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Racial/ethnic differences in serum sex steroid hormone concentrations in US adolescent males

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Abstract

Objective—Contrary to the hypothesis that the racial/ethnic disparity in prostate cancer has a hormonal basis, we did not observe a difference in serum testosterone concentration between non-Hispanic black and white men in the Third National Health and Nutrition Examination Survey (NHANES III), although non-Hispanic black men had a higher estradiol level. Unexpectedly, Mexican-American men had the highest testosterone level. Next, we evaluated whether the same patterns are observed during adolescence, the time of prostate maturation.

Methods—We measured serum testosterone, estradiol, and sex hormone binding globulin (SHBG) by immunoassay in 134 males aged 12–19 in NHANES III. Mean concentrations were compared by race/ethnicity adjusting for age, Tanner stage, percent body fat, waist, physical activity, tobacco smoke, and the other hormones.

Results—After multivariable adjustment, in the 12–15 year-old males, testosterone concentration was lower in non-Hispanic blacks than whites (P=0.043), SHBG concentration did not significantly differ between the two groups. Mexican-Americans had the highest testosterone (versus non-Hispanic black: P=0.002) and lowest SHBG (versus non-Hispanic white: P=0.010; versus non-Hispanic black: P=0.047) concentrations. Estradiol concentration was lower in non-Hispanic blacks (P=0.11) and Mexican-Americans (P=0.033) compared with non-Hispanic whites. After multivariable adjustment, in the 16–19 year-old males, testosterone, estradiol, and SHBG concentrations did not differ between non-Hispanic blacks and whites. Mexican-Americans had the highest testosterone concentration (versus non-Hispanic white: P=0.08), but did not differ from

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the other groups on estradiol and SHBG concentrations. In both age groups, these patterns were generally present, but less pronounced after adjusting for age and Tanner stage only.

Conclusion—In adolescent males, non-Hispanic blacks did not have a higher testosterone concentration than non-Hispanic whites, and Mexican-Americans had the highest testosterone concentration, patterns similar to adult males.

Keywords

testosterone; adolescence; race and ethnicity

Introduction

In the US, black men have the highest prostate cancer incidence (annual: 230.8 per 100,000 men) and mortality (54.9 per 100,000) rates and Hispanic men the lowest rates (126.7 and 18.5 per 100,000, respectively) when compared with white men (142.8 and 22.4 per 100,000, respectively) [1]. The disparity in these rates between blacks and whites has long been thought to be explained, in part, by racial differences in circulating testosterone concentration [2]. However, our prior findings in a nationally representative sample of US men do not support this hypothesis: we observed that serum testosterone concentration was not statistically significantly different between non-Hispanic black and non-Hispanic white men when taking into account age, percent body fat, alcohol, smoking, and physical activity [3]. Other studies also reported no statistically significant difference [4–13], including in young and adolescent males [14–16], whereas others reported higher testosterone levels in black compared with white men [17–19], including in young adult males (≥18 years) [20, 21]. Although testosterone levels did not differ, in our prior study we observed that non-Hispanic black men had a higher estradiol concentration, especially in young and mid-adulthood, than non-Hispanic white men [3]. Some studies in older adults [19], young adults [5], and adolescents [14–16, 22] had similar findings, whereas other studies did not find differences in estradiol level between black and white adult, young adult, and adolescent males [8, 9, 18, 20, 21].

While the lower risk of prostate cancer in Hispanic men has not been attributed to racial/ethnic variation in sex steroid hormones, we also previously found in NHANES III that Mexican-American men had the highest testosterone level, but had an estradiol level similar to non-Hispanic whites [3]. Other studies have reported that Hispanic men had a testosterone level similar to white men [13, 17, 18] or a slightly lower level than in whites [11]. No racial/ethnic differences in estradiol level were reported in the only other study that included Hispanic men [18].

Because sex steroid hormones are necessary for pubertal development and sexual function, we hypothesized that racial/ethnic variation in levels at the time of prostate maturation could, in part, explain the variation in prostate cancer rates among black, white, and Hispanic men, irrespective of variation or lack of variation in hormone levels by race/ethnicity in adulthood. Therefore, we evaluated racial and ethnic differences in sex steroid hormone and SHBG concentrations in adolescence (12–19 years old) in a US nationally representative sample. Importantly, we were able to take into account age and stage of puberty, but also body fatness, other factors that may differ by race/ethnicity and influence hormone levels, and mutually for the other hormones.

Methods

Study population

The National Center for Health Statistics conducted the Third National Health and Nutrition Examination Survey (NHANES III), a cross-sectional study of the US civilian non-institutionalized population aged two months or older, between 1988 and 1994. NHANES III used a multistage, stratified and clustered probability sampling in which Mexican-Americans, non-Hispanic blacks, the elderly and young children were oversampled to ensure adequate samples sizes.

NHANES III had two phases (1988–1991 and 1991–1994) from which independent, unbiased national estimates of health and nutrition can be calculated. Participants were interviewed at home and asked detailed demographic and health-related questions. Participants also underwent extensive physical and laboratory examinations in a mobile examination center or at a home visit. Trained-personnel collected blood samples from participants after an overnight fast under standardized conditions [23]. During the examination a trained examiner measured the participants' height, weight, waist circumference, and skinfolds. Tanner staging (five stages each for genitalia and pubic hair) was performed by a physician trained to use the standardized protocol on 8 to 18 year old participants. For this analysis, we assigned 19 year olds the highest Tanner stage (V). We estimated percent body fat from tricep and subscapular skinfold measurements, pubic hair Tanner staging, and equations for white and black youth from Slaughter et al. [24]; we applied the formula for white youth to Mexican-American youth. Physical activity was assessed by questionnaire. Tobacco smoke exposure was assessed by urinary cotinine levels.

Stored serum volume was adequate for measuring hormones for 161 of the 278 12–19 year-old males who participated in the morning session of Phase I. Details about the choice of hormones, session, and phase have been reported previously [3]. We excluded participants with missing hormone measurements (N=5), Tanner staging (N=18), or other covariates (N=4) leaving 134 for this analysis. Of these, 33 were non-Hispanic black, 38 were non-Hispanic white, and 63 were Mexican-American.

Measurement of serum sex steroid hormones

Serum concentrations of total testosterone, total estradiol, and sex hormone binding globulin (SHBG) were measured by competitive electrochemiluminescence immunoassay. Assay details including sensitivity and variability have been reported previously [3]. Free testosterone and free estradiol concentrations were estimated from total testosterone and total estradiol, respectively, SHBG, and albumin concentrations using mass action equations [25, 26].

Statistical Analyses

The statistical analysis was performed using SUDAAN [27] as implemented in SAS version 9.2 (Cary, NC). Sampling weights were applied to take into account selection probabilities, over-sampling, non-response, and differences between the sample and the US adolescent male population. Because androgen levels rise steeply during adolescence, we dichotomized the participants into two age groups: 12–15 years old (early adolescence) and 16–19 years old (late adolescence). To normalize the hormone distributions, we transformed the concentrations using the natural logarithm. Separately by age group, we compared whether age-adjusted characteristics differed by race/ethnicity using regression modeling. We ran linear regression models separately for the 12–15 year olds and the 16–19 year olds adjusting for age as a continuous variable (to minimize any residual difference in age among the three racial/ethnic groups within the two age groups), and Tanner stage (to minimize

differences in when the racial/ethnic groups enter puberty) for genitalia (3 categories: combined stages 1 and 2, 3 and 4 and 5) and pubic hair (same as genitalia). We also ran multivariable models further adjusting for factors that differ by race/ethnicity and that may influence hormone levels: percent body fat (continuous), waist circumference (continuous), physical activity frequency (0–2 times/week and ≥3 times/week), and cotinine level (continuous). In the multivariable models, we also mutually adjusted for total testosterone, total estradiol, and SHBG because these hormones compete for binding to SHBG (correlations: in 12–15 year olds, total testosterone and total estradiol = +0.66, total testosterone and SHBG = −0.25, total estradiol and SHBG = −0.51, free testosterone and free estradiol = +0.74; in the 16–19 year olds, total testosterone and total estradiol = +0.65, total testosterone and SHBG = −0.04, total estradiol and SHBG = −0.30, free testosterone and free estradiol = +0.78). In the multivariable models for free hormones, we mutually adjusted free testosterone and free estradiol. All P-values were from two-sided tests.

The protocols for the conduct of NHANES III were approved by the Institutional Review Board of the National Center for Health Statistics, US Centers for Disease Control and Prevention. Informed consent was obtained from all participants. The assay of these stored serum specimens for the measurement of concentrations of sex steroid hormones was approved by the Institutional Review Boards at the Johns Hopkins Bloomberg School of Public Health and the National Center for Health Statistics, US Centers for Disease Control and Prevention.

Results

Mean age varied slightly among the three racial/ethnic groups in the 12–15 year old males, and in the 16–19 year old males; thus, we adjusted the results in Table 1 for the residual variation in age within each group. In the 12–15 year olds, non-Hispanic blacks were the leanest and were more advanced in puberty, and non-Hispanic whites were the least physically active and had the highest cotinine level. In the 16–19 year olds, non-Hispanic blacks were the leanest, were more advanced in puberty, were the most physically active, and had the lowest cotinine levels.

Table 2 shows geometric mean hormone concentrations adjusted for age and Tanner-stage given the residual differences in age and the differences in Tanner stage among the racial/ethnic groups within the younger and within the older adolescent strata. Total and free testosterone and total and free estradiol were lower and SHBG higher in the 12–15 year olds than in the 16–19 year olds.

In 12–15 year olds, none of the hormones was statistically significantly different between any of the racial/ethnic groups, although several patterns were present (Table 2). Total and free testosterone concentrations were lower in non-Hispanic blacks than in non-Hispanic whites; Mexican-Americans had the highest concentrations (total testosterone versus non-Hispanic white P=0.077). Total estradiol concentrations were similar between non-Hispanic blacks and Mexican-Americans, but possibly higher in non-Hispanic whites. For free estradiol, concentrations were highest in non-Hispanic whites, intermediate in Mexican-Americans, and lowest in non-Hispanic blacks. SHBG was lowest in Mexican-Americans but similar between non-Hispanic blacks and non-Hispanic whites.

In the 16–19 year olds, only one difference approached statistical significance: Mexican-Americans had higher total testosterone than did non-Hispanic whites (P=0.053); non-Hispanic blacks had an intermediate concentration (Table 2). The same pattern was present for free testosterone. Total and free estradiol, and SHBG concentrations appeared to be higher in non-Hispanic blacks compared with the other two groups.

Table 3 shows the geometric mean hormone concentrations after adjusting for age and Tanner stage, for factors that influence hormone levels, and mutually adjusting for the other hormones (testosterone, estradiol, and SHBG mutually adjusted; and free testosterone and free estradiol mutually adjusted).

In 12–15 year olds, the hormone patterns by race/ethnicity observed after this multivariable-adjustment were generally similar to, but more pronounced than the patterns after only age and Tanner stage adjustment. The more pronounced patterns for total and free testosterone were, in part, explained by adjustment for percent body fat and waist circumference. Total (P=0.043) and free (P=0.030) testosterone concentrations were lower in non-Hispanic blacks than non-Hispanic whites. Mexican-Americans had the highest total and free testosterone concentrations (Table 3); these differences were statistically significant when compared with non-Hispanic blacks (total: P=0.002; free: P=0.005). Total and free estradiol concentrations were similar between non-Hispanic blacks and Mexican-Americans, but higher in non-Hispanic whites; the difference between Mexican-Americans and non-Hispanic whites in for total estradiol concentration was statistically significant (P=0.033). SHBG was lowest in Mexican-Americans (versus non-Hispanic white: P=0.010; versus non-Hispanic black: P=0.047) and similar between non-Hispanic blacks and non-Hispanic whites.

In the 16–19 year olds, the hormone patterns by race/ethnicity after multivariable adjustment were similar to those after age and Tanner stage adjustment, although the hormone concentrations for Mexican-Americans were more extreme after multivariable adjustment. Total and free testosterone did not statistically significantly differ between non-Hispanic blacks and non-Hispanic whites (Table 3). Mexican-Americans possibly had higher total (P=0.080) and free (P=0.080) testosterone concentration than non-Hispanic whites, but not than non-Hispanic blacks. Total and free estradiol, and SHBG concentrations did not statistically significantly differ among the three groups, with the possible exception of Mexican-Americans having lower free estradiol than non-Hispanic blacks (P=0.060).

Discussion

We hypothesized that racial/ethnic variation at the time of prostate maturation could, in part, explain the variation in US prostate cancer rates [1] among black, white, and Hispanic men, irrespective of variation or lack of variation in hormone levels by race/ethnicity in adulthood. However, as we previously observed in adult men (≥20 years) in NHANES III, in males during early (12–15 years) and later (16–19 years) adolescence, testosterone concentration was not higher in non-Hispanic blacks compared with non-Hispanic whites, and was highest in Mexican-Americans. Unlike what we previously observed in adults, estradiol levels were not highest in non-Hispanic blacks after multivariable adjustment. Mexican-American males had the lowest SHBG concentration in early adolescence, but levels did not differ among the groups in later adolescence, a pattern that differed from adult males. The hormone patterns by race/ethnicity generally were similar when adjusting for age and Tanner stage and after further multivariable adjustment, although the patterns were more pronounced after this further multivariable adjustment.

We identified seven studies (in addition to our own) that have investigated black and white differences in sex steroid hormone levels in adolescent males (Table 4); one did not test for statistical differences by race in males [28]. For testosterone, our findings are consistent with the studies by Hill et al. (adolescents) [14], Srinivasan et al. (adolescents) [15], Richards et al. (children and adolescents) [16], and Morrison et al. (children and adolescents) [22], which did not find statistically significant differences in total or free testosterone in male children and adolescents. The exceptions were the studies by Winters et al. (young adults) [21] and Ross et al. (young adults) [20], who reported statistically significantly higher

testosterone in 18–24 year old black than white males. For estradiol, our results are possibly consistent with those of Winters et al. (young adults) [21], which also did not find statistically significant differences in estradiol levels by race. In contrast, Hill et al. (adolescents) [14], Srinivasan et al. (adolescents) [15], Richards et al. (children and adolescents) [16], and Morrison et al. (children and adolescents) [22] reported higher levels in blacks than whites. For SHBG, our findings differ from those of Winters et al. (young adults) [21]. Differences among the studies are likely, in part, due to the inclusion of differing age ranges and differing extents of adjustment for age, puberty stage, and other factors that influence hormone and SHBG levels.

Variation in sex steroid hormones comparing adolescent Mexican-American males to other racial/ethnic groups has not been investigated other than in NHANES III. After our original publication on racial/ethnic variation in hormone concentrations in men [3], Mazur reanalyzed the data to further assess influential factors [29]. Although we had measured hormone levels in adolescents, we did not include them in our first paper to be able to address in greater detail the influence of puberty status later. Mazur included both adults and adolescents in his paper and reported no association between being black or Mexican-American and testosterone or SHBG concentration in the adolescent males when taking into account age, pubic hair development, BMI and triceps skinfold. Unlike Mazur, in our current paper, we used sampling weights to account for the oversampling of non-Hispanic blacks and Mexican-Americans, among other groups, as indicated by the National Center for Health Statistics [23]. We also adjusted for a different set of factors with possible influence on circulating hormone concentrations. The differences we observed for total and free testosterone (higher), total estradiol (lower), and SHBG (lower) between Mexican-American adolescents and the other two racial/ethnic groups require further investigation in other studies.

Several aspects of our study merit discussion. Although our sample size was small, the adolescent males were sampled from the US population to be nationally representative. We included adolescents who are Mexican-American, the most common group of Hispanics at the time of NHANES III [32]; whether their results would apply to Hispanics of other countries of origin is unknown. Because US racial and ethnic groups are known to enter into puberty at different ages on average [30, 31], and because testosterone rises steeply in puberty in males, we adjusted for both age and Tanner stage. Furthermore, because US racial/ethnic groups tend to vary in their body fat composition and distribution, and body fat influences hormone levels, we adjusted for measures of total and central body fat. However, the approach we used to estimate percent body fat [24] was not available for Mexican-American adolescents; we used the method available for whites with the assumption that the accuracy of the estimate was comparable.

Although it has been hypothesized that high prostate cancer risk among black men can be attributed to higher testosterone levels, our previous findings in men and current findings in adolescent males in NHANES III do not the support this hypothesis. We presented age and Tanner stage-adjusted results and results after further multivariable adjustment. We used both adjustment strategies because they lead to difference inferences. The former results provide a sense of the racial/ethnic patterns in hormones levels at the same point during puberty in the US population. As such, any racial/ethnic variation in these hormone levels, in theory, could explain the racial/ethnic patterns of prostate cancer risk seen in the US population. However, again, we did not find possibly explanatory patterns for testosterone. The latter results provide a sense of whether there are remaining racial/ethnic patterns in hormones levels beyond those due to modifiable factors that are already known to influence hormone levels and that vary by race/ethnicity, such as the extent of body fatness. In the multivariable-adjusted analysis, we also mutually adjusted testosterone, estradiol, and

SHBG (and separately free testosterone and free estradiol) to be able to isolate the associations for these correlated hormones and to report on bioavailable hormones levels. The results from this multivariable-adjusted analysis allow us to consider the following: 1) whether intervening on the modifiable factors would create more similar racial/ethnic patterns in hormone levels, and thus, in theory, reduce the racial/ethnic disparity in prostate cancer incidence and mortality, or 2) whether the patterns may reflect inherent racial/ethnic differences in hormone levels, and thus, the disparity in prostate cancer burden must be addressed through secondary and tertiary prevention strategies. Again, we did not find possibly explanatory patterns in non-Hispanic black versus non-Hispanic white men for testosterone. We noted more pronounced racial/ethnic differences in testosterone levels, which were driven by higher levels in Mexican-Americans, after multivariable adjustment. At this time we cannot determine if these patterns truly reflect inherent racial differences or whether we have not sufficiently taken into account those factors that influence testosterone levels and that differ by race/ethnicity.

We should also note that the adolescents (recruited in the late 1980s/early 1990s) we studied have not yet reached the age range for prostate cancer risk. So, it is unclear whether these adolescents in the future, when they reach mid- and older adulthood, would experience the same racial/ethnic disparities in prostate cancer as the men being diagnosed with the disease now. Further, in this cross-sectional study, we did not study prostate cancer as the outcome, so we cannot determine whether the small racial/ethnic differences we observed in hormone levels at the time of prostate maturation influence prostate cancer risk. Finally, we could not address whether racial/ethnic variation in the cumulative exposure to adult-level hormones (i.e., non-Hispanic black males enter puberty earlier), rather than hormone levels *per se*, might explain the racial/ethnic disparity in prostate cancer rates. A large multiracial/ethnic, long-term prospective study with biospecimens would be required to evaluate whether racial/ethnic variation in hormone levels in adolescence and/or the cumulative exposure to adult hormone levels starting in adolescence explains the racial/ethnic disparity in prostate cancer rates.

In summary, our previous findings in men and current findings in male adolescents do not the support the hypothesis that the higher prostate cancer rate in black men compared to men of other racial/ethnic groups is due to higher testosterone levels at the time of prostate maturation in adolescence or in adulthood. However, our findings do lead to the question of why Mexican-American adolescents and adults have higher testosterone concentrations than non-Hispanic whites and non-Hispanic blacks and whether this difference influences their lower risk of prostate cancer later in life.

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Table 1

Age-adjusted characteristics of 134 adolescent males, NHANES III (Phase I), 1988–1991

	12–15 Year Olds			16–19 Year Olds		
	Non-Hispanic white	**Non-Hispanic black**	**Mexican-American**	**Non-Hispanic white**	**Non-Hispanic black**	**Mexican-American**
No. of participants	14	17	26	19	21	37
Age (yr), mean (95% CI)						
	13.2	13.6	13.8	17.9	17.4	17.5
	(12.5, 13.8)	(12.8, 14.5)	(13.4, 14.2)	(17.1, 18.6)	(17.0, 17.8)	(17.1, 17.9)
Body fat (%), mean (95% CI)						
	21.4	16.7	21.6	24.9	14.1	23.6
	(17.2, 25.6)	(9.2, 24.1)	(17.7, 25.5)	(16.9, 32.8)	(11.5, 16.8)	(21.3, 26.0)
Waist circumference (cm), mean (95% CI)						
	76.7	74.7	75.2	85.1	76.8	81.6
	(70.8, 82.7)	(65.6, 83.8)	(70.0, 80.3)	(78.3, 92.0)	(73.9, 79.7)	(77.6, 85.7)
Weight (lb), mean (95% CI)						
	123.6	123.6	123.3	170.6	156.3	155.5
	(110.2, 137.0)	(107.4, 139.7)	(107.5, 139.0)	(152.2, 189.1)	(146.4, 166.3)	(143.0, 167.9)
Height (in), mean (95% CI)						
	65.0	64.8	63.1	70.0	68.9	68.0
	(63.5, 66.4)	(63.4, 66.2)	(61.8, 64.5)	(69.4, 70.6)	(67.3, 70.5)	(67.3, 68.6)
Cotinine level (ng/mL)[a], mean (95% CI)						
	1.5	0.5	0.2	1.7	0.5	1.8
	(0.8, 2.9)	(0.1, 1.5)	(0.1, 0.4)	(0.4, 8.1)	(0.2, 1.5)	(0.7, 4.7)
Physical activity, times/wk (%)						

	12–15 Year Olds			16–19 Year Olds		
	Non-Hispanic white	Non-Hispanic black	Mexican-American	Non-Hispanic white	Non-Hispanic black	Mexican-American
0–2	10.6	2.6	3.2	10.8	2.4	10.5
≥3	89.4	97.4	96.8	89.2	97.6	89.5
Tanner stage – pubic hair (%)						
Stages 1 and 2	37.1	6.1	35.5	0.0	0.0	0.0
Stages 3 and 4	29.1	64.8	41.1	9.7	4.8	18.2
Stage 5	33.8	29.1	23.4	90.3	95.2	81.8
Tanner stage – genitalia (%)						
Stages 1 and 2	23.9	5.5	13.1	0.0	0.0	0.0
Stages 3 and 4	52.8	54.9	66.4	10.1	0.0	19.6
Stage 5	23.3	39.6	20.5	89.9	100.0	80.4

[a]Geometric mean based on log-transformed cotinine level (an indicator of exposure to tobacco smoke)

Table 2

Age and Tanner stage-adjusted geometric mean (95% confidence interval) serum concentrations[a] of sex steroid hormones and SHBG by race/ethnicity in 134 adolescent males, NHANES III (Phase I), 1988–1991

	12–15 year olds (N = 57)			16–19 year olds (N = 77)		
		Pairwise Comparisons			Pairwise Comparison	
Hormone	**Mean (95% CI)**	**versus Non-Hispanic white**	**versus Non-Hispanic black**	**Mean (95% CI)**	**versus Non-Hispanic white**	**versus Non-Hispanic black**
Testosterone (ng/mL)						
Non-Hispanic white	2.17 (1.57, 3.00)	--	--	4.72 (3.77, 5.91)	--	--
Non-Hispanic black	1.38 (0.79, 2.40)	0.12	--	5.86 (4.85, 7.09)	0.17	--
Mexican-American	2.51 (1.79, 3.51)	0.51	0.077	6.02 (5.24, 6.91)	0.053	0.811
Free Testosterone (ng/mL)						
Non-Hispanic white	0.029 (0.021, 0.040)	--	--	0.110 (0.082, 0.148)	--	--
Non-Hispanic black	0.019 (0.009, 0.039)	0.28	--	0.126 (0.102, 0.157)	0.41	--
Mexican-American	0.041 (0.026, 0.064)	0.24	0.12	0.136 (0.113, 0.164)	0.19	0.59
Estradiol (pg/mL)						
Non-Hispanic white	24.69 (21.58, 28.23)	--	--	35.19 (30.28, 40.91)	--	--
Non-Hispanic black	20.03 (15.35, 26.13)	0.20	--	38.06 (31.66, 45.76)	0.53	--
Mexican-American	21.95 (18.15, 26.53)	0.29	0.57	35.48 (32.98, 38.17)	0.92	0.48
Free Estradiol (pg/mL)						
Non-Hispanic white	0.521 (0.438, 0.619)	--	--	0.953 (0.798, 1.137)	--	--
Non-Hispanic black	0.437 (0.299, 0.639)	0.43	--	0.989 (0.812, 1.204)	0.77	--
Mexican-American	0.509 (0.372, 0.696)	0.89	0.54	0.925 (0.828, 1.033)	0.78	0.55
SHBG (nmol/L)						
Non-Hispanic white	56.10 (46.75, 67.32)	--	--	23.07 (16.92, 31.46)	--	--
Non-Hispanic black	53.01 (37.22, 75.51)	0.77	--	30.09 (25.78, 35.11)	0.17	--
Mexican-American	39.97 (28.41, 56.24)	0.084	0.28	26.82 (24.11, 29.85)	0.33	0.18

[a] Geometric mean adjusted for age (continuous) and Tanner stage (categorical).

Table 3

Multivariable-adjusted geometric mean (95% confidence interval) serum concentrations[a] of sex steroid hormones and SHBG by race/ethnicity in 134 adolescent males, NHANES III (Phase I), 1988–1991

	12–15 year olds (N = 57)			16–19 year olds (N = 77)		
		Pairwise Comparisons			Pairwise Comparison	
Hormone	**Mean (95% CI)**	**versus Non-Hispanic white**	**versus Non-Hispanic black**	**Mean (95% CI)**	**versus Non-Hispanic white**	**versus Non-Hispanic black**
Testosterone (ng/mL)						
Non-Hispanic white	2.14 (1.78, 2.57)	--	--	4.79 (4.01, 5.72)	--	--
Non-Hispanic black	1.32 (0.86, 2.02)	0.043	--	5.54 (4.95, 6.21)	0.23	--
Mexican-American	3.04 (1.96, 4.73)	0.14	0.002	6.07 (5.33, 6.91)	0.080	0.23
Free Testosterone (ng/mL)						
Non-Hispanic white	0.030 (0.024, 0.038)	--	--	0.110 (0.090, 0.133)	--	--
Non-Hispanic black	0.017 (0.011, 0.026)	0.030	--	0.126 (0.111, 0.144)	0.28	--
Mexican-American	0.038 (0.026, 0.055)	0.29	0.005	0.143 (0.122, 0.167)	0.080	0.17
Estradiol (pg/mL)						
Non-Hispanic white	24.81 (23.04, 26.72)	--	--	35.81 (31.80, 40.33)	--	--
Non-Hispanic black	20.52 (16.99, 24.79)	0.11	--	36.61 (32.71, 40.96)	0.83	--
Mexican-American	20.27 (17.27, 23.78)	0.033	0.92	34.00 (31.21, 37.05)	0.57	0.23
Free Estradiol (pg/mL)						
Non-Hispanic white	0.515 (0.466, 0.570)	--	--	0.975 (0.856, 1.111)	--	--
Non-Hispanic black	0.471 (0.367, 0.603)	0.56	--	0.951 (0.852, 1.061)	0.82	--
Mexican-American	0.473 (0.383, 0.585)	0.48	0.97	0.855 (0.780, 0.937)	0.20	0.060
SHBG (nmol/L)						
Non-Hispanic white	56.45 (49.78, 64.00)	--	--	24.10 (21.26, 27.32)	--	--
Non-Hispanic black	53.49 (43.29, 66.10)	0.73	--	25.94 (21.34, 31.54)	0.56	--
Mexican-American	37.77 (29.86, 47.76)	0.010	0.047	26.14 (22.76, 30.02)	0.43	0.94

[a] Geometric mean adjusted for age, Tanner stage, percent body fat, waist circumference, frequency of physical activity, cotinine (as an indicator of tobacco smoke exposure), and mutually for the other hormones **(total testosterone, total estradiol, and SHBG in one model; free testosterone and free estradiol in another model)**.

Table 4

Studies[a] evaluating black and white differences in circulating sex steroid hormones concentrations in children, adolescent males, and young adults

Author, Year (reference)	Study population (N)	Age range (years)	Adjustment factors	Racial difference in sex steroid hormone concentrations			
				Testosterone	Free testosterone	Estradiol	SHBG
Hill et al., 1984 (14)	Urban North American black (N=80) and white (N=100), and rural black South African (N=90) males	11–18	Age	Not statistically significantly different	Not done	11–13 years old: North American whites > South African blacks & North American blacks, P<0.01 >15 years old: South African blacks > North American whites P<0.01 >18 years old: South African blacks > North American whites	Not done
Srinivasan et al., 1986 (15)	The Bogalusa Heart Study Black (N=258) and white (N=251) males	11–17	Age, body fatness (subscapular skinfold thickness)	Not statistically significantly different	Not done	Blacks > whites. P<0.01	Not done
Ross et al., 1986 (20)	University of Southern California and California State University of Los Angeles Black (N=50) and white (N=50) males	18–22	Time of sampling and age, weight, alcohol, smoking, and prescription drugs use	Black > white, P<0.05	Black > white, P<0.05	Black > white, not statistically significantly different	Black > white, not statistically significantly different
Richards et al., 1992 (16)	The Bogalusa Heart Study Black (N=519) and white (N=519) males	6–18	Tanner stage and anthropometricmeasures	Not statistically significantly different	Not done	Blacks > whites, P≤0.05	Not done
Winters et al., 2001 (21)	Graduate and undergraduate students at the University of Pittsburgh black (N=23) and white (N=23) males	18–24		Black > white, P<0.01	Black > white, not statistically significantly different	Blacks > white, not statistically significantly different	Black > white, P=0.015
Morrison et al., 2002 (22)	The Sex Hormone and Lipoproteins in Adolescent Males Study Black (N=251) and white (N=285) males	10–15	Pubertal maturation stage	Not done	Black > white, not statistically significantly different	Black > white, P<0.001	Not done
Lopez et al. (2011)	National Health and Nutrition Examination Survey III (N=134) Non-Hispanic Black, Non-Hispanic White, and Mexican-American males	12–19	Age, Tanner stage, percent body fat, waist circumference, frequency of physical activity, cotinine, and mutually for the other hormones	12–15 years: Non-Hispanic black < non-Hispanic white, P<0.043 16–19 years: Not statistically significantly different	12–15 years: Non-Hispanic black < non-Hispanic white, P<0.03 16–19 years: Not statistically significantly different	12–15 years: Not statistically significantly different 16–19 years: Not statistically significantly different	12–15 years: Not statistically significantly different 16–19 years: Not statistically significantly different

[a]The study by Hui et al. did not test for differences in sex hormone concentrations by race and thus is not summarized in this table (28).