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Simple Anthropometrics Are More Correlated with Health Variables than Are Estimates of Body Composition in Yup'ik People

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Abstract

We aimed to: 1) evaluate the relationships between several indices of obesity with obesity-related risk factors; 2) compare the accuracy of body composition estimates derived from anthropometry and bioimpedance analysis (BIA) to estimates of body composition assessed by doubly-labeled water (DLW); and 3) establish equations for estimating fat mass (FM), fat-free mass (FFM), and percent body fat (PBF) in Yup'ik Eskimo people. Participants included 1056 adult Yup'ik People from 11 communities in Southwestern Alaska. In a substudy of 30 participants, we developed population-specific linear regression models for estimating FM, FFM, and PBF from anthropometrics, age, sex, and BIA against criterion measures derived from total body water assessed with DLW. These models were then used with the population cohort and we analyzed the relationships between obesity indices and several health-related and disease status variables: 1. fasting plasma lipids, 2. glucose, 3. HbA1c, 4. adiponectin, 5. blood pressure, 6) diabetes (DM), and 7) cerebrocoronary vascular disease (CCVD) which includes stroke and heart disease. The best model for estimating FM in the substudy used only three variables – sex, waist circumference (WC), and hip circumference and had multiple R^2=0.9730. FFM and PBF were calculated from FM and body weight. WC and other anthropometrics were more highly correlated with a number of obesity-related risk factors than were direct estimates of body composition. We conclude that body composition in Yup'ik People can be accurately estimated from simple anthropometrics.

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Conflict of interest

None of the authors has any financial interest in this work.

Keywords

Doubly labeled water; fat mass; percent body fat; lipids; blood pressure; adiponectin; diabetes; stroke; cardiovascular disease; body mass index; waist circumference; Alaska Native people

Introduction

In an effort to help prevent further increases in the prevalence of obesity and associated comorbidities in minority and isolated populations with limited health care resources, identifying accurate, yet simple methods to quantify body adiposity and obesity-related health risk are desirable.

It is unknown whether simple, indirect measures of obesity predict obesity-related health risk as accurately as direct measures in Alaska Native people. We, therefore, determined if anthropometry and bioimpedance analysis (BIA) can accurately assess body composition in Yup'ik People. We assessed the relationships of direct and indirect measures of adiposity with obesity-related health variables, including diabetes (DM), cerebrocoronary vascular disease (CCVD) (stroke and heart disease), fasting plasma lipids, glucose, HbA1c, blood pressure, and adiponectin, an adipocyte derived hormone positively associated with insulin sensitivity and HDL cholesterol levels [1].

Methods

A cross-sectional health study was conducted from 2003–2007 among 1056 Yup'ik People aged 18–94 years living in 11 rural Yup'ik communities in Southwestern Alaska. Participants included men and non-pregnant women (by self-report). In a substudy of 30 participants, anthropometry, age, and sex were used to estimate fat mass (FM) determined by the doubly labeled water (DLW) method, which was considered the true value. FM estimates using anthropometry were more strongly correlated with DLW FM (r=0.986) than were estimated FFM or percent body fat (PBF) estimates with DLW values. Therefore, we chose to estimate FM rather than FFM or PBF. Fat-free mass (FFM) and PBF were calculated from body weight and FM. We compared these estimates and PBF estimated by BIA with the "true" FM, FFM, and PBF by correlation analysis. We estimated body composition for each person in the population sample using BIA and the predictive equations derived in the substudy and correlated these estimates and simple anthropometrics with the health-related and disease variables: blood pressure, lipids, fasting plasma glucose, HbA1c, adiponectin, DM, and CCVD. The Tanita TBF-300A tetrapolar foot-to-foot BIA analyzer (Tanita Corporation, Tokyo, Japan) was used to measure impedance (ohms) and obesity-related risk factors were measured as previously described [2]. The same observers for laboratory methods were used to obtain all measurements. Total body water (kg) was determined using the DLW method [3]. FFM was calculated as (total body water)/0.73, assuming a hydration constant of 0.73, and FM was calculated as body weight -FFM. (DLW details in online appendix)

Disease diagnoses were abstracted from medical records. The following ICD-9 codes (2010) were included for disease diagnosis: DM – 250; CCVD – 410–414, 425, 426, 428, 429, 433, 434, 436–438, 786, and V45.82.

Statistical analyses

The best parsimonious regression model estimating FM in the substudy was determined by stepwise multiple linear regression and evaluated for multicolinearity by standard methods and for agreement with the DLW-determined FM with the Bland-Altman method. Variables considered for inclusion were age, sex, weight, height, waist circumference (WC), BMI, waist-to-height ratio, hip circumference (HC), arm circumference, thigh circumference, raw impedance, total body water, BIA estimates of FM, FFM, and PBF (FM_{BIA}, FFM_{BIA}, PBF_{BIA}). A second model also used skinfold thickness, but because this model performed only slightly better and skinfold thickness measurements add to protocol time and participant burden, we did not consider it further. This estimate of FM, the derived estimates of FFM and PBF, anthropometrics, and body composition estimates from BIA were correlated with the obesity-related risk factors using Spearman's correlation coefficients partialled for age and sex. The association of the obesity indices with the disease variables was determined using logistic regression that included age and sex as covariates. All continuous variables were standardized to have mean=0 and SD=1, and odds ratios with 95% confidence intervals are reported.

All protocols were approved by the Alaska Area, Indian Health Service and the University of Alaska Fairbanks Institutional Review Boards, and the Yukon-Kuskokwim Health Corporation Human Studies Committee. Participants provided written informed consent.

Results

The model to estimate DLW-determined FM from demographic and anthropometric data in the substudy of 30 participants used only three variables: FM(kg) = −47.99639 −8.96151*male +0.58113*WC(cm) +0.254638*HC(cm). Multiple R^2 was 0.9730. Furthermore, DLW-derived FM was highly correlated with BMI, WC, HC, WC*HC, waist-to-height ratio, and BIA-estimated PBF (all r>0.9), but less strongly correlated with waist-to-hip ratio (r=0.58). Correlations of the aforementioned anthropometrics with DLW-derived FFM and PBF were lower (all r<0.80) than with DLW-derived FM.

Correlations and standardized odds ratios of the multiple obesity indices with obesity-related risk factors from the population study are shown in Table 1. None of the correlations were significant for total cholesterol (data not shown).

The simple anthropometric measurements were as strongly correlated with each of the obesity-related risk factors (other than LDL cholesterol) as were the more sophisticated measures of adiposity (FM, FFM, and PBF). In fact WC was consistently among the most highly correlated obesity indices with obesity-related risk factors. For the disease variables, the strongest odds ratios were seen from the modeled PBF (OR=2.51) and the modeled FFM (OR=1.54) with DM and CCVD respectively.

Overall, most of the correlations and odds ratios for each of the obesity-related risk factors and disease variables were of similar magnitude regardless of the body index used.

Discussion

In general, the simple measures of WC and other anthropometrics were as strongly associated with obesity-related risk factors as the more complex estimates, suggesting that for a particular application and study setting, the method used to estimate body composition or obesity can be chosen on the basis of feasibility or availability of equipment or trained observers. Moreover, body composition estimates (FM, FFM, and PBF) estimated from the DLW substudy and from BIA were highly associated with several obesity-related risk factors and disease parameters in this study population.

Our results agree with other reports that simple measurements that estimate body adiposity are strongly correlated with FM and PBF estimates from DLW, and that these same measures are as strongly associated with obesity-related risk factors and disease variables as more direct measurements of adiposity [4,5]. Some investigators have assumed that direct measures of adiposity provide better predictive power than indirect measures when assessing associations between obesity and health risk [6]. However, in the present study, anthropometric estimates of body adiposity (WC, BMI, HC, WC*HC, and waist to height ratio) were at least as strongly associated with several obesity-related risk factors and disease variables as were the estimates of FM, FFM, and PBF derived from anthropometrics and DLW. The risk factors were more highly correlated with the simple anthropometrics in their original forms than when transformed to estimate body composition according to DLW. Similar findings that simple anthropometrics are highly associated with obesity-related risk factors have been reported with other methods including DXA and BIA [7–9]. The body size estimates mostly strongly related to disease were derived from the DLW model (PBF for diabetes, and FFM for CCVD). Several investigators have concluded that WC and other anthropometrics are among the best predictors of metabolic health outcomes [7,10–12]. Our results support the hypothesis that simple, indirect measures of adiposity such as WC, BMI and other anthropometrics are strongly associated with selected obesity-related risk factors and disease variables and are thus likely to predict clinical endpoints in Yup’ik People.

Waist circumference estimates abdominal distribution of fat that is not captured by estimates of total adiposity [13]. The variables that best estimate fat mass are not necessarily the same as those that are related to health measures. It is likely that the regional distribution of body fat, rather than total adiposity, is more important for health outcomes. However, body composition estimates including FM, FFM, and PBF, may also be important in physiologic, genetic, and longitudinal studies.

Strengths of the study include the large sample size and that several different obesity indices were evaluated simultaneously, many types of obesity-related biomarkers were analyzed, and the same standard protocols were used to measure the anthropometric variables in both the DLW and population studies.

The small sample size of the DLW subset did not allow us to evaluate sex specific models to estimate body composition. Also, while we used leave-one-out cross-validation methods to choose full and reduced models to predict body composition with the lowest generalization error (not shown), it is still possible that due to small sample size we still may have overfit the models.

In summary, obesity-related risk can be assessed accurately in Yup'ik People with simple anthropometric measures. Simple anthropometrics or BIA can also provide accurate estimates of adiposity. These findings may facilitate research and health counseling in remote areas where more sophisticated measures of body composition are impractical.

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Table 1

Associations of Body Size Measures with Obesity-Related Risk Factors and Diseases

	←———Risk Factors———→								←———Diseases———→	
Body Size Measurements	**HDL**	**LDL**	**Triglyceride**	**glucose**	**HbA1c**	**adiponectin**	**syst bp**	**diast bp**	**DM**	**CCVD**
BMI	−0.39 (−0.44, −0.34)	0.15 (0.09, 0.21)	0.39 (0.34, 0.44)	0.23 (0.17, 0.28)	0.12 (0.06, 0.18)	−0.4 (−0.45, −0.34)	***0.23 (0.18, 0.29)***	0.39 (0.34, 0.44)	1.74 (1.18, 2.56)	1.38 (1.04, 1.84)
WC	***−0.43 (−0.47, −0.38)***	***0.17 (0.11, 0.22)***	***0.41 (0.36, 0.46)***	***0.24 (0.18, 0.30)***	0.14 (0.08, 0.19)	***−0.43 (−0.48, −0.38)***	***0.23 (0.17, 0.28)***	0.39 (0.34, 0.44)	1.98 (1.32, 2.98)	1.37 (1.02, 1.84)
Hip Circumference	−0.36 (−0.42, −0.31)	0.15 (0.09, 0.21)	0.34 (0.28, 0.39)	0.19 (0.13, 0.25)	0.08 (0.02, 0.14)	−0.34 (−0.40, −0.29)	0.20 (0.15, 0.26)	0.34 (0.29, 0.39)	1.64 (1.13, 2.38)	1.38 (1.03, 1.83)
Total Skinfold	−0.37 (−0.42, −0.32)	0.16 (0.10, 0.22)	0.38 (0.33, 0.43)	0.19 (0.13, 0.25)	0.11 (0.05, 0.17)	***−0.43 (−0.48, −0.38)***	0.22 (0.16, 0.28)	0.38 (0.33, 0.43)	1.83 (1.17, 2.88)	1.35 (0.99, 1.84)
Waist to Hip Ratio	−0.34 (−0.39, −0.28)	0.16 (0.10, 0.21)	0.38 (0.32, 0.43)	0.22 (0.16, 0.28)	***0.15 (0.09, 0.21)***	−0.39 (−0.44, −0.34)	0.18 (0.12, 0.24)	0.32 (0.26, 0.37)	1.91 (1.27, 2.88)	1.19 (0.86, 1.63)
Waist*Hip	−0.42 (−0.46, −0.36)	***0.17 (0.11, 0.22)***	0.40 (0.34, 0.44)	0.23 (0.17, 0.28)	0.11 (0.05, 0.17)	−0.41 (−0.46, −0.36)	0.22 (0.17, 0.28)	0.38 (0.33, 0.43)	1.71 (1.21, 2.42)	1.43 (1.10, 1.88)
Waist to Height Ratio	−0.40 (−0.45, −0.35)	0.16 (0.10, 0.22)	***0.41 (0.36, 0.46)***	***0.24 (0.18, 0.29)***	0.14 (0.08, 0.20)	−0.42 (−0.47, −0.37)	***0.23 (0.17, 0.29)***	***0.40 (0.35, 0.45)***	2.00 (1.31, 3.06)	1.34 (0.99, 1.82)
FM (model)	−0.42 (−0.47, −0.37)	0.16 (0.10, 0.22)	***0.41 (0.36, 0.46)***	0.23 (0.17, 0.28)	0.12 (0.06, 0.18)	−0.42 (−0.47, −0.37)	0.21 (0.16, 0.27)	0.38 (0.33, 0.43)	1.89 (1.28, 2.80)	1.38 (1.03, 1.84)
FM (BIA)	−0.39 (−0.44, −0.34)	***0.17 (0.11, 0.22)***	0.39 (0.33, 0.44)	0.22 (0.16, 0.28)	0.12 (0.06, 0.17)	−0.41 (−0.46, −0.36)	0.20 (0.15, 0.26)	0.39 (0.33, 0.44)	1.77 (1.23, 2.54)	1.40 (1.06, 1.84)
FFM (model)	−0.29 (−0.34, −0.23)	0.07 (0.01, 0.13)	0.25 (0.20, 0.31)	0.14 (0.08, 0.19)	0.07 (0.01, 0.13)	−0.27 (−0.32, −0.21)	0.13 (0.07, 0.19)	0.24 (0.18, 0.29)	1.36 (0.85, 2.19)	***1.54 (1.12, 2.11)***
FFM (BIA)	−0.35 (−0.40, −0.29)	0.07 (0.01, 0.13)	0.30 (0.25, 0.36)	0.16 (0.10, 0.22)	0.09 (0.03, 0.15)	−0.31 (−0.37, −0.26)	0.16 (0.10, 0.22)	0.25 (0.20, 0.31)	1.46 (0.95, 2.24)	1.47 (1.08, 2.00)
PBF (model)	−0.40 (−0.45, −0.35)	0.15 (0.10, 0.21)	0.40 (0.35, 0.45)	0.22 (0.17, 0.28)	0.12 (0.06, 0.18)	−0.41 (−0.46, −0.36)	***0.23 (0.17, 0.29)***	0.36 (0.31, 0.41)	***2.51 (1.40, 4.50)***	1.12 (0.80, 1.56)
PBF (BIA)	−0.38 (−0.43, −0.32)	***0.17 (0.11, 0.22)***	0.37 (0.32, 0.43)	0.23 (0.17, 0.29)	0.13 (0.07, 0.19)	−0.41 (−0.46, −0.36)	0.21 (0.15, 0.27)	0.38 (0.33, 0.43)	2.26 (1.37, 3.71)	1.21 (0.88, 1.66)

N=1056

DM = diabetes mellitus (22 cases); CCVD = cerebrocoronary vascular diseases, which includes stroke and heart disease (49 cases).

Values listed for the continuous variables are Spearman's Correlation coefficients and 95% CI, partialled for age and sex. Values listed for dichotomous variables (DM & CCVD) are odds ratios per standard deviation of the body size measurement with 95% confidence intervals, adjusted for age and sex. The obesity-indices most strongly correlated with each obesity-related risk factor and the obesity indices with the greatest odds ratio for each disease variable are indicated by ***bold and italic*** text.

FM (model) and FM (BIA) were estimated from the DLW substudy and from BIA, respectively. FFM and PBF were estimated from body weight and these estimates. All correlations were significant at $p<0.001$ except for FFM (model) and FFM (BIA) with LDL, and FFM (model) and hip circumference with HbA1c, all of which were significant at $p<0.02$.