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A new surrogate variable for erectile dysfunction status in the Massachusetts male aging study

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Abstract

Erectile dysfunction (ED) is the subject of a vast clinical literature, but little information has been gathered from random samples of the general public. The Massachusetts Male Aging Study (MMAS) addressed this important aspect of men's health. The MMAS was conducted in two waves, with baseline data collection in 1987–1989 and follow-up in 1995–1997. Subsequent to the baseline MMAS survey, a consensus developed that subjective measures are optimal for defining ED. Unfortunately, the baseline questionnaire did not ask subjects directly about their erectile functioning. Thus, we previously assigned the MMAS subjects a degree of impotence at baseline using a series of related questions, employing a discriminant formula constructed from a separate sample of urology clinic patients. At follow-up the men classified themselves directly in addition to answering the original series of related questions. In the present article, we report the results of a new discriminant function, based on the MMAS men at follow-up. We also compare the two methods and discuss our reasons for preferring the internally calibrated method.

Keywords: Erectile dysfunction; Aging; Prevalence; Population study; Men; Discriminant analysis

1. Introduction

Erectile dysfunction (ED) is the subject of a vast clinical literature, but little available information on the epidemiology of the condition is based on random samples of community-dwelling individuals. The Massachusetts Male Aging Study (MMAS) addressed this important aspect of men's health through a population-based sampling frame, conducting in-person interviews in the subjects' homes. The MMAS was a cohort study conducted in two waves, with baseline data collection in 1987–1989 and follow-up in 1995–1997.

The common term "impotence" has been replaced in the last 5 years by "erectile dysfunction" at the urging of a National Institutes of Health consensus panel that convened in 1992, halfway between the two waves of the MMAS. The panel published a working definition of ED [1]—"the persistent inability to attain and maintain a penile erection adequate for satisfactory sexual performance"—and called for "major research efforts" to improve diagnostic classification for epidemiologic purposes. It bears emphasizing that this definition is based on a subjectively identified state for each man that depends on his perception of satisfactory sexual performance.

It was left to the research community to operationalize the NIH consensus definition in further studies. Clinical questionnaires have been developed (e.g. [2, 3]), but asking sensitive questions in a primary provider's office, once the patient has sought treatment, is far different from administering a standardized instrument as a stranger in the field.

In this report we describe and compare two techniques by which we have classified the subjects in the MMAS regarding their erectile dysfunction status. These include the original classification technique based on data from a separate clinic sample and a new technique based on data from the follow-up wave of the MMAS. The techniques have been adapted to meet the rapidly evolving views and improved understanding of erectile dysfunction in the clinical community, while maintaining a balance between external and internal validity.

2. Methods

2.1 Sampling and data collection

The baseline Massachusetts Male Aging Study was a random sample, cross-sectional, multidisciplinary survey of

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health and aging in men, conducted in 11 cities and towns in the area of Boston, MA. Communities were randomly selected with probabilities proportional to population within each of six strata defined by community size and median income. Men born between 1917 and 1946 were drawn at random from the annual state census listings. Sampling fractions were adjusted to produce a uniform age distribution between 40 and 70 years. Introductory letters were sent to 5287 men, followed by telephone recruitment. No financial incentive was offered. Of 4104 successful telephone contacts, 1526 men and 23 household members declined to cooperate and 756 were deceased. A total of 1709 respondents (53% of those eligible) enrolled in the study and completed the in-home protocol. The MMAS participants were typically Caucasian (95%), employed (78%), and married (75%). The low (5%) proportion of non-Caucasians is consistent with the composition of the Massachusetts population at the time of the sampling.

The follow-up phase of MMAS was conducted in 1995–1997. Of the original 1709 participants, 180 were confirmed deceased and 10 resided outside of the U.S.; 1156 were successfully reinterviewed (76% of survivors living in the U.S.). Protocols and instruments were adapted from baseline with minimal deletions and refinements.

The field protocol of the MMAS has been previously described [4–7]. Briefly, a trained interviewer visited each subject in his home and completed the health questionnaire, psychological instruments, physiological measurements, and blood sampling. Weight, height, and blood pressure were measured, and blood was drawn for analysis of lipids and sex steroid hormones. A 23-item sexual activity questionnaire was self-administered in private and returned to the interviewer in a sealed envelope [6].

2.2. Attribution of erectile function

The MMAS sexual activity questionnaire included questions related to erectile function, but concentrated on specific items (e.g., frequency of intercourse), rather than the global subjective self-assessment of ED that was later formalized by the NIH consensus conference [1]. To establish a relation between the MMAS responses and a subject's global self-assessment of ED at baseline, we recruited a supplemental sample of men presenting at the Boston University Medical Center urology clinic during a 6-month period in 1990. Men in this clinic sample were asked to complete a self-administered questionnaire consisting of the MMAS questions and one additional global question, reproduced here as Table 1.

Of 398 questionnaires distributed, 303 (76%) were returned with complete responses. The clinic sample was selected as a convenience sample for establishing the link between subjectively defined erectile dysfunction and the MMAS instrument. No information was collected other than the MMAS 23-item sexual activity questionnaire and the single subjective assessment.

Quadratic discriminant analysis was used to calculate each subject's likelihood of having each of the four degrees of erectile dysfunction, as described in Feldman *et al*. [8] and Seber [9]. The subject was assigned the degree of erectile dysfunction into which he had the greatest probability of falling. These assignments were used in MMAS baseline analyses to estimate the prevalence of erectile dysfunction and its relationship to age, health status, and behavior [4,10]. For the remainder of the present article, we refer to these assignments as the "clinic method" for attributing ED status at baseline.

Table 1
Global question for self-rating of ED

IMPOTENCE means being unable to get and keep an erection that is rigid enough for satisfactory sexual activity. How would you describe yourself? (Circle one letter)	
(a) Not impotent:	always able to get and keep an erection good enough for sexual intercourse.
(b) Minimally impotent:	usually able to get and keep an erection good enough for sexual intercourse.
(c) Moderately impotent:	sometimes able to get and keep an erection good enough for sexual intercourse.
(d) Completely impotent:	never able to get and keep an erection good enough for sexual intercourse.

The MMAS follow-up questionnaire on sexual activity included the global, subjective, four-level self-assessment of impotence shown in Table 1 as well as the original sexual activity questionnaire. We therefore had the opportunity to construct new discriminant formulae using internal data—about the MMAS men themselves—rather than the external sample of clinic patients employed in the clinic method. Again, quadratic discriminant analysis was applied. As it was with the clinic method, the resulting formula was then applied to baseline data, providing an additional class assignment at baseline based on internal rather than external calibration. This latter assessment is therefore an alternate method of attributing ED status at baseline; we refer to this as the "MMAS method" to emphasize its internal nature.

Agreement between two categorization methods was assessed using the weighted kappa statistic [11,12]. Weighted kappa is a statistic that awards full credit for agreement if the two raters agree exactly on a subject's rating, and diminishing partial credit for agreement as ratings diverge. The precise amount of credit is determined by the weights, which, as noted in Graham and Jackson [13], are somewhat arbitrary. In the cases of the two kappas reported in this article, the absolute error and squared-error weighted kappas differed only in the hundredths digit. The reported kappas use squared-error weights, which are the most commonly reported. As recommended by Landis and Koch [14], a kappa of 0.6 or greater is considered substantial. We also report Pearson's correlation coefficients as a measure of association.

3. Results

3.1. Description of the discriminant functions

As reported by Feldman et al. [8], the clinic method had the following characteristics. It used nine questions, includ-

Table 2
Sexual activity questions used in the construction of the two ED measures

Question	Clinic method	MMAS method
In an average month, how often do you have sexual intercourse or activity?[a]	✔	✔
Missing frequency of sexual intercourse or activity question?[b]		✔
During an average 24-hour day, how often do you have a full hard erection?[a]	✔	✔
Missing frequency of erections question?[b]		✔
During the last 6 months have you ever had trouble getting an erection before intercourse begins?[c]	✔	✔
During the last 6 months have you ever had trouble keeping an erection once intercourse has begun?[c]	✔	✔
How frequently do you awaken from sleep with a full erection?[d]	✔	✔
How satisfied are you with your sex life?[e]	✔	
How satisfied are you with your sexual relationship with present partner or partners?[e]	✔	
How satisifed do you think your partner(s) is (are) with your sexual relationship?[e]	✔	
Has the frequency of your sexual activity with a partner been as much as you desire, less than you desire, or more than you desire?[b]	✔	
How often do you ejaculate by masturbation?[d]		✔
Missing ejaculate by masturbation question?[b]		✔
How often do you ejaculate in sex with a partner?[d]		✔
Missing ejaculate in sex with a partner question?[b]		✔
How do you feel about the following statement? “Men’s interest in sexual activity tends to decline as they get older: That is, the older you are the less interest you have in sexual matters.”[f]		✔
Compared to when you were an adolescent (around 18–20 years), do you feel sexually aroused?[g]		✔

[a] Enter number in box.
[b] Yes, No.
[c] Yes, No, Have not had intercourse in last 6 months.
[d] Scale form Daily to Not at all in the last six months.
[e] Scale from 1 (extremely satisifed) to 5 (extremely dissatisfied).
[f] Scale from 1 (completeley agree) to 5 (completely disagree).
[g] More than when an adolescent, About the same as when an, Less than when an adolescent.

ing questions about how often the men had erections, sexual intercourse or activity, whether they had trouble getting or keeping an erection, how frequently they woke from sleep with a full erection, whether their sexual activity was as frequent as they wished, and several questions about their satisfaction with their sex life and relationships. The questions are presented in Table 2. Of the 1290 men classifiable using the clinic method (75% of the total of 1709 men), 633 (49%) were classified as not at all impotent, 210 (16%) were minimally impotent, 322 (25%) were moderately impotent, and 125 (10%) were completely impotent. Thus, 51% of the classifiable men were classified as having some level of ED when using the clinic method.

The MMAS method used 13 questions, of which four were indicators of missing values on four of the other items. Appendix 1 summarizes the justification of this technique. Of the questions used in the clinic method, the satisfaction questions and the question about whether their sexual activity with a partner was as frequent as they desired were omitted. These were omitted because they are not included in validated clinical measures of ED [2,3] and because they refer to a current partner, so that the question was not applicable to men without partners. For example, one question in the clinic method is:

How satisfied are you with your sexual relationship with present partner or partners?
(a) Extremely satisfied.
(b) Somewhat satisfied.
(c) Neither satisfied nor dissatisfied.
(d) Somewhat dissatisfied.
(e) Extremely dissatisfied.

How might a man currently without a partner respond to this question? Any two men might answer differently for unpredictable reasons, and others would not respond at all. Conceptually, then, it seemed advantageous to discard the satisfaction questions. In addition, including the questions did not add to the accuracy of the discriminant functions in the sample used to generate the functions.

In their place were included questions about the frequency of ejaculation during sex and during masturbation, whether the subjects think that in general the interest in sex declines as men get older, and how sexually aroused they feel, relative to when they were adolescents. These questions were included because of their content validity and because their inclusion in forming the discriminant functions led to more accurate formulae.

Additional covariates were tested for inclusion as well. Of primary interest, we checked whether including age as a covariate would improve the accuracy of the discriminant functions. It did not. The fact that age did not improve the discriminant analysis implies that the effect of aging was adequately expressed through the specific symptoms included in the analysis. The discriminant analysis was successful, in the sense that the correlation between the discriminant-function-based categorization and the subjective self-assessment in the follow-up sample was 0.66 and the

Table 3
Sexual activity activity profile of Massachusetts Male Aging Study men: grouped by assigned degree of erectile dysfunction based on two methods of assignment

	Assigned degree of erectile dysfunction			
	None	Minimal	Moderate	Complete
Clinic method: 1290 subjects classifiable				
Subjects	633 (49%)	210 (16%)	322 (25%)	125 (10%)
Sexual activity (mean frequency/mo)	8.4	8.0	4.9	2.6
Full erection (median frequency/mo)	30	30	12	3
Awaken with erection (median frequency/mo)	8–12	8–12	2–3	<1
Satisfied with frequency of activity (%)	67	67	32	30
Satisfaction with sex life[a]	1.7	2.2	2.8	3.9
Satisfaction with partner[a]	1.7	2.0	2.8	3.4
Partner's satisfaction[a]	1.6	2.0	2.6	3.5
MMAS method: 1626 subjects classifiable				
Subjects	917 (56%)	380 (23%)	127 (8%)	202 (12%)
Sexual activity (mean frequency/mo)	8.6	6.9	3.7	1.6
Missing sexual activity question (%)	0	2	2	11
Full erection (median frequency/mo)	30	30	4	0
Missing full erection question (%)	0	5	9	12
Awaken with erection (median frequency/mo)	8–12	8–12	1	0[b]
No ejac. during masturbation in last 6 mo (%)	21	20	50	38
Missing ejac. during masturbation quest. (%)	19	23	2	18
No ejac. during intercourse in last 6 mo (%)	12	9	22	44
Missing ejac. during intercourse quest. (%)	16	14	17	53
"Men's interest declines"[a]	3.3	3.2	2.6	2.7
Less aroused than when adolescent? (%)	55	71	89	86

[a]Mean on scale from 1 (completely agree) to 5 (completely disagree).
[b]Not at all in last 6 months.

weighted kappa showed a substantial agreement of 0.66. In addition, 90% of subjects were correctly classified (66%) or were classified to an adjacent category (24%), so that only 10% in total were misclassified from none to moderate (2%) or complete (1%), minimal to complete (1%), moderate to none (1%), or complete to minimal (2%) or none (3%).

The 13 questions used in the MMAS method are presented in Table 2. As summarized in Table 3, of the 1626 subjects who were classified (95% of the 1709 men), 917 (56%) were classified as not at all impotent, 380 (23%) were minimally impotent, 127 (8%) were moderately impotent, and 202 (12%) were classified as completely impotent. Thus, under the MMAS method, 44% of the subjects were classified as having some level of ED. Appendix 2 contains more technical details regarding discriminant analysis and the SAS [15] code used to carry it out.

In Table 3 we present information summarizing the assignments made by the two methods. A summary statistic for each contributory variable is presented for each assigned group. For example, we see that using the clinic method, the men who were classified as having no impotence had sexual activity or intercourse an average of 8.4 times per month. Those classified as minimally impotent had sexual activity 8.0 times per month on average, those classified as moderately impotent 4.9 times per month, and the completely impotent had sexual activity 2.6 times per month. The MMAS method found mean amounts of sexual activity per month were 8.6, 6.9, 3.7, and 1.6 for those classified as not impotent, and minimally, moderately, and completely impotent, respectively.

3.2. Comparing the two techniques

In this section we summarize numerical comparisons of the two techniques. One primary result seen in Table 3 is that the MMAS method was able to classify 1626 men, 26% more than the 1290 classifiable with the clinic method. Thus, the MMAS classified 95% of the 1709 men, while the clinic method classified 75%. Another striking difference is that the "Moderately impotent" group, which was the second largest using the clinic method, is now the smallest. In contrast, the proportion of men who are completely impotent increased slightly. The minimally impotent group had the largest proportional increase, nearly doubling in size even though the total classifiable sample increased by only about a quarter. Overall, the proportion of men classified as having some degree of impotence (minimal, moderate, or complete) decreased from 51% to 44%.

In Table 4, we show how the 1709 men were classified using both methods. In summary, 4.0% of men could not be classified by either method. In total 351 (20.6%) of the men could not be classified using the clinic method but were classifiable with the MMAS method. Of these, 43.6% were classified as not impotent, 14.1% as minimally impotent,

Table 4
Assignment status of 1709 men based on clinic and MMAS methods

	Clinic method					
MMAS method	Missing	None	Minimal	Moderate	Complete	All
Missing	68 (4.0)	6 (0.4)	0 (0)	5 (0.3)	4 (0.2)	83 (4.9)
None	153 (9.0)	596 (34.9)	41 (2.4)	64 (3.7)	63 (3.7)	917 (53.7)
Minimal	49 (2.9)	7 (0.4)	162 (9.5)	156 (9.1)	6 (0.4)	380 (22.2)
Moderate	24 (1.4)	0 (0)	6 (0.4)	80 (4.7)	17 (1.0)	127 (7.4)
Complete	125 (7.3)	24 (1.4)	1 (0)	17 (1.0)	35 (2.0)	202 (11.8)
All	419 (24.5)	633 (37.0)	210 (12.3)	322 (18.8)	125 (7.3)	1709 (100)

N, (%) of 1709 total subjects.

6.8% as moderately impotent, and 35.4% completely impotent. Thus, these men were disproportionately from the completely impotent group.

As shown in Table 4, 1275 men received a classification under both methods. Over two-thirds (68.5%) of these men received the same assessment under both methods. In addition, 27.2% of the men classifiable using both methods were classified as having a greater degree of ED using the clinic method. In contrast, only 4.3% of those classifiable using both methods were classified as having a greater degree of ED using the MMAS method than the clinic method. The correlation between the two methods was 0.53 and the weighted kappa was 0.49.

One interesting observation to be made from Table 4 is that of the 125 men classified as completely impotent using the clinic method, 63 were classified as not at all impotent using the MMAS method. Further investigation showed that of these men, all but two reported ejaculation during either sex or masturbation at least once during the last 6 months. Only two men in this group of 63 reported neither erections nor sexual activity in an average day or week, respectively. None of these men reported having trouble getting or keeping an erection.

The results of some comparative analyses useful in assessing construct validity are presented in Table 5. In Table 5, we show the results of cross-sectional logistic regressions predicting ED state at time 1 using covariates measured at time 1. Here ED is dichotomized as none or minimal vs. moderate or complete. Each row represents a different covariate, named in column 1. In column 2 we show the odds ratio and 95% confidence interval (CI) associated with the predictor using the clinic method of generating the outcome variable. In column 3, we show the odds ratio and 95% CI for the MMAS method.

The covariates considered include age (for which the odds ratio is expressed for a 10-year increase in age), current cigarette smoking, presence or absence of diabetes by self-report, presence or absence of high blood pressure by self-report, and presence or absence of depression assessed by a score of 16 or greater on the CES-D [16,17]. All of these factors have been identified in previous research as possible risk factors for ED [18–22]. For two of the six items, age and smoking, the MMAS method generated a substantially stronger association than the clinic method. For the relationship between smoking and ED, the confidence interval for the odds ratio generated by the clinic method included 1, but the confidence interval for the MMAS method excluded 1. Thus, using the clinic definition of ED, one would arrive at a different conclusion than if the MMAS method were used. In addition, the effect of age was much stronger using the MMAS method, and the confidence intervals for two odds ratios generated by the two methods did not overlap. For the four medical conditions, the MMAS and clinic methods were roughly equivalent. Both methods resulted in positive associations with ED, consistent with the existing literature.

Finally, in another age comparison, we found that 7.04% of 40–50-year-old men were classified as completely impotent using the clinic method vs. only 4.52% using the MMAS method. Among the 50–60-year-old men, the rates were 8.56% and 8.39%, using the clinic and MMAS methods, respectively. Thus, the rate was nearly constant over that 20-year range when using the clinic method, but shows a sizeable increase when using the MMAS method. Among men aged 60–70, the rates were 14.32% (clinic) and 24.95% (MMAS) using the two methods.

4. Discussion

The fact that the two methods showed different associations with covariates and the fact that the weighted kappa

Table 5
Cross-sectional associations of select covariates with erectile dysfunction estimated by logistic regression from the baseline phase of Massachusetts Male Aging Study (1987–1989)

Covariate	Clinic method OR (95% CI)	MMAS method OR (95% CI)
Age	1.57 (1.37, 1.81)	2.56 (2.18, 3.02)
Smoking	0.94 (0.72, 1.22)	1.39 (1.07, 1.80)
Diabetes	2.67 (1.73, 4.16)	2.96 (2.01, 4.32)
Hypertension	1.78 (1.39, 2.28)	1.47 (1.14, 1.89)
Heart disease	2.67 (1.90, 3.77)	2.53 (1.83, 3.45)
Depressive symptoms	2.03 (1.39, 2.96)	1.85 (1.30, 2.59)

Odds ratio (OR) in favor of erectile dysfunction (moderate or complete). For age, OR expressed per 10-year interval; for other covariates, OR for presence of attribute in relation to absence of attribute.

indicated a less-than-substantial agreement between the two methods are evidence that they have different meanings. Presented with these two alternative methods, the natural question is: Which one is preferable? Because we do not know the true ED status of the men at baseline, we cannot determine which method is more valid (i.e., closer to the truth). In other words, we cannot directly assess the criterion validity of either approach. Instead, we can only describe which method performs better given the available evidence.

The arguments supporting the MMAS method can be summarized as follows: (1) the baseline sample is more similar to the follow-up sample than to the clinic sample, (2) the MMAS method retains more data than the clinic method, and (3) the MMAS method has better construct validity. A detailed discussion of each of these arguments follows.

4.1. Samples more similar

Unfortunately, the clinic data set does not include information on important covariates, such as age. If these were included, we could compare the characteristics of the clinic sample to the MMAS sample at baseline and determine whether the two samples were similar. Given the self-selected nature of the clinic sample, it is likely that they were different from the population-based MMAS sample on factors such as health status and age. In addition, we do not know why they chose to go to the clinic. In fact, in using the clinic method, we incorporate some selection bias; we are applying the results from a self-selected (clinic) sample to the general (randomly selected MMAS) population. The MMAS men at follow-up are also somewhat selected in that they are survivors and were available for follow-up; however, it certainly seems plausible that despite being 8 years older, they may be more similar to the MMAS men at baseline than are the clinic men.

One important difference between the clinic sample and the general population is that in presenting at a urology clinic, they may have already perceived that they had ED and decided to seek help. Only a small proportion of men with ED seek medical treatment, because of a reluctance to admit a problem, a belief that loss of function is an inevitable consequence of aging, or inadequate knowledge of therapeutic options [6]. Thus, men seeking treatment may identify as ED the same symptoms that randomly selected men would not. Alternatively, they may be younger on average than the randomly selected men. Older men are more likely to be satisfied with the same objective poor performance than younger men [6]. This might make younger men more likely to visit a clinic, and would mean that they would be more likely to interpret their symptoms as ED than a man in the MMAS sample.

In either case, we would expect that the clinic method would generate a more severe diagnosis for a randomly selected man than he would for himself. In fact, in comparing the two methods, we see that the clinic method did indeed attribute a larger proportion of men as having some level of dysfunction. It also categorized a larger proportion of men as having moderate or complete ED; it classified 27.2% of the men as having a greater degree of ED than the MMAS method did.

4.2. Practical missing data considerations

The clinic method generated an ED state for 75% men assessed at baseline. The remainder were missing one or more of the nine questions that are used in the method. In contrast, the MMAS method generated values for 95% of the men. Thus, using the clinic method would violate the general principle of retaining as many subjects as possible. In addition, using the clinic method would also represent another type of self-selection of the sample, because men who chose to answer all nine questions in the clinic method may be different from men who chose not to answer one or more of the questions. For example, the MMAS classifications of the men who were not classifiable with the clinic method suggests that the clinic method may have failed to classify some of the most affected men. In other words, the MMAS method would allow us to keep more men in the study, preserve more of the randomly sampled nature of the MMAS men, and classify more men who were severely affected.

4.3. Better construct validity

We would expect that the preferable imputation method would result in stronger associations with possible correlates of ED, but also remain consistent with existing knowledge. Our results show that the MMAS method produced a stronger overall age–ED association than did the clinic method, and also a more credible increasing trend with age. The age–ED association is well documented in the literature [1]. Recent findings have shown that cigarette smoking is an independent predictor of ED among middle-aged men [18]. The MMAS method produced a statistically significant positive relationship between current cigarette smoking and ED, while the clinic method did not. Associations between ED and chronic medical conditions such as heart disease, hypertension, and diabetes were consistent with the literature using both methods.

Finally, the associations with the constituent questions were more plausible using the MMAS method. Nearly all of the men who moved from the most affected category under the clinic method to the least affected category under the MMAS method were able to ejaculate, had either erections or sexual activity, and had no trouble getting or keeping erections. Thus, the clinic method assignment to the completely impotent group for these men seems highly suspect; the MMAS method assignment to the not at all impotent groups seems plausible.

It should be noted that the utility of either technique depends on the desirability of a subjective assessment of ED, as expressed in the NIH consensus panel [1]. Many men who perceive themselves to be impotent eventually receive

clinical diagnoses of premature ejaculation, retarded orgasm, decreased libido, or even infertility. We attempt to minimize errors of this sort by defining the answers to the single subjective question, as shown in Table 1. While comparisons with clinical questionnaires [2,3] are ongoing, we use the answers to the single subjective question as the gold standard without assessing the relationship between the single question and clinical diagnosis.

5. Summary

The epidemiology of erectile dysfunction is a rapidly developing field of study; it is often the case that rich and valuable data sets do not contain a measure that turns out to be of later interest. In this case, definitions of ED changed during the course of the MMAS. In addition, over time, thinking about the causes of ED has shifted from attributing ED primarily to psychogenic causes to attributing ED to organic causes, and it is now well-accepted that ED can be assessed subjectively. Assessment of ED in a field setting or in a population-based study have rarely been addressed: there is still no "gold standard" for defining ED. In the MMAS, we have developed a new method of classifying men according to a standard that did not yet exist when the study was designed.

This method is not intended to replace existing instruments. If validated with an external sample, it could be used in large population-based studies where it is impractical or inappropriate to include these instruments. If the method were thus shown to be generalizable to other studies, it would be much more valuable.

We have developed an improved method of defining ED in a population-based epidemiological study. The MMAS method is less susceptible to selection bias, results in less missing data, and has greater construct validity than the previously described method based on external data [8]. Although this changes our original estimates of epidemiologic parameters of ED, it represents an improvement, a refinement, over our own previous results.

Appendix 1

The missing data procedure

In this appendix we show why the approach to the missing data that we have taken is appropriate.

As shown in Table 2, questions that include a missing data indicator variable (questions 1, 3, 8, and 10) are expressed as two separate variables. For example, the frequency of sexual activity question is:

(1) In an average week, how often do you have sexual intercourse or activity? (Enter number in box.)

This question is missing for 4% of the men at time 1. The mean answer among men who answered this question is 2.13. For the men who did not answer this question, we insert this mean, 2.13.

We augment the data by including the following question:

(2) Missing frequency of sexual intercourse or activity question (1)?
(a) No.
(b) Yes.

For those men who were missing the frequency question, the answer to this question takes the value 1, for those who answered the frequency question, the answer takes the value 0.

While this type of procedure can lead to incorrect variances when parameter estimates are of interest, no error in prediction is caused, in a sense described below. In this case, we are interested solely in prediction, so our results will not suffer from error.

The heuristic logic for this result can be easily seen in the context of ordinary least squares regression with an indicator variable (i.e., ANCOVA). First, suppose that we have a simple linear regression with one continuous predictor. To concretize this, suppose the regression equation is:

$$y = \alpha + \beta x \tag{1}$$

in this case, the predicted value for a subject i is $\hat{y}_i = \hat{\alpha} + \hat{\beta} x_i$ where $\hat{\alpha}$, $\hat{\beta}$ can be found from the usual regression results. Suppose an observation j were added to the data set that had a value x_j equal to the mean of the original sample of x's and any arbitrary value y_j. If the regression model Eq. (1) were fit again with this extra observation, the estimated slope $\hat{\beta}^j$ would be equal to the original slope $\hat{\beta}$. If an indicator variable z were included that took a value of 0 for the original subjects and a value of 1 for subject j, we could write another regression equation as

$$y^j = \alpha^j + \beta^j x^j + \gamma^j z^j \tag{2}$$

where a superscript j indicates that observation j is included in the analysis. In this case, not only is $\hat{\beta}^j = \hat{\beta}$ but also $\hat{\alpha}^j = \hat{\alpha}$. So for an observation in the original data set (i.e., any observation other than j) the predicted value $\hat{y}_i$ from Eq. (2) is still $\hat{\alpha} + \hat{\beta} x_i$, because $z_i = 0$. In other words, the prediction is unchanged by adding the additional observation. This will be true regardless of how many observations are added. The application of this result to the missing data case is obvious. [We repeat here that the variances of the parameter estimates will be affected by this technique, i.e., $\mathrm{Var}(\hat{\beta}) \neq \mathrm{Var}(\hat{\beta}^j)$. This missing data technique is applicable when the purpose is simply prediction of new values, but is not appropriate for inference about parameter estimates.]

A simpler way of thinking about this is that because the imputed values are all at the mean of the observed values, they do not affect the slope that would be observed using only the observed values. And the imputed values do not affect the intercept because they get their own intercept from the missing value indicator.

This technique is desirable in that it allows the maximum number of subjects to be retained and yet allows completely

observed subjects to retain the predicted value they would have received if the subjects missing values had been excluded. This result carries through for discriminant analysis.

Appendix 2

SAS code used to perform the discriminant analysis for the MMAS method

This is the SAS code for the MMAS method:

```
proc discrim method=normal pool=test crossvalidate
posterr outstat=calib;
class ed4;
priors proportional;
var sexmo_2 sexmo_2m erctda_2 ertda_2m tblbef_2
tbldur_2 full_2
ejacm ejacm_m ejacs ejacs_m intrst_2 adol;
run;
```

In brief, the analysis computes the generalized distance between an observation and each of the group means. A simple function of these distances are then normalized to sum to one; this results in the probability that the observation comes from the group. Computing the generalized distance requires a matrix function involving the estimated variance–covariance matrix in each of the four groups. This function involves 104 parameters for each group (13 measures of central tendency and 91 unique elements from the 13×13 variance–covariance matrix). Thus, for reasons of complexity and space, we do not offer more specific details about the discriminant functions here. For readers who are interested, we will provide the details of the discriminant functions via e-mail.

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