Racial Differences in the Association between Body Mass Index (BMI) and serum IGF-1, IGF-2, and IGFBP-3

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Abstract

African American (AA) race/ethnicity, lower body mass index (BMI), and higher insulin-like growth factor 1 (IGF-1) levels are associated with premenopausal breast cancer risk. This cross-sectional analysis investigated whether BMI or BMI at age 21 years contribute to racial differences in IGF-1, IGF-2, IGFBP-3, or free IGF-1. Participants included 816 white and 821 AA women between ages 40 and 79 years across a wide BMI range (18.5–40 kg/m^2). Compared with white women, AA women had higher mean IGF-1 (146.3 vs. 134.4 ng/ml) and free IGF-1 (0.145 vs. 0.127) levels, and lower IGF-2 (1633.0 vs. 1769.3 ng/ml) and IGFBP-3 (3663.3 vs. 3842.5 ng/ml) levels (all p<0.01; adjusted for age, height, BMI, BMI at age 21, and menopause status). Regardless of race, IGF-1 and free IGF-1 levels sharply rose as BMI increased to 22–24 kg/m^2, then declined thereafter, while IGF-2 and IGFBP-3 levels tended to rise with BMI. In contrast, BMI at age 21 was inversely associated with all IGF levels, but only among white women (p-interaction = 0.01). With the decline in IGF-1 with BMI at age 21 among whites, racial differences in IGF-1 significantly increased among women who were obese in early adulthood. In summary, BMI was associated with IGF-1 levels regardless of race/ethnicity, while obesity during childhood or young adulthood may have a greater impact on IGF-1 levels among white women. The effects of obesity throughout life on the IGF axis and racial differences in breast cancer risk require study.

Keywords

Insulin-like growth factor; obesity; race; breast cancer

Introduction

African American women are at greater risk for premenopausal breast cancer and hormone receptor negative (ER-/PR-) tumors, and have an overall poorer prognosis, compared to white

women (Brinton et al., 2008; Hausauer et al., 2007; Pfeiffer et al., 2008). It is unclear why ER-/
PR- tumors are more common among African American women (Brinton et al., 2008), however
IGF-1 and free (unbound) IGF-1 levels are also associated with premenopausal breast cancer
risk and therefore may have a role in breast tumor progression in the absence of ER or PR
activation (Renehan et al., 2006).

IGF-1 production is stimulated by growth hormone (GH) and is a key mediator of mitogenic
and anti-apoptotic activity (Gennigens et al., 2006). IGF binding protein-3 (IGFBP-3) regulates
IGF-1 bioavailability and also has functional activity to induce or inhibit apoptosis
independently of IGF-1 bioavailability. Analyses of data from NHANES III, Nurses Health
Study II (NHS II), and the Multiethnic Cohort Study (MEC) found African-American women
had higher IGF-1 levels and lower IGFBP-3 levels compared to white women (Berrigan et al.,
2008; DeLellis et al., 2004; Pinheiro et al., 2005), consistent with higher IGF-1 bioavailability
and a potential role for the IGF axis in premenopausal breast cancer risk among African
American women.

Aside from race/ethnicity, IGF-1 levels may also be associated with obesity or energy
availability. Several studies found an inverse association between body mass index (BMI) and
IGF-1 levels in whites (Gram et al., 2006; Jernstrom et al., 2001; Henderson et al., 2006). In
contrast, analysis of MEC data found BMI was not associated with IGF-1 levels among African
Americans (Henderson et al., 2006). The prevalence of obesity is increasing nationally and is
highest among African American women (Flegal et al., 2002), however it is unclear if race/
ethnicity differences in the relationship between obesity and the IGF axis may contribute to
differences in breast cancer risk between race/ethnicity groups.

Our goal was to investigate the role of obesity upon serum IGF-1, IGFBP-3, and IGF-2 levels
in a large sample of white and African-American women to help clarify whether obesity
contributes to racial differences in the IGF axis.

Materials and Methods

Participants

Women in this study were selected from members of the Southern Community Cohort Study,
a prospective cohort investigation initiated in 2001 designed to identify the determinants of
cancer incidence and mortality in a racially diverse population. Detailed methods of the
Southern Community Cohort Study (SCCS) have been reported (Signorello et al., 2005), and
study information is also available at www.southerncommunitystudy.org. Briefly, adult men
and women visiting one of 71 community health centers located throughout the southeastern
U.S were approached for recruitment. Potential participants were eligible if they were between
40 and 79 years of age and had not been under treatment for cancer (except nonmelanoma skin
cancer) within the past year. All SCCS protocols have been approved by IRBs at Vanderbilt
University Medical Center and Meharry Medical College in Nashville, TN.

In 2006, a project was developed within a stratified sample of SCCS female participants to
investigate racial/ethnic differences in blood biomarkers potentially relevant to breast cancer
risk. This sample included 1000 African American and 1000 white female participants
randomly selected from female SCCS cohort members with frozen-stored blood and without
a prior breast cancer diagnosis. Furthermore, sampling was stratified by categories of BMI
(18.5–24.9, 25.0–29.9, 30.0–45.0), age (5-year intervals), and menopausal status
Premenopausal women included women with at least one menstrual cycle within the past six
months, while postmenopausal women were six months or more since their last cycle whether
due to natural aging, hysterectomy with or without oophorectomy, or other causes.

Data and Sample Collection

All SCCS participants provided written informed consent prior to completing a comprehensive, in-person, baseline interview administered by a trained interviewer. The computer-assisted interview included demographics, weight and height, and a wide range of other potential cancer risk factors. Women reporting six or more months since their last menstrual cycle were asked why their periods had stopped. A blood sample was collected from participants at recruitment. Blood samples were refrigerated immediately after collection, and then shipped cold on that day to Vanderbilt University. Blood was processed and stored frozen at $-80°C$ on average within 1.2 days (range 1–5 days) after collection.

Laboratory Assays

Serum concentrations of IGF-I, IGF-2, and IGFBP-3 were determined with the use of commercially available ELISA kits (DSL, Inc., Webster, TX). The calibrators used in the assays ranged between 4.5–640 ng/ml for IGF-I, 50–2000 ng/ml for IGF-II, and 2.5–100 ng/ml for IGFBP-3. For IGFBP-3 measurement, plasma samples were diluted at 1:100 in an assay buffer. The intra-assay CVs were 4.0%, 2.4%, and 1.8%, and inter-assay CVs were 6.5%, 7.4%, and 7.1%, respectively, for IGF-I, IGF-2, and IGFBP-3. Each assay has no cross-reaction with other members of the IGF family. Complete data for blood IGF values were available for 1984 study participants. The molar ratio of IGF-1 to IGFBP-3 representing an index of free IGF-1 was calculated as (IGF-1 (ng/ml) $\times$ 1.30)/(IGFBP-3 (ng/ml) $\times$ 0.36). We did not find an association between IGF markers and transport time, duration of blood storage in freezer, or the time between the last meal and blood collection.

Data Analyses

From the initial sample of 1984 participants with IGF data, we excluded women taking hormone replacement therapy (n=202), insulin for the treatment of diabetes (n=111), or missing weight at age 21 data (n=33). We further excluded one participant with an IGF-1 value more than 8 SDs from the group mean. The final study population included 1637 participants (816 white and 821 African American women). Wilcoxon signed rank and chi-square (χ^2) tests were used to compare median values and categorical levels, respectively, between African American and white women.

We calculated mean IGF marker levels within white or African American participants after adjusting for age (5 year intervals), BMI (categorized at 2 unit intervals to accommodate nonlinear association), height in meters (continuous), menopausal status at blood collection (premenopausal, postmenopausal) and BMI at age 21 years (<20, 20–24, 25–29, and 30 or more) in a linear regression model. Additional control for time of day of blood collection or year of blood collection (storage time) did not affect our results. Tests for trend were performed by including the categorical variable for the covariate of interest as a continuous variable in the full model. Tests for interaction represented differences with race in the association between each IGF marker and another covariate, and were evaluated by the significance of a race $\times$ covariate cross-product term in a model that also included each main effect term and other listed factors. Distributions of all IGF markers approached a normal distribution, with low kurtosis and skewness, such that log transformation of the IGF data did not lead to normalization of these distributions. A Box-Cox procedure suggested raising values of IGF-1 and IGF-2 to the power 0.75 or transforming IGFBP-3 and free IGF1 values with a square root function. However, study results using either the natural scale for each IGF marker or the transformed variable were almost identical. We therefore report mean IGF levels, standard errors, and p-values from statistical tests using IGF values on the natural scale of each IGF marker.

RESULTS

Study Population

African American and white women were selected to have a similar age and BMI (Table 1). African American and white women also had a similar BMI at age 21 (Wilcoxon p=0.88, χ^2 p=0.41) and height (Wilcoxon p=0.07, χ^2 p=0.19). There were 714 postmenopausal women, including 383 women that were postmenopausal because of a clinical intervention such as surgery.

IGFs by menopausal status and race

Premenopausal women had consistently higher IGF levels than postmenopausal women after controlling for age and other factors. These differences in IGF levels associated with menopausal status were similar between African American and white women (p-interaction > 0.05 for all tests of a race by menopause interaction) (Table 2). Racial differences in IGF levels persisted among postmenopausal women regardless of whether they experienced a natural or a surgical menopause (all p-interactions > 0.05).

African American premenopausal and postmenopausal women had significantly higher IGF-1 levels, and significantly lower IGF-2 levels, compared to similar white women (Table 2). IGFBP-3 levels were higher among whites than African Americans, although differences in IGFBP-3 levels between white and African American women were statistically significant only among premenopausal women. Free IGF-1 levels were significantly higher among premenopausal and postmenopausal African American women compared to similar white women. Indeed, free-IGF levels were highest among premenopausal African American women, followed by postmenopausal African American women, premenopausal white women, and postmenopausal white women, respectively.

IGFs and BMI, by race and menopausal status

IGF-1 levels were higher among African American compared to white women across the range of BMI categories (Table 3 and Figure 1). However, the relationship between IGF-1 and BMI was similar between African American and white women (p-interactions > 0.05). The highest IGF-1 levels were found among participants with a BMI between 22 and 24 kg/m^2, with a significant declining trend between BMI and IGF-1 thereafter within both race groups (p-trend<0.05). In contrast, IGF-2 levels tended to increase somewhat with BMI with African America and white women, while IGFBP-3 levels rose slightly (not significantly) as BMI increased beyond 20 kg/m^2. Free IGF-1 levels across BMI categories followed the pattern established by IGF-1 for both African American and white women, with the highest free IGF-1 levels among African American women with a BMI between 22 kg/m^2 and 24 kg/m^2 and then significantly decreasing with a greater BMI. Further investigation of the association between IGF-1 or free IGF-1 with BMI found a similar pattern within premenopausal or postmenopausal women (Table 4), although IGF-1 levels were not lower among the six African American premenopausal women with a BMI less than 20 kg/m^2.

BMI at age 21 and height provide two metrics of body size during growth and development. BMI at age 21 was inversely associated with IGF-1, IGF-2, and IGFBP-3, but only among white women (Table 3). Thus, with increasing BMI at age 21, racial differences in IGF-2 and IGFBP-3 diminished, while racial differences in IGF-1 significantly increased (p-interaction = .01). Racial differences in free IGF-1 remained fairly constant across the range of BMI at age 21 (Figure 2). Inverse associations between IGF-1 and BMI at age 21 were consistent within premenopausal and postmenopausal white women (Table 4), and similar trends were observed with IGF-2 or IGFBP-3 (not shown). Height was not significantly associated with adjusted IGF levels (not shown).

DISCUSSION

African America women are at greater risk for premenopausal breast cancer and ER-/PR-tumors compared to white women (Brinton et al., 2008; Hausauer et al., 2007). We found African American women had significantly higher IGF-1 and free IGF-1 levels, and lower IGF-2 and IGFBP-3 levels, compared to white women. Any explanation is speculative but may involve race/ethnicity differences in estrogen (Setiawan et al., 2006; Pinheiro et al., 2005) or vitamin D levels (Egan et al., 2008) that may in turn affect IGF levels (Lukanova et al., 2004; Janssen et al., 1998; Jorgensen et al., 2004; Rozen et al., 1997). While beyond the scope of this manuscript, differences in diet, physical activity, or reproductive history need to be considered in future analyses (Probst-Hensch et al., 2003; Holmes et al., 2002; Gapstur et al., 2004; McGreevy et al., 2007). Furthermore, perhaps one-third of circulating IGF-1 and two-thirds of IGF-2 and IGFBP-3 levels may be attributable to genetic factors (Harrela et al., 1996), and differences in the prevalence of these genetic determinants between race/ethnicity groups may contribute to race/ethnicity differences in circulating IGF levels (Jernström et al., 2001).

IGF-1 levels were sharply lower among women with a BMI less than $20 \, kg/m^2$, then rose before beginning a significant inverse trend starting with a BMI greater than $22 \, kg/m^2$. IGF-1 and free IGF-1 levels were lower with increasing BMI regardless of menopausal status. This is consistent with several prior analyses (Gram et al., 2006; Jernstrom et al., 2001; Lukanova et al., 2004), although studies of premenopausal white women have not always seen lower IGF-1 levels with a low ($< 20 \, kg/m^2$) BMI (Schernhammer et al., 2007; Lukanova et al., 2004). IGF-1 levels are strongly affected by energy availability, and lean or fasting individuals in a state of relative energy deprivation may down-regulate GH receptor levels or increased resistance to GH signaling, decreasing IGF-1 synthesis (Clemmons and Underwood, 1991). This pathway may also affect IGFBP-3 and IGF-2, as we found the lowest IGFBP-3 and IGF-2 levels with a BMI less than $20 \, kg/m^2$. The pathophysiology linking obesity to lower GH and IGF-1 levels is not well understood but may involve a negative feedback loop by which lower GH secretion is mediated through decreased IGFBP-1 with visceral fat accumulation (Gram et al., 2006).

The Multiethnic Cohort Study reported obesity lowers IGF-1 levels in white but not African American participants (Henderson et al., 2006). However, we found that although African American women had higher IGF-1 levels, the associations between BMI on IGF levels were consistent with race/ethnicity. Two studies found ovulatory function did not mediate the association between BMI and premenopausal breast cancer (Michels et al., 2006; Palmer et al., 2007), and we might hypothesize that the protective association between BMI and premenopausal breast cancer risk may be attributable to the decrease in IGF-1 associated with obesity and that this protective effect could generalize across race/ethnicity. However, the literature regarding BMI and premenopausal breast cancer among African Americans is decidedly mixed (Hall et al., 2000; Mayberry, 1994; Zhu et al., 2005; Palmer et al., 2007). For example, Hall and colleagues analyzed data from the Carolina Breast Cancer Study and found a BMI greater than $30 \, kg/m^2$ was significantly associated with lower premenopausal breast cancer risk among whites (OR=0.46, 95% CI (0.26, 0.80)) but not African Americans (OR=0.89, 95% CI (0.38, 2.07)) (Hall et al., 2000). In contrast, Zhu and colleagues found BMI was associated with a nonsignificant increase in premenopausal breast cancer risk among African Americans (OR=2.49 (95% CI (0.82, 7.59)) (Zhu et al., 2005). Higher overall IGF-1 levels among African Americans may play a role, and reconciling the possible interactions between IGF levels, obesity, and race becomes more complicated if BMI affects tissue IGF-1 receptor expression and potential susceptibility to circulating IGF-1 levels (Suga et al., 2001). Biomarker assays in blood and in target tissue, in addition to body size measures, may be required.

BMI at age 21 years was inversely associated with all IGF markers levels in later life, but only among white women. The decline in IGF-1 among whites and the constant levels among African Americans with BMI at age 21 resulted in considerably lower IGF-1 levels for whites than African Americans for those who were obese in early adulthood. The reason is not clear but appears consistent with an analysis from the NHS II showing that BMI at age 18 was associated with reduced IGF-1 levels among white premenopausal women (Schernhammer et al., 2007). Our findings also raise the possibility that lower IGF-1 status may be implicated in a pre-menopausal breast cancer risk reduction with obesity among whites but not African Americans. The investigation of early-life obesity and breast cancer among African Americans is limited, with Zhu et al reporting no association between BMI at age 18 and premenopausal breast cancer while Palmer et al reporting early-life BMI was associated with a reduced risk among African Americans (Zhu et al., 2005; Palmer et al., 2007). BMI at age 21 also appeared to decrease the racial differences in IGF-2 and IGFBP-3 associated with steroid hormone activity and breast cancer risk (Figueroa et al., 1993; Gronbaek et al., 2004; Allen et al., 2005). Thus, the relevance of early-life obesity on race/ethnicity differences in IGF-1 in the context of decreasing race/ethnic differences in IGFBP-3 or IGF-2 remains to be investigated.

Strengths of this analysis include evaluation of a large number of African American and white women after excluding participants taking hormone replacement therapy or insulin. Furthermore, the range of BMI available for analyses extended beyond most studies. Rather than using only correlation coefficients to summarize IGF and BMI associations, we evaluated non-linear trends graphically over BMI values and controlled for potential confounders such as menopausal status and the reason for menopause. We excluded women with any cancer treatment within the past year, and lifetime cancer history was not significantly associated with any IGF level (all $p > 0.56$). The women evaluated were all participants in the Southern Community Cohort Study and of generally similar socioeconomic status regardless of race. Hence, not only is the underlying study base population well defined, but also differences in education, income, or other attributes which sometimes exist in comparisons of African Americans and whites were minimized by the study design.

Our study has some limitations. Although temporal inference from BMI at age 21 to current IGF levels may be reasonable, the cross-sectional approach did not allow us to determine the temporal relationship between IGF markers and current BMI. BMI is based on self-reported data, although we have reported that self-reported BMI is correlated with blood leptin levels (Fowke et al., 2007). IGF measurements were based on a single serum sample stored at $-80°$ C for up to four years, although IGF marker assays appear reliable when biospecimens are properly stored (Berrigan et al., 2007). Our IGF values are similar to those reported by MEC, NHS, NHANES and other research groups. Oral contraceptive use is associated with lower IGF-1 levels (Jernström et al., 2001), however we did not have data to exclude current oral contraceptive users from our analysis. If oral contraceptive use lowers IGF-1 among premenopausal women (Jernström et al., 2001) differences between pre- and postmenopausal women may be conservative. Generalization of our results to African American and white women will require confirmatory analyses in other studies. Our study also did not allow us to determine the combined effect of past and present obesity with the IGF axis on the risk of ER-/PR- breast cancer among African American women. Finding such relationship(s) requires further follow-up investigations in our cohort.

Conclusion

BMI was associated with IGF-1 levels regardless of race/ethnicity, while obesity during childhood or young adulthood may have a greater impact on IGF-1 levels among white women. The separate effects of obesity throughout life and the IGF axis on the risk of ER-/PR- breast cancer among African American women require investigation.

Acknowledgments

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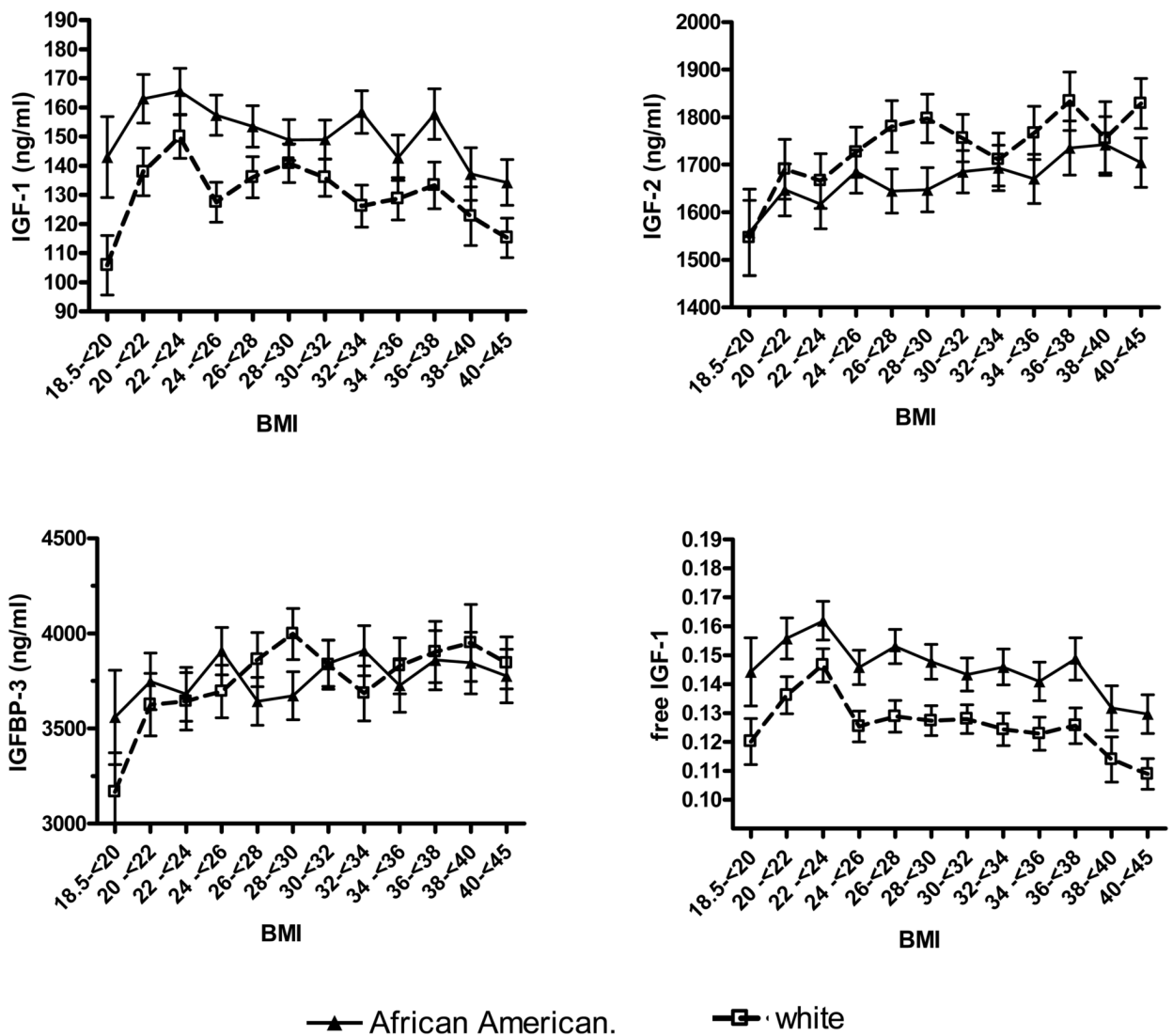
Figure 1.
IGF Levels by BMI and race
Test for trend (Af. Amer, white; respectively; where BMI > 22): IGF-1: p<0.01, p<0.01; IGF-2: p=0.15, p=0.06; IGFBP-3: p=0.66, p=0.40; free IGF1: p<0.01, p<0.01. adjusted for age, height, bmi at age 21, and menopausal status.
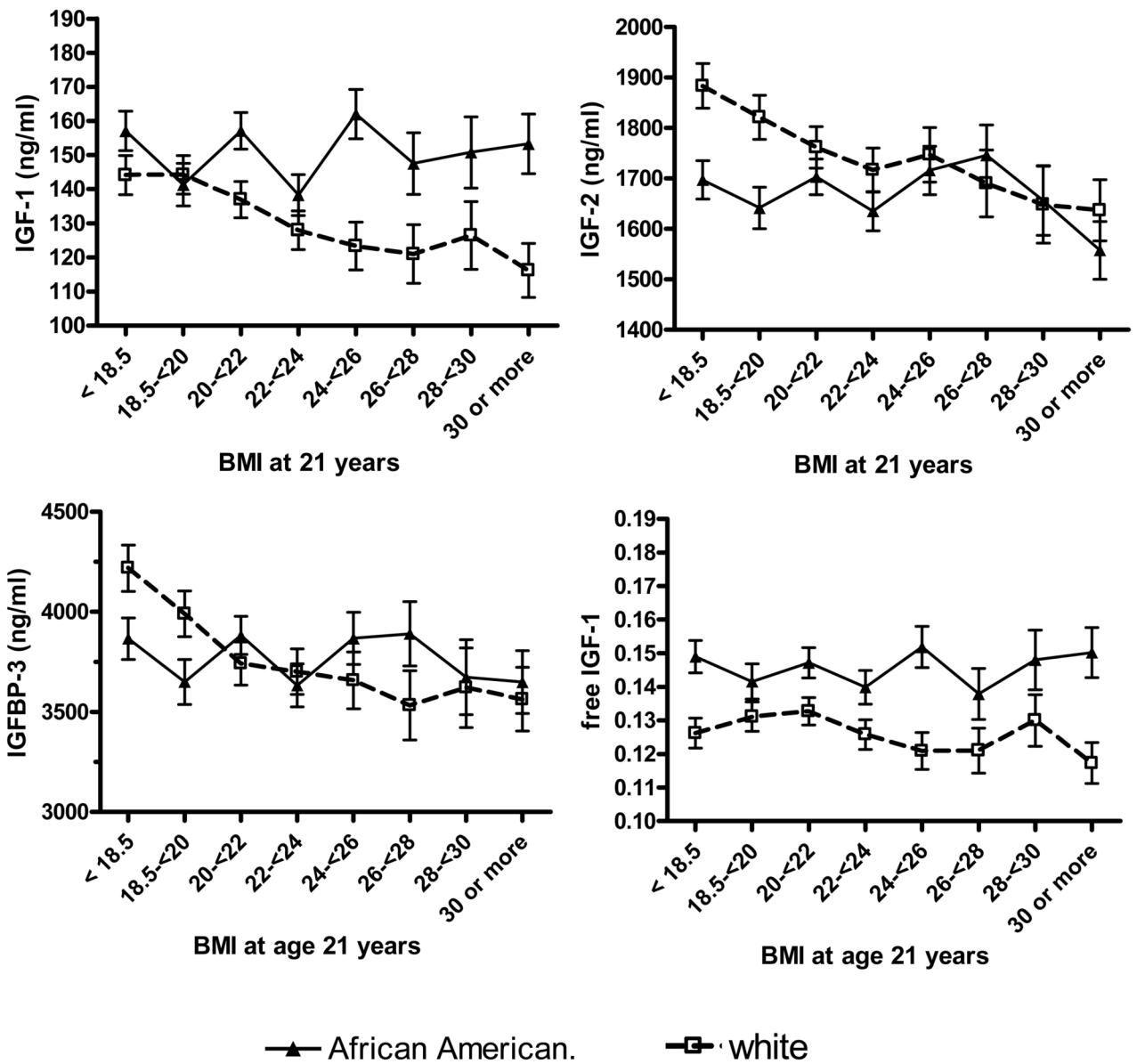
Figure 2.
IGF levels by BMI at age 21 and race
Test for trend (Af. Amer, white; respectively): IGF-1: p=0.33, =0.81; IGF-2: p=0.38, p=0.71;
IGFBP-3: p=0.18, p=0.83;free IGF1: p=0.98, p=0.53; adjusted for age, BMI, menopausal
status, and BMI at age 21 years.

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Table 1

Study Population Characteristics

		White (n=816)		African American (n=821)	
		n	**%**	**n**	**%**
Age (years)	40 – 44	301	36.9%	311	37.9%
	45 – 49	211	25.9%	219	26.7%
	50 – 54	107	13.1%	120	14.6%
	55 – 59	79	9.7%	69	8.4%
	60 – 64	70	8.6%	34	4.1%
	65 – 69	25	3.1%	39	4.8%
	70 – 79	23	2.8%	29	3.5%
BMI	18 – 19	35	4.3%	19	2.3%
	20 – 24	169	20.7%	196	23.9%
	25 – 29	211	25.8%	205	25.0%
	30 – 34	205	25.1%	209	25.5%
	35 – 39	114	14.0%	125	15.2%
	40 – 45	82	10.1%	67	8.2%
BMI at age 21 yrs	13 – 19	283	34.7%	268	32.6%
	20 – 24	366	44.9%	370	45.1%
	25 – 29	103	12.6%	125	15.2%
	30 – 51	64	7.8%	58	7.1%
Height (meters)	1.22 –1.49	29	3.6%	24	2.9%
	1.50 –1.59	196	24.0%	176	21.4%
	1.60 –1.64	222	27.2%	203	24.7%
	1.65 – 1.69	191	23.4%	229	27.9
	1.70 –1.96	178	21.8%	189	23.0
Premenopausal		458	56.1%	465	56.6%
Postmenopausal		358	43.9%	356	43.4%
Natural menopause		161	19.7%	170	20.7%
Surgical or other menopause		197	24.2%	186	22.7%

Table 2

Adjusted IGF levels; by race/ethnicity and menopausal status

	White		African American		
All[*]	Mean	SE	Mean	SE	p
IGF-1 (ng/ml)	134.5	2.9	146.8	2.9	<0.01
IGF-2 (ng/ml)	1773.9	20.2	1639.7	20.4	<0.01
IGFBP-3 (ng/ml)	3874.6	54.1	3703.0	54.5	<0.01
free IGF-1	0.126	0.002	0.144	0.002	<0.01
Premenopausal[**]					
IGF-1 (ng/ml)	148.4	11.9	157.0	11.7	0.02
IGF-2 (ng/ml)	1897.2	82.7	1745.5	82.0	<0.01
IGFBP-3 (ng/ml)	4183.3	212.6	3950.3	210.6	<0.01
free IGF-1	0.128	0.010	0.146	0.010	<0.01
Postmenopausal[***]					
IGF-1 (ng/ml)	128.2	3.9	144.7	3.9	<0.01
IGF-2 (ng/ml)	1778.7	28.5	1666.9	28.6	<0.01
IGFBP-3 (ng/ml)	3872.5	79.4	3771.4	79.6	0.25
free IGF-1	0.119	0.003	0.140	0.003	<0.01
Surgical Menopause[****]					
IGF-1 (ng/ml)	126.7	5.2	147.4	5.4	<0.01
IGF-2 (ng/ml)	1800.0	41.0	1723.9	42.6	0.09
IGFBP-3 (ng/ml)	3934.6	111.6	3951.6	115.9	0.89
free IGF-1	0.117	0.004	0.136	0.004	<0.01
Natural Menopause[****]					
IGF-1 (ng/ml)	132.9	6.3	145.8	6.3	0.06
IGF-2 (ng/ml)	1764.9	42.3	1608.1	42.7	<0.01
IGFBP-3 (ng/ml)	3846.5	119.9	3615.8	121.1	0.08
free IGF-1	0.124	0.005	0.145	0.005	<0.01

Mean IGF levels adjusted for

*
age, height, BMI, BMI at age 21 and menopausal status;

**
age, height, BMI, and BMI at age 21;

***
age, height, BMI, BMI at age 21, and reason for menopause;

****
age, height, BMI, and BMI at age 21

Table 3

Relationship between mean IGF levels with BMI or BMI at age 21, by race/ethnicity

		n		IGF-1 (ng/ml)		IGF-2 (ng/ml)		IGFBP-3 (ng/ml)		Free IGF-1	
		AA	W	AA	W	AA	W	AA	W	AA	W
BMI	18–19	19	35	133.3	114.1	1526.9	1638.4	3448.7	3445.4	0.139	0.119
	20–24	196	169	154.4	145.6	1616.1	1748.1	3689.7	3821.1	0.151	0.137
	25–29	205	211	146.3	141.4	1641.3	1837.6	3649.9	4058.2	0.146	0.127
	30–34	209	205	149.9	131.9	1676.0	1783.7	3818.3	3897.4	0.144	0.123
	35–39	125	114	140.8	131.0	1736.6	1813.5	3858.6	3937.5	0.134	0.122
	40–45	67	82	134.0	114.9	1709.7	1856.2	3794.1	3918.2	0.129	0.106
	p-trend			<0.01	<0.01	0.12	0.05	0.61	0.34	<0.01	<0.01
BMI age 21	12–19	268	283	147.0	144.5	1673.6	1881.8	3766.2	4174.7	0.144	0.126
	20–24	370	366	147.9	133.7	1679.6	1791.0	3780.2	3843.5	0.143	0.126
	25–29	125	103	146.1	126.3	1701.3	1724.9	3759.9	3742.0	0.141	0.121
	30–45	58	64	149.1	119.3	1551.2	1697.4	3609.3	3735.4	0.148	0.115
	p-trend			0.59	<0.01	0.63	<0.01	0.99	<0.01	0.89	0.06

IGF levels adjusted for age, height, menopausal status, and BMI or BMI at age 21 years. AA=African American, W=white

Table 4

IGF-1 and Free-IGF levels and BMI, by race/ethnicity and menopausal status

BMI	IGF-1 (ng/ml)				Free IGF-1			
	Premenopausal		Postmenopausal		Premenopausal		Postmenopausal	
	AA	W	AA	W	AA	W	AA	W
18–19	166.8	105.6	132.2	107.2	0.138	0.112	0.139	0.116
20–24	164.7	145.5	169.2	134.1	0.160	0.136	0.148	0.127
25–29	162.5	139.7	146.3	133.6	0.156	0.123	0.142	0.119
30–34	164.1	136.3	146.8	120.4	0.150	0.122	0.143	0.113
35–39	154.7	128.9	132.7	131.9	0.142	0.109	0.128	0.127
40–45	139.9	116.3	134.1	110.4	0.132	0.098	0.129	0.107
BMI age 21								
12–19	155.8	140.0	143.2	142.2	0.143	0.117	0.142	0.126
20–24	159.7	133.0	145.8	125.2	0.146	0.122	0.140	0.121
25–29	158.9	121.8	141.3	117.9	0.147	0.114	0.130	0.117
30–45	160.8	120.1	143.9	106.3	0.150	0.113	0.140	0.108

Controlling for age, height, and BMI or BMI at age 21 years. Postmenopausal analysis also controlled for reason of menopause (surgical or natural). AA=African American, W=white