RESEARCH
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New Equations to Predict Body Fat in Asian-Chinese Adults Using Age, Height, Skinfold Thickness, and Waist Circumference

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ABSTRACT

Background Adiposity is an independent predictor of metabolic disease. However, highly accurate body fat assessment is not routinely done due to limited access to expensive and labor-intensive methods.

Objective The aim of the study was to develop body fat prediction equations for Asian-Chinese adults using easily attainable anthropometric measurements.

Design Prediction equations of body fat were developed using anthropometric and skinfold thickness measurements obtained from a cross-sectional study. These new equations were then validated using baseline data from an independent randomized controlled study.

Participants/setting Healthy participants with no major diseases and not taking long-term medications were recruited in an ongoing cross-sectional study that began in June 2014 (n=439, 170 males, 269 females), as well as a randomized controlled trial (n=108, 58 males, 50 females) conducted from January 2013 to October 2014. Both the studies were conducted at Clinical Nutrition Research Center located in Singapore.

Main outcome measures Data used to develop and validate equations were from two original studies that assessed body fat by dual-energy x-ray absorptiometry, age, waist circumference, height, and biceps and triceps skinfolds.

Statistical analysis performed Sex-specific percent body fat prediction equations were developed using stepwise regression with Akaike Information Criterion on the cross-sectional data. The equations were then validated using data from the randomized controlled study and also compared against Asian-specific Davidson equations.

Results The best body fat prediction model (R^2=0.722, standard error of estimation=2.97 for females; R^2=0.815, standard error of estimation=2.49 for males) for both sexes included biceps and triceps skinfolds, waist circumference, age, and height. The new equations developed resulted in modest discrepancies in body fat of 1.8%±2.7% in males (P<0.001) and 0.7%±3.1% in females (P=0.125; not significant) compared with the Asian-specific Davidson equations (−7.4%±3.2% [P<0.001] and −7.4%±2.7% [P<0.001], respectively).

Conclusions Sex-specific equations to predict the percent body fat of Asian-Chinese adults with a higher degree of accuracy were developed. Ease of use in both field and clinical settings will be a major advantage.
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BODY COMPOSITION IS ROUTINELY ASSESSED TO determine risks for metabolic diseases. Hydrostatic weighing has long been regarded as the "gold standard" for estimating body compositions, which is based on the Archimedes principle of measuring body volume and density.[1] Because hydrostatic weighing is based on submerging an individual in a water tank, such methods are of limited appeal, especially in Asia, because they are time-consuming, labor-intensive, expensive, and less user-friendly. Advances in imaging techniques include the use of dual-energy x-ray absorptiometry (DEXA), which estimates body compositions at relatively high levels of accuracy and precision.[2] The availability of the DEXA method provides a

unique opportunity to assess body fat of the Asian-Chinese population at relatively high accuracy.

However, the DEXA equipment is bulky and expensive and, more importantly,[3] is not widely applicable for population-based community screening. As a result, simple prediction equations that predict body composition using routine anthropometric measurements have been of considerable interest. A widely used and noninvasive method of estimating body fat has been the measurement of skinfold as a proxy indicator of body fat, which was reported in the classical work by Durnin and Womersley (DW) in the 1970s.[4]

It is widely reported that the body composition of Asians is markedly different than that observed in whites despite having a similar body mass index (BMI).[5] Yajnik and colleagues have also coined the term "thin-fat phenotype" in Indians, where a majority of fat is deposited in the visceral and internal organs.[6] Given the differences in body composition and fat distribution observed between white subjects and Asians,[7] using equations derived from white subjects to predict the body composition of Asians may be less accurate. For example, it has been reported that the application of the DW equation to predict body fat in Asians leads to over- or underestimation.[8] This is because Asians have been reported to have different fat distribution than white subjects, notably central adiposity.[9] Furthermore, fat deposition in the body, especially in the viscera, has been shown to be an independent risk factor for metabolic diseases.[10] The absence of waist circumference as a predictor in the DW equation reduces its accuracy in predicting body fat in Asians.[11]

Based on this rationale, Davidson and colleagues modified the DW equations and developed new race- or ethnicity-specific equations based on 294 Asians mainly from Japanese, Chinese, or Korean descent.[11] These authors also acknowledge that their study sample were New York City residents and so validation studies were recommended for application in other races or ethnicities. Hence, the accuracy of these equations in predicting the body fat of Asian-Chinese persons specifically is uncertain and requires further investigation. Furthermore, Davidson's equations require skinfold measurement at four locations (biceps, triceps, subscapular, and suprailiac), some of which may be challenging to acquire due to cultural constraints surrounding exposure of female body parts, notably suprailiac and subscapular skinfolds, to strangers.[12]

Therefore, the objective of this study was to develop simple prediction equations of percentage body fat in Chinese subjects using easily accessible anthropometric measurements in a clinical setting, such as skinfold thicknesses at biceps and triceps, height, and waist circumference along with age.

RESEARCH SNAPSHOT

Research Question: Can the body fat percentage of healthy Asian-Chinese adults be accurately predicted using anthropometric measurements?

Key Findings: Sex-specific equations that predict body fat percent in healthy Asian-Chinese adults were developed using 439 Chinese participants (170 males, 269 females) and validated in an independent study population (58 males, 50 females). Validation analysis revealed modest, mean discrepancies in body fat of 1.8%±2.7% in males ($P<0.001$) but not in females 0.7%±3.1% ($P=0.125$) using newly developed equations.

METHODS

Study Design and Participants

To develop an equation to predict the percentage body fat of Chinese Singaporeans, data from an ongoing cross-sectional study, conducted at the Clinical Nutrition Research Centre located in Singapore since June 2014, were used. The original study recruited participants who were between 21 and 100 years old, both males and females of all ethnic groups, not diagnosed with any major diseases, not taking any regular medication, and not pregnant. A total of 439 participants (170 males and 269 females) with both DEXA and anthropometric measurements from the original study were included in the development of equations that predict percent body fat. These 439 participants were recruited between June 17, 2014, and February 27, 2017. To validate our equations, the pre-intervention baseline data from a 12-month weight loss clinical study, also conducted at Clinical Nutrition Research Centre, Singapore, from January 2013 to October 2014, were used. Participants were 108 Chinese adults (58 males and 50 females) 21 to 60 years of age, with a BMI of 25 to 40 kg/m^2, healthy, and not pregnant. Table 1 and Table 2 summarize the demographics of participants recruited in these studies. The National Healthcare Group Domain Specific Review Board, Singapore, approved the protocols for both the cross-sectional study and the randomized controlled trial. All participants provided written informed consent prior to study commencement.

Anthropometric Measurements

In both studies anthropometric measurements were taken in a fasting state following standard protocols.[13] Weight (in kilograms) was measured to the nearest 0.1 kg in light clothing without footwear using an electronic scale (Seca Limited) and height (in centimeters) was measured using a stadiometer (Seca Limited) to the nearest 0.1 cm. Waist circumference was taken at the smallest reading above the umbilicus or navel and below the xiphoid process using a standard nonelastic measuring tape (Lufkin W606PM). All anthropometric measurements were done in duplicate. The quality of the measurements was assessed and a third measurement was taken if the deviation between the first two measurements was >10% for skinfold measurements and >2% for waist circumference. The final measurement value was taken to be the average of the duplicate or triplicate measurements. Skinfold thickness was measured to the nearest 0.1 mm using Holtain Skinfold Calipers at the following four sites: biceps, triceps, subscapular, suprailiac, on the right site of the body using standard procedures as outlined by Lohman and colleagues.[13] DEXA was also performed (QDR 4500A, fan-beam densitometer, Hologic), and these values were used to determine the participant's lean body mass and muscle mass.

Statistical Analysis

Sex-specific equations were explored using four anthropometric measurements and their combinations, namely waist circumference, height, and skinfold thicknesses from biceps and triceps. Age was included as a continuous variable in the development of equations. The relationship between both the skinfold thickness measurements and DEXA body fat was nonlinear, except for waist circumference and height, thus