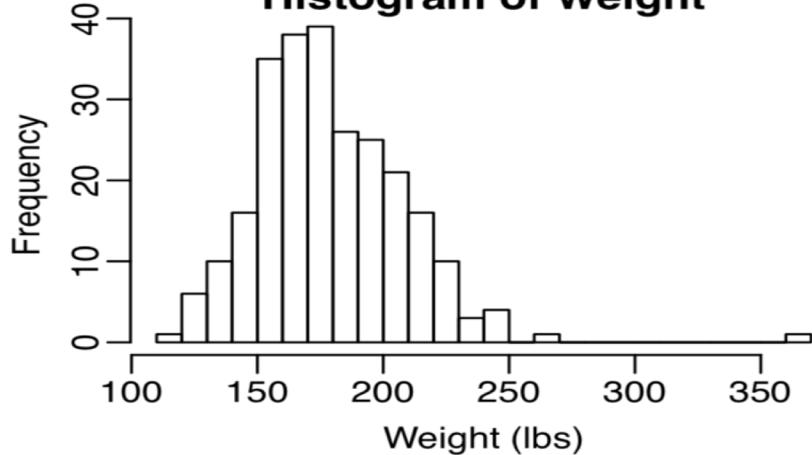
### Histogram of Body Fat %



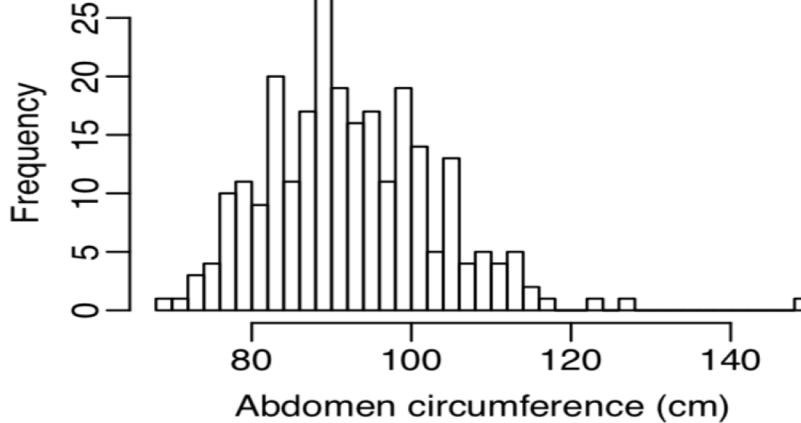
### Histogram of Height



### Histogram of Weight



### Histogram of Abdomen circumference



```
newBodyFat <- BodyFat[BODYFAT != 0 & WEIGHT < 360 & HEIGHT > 30 ,] # Filtering the data
dim(newBodyFat) # To check if the data is cleaned

## [1] 249 17

attach(newBodyFat) # re-attach to use this data set.

## The following objects are masked from BodyFat:
##
##      ABDOMEN, ADIPOSITY, AGE, ANKLE, BICEPS, BODYFAT, CHEST,
##      DENSITY, FOREARM, HEIGHT, HIP, IDNO, KNEE, NECK, THIGH,
##      WEIGHT, WRIST
```

# Choose the best predictor

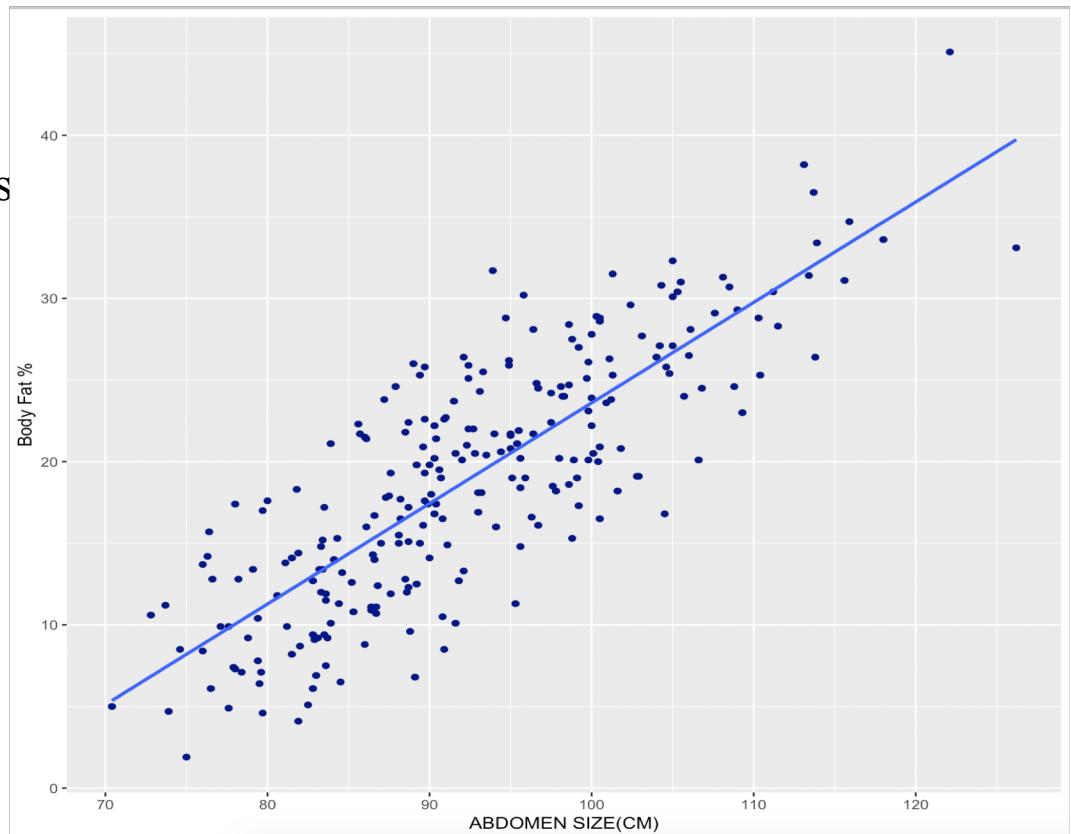
- Highest multiple R-squared
- Multiple linear model with all variables
  - summary of the model
- choose abdominal circumferences

Residuals:					
	Min	1Q	Median	3Q	Max
	-9.9844	-2.8895	-0.1751	2.6836	9.0965
Coefficients:					
	Estimate	Std. Error	t value	Pr(> t )	
(Intercept)	-19.56554	37.34453	-0.524	0.600830	
AGE	0.06603	0.02980	2.216	0.027655 *	
WEIGHT	-0.07911	0.10394	-0.761	0.447381	
HEIGHT	0.17563	0.51011	0.344	0.730928	
ADIPOSITY	0.64159	0.72460	0.885	0.376829	
NECK	-0.35493	0.21716	-1.634	0.103508	
CHEST	-0.14986	0.10312	-1.453	0.147491	
ABDOMEN	0.82381	0.08628	9.548	< 2e-16 ***	
HIP	-0.17928	0.13713	-1.307	0.192373	
THIGH	0.15390	0.13676	1.125	0.261596	
KNEE	-0.06194	0.22725	-0.273	0.785413	
ANKLE	0.13462	0.20558	0.655	0.513224	
BICEPS	0.16021	0.15784	1.015	0.311144	
FOREARM	0.23276	0.19268	1.208	0.228259	
WRIST	-1.66481	0.49301	-3.377	0.000859 ***	
---					
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '					

	WEIGHT	HEIGHT	ADIPOSITY	NECK	CHEST	ABDOMEN	HIP	THIGH	KNEE	ANKLE	BICEPS	FOREARM	WRIST
Multiple R-squared	0.3717	0.001431	0.5488	0.231	0.4803	0.6725	0.3904	0.2907	0.2307	0.05403	0.2247	0.1253	0.1074

$$\text{SLR model: } Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i, \varepsilon_i \sim N(0, \sigma^2)$$

- independent variable(x)
  - Abdominal circumferences
  - unit: cm
- dependent variable(y)
  - body fat
  - unit: %



$$\text{Body fat (\%)} = -37.991 + 0.616 \cdot \text{abdomen circumference}$$

- intercept = -37.991
  - unit: cm
- slope = 0.616
  - unit: % / cm
- hypothesis test
  - p-value:  $< 2.2 \cdot 10^{-16}$
  - reject the null hypothesis
- 95% confidence interval
  - slope: (0.562, 0.70)
  - intercept: (-43.00, -32.99)

```
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -37.99141   2.54124 -14.95 <2e-16 ***
ABDOMEN      0.61589   0.02735  22.52 <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.36 on 247 degrees of freedom
Multiple R-squared:  0.6725, Adjusted R-squared:  0.6712
F-statistic: 507.2 on 1 and 247 DF,  p-value: < 2.2e-16
```

	2.5 %	97.5 %
(Intercept)	-42.996683	-32.9861436
ABDOMEN	0.562028	0.6697498

# Testing the model

- 95% predict interval for 100 cm abdominal circumference
  - Prediction: 23.597
  - Interval: (14.983, 32.211)
  - Actual data: 27.8, 22.2, 23.9

	fit	lwr	upr
1	23.59748	14.98343	32.21152

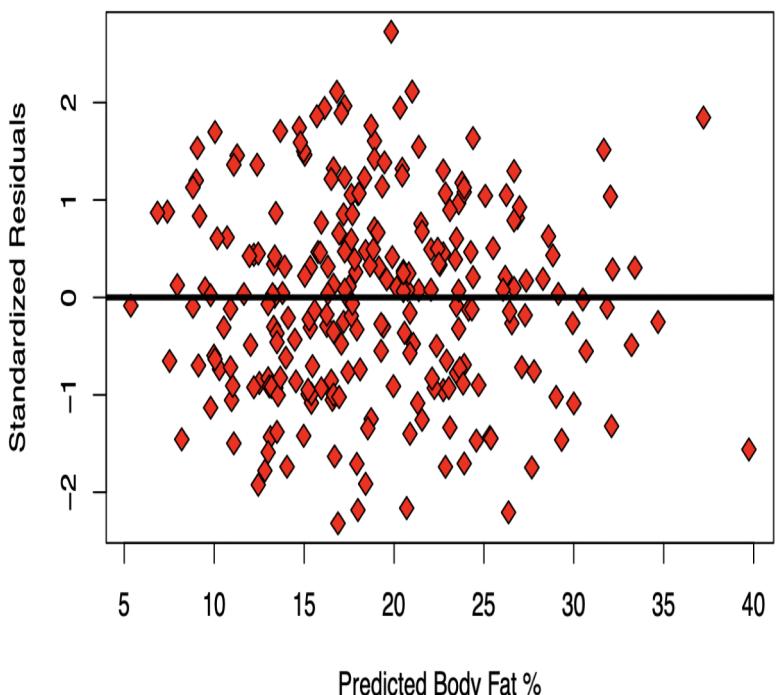
> BodyFat[ABDOMEN==100, ]										
	IDNO	BODYFAT	DENSITY	AGE	WEIGHT	HEIGHT	ADIPOSITY	NECK	CHEST	ABDOMEN
5	5	27.8	1.0340	24	184.25	71.25		25.6	34.4	97.3
56	56	22.2	1.0473	54	198.00	72.00		26.9	39.9	107.6
219	219	23.9	1.0433	52	199.25	71.75		27.2	39.4	106.8

# Evaluation of our model

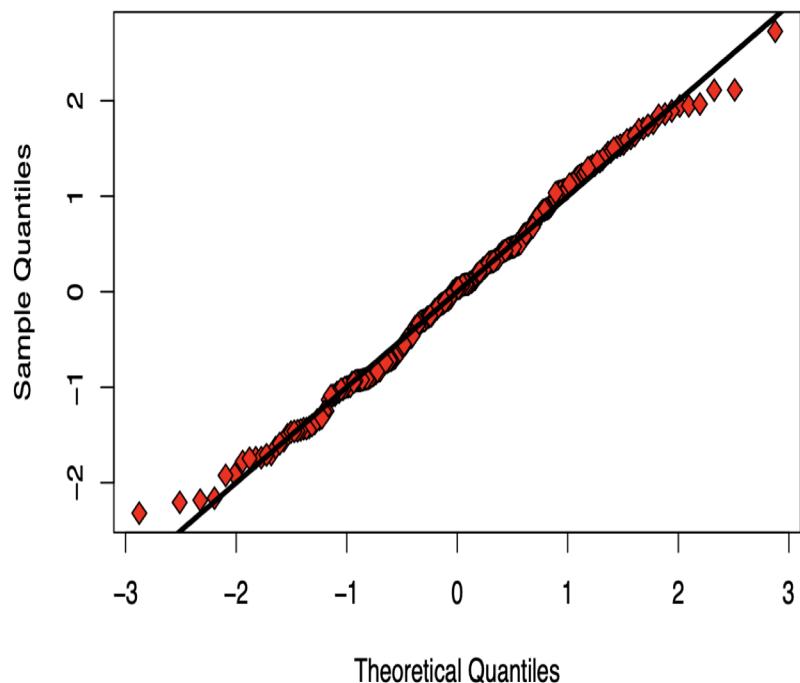
1. **Linearity:** Seems reasonable. Not only visually convincing but also statistically significant.
2. **Additivity:** Reasonable in general. Body fat is additive as abdomen gets bigger.
3. **Constant effects:** Reasonable but may not. Because muscular man could have the same abdomen size
4. **Fixed X:** This seems reasonable for this data.

## Normality Assumption

Standardized Residual Plot

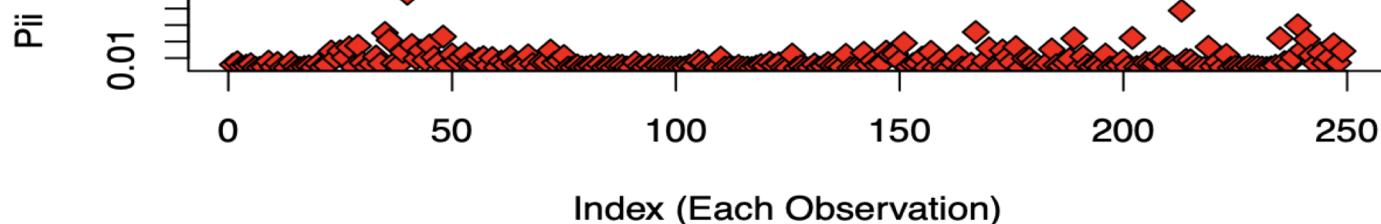


Normal Q-Q Plot

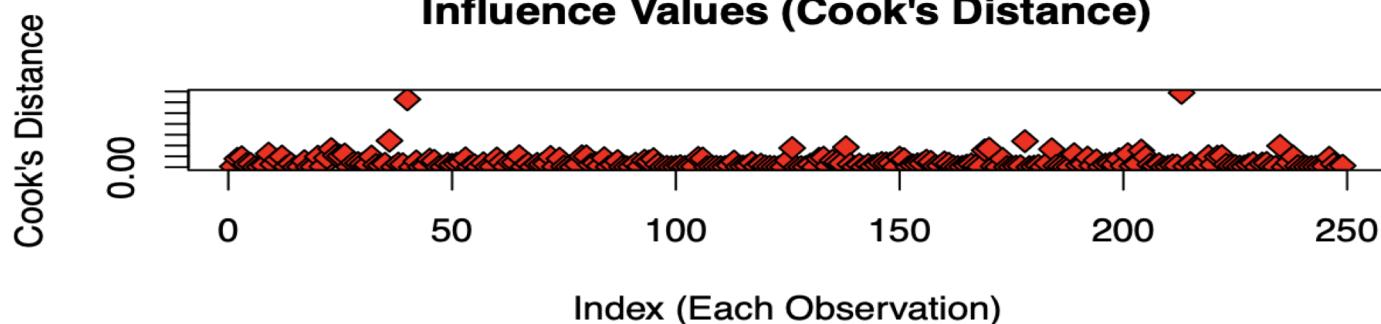


## Leverage Points

### Influence Values (Pii)



### Influence Values (Cook's Distance)



# Rule of Thumb

$$\text{Body Fat \%} = -38 + 0.6 * \text{Abdomen}$$

1. Multiply your abdomen by 0.6 and subtract 38
2. For every 5 cm increase in abdomen size, a man would gain 1 % of body fat.

Caution: Our SLR model only explains 67% of variance and also only predicts for grown men. It could be inaccurate for women or children. 63cm (24 inches) = 0 body fat. 226cm (89 inches) 100 body fat.

Thank you!