# Exploring Anthropometric Measurements for Prediction of Body Build Weight and Gender

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# Outline

# Background

- Anthropometric measurements evaluate the size, shape, and composition of the human body
  - Constant measures: skeletal measurements and three “bony” girths
  - Changeable girths: shoulder, chest, waist, navel, hip, thigh, bicep, forearm, calf

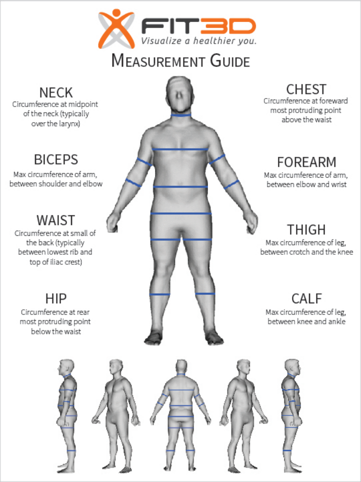


Figure: Fit3D Male Measurement Guide

http://healthandfitnesstesting.nz/resources/fit3d-male-measurement-guide/

# Objective

Our objective was to evaluate the relationships between body measurements, and to develop and evaluate prediction models for body build weight and gender.

- Aim 1a: Predicting weight from body build measures
- Aim 1b: Utility of BMI in relation to body build weight
- Aim 2: Predicting gender from skeletal measures

# Methods

- Description of data set:
  - 247 males and 260 females
  - Twenties to early thirties
  - Physically active
  - Nine skeletal and twelve girth measurements
  - Additional variables: height, weight, age, gender
- Transformation of variables:
  - Log transformation of weight

# Aim 1a: Predicting weight from body build measures

Linear model

- Model 1.1
  - All skeletal measurements + height + gender + age
  - Model selection: AIC criteriion
- Model 1.2
  - Nine skeletal measurements + three constant girth measurements + height + gender +age
  - Model selection: AIC criteriion

# Aim 1a: Predicting weight from body build measures

Quadratic model

- Method 1: sum, square, and multiplied by height
  - Model 2.1
    - Quadratic term of all girth measures + age + gender
  - Model 2.2
    - Quadratic term of all girth measures + age
  - Model 2.3
    - Quadratic term of three constant girth measures + gender + age
- Method 2: multiplied by height, sum,and square
  - Model 2.4
    - Quadratic term of all girth measures + age + gender
  - Model 2.5
    - Quadratic term of three constant girth measures + gender + age

# Aim 1b: Utility of BMI in relation to body build weight

- Body build weight
  - Predicted weight from our linear model
  - Normal weight given the body build frame
- Regressed the body build weight (log transformed) on BMI with/without gender to evaluate the utility of BMI in relation to body build weight
- High or low fat mass
  - Difference between measured waist girth and body build waist girth predicted by chest, biiliac, and bitrochanteric diameters as well as chest depth
  - A difference of $>$ 5 cm or $<$ -5 cm was defined as high or low fat mass
- High or low muscle mass
  - Difference between measure forearm girth the body build one predicted by wrist girth, chest diameter and chest depth
  - A difference of $>$ 1 cm or $<$ -1 cm was defined as high or low muscle mass

# Aim 2: Predicting gender from skeletal measures

- Logistic regression using forward and backward stepwise selection methods
  - P-value for addition: 0.1
  - P-value for removal: 0.25
- Model selection completed with and without height
- Akaike information criterion
- Sensitivity and specificity
- Internal validation: ten-fold cross validation

# Results

**Table 1. Baseline characteristics (Median ($25^{th}$, $75^{th}$ percentile) or N(%))**

| | Overall (N=507) | Female (N=260) | Male (N=247) |
|---|---|---|---|
| Age (years) | 27 (23, 36) | 26 (22, 34) | 29 (24, 37) |
| Height (cm) | 170.3 (163.8, 177.8) | 164.5 (160, 169.5) | 177.8 (172.8, 182.9) |
| Weight (kg) | 68.2 (58.4, 78.9) | 59 (54.4, 65.7) | 77.3 (70.9, 85.5) |
| BMI Category | | | |
| Less than 18.5 $kg/m^2$ | 13 (2.6) | 12 (4.6) | 1 (0.4) |
| 18.5-25 $kg/m^2$ | 344 (67.9) | 203 (78.1) | 141 (57.1) |
| 25-30 $kg/m^2$ | 132 (26.0) | 36 (13.9) | 96 (38.9) |
| Over 30 $kg/m^2$ | 18 (3.5) | 9 (3.4) | 9 (3.6) |

# Aim 1a: Predicting weight from body build measures

- Best linear model: Model 1.2
  - log(weight) = skeletal biacromial + skeletal biiliac + skeletal bitrochanteric + skeletal chest depth + skeletal chest + skeletal elbow + knee girth + ankle girth + wrist girth + age + height + gender + intercept
  - Ten-fold cross validation yielded a pseudo $R^2$ of 0.9140.
- Best quadratic model: Model 2.2
  - Trasformation method 1: sum, square, and multiplied by height
  - All girth measures in quadratic form + age
  - Ten-fold cross validation yielded a pseudo $R^2$ of 0.9594.
- Linear model was chosen due to simpler form and better interpretability.

# Aim 1b: Utility of BMI in relation to body build weight

- Regressing body build weight on BMI
  - adjusted $R^2$=0.540
  - pseudo-$R^2$ = 0.536 by ten-fold cross-validation
- Regressing body build weight on BMI and gender
  - adjusted $R^2$=0.748
  - pseudo-$R^2$ = 0.750 by ten-fold cross-validation
- Models assessing fat mass and muscle mass
  - Fat mass: adjusted $R^2$ = 0.776
  - Muscle mass: adjusted $R^2$ = 0.787

# Aim 2: Predicting gender from skeletal measures

Logit(gender)= chest depth + bitrochanteric + biacromial + wrist + knee + elbow + height + intercept

- Forward stepwise regression
- AIC: 127.0
- Sensitivity: 96.5%
- Specificity: 95%
- Internal validation $R^2$: 0.8420

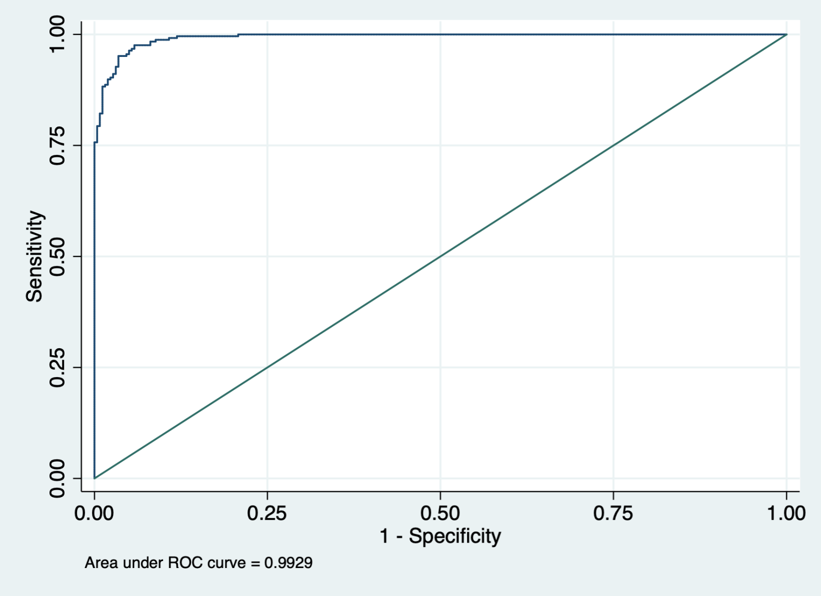


Figure: ROC curve of the prediction model

# Discussion

- Aim 1a
  - Both linear and quadratic models show good predictability.
  - Linear model was chosen due to simpler form
  - The best model contains skeletal biacromial, skeletal biiliac, skeletal bitrochanteric, skeletal chest depth, skeletal chest, skeletal elbow, knee girth, ankle girth, wrist girth, age, height, and gender.
- Aim 1b
  - BMI is a poor predictor for the body build weight.
  - Subjects with high fat or muscle mass
    - A larger body frame for their height
    - BMI tends to classify them as overweight or obese
    - Does not tell whether extra weight is due to fat or muscle
  - Similar for subject with low fat or muscle mass

# Discussion

- Aim 2
  - Height, chest depth, bitrochanteric, biacromial, wrist, knee, and elbow skeletal measurements best predicted gender.
  - Addition of height adds predictive ability.

- Limitations
  - Different model selection methods in each aim
  - Lack of external validation

# References

1. Heinz G, Peterson LJ, Johnson RW, Kerk CJ. Exploring Relationships in Body Dimensions. Journal of Statistics Education. 2003;11(2):null-null. doi:10.1080/10691898.2003.11910711
2. Marks GC, Habicht J, Mueller WH. Reliability, dependability, and precision of anthropometric measurements. BioMed Research International 5 The second national health and nutrition examination survey 1976–1980. American Journal of Epidemiology. 1989:578–587.
3. Pollock ML, Laughridge EE, Coleman B, Linnerud AC, Jackson A. Prediction of body density in young and middle-aged women. Journal of Applied Physiology. 1975;38(4):745-749. doi:10.1152/jappl.1975.38.4.745
4. Pollock ML, Hickman T, Kendrick Z, Jackson A, Linnerud AC, Dawson G. Prediction of body density in young and middle-aged men. Journal of Applied Physiology. 1976;40(3):300-304. doi:10.1152/jappl.1976.40.3.300
5. Wilmore JH, Behnke AR. An Anthropometric Estimation of Body Density and Lean Body Weight in Young Women. Am J Clin Nutr. 1970;23(3):267-274. doi:10.1093/ajcn/23.3.267

6. Wilmore JH, Behnke AR. An anthropometric estimation of body density and lean body weight in young men. Journal of Applied Physiology. 1969;27(1):25-31. doi:10.1152/jappl.1969.27.1.25
7. Thorland WG, Johnson GO, Cisar CJ, Housh TJ. Estimation of Minimal Wrestling Weight Using Measures of Body Build and Body Composition. Int J Sports Med. 1987;08(6):365-370. doi:10.1055/s-2008-1025687
8. Sebo P, Beer-Borst S, Haller DM, Bovier PA. Reliability of doctors' anthropometric measurements to detect obesity. Preventive Medicine. 2008;47(4):389-393. doi:10.1016/j.ypmed.2008.06.012
9. Deurenberg P, Deurenberg Yap M, Wang J, Lin FP, Schmidt G. The impact of body build on the relationship between body mass index and percent body fat. International Journal of Obesity. 1999;23(5):537-542. doi:10.1038/sj.ijo.0800868
10. Pasco JA, Holloway KL, Dobbins AG, Kotowicz MA, Williams LJ, Brennan SL. Body mass index and measures of body fat for defining obesity and underweight: a cross-sectional, population-based study. BMC Obes. 2014;1. doi:10.1186/2052-9538-1-9

11. Romero-Corral A, Somers VK, Sierra-Johnson J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. International Journal of Obesity. 2008;32(6):959-966. doi:10.1038/ijo.2008.11
12. Behnke, A. R., and Wilmore, J. H. (1974), Evaluation and Regulation of Body Build and Composition, Englewood Cliffs, NJ: Prentice Hall.
13. Song, X., et al. "Comparison of various surrogate obesity indicators as predictors of cardiovascular mortality in four European populations." European Journal of Clinical Nutrition67.12 (2013): 1298.
14. Joyce, C., and Stover, E. (1991), Witnesses from the Grave: The Stories Bones Tell, Boston, MA: Little, Brown, and Company, p. 80, pp. 177-178.
15. Wingate, A. (1992), Scene of the Crime: A Writer's Guide to Crime-Scene Investigations, Cincinnati, OH: Writer's Digest Books, p. 148.

16. Innes, B. (2000), Bodies of Evidence: The Fascinating World of Forensic Science and How it Helped Solve More Than 100 True Crimes, Pleasantville, NY: Reader's Digest Association, pp. 71-72.
17. Nickell, J., and Fischer, J. F. (1999), Crime Scene: Methods of Forensic Detection, Lexington, KY: The University Press of Kentucky.

*Questions?*