An Inverse Association Between Calcium and Adiposity in Women with High Fat and Calcium Intakes

Objectives: To assess the association between calcium intake and body composition in African Black and White women.

Design: Cross-sectional survey.

Setting: Metabolic unit.

Participants: A convenience sample of 106 White and 102 Black healthy urban women, 20–50 years old, stratified for body mass index (BMI).

Main Outcome Measures: Dietary calcium intake, fat intake, BMI, percentage body fat, fasting plasma glucose and insulin, homeostasis model assessment of insulin resistance (HOMA-IR), oral glucose tolerance test (OGTT), blood pressure.

Methods: After an overnight fast, weight, height and blood pressure were measured, subjects underwent a 75-g OGTT, and blood samples were taken. Food frequency questionnaires were completed, and body composition was measured by anthropometry and air displacement plethysmography.

Results: Mean calcium and fat intakes were significantly higher in White women (1053.8 mg/day and 103.1 g/day, respectively) than in the Black women (523 mg/day and 69.2 g/day), resulting in higher calcium:fat-intake ratio in White women. After adjustment for age and total energy intake, significant negative correlations were found between calcium intake and fasting insulin ($r=-.337$, $P=.01$) and HOMA-IR ($r=-.334$, $P=.01$) in the White subjects. The calcium:fat ratio correlated negatively with BMI ($r=-.328$, $P<.012$), percentage body fat ($r=-.336$, $P=.01$), fasting insulin ($r=-.374$, $P=.004$), postprandial insulin ($r=-.328$, $P=.01$), and HOMA-IR ($r=-.365$, $P=.005$). In the Black subjects, a significant negative correlation was found between calcium intake and blood pressure.

Conclusion: The association between calcium intake and percentage body fat, BMI, fasting glucose, and insulin were significant only with high intake of fat and calcium, which is not characteristic of the habitual diet of African women. (*Ethn Dis*. 2007;17:6–13)

Key Words: Adipocytes, Calcium, Dietary Fat, Lipogenesis, Lipolysis, Weight Management

H. Salome Kruger, PhD; Petro H. Rautenbach, MSc; Christina S. Venter, DSc; Hattie H. Wright, PhD; Peter E. H. Schwarz, MD

Introduction

The incidence of obesity is increasing in developing countries such as South Africa,[1] and with that increase, chronic diseases associated with obesity, namely diabetes mellitus, coronary heart disease, and hypertension, are similarly increasing.[2] A study of rural and urban Black South African women concluded that approximately one quarter to more than half of the subjects in the different age groups were obese.[3] The prevalence of obesity is higher among Black women than among White women in South Africa.[1] Results from both the coronary artery risk development in young adults (CARDIA) and atherosclerosis risk in communities (ARIC) studies have shown that Black as well as White women should avoid excess adiposity to improve their health.[4]

The optimal dietary composition necessary to promote weight loss and prevent weight gain must be understood to develop practical guidelines for diabetes prevention.[5] While much attention has been focused on macronutrient intake, particularly dietary fat, and body weight regulation,[6] an emerging body of literature suggests that dietary calcium may play a role in the regulation of body weight and body fat and development of the metabolic syndrome.[7,8] High-calcium diets may protect against fat gain by creating a balance of lipolysis over lipogenesis in adipocytes.[9] High calcium intake depresses 1,25-hydroxy vitamin D and parathyroid hormone and leads to decreases in intracellular calcium, thereby inhibiting lipogenesis and stimulating lipolysis.[10] A diet deficient in calcium is associated with higher body weight, and augmenting calcium intake may reduce weight and fat gain or enhance fat loss.[11] Implicit in the hypothesis that a high-calcium diet promotes maintenance of lower body fat mass in humans by enhancing lipolysis is the assumption that high-calcium diets promote greater rates of whole-body fat oxidation.[8] Literature has shown a relationship between calcium intake and body fat percentage,[12] body mass index (BMI),[12,13] and blood pressure.[7] Epidemiologic and limited experimental data from some studies suggest that differences in calcium intake may be associated with changes in body weight

…an emerging body of literature suggests that dietary calcium may play a role in the regulation of body weight and body fat and development of the metabolic syndrome.[7,8]

From the School of Physiology, Nutrition and Consumer Science, North-West University, Potchefstroom 2520, South Africa (HSK, PHR, CSV, HHW); Department of Endocrinopathies and Metabolic Diseases, Medical Faculty Carl-Gustav-Carus, Dresden University of Technology, Fetscherstrasse 74, D-01307 Dresden, Germany (PEHS).

Address correspondence and reprint requests to H. Salome Kruger, PhD; School of Physiology, Nutrition and Consumer Science; North-West University; Potchefstroom 2520; South Africa; +27-18-299-2482; +27-18-299-2464 (fax); vgehsk@puk.ac.za

of .35 kg/year.[14] The habitual diet of Black women in South Africa is low in calcium.[15] The aim of this study was to assess the association between dietary calcium intakes and body composition in apparently healthy Black and White South African women.

METHODS

Study Design and Subject Selection

The first phase of the study was a case-control, cross-sectional survey involving 102 urban Black women volunteers working at a governmental institution in Potchefstroom district in the North-West Province, South Africa. A dietician, employed at the institution, recruited the subjects according to their BMI as measured at the medical station at the institution. Three groups of subjects were selected on the basis of World Health Organization guidelines[16]: 1) normal range (lean) was defined as BMI 18.5–24.9 kg/m^2; 2) overweight (pre-obese) was defined as BMI 25–29.9 kg/m^2; and 3) obese was defined as BMI $\geq$30 kg/m^2. The inclusion criteria were apparently healthy Black women aged 20–50 years. The dietician attempted to recruit only HIV negative subjects (according to their status as determined three months before the study), but the negative status of all subjects could not be guaranteed. Pregnant and lactating women and those with oral temperatures $>$37°C, were excluded. Patients with chronic diseases were included if they were stabilized on chronic medication. The study was repeated a year later, with a sample of 106 White South African female volunteers, recruited in the same way.

Ethical considerations

The study was approved by the ethics committee of the North-West University. All subjects were invited to participate and informed about the objectives and procedures of the study, and assistance was available to provide information and answer questions in their home language. All subjects signed an informed consent form. Subjects identified with hypertension, diabetes, or other abnormalities for the first time in the study were referred to local clinics, hospitals, or their physicians. All subjects received a short report with their health information. Subjects received breakfast after the fasting blood samples were drawn and a small financial compensation.

Organizational Procedures

Permission to conduct the study with participants from a local governmental institution was obtained from the relevant authorities. A dietician from the institution assisted in the recruitment, selection, and screening of subjects. For a period of approximately three weeks, each afternoon 10 subjects reported to a metabolic unit facility (consisting of 10 single bedrooms, two bathrooms, a living room and kitchen) and were introduced to the setup and experimental procedures. During the course of the evening, demographic questionnaires were completed and all anthropometric measurements were taken, except weight and height measurements. All participants received an identical light supper that excluded alcohol and caffeine at 8:00 pm, went to sleep before 11:00 pm, and fasted overnight.

Beginning at 6:00 am, weight, height, and blood pressure measurements were done. Fasting blood samples were taken from the vena cephalica by a registered nurse. All individuals underwent a 75-g oral glucose tolerance test (OGTT) after an overnight period of fasting (10 hours minimum); plasma glucose and insulin were measured at fasting and at 30, 60, 90, and 120 minutes after glucose challenge.

Subjects received a breakfast, and food frequency questionnaires were administered by trained fieldworkers. A personal information sheet was given to each subject regarding her own blood pressure and fasting blood glucose to advise each subject and to refer them for further testing and treatment if needed.

Questionnaires

The questionnaires were designed or adapted for this study population and were validated with appropriate methods. Questionnaires were completed during individual interviews conducted by trained fieldworkers. Dietary intakes were measured with a quantitative food frequency questionnaire developed after a pilot study in which all foods eaten by this population were assessed. This questionnaire has been validated previously in a subsample of 100 subjects against a seven-day weighed record and 24-hour urine nitrogen excretion.[15] Books of photographs of three portion sizes of the most commonly eaten foods, food models, household utensils, and food packages were used to determine quantities eaten. Nutrient intakes were analyzed with a program based on the South African Food Composition Tables.[17] For the purpose of this study, a high-fat intake was defined as a total fat intake $>$90 g/day, with the percentage of energy provided by fat $>$30%, and a high calcium intake was defined as a calcium intake $>$600 mg per day. Such intakes are higher than what has been found in adult Black women in this province in an earlier study.[15]

Anthropometric Measurements

Weights were measured before breakfast with the women in light nightwear to the nearest .01 kg on a portable electronic scale (Precision Health scale, A&D Company, Saitama, Japan). Height was measured to the nearest .1 cm with an Invicta IP stadiometer (London, UK) without shoes and with the head in the Frankfort plane. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Air displacement plethysmography (ADP) was measured in the

BODPOD system (Life Measurement Inc, Concord, Calif). The women wore tight-fitting underclothes and swim caps only. The instrument was calibrated each day before measurements. The women were weighed on the BODPOD electronic scale, and body density was calculated. Body density was used to calculate percentage body fat according to the model of Siri.[18] BODPOD measurements were done by trained biokineticists.

Clinical Examinations

Two registered nurses examined the subjects for signs of malnutrition. Oral temperatures were taken, and blood pressure was recorded in duplicate by using a sphygmomanometer (Tycos, Arden, NC, USA) with adjustable cuffs of different sizes. The first and fifth Korotkoff sounds were recorded in subjects lying in bed for at least 10 minutes.

Biochemical Analysis

Plasma glucose was measured by using the hexokinase method (interassay coefficient of variance [CV]: 1.5%). Analysis of insulin levels was performed by enzyme immunoassay (BioSource EUROPE S.A Belgium; interassay CV: 7.5%, no cross-reactivity with human proinsulin).

Statistical Analysis

All processed data were transferred to Microsoft Excel and further statistically analyzed by means of the software computer package Statistica (Statsoft, Inc, 2004). Means and 95% confidence intervals for normally distributed data and medians and the interquartile range for skewed data were calculated. A ratio of calcium intake to fat intake in milligrams per gram was calculated for each subject. All data deviated to some extent from the normal distribution and were logarithmically transformed for subsequent analyses. To test for differences between variables for Black and White women, *t* tests were used to detect differences between variables, and the χ^2 test was used for expected vs observed frequencies to detect differences in distribution for sociodemographic characteristics. Pearson partial correlations were performed to assess the association between dietary calcium intake and body composition variables, while adjusting for age, dietary energy intake, and smoking. Early-phase insulin secretion was calculated by using the formula: (insulin 30′- fasting insulin)/(plasma glucose 30′- fasting plasma glucose).[19] To determine the parameters for insulin resistance the homeostasis model assessment (HOMA) was used with the formula: insulin (0 min) × plasma glucose (0 min)/22.5).[20] Calculating the area under the curve (AUC) for plasma glucose was performed with the following formula: AUC (INS) =15 × ("INS 0 min" + 2 × "INS 30 min"+ 2 ×"PG60 min" + 2 × "INS 90 min" + "INS 120 min").[21] A level of $P<.05$ was considered significant, and all tests were two-sided.

Table 1. Number of subjects (percentage) in each body mass index category

Variables	Normal Weight (BMI 18.5–24.9)	Overweight (BMI 25–29.9)	Obese (BMI >30)
Black women (n=102)	39 (38.2%)	25 (24.5%)	38 (37.2%)
White women (n=106)	38 (35.8%)	29 (27.4%)	39 (36.8%)

BMI=body mass index.
No statistical test applied, only distribution of subjects per BMI category shown.

RESULTS

Table 1 indicates how the subjects were divided into the different BMI groups. Table 2 shows how the groups differed according to sociodemographic characteristics. Most Black women had only matric and most White women had university degrees or were studying at a university. The average monthly income in the Black women was lower than in the White group. Most Black women were single, and approximately half of the White women were married. Contraceptive use in both groups was low. Almost twice as many of the White women compared to the Black women smoked.

Selected variables that may affect the association between dietary calcium intake and body composition, and related variables, are reported in Table 3; dietary intakes are shown in Table 4. Because the distribution of fasting plasma insulin concentration deviated markedly from the normal distribution, medians and interquartile ranges are presented. None of the Black subjects and only three of the White subjects took calcium supplements, 300–600 mg per day. Calcium supplement intakes were added to dietary calcium intakes. Mean dairy intake of the White women was two portions per day, compared with one portion daily of the Black women (Table 4).

Since the distribution of all variables deviated to some extent from the normal distribution, all variables were logarithmically transformed for correlation analysis. Energy intake correlated positively with BMI and body fat percentage in the White women only. Age correlated positively with BMI and body fat percentage, and calcium intake correlated positively with dietary energy intake in both Black and White women. Thus, a positive correlation was noted between calcium intake, energy intake, BMI, and body fat percentage, respectively. Pearson partial correlation analyses were done, adjusted for age, dietary energy intake, and smoking. Tables 5 and 6 show these partial correlations.

No statistically significant correlations were found between number of dairy portions in the diet and BMI ($r=-.112$, $P=.28$) or percentage body

Table 2. Demographic details and use of medication of study groups (% subjects)

Variables	Black women (n=102)	White women (n=106)
Monthly income*		
R1000–R2000 (% subjects)	27.45	26.96
R2001–R3000 (% subjects)	34.31	10.43
R3001–R4000 (% subjects)	12.74	13.91
R4001–R5000 (% subjects)	4.90	13.91
>R5000	20.58	34.78
Educational status*		
Grade 8–9	12.7	.9
Grade 10–11	13.7	.9
Matriculating	61.8	27.0
Diploma	7.8	0
Degree	3.9	71.2
Marital status*		
Single	79.4	48.7
Married	18.6	44.3
Divorced	2.0	4.3
Widowed	0	2.6
Smokers	6.8	13.9
Chronic medication:		
Contraceptive agents		
Contraceptive injection	26.5	5.2
Oral contraceptive: estrogen + progestins	15.7	20.0
Antihypertensive medication	7.8	.9
Hormone replacement therapy	0	4.3
Antidepressants	0	11.3
Hypolipidemic agents	0	2.6
Thyroxine	0	3.5
Anti-epileptic agents	0	3.5

* Statistically significant differences in distribution between Black and White women, χ^2 test.

fat (r=−.138, P=.18) in White or Black women (r=−.08, P=.42 and r=−.04, P=.72 respectively). Most dairy foods consumed by the subjects were high in fat, for example cheese. When the additional calcium from supplement intake was taken into account, a significant negative correlation was seen between calcium intake and BMI (r=−.263, P=.01) and between calcium intake and percentage body fat (r=−.250, P=.02) of the White women.

Significant negative correlations were found in the White women, between the calcium-to-fat intake ratio and BMI, percentage body fat, fasting insulin, HOMA-IR, and insulin $_{AUC}$ (Table 6). After adjustment for BMI, dietary calcium intake still correlated significantly negatively with HOMA-IR (r=−.304, P=.02) and fasting plasma insulin concentration (r=−.308, P=.02). In the Black women, calcium intake correlated significantly negatively with systolic as well as diastolic blood pressure, but these correlations were no longer significant when adjustment for age, smoking, and total energy intake was done.

DISCUSSION

Significant differences were seen between the two groups of women regarding their dietary intake and socioeconomic background. The mean energy, fat, and calcium intakes of the White women were significantly higher than those of the Black women. Economic status may have contributed to this, as seen from the average income of the groups (Table 2). A major finding in this study is that White women with lower intakes of calcium had higher BMI and percentage body fat than women who had higher intakes of calcium. Possible mechanisms for this effect include an inhibiting effect of calcium on fat absorption.[9]

Low-calcium diets may favor increased adipose tissue energy storage, and the converse may be true for high calcium intake.[9] Davies et al[14] reevaluated five clinical studies of calcium intake in women to explore associations between calcium intake and body weight. They found a negative association between calcium intake and weight and calculated that the odds ratio for being overweight was 2.25 for young women in the lower half of the calcium intake. These authors estimated that a 1000-mg difference in calcium intake was associated with an 8-kg difference in mean body weight and that variations in calcium intake could account for ≈3% of the variance in body weight. Low calcium intake tends to be a marker for a poor diet, and a poor diet is a good predictor of obesity.[22]

The significant negative correlation between calcium and BMI as well as with percentage body fat was only seen in White women and not in the Black women. This difference might be attributed to the difference in dietary composition between the two groups (Table 4). Mean total dietary calcium intake was significantly higher in the White women, with a mean intake of 1053.8 mg/day (95% CI 951.9–1155.7), whereas the mean calcium intake in the Black women was 523.15 mg/day (95% CI 436.8–562.1). Mean fat intake in the Black subjects was 69.2 g/day and 103.1 g/day in the White women. Thus the calcium-to-fat intake ratio in White women was higher than in Black women (11.0 and 7.73 respectively, Table 4). Dietary calcium may have an

Table 3. Descriptive statistics of age and health profile variables (mean, 95% CI/median, Q1, Q3)

	Black Women (n=102)		White Women (n=106)	
Variables	**Mean**	**95% CI**	**Mean**	**95% CI**
Age (years): total group	31.3	29.6–33.0	31.4	29.6–33.2
BMI 18.5–24.9	28.6	26.1–31.1	28.4	25.6–31.2
BMI 25–29.9	30.5	27.1–33.9	31.6	27.9–35.4
BMI ≥30	32.8	30.6–35.0	34.1	31.2–37.0
Weight (kg): total group	70.6*	67.4–73.7	80.5*	76.4–84.6
BMI 18.5–24.9	56.2*	54.5–57.9	60.0*	57.6–31.2
BMI 25–29.9	68.0*	65.7–70.3	78.4*	75.6–81.1
BMI ≥30	79.1*	75.6–82.5	102.0*	96.5–107.5
Height (cm): total group	158.9*	157.9–159.2	168.1*	166.7–169.4
BMI 18.5–24.9	160.6*	158.5–162.6	167.1*	164.6–169.5
BMI 25–29.9	158.4*	156.2–160.5	170.0*	167.8–172.1
BMI ≥30	158.0*	156.7–159.2	167.6*	165.3–169.9
Body mass index (kg/m^2)	28.0	26.7–29.2	28.5	27.1–29.9
BMI 18.5–24.9	21.9	21.4–22.4	21.4	20.9–22.0
BMI 25–29.9	27.2	26.6–27.7	27.1	26.5–27.8
BMI ≥30	34.8	33.4–36.2	36.3	34.5–38.0
%Body fat (%): total group	39.7*	37.1–42.4	31.5*	28.4–34.6
BMI 18.5–24.9	22.5*	21.3–23.8	15.4*	13.9–17.0
BMI 25–29.9	30.4	28.1–32.7	28.9	26.5–31.4
BMI ≥30	40.0*	37.8–42.3	48.3*	43.7–52.8
Systolic blood pressure (mm Hg): total group	129.8*	125.9–133.66	118.87*	116.6–121.2
BMI 18.5–24.9	123.8*	120.5–127.2	111.6*	108.8–114.3
BMI 25–29.9	129.1	122.3–135.9	120.9	115.8–125.9
BMI ≥30	133.4*	127.7–139.0	124.5*	121.1–127.8
Diastolic blood pressure (mm Hg): total group	77.7	75.6–79.8	75.3	73.5–77.1
BMI 18.5–24.9	73.0	70.4–75.7	70.71	67.8–73.6
BMI 25–29.9	77.0	72.6–81.4	76.5	72.8–80.1
BMI ≥30	80.4	77.7–83.2	78.9	76.4–81.4
Fasting plasma glucose (mmol/L): total group	5.18*	4.95–5.42	4.69*	4.59–4.79
BMI 18.5–24.9	4.81*	4.69–4.93	4.37*	4.25–4.48
BMI 25–29.9	5.04*	4.83–5.26	4.70*	4.60–4.80
BMI ≥30	5.41	5.05–5.77	5.00	4.80–5.20
Variables	**Median**	**Quartile 1–3**	**Median**	**Quartile 1–3**
Fasting insulin (pmol/L):all	84.8	69.0–107.0	86.0	70.00–104.0
BMI 18.5–24.9	77.5	61.0–91.0	71.0	66.0–81.0
BMI 25–29.9	80.5	64.0–105.0	86.0	70.0–99.0
BMI >30	87.0	75.0–121.0	104.0	91.0–139.0
Variables	**Median**	**Quartile 1,3**	**Median**	**Quartile 1,3**
120 min insulin (pmol/L):all	339.0	230.0–521.0	309.0	191.0–524.0
BMI 18.5–24.9	292.0	200.0–469.0	227.0	154.0–315.0
BMI 25–29.9	314.5	242.0–583.0	420.0	201.0–641.0
BMI >30	370.0	274.0–601.0	359.0	237.0–641.0

CI=confidence interval; Q1, Q3=Quartile 1 and 3; 120min insulin=insulin concentration at 120 minutes in the oral glucose tolerance test.
* denotes statistically significant difference between Black and White women (P<.05), t test.

effect on the absorption of fatty acids[23,24] and triacylglycerols from the gastrointestinal tract.[25] The calcium and fat content in the diet may influence the degree of fat absorption from the gastrointestinal tract. The relatively low calcium and fat intakes of the Black women may be an explanation why calcium intake was not associated with BMI and percentage body fat in the Black women. The results of this study differ from those of of Buchowski et al[26] in African American women, where a negative correlation was found between calcium intake and BMI. Jacqmain et al[27] examined the relationship between calcium intake and body composition in adults participating in the Quebec Family Study and found that body weight, body fat, BMI, waist circumference, and total abdominal adipose tissue were significantly greater in adults who consumed <600 mg calcium per day than in those who consumed higher levels of calcium. Apparently, according to this study,[27] a daily calcium intake >600 mg is

Table 4. Dietary intakes of the Black women and the White women

Variables	Black Women (n=102)			White Women (n=106)		
	Mean	95% CI	Median	Mean	95% CI	Median
Total energy intake (kJ)	7814*	7377–8251	7170	10955*	10344–11565	10692
% Energy from fat (%)	33.7	32.7–34.7	33.4	35.0	34–37	35.0
Total dietary fat intake (g)	69.15*	64.8–73.5	64.6	103.1*	95.0–111.2	96.45
Ca: fat ratio (mg/g)	7.73*	7.28–8.17	7.41	11.00*	9.98–12.01	10.21
Total dietary calcium intake (mg)	523.2*	436.8–562.1	479.0	1054*	951.9–1155.7	961.5
Total dairy intake (portions†)	1.01*	.91–1.11	.96	2.02*	.16–6.87	1.70

CI=confidence interval.

* Statistically significant difference between Black and White women ($P<.05$), t test.

† One dairy portion as the equivalent of 250 mL milk, milk drink or yogurt or 30 g cheese.

Table 5. Unadjusted correlation between dietary intakes, body composition and biochemical variables of Black subjects (n=95)

Variable	Body Mass Index	Systolic Blood Pressure	Diastolic Blood Pressure	Fasting Insulin	Fasting Glucose	Glucose AUC	120 min Insulin in OGTT	HOMA-IR	Early-Phase Insulin Secretion	Insulin AUC
Dietary calcium intake	−.122	−.294	−.307	−.050	−.130	−.175	−.117	−.077	.109	−.0655
	P=.240	P=.004*	P=.003*	P=.632	P=.209	P=.090	P=.260	P=.456	P=.289	P=.533
Calcium: Fat Ratio	−.094	−.106	−.091	−.141	−.104	−.802	.080	−.155	.039	.161
	P=.369	P=.305	P=.379	P=.176	P=.321	P=.440	P=.436	P=.133	P=.710	P=.118

* Statistically significant correlation ($P<.05$).

%BF was measured in only 52 Black women, correlation between percentage body fat and dietary calcium: r=−.11, P=.44 (NS).

OGTT=oral glucose tolerance test; HOMA-IR=homeostasis model assessment for insulin resistance; AUC=area under curve in the OGTT; early phase insulin secretion=$(I_{30}–I_0)/(PG_{30}–PG_0)$, I_{30} , PG_{30} = plasma insulin and glucose at 30 minutes in the OGTT, I_0 , PG_0=fasting plasma insulin and glucose in the OGTT.

Table 6. Partial correlation between dietary intakes, body composition and biochemical variables of White subjects (n=103, correlation coefficient, r, level of significance)

Variable	Body Mass Index	%Body Fat	Systolic Blood Pressure	Diastolic Blood Pressure	Fasting Plasma Glucose	Fasting Plasma Insulin	120 min Insulin in OGTT	HOMA-IR	Early-Phase Insulin Secretion	Insulin AUC
Dietary Calcium Intake	−.255	−.252	−.113	−.0925	−.199	−.206	−.225	−.334	−.180	−.351
	P=.010*	P=.011*	P=.260	P=.357	P=.046*	P=.05*	P=.09	P=.01*	P=.175	P=.007*
Calcium: Fat Ratio	−.378	−.401	−.154	−.190	−.229	−.212	−.241	−.267	−.211	−.232
	$P\leq$.001*	$P\leq$.001*	P=.124	P=.056	P=.021*	P=.04*	P=.02*	P=.01*	P=.04*	P=.079

* Significant correlation at $P<.05$.

OGTT=oral glucose tolerance test; HOMA-IR=homeostasis model assessment for insulin resistance; AUC=area under curve in the OGTT; early phase insulin secretion = $(I_{30}–I_0)/(PG_{30}–PG_0)$, I_{30} , PG_{30} = plasma insulin and glucose at 30 minutes in the OGTT, I_0 , PG_0 = fasting plasma insulin and glucose in the OGTT.

necessary for an effect on body fat. Only 25% of the Black subjects had a daily calcium intake >600 mg/day, compared to 83% of the White women.

In White women, a significant negative correlation was seen between calcium intake and insulin resistance assessed by HOMA, as well as fasting insulin and $insulin_{AUC}$, which all indicate that lower calcium intakes were associated with higher insulin resistance in these women. Insulin resistance could favor fatty acid synthesis and increased percentage body fat. After adjustment for BMI, dietary calcium intake still correlated significantly negatively with HOMA-IR (r=−.304, P=.02) and fasting plasma insulin concentration (r=−.308, P=.02). The association between calcium intake and plasma insulin concentration seems to be independent on the association between calcium intake and body composition.

A recently published multicenter, population-based, prospective, observational study found that increased dairy consumption had a strong inverse association with the 10-year cumulative incidence of obesity (ie, BMI≥30) and with the insulin-resistance syndrome in

A major finding in this study is that White women with lower intakes of calcium had higher BMI and percentage body fat than women who had higher intakes of calcium.

overweight adults (BMI 25 at baseline; n=923). The odds of obesity, abnormal glucose homeostasis, and elevated blood pressure were 20% lower at each additional daily increment of dairy consumption.[9]

A negative correlation was found in the Black population between dietary calcium intake and systolic blood pressure and diastolic blood pressure, respectively (Table 5). A possible reason for the lack of association between number of dairy portions per day and BMI or percentage body fat could be that most of the dairy portions were also high in fat, for example cheese. The effect of fat intake on body composition was probably stronger than the effect of calcium intake.

We do not have a clear explanation for the differences seen between Black and White women. However, a higher calcium and fat intake than those of the Black women in this study, which were similar to previously reported calcium intakes of Black South African women,[15] seems to be necessary for an effect on body composition and fasting glucose and insulin.

In conclusion, the results of this study are consistent with the hypothesis that the relationship between adiposity, insulin resistance, and calcium intake may be inverse. However, most of the associations were only seen in White women. We believe the reason for this might be the fact that the Black women had significantly lower intakes of calcium and fat than the White women and that higher calcium and fat intakes are necessary for this association. Low calcium intakes are apparently characteristic of the diets of Black South African women. Given the high prevalence of obesity among Black South African women, along with its significant medical consequences, the importance of environmental factors in the rapid rise in the prevalence of obesity, and the relative cost-effectiveness and safety profile of calcium and dairy supplementation, we believe that more research is necessary to determine whether the body weight of overweight adults can be altered by either dietary calcium or low-fat dairy food supplementation. Low-fat dairy food supplementation could be a simple public health approach to prevent obesity among Black South African women. Primary care providers should include recommendations about adequate calcium intake in standard dietary counseling about weight management.

ACKNOWLEDGMENTS

This study was funded by the National Research Foundation of South Africa (GUN numberr 2054068), the Medical Research Council of South Africa, the North-West University (Potchefstroom campus), the Technical University of Dresden (funding grant MeDDrive) and the Deutsche Diabetes Stiftung. We thank Dr. Alta Schutte for the coordination of the study, Dr. Elmarie Jonker and Maretha Oppermann for assistance with dietary intake assessment and computerization of the data, and Chrissie Lessing for drawing blood samples and organizing analyses of blood samples. All body composition measurements were done under supervision of Dr. Colette Underhay.

REFERENCES

1. Puoane T, Steyn K, Bradshaw D, et al. Obesity in South Africa: the South African demographic and health survey. *Obes Res.* 2002; 10:1038–1048.
2. Bradshaw D, Bourne D, Schneider M, Sayed R. Mortality patterns of chronic diseases of lifestyle in South Africa. In: Fourie J, Steyn K, eds. *Chronic Diseases of Lifestyle in South Africa.* Cape Town: Medical Research Council; 1995:5–36.
3. Mollentze WF, Moore AJ, Steyn AF, et al. Coronary heart disease risk factors in a rural and urban Orange Free State Black population. *S Afr Med J.* 1995;85:90–96.
4. Folsom AR, Burke GL, Byers CL. Implications of obesity for cardiovascular disease in Blacks: the CARDIA and ARIC studies. *Am J Clin Nutr.* 1991;53:1604S.
5. Valensi P, Schwarz PEH, Hall M, Felton AM, Maldonato A, Mathieu C. Pre-diabetes essential action: a European perspective. *Diabetes Metab.* 2005;31:606–620.
6. Astrup A, Grunwald GK, Melanson EL, Saris WH, Hill JO. The role of low-fat diets in body weight control: a meta-analysis of *ad libitum* dietary intervention studies. *Int J Obes Relat Metab Disord.* 2000;24:1454–1552.
7. Azadbakht L, Mirmiran P, Esmaillzadeh A, Azizi F. Dairy consumption is inversely associated with the prevalence of the metabolic syndrome in Tehranian adults. *Am J Clin Nutr.* 2005;82:523–530.
8. Melanson EL, Sharp TA, Schneider J, Donahoo WT, Grunwald GK, Hill JO. Relation between calcium intake and fat oxidation in adult humans. *Int J Obes Relat Metab Disord.* 2003;27:196–203.
9. Zemel MB, Shi H, Greer B, Dirienzo D, Zemel PC. Regulation of adiposity by dietary calcium. *FASEB J.* 2000;4:1132–1138.
10. Schrager S. Dietary calcium intake and obesity. *J Am Board Fam Pract.* 2005;18:205–210.
11. Shapses SA, Heshka S, Heymsfield SB. Effect of calcium supplementation on weight and fat loss in women. *J Clin Endocrinol Metab.* 2004;89(2):632–637.
12. Shahkhalili Y, Murset C, Meirim I, et al. Calcium supplementation of chocolate: effect of cocoa butter digestibility and blood lipids in humans. *Am J Clin Nutr.* 2001;73(2): 246–252.
13. Carruth BR, Skinner JD. The role of dietary calcium and other nutrients in moderating body fat in preschool children. *Int J Obes Relat Metab Disord.* 2001;25:559–566.
14. Davies KM, Heany RP, Recker RR, et al. Calcium intake and body weight. *J Clin Endocrinol Metab.* 2000;85:4635–4638.
15. MacIntyre UE, Venter CS, Vorster HH. A culture-sensitive quantitative food frequency questionnaire used in an African population: 2. Relative validation by 7-day weighed records and biomarkers. *Public Health Nutr.* 2000; 4(1):63–71.
16. World Health Organization. *Obesity: Preventing and Managing the Global Epidemic: Report of a WHO Consultation in Obesity, Geneva, June 30, 1997.* Geneva: WHO; 1998.
17. Langenhoven ML, Conradie PJ, Wolmarans P, Faber M. *MRC Food Quantities Manual.* 2nd ed. Parow: Medical Research Council; 1991.

18. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A, eds. *Techniques for Measuring Body Composition*. Washington: National Academy of Science; 1961:223–243.
19. Kahn SE, Montgomery B, Howell W, et al. Importance of early phase insulin secretion to intravenous glucose tolerance in subjects with type 2 diabetes mellitus. *J Clin Endocrinol Metab*. 2001;86:5824–5829.
20. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treatcher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985;28:412–419.
21. Soonthornpun S, Setasuban W, Thamprasit A, Chayanunnukul W, Rattarasarn C, Geater A. Novel insulin sensitivity index derived from oral glucose tolerance test. *J Clin Endocrinol Metab*. 2003;88:1019–1023.
22. Miller GD, Jarvis JK, McClean LD. The importance of meeting calcium needs with food. *J Am Coll Nutr*. 2001;47:57–60.
23. Denke MA, Fox MM, Schulte MC. Short-term dietary calcium fortification increases fecal saturated fat content and reduces serum lipids in men. *J Nutr*. 1993;123:1047–1053.
24. Welberg JW, Monkelbaan JF, De Vreis EG. Effects of supplemental dietary calcium on quantitative and qualitative fecal fat excretion in man. *Ann Nutr Metab*. 1994;38:185–191.
25. Parikh SJ, Yanovski JA. Calcium uptake and adiposity. *Am J Clin Nutr*. 2003;77:281–287.
26. Buchowski MS, Semenya J, Johnson AO. Dietary calcium intake in lactose maldigesting intolerant and tolerant African American. *J Am Coll Nutr*. 2002;21(1):47–54.
27. Jacqmain M, Doucet E, Despres JP, Bouchard C, Tremblay A. Calcium intake, body composition, and lipoprotein-lipid concentration in adults. *Am J Clin Nutr*. 2003;77:1448–1452.

AUTHOR CONTRIBUTIONS

Acquisition of data: Rautenbach, Venter, Wright
Data analysis interpretation: Kruger, Rautenbach, Schwarz
Manuscript draft: Kruger, Rautenbach, Venter, Wright
Statistical expertise: Kruger, Schwarz
Acquisition of funding: Kruger, Schwarz
Administrative, technical, or material assistance: Kruger, Rautenbach, Wright, Schwarz
Supervision: Kruger, Venter, Schwarz