Developing an Objective Evaluation Method to Estimate Diabetes Risk in Community-Based Settings

Sonjia Kenya, Ed.D., M.S., M.A.,* Qing He, M.D., Robert Fullilove, Ed.D., and Donald P. Kotler, M.D.

Abstract

Background: Exercise interventions often aim to affect abdominal obesity and glucose tolerance, two significant risk factors for type 2 diabetes. Because of limited financial and clinical resources in community and university-based environments, intervention effects are often measured with interviews or questionnaires and correlated with weight loss or body fat indicated by body bioimpedance analysis (BIA). However, self-reported assessments are subject to high levels of bias and low levels of reliability. Because obesity and body fat are correlated with diabetes at different levels in various ethnic groups, data reflecting changes in weight or fat do not necessarily indicate changes in diabetes risk. To determine how exercise interventions affect diabetes risk in community and university-based settings, improved evaluation methods are warranted.

Methods: We compared a noninvasive, objective measurement technique—regional BIA—with whole-body BIA for its ability to assess abdominal obesity and predict glucose tolerance in 39 women. To determine regional BIA's utility in predicting glucose, we tested the association between the regional BIA method and blood glucose levels.

Results: Regional BIA estimates of abdominal fat area were significantly correlated ($r = 0.554$, $P < 0.003$) with fasting glucose. When waist circumference and family history of diabetes were added to abdominal fat in multiple regression models, the association with glucose increased further ($r = 0.701$, $P < 0.001$).

Conclusions: Regional BIA estimates of abdominal fat may predict fasting glucose better than whole-body BIA as well as provide an objective assessment of changes in diabetes risk achieved through physical activity interventions in community settings.

Introduction

ALIGNED WITH THE OBJECTIVES of the Centers for Disease Control and Prevention and the National Institutes of Health, many interventions aim to increase levels of physical activity in order to reduce the risk for obesity, type 2 diabetes, and other complications associated with obesity.^{1–6} Several community- or university-based physical activity interventions measure effects through questionnaires or interviews that require each participant to report his or her daily level of exercise at routine time intervals.^{7–12} These self-report methods have fair to low degrees of validity,^{13,14} but there are more accurate and objective methods to evaluate the effects of physical activity interventions on body fat and glucose tolerance, two significant factors in the development of type 2 diabetes.^{15–20}

Exercise interventions in clinical environments measure physiological changes using high technology reference methods, such as dual energy X-ray absorptiometry, magnetic

resonance imaging, and intravenous glucose tolerance test. However, the cost and complexity associated with these studies limit the number of participants who can validate intervention effects.^{21–24} Conversely, community- and university-based exercise interventions aim to affect larger populations, but the cost and expense of objective clinical assessments often limit program evaluation to self-report questionnaires or interviews.^{9–14} Some studies aim to achieve a balance between clinical and community-based methods by taking into account changes in body weight, total body fat, and/or waist and hip circumference.^{25–27} The foremost goal of many exercise investigations is to develop successful programs to reduce obesity and risk for type 2 diabetes, but few community- or university-based interventions measure glucose levels, a significant factor in determining diabetes risk.^{28,29}

An important barrier in measuring glucose levels in non-clinical environments is the requirement for blood to be drawn. However, previous studies have established that

St. Luke's-Roosevelt Hospital, Columbia University College of Physicians and Surgeons and Columbia University Mailman School of Public Health, New York, New York.

*Present address: Jay Weiss Center for Social Medicine and Health Equity, Miller School of Medicine, University of Miami, Miami, Florida.

glucose tolerance is also associated with level of physical activity as well as certain phenotypic characteristics, such as waist circumference and total body fat.^{15–19} Currently, total body fat is frequently used as a risk factor for diabetes, but regional body fat assessment may be a better indicator of glucose tolerance.

Typically, total body adiposity and especially abdominal obesity are associated with elevated fasting glucose levels.^{15–19} There are several methods available for measuring body fat, abdominal adiposity, and glucose tolerance; however, the reference methods (e.g., dual energy X-ray absorptiometry, magnetic resonance imaging, and intravenous glucose tolerance test) are not widely available to all investigators, as they are expensive and require highly trained technicians to administer. Simple, less expensive body fat measurement tools such as bioimpedance analysis (BIA), combined with specific anthropometric measures of truncal obesity, may predict glucose tolerance or risk for glucose intolerance. However, it is difficult to use these measures in nonclinical environments because it remains unclear whether total body fat or abdominal fat alone is most clearly associated with glucose levels, and the surrogate techniques comparable to the reference standards have not been clearly established.

BIA has been widely used to assess body fat cross-sectionally and prospectively in large, clinical and community-based study populations.^{19,20,30–32} More recently, segmental BIA has been used to measure fat in different regions of the body, and its efficacy in assessing abdominal obesity has been validated.³³ In an effort to develop objective measures of health interventions aimed at improving glucose tolerance in nonclinical environments, the purpose of the present study was to investigate whether utilizing a measure designed to assess fat in the abdominal region (segmental BIA) would yield a more significant association with glucose levels than traditional whole-body BIA. Thus, our ultimate goal was to improve upon objective, noninvasive assessment methods currently available in nonclinical settings and test experimental methods for the ability to identify risk factors associated with type 2 diabetes, such as abdominal fat and glucose intolerance.

Subjects and Methods

Participants

A convenience sample of 39 female participants was recruited through fliers advertising the study, which were posted around the college campus approximately 2 weeks prior to the study date. The inclusion criteria for participants were as follows: female; 18 years of age or older; absence of acute medical condition; attending the college campus where the study was conducted; and willingness to adhere to study requirements. The study was approved by the Institutional Review Boards at St. Luke's Roosevelt Hospital Center and at the college campus in New York City where the study was conducted.

Measurements

Participants removed shoes prior to all measurements. Height was measured using a standard tape measure adhered to a wall. Body weight was measured using a digital scale (Tanita Corp., Tokyo, Japan). Standardized anthropometric

measurements, including mid-arm, hip, waist, and mid-thigh circumferences were taken by an experienced technician employed in the Body Composition Unit of St. Luke's Roosevelt Hospital Center. Blood pressure and fasting glucose levels using a fingerstick and the Accu-Chek[®] Advantage portable glucometer (Roche Pharmaceuticals, Basel, Switzerland) were administered by an attending physician from St. Luke's Roosevelt Hospital Center. Both whole-body and segmental BIA measurements were taken by a trained body composition research technician. Whole-body BIA was measured using the portable Quantum BIA-101Q system (RJL Systems, Clinton Township, MI) with standard tetrapolar electrode placement, including two leads attached to electrodes placed on the right hand and two leads attached to electrodes adhered to the right foot.

Regional BIA estimated fat content in the lower abdominal and in the upper abdominal area, as described previously.³³ For measuring lower abdominal fat content, two 2-inch surface electrodes were placed at the level of the xiphoid process and the anterior superior iliac spine, in addition to surface electrodes placed on the wrist and ankle. For measuring upper abdominal fat content, surface electrodes were placed on the xiphoid process and at the level of the sternoclavicular joint, in addition to the wrist and ankle.

Data analysis

The portable Quantum BIA-101Q system is designed to operate with Cyprus software (RJL Systems) for body composition analysis. Whole-body resistance and reactance readings were used to calculate total body fat and lean mass as described previously.³⁴ Analysis of variance (Bonferroni) and univariate and multiple regression analysis models were tested using SPSS statistical software (SPSS Inc., Chicago, IL).

Data are expressed as mean $\pm$ SD. A *P* value of <0.05 was considered statistically significant.

Results

Descriptive characteristics of the study population are presented in Table 1. Cross-sectional studies were performed on 39 female participants at a predominantly black 4-year community college in New York City. The age of the women was 35 ± 12 years, and the majority (56.1%) of participants self-identified as black or African ($n=23$). The remaining participants self-identified as white ($n=3$), Hispanic ($n=4$), Asian ($n=5$), Guyanese ($n=1$), and other ($n=3$).

The body mass index of the study population was 28 ± 6 kg/m² with a body weight of 75 ± 19 kg. Waist circumference was 84 ± 18 cm. Mean fasting glucose was 95 mg/dL. Although this falls within the normal reference range, it is

TABLE 1. BASELINE PARTICIPANT CHARACTERISTICS

	Mean $\pm$ SD	Range
Age (years)	35 ± 12	20–65
Weight (kg)	75 ± 19	42–122
Height (cm)	164 ± 7	152–185
Body mass index (kg/m ²)	28 ± 6	17–44
Waist circumference (cm)	84 ± 18	43–123
Fasting glucose (mmol/dL)	95 ± 14	70–124

TABLE 2. CORRELATIONS WITH FASTING GLUCOSE LEVEL

Independent variable	r	P value
Whole-body BIA	0.424	<0.009
Upper abdomen regional BIA	0.541	<0.001
Lower abdomen regional BIA	0.544	<0.001
Upper + lower regional BIA	0.554	<0.003
Waist circumference	0.547	<0.001
Body mass index	0.456	<0.004

BIA, bioimpedance analysis.

on the cusp of prediabetes, which is diagnosed when fasting glucose levels reach 100 mg/dL. As normal fasting glucose ranges from 70 to 99 mg/dL, we considered this high among a relatively young study population.^{35,36} The National Institute for Diabetes and Digestive and Kidney Diseases encourages all persons over 45 years to be screened for prediabetes, and the mean age of our sample was just 35 years old.³⁵

Simple associations between fasting glucose levels and BIA measures are presented in Table 2. Total abdominal fat measured using segmental BIA showed a stronger association ($r=0.554$; $P<0.003$) with fasting glucose levels than did whole-body BIA ($r=0.424$; $P<0.009$).

The associations between fasting glucose levels and other independent variables were tested. Fasting glucose had a similar association to waist circumference ($r=0.554$; $P<0.001$) as to segmental BIA of the abdomen region. The association between fasting glucose and body mass index was weaker ($r=0.456$; $P<0.004$) than with either waist circumference or segmental BIA.

As reflected in Table 3, the model r increased from univariate models when the independent variables of segmental BIA of the lower abdominal area, waist circumference, and family history of diabetes were added to the model ($r=0.70$; $P<0.0001$). When age was added to this model, the association increased to $r=0.73$ and $P<0.001$.

Discussion

To our knowledge, this study is one of the first to test the association between segmental BIA of the abdomen region and fasting serum glucose levels.³⁷ In recent years, it has become increasingly important to develop inexpensive, easily administered models to test health risks prevalent in the general population, such as type 2 diabetes mellitus. A major goal of Healthy People 2020, which outlines the health priorities for the U.S. population, is to reduce racial disparities

amongst different segments of the population.³⁸ Aligned with this goal, health professionals are urged to develop more accessible measures of physiological signs that indicate risk for health problems prevalent in low-income, minority communities. Type 2 diabetes mellitus affects African-American and Hispanic populations more than other demographic groups.³⁹ Early diagnosed indications of glucose intolerance, a risk factor for diabetes, may delay or prevent the onset of the disease if appropriate interventions are taken. Because dietary modifications and increased physical activity can positively affect glucose tolerance and reduce the risk for developing diabetes, knowing one's glucose levels or risk for becoming glucose intolerant may motivate individuals to take preventative steps towards reducing their diabetes risk.

Many technologically advanced, more sensitive tests of glucose tolerance exist than those reported in this study. However, most advanced methods require blood to be drawn, which may not be feasible in low-income community based settings. In addition, more advanced methods are expensive and labor-intensive, and community health centers serving low-income populations often face administrative and financial obstacles that challenge their efforts to provide disease screening and preventive health services. In this study, we used the portable Quantum BIA-101Q system, which costs approximately \$2,000, and electrodes that cost about 5¢ each.⁴⁰ As each regional BIA test requires four electrodes, we estimate that 1,250 people could be assessed for diabetes risk at a cost of \$1.68 per person.⁴⁰

We attempted to develop an inexpensive, noninvasive assessment of diabetes risk. It should be noted, however, that the BIA method discussed here measures upper body fat, not visceral fat, and there is a lack of scientific consensus as to which exact body compartments are most related to glucose tolerance.^{33,41}

Nonetheless, this study demonstrated, as have others, that waist circumference is strongly associated with total and intra-abdominal fat. Many studies have utilized high technology equipment to observe the relationship between abdominal fat compartments and glucose tolerance. However, our study confirmed the stability of the relationship between total abdominal fat and glucose tolerance, and we were able to identify the association using inexpensive, practical equipment that a layperson could become capable of administering.

We found the association of measurements to fasting glucose levels was strengthened when a family history of diabetes is taken into account. The regression model that yielded the strongest association with glucose levels included segmental BIA of abdominal fat, waist circumference, and a family history of diabetes.

Our findings may have implications for studies of large populations, and further development may yield an inexpensive, noninvasive, portable glucose assessment tool that can be used in community-based health centers. Currently body mass index is frequently used to estimate health risks associated with weight, such as glucose intolerance.⁷ However, the regional BIA measurement of abdominal fat tested in this study showed a stronger relationship to glucose levels than body mass index. A significant limitation in this study is the relatively small sample. However, if future studies with larger populations show close associations between glucose tolerance and abdominal fat measured using segmental BIA,

TABLE 3. MULTIPLE REGRESSION ANALYSIS OF FASTING GLUCOSE LEVEL

Dependent variable	Independent variables	r	P value
Fasting glucose	Lower abdominal BIA, waist circumference, family history of diabetes	0.701	<0.0001
Fasting glucose	Lower abdominal BIA, waist circumference, family history of diabetes, age	0.731	<0.0001

BIA, bioimpedance analysis.

it may become feasible to use segmental BIA of the abdomen area to assess diabetes risk and potentially other metabolic health risks.

In summary, segmental BIA, waist circumference, and family history of diabetes are more strongly associated to glucose levels than body mass index, and each variable independently contribute to the estimation of glucose tolerance. When combined, the predictive power is greater than any single measurement. Further research is warranted to test these associations on larger, more diverse study populations.

What this article adds to our knowledge

This article contributes data supporting that glucose intolerance, a risk factor for diabetes, may be predicted through noninvasive, inexpensive, clinically sound methods that are more effective than current community-based therapies. The work reported here may enhance the ability to identify glucose-intolerant individuals in community settings and encourage the adoption of health-protective behaviors to prevent the development of type 2 diabetes.

Policy implications

Aligned with Healthy People 2020, this article describes methods that may reduce health disparities in type 2 diabetes by increasing the ability of providers to identify glucose intolerance in underserved communities. In addition, the data reported here suggests that school-based health centers may identify students at risk for developing type 2 diabetes and intervene to prevent the development of the disease. If future studies demonstrate the methods described herein as effective indicators of glucose intolerance with larger populations, school policies may adopt measures to identify students at risk for diabetes in order to implement preventive health education.

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Author Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
 Sonjia Kenya, Ed.D., M.S., M.A.
 Jay Weiss Center for Social Medicine and Health Equity
 Miller School of Medicine
 University of Miami
 1400 NW 10th Avenue, Suite 801
 Miami, FL 33136

E-mail: skenya@med.miami.edu