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Metabolic Factors Associated with Benign Prostatic Hyperplasia

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Abstract

Context—Benign prostatic hyperplasia poses a significant public health problem, but its etiology remains unclear. Obesity and associated abnormalities in glucose homeostasis may play a role in benign prostatic hyperplasia development by influencing prostate growth.

Objective—The objective of this study was to determine whether obesity, fasting plasma glucose concentration, and diabetes are associated with radiologically determined prostate enlargement, an objective measure of benign prostatic hyperplasia.

Design—This study was a cross-sectional analysis with robust variance estimates to account for multiple measures over time in the same individuals.

Setting—This prospective cohort study was composed of community volunteers.

Patients—Patients studied were 422 adult men enrolled in The Baltimore Longitudinal Study of Aging.

Main Outcome Measurements—Total prostate volume as determined by pelvic magnetic resonance imaging was measured.

Results—Among 422 participants, 91 (21.6%) had prostate enlargement (defined as total prostate volume ≥ 40 cc) at first visit. Compared with men of normal weight [body mass index (BMI) < 25 kg/m^2], the age-adjusted odds ratio (OR) for prostate enlargement for overweight men (BMI, 25–29.9 kg/m^2) was 1.41 (95% CI, 0.84–2.37), for obese men (BMI, 30–34 kg/m^2) was 1.27 (95% CI, 0.68–2.39), and for severely obese men (BMI ≥ 35 kg/m^2) was 3.52 (95% CI, 1.45–8.56) ($P = 0.01$). Men with elevated fasting glucose (> 110 mg/dl) were more likely to have an enlarged prostate than men with normal fasting glucose (≤110 mg/dl) (OR, 2.98; 95% CI, 1.70–5.23), as were men with a diagnosis of diabetes (OR, 2.25; 95% CI, 1.23–4.11).

Conclusions—Obesity, elevated fasting plasma glucose, and diabetes are risk factors for benign prostatic hyperplasia.

Benign prostatic hyperplasia is a highly prevalent disease of older men caused by nonmalignant, unregulated growth of the prostate gland. In severe cases, benign prostatic hyperplasia may cause sepsis, irreversible bladder damage, renal failure, or death (1). The prevalence among U.S. men aged 60 yr or older is 40% and among men aged 80 yr or older is

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90% (1). Globally, the prevalence among men aged 60 yr or older exceeds 50% (2,3). In 2000, the most recent year for which comprehensive data are available, benign prostatic hyperplasia generated 1.1 billion dollars in health care expenditures and accounted for over 4.4 million office visits, 117,000 emergency room visits, and 105,000 hospitalizations in the United States (4).

The etiology of benign prostatic hyperplasia is not well understood. Androgens, essential for normal prostate growth and development, play a prominent role (5,6). However, there is also evidence that metabolic disturbances may promote prostate hyperplasia and benign prostatic hyperplasia pathogenesis. IGFs are potent inducers of prostate growth *in vitro* (7,8), and higher serum concentrations of insulin and IGF-I are associated with clinical benign prostatic hyperplasia (9,10).

The metabolic syndrome is a clinical constellation of metabolic abnormalities associated with an increased risk of cardiovascular disease. Two principal components of the metabolic syndrome are obesity and abnormal glucose homeostasis (11). Although some prior observational studies have detected associations of obesity (9,12,13) and abnormal glucose homeostasis (9,14) with benign prostatic hyperplasia, others have not (15–17). All of these prior studies used surgery for prostate enlargement and/or lower urinary tract symptoms as surrogate measures of clinical benign prostatic hyperplasia. The specificity of these surrogates is uncertain, which may in part explain the inconsistency of prior findings.

Prostate volume, in contrast, is an objective, quantitative measure of benign prostatic hyperplasia and a strong predictor of adverse clinical outcomes (18,19). Some studies have observed positive associations of obesity (20–25) and serum insulin concentration (21,26) with prostate volume.

Obesity and abnormal glucose homeostasis, like benign prostatic hyperplasia, are highly prevalent among older men (27,28). Further analysis of obesity, abnormal glucose homeostasis, and prostate volume may yield substantive clues to benign prostatic hyperplasia etiology and suggest novel interventions for prevention and treatment. Therefore, we examined the associations of obesity, fasting plasma glucose concentration, and diabetes with serial measures of prostate volume in an ongoing prospective of study of aging.

Patients and Methods

Study participants

The Baltimore Longitudinal Study of Aging (BLSA) is an ongoing, open cohort study of the physiology of aging directed by the U.S. National Institute on Aging and approved by the combined Institutional Review Board of the Johns Hopkins Medical Institutions and the Gerontology Research Center of the National Institute on Aging. Participants generally represent higher socioeconomic strata and return at approximately 2-yr intervals for comprehensive physiological, psychological, and biochemical testing (29).

Between January 1, 1993 and July 1, 2002, male participants in the BLSA underwent serial prostate examinations and anthropometric measures. At every visit, each man underwent pelvic magnetic resonance imaging (MRI) analysis of prostate volume. In addition, the following anthropometric and urological evaluations were performed: height, weight, waist circumference, and hip circumference measurement; digital rectal examination by a urologist; serum prostate-specific antigen (PSA) testing; and lower urinary tract symptom assessment with a validated questionnaire. In accordance with established clinical guidelines, men with a serum PSA concentration more than or equal to 4.0 ng/ml and/or an abnormal digital rectal examination underwent prostate biopsy for the detection of prostate cancer.

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A total of 540 men had 1100 separate prostate MRI volume measurements during the study period. We excluded those men with a history of prostate cancer before the study or those diagnosed with prostate cancer during the study (n = 42); those with incomplete PSA data because lack of PSA screening potentially may have altered the opportunity for prostate cancer detection in these men (n = 6); those with incomplete anthropometric data (n = 30); those taking finasteride, a medication that decreases prostate volume (n = 20); and those who had undergone surgery for prostate enlargement before the study (n = 20). Men who underwent surgery for prostate enlargement during the study were censored at date of surgery. This left 422 men with 791 serial prostate volume measurements. Of these, 219 (52%) had two or more serial volume measurements (median, two measurements per participant; range, one to five measurements per participant). The mean time interval between repeated measurements was 2.7 yr (median, 2.1 yr; range, 1.7–7.7 yr).

Corresponding anthropometric data and diabetes status were available for all 791 prostate volume measurements. As part of a separate study, fasting plasma glucose levels were measured in BLSA men between January 1993 and June 2002 (30). Because obese and diabetic men are known to have lower serum testosterone concentrations, and testosterone influences prostate growth, we also investigated whether the association of obesity, fasting glucose, and diabetes was influenced by testosterone. Serum testosterone and SHBG were measured in BLSA participants who had study visits between February 1993 and June 1998 and had adequate sera for analysis (31). For the present study, we linked the anthropometric, glucose, and hormone data sets. Of the 422 participants with 791 prostate volume measurements, glucose levels were available in 314 (548 measurements), and hormone levels were available in 225 (259 measurements).

Prostate imaging and volume determination

MRI was performed with a General Electric 1.5 Signa scanner with a phased array pelvic coil (General Electric Medical Systems, Milwaukee, WI) using the same protocol for each participant. Three scans were taken (T1, axial; T2, axial; and T2, sagittal), with the participant in the supine position. The T2 axial image was used to determine prostate volume because this view provides the most accurate volume assessment (32). Total prostate volumes were calculated using a semiautomated software image analysis system (32).

Outcome assessment

The primary outcome measure was MRI-determined total prostate volume. Total prostate volume was assessed as both a continuous outcome and a binary outcome: enlarged (≥40 cc) *vs.* nonenlarged (<40 cc). This 40-cc volume cutoff represents the threshold above which men who are not treated with medication or surgery will experience progressive deterioration of symptoms and significantly decreased urinary flow rates within 4 yr of follow-up (33). It also corresponded to the 75th percentile of all volume measures in this study population, which is another standard used for defining prostate enlargement and benign prostatic hyperplasia (34).

The secondary outcome measure was the severity of lower urinary tract symptoms as determined by the American Urological Association Symptom index, a validated questionnaire that scores the severity of urinary symptoms on a graded scale ranging from 0 (none) to 30 (severe) (35). Urinary symptom scores were available for 367 participants at 651 separate follow-up visits. The urinary symptom score was assessed as a continuous outcome using all observations and as a binary outcome using selected observations: no to mild symptoms (score < 7; n = 290 participants, 459 visits) and high-moderate to severe symptoms (≥15; n = 44 participants, 57 visits). Men with low-moderate symptoms (8–14; n = 102, 135 visits) were

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excluded to increase the specificity of the score in assessing benign prostatic hyperplasia for epidemiological studies (36).

Exposure assessment

Using weight and height measures at each participant visit, body mass index (BMI) was calculated (body weight in kilograms divided by the square of height in meters) and categorized based on national guidelines (37) as follows: less than 25 kg/m^2 (normal), 25–29.9 kg/m^2 (overweight), 30–34.9 kg/m^2 (obese), and more than or equal to 35 kg/m^2 (very obese).

Waist circumference was categorized as less than or equal to 102 cm (nonobese) and more than 102 cm (obese) (11). Waist-to-hip ratio was calculated from waist and hip circumference measures and was categorized as less than or equal to 0.90 (nonobese) and more than 0.90 (obese) (11).

Fasting plasma glucose concentration was determined as described previously (30). Fasting plasma glucose concentration was categorized in quartiles, and clinically elevated glucose was categorized as more than 110 ng/ml (elevated) and less than or equal to 110 ng/ml (normal) (11,38). Diabetes mellitus was defined in accordance with American Diabetes Association criteria as described previously (30). Diagnoses were made by fasting glucose levels and/or history of treatment with insulin or oral hypoglycemic agents. Most participants with diabetes were noninsulin-dependent.

Serum testosterone and SHBG concentrations were determined as described previously (31). Free testosterone index, which correlates highly with serum free testosterone (39,40) and is an indicator of the amount of serum testosterone able to diffuse into the prostate, was calculated as the molar ratio of testosterone to SHBG.

All samples for glucose and hormone concentrations were obtained between 0700 and 0930 h after an overnight fast.

Statistical analysis

All statistical analyses were performed using Stata version 8.0 (Stata Corporation, College Station, TX). Generalized estimating equations regression modeling (linear for prostate volume and lower urinary tract symptom score and logistic for prostate enlargement and high-moderate to severe lower urinary tract symptoms) was performed with robust variance estimates to account for multiple measures over time in the same individuals (41,42). Data were assumed to be clustered by participant. All models included adjustment for age. Associations of BMI (national guideline cutoff points), fasting glucose (quartile and clinically elevated cutoff points), and diabetes with prostate enlargement and high moderate to severe lower urinary tract symptoms were determined by entering these exposures into the model as a series of indicator variables. Associations of obese waist circumference and obese waist-to-hip ratio with prostate enlargement and high moderate to severe lower urinary tract symptoms were also estimated. Tests for trends in the association of prostate enlargement and high moderate to severe lower urinary tract symptoms across levels of BMI, waist circumference, waist-to-hip ratio, and fasting glucose were performed by entering these measures into the model as a continuous term, the coefficient for which was evaluated by the Wald test.

To assess whether overall obesity or central obesity was the greater contributor risk, we mutually adjusted BMI and waist circumference in a subanalysis. To assess whether fasting glucose, diabetes, or testosterone mediated or otherwise accounted for the effect of obesity, in sub-analyses, we mutually adjusted the measures of obesity, fasting glucose, and diabetes and separately adjusted for serum testosterone concentration or the free testosterone index.

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The sample sizes for this study were based on the availability of existing data. The smallest sample size for the primary exposures was for fasting glucose concentration. In the power calculations, we used the first measurement of MRI volume for each man (56 enlarged prostate, 259 nonenlarged prostate) and the observed prevalence of elevated fasting glucose in the men without an enlarged prostate (12.4%). We estimated the minimum odds ratio (OR) that would be detected as statistically significant with 80% power for a two-sided test with $\alpha = 0.05$ was 2.75. Thus, this study was powered to detect important associations but not modest associations.

Results

Participants

Of the 422 participants with prostate volume measurements, 291 (69%) were white, 95 (23%) were black, and 36 (8%) were of other ethnicities. The mean participant age for all visits was 58 yr (range, 27–84 yr), and the mean prostate volume was 33.0 cc (median, 29.3 cc; range, 8.7–237.3 cc). Participants with enlarged prostates were older (mean age, 64.8 yr; SD 9.8) than those with nonenlarged prostates (mean age, 54.7 yr; SD 12.2) ($P < 0.001$).

Compared with men with nonenlarged prostates, those with enlarged prostates had significantly higher age-adjusted weight and BMI (Table 1). The mean age-adjusted lower urinary tract symptom score among participants with a nonenlarged prostate (n = 513 observations) was 5.7 (SD 5.1) and among those with an enlarged prostate (n = 138 observations) was 8.0 (SD 5.8) ($P < 0.001$). Forty-five participants (n = 79 observations) were diagnosed with diabetes before or at the time of at least one visit during the study period.

Prostate volume

BMI was positively associated with prostate volume: for each 1 kg/m^2 increase in BMI, prostate volume increased by 0.41 cc (95% CI, −0.15 to 0.84; $P = 0.06$). Compared with men with normal range BMI, overweight and obese men had an increased odds of prostate enlargement ($P = 0.01$); the risk for very obese men was particularly high (Table 2). When restricting the analysis to men in the usual age range for diagnosis of benign prostatic hyperplasia (≥ 40 yr, n = 366), the associations of BMI with prostate volume ($P = 0.05$) and prostate enlargement ($P = 0.01$) were comparable with the overall cohort.

Waist circumference was not associated with prostate volume ($P = 0.28$). An obese waist circumference was nonstatistically significantly associated with prostate enlargement (Table 2). However, men at or above the 50th percentile of waist circumference (96.5 cm) had increased odds of prostate enlargement compared with men below the 50th percentile (OR, 1.58; 95% CI, 1.06–2.36). This association was attenuated after further adjustment for BMI (OR, 1.19; 95% CI, 0.72–1.97). There were no significant associations of waist-to-hip ratio with prostate volume ($P = 0.72$) or prostate enlargement (Table 2).

Fasting plasma glucose was not associated with prostate volume ($P = 0.31$). However, higher fasting plasma glucose concentration was positively associated with prostate enlargement (Table 3). The risk of prostate enlargement was confined to men in the highest quartile of fasting glucose level and was particularly pronounced among men with clinically elevated levels compared with men with normal levels (Table 3). Adjustment for BMI produced similar risk estimates for clinically elevated compared with normal fasting glucose levels (OR, 2.82; 95% CI, 1.56–5.08). Exclusion of men with diabetes at the time of prostate volume measurement (n = 49 observations) attenuated the associations between fasting glucose and prostate enlargement (Table 4).

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Diabetes was positively associated with prostate volume ($P = 0.05$) and prostate enlargement (OR, 2.25; 95% CI, 1.23–4.11). Further adjustment for BMI resulted in slight attenuation of the association with prostate enlargement (OR, 1.90; 95% CI, 1.02–3.53).

Lower urinary tract symptoms

No significant associations were present for BMI ($P = 0.50$), waist circumference ($P = 0.96$), or waist-to-hip ratio ($P = 0.65$) with lower urinary tract symptom score. Although not statistically significant, the OR for high moderate to severe lower urinary tract symptoms was above 1 for obese BMI, waist circumference, and waist-to-hip ratio (Table 5). Both elevated fasting glucose (OR, 2.60; 95% CI, 1.01–6.70) and diabetes (OR, 2.80; 95% CI, 1.10–7.10) were associated with high-moderate to severe lower urinary tract symptoms, which persisted after adjustment for BMI ($P = 0.06$ and 0.07, respectively).

Adjustment for testosterone or free testosterone index

Adjustment for testosterone or free testosterone index did not attenuate the associations of BMI ($P = 0.04$ and 0.001, respectively) or elevated fasting glucose ($P = 0.003$ and $P < 0.001$, respectively) with prostate enlargement. For the association of diabetes with prostate enlargement, further adjustment for serum total testosterone ($P < 0.002$) or free testosterone index ($P < 0.001$) strengthened the results.

Discussion

In this cohort of community-dwelling U.S. men, obesity, elevated fasting glucose, and diabetes were associated with prostate enlargement, an objective indicator of benign prostatic hyperplasia. Compared with their peers with normal range values, very obese men were 3.5-fold more likely, men with elevated glucose 3-fold more likely, and diabetic men 2-fold more likely to have an enlarged prostate. Overall obesity, rather than central obesity, appeared to be the more important predictor. The association for elevated fasting glucose in men without diabetes was attenuated, suggesting that larger perturbations in glucose homeostasis were more strongly associated with prostate enlargement. These results indicate that obesity, elevated fasting glucose, and diabetes are risk factors for benign prostatic hyperplasia and are consistent with previous observations of obesity, serum insulin, and prostate volume (20,22–26).

Overall obesity, fasting glucose, and diabetes were also positively associated with lower urinary tract symptoms. Unlike the findings for prostate enlargement, these results did not attain statistical significance, in part because of the smaller sample size available for assessment of lower urinary tract symptoms. Lower urinary tract symptoms are often a clinical manifestation of benign prostatic hyperplasia, and the findings of the present study were similar to those observed in two prior observational studies. Obese men aged 40–75 yr enrolled in the U.S. Health Professionals Follow-up Study had increased frequency and severity of obstructive urinary symptoms (12), as did those aged 60 yr or older in the Third National Health and Nutrition Examination Survey (13). However, neither of these two studies analyzed the association of obesity with prostate volume. Lower urinary tract symptoms alone represent a nonspecific surrogate for benign prostatic hyperplasia, and symptom severity does not correlate with prostate volume (43). Volume-determined prostate enlargement, however, is a specific measure of benign prostatic hyperplasia that strongly predicts adverse clinical outcomes, including acute urinary retention, renal failure, and need for noncancer prostate surgery (18, 19,44,45).

Previous etiological models of benign prostatic hyperplasia have focused primarily on the role of sex steroid hormones (5,6). Both androgens and estrogens may stimulate prostate growth. Adipose tissue, which accumulates with age, aromatizes circulating testosterone into estrogen

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(46), and it has been hypothesized that alterations in the balance between testosterone and estrogen levels in prostate tissue with age may contribute to benign prostatic hyperplasia (47). In our study, the associations of obesity, elevated fasting glucose, and diabetes with prostate enlargement remained significant after adjusting for serum total or calculated free testosterone. These findings suggest that obesity and abnormal glucose homeostasis potentially influence prostate growth through mechanisms other than testosterone.

An alternative mechanism for benign prostatic hyperplasia may be related to metabolic disturbances. Obesity and elevated fasting glucose are components of the metabolic syndrome (11); both obesity and the metabolic syndrome are associated with systemic inflammation and oxidative stress (48). Inflammation has been implicated as a primary stimulus for prostate carcinogenesis (49), and it is possible that benign prostatic hyperplasia represents an alternate, nonmalignant pathway of unregulated prostate growth promoted by oxidative stress, inflammatory mediators, and IGFs (36,50,51). Indeed, analyses of surgical specimens have shown that benign prostatic hyperplasia is usually associated with inflammation (52–54) and that the extent and severity of the inflammation corresponds to the amount of prostate enlargement (55).

The finding in our study that obesity and abnormal glucose homeostasis are associated with benign prostatic hyperplasia is consistent with global geographic differences in the distribution and severity of benign prostatic hyperplasia. Southeast Asian men have a lower prevalence and severity of autopsy-diagnosed benign prostatic hyperplasia than age-matched North American men (56). Likewise, although Chinese men have smaller prostates than age-matched Australian men, this difference disappears in native-born Chinese men who immigrate to Australia, implying that prostate growth may accelerate after exposure to a Western lifestyle (57). Because obesity, impaired glucose homeostasis, and diabetes result primarily from physical inactivity and dietary factors endemic to Westernized societies (58), our results, together with the geographic distribution of benign prostatic hyperplasia, indicate that lifestyle and diet may possibly contribute to benign prostatic hyperplasia pathogenesis. Associations of benign prostatic hyperplasia with decreased physical activity (17,59), increased beef intake (60), and decreased vegetable intake (61) further support this connection.

A substantial strength of the present study is its unique use of repeated, MRI-determined prostate volume measures. MRI is highly accurate for determining true prostate volume (62) and, unlike prior studies of prostate volume, half of the participants contributed at least two different sets of measures over an 8-yr period (although the potential existed for nondifferential measurement error of prostate volume). Another strength of this study is the relevance of the study population composition: older, community-dwelling men. Although the BLSA cohort has limited racial variation, and most participants represent higher socioeconomic and educational levels, the prevalence of benign prostatic hyperplasia does not appear to vary greatly by race in the United States (63,64). In the analysis, we took into account two major predictors of prostate volume: age and serum testosterone level. However, we cannot rule out confounding by possible modifiable risk factors for benign prostatic hyperplasia, including physical activity (17,59), smoking (17), and alcohol intake (65). We also cannot rule out that our findings for obesity, fasting glucose, and diabetes with prostate enlargement are due to their correlations with other components of the metabolic syndrome, such as dyslipidemia.

In summary, obesity, elevated fasting plasma glucose, and diabetes are risk factors for benign prostatic hyperplasia. These results suggest that the rising prevalences of obesity and diabetes (27,28), coupled with the rapid aging of the U.S. population (66), may contribute to an increase in benign prostatic hyperplasia prevalence and exacerbate the problems this disease poses to public health. Still, the potential link between benign prostatic hyperplasia and physical inactivity and diet also raises the possibility that the same general practices recommended for

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promotion of good health, including exercise and healthy diet, may alter the natural history of benign prostatic hyperplasia or prevent or attenuate its clinical manifestations.

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Abbreviations

BLSA	Baltimore Longitudinal Study of Aging
BMI	body mass index
MRI	magnetic resonance imaging
OR	odds ratio
PSA	prostate-specific antigen

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TABLE 1

Age-adjusted anthropometric characteristics of men with nonenlarged (<40 cc) *vs.* enlarged (≥40 cc) MRI-determined prostate volume among 422 men in the BLSA, 1993–2002

	Prostate volume < 40 cc (n = 610 observations) [mean (SD)]	**Prostate volume ≥ 40 cc (n = 181 observations) [mean (SD)]**	***P***
Height (cm)	176.6 (9.9)	176.7 (9.4)	0.97
Weight (kg)	85.5 (17.3)	88.8 (24.2)	0.04
BMI (kg/m^2)	27.4 (4.9)	28.4 (6.7)	0.03
Waist circumference (cm)	96.1 (14.8)	97.6 (16.1)	0.17
Waist-to-hip ratio	0.94 (0.07)	0.94 (0.08)	0.62

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TABLE 2

Age-adjusted ORs for prostate enlargement (MRI-determined volume ≥40 cc *vs.* <40 cc) by measures of obesity in 422 men (791 observations) in the BLSA, 1993–2002

	BMI (kg/m^2)				
	<25 (normal)	**25.0–29.9 (overweight)**	**30–34.9 (obese)**	**≥35 (severely obese)**	***P***
No. of observations	202	401	154	34	
OR	1.00	1.41	1.27	3.52	0.01
95% CI		0.84–2.37	0.68–2.39	1.45–8.56	
	Waist circumference (cm)				
	≤102	>102			
No. of observations	548	243			
OR	1.00	1.17			0.10
95% CI		0.77–1.79			
	Waist-to-hip ratio				
	≤0.90	>0.90			
No. of observations	216	575			
OR	1.00	0.78			0.70
95% CI		0.50–1.24			

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TABLE 3

Age-adjusted ORs for prostate enlargement (MRI-determined volume $\geq$40 cc *vs.* <40 cc) by fasting plasma glucose concentration in 314 men (548 observations) in the BLSA, 1993–2001

	By quartile				
	1	**2**	**3**	**4**	***P***
Fasting plasma glucose (ng/dl)	<90	90–95.9	96–104	>104	
No. of observations	113	134	157	144	
OR	1.00	1.09	0.63	2.00	0.03[a]
95% CI		0.53–2.26	0.33–1.46	1.06–3.78	
	By cutoff for clinical elevation (11,38)				
Fasting plasma glucose (ng/dl)	≤110		>110		
No. of observations	465		83		
OR	1.00		2.98		<0.001[b]
95% CI			1.70–5.23		

[a] Comparing 4th with 1st quartiles.

[b] Comparing elevated (>110 ng/dl) with nonelevated (≤110 ng/dl).

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TABLE 4

Age-adjusted ORs for prostate enlargement (MRI-determined volume ≥ 40 cc *vs.* < 40 cc) by fasting plasma glucose concentration in 290 men (499 observations) without diabetes mellitus in the BLSA, 1993–2001

	By quartile				***P***
	1	**2**	**3**	**4**	
Fasting plasma glucose (ng/dl)	<90	90–95.9	96–102	>102	
No. of observations	111	131	135	122	
OR	1.00	1.18	0.67	1.34	0.42[a]
95% CI		0.57–2.46	0.31–1.47	0.65–2.77	
	By cutoff for clinical elevation (11,38)				
Fasting plasma glucose (ng/dl)	≤110		>110		
No. of observations	457		42		
OR	1.00		1.70		0.16[b]
95% CI			0.81–3.56		

[a] Comparing 4th with 1st quartiles.

[b] Comparing elevated (>110 ng/dl) with nonelevated (≤110 ng/dl).

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TABLE 5

Age-adjusted ORs for high-moderate to severe lower urinary tract symptoms (American Urological Association symptom index ≥ 15 *vs.* ≤ 7) by measures of obesity in 329 men (516 observations) in the BLSA, 1993–2001

	BMI (kg/m^2)				***P***
	<25 (normal)	**25.0–29.9 (overweight)**	**30–34.9 (obese)**	**≥35 (severely obese)**	
No. of observations	146	252	95	23	
OR	1.00	2.18	2.15	3.47	0.17
95% CI		0.68–7.02	0.55–8.39	0.54–22.3	
	Waist circumference (cm)				
	≤102	>102			
No. of observations	360	156			
OR	1.00	1.54			0.30
95% CI		0.77–3.09			
	Waist-to-hip ratio				
	≤0.90	>0.90			
No. of observations	161	355			
OR	1.00	1.99			0.30
95% CI		0.90–4.44			