Estradiol and Testosterone Effects on Lipids in Black and White Boys Aged 10 to 15 Years

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Previous studies of lipids in adolescent males have shown greater increases in triglycerides and decreases in high-density lipoprotein cholesterol (HDL-C) in white boys compared with black boys, significant correlations between sex hormones and lipids, and complex body mass index (BMI) hormone-lipid associations. Within this frame of reference, we assessed race, BMI, and sex hormones as predictors of lipid parameters in 536 black and white boys recruited from area schools. Black boys were more advanced in puberty than white boys. After adjusting for pubertal stage, estradiol (E_2) levels were higher in black boys but free testosterone (T) levels did not differ. Age, pubertal stage, race, BMI, free T, and E_2 were entered as explanatory variables for lipids in backward stepwise regression analyses. The BMI and race were retained in every model. Black boys had lower triglycerides and apolipoprotein B (apo B) and higher HDL-C. E_2 was inversely associated with total cholesterol (TC), triglycerides, low-density lipoprotein cholesterol (LDL-C), apo B, and the LDL-C/HDL-C ratio. Free T was inversely associated with HDL-C and positively associated with apo B. Given the increases in free T and E_2 during adolescence and the association of these hormones with both atherogenic and protective lipid parameters, racial differences in E_2 could contribute to the more atherogenic lipid profile found in white boys after puberty.

PUBERTAL MATURATION is a period of profound changes in body mass and sex steroid hormones. Important changes also occur in the lipid profile.[1-5] In boys, high-density lipoprotein cholesterol (HDL-C) concentrations decrease markedly, while low-density lipoprotein cholesterol (LDL-C) concentrations decrease in early puberty and increase in late puberty.[1-7] The decrease in HDL-C has been reported as greater in white boys than in black boys.[4,5] By contrast, HDL-C levels in girls exhibit only minor fluctuations, while LDL-C levels decrease markedly.[5,8,9] As a consequence of these sex-specific changes, adult men, especially white men, have more atherogenic lipid profiles than women.[4]

The Princeton Maturation Study showed in a small sample of boys that estradiol (E_2), free testosterone (T), and the body mass index (BMI) were significant predictors of HDL-C and LDL-C concentrations cross-sectionally and of changes in these parameters longitudinally.[6,7] These last reports from the Princeton Lipid Research Clinics (LRC) Study did not address racial differences in the BMI-hormone-lipid complex. Within this frame of reference, the Sex Hormones and Lipoproteins in Adolescent Males Study measured the BMI and sex steroid hormone and lipid levels in a large cohort of 10- to 15-year-old black and white boys to assess the BMI-hormone-lipid relationships and to evaluate possible racial differences in these relationships.

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SUBJECTS AND METHODS

Study Population

The Sex Hormones and Lipoproteins in Adolescent Males Study has been described previously.[10] Briefly, over 500 boys in grades 5 to 9 at selected Cincinnati elementary and high schools were recruited for the study targeting males 10 to 15 years of age. Demographic data were collected by interview with the subjects' parents, including the subjects' date of birth and race. The Institutional Review Board at the University of Cincinnati College of Medicine approved the study purpose and design. Signed informed consent was obtained from the parents or guardians for all participants.

Clinical Assessments

As previously reported,[10] height was measured to the nearest 0.25 in with the subjects' shoes off, feet together, and head in the Frankfort horizontal plane. Weight was measured to the nearest 0.1 kg using a calibrated hospital scale with the subjects' shoes, sweaters, coats, and jackets removed. The BMI was used to characterize obesity because of the low technical errors associated with this measure and because it has been shown to correlate highly with direct measures of obesity.[11] The stages of puberty were scored by measurement of testicular volume compared with Prader beads and visual assessment of pubic hair following the modification of Tanner Staging by Biro et al.[12] Stage 1 indicates a lack of pubic hair and a testicular volume <3 cc; stage 2a is a lack of pubic hair and a testicular volume of 3 cc or greater; and stages 2b, 3, 4, and 5 have pubic hair at Tanner stages 2, 3, 4, and 5, respectively. Stage 1 represents prepuberty, stages 2a and 2b represent early puberty, stages 3 and 4 represent midpuberty, and stage 5 represents late puberty. Ten milliliters of fasting blood (<12 hours) was drawn into tubes containing EDTA for determination of lipids, and 20 mL into empty tubes for hormone assays. Following blood aspiration, the vacutainers were kept cool and delivered to the laboratory within 2 hours.

Laboratory Measurements

Measurements of plasma total cholesterol (TC), triglyceride, HDL-C, and calculated LDL-C were performed in a National Heart, Lung, and Blood Institute/Centers for Disease Control–standardized Lipid Laboratory on a Hitachi 705 (Roche Diagnostics, Indianapolis, IN) instrument using enzymatic procedures for cholesterol and triglyceride measurements, as well as triglyceride blanking, and the modified LRC procedure (heparin–2-mol/L $MnCl_2$) for HDL-C.[13-15] Apolipoprotein B

(apo B) was analyzed by electroimmunoassay.[16] The coefficient of variation was less than 2% for TC, less than 2% for triglycerides, less than 5% for HDL-C, and less than 10% for LDL-C. Total T was quantified by the method of Coyotupa et al,[17] with the antibody for this assay as described by Nolten et al.[18] Free T was analyzed with a clinical adsorption assay according to Moll and Rosenfield.[19] The total concentration of E_2 was measured by competitive protein binding methods.[20,21] The coefficient of variation was 8.0% for total T, 6.0% for free T, and 3.3% for E_2.

Statistical Analysis

The mean age of the black and white boys was compared using Student's *t* test. Comparisons of the anthropometric, lipid, and sex steroid hormone variables were made using Student's *t* test and analysis of covariance adjusting for pubertal stage—prepubertal, early pubertal, midpubertal, and late pubertal. Differences in the relation of age to pubertal stage by race were assessed using a 2-way ANOVA. The effects tested in this model were race, maturation stage, and their interaction. The associations among the BMI, lipids, and hormones were assessed using Pearson's correlation coefficients. In these analyses, the natural logarithms of the BMI, triglycerides, E_2, and free T were used. Racial differences in the correlation coefficients were tested for significance using Fisher's *Z* test. Because of the dramatic changes in the BMI, sex hormone concentrations (both increasing), and lipid parameters (some increasing and others decreasing), bivariate correlations cannot adequately describe the BMI-hormone-lipid relationships in a cohort of adolescent boys. Accordingly, backward stepwise regression analyses were conducted to identify significant predictors of lipid and lipoprotein concentrations in multivariate analyses. In these models, age, race, pubertal stage, BMI, free T, and E_2 were tested as explanatory variables. Because of the completeness of the analysis data set, missing data were not a problem for the backward stepwise procedure. Unless otherwise specified, statistical testing was performed at the .05 significance level. In the regression models, explanatory variables were kept in the models with a *P* value of .10. TC, triglycerides, HDL-C, and LDL-C are presented as millimolars, and apo B as milligrams per deciliter. The conversion from millimolars to milligrams per deciliter is 38.67 mg/dL per 1 mmol/L for cholesterol and 90.9 mg/dL per 1 mmol/L for triglycerides. The stages of maturation were coded as indicator variables for the prepubertal through mid-late stages, respectively, and race was coded as whites = 0 and blacks = 1. All analyses were performed using SAS software.[22]

RESULTS

Measurements were obtained on 285 white boys and 251 black boys, representing 74% and 68% of white and black students enrolled in the target schools, respectively. Table 1 presents the characteristics of the study population. Few black boys (n = 17, 6.8%) and white boys (n = 16, 5.6%) were 15 years old. The number of boys in the other 1-year age groups ranged from 25 (10.0%, age 10) to 65 (25.9%, age 12) for black boys and from 43 (15.1%, age 10) to 64 (22.5%, age 12) for white boys. Black boys were marginally older than white boys ($P = .06$), but the difference amounted to only 2.5 months. Black boys were significantly taller and heavier and had a higher BMI (all $P < .001$). Black boys had higher TC, with much of this difference due to higher HDL-C in black boys. Differences in LDL-C were not significant, but black boys had significantly higher HDL-C ($P < .001$), lower triglycerides ($P < .001$), and a lower LDL-C/HDL-C ratio ($P = .02$). Black boys had higher mean E_2 and free T (both $P \leq .001$).

Table 1. Age, Body Composition Measures, Lipid Parameters, and Sex Steroid Hormones in Black and White Males Aged 10 to 15 Years, by Race (mean ± SD): The Sex Hormones and Lipoproteins in Adolescent Males Study

Variable	Black Males (n = 251)	White Males (n = 285)	*P*	Adjusted *P**
Age (yr)	12.9 ± 1.4	12.7 ± 1.5	.06	.05
Body composition				
Height (cm)	160.3 ± 12.0	156.0 ± 12.1	<.001	.41
Weight (kg)	51.3 ± 13.9	46.1 ± 12.8	<.001	.03
BMI (kg/m²)	19.7 ± 3.7	18.6 ± 3.1	<.001	.02
Lipids				
TC (mmol/L)	4.3 ± 0.8	4.0 ± 0.7	.002	<.001
Triglycerides (mmol/L)	0.6 ± 0.3	0.8 ± 0.4	<.001	<.001
HDL-C (mmol/L)	1.6 ± 0.3	1.4 ± 0.3	<.001	<.001
LDL-C (mmol/L)	2.5 ± 0.7	2.4 ± 0.6	.13	.03
LDL-C/HDL-C ratio	1.7 ± 0.6	1.8 ± 0.6	.02	.01
Apo B (mg/dL)	83.3 ± 20.3	88.5 ± 24.0	.01	.03
Sex hormones				
E_2 (pmol/L)	111.9 ± 95.2	75.5 ± 69.3	<.001	.01
Free T (nmol/L)	23.7 ± 24.7	17.0 ± 21.3	.001	.79

*Reflects adjustment in the models for pubertal maturation stage.

Pubertal Maturation and Racial Differences in Body Composition, Lipids, and Sex Hormones

As expected, there was a strong association between age and pubertal stage, but there were white boys in every pubertal stage at age 13 and black boys in every pubertal stage at ages 12 and 13. Also, as expected, there were significant associations between the pubertal stage and height, weight, and BMI, with stepwise increments in these body size variables (Table 2). There was a significant race × age interaction in the model for pubertal stage ($P = .005$), with black boys being more advanced in puberty than white boys. After controlling for pubertal stage, the racial differences in height, weight, and BMI were no longer significant. The racial differences in TC and HDL-C (blacks higher) and triglycerides, apo B, and the LDL-C/HDL-C ratio (blacks lower) remained significant. After controlling for pubertal stage, the difference in LDL-C was significant. There was measurable sex hormone activity in boys of each race who were classified as prepubertal, ie, prior to the development of secondary sex characteristics or enlargement of the testes. As expected, serum concentrations of E_2 and free T were incrementally higher at each later stage of pubertal development in each race (Table 2). After controlling for pubertal stage, free T levels did not differ between the races ($P > .1$), but E_2 levels remained significantly higher in black boys. The racial difference in E_2 levels appeared in the middle to late stages ($P < .001$).

Lipid Parameters, BMI, and Sex Hormone Correlations

With advancing puberty, the BMI, E_2, and free T were higher in boys of both races (Table 2), and the 3 factors were significantly intercorrelated. The correlation between E_2 and free T was .82 in white boys and .84 in black boys. The correlation varied across pubertal stage, being lower in the prepubertal and late pubertal stages ($r = .49$ and .43, respectively) than in the early ($r = .66$) and middle ($r = .80$) stages (data not shown). In both black and white boys, the BMI was

Table 2. Age, Body Composition Measures, Lipid Parameters, and Sex Steroid Hormones in Black and White Males Aged 10 to 15 Years, by Pubertal Stage (mean ± SD): The Sex Hormones and Lipoproteins in Adolescent Males Study

	Prepubertal		Early		Middle		Late	
Parameter	Black Males (n = 23)	White Males (n = 58)	Black Males (n = 93)	White Males (n = 130)	Black Males (n = 120)	White Males (n = 87)	Black Males (n = 15)	White Males (n = 10)
Age (yr)	11.5 ± 1.00	11.2 ± .90	12.2 ± 1.16	12.4 ± 1.15	13.6 ± 1.19	14.0 ± .97	14.3 ± .89	14.2 ± .71
Height (cm)	146.4 ± 8.73	144.4 ± 7.88	154.1 ± 9.70	152.8 ± 8.62	166.3 ± 9.41	166.9 ± 8.94	171.6 ± 6.42	170.5 ± 4.37
Weight (kg)	39.8 ± 13.90	36.9 ± 9.26	46.3 ± 13.42	42.4 ± 9.81	55.7 ± 11.69	55.1 ± 10.56	64.5 ± 8.66	67.6 ± 9.46
BMI (kg/m^2)	18.3 ± 4.78	17.5 ± 2.90	19.3 ± 4.08	18.0 ± 2.86	20.0 ± 3.20	19.7 ± 2.84	21.8 ± 1.98	23.3 ± 3.45
Lipids (mmol/L)								
TC	4.51 ± .83	4.26 ± .60	4.41 ± .89	4.15 ± .69	4.11 ± .72	3.80 ± .74	4.07 ± .71	3.68 ± .68
Triglyceride	.59 ± .24	.74 ± .38	.66 ± .36	.75 ± .43	.60 ± .33	.79 ± .44	.51 ± .23	.71 ± .33
HDL-C	1.68 ± .32	1.49 ± .26	1.64 ± .39	1.42 ± .27	1.49 ± .31	1.28 ± .25	1.53 ± .18	1.24 ± .24
LDL-C	2.62 ± .85	2.50 ± .51	2.54 ± .79	2.45 ± .62	2.41 ± .61	2.24 ± .65	2.36 ± .64	2.19 ± .59
LDL-C/HDL-C	1.65 ± .74	1.72 ± .45	1.65 ± .62	1.79 ± .58	1.69 ± .57	1.80 ± .60	1.56 ± .47	1.79 ± .53
Apo B (mg/dL)	82.9 ± 21.33	90.9 ± 25.11	85.5 ± 22.29	90.4 ± 26.26	81.6 ± 19.11	84.9 ± 19.44	83.8 ± 13.29	81.5 ± 18.03
Sex steroid hormones								
E_2 (pmol/L)	37.35 ± 26.37	25.06 ± 22.07	57.20 ± 48.50	53.82 ± 49.32	161.00 ± 98.37	134.83 ± 72.20	184.96 ± 91.66	145.37 ± 45.33
Free T (nmol/L)	2.21 ± 3.94	1.78 ± 4.10	9.93 ± 12.51	8.84 ± 13.37	35.27 ± 24.81	36.76 ± 22.09	54.44 ± 23.60	43.74 ± 8.85

positively correlated with triglycerides and LDL-C and inversely correlated with HDL-C (Table 3). Consistent with these results, the BMI was also positively correlated with the LDL-C/HDL-C ratio (data not shown). The correlations for the BMI with HDL-C and free T were approximately twice as great in white boys versus black boys. E_2 and free T were both significantly and inversely correlated with all lipid variables in black and white boys, except for triglycerides in white boys and apo B in black and white boys (Table 3). Within each racial group, the free T and E_2 correlations with each lipid parameter were similar in sign and magnitude, reflecting the strong correlation between the 2 hormones.

Predictors of Lipid Levels in Adolescent Boys

In multivariate analysis (backward stepwise regression), the BMI was retained in every model as a significant predictor of the lipid parameters assessed (Table 4). The BMI was positively associated with TC, triglycerides, LDL-C, and apo B and negatively associated with HDL-C. It was also positively associated with the LDL-C/HDL-C ratio. In these analyses, race was also in all final models. Black boys had higher TC, HDL-C, and LDL-C and lower apo B and LDL-/HDL-C ratio. There was a marginally significant ($P = .082$) race × age interaction in the model for triglycerides such that triglycerides increased less with increasing age in black boys. In the final triglyceride model, age was a significant positive predictor ($P = .041$); race was not significant, but it was retained in the model because of the interaction. In the final models, E_2 was significantly and negatively associated with TC, triglycerides, LDL-C, and apo B. Higher E_2 was also associated with a lower LDL-C/HDL-C ratio. There was a significant interaction between race and E_2 for apo B, such that increasing E_2 had a negative effect on apo B in white boys but a slightly positive effect in black boys. Free T was negatively associated with HDL-C and positively associated with apo B and the LDL-C/HDL-C ratio. Pubertal stage was not retained in any model, but age was a significant predictor of HDL-C (negative) and triglycerides (positive) and a marginally significant negative predictor of TC ($P = .086$). To verify that the final models did not have multicollinearity problems, additional regression models were performed and the variance inflation factor for each variable was generated. All variance inflation factors were less than 5, indicating that multicollinearity was not an issue in any of the final regression models. The total variances accounted for in the final models were modest, from 0.074 (LDL-C and apo B) to 0.202 (HDL-C) (Table 4).

Table 3. Pearson's Correlation Coefficients Between Lipids and BMI (kg/m^2) and Sex Hormones in Adolescent Black and White Males Aged 10 to 15 Years, by Race: The Sex Hormones and Lipoproteins in Adolescent Males Study

	ln BMI		ln E_2		ln Free T	
Variable	WM	BM	WM	BM	WM	BM
TC	NS	NS	−.28	−.28	−.23	−.21
ln triglycerides	.26	.25	NS	−.11	NS	−.13
HDL-C	−.40	−.21*	−.30	−.22	−.36	−.23
LDL-C	.10	.14	−.18	−.19	−.12	−.10
Apo B	.13	.11	−.20	NS	NS	NS
ln BMI	—	—	.35	.23	.40	.24*
ln E_2	.35	.23	—	—	.82	.84
ln free T	.40	.24*	.82	.84	—	—

NOTE. ln indicates that the natural log of the variable was used. Critical values for correlation coefficients (2-tail tests, n = 250): .05 < P < .10, r = .10; P < .05, r = .12; P = <.01, r = .16; P = <.001, r = .21.

*Racial difference in correlation coefficients statistically significant at P < .01.

DISCUSSION

Puberty in males is associated with marked increases in the BMI, free T, and E_2, as well as profound changes in lipids. Previous studies of lipid changes in adolescent males have described the increases in triglycerides and decreases in HDL-C associated with advancing pubertal stage,[1-2] the correlations between sex hormones and lipids,[3] the BMI–pubertal stage–lipid associations without sex hormones by race,[8,9] and the BMI-hormone-lipid associations without race.[6,7] This study extends the previous findings by analyzing race, BMI, and sex hormones as predictors of lipid parameters in multivariate analyses. In backward stepwise regression, race, BMI, and

Table 4. Predictors of Lipid Parameters in Black and White Adolescent Boys

Dependent Variable	Parameter	β Coefficient	SE (B)	$P > [T]$	Model R^2	P
TC (mmol/L)	Intercept	4.011	0.576	.0001	.117	.0001
	Race	0.283	0.065	.0001		
	Age	−0.053	0.031	.086		
	ln BMI	0.611	0.195	.002		
	ln E_2	−0.201	0.046	.0001		
Triglycerides (mmol/L)	Intercept	−2.289	0.458	.0001	.131	.0001
	Race	0.444	0.383	.246		
	Age	−0.054	0.026	.041		
	Age × race	0.052	0.030	.082		
	ln BMI	0.888	0.130	.0001		
	ln E_2	−0.057	0.031	.066		
HDL-C (mmol/L)	Intercept	3.086	0.263	.0001	.202	.0001
	Race	0.219	0.026	.0001		
	Age	−0.024	0.014	.083		
	ln BMI	−0.390	0.078	.0001		
	ln free T	−0.025	0.011	.024		
LDL-C (mmol/L)	Intercept	1.018	0.484	.036	.074	.0001
	Race	0.127	0.057	.028		
	ln BMI	0.741	0.170	.0001		
	ln E_2	−0.169	0.031	.0001		
LDL-C/HDL-C ratio	Intercept	−0.941	0.449	.037	.118	.0001
	Race	−0.149	0.049	.003		
	ln BMI	1.052	0.148	.0001		
	ln E_2	−0.151	0.045	.001		
	ln free T	0.064	0.025	.011		
Apo B (mg/dL)	Intercept	34.313	18.576	.065	.074	.0001
	Race	−23.726	8.538	.006		
	ln BMI	21.878	5.891	.0002		
	ln E_2	−4.511	2.045	.028		
	ln E_2 × race	−4.698	2.013	.020		
	ln free T	1.734	.993	.081		

either free T or E_2 remained in the models predicting lipid levels while pubertal stage was removed. This suggests that the salient effects of puberty reported by previous studies[1,2,8,9] are mediated through the pubertal changes in body mass and sex hormones.

The most profound changes in male lipid profiles during adolescence occur for HDL-C and triglycerides, and previous reports have indicated that these changes are greater in white boys than in black boys.[3,4] Although black boys in the current cross-sectional study had higher HDL-C and lower triglycerides, racial differences in these lipids did not appear to increase with age. This could be due to the fact that the previous studies included boys up to 17 years of age instead of 15 years as in the current study.

Consistent with previous findings in adolescent boys,[3-7,23] the current study found significant hormone-lipid correlations. However, given the pubertal changes occurring simultaneously in the BMI, free T, E_2, and lipids, correlation analyses can only describe bivariate associations and cannot assess the complex interactions occurring among predictors and the effects of each predictor, given the other variables. Thus, the correlation analyses in this study indicate similar associations of both free T and E_2 with each lipid parameter. For this reason, stepwise regressions were used. These analyses indicate different associations for free T and E_2 with various lipids and provide evidence of the atherogenic effects of increasing free T on adolescent male lipid profiles. Increasing free T levels were predictive of lower HDL-C after controlling for the significant effects of age, race, and BMI. Moreover, the analysis shows that the other potential explanatory factors for HDL-C did not remain in the model, and the effects of free T on HDL-C did not differ significantly between the races. In addition, and importantly, increasing free T was associated with increasing apo B and LDL-C/HDL-C ratios in boys of both races.

In contrast to this study and previous studies of adolescents, some adult studies have shown positive associations between T and HDL-C.[24,25] Freedman et al[24] studied 3,562 white men aged 31 to 45, reporting a positive association between T and HDL-C and a negative association between T and body mass. Adjusting for body mass reduced the T to HDL-C correlation by 30%, suggesting that a significant portion of the T to HDL-C correlation could be mediated through T–body mass associations. Khaw and Barrett-Connor[25] also reported positive correlations between T and HDL-C in white men 30 to 79 years of age. One adult study with findings consistent with the current report was reported by Stefanick et al.[26] They controlled for the effects of adiposity, smoking, and alcohol consumption and found that T levels were inversely associated with HDL-C and positively associated with apo B.

The findings of the current study also raise important questions about the potential antiatherogenic effects of E_2 in male pubertal lipid changes. In multiple regression analysis, increasing E_2 was predictive of lower triglycerides, LDL-C, apo B, and LDL-C/HDL-C ratio in boys of each race. However, a

number of adult studies comparing estrogens in men with and without coronary heart disease (CHD) have reported higher concentrations of E_1 and/or E_2 in men with CHD.[27-29] Zumoff et al[30] later showed that obese young men have elevated E_2 levels compared with non-obese young men. Stefanick et al[26] controlled for adiposity and found that plasma E_2 was inversely correlated with TC, LDL-C, and apo B in a sample of healthy middle-aged men. In the current cross-sectional analysis, the wide range of hormone and lipid values in the population sample serves to increase the variance estimates, potentially resulting in underestimates of the effects of E_2 on lipid parameters. Longitudinal analyses controlling for interparticipant differences are needed to fully evaluate these effects. Supportive evidence for an antiatherogenic role for E_2 in males comes from studies in which the aromatization of T to E_2 was blocked or deficient. Because the aromatization of free T is a major source of male E_2,[31] blocking or decreasing this conversion markedly decreases E_2 levels; it also decreases HDL-C.[32-35] In 2 reported cases of men with aromatase defects, the associated low HDL-C was increased with estrogen replacement.[36,37]

It is possible that the effects of obesity could partially explain the hormone-lipid associations. Obesity increases E_2 in males, converting free T to E_2 and decreasing free T.[30,31,38] However, at the same time, obesity also increases hepatic lipase,[39] which in turn elevates triglyceride and decreases HDL-C.[39-40] E_2 decreases hepatic lipase.[38] Thus, the effects of obesity and E_2 may compete, with (1) E_2 exerting beneficial effects on lipids and (2) obesity increasing E_2 but having deleterious effects on lipids. In the current study, black boys had higher E_2 than white boys. We speculate that black boys should have lower hepatic lipase than white boys, a racial difference recently reported in adults.[41] Because the racial differences in adult hepatic lipase were partially due to the relative prevalence of one gene,[41] E_2 may be only one factor explaining the differences in hepatic lipase.

It is interesting to note that E_2 and free T did not remain together in the same lipid models as explanatory factors, except in the models for apo B and the LDL-C/HDL-C ratio. This may reflect the high correlation ($r > .82$) between these 2 hormones during the ages covered by this analysis (Table 3). When both sex hormones are increasing markedly, increases in one serve, to some extent, as a marker for the other, especially given the role of free T as a source for male E_2.[31] In adults, the 2 hormones are not correlated.[34] When both free T and E_2 remained in the models, E_2 had an antiatherogenic effect and free T had an atherogenic effect. It is interesting to note that although black boys had lower apo B than white boys, there was an interaction between race and E_2 in the model for apo B such that increasing E_2 predicted lower apo B in white boys and slightly higher apo B in black boys. This remains to be explained. Longitudinal studies may help to resolve these issues.

Puberty is a period in flux. Growth is rapid yet occurs at different ages in different boys, with changing blood chemistry. The cross-sectional examination of these factors may be subject to increased variability in the measurements, and hence to lower estimates of interrelationships than actually exist. The percent variability in the lipid parameters explained by these models was modest. However, the results of this evaluation indicate that E_2, which derives in large part from the aromatization of free T, is a significant predictor of lipids in adolescent males and could partially explain the racial differences in adolescent male lipid profiles.

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