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The Association Between Race, Obesity, and Sperm Quality Among Men Attending a University Physician Practice in Washington, DC

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Abstract

A decades-long decline in sperm counts in Western countries has coincided with an increase in obesity rates, prompting study into their association. Few of these studies have incorporated men of color, the sperm health of whom is relatively unknown. The present exploratory study evaluated the association between body mass index (BMI), race, ethnicity, and sperm parameters among a diverse sample of U.S. men attending a Washington, DC physician practice. Semen samples were collected and processed at a single laboratory and sperm concentration, motility, morphology, and count were evaluated according to World Health Organization (WHO) 5th edition criteria. Multivariate models accounted for covariates related to sperm health. The study population ($n = 128$) was largely obese (45.3%) or overweight (34.4%), and 36.0% were black or Hispanic. Black men had lower adjusted sperm concentration compared to white men (75.0 million/mL to 107.4 million/mL, $p = .01$) and were more likely to have oligozoospermia ($p = .01$), asthenozoospermia ($p = .004$), and low sperm count ($p < .0001$). Hispanic men had higher adjusted sperm concentration compared to non-Hispanic men (124.5 million/mL to 62.1 million/mL, $p = .007$) and were less likely to have teratozoospermia ($p = .001$). Obesity and BMI were associated with lower sperm motility and count in crude models only. Given the study's sample size its findings should be interpreted with caution but align with the limited epidemiological literature to date that has evaluated racial and ethnic differences in semen quality. Heightened clinical research attention is needed to ensure men of color are included in representative numbers in studies of urologic and andrologic health.

Keywords

male infertility, physiological and endocrine disorders, male reproductive health, sexuality, men of color, special populations, obesity, behavioral issues

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A decades-long decline in sperm counts in Western countries (Levine et al., 2017) is causing increased scrutiny into how personal and health behaviors affect semen quality, fertility, and overall reproductive health. The rapid rise in obesity rates is also causing more research attention on how body weight affects male fecundity and pregnancy outcomes (Palmer et al., 2012); however, it remains unclear whether body mass index (BMI) directly influences semen quality or quantity (MacDonald et al., 2010; Sermondade et al., 2013).

Few BMI and semen quality studies have sampled from ethnically diverse populations or reported on racial and ethnic differences in sperm parameters. Two major U.S. studies consisting of 80.6% and 85.0% white men, respectively (Chavarro et al., 2010; Eisenberg et al., 2014), did not report on parameters by race or ethnicity. Non-BMI focused studies in the United States, United Kingdom, and Canada identified lower semen quality in nonwhite and black men in both fertile and subfertile study populations (Glazer et al., 2019; Povey et al., 2012; Punjani et al., 2019; Redmon et al., 2013; Swan et al., 2003), although such differences are rarely interpreted because nonwhite percentages have been too small (Povey et al., 2012; Redmon et al., 2013). Studies with

larger nonwhite populations (>30%) have typically involved multiple study centers, at times resulting in an emphasis on regional rather than racial differences (Swan et al., 2003). A 2017 U.S. study comparing semen quality among Asian and white men from the same infertility clinic in California reported Asian men had lower semen volume but higher sperm concentration compared to white men (Khandwala et al., 2017).

Nationally representative population sperm parameters among men of color in the U.S. remain largely unknown (Glazer et al., 2019). Populations of color may be less likely to seek infertility evaluation (Chandra et al., 2014); clinical studies of the fertility experience of women of color are limited and report contradictory findings (Dayal et al., 2009; Wellons et al., 2012). In establishing reference values for semen quality in its 2010 guidelines, the World Health Organization acknowledged that Northern Europe was overrepresented and Africa and parts of Central and South America were underrepresented (Cooper et al., 2010), potentially excluding important nonwhite populations from the current standards.

Amid mixed existing results on the effect of BMI on semen quality and the limited data on men of color, this exploratory analysis sought to evaluate the association between race, BMI, and standard sperm parameters among a diverse sample of urban men attending a physician clinic in Washington, D.C. Study authors hypothesized that BMI would be inversely associated with sperm parameters and that there would be differences by race and ethnicity.

Methods

Study Population

From 2012 to 2016, researchers in partnership with physicians at a university-based practice in Washington D.C. recruited men ages 18–55 from the in vitro fertilization (IVF), endocrinology, and general internal medicine clinics. The present analysis is part of a larger ongoing male cohort study evaluating the effect of BMI and diabetes on male reproductive health, and as such endocrinology and internal medicine participants were eligible if they had a BMI ≥ 30 or uncontrolled diabetes, as determined by a medically charted hemoglobin A1C value of ≥ 7.0. Eligible IVF men were asked if a portion of their semen sample submitted as part of their couples' fertility evaluation could be used for the study. After providing written consent, participants completed a demographic and lifestyle questionnaire and provided a single semen sample via masturbation at the practice's andrology laboratory. Participants received a $50 gift certificate and the results of their semen analysis if requested. Four hundred thirty-seven men at the practice were recruited and received a packet of information about the study, of whom $n = 135$ enrolled (31%); participation rates were comparable between the IVF (37%) and endocrine/internal medicine clinics (27%). Primary reasons for refusal were lack of interest and/or time. The George Washington University Institutional Review Board approved the study protocols (IRB; #051204).

Semen Analysis

All semen samples were collected and processed at the same andrology laboratory by experienced technicians blinded to the sociodemographic and health characteristics of the participants. Samples were provided by masturbation in the andrology laboratory after a suggested 3 days' abstinence time, recorded on the day of collection. The samples were allowed to liquefy for up to 60 min after which they were analyzed according to World Health Organization (WHO) 5th Edition guidelines (World Health Organization, 2010). Briefly, samples were gently mixed, transferred to a 15 mL falcon tube, and analyzed for physical characteristics. A wet preparation was then made for microscopic evaluation by aliquoting 7–10 μL of semen onto a clean glass slide and covering it with a 20×20 mm coverslip. Sperm concentration was evaluated by counting the number of sperm per 10 square row using a Makler Chamber® under 20× objective magnification; samples with counts >100 million/mL were diluted for more accurate evaluation. Total sperm count (e.g., number of sperm in the ejaculate) was calculated by multiplying the sperm concentration by the semen volume. Sperm motility was assessed by evaluating motile and nonmotile sperm using a

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Makler Chamber® until 100 sperm were counted. For analysis of sperm morphology, a 10 µL aliquot of semen was spread over a slide's surface and then air-dried and stained. An oil immersion microscope lens with a 100× objective was used to classify spermatozoa as normal or abnormal using the rigorous strict criteria for normal morphology described by Kruger et al., 1988.

Statistical Analysis

Outcome Variables. Summary statistics for sperm concentration (millions/mL), percent total motile sperm, percent strict normal morphological forms, and total sperm count (millions/ejaculate) were evaluated (Cooper et al., 2010). Cases of oligozoospermia (sperm concentration <15 million/mL), asthenozoospermia (total sperm motility <40%), teratozoospermia (sperm morphology <4% normal forms), and low sperm count (<39 million/ejaculate) were examined descriptively in accordance with current WHO 5th Edition 5% lower reference limits (Cooper et al., 2010).

Predictor Variables. Medically charted BMI was categorized as normal (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥30 kg/m^2) according to Centers for Disease Control and Prevention guidelines (Body Mass Index: Considerations for Practitioners, 2011). Participants who were missing data on BMI were categorized according to self-report height and weight. Self-identified ethnicity (Hispanic or non-Hispanic) and race (white, black or African-American, or other race) were evaluated. "Other" race consisted of Asian, Hawaiian or Pacific Islander, American Indian or Alaska Native, two or more races, or self-identifying as "other race." Five participants self-identified as both Hispanic and either white, black, or other race.

Covariates. Additional demographic, health, and lifestyle variables were considered as covariates and categorized as follows: age (<40 years, ≥40 years), college graduate (yes or no), smoking status (never, former, and current), ever-induced pregnancy (yes or no), and diabetes diagnosis (yes or no). Alcohol use (none, 1–2 occasions per week, 3 or more occasions per week), underwear preference (briefs/boxer briefs, or boxers), and bicycling frequency (none, occasional, and moderate to frequent) within 3 months of study enrollment were also evaluated. Diabetes was determined if a participant had a medically charted hemoglobin A1C value ≥ 7.0, indicating uncontrolled diabetes, or was on a prescribed diabetes medication at enrollment as determined by medical record. Participants reported on prior testicular injuries, abnormalities, or infections such as epididymitis, orchitis, and varicocele, or exposures to specific industrial or environmental chemicals such as concrete dust, lead, or polychlorinated biphenyls.

Analysis. Chi-square and Fisher exact tests were used to evaluate differences in categorical demographic, health, and lifestyle behavior variables by BMI, race, and ethnicity. Kruskal–Wallis tests were used to evaluate differences in continuous age and abstinence time across BMI, race, and ethnicity groups. Analysis of variance (ANOVA) models assessed differences in least squared mean sperm parameters across groups. All potential covariates were entered individually into ANOVA models. Covariates significant at $p < .20$ in crude models for each parameter were included in the adjusted model for that parameter along with *a priori* variables identified to be important in prior studies: obesity, ethnicity, race, categorical age, and abstinence time. Adjusted analysis of covariance (ANCOVA) models were also examined using continuous values for BMI and age. ANCOVA models aggregated participants from the IVF and endocrine and internal medicine clinics, and the influence of clinic (IVF vs. endocrine and internal medicine) was examined as a random effect using mixed linear modeling. This approach allowed for the remaining variables in the adjusted model to be evaluated independent of the correlated effect of clinic. If clinic did not alter a mixed linear modeling result for a sperm parameter, it was then evaluated as a covariate to examine its influence on the overall ANCOVA result. Of the sperm parameters analyzed, clinic influenced the adjusted result for sperm motility and was included as a covariate in the adjusted model.

Sensitivity analyses that excluded exceptional cases were conducted separately. These included three nonazoospermic participants who had a sperm concentration of less than 1.0 million/mL and two participants with normal sperm concentration who were taking a prescribed testosterone replacement medication at enrollment. Six participants with azoospermia and one with an outlier sperm concentration of 305 million/mL were excluded from the final analysis, which is consistent with other studies (Chavarro et al., 2010; Eisenberg et al., 2014), resulting in 128 participants included in the final analysis.

SAS software version 9.4 (Cary, NC) was used for data analysis. Findings were considered statistically significant at $p < .05$.

Results

Descriptive Results. Table 1 displays the descriptive characteristics of the study population ($n = 128$) and Tables 1 and 2 in the supplemental material compare them by BMI class and race and ethnicity, respectively. Mean age was 40.0 ± 7.1 and 36.0% of participants were black ($n = 33$, 25.8%) or Hispanic ($n = 13$, 10.2%, Table 1). The study

Table 1. Demographic, Lifestyle, and Sperm Characteristics of the Study Population ($n = 128$).

	% (*N*)
Abnormal sperm parameters[a]	
Oligozoospermia (<15 million/mL concentration)	8.6 (11)
Asthenozoospermia (<40% motility)	13.3 (17)
Teratozoospermia (<4% normal morphology)	66.4 (85)
Low sperm count (<39 million)	14.8 (19)
BMI[b]	
Mean ± *SD*	31.4 ± 7.8
Median [IQR]	29.6 [9.3]
Normal weight	17.2 (22)
Overweight	34.4 (44)
Obese	45.3 (58)
Missing	3.1 (4)
Ethnicity	
Non-Hispanic	78.9 (101)
Hispanic	10.2 (13)
Missing	10.9 (14)
Race	
White	51.6 (66)
Black	25.8 (33)
Other race	13.3 (17)
Missing	9.4 (12)
Age	
Mean ± *SD*	40.0 ± 7.1
Median [IQR]	39.2 [10.8]
<40	53.0 (70)
≥40	47.0 (62)
Abstinence time	
Mean ± *SD*	5.0 ± 8.7
Median [IQR]	4.0 [2.0]
Clinic	
IVF	58.6 (75)
Endocrine/internal medicine	41.4 (53)
Smoking	
Never	60.2 (78)
Former	26.6 (34)
Current	10.9 (14)
Missing	2.3 (3)
Frequency of alcohol consumption[c]	
None	24.2 (31)
1 to 2 times/week	46.1 (59)
3 or more times/week	27.3 (25)
Missing	2.3 (3)
Diabetes diagnosis	
No	84.4 (108)
Yes	12.5 (16)
Missing	1.6 (4)
Ever induced a pregnancy	
Yes	53.1 (68)
No	45.3 (58)
Missing	1.6 (2)
College degree	
Yes	72.7 (93)
No	25.8 (33)
Missing	1.6 (2)
Bicycling habits[c]	
Never	54.7 (70)
Occasional	25.8 (33)
Moderate to frequent	14.1 (18)
Missing	5.5 (7)
Most frequent underwear type[c]	
Boxers	28.1 (36)
Briefs or boxer briefs	66.4 (85)
Missing	5.5 (7)

Note. BMI = body mass index; IVF = in vitro fertilization.
[a]Abnormal sperm parameters categorized according to World Health Organization lower reference values for human semen characteristics (5th edition, 2010).
[b]BMI categorized according to Centers for Disease Control and Prevention guidelines for normal weight (18.5–124.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥30 kg/m^2).
[c]Within 3 months of study enrollment.

population was largely overweight ($n = 44$ of 128, 34.4%) and obese ($n = 58$ of 128, 45.3%, Table 1) and higher percentages of these participants were 40 and older, nondrinkers and enrolled from the endocrine and internal medicine clinics compared to normal weight men (Table 1 in the supplemental material). Higher percentages of black men were obese, nondrinkers, had less than a college degree, and were enrolled from the endocrine and internal medicine clinics (Table 2 in the supplemental material).

In the total sample overall, few participants had oligozoospermia (8.6%), asthenozoospermia (13.3%), or low sperm count (14.8%; Table 1). These conditions were more prevalent in black men (oligozoospermia: 21.2%; asthenozoospermia: 30.3%; and low sperm count: 39.4%) compared to white men (4.6%; 9.1%; and 7.6% for the conditions, respectively) and these differences were statistically significant at .01 and lower (Table 2). Obese men had a higher prevalence of asthenozoospermia (20.7%) and low sperm count (25.9%), compared to normal weight (asthenozoospermia: 9.1%; low sperm count: 0%) and overweight men (asthenozoospermia: 4.6%; low sperm count: 9.1%, $p = .04$ and $p = .005$, respectively). By contrast, teratozoospermia was similar among BMI categories (normal: 68.2%; overweight: 65.9%; and obese: 65.5%, $p = .97$) and racial groups (white: 65.2%; black: 75.8%; and other: 70.6%; $p = .54$), composed two-thirds of the study population ($n = 85$ of 128), and was less prevalent among Hispanic ($n = 3$ of 13, 23.1%) than non-Hispanic men ($n = 71$ of 101, 70.3%; $p = .001$; Table 2). Close to 30% of participants were normal for all

Table 2. Categorical Sperm and Reproductive Characteristics by BMI Class, Ethnicity, and Race ($n = 128$).

Significant values bolded		Concentration, % (*N*)		Motility, % (*N*)		Morphology, % (*N*)		Total sperm count, % (*N*)		Ever induced pregnancy, % (*N*)	
	N	Normal	Oligo.[a] (<15 million/mL)	Normal	Astheno.[a] (<40% motile)	Normal	Terato.[a] (<4% normal)	Normal	Low[a] (<39 million)	Yes	No
BMI class[b]											
Normal	22	100.0 (22)	0.0 (0)	89.9 (20)	9.1 (2)	31.8 (7)	68.2 (15)	100.0 (22)	0.0 (0)	54.6 (12)	45.4 (10)
Overweight	44	93.1 (41)	6.8 (3)	95.5 (42)	4.6 (2)	34.1 (15)	65.9 (29)	90.9 (40)	9.1 (4)	43.2 (19)	56.8 (25)
Obese	58	87.9 (51)	12.1 (7)	79.3 (46)	20.7 (12)	34.5 (20)	65.5 (38)	74.1 (43)	25.9 (15)	62.1 (36)	37.9 (22)
		p value[a]	0.25	*p* value[c]	**0.04**	*p* value[d]	0.97	*p* value[c]	**0.005**	*p* value[d]	0.17
Ethnicity											
Non-Hispanic	101	93.0 (94)	6.9 (7)	90.1 (91)	9.9 (10)	29.7 (30)	70.3 (71)	87.1 (88)	12.9 (13)	50.5 (51)	49.5 (50)
Hispanic	13	100.0 (13)	0.0 (0)	100.0 (13)	0.0 (0)	76.9 (10)	23.1 (3)	92.3 (12)	7.7 (1)	53.8 (7)	46.1 (6)
		p value[c]	0.99	*p* value[c]	0.60	*p* value[c]	**0.001**	*p* value[c]	0.99	*p* value[d]	0.82
Race											
White	66	95.4 (63)	4.6 (3)	90.9 (60)	9.1 (6)	34.8 (23)	65.2 (43)	92.4 (61)	7.6 (5)	46.9 (31)	53.0 (35)
Black	33	78.7 (26)	21.2 (7)	69.7 (23)	30.3 (10)	24.2 (8)	75.8 (25)	60.6 (20)	39.4 (13)	72.7 (24)	27.2 (9)
Other	17	100.0 (17)	0.0 (0)	100.0 (17)	0.0 (0)	29.4 (5)	70.6 (12)	100.0 (17)	0.0 (0)	52.9 (9)	47.1 (8)
		p value[a]	**0.01**	*p* value[b]	**0.004**	*p* value[c]	0.54	*p* value[c]	<**0.0001**	*p* value[d]	0.05

Note. BMI = body mass index; Oligo. = oligozoospermia; Astheno. = asthenozoospermia; Terato. = teratozoospermia. $N = 4$ missing values for BMI, $N = 12$ missing values for race, and $N = 14$ missing values for ethnicity.
[a]Abnormal sperm characteristics were categorized according to the World Health Organization's 5th Edition 5% lower reference limits for human semen (2010).
[b]BMI categorized according to Centers for Disease Control and Prevention guidelines for normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥30 kg/m^2). Four participants with missing BMI values were not categorized.
[c]Determined via a Fisher's exact test to account for cells with five participants or fewer.
[d]Determined via a Chi-square test.

Table 3. Crude Least Squared Mean Sperm Parameters by Obesity Status, Ethnicity, and Race ($n = 128$).

Significant values bolded	Concentration (millions/mL)		Motility (percentage)		Normal morphology (percentage)		Total sperm count (millions/ejaculate)	
Predictor	Mean[a]/Est (95% CI)	*p* value	Mean/Est (95% CI)	*p* value	Mean/Est (95% CI)	*p* value	Mean/Est (95% CI)	*p* value
Obesity status/BMI								
Nonobese[b] (Ref)	70.8 (60.3, 81.4)	Ref	62.4 (58.0, 66.9)	Ref	3.0 (2.5, 3.4)	Ref	210.9 (169.5, 252.4)	Ref
Obese	66.1 (54.9, 77.4)	0.55	**53.7 (48.9, 58.4)**	0.009	2.9 (2.5, 3.4)	0.98	178.7 (134.6, 223.0)	0.30
Unit increase in BMI	–0.7 (–1.7, 0.3)	0.18	**–0.5 (–0.9, –0.1)**	0.01	–0.001 (–0.04, 0.04)	0.93	**–4.9 (–8.7, –1.1)**	0.01
Ethnicity								
Non-Hispanic (Ref)	68.2 (60.1, 76.3)	Ref	59.4 (56.1, 62.6)	Ref	2.9 (2.6, 3.2)	Ref	202.5 (168.5, 236.3)	Ref
Hispanic	78.4 (55.8, 101.0)	0.40	67.3 (58.3, 76.3)	0.10	**4.2 (3.4, 5.1)**	0.005	246.4 (151.9, 340.9)	0.39
Race								
White (Ref)	80.4 (60.5, 100.2)	Ref	61.9 (57.6, 66.3)	Ref	3.0 (2.6, 3.4)	Ref	239.5 (201.2, 277.9)	Ref
Black	**44.4 (30.1, 58.3)**	0.002	**46.5 (53.0, 70.1)**	0.01	2.4 (1.8, 3.0)	—	**87.3 (33.1, 141.5)**	<0.0001
Other	78.8 (68.7, 88.9)	0.99	61.5 (40.3, 53.6)	0.99	2.9 (2.1, 3.8)	—	221.2 (145.7, 296.7	0.90
p value (variable)	—	0.002	—	0.0003	—	0.24	—	<0.0001

Note. Est = estimate; CI = confidence interval; BMI = body mass index; Ref = reference.
[a]Least squared mean.
[b]BMI<30 kg/m^2.

parameters evaluated and of the 90 participants who were abnormal for at least one parameter, 71.1% were abnormal for sperm morphology but normal for the remaining parameters (data not reported).

Slightly over half of study participants had ever induced a pregnancy, and this did not vary significantly by BMI, race, or ethnicity (Table 2). Self-reported cases of previous testicular inflammation, injury or abnormality, or exposure to environmental or workplace chemicals did not differ by BMI or race/ethnicity (data not reported).

ANCOVA Results. Crude and adjusted regression results are displayed in Tables 3 and 4, respectively. Obese compared to nonobese weight (53.7% motile vs. 62.4% motile, $p = .009$) as well as unit increases in BMI (−0.5% motility per unit increase, $p = .01$) were inversely associated with sperm motility in crude models; unadjusted unit increases in BMI were also associated with lower total sperm count (−4.9 million per unit increase, $p = .01$). Obesity and BMI were otherwise not associated with sperm parameters. In adjusted models, obese men had nonsignificant higher mean sperm values compared to nonobese men. Sensitivity

Table 4. Adjusted Least Squared Mean Sperm Parameters by Obesity Status, Ethnicity, and Race (n = 128).

Significant values bolded	**Concentration (millions/mL)[a] n = 100**		**Motility (percentage)[b] n = 95**		**Morphology (percentage)[c] n = 99**		**Total sperm count (millions)[d] n = 96**	
Predictor	Mean[e]/Est (95% CI)	p value	Mean/Est (95% CI)	p value	Mean/Est (95% CI)	p value	Mean/Est (95% CI)	p value
Obesity status								
Nonobese[f] (Ref)	88.1 (63.3, 112.8)	Ref	58.7 (47.5, 69.8)	Ref	3.5 (2.6, 4.4)	Ref	256.1 (158.1, 354.2)	Ref
Obese	98.6 (69.7, 127.2)	0.25	65.2 (52.6, 77.8)	0.20	4.1 (3.0, 5.1)	0.12	299.6 (191.4, 407.8)	0.22
Ethnicity								
Non-Hispanic (Ref)	62.1 (49.5, 74.7)	Ref	59.4 (53.3, 65.5)	Ref	2.8 (2.5, 3.2)	Ref	209.8 (161.9, 257.6)	
Hispanic	**124.5 (78.3, 170.8)**	0.007	64.5 (45.6, 83.3)	0.57	4.7 (2.9, 6.5)	0.04	346.0 (169.2, 522.8)	0.11
Race								
White (Ref)	107.4 (80.6, 134.3)	Ref	64.9 (53.6, 76.2)	Ref	4.2 (3.2, 5.1)	Ref	321.5 (219.2, 423.8)	Ref
Black	**75.0 (46.3, 103.6)**	0.01	58.3 (45.5, 71.2)	—	3.3 (2.2, 4.4)	—	219.8 (106.8, 332.8)	—
Other	97.6 (66.9, 128.3)	0.67	62.6 (49.9, 75.2)	—	3.9 (2.7, 5.0)	—	292.3 (173.3, 411.3)	—
p value (variable)	—	0.03	—	0.42	—	0.09	—	0.07

Note. Est = estimate; CI = confidence interval; Ref = reference.
The clinic variable was evaluated first as a random effect and then as a covariate in all adjusted parameter models and only affected the result for the sperm motility model. As a result, clinic was included in the adjusted sperm motility model but omitted from the adjusted sperm concentration, sperm morphology, and total sperm count models.
[a]Adjusted for obesity status (categorical), age (categorical), race, ethnicity, abstinence time, and smoking; R^2 = 0.18; $F(8)$ = 2.57; p = .01. N listed represents the observations read (of a total N of 128) in the adjusted model.
[b]Adjusted for obesity status, age, race, ethnicity, abstinence time, alcohol use, diabetes diagnosis, ever induced pregnancy, college degree, briefs, and clinic; R^2 = 0.24, $F(13)$ = 1.98, p = .03. N listed represents the observations read (of a total of 128) in the adjusted model.
[c]Adjusted for age, obesity status, race, ethnicity, and abstinence time. R^2 = .10, $F(6)$ = 1.85, p = .10. N listed represents the observations read (of a total of 128) in the adjusted model.
[d]Adjusted for age, obesity status, race, ethnicity, abstinence time, alcohol use, college degree, and bicycling frequency. R^2 = 0.29; $F(11)$=3.09, p = .002. N listed represents the observations read (of a total of 128) in the adjusted model.
[e]Least squared mean.
[f]Defined as $<$30 kg/m^2.

analyses showed similar crude and adjusted results comparing participants with severe obesity (BMI $\geq$ 40, n = 18) to nonobese participants (n = 66) (data not reported).

Compared to white men, black men had lower sperm concentration (44.4 million/mL to 80.4 million/mL, p = .002), motility (46.5% to 61.9%, p = .01, Table 3), and count (87.3 million to 239.5 million, $p < .0001$) in crude models and lower sperm concentration in adjusted models (75.0 million/mL to 107.4 million/mL, p = .01, Table 4). Hispanic men had higher adjusted sperm concentration (124.5 million/mL to 62.1 million/mL, p = .007, Table 4) and crude sperm morphology (4.2% to 2.9% normal forms, p = .005) to non-Hispanic men. Adjusted findings for sperm concentration and race/ethnicity held when BMI and age were evaluated as continuous as opposed to categorical covariates (Table 3 in the supplemental material). White and other-race men, which included Asians and multiracial participants, had similar sperm parameters.

Removing three nonazoospermic participants who had a sperm concentration $<$ 1.0 million/mL and two participants on a testosterone medication in separate sensitivity analyses showed similar results for BMI/obesity and race/ethnicity.

Discussion

This exploratory investigation found suggestive differences in sperm parameters by ethnicity and race, in line with the limited Western and U.S. epidemiological literature that has evaluated men of color. In the present study, black men had lower sperm concentration to white men by over 30 million/mL after controlling for obesity/BMI, ethnicity, age, abstinence time, and smoking status. Black men were also more likely than white or other race men to have oligozoospermia, asthenozoospermia, and low sperm count. Hispanic men had higher adjusted sperm concentration to non-Hispanic men and were significantly less likely to have teratozoospermia. Black (25.8%) and Hispanic men (10.2%) comprised 36% of the study population. To our knowledge, one other U.S. study included similar proportions of nonwhite men attending a single study center in comparing the semen quality of Asian men (n = 701, 36%) to white men (n = 1230, 64%) at an infertility clinic. In that study, Asian men had higher sperm concentration but lower semen volume than white men (Khandwala et al., 2017).

The few studies that included similar proportions of nonwhite participants to the present study have largely sampled from multiple study sites but also identified lower sperm parameters in black and nonwhite men. A large, multicenter study of U.S. men (n = 7,132; 44.9% nonwhite) identified via an insurance provider reported lower unadjusted sperm concentration as well as higher percentages of oligozoospermia and low sperm count in black men, who constituted 9% of the study population (Glazer et al., 2019). In a convenience sample of U.S. veterans (n = 714, 49% nonwhite) who used Veteran

Affairs' fertility clinics from 2001 to 2010, black and Hispanic men (16% and 23% of the study population, respectively) had lower age-adjusted sperm concentrations and counts than white men (Lindaman et al., 2017). In a study of fertile men sampled from four U.S. states ($n = 493$), Swan and colleagues reported lower adjusted semen volume in nonwhite men (31.4% of the study population) compared to white men; however, the study focused on regional differences as opposed to racial or ethnic group differences (Swan et al., 2003). In one of the few semen quality studies featuring a racially diverse cross-section of men attending a single center ($n = 3{,}956$, 43.7% nonwhite), African Canadians, who constituted 7% of the sample, had higher odds of azoospermia, oligospermia, and low semen volume compared to white Canadians (Punjani et al., 2019). Sperm health studies in the United States and United Kingdom comprised of smaller proportions of nonwhite participants than the present study have reported similar findings among black men (Povey et al., 2012; Redmon et al., 2013). The small percentages of black men in many of these studies impeded a comprehensive interpretation for the racial differences, which was the same challenge in the present study for interpreting higher morphology and adjusted sperm concentration among Hispanic men.

The factors underlying findings of lower semen quality in black and nonwhite men are likely multifactorial. A few studies have suggested genetic, sociodemographic, dietary, or cultural factors (Glazer et al., 2019; Punjani et al., 2019). Racial groups if of lower income may not seek fertility evaluation or expensive assisted reproduction technologies and thus might present with worse sperm health when enrolling in semen quality studies (Glazer et al., 2019). Because of the general lack of data on the sperm health of men of color, the etiology for the differences remains unknown. In the present study, higher percentages of black participants were older and obese or diabetic. Although these variables were evaluated and controlled for in adjusted models, they may have encompassed underlying endocrinal and metabolic conditions known to affect sperm health (Eisenberg et al., 2015). The interaction of metabolic conditions related to obesity and diabetes can lead to increased oxidative stress, resulting in the production of reactive oxygen species to which sperm is highly vulnerable (Du Plessis et al., 2010). Of the aforementioned studies reporting racial differences in sperm parameters (Glazer et al., 2019; Lindaman et al., 2017; Povey et al., 2012; Punjani et al., 2019; Redmon et al., 2013; Swan et al., 2003), no study evaluated diabetes status and only three (Povey et al., 2012; Redmon et al., 2013; Swan et al., 2003) evaluated BMI; these three studies had low percentages of black participants (7%, 2%, and data not reported, respectively) and study authors chose to omit BMI in multivariate analyses. Future studies that evaluate the association between BMI and semen quality should sample from racially and ethnically diverse populations and also evaluate the influence of related metabolic comorbidities.

Obesity and BMI were inversely associated with sperm motility and count in crude but not adjusted models and were null for the remaining parameters. While several global studies have found inverse associations between BMI and multiple parameters (Andersen et al., 2015; Belloc et al., 2014), the findings of the present study add to the growing, albeit conflicting literature on the relationship between BMI and sperm parameters in North America and the United States (Bieniek et al., 2016; Chavarro et al., 2010; Eisenberg et al., 2014; Relwani et al., 2011). Similar to the present study, a few U.S. studies found comparable if not slightly higher adjusted values for some parameters in men with higher BMI when sperm parameters were evaluated as continuous outcomes (Chavarro et al., 2010; Eisenberg et al., 2014). The mixed results of global and U.S. studies on the association of BMI and sperm parameters may be the result of inherent differences in study populations, including whether men are sampled from fertility clinics or the general population, or the varying statistical approaches used to address confounding or account for metabolic conditions related to body mass or adiposity.

The prevalence of teratozoospermia was higher in the present study (67%), in contrast to other BMI and sperm parameter studies where the prevalence of teratozoospermia was 3.9% in a population-based sample (Eisenberg et al., 2014) and 21.6% in a fertility clinic-based sample (Chavarro et al., 2010). Of the participants in the present study with at least one abnormal parameter ($n = 90$), a majority ($n = 64$) were abnormal for sperm morphology only. Laboratory analysis of sperm morphology is the most subjective and widely debated of the basic parameters due to the WHO's strict criteria for normal and lower limit reference value of 4% (Menkveld et al., 2011; Pacey, 2010). It is possible that the physician practice's andrology laboratory scored abnormal spermatozoa more strictly than laboratories of other studies; however, any outcome misclassification would be nondifferential and would not systematically bias the ability to detect differences by BMI, race, or ethnicity.

Studying a single university outpatient physician practice in the present study allowed for the detailed collection of a larger number of health and lifestyle covariates than most prior studies on sperm quality including diverse populations however residual confounding remains a possibility. Socioeconomic status (SES) was not assessed and the closest approximation was college degree, which was reported by most participants and met the threshold for inclusion in the adjusted model for sperm motility.

The relationships between SES, race/ethnicity, and male reproductive health are multifactorial and complex and were not fully captured in the present study.

This cross-sectional study is limited by a small sample size and its findings should be interpreted with caution. Data were not available on reproductive hormones and additional measures of sperm quality such as DNA fragmentation or vitality. The sampled population was older (mean age 40) than other BMI and semen quality studies (Bieniek et al., 2016; Chavarro et al., 2010; Eisenberg et al., 2014), and most participants were overweight (34.4%) or obese (45.3%). To address these limitations, BMI and age were evaluated as continuous variables and results were similar. That most of the study population was overweight or obese (a combined 79.7%) limits the study's generalizability; however, as others have noted (Eisenberg et al., 2014) nearly three in four U.S. men (74.4%) are overweight or obese (Fryar et al., 2018) and thus further U.S. studies are needed on the impact of higher BMI, adiposity, and related comorbidities on sperm health. Due to this study's exploratory nature, several clinics at the physician practice were used to enroll participants, resulting in a study sample that is somewhat selective. While notable exceptions exist (e.g., Eisenberg et al., 2014; Redmon et al., 2013; Swan et al., 2003), a number of sperm health studies are selective to some degree in that they tend to enroll participants attending fertility clinics rather than from the general population. In the present study, statistical methods were used to account for the influence of clinic (IVF, endocrine and internal medicine) in multivariate models.

A strength of this study was its inclusion of larger percentages of nonwhite participants evaluated from a single study center, inherently controlling for geographic and multicenter confounding, as well as the inclusion of several relevant health lifestyle covariates in adjusted models to allow for initial inferences of the racial differences in sperm parameters. Black men constituted one-fourth of the study population, a higher percentage than most existing sperm parameter studies to date. Although studies are emerging, racial and ethnic sperm health continues to be understudied and relationships between sperm quality, obesity, and its related comorbidities remain confined by mostly a study of homogenous populations.

Conclusion

The present study found suggestive differences in sperm parameters by ethnicity and race and these findings are consistent with other studies and may be related to conditions comorbid to obesity. Findings should be interpreted with caution due to the study's sample size. BMI results were mostly null but should be studied further given the rise of obesity in U.S. adults. Further study is also needed on the impact of other comorbid metabolic conditions on sperm health. Amid the current heightened awareness of declining sperm counts, continued effort should be made to design fertility studies that recruit and incorporate men of color.

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Supplemental Material

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