# Ability of Anthropometric Measurements to Predict Metabolic Health among Patients in Alberta: A Population-Based Study in Primary Care

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**Conflicts of Interest:** None

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**ABSTRACT**

**Purpose:** This study compared anthropometric and body fat percent (BF%) equations in relation to measures of metabolic health.

**Methods:** BF% calculations (Bergman, Fels, and Woolcott) and anthropometric measurements were used to determine obesity among patients attending primary care in Alberta, Canada. Anthropometric variables included body mass index (BMI), waist circumference, waist:hip, waist:height and calculated BF%. Metabolic Z-score was computed as the sum of triglycerides, total cholesterol, and fasting glucose and the number of standard deviations from the sample mean.

**Results**: 514 individuals were included (41.2% male, age: 53 ± 16y, BMI: 27.4 ± 5.7kg/$m^2$). Body mass index ≥ 30 kg/$m^2$ detected the smallest number of participants (n=137) as having obesity, while Woolcott BF% equation categorized the largest number of participants as having obesity (n=369). No anthropometric or BF% calculation predicted metabolic z-score in males (all $p \geq 0.05$). In females, age-adjusted waist:height had the highest prediction power ($R^2$=0.204, $p<0.001$), followed by age-adjusted waist circumference ($R^2$=0.200, $p<0.001$) and age-adjusted BMI ($R^2$=0.178, $p<0.001$).

**Conclusions**: This study did not find evidence that BF% equations more strongly predicted metabolic Z-scores than other anthropometric values. In fact, all anthropometric and BF% variables were weakly related to metabolic health parameters, with are apparent sex differences.

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## INTRODUCTION

Body mass index (BMI) is frequently used to identify obesity and comorbidity risk. However, BMI is not an accurate indicator of adiposity as implied by a wide variability of body fat percent (BF%) and visceral adiposity within each BMI category [1]. Newer equations to estimate BF% have been proposed as surrogate measures of body composition. Such calculations require anthropometric measurements that are portable, low-burden, and low-cost. These equations may be better predictors of health outcomes when compared to BMI and waist circumference [2], although these findings have not been consistently demonstrated [3].

The present study compared BF% calculations among patients attending primary care in Alberta, Canada in relation to metabolic health. We hypothesized that BF% calculations would be stronger predictors of metabolic parameters compared to BMI, waist circumference, waist:hip, and waist:height.

## METHODS

*Study design and participants*

This study was reviewed and approved by the Health Research Ethics Board at the University of Alberta. Data from the Canadian Primary Care Sentinel Surveillance Network (CPCSSN) was used, as previously described [4,5]. Patients age >18 years with data in the CPCSSN from 2004 to 2014 were included, with no exclusion based on ethnicity or comorbidity; patients with missing data were not excluded and the last recorded values of outcomes were used for these analyses.

Demographic variables included patient age and sex. Body weight, height, BMI, waist circumference, and hip circumference were obtained from medical records. BF% was calculated as follows:

1) Bergman *et al.* [6]: $\frac{Hip\ circumference\ (cm)}{Height\ (m)^{1.5}} - 18$
2) Fels [7]: $1.26\ x\ \left(\frac{Hip\ circumference\ (cm)}{Height\ (m)^{1.4}}\right) - 32.85$
3) Woolcott and Bergman [8]: 64 – (20 * [height (m) /waist circumference (m)]) + (12*sex)

where sex=0 for male and 1 for female in equation 3.

To ascertain metabolic health, triglycerides, total cholesterol, and fasting glucose were first summed together. The z-score was calculated as the number of standard deviations from the sample mean for each individual (i.e. [value-mean/standard deviation]), similar to previous reports [2]. Individuals were categorized as either having obesity or not having obesity according to the following definitions: BMI ≥ 30 kg/$m^2$, waist circumference ≥88 cm for females and ≥102 cm for males, BF% ≥ 25% in males and ≥ 35% in females, as previously used [9,10].

SAS (SAS Institute Inc. Cary, NC) version 9.3 and SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA) were used to perform the statistical analysis. All tests were two-tailed tests and significance considered at p <0.05. McNemar's test assessed the differences in the number of individuals diagnosed as having obesity by different criteria. Independent t-tests were used to compare the means of variables between males and females. Multiple linear regression tested the association between BMI, waist circumference, waist:hip, waist:height, and BF% calculations and metabolic risk z-score, stratified by sex. For each indicator of body size/composition, two models were built to evaluate the with metabolic risk alone and with age.

**RESULTS**

Anthropometric and metabolic variables are presented in **Table 1**. Mean age of the sample was 53 ± 16 years (range: 18 – 91 years) and mean BMI was 27.4 ± 5.7kg/m$^2$ (range: 16.7 – 63.0 kg/m$^2$). The overlap of those having obesity by various definitions are presented in **Figure 1**. The number of participants in each category was significantly different on all accounts ($p<0.001$, McNemar's test). BMI categorized the smallest number of participants as having obesity (n=137), while BF% from the Woolcott equation categorized the largest number of participants as having obesity (n=369).

Regression models to predict metabolic Z-scores are presented in **Table 2**. Models with age generally had greater predictive power. No model predicted metabolic Z-score in males. Conversely, all models were significant in females. Notably, waist:height with age had the highest prediction power ($R^2$=0.204, $p<0.001$), followed by age-adjusted waist circumference ($R^2$=0.200, $p<0.001$) and age-adjusted BMI ($R^2$=0.178, $p<0.001$).

**Discussion**

We found that anthropometric parameters predicted metabolic Z-score marginally better than calculated BF%, in females only. However, approximately 80% (or more) of the variability in metabolic Z-scores was unexplained across all measurements, suggesting that anthropometric-based calculations of body size and composition are poorly associated with metabolic health.

Previous research has suggested that BF% equations are more closely related to objectively-measured body composition than BMI [11,12], and may therefore represent an accessible tool to predict metabolic health in clinical settings. In our study, even the strongest model (using waist:height) predicted approximately 20% of metabolic Z-score variability in females, similar to previous research [2]. Poor ability of calculated BF% to predict metabolic health could be partially attributed to the weak relationship between anthropometrics and measured body composition [13], the latter being more closely linked to cardiovascular risk factors [14]. Our results also suggest that age marginally affects the relationship between anthropometric variables and metabolic health, potentially due to the change in fat distribution that occurs with senescence [15]. Tools that either directly and accurately measure body composition or consider lifestyle factors (e.g. the Edmonton Obesity Staging System [16]) may be more beneficial than anthropometrics for assessing metabolic risk and monitoring progress of health interventions.

In our data, no anthropometric measurement predicted metabolic Z-score in males while all predictive models were significant in females. Previous evidence suggests equations might underestimate BF% in males and overestimate body fat in females [13]. These equations do not consider sex, but rather hip circumference and height only. Since females are usually shorter than males and have a higher average BF%, body composition equations combining both sexes may overestimate the strength of association between height and body fat [13]. Further, BMI is more strongly related to BF% in females [9], which might explain why this anthropometric measure was a better predictor of metabolic Z-score in females in our study.

Our study is the first to assess predicted BF% in relation to metabolic health among Canadians in primary care. Nevertheless, this investigation is not designed to assess the role of anthropometric measures of adiposity on the development of metabolic conditions due to our cross-sectional and retrospective approaches; data collection was also not standardized. Furthermore, CPCSSN data are not collected from all primary care practices in Canada and may not be representative of the entire population with obesity.

In conclusion, BF% equations did not predict metabolic Z-scores better than singular anthropometric variables in adults in primary care practice in Canada. In fact, all measures weakly predicted metabolic Z-scores, with apparent variation between sexes. Future research should determine clinically viable and accurate strategies to identify individuals at risk for developing poor metabolic health while considering sex differences.

**Acknowledgement**

The data has been made available to the investigators by the College of Family Physicians of Canada on behalf of the Canadian Primary Care Sentinel Surveillance Network. The views and opinions expressed in this document do not necessarily reflect those of the College of Family Physicians of Canada or the Canadian Primary Care Sentinel Surveillance Network.

**Financial Support**: C. M. Prado is supported by a Canadian Institutes of Health Research (CIHR) New Investigator Salary Award and the Campus Alberta Innovates Program.

**REFERENCES**

1. Okorodudu DO, Jumean MF, Montori VM, Romero-Corral A, Somers VK, Erwin PJ, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. Int J Obes (Lond). 2010/02/04. 2010;34: 791–799. doi:10.1038/ijo.2010.5
2. Siervo M, Prado CM, Stephan BC, Lara J, Muscariello E, Nasti G, et al. Association of the body adiposity index (BAI) with metabolic risk factors in young and older overweight and obese women. Eat Weight Disord. 2014;19: 397–402. doi:10.1007/s40519-013-0077-0
3. Ramírez-Vélez R, Correa-Bautista JE, González-Ruíz K, Vivas A, Triana-Reina HR, Martínez-Torres J, et al. Body Adiposity Index Performance in Estimating Body Fat

Percentage in Colombian College Students: Findings from the FUPRECOL—Adults Study. Nutrients. 2017;9: 40. doi:10.3390/nu9010040

4. Morkem R, Barber D, Williamson T, Patten SB. A Canadian Primary Care Sentinel Surveillance Network Study Evaluating Antidepressant Prescribing in Canada From 2006 to 2012. Canadian journal of psychiatry Revue canadienne de psychiatrie. 2015;60: 564–570. doi:10.1177/070674371506001207

5. Birtwhistle R v. Canadian Primary Care Sentinel Surveillance Network: A developing resource for family medicine and public health. Canadian Family Physician. 2011;57: 1219–1220. Available: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3192094/

6. Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG, et al. A Better Index of Body Adiposity. Obesity (Silver Spring, Md). 2011;19: 1083–1089. doi:10.1038/oby.2011.38

7. Johnson W, Chumlea WC, Czerwinski SA, Demerath EW. Concordance of the Recently Published Body Adiposity Index With Measured Body Fat Percent in European-American Adults. Obesity (Silver Spring, Md). 2012;20: 900–903. doi:10.1038/oby.2011.346

8. Woolcott OO, Bergman RN. Relative fat mass (RFM) as a new estimator of whole-body fat percentage ─ A cross-sectional study in American adult individuals. Scientific Reports. 2018;8: 10980. doi:10.1038/s41598-018-29362-1

9. Romero-Corral A, Somers VK, Sierra-Johnson J, Thomas RJ, Bailey KR, Collazo-Clavell ML, et al. Accuracy of Body Mass Index to Diagnose Obesity In the US Adult Population. International journal of obesity (2005). 2008;32: 959–966. doi:10.1038/ijo.2008.11

10. Grundy SM. Obesity, Metabolic Syndrome, and Cardiovascular Disease. The Journal of Clinical Endocrinology & Metabolism. 2004;89: 2595–2600. doi:10.1210/jc.2004-0372

11. Silva MI, Vale BS, Lemos CC, Torres MR, Bregman R. Body adiposity index assess body fat with high accuracy in nondialyzed chronic kidney disease patients. Obesity (Silver Spring). 2013/04/18. 2013;21: 546–552. doi:10.1002/oby.20261

12. Alvim R de O, Mourao-Junior CA, de Oliveira CM, Krieger JE, Mill JG, Pereira AC. Body Mass Index, Waist Circumference, Body Adiposity Index, and Risk for Type 2 Diabetes in Two Populations in Brazil: General and Amerindian. PLoS ONE. 2014;9: e100223. doi:10.1371/journal.pone.0100223

13. Freedman DS, Thornton JC, Pi-Sunyer FX, Heymsfield SB, Wang J, Pierson Jr. RN, et al. The body adiposity index (hip circumference / height(1.5)) is not a more accurate measure of adiposity than is BMI, waist circumference, or hip circumference. Obesity (Silver Spring). 2012/04/10. 2012;20: 2438–2444. doi:10.1038/oby.2012.81

14. Zeng Q, Dong S-Y, Sun X-N, Xie J, Cui Y. Percent body fat is a better predictor of cardiovascular risk factors than body mass index. Brazilian Journal of Medical and Biological Research. 2012;45: 591–600. doi:10.1590/S0100-879X2012007500059

15. Kuk JL, Saunders TJ, Davidson LE, Ross R. Age-related changes in total and regional fat distribution. Ageing research reviews. 2009;8: 339–348. doi:10.1016/j.arr.2009.06.001

16. Sharma AM, Kushner RF. A proposed clinical staging system for obesity. Int J Obes (Lond). 2009/02/04. 2009;33: 289–295. doi:10.1038/ijo.2009.2

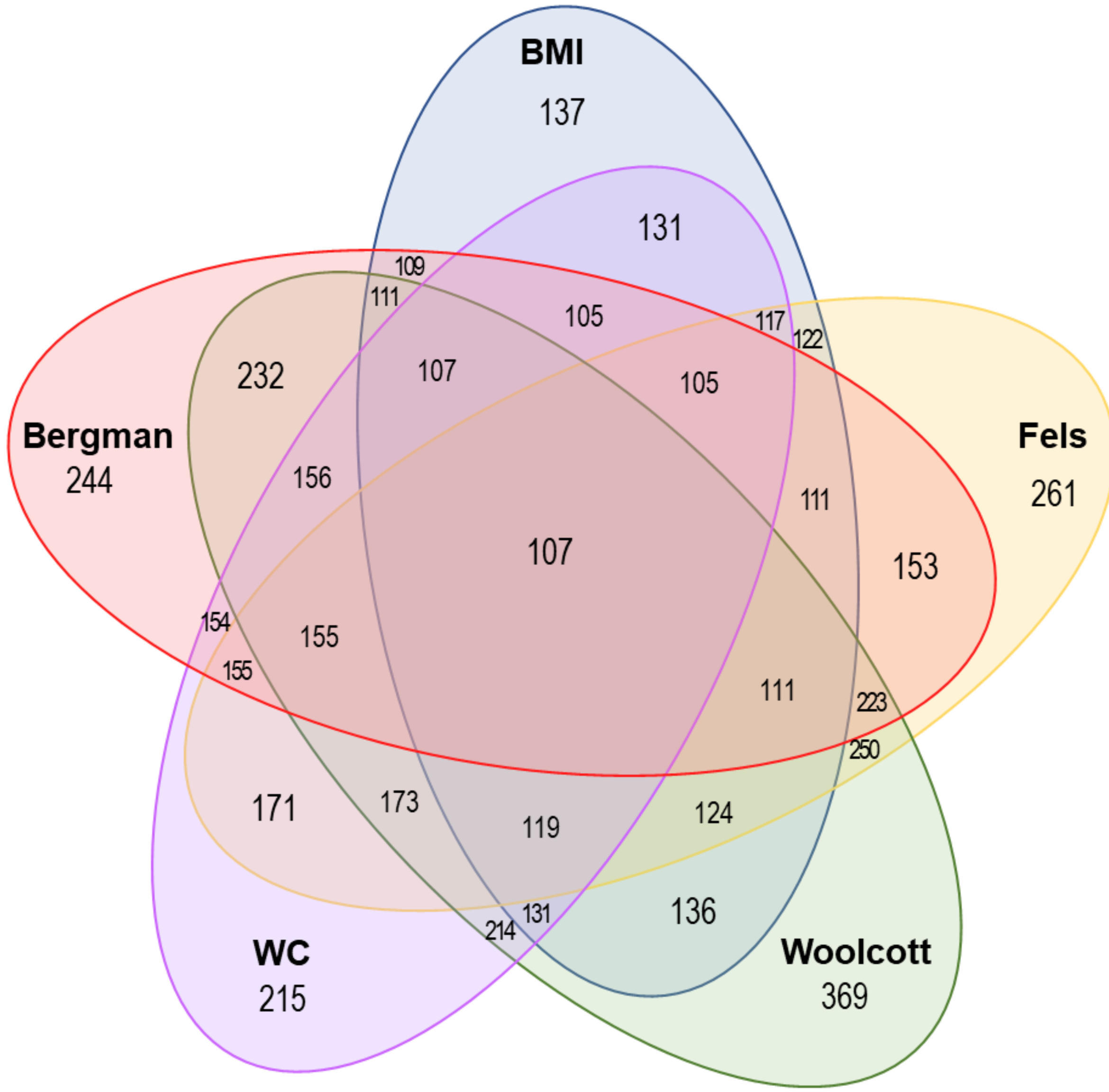


**Figure 1. Prevalence and overlap of obesity defined by different measures.** Venn diagram showing the number of individuals categorized as having obesity according to body mass index (BMI), waist circumference (WC), and body fat percentage calculated using equations from Fels *et al.*, Woolcott *et al.*, and Bergman *et al.* and their overlap.

**Table 1. Anthropometric and metabolic characteristics of patients in primary care**

| | N | | Females | Males | p-value |
|---|---|---|---|---|---|
| | **Females** | **Males** | | | |
| Age (years) | 301 | 212 | 51 ± 16 | 57 ± 14 | <0.001 |
| Weight (kg) | 302 | 211 | 70.1 ± 17.4 | 90.1 ± 19.0 | <0.001 |
| Height (cm) | 302 | 211 | 162.5 ± 6.5 | 175.7 ± 9.1 | <0.001 |
| Body mass index ($kg/m^2$) | 302 | 209 | 26.4 ± 5.8 | 28.9 ± 5.2 | <0.001 |
| Waist circumference (cm) | 301 | 211 | 86.8 ± 14.5 | 100.0 ± 17.4 | <0.001 |
| Waist/hip ratio | 302 | 212 | 0.80 ± 0.08 | 0.95 ± 0.08 | <0.001 |
| BF% Bergman | 301 | 210 | 32.2 ± 6.6 | 27.5 ± 9.5 | <0.001 |
| BF% Fels | 301 | 210 | 33.59 ± 8.60 | 27.8 ± 11.9 | <0.001 |
| BF%, Woolcott | 301 | 210 | 37.41 ± 8.26 | 27.10 ± 11.77 | <0.001 |
| Total cholesterol (mmol//L) | 264 | 197 | 5.1 ± 1.0 | 4.9 ± 0.9 | 0.013 |
| LDL-c (mmol/L) | 265 | 194 | 2.9 ± 0.8 | 2.9 ± 0.8 | 0.328 |
| HDL-c (mmol/L) | 266 | 197 | 1.6 ± 0.4 | 1.3 ± 0.3 | <0.001 |
| Triglycerides (mmol/L) | 259 | 193 | 1.3 ± 0.8 | 1.5 ± 1.0 | 0.017 |
| Fasting glucose (mmol/L) | 258 | 194 | 5.1 ± 0.9 | 5.6 ± 1.4 | <0.001 |
| HbA1c (%) | 152 | 130 | 5.8 ± 0.8 | 5.9 ± 0.6 | 0.322 |
| Systolic blood pressure (mmHG) | 302 | 211 | 118.8 ± 15.8 | 124.5 ± 15.3 | <0.001 |
| Diastolic blood pressure (mmHG) | 301 | 211 | 73.1 ± 10.8 | 76.2 ± 10.3 | 0.001 |
| Metabolic risk z-score | 275 | 202 | -0.07 ± 0.6 | 0.07 ± 0.7 | 0.024 |

BF%: body fat percent; LDL-c: low density lipoprotein cholesterol; HDL-c high density lipoprotein cholesterol; HbA1c: glycosylated hemoglobin, type A1c

**Table 2.** Regression analysis to evaluate the predictive value of each adiposity index with cumulative metabolic risk z-score (dependent variable).

| Group Models | β | SE | t | $R^2$ | p-value |
|---|---|---|---|---|---|
| **Males** | | | | | |
| BMI | 0.012 | 0.010 | 1.20 | 0.007 | 0.231 |
| BMI + age | 0.011 | 0.010 | 1.12 | 0.016 | 0.264 |
| Waist circumference | 0.002 | 0.003 | 0.55 | 0.002 | 0.582 |
| Waist circumference + age | 0.002 | 0.003 | 0.63 | 0.010 | 0.527 |
| Waist/hip ratio | 0.906 | 0.622 | 1.46 | 0.011 | 0.147 |
| Waist/hip ratio +age | 1.002 | 0.623 | 1.60 | 0.022 | 0.110 |
| Waist/height ratio | 0.190 | 0.476 | 0.40 | 0.001 | 0.690 |
| Waist/height + age | 0.255 | 0.479 | 0.53 | 0.009 | 0.594 |
| BF% Bergman | -0.001 | 0.005 | -0.28 | 0.004 | 0.780 |
| BF% Bergman + age | -0.001 | 0.005 | -0.17 | 0.008 | 0.864 |
| BF% Fels | -0.001 | 0.004 | -0.26 | 0.003 | 0.797 |
| BF% Fels + age | -0.001 | 0.004 | -0.15 | 0.008 | 0.878 |
| BF% Woolcott | 0.001 | 0.004 | 0.28 | 0.004 | 0.779 |
| BF% Woolcott + age | 0.001 | 0.004 | 0.34 | 0.008 | 0.731 |
| **Females** | | | | | |
| BMI | 0.034 | 0.006 | 5.53 | 0.101 | <0.001 |
| BMI + age | 0.031 | 0.006 | 5.27 | 0.178 | <0.001 |
| Waist circumference | 0.016 | 0.003 | 6.56 | 0.136 | <0.001 |
| Waist circumference + age | 0.014 | 0.002 | 6.00 | 0.200 | <0.001 |
| Waist/hip ratio | 2.319 | 0.432 | 5.36 | 0.095 | <0.001 |
| Waist/hip ratio + age | 2.012 | 0.421 | 4.78 | 0.165 | <0.001 |
| Waist/height ratio | 2.79 | 0.396 | 7.05 | 0.154 | <0.001 |
| Waist/height + age | 2.41 | 0.395 | 6.12 | 0.204 | <0.001 |
| BF% Bergman | 0.026 | 0.006 | 4.61 | 0.072 | <0.001 |
| BF% Bergman + age | 0.021 | 0.006 | 3.67 | 0.137 | <0.001 |
| BF% Fels | 0.020 | 0.004 | 4.60 | 0.072 | <0.001 |
| BF% Fels + age | 0.016 | 0.004 | 3.70 | 0.138 | <0.001 |
| BF% Woolcott | 0.032 | 0.005 | 6.15 | 0.122 | <0.001 |
| BF% Woolcott + age | 0.028 | 0.005 | 5.25 | 0.178 | <0.001 |

BMI: body mass index; BF%: body fat percent