ORIGINAL INVESTIGATION

Predictors and Prevalence of Erectile Dysfunction in a Racially Diverse Population

Christopher S. Saigal, MD, MPH; Hunter Wessells, MD; Jennifer Pace, BS; Matt Schonlau, PhD; Timothy J. Wilt, MD, MPH; for the Urologic Diseases in America Project

Background: To our knowledge, the burden of disease attributed to erectile dysfunction (ED) has not been adequately quantified across a complete spectrum of age and race using a global disease definition, as recommended by the National Institutes of Health consensus statement. To obtain a better understanding of the national estimates of prevalence and risk factors for ED, we analyzed data from the 2001-2002 National Health and Nutrition Examination Survey.

Methods: The National Health and Nutrition Examination Survey collects data by household interview. The sample design is a stratified, multistage, probability sample of clusters of persons representing the civilian noninstitutionalized population. Data include medical histories in which specific queries are made regarding urological symptoms (including ED). These items were selected for analysis in 3566 men, 20 years and older.

Results: In men 20 years and older, ED affected almost 1 in 5 respondents. Hispanic men were more likely to report ED (odds ratio [OR], 1.89), after controlling for other factors. The prevalence of ED increased dramatically with advanced age; 77.5% of men 75 years and older were affected. In addition, there were several modifiable risk factors that were independently associated with ED, including diabetes mellitus (OR, 2.69), obesity (OR, 1.60), current smoking (OR, 1.74), and hypertension (OR, 1.56).

Conclusions: The burden of ED on the US population is significant. Hispanic men had an elevated risk for ED, a finding that requires confirmation in prospective studies. Obesity, hypertension, smoking, and diabetes mellitus are significantly associated with ED risk. Mitigation of these risk factors may ameliorate the burden of ED.

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Author Affiliations:
Departments of Urology, The David Geffen School of Medicine at UCLA, Los Angeles, Calif (Dr Saigal), and University of Washington School of Medicine, Seattle (Dr Wessells); RAND Corporation, Santa Monica, Calif (Ms Pace and Dr Schonlau); and Minneapolis VA Center for Chronic Disease Outcomes Research, Minneapolis, Minn (Dr Wilt).

Group Information: Information about the Urologic Diseases in America Project is available at http://kidney.niddk.nih.gov/statistics/uda.

THE INTRODUCTION OF ORAL phosphodiesterase inhibitor therapy in 1998 was associated with a surge in resource use for erectile dysfunction (ED), as demonstrated by a 50% increase in physician office visits for ED from 1996 to 2000.[1] Although much is known about the pathophysiologic features of ED, to our knowledge, the burden of disease attributed to ED has not been adequately quantified across a complete spectrum of age and race since the introduction of oral treatment options. As public awareness of ED and the prevalence of risk factors such as diabetes mellitus and hypertension continue to increase in the aging US population,[2,3] it is possible that the incidence and prevalence of ED is increasing as well.

Few studies have assessed the national prevalence of ED. Population-based data from the Massachusetts Male Aging Study (MMAS)[4] documented an almost 35% prevalence of moderate or complete ED in white men between the ages of 40 and 70 years. While these data provide an estimate of the burden ED places on white men, the analysis fails to address nationwide variation in race and ethnicity. In addition, this study fails to address the prevalence of ED in men older than 70 years, and was conducted before the widespread adoption of oral medical therapy for the condition. Estimates of sexual dysfunction in men from the National Health and Social Life Survey (NHSLS) suggested a similar prevalence of ED, but they are based on survey data from 1992.[5] In addition, these data were only collected from men 59 years and younger, although the prevalence of ED increases with age.[4] Bacon and colleagues[6] reported information on sexual function in men older than 50 years. However, their cohort consisted of health professionals and is, thus, not nationally representative. The National Institutes of

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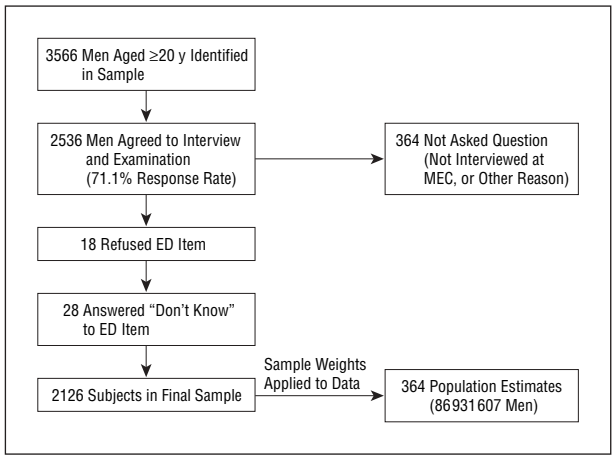

Figure. Derivation of analytic sample. ED indicates erectile dysfuntion; MEC, Mobile Examination Center.

Health Consensus Development Panel on Impotence concluded that there was a clear need for national epidemiologic data to provide answers to questions regarding the prevalence and risk factors for ED.[7]

To obtain a better understanding of the national estimates of prevalence and risk factors for ED, we analyzed data from the 2001-2002 release of the National Health and Nutrition Examination Survey (NHANES).

METHODS

The NHANES, conducted by the National Center for Health Statistics, collects data by household interview supplemented by medical examination.[8] The sample design is a stratified, multistage, probability sample of clusters of persons representing the civilian noninstitutionalized population; African Americans and Mexican Americans are oversampled. The NHANES used a 4-stage probability design. First, counties (or groups of counties) are sampled as primary sampling units, then segments (clusters of blocks) within counties, and then households within segments; finally, individuals within households are sampled. The sample size for the entire survey for the 2-year period was 11 039, with a response rate of 71.1% for men 20 years and older. Data include medical histories in which specific queries are made regarding sexual function. These items were selected for analysis. The National Center for Health Statistics releases a sampling weight, a masked stratum, and a masked primary sampling unit variable to be used in NHANES analyses. The weights reflect nonresponse and poststratification adjustments to match population control totals at each stage of selection. All 3 variables affect the variance estimation. Programming was performed using SAS statistical software, version 8 (SAS Institute Inc, Cary, NC). This software uses Taylor series approximation to estimate variances.

Our assessment of erectile function was based on respondent answers to survey item KIQ400. This item asks a subject, "How would you describe your ability to get and keep an erection adequate for satisfactory intercourse?" Responses included "always or almost always able," "usually able," "sometimes able," "never able," and "don't know." This question, based on recommendations from the National Institutes of Health Consensus Development Panel on Impotence, has demonstrated acceptable accuracy in detecting ED in men undergoing a detailed clinical examination for ED, with a reported area under the receiver operating characteristic curve of 0.89.[9] Sample weights provided by the National Center for Health Statistics were applied to the data. Data presented herein reflect the national estimates produced after application of sampling weights to raw sample counts. The distribution of responses to this item was analyzed by age, race, and selected comorbid conditions.

To facilitate multivariable analysis, the existing ED item was recoded into a binary variable. Those men reporting being always or almost always able or usually able to maintain an erection sufficient for sexual intercourse were coded as not having ED, while those responding that they were sometimes able or never able to have an erection sufficient for sexual intercourse were coded as having ED. Those who refused to answer the question or responded "don't know" were excluded. Definitions for comorbid conditions considered possible risk factors for ED were created using specific responses to items in the NHANES survey. Obesity was defined as a body mass index (calculated as weight in kilograms divided by the square of height in meters) of 30 and above, using height and weight questions collected from subjects. Smoking history and frequency were categorized as currently (every day or some days) a smoker vs formerly or never a smoker. To be classified as a former smoker, a subject must have smoked at least 100 cigarettes in the past.

Logistic regression was performed to obtain odds ratios for ED risk factors identified in univariate analysis.

RESULTS

PREVALENCE OF ED BY AGE AND RACE

A total of 2536 men 20 years and older responded to the 2001-2002 NHANES. Eighteen men refused to answer the question regarding ED, and 28 answered "don't know" regarding their ability to achieve an erection. Three hundred sixty-four men were not asked the ED question either because they were not examined in the Mobile Examination Center, where the question was administered (n=150), or for reasons not specified in the survey (n=214). The **Figure** describes the distribution of patients in the survey. The final evaluable sample size was 2126. Compared with subjects who answered the study question, the 46 men who answered either don't know or refused to answer the question were more likely to be African American or Hispanic and to have diabetes mellitus (**Table 1**). Subjects who were never asked the ED question were of similar ethnicity and race as study subjects and had a similar prevalence of comorbid conditions (Table 1). The overall prevalence of ED was 18.4%, as measured by respondents who reported being sometimes able or never able to maintain an erection adequate for sexual intercourse (**Table 2**). The prevalence of ED as previously defined increased steadily with age, from 6.5% in men aged 20 to 29 years to 77.5% in those 75 years and older (Table 2). The percentage of subjects with the most severe ED, measured by reporting being never able to maintain an erection, increased from 2% to 47% between those age categories. The distribution of responses to the ED question is presented by race and ethnicity in **Table 3**. No significant differences were noted in the distribution of responses by race or ethnicity in univariate analysis. However, Hispanic men younger than 50 years had more than twice the prevalence of ED compared with similar non-Hispanic men (12.5% vs 4.9%).

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Table 1. Subject Demographics*

Characteristic	Evaluable Subjects (N = 2126)	Those Who Refused to Answer the ED Item (n = 18)	Those Who Answered "Don't Know" to the ED Item (n = 28)	Those Who Were Not Asked the Question for Another Reason (n = 364)
Age, mean, y	44	53	49	43
Race†				
White	74	65	36	64
African American	10	4	23	10
Hispanic	13	17	40	14
Other	3	14	0	10
Affected with diabetes mellitus	8	17	13	6
Affected with hypertension	23	6	26	23
Affected with obesity	25	33	27	23
Affected with heart disease	7	2	9	7
Current smoker	27	34	18	27

Abbreviation: ED, erectile dysfunction.
*Data are given as percentage of each group unless otherwise indicated. The number of subjects in each group is the unweighted count.
†Percentages may not total 100 because of rounding.

Table 2. Data for Responses to the ED Question by Age*

	Response†			
Age, y	Always or Almost Always Able	Usually Able	Sometimes Able	Never Able
All	56 526 881 (65.0) [62 to 68]	14 367 656 (16.5) [15 to 18]	10 651 460 (12.3) [11 to 14]	5 385 611 (6.2) [5 to 8]
20-29	13 671 744 (81.0) [78.2 to 83.8]	2 103 850 (12.5) [9.1 to 15.8]	794 294 (4.7) [2.5 to 6.9]	308 897 (1.8) [0.6 to 3.1]
30-39	15 699 319 (88.4) [84.5 to 92.3]	1 382 677 (7.8) [4.9 to 10.7]	599 488 (3.4) [1.3 to 5.4]	76 033 (0.4) [–0.2 to 1.0]
40-49	15 364 018 (71.7) [67.1 to 76.4]	4 288 366 (20.0) [15.5 to 24.6]	1 497 827 (7.0) [4.3 to 9.7]	264 025 (1.2) [0 to 2.5]
50-59	8 695 810 (56.5) [49.8 to 63.2]	3 017 870 (19.6) [13.7 to 25.5]	3 060 256 (19.9) [14.7 to 25.1]	620 364 (4.0) [0.9 to 7.2]
60-69	2 234 096 (28.7) [22.0 to 35.4]	2 142 927 (27.5) [22.0 to 33.1]	2 103 568 (27.0) [22.9 to 31.2]	1 302 519 (16.7) [11.4 to 22.1]
70-74	608 633 (18.8) [10.6 to 26.9]	682 893 (21.0) [13.5 to 28.6]	1 256 022 (38.7) [28.9 to 48.5]	698 312 (21.5) [13.6 to 29.4]
≥75	253 260 (5.7) [1.3 to 10.0]	749 072 (16.8) [12.4 to 21.2]	1 340 004 (30.1) [24.4 to 35.7]	2 115 461 (47.5) [40.3 to 54.6]

Abbreviation: See Table 1.
*Data are given as number (percentage) [95% confidence interval] of subjects for each age group. Percentages may not total 100 because of rounding.
†The exact question asked was as follows: "How would you describe your ability to get and keep an erection adequate for satisfactory intercourse?"

PREVALENCE OF ED IN SUBJECTS WITH COMORBIDITIES

In univariate analyses, ED was more prevalent in respondents reporting 1 of several comorbid conditions compared with its prevalence in the general population (**Table 4**). The prevalence of ED in diabetic men was 49.3%, compared with 15.6% in men without diabetes mellitus. Erectile dysfunction was more prevalent in men reporting obesity, hypertension, or heart disease when compared with its prevalence in men without those conditions. Men who reported being past smokers also more commonly had ED than the general population, although on univariate analysis, current smokers had a somewhat lower prevalence of ED. Men who were current smokers were significantly younger than those who reported never smoking or being past smokers (data not shown).

MULTIVARIABLE MODEL

Age, race, and several comorbid medical conditions remained associated with ED in the multivariable model (**Table 5**). Increasing age was most strongly associated with ED. There was a consistent increase in the odds of ED with each decade after the age of 40 years. After controlling for other factors, men aged 60 to 69 years and men 70 years and older had approximately 9- and 30-fold increases in the odds of reporting ED, respectively, compared with men aged 20 to 29 years. Hispanic men had approximately 1.9 times the odds for ED, compared with white men. Because NHANES sampling methods are designed in part to provide national prevalence estimates specifically for Mexican Americans (vs all Hispanics), an analysis was repeated using only Mexican American subjects. The results of the model remained the same whether Mexican American men only or all Hispanic men were included in the model. The results of the model also remained the same when age, body mass index, and lifetime number of cigarettes smoked were treated as continuous variables. Diabetes mellitus imparted the greatest increase in risk of all medical comorbidities included in the model. Obesity and hypertension were also more commonly associated with ED. Heart disease was not associated with increased odds for ED after controlling for other factors. However, when hypertension, obesity, and diabetes mellitus were removed from the model, heart disease became a significant (P=.007) risk factor for ED (data not shown). Current smokers were more likely to

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Table 3. Data for Responses to the ED Question By Race

Response by Race or Ethnicity*	No. of Subjects	% of Subjects†
White (non-Hispanic)		
Always or almost always able	42 166 116	65.8 (61.2 to 70.3)
Usually able	9 720 185	15.2 (12.5 to 17.8)
Sometimes able	7 719 574	12.0 (10.6 to 13.5)
Never able	4 513 273	7.0 (5.0 to 9.0)
Mexican American		
Always or almost always able	4 254 622	64.2 (59.6 to 68.8)
Usually able	1 331 461	20.1 (15.3 to 24.9)
Sometimes able	668 185	10.1 (7.4 to 12.7)
Never able	374 352	5.6 (3.9 to 7.4)
African American (non-Hispanic)		
Always or almost always able	5 320 404	61.5 (56.5 to 66.5)
Usually able	1 930 336	22.3 (19.5 to 25.1)
Sometimes able	1 092 557	12.6 (9.4 to 15.9)
Never able	307 653	3.6 (1.3 to 5.8)
Other Hispanic		
Always or almost always able	3 019 237	63.9 (52.3 to 75.4)
Usually able	657 696	13.9 (0.6 to 27.3)
Sometimes able	882 115	18.7 (2.7 to 34.6)
Never able	166 660	3.5 (0.7 to 6.4)
Other or multiracial		
Always or almost always able	1 766 502	62.9 (49.8 to 76.1)
Usually able	727 977	25.9 (12.8 to 39.1)
Sometimes able	289 029	10.3 (3.3 to 17.3)
Never able	23 673	0.8 (−1.0 to 2.7)

Abbreviation: See Table 1.
*The exact question asked was as follows: "How would you describe your ability to get and keep an erection adequate for satisfactory intercourse?"
†Data are given as mean (95% confidence interval). Percentages may not total 100 because of rounding.

Table 4. Associations Between ED and Various Comorbid States

Comorbid Diagnosis	ED Absent*	ED Present*	Prevalence of ED Among Men With a Comorbid Diagnosis,%
Diabetes mellitus	3 675 146	3 572 607	49.3
Obesity	16 206 023	4 990 098	23.5
Heart disease	3 055 592	3 344 306	52.3
Hypertension	13 124 111	7 184 282	35.4
Smoking	20 088 443	3 543 914	15.0

Abbreviation: See Table 1.
*Data are given as number of men.

report ED, compared with those who had never smoked. When age was removed as a covariate from the model, current smoking was not significantly (P=.21) associated with ED.

COMMENT

Our study provides a comprehensive national assessment of subject-reported ED. It provides valid estimates according to age, race, and selected comorbid conditions. Our results indicate that reported ED is quite common in men 50 years and older. Erectile dysfunction affected almost 1 in 5 male respondents, and more than half of the population of men 70 years and older were affected. Men aged 60 to 69 years had an approximately 9-fold increased risk for ED when compared with men 29 years and younger. In addition, there were several modifiable risk factors that were independently associated with ED, including diabetes mellitus, obesity, smoking, and hypertension.

Table 5. Data Associated With Various Correlates for ED

Correlate	Odds Ratio (95% Confidence Interval)
Age, y	
20-29	1.00
30-39	0.58 (0.25-1.33)
40-49	1.24 (0.67-2.28)
50-59	3.78 (2.35-6.07)
60-69	8.98 (4.76-16.94)
≥70	31.34 (16.27-60.39)
Race	
White	1.00
Hispanic	1.89 (1.22-2.93)
African American	1.03 (0.74-1.45)
Other	0.67 (0.29-1.47)
Comorbid state*	
Diabetes mellitus	2.69 (1.62-4.46)
Obesity	1.60 (1.10-2.33)
Heart disease	1.44 (0.87-2.38)
Hypertension	1.56 (1.07-2.29)
Current smoker	1.74 (1.16-2.62)
Former smoker	1.42 (0.98-2.05)

Abbreviation: See Table 1.
*The reference for each comorbidity is absence of that comorbidity.

Our study found that ethnicity was associated with ED prevalence. Notably, Hispanic men surveyed in this cycle of the NHANES had about twice the risk for ED as whites, after controlling for other factors. The increased risk in this group seemed to be primarily driven by the high prevalence of ED in Hispanic men younger than 50 years. Although the prevalence of comorbidities that increase risk for ED was similar or lower in Hispanic men younger than 50 years compared with men of other ethnicities younger than 50 years, younger Hispanics had more than twice the prevalence of ED. Several hypotheses may explain this finding. While Hispanic men had an increased risk for ED after controlling for factors demonstrated to increase ED risk, the severity of these self-reported comorbidities was not accounted for in the model. It is possible that Hispanic men had more poorly controlled diabetes mellitus or hypertension, with a resulting increase in ED. Reduced access to care in ethnic populations could explain worse glycemic or blood pressure control. However, an increased risk for ED was not found among African Americans, who may also have reduced access to care when compared with whites. Alternatively, cultural differences may explain this finding. The interpretation of ED can vary with culture.[10] It is possible that the meaning of the statement "erection sufficient for intercourse" was construed differently by men from the Hispanic community. In addition, some data indicate that Hispanics are more likely than non-Hispanics to report physical symptoms on scales mea-

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suring psychological distress.[11,12] Finally, specific polymorphisms of the gene encoding endothelial nitric oxide synthetase, an enzyme critical to erectile function, have been associated with ED in Mexican populations, suggesting a possible genetic susceptibility.[13] Although many hypotheses may explain the increased risk for ED among Hispanics, prospective studies are needed to confirm and further explore this finding.

Several modifiable comorbid conditions were also associated with a higher risk of ED. Obesity, diabetes mellitus, smoking, and hypertension may lead to ED through several possible pathophysiologic mechanisms, including endothelial dysfunction, damage to cavernosal nerves, and an increased serum estrogen-testosterone ratio.[14-17] Thus, these findings were expected. Patient-reported heart disease was not significantly associated with increased risk for ED in multivariable modeling, although ED was much more prevalent in men with a history of heart disease compared with men from the general population in the univariate analysis. Obesity, diabetes mellitus, smoking, and hypertension increase the risk for heart disease; it is possible that the increased risk associated with these conditions explains most of the increased ED seen in men with heart disease in univariate analysis. This hypothesis is supported by the fact that when these conditions were removed from the multivariable model, heart disease became a significant risk factor for ED. Smoking is also associated with endothelial dysfunction,[18] and a current smoking habit and previous smoking were correlated with ED on multivariate analysis. However, in univariate analysis, the relationship of ED to current smoking was confounded by age. Current smokers tended to be much younger than those who had previously smoked or who had never smoked. Because increased age is a strong risk factor for ED, these younger men did not have an increased prevalence for ED on univariate analysis. The explanatory power of this relationship was confirmed when age was removed from the multivariable model and the odds ratio for current smoking became nonsignificant.

Our estimate of the prevalence of ED is lower than estimates of "sexual dysfunction" (31%) and "moderate or complete impotence" (35%) taken from the NHSLS and MMAS, respectively.[4,5] The difference between these prior estimates and ours is likely due to definitional issues. The first wave of the MMAS did not include a global self-assessment of ED. The NHANES uses a global subjective definition, as recommended by the National Institutes of Health.[7] The MMAS subjects were categorized using data from a referent group of clinic patients who answered a question regarding impotence. The varied meanings that impotence had to these subjects may explain differences in prevalence in the 2 studies. The NHSLS was designed to capture information on the construct of sexual dysfunction, which includes ED and other components of male sexuality (eg, premature ejaculation). Nevertheless, the MMAS and the NHSLS observed an increase in sexual problems with age, findings in concert with ours. Similar results regarding the substantially increased risk of ED with increased age were also reported by the Health Professionals Follow-up Study,[19] a large study of mainly white health care professionals older than 50 years.

The elevated risk for ED we found in Hispanic men was not reported in the NHSLS, which included samples of Hispanics and African Americans. Several possible reasons may explain this discrepancy. The NHSLS used a binary indicator to determine if a subject had trouble maintaining or achieving an erection. The NHANES used a response scale that may have allowed men who are sometimes able to have an erection to describe their condition more precisely. Men who were sometimes able to achieve erections sufficient for intercourse in the NHSLS may have preferentially reported no problem when forced to choose from 2 choices in the NHSLS. In addition, the NHSLS analysis only included men who had at least 1 sexual partner in the prior 12 months. This limitation may have excluded men whose ED did not allow them to engage in sexual intercourse with a partner.

Several studies[4,20-22] have found increased odds for ED associated with hypertension, diabetes mellitus, and obesity, findings that are confirmed in our study's ethnically and racially diverse population-based sample. Modification of these comorbidities may reduce the risk for ED or modulate its severity.[21,23] Data regarding the risk smoking poses for development of ED are conflicting. Investigators from the MMAS did not find an increased prevalence of ED among smokers; however, smoking increased the association of other risk factors, such as hypertension, with ED.[4] In a follow-up study of the MMAS cohort, smoking was not associated with incident development of ED.[24] Conversely, Mannino et al[25] reported an odds ratio of 1.8 for impotence in a survey of veterans who were current smokers, after controlling for vascular disease, among other factors. Although our findings were similar to those of the study by Mannino et al, the effects of smoking in our population were modulated by the fact that current smokers were significantly younger than former smokers and those who never smoked.

Our study has limitations. Data on comorbidity were collected by subject self-report. These data may be subject to recall or comprehension bias. A previous study[26] of the validity of self-reported weight in the NHANES found that a positive discrepancy between reported and measured weight was found for several groups, including Mexican Americans (16% more likely to overestimate weight). Given the variable direction of self-reporting bias, which can depend on the disease in question and the group being studied, it is difficult to estimate the direction and degree of bias introduced by use of self-reported data. The ethnic and comorbid characteristics of nonresponding subjects and of those who answered don't know to the study question differed in significant ways from respondents. Given that these subjects were more likely to be African American, Hispanic, or diabetic, we believe that this bias would result in underreporting the prevalence of ED, because these groups have more comorbidities associated with ED. We had no data regarding the availability of regular sexual partners for our subjects; this may have affected their assessments of their sexual function. We did not control for medication use or surgical history, both of which can affect sexual function. Although we attempted to control for relevant comorbidities in our multivariable model, unmeasured factors may have influenced the results.

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Erectile dysfunction is common and increases with age, and the prevalence varies by race and modifiable comorbid conditions. The burden of ED on the US population is significant, with 1 in 5 men older than 20 years affected. Hispanic men had an elevated risk for ED, a finding that requires confirmation in prospective studies. Obesity, hypertension, smoking, and diabetes mellitus significantly increase ED risk.

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Correspondence: Christopher S. Saigal, MD, MPH, Department of Urology, The David Geffen School of Medicine at UCLA, Campus Box 951738, Los Angeles, CA 90095-1738 (csaigal@ucla.edu).
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