Meta-Analysis of High-Risk Sexual Behavior in Persons Aware and Unaware They are Infected With HIV in the United States

Implications for HIV Prevention Programs

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Objectives: To compare the prevalence of high-risk sexual behaviors in HIV+ persons aware of their serostatus with that in HIV+ persons unaware of their status in the United States and to discuss implications for HIV prevention programs.

Methods: A meta-analysis was conducted on 11 independent findings. Six findings compared HIV+ aware persons with independent groups of HIV+ unaware persons (between-group comparisons), and 5 findings compared seroconverting individuals before and after being notified of their HIV+ status (within-subject comparisons). Outcomes were self-reported unprotected anal or vaginal intercourse (UA V) during specified recall periods.

Results: The analysis integrating all 11 findings indicated that the prevalence of UA V with any partner was an average of 53% (95% confidence interval [CI]: 45%–60%) lower in HIV+ persons aware of their status relative to HIV+ persons unaware of their status. There was a 68% reduction (95% CI: 59%–76%) after adjusting the data of the primary studies to focus on UA V with partners who were not already HIV+. The reductions were larger in between-group comparisons than in within-subject comparisons. Findings for men and women were highly similar.

Conclusions: The prevalence of high-risk sexual behavior is reduced substantially after people become aware they are HIV+. Increased emphasis on HIV testing and counseling is needed to reduce exposure to HIV from persons unaware they are infected. Ongoing prevention services are needed for persons who know they are HIV+ and continue to engage in high-risk behavior.

Key Words: HIV-positive persons, HIV/AIDS, high-risk sexual behavior, HIV transmission, meta-analysis

Sexually transmitted HIV infection may stem from 2 groups of people: HIV+ persons unaware they are infected and HIV+ persons aware of their infection status. The Centers for Disease Control and Prevention (CDC) estimates that 850,000 to 900,000 persons are living with HIV in the United States and that approximately 650,000 are aware of their status and 250,000 are not. Little is known about the relative difference between these 2 groups in exposing uninfected sex partners to HIV. A better understanding of this relative difference can help to guide public health strategies and allocation of resources to fight the HIV/AIDS epidemic in the United States.

To reduce the risk of HIV transmission, the CDC recommends a variety of interventions in medical care and community settings for those who are aware of their status. Linkage to medical care and antiretroviral therapy, which may reduce viral load and transmission risk, and ongoing behavioral interventions are important approaches for those who know they are living with HIV. To reach those who are unaware of their infection, the CDC recommends making HIV counseling and testing more accessible and acceptable for people at high risk for HIV infection. Of course, both strategic pathways are important, and prevention efforts can be informed by even roughly estimating the differences in sexual risk behaviors between awareness groups. We performed a meta-analysis of findings that compared the prevalence of unprotected anal and vaginal intercourse (UA V) between persons who were aware and unaware of their HIV infection.

METHODS

Literature Search and Study Selection

Electronic databases, including MEDLINE, PubMed, PsycINFO, AIDSLINE, and SocioFile from January 1987 through January 2004, were searched to identify relevant published articles and conference abstracts. We crossed multiple search terms (ie, keywords and medical subject headings) reflecting 2 categories: (1) HIV status (HIV, AIDS, antibody, positive, counseling, testing, and aware) and (2) sexual behavior or sexually transmitted diseases (sexual behavior, sex, unsafe, unprotected, condom, anal, vaginal, intercourse, risk, high risk, exposure, transmission, sexually transmitted disease, STD, sexually transmitted infection, STI, gonorrhea, and syphilis). Additional material was identified from reference...
lists of pertinent articles. Studies were included in the meta-
analysis if they met all the following criteria:
1. Data from the United States
2. Compared a group of HIV+ aware persons with an inde-
dependent group of HIV+ unaware persons (ie, between-group
comparison) or measured seroconverting individuals before
and after notification of HIV+ status (ie, within-subject
comparison)
3. Measured any of the following sexual behaviors during
a specified recall period:
   a. Unprotected insertive or receptive anal intercourse or
      unprotected vaginal intercourse
   b. Consistency of condom use during sexual intercourse
   c. Other sexual risk measures that combined components
      of the previous categories
4. Data were reported or available to calculate the prevalence
   of UAV (ie, 1 or more instances during the recall period)
A total of 620 abstracts were screened. Although many
studies identified in the search examined the prevalence of
sexual behavior or the effects of HIV testing and counseling,
few of the screened sources provided the specific types of
comparisons (criterion 2) needed for this meta-analysis. Four
studies9–11 published in peer-reviewed journals and 4 multisite
data sets met inclusion criteria. The 4 data sets were (1) the
Multicenter AIDS Cohort Study (MACS),12 (2) the HIV Epi-
demiology Research Study (HERS),13 (3) the Supplement to
HIV/AIDS Surveillance (SHAS phase 1, 1995–2000),14 and
(4) SHAS phase 2 (2000–2003).15 The 2 SHAS data sets were
independent (no dual participation). We obtained the data
necessary for our meta-analysis directly from the investigators.
The Women’s Interagency HIV Study (WIHS) was also eligi-
gible for inclusion but not used because it had too few
seroconversions for a meaningful analysis.

Data Abstraction
Using a standardized spreadsheet, information on the
following variables was abstracted: author(s), location and/or
setting of data collection, study period, sample characteristics
(eg, gender), sample size, type of comparison (between-group
vs. within-subject), data collection methods (self-administered
vs. interviewer-administered questionnaire), sexual behavior
measured, recall period, and findings.

The data abstraction was guided by the following rules:
1. If a study had independent samples of participants (eg, men,
   women) and reported data on each sample, we calculated an
effect size (ES) for each independent sample.5,14,15
2. To ensure independence of data in the meta-analysis, only 1
   sexual behavior measure per study was used in calculating
   the overall ES. If separate data were available for unpro-
tected insertive and receptive anal intercourse, we included
only insertive activity because it has a higher risk of
transmitting HIV when performed by an HIV+ person.16
   One study8 used a composite index (UAV or oral sex).

Calculation of Effect Size
Effect sizes were estimated with a prevalence ratio (PR).
For between-group comparisons, the HIV+ aware groups’
prevalence of UAV was divided by the HIV+ unaware groups’
prevalence of UAV, resulting in the PR. For within-subject
comparisons, PR was calculated by dividing the prevalence of
UAV at the postnotification period by the prevalence at the
prenotification period. For each type of comparison, 1−PR
was then calculated to reflect the percentage reduction in
the prevalence of UAV in aware groups relative to unaware groups
(or prenotification vs. postnotification period).

Standard meta-analytic methods were used.17,18 A
random-effects model for aggregating individual ESs was
used because it provides a more conservative estimate (than
a fixed-effects model) of the variance and generates more
accurate inferences about a population of studies beyond those
included in the review.19 We first used the natural logarithm
to obtain the log PR (lnPR) and calculated its corresponding
weight (ie, inverse variance) for each independent sample. For
within-subject comparisons, the variance of lnPR was adjusted
for nonindependence of pre- and postnotification sexual
behavior before aggregation (Appendix). To calculate the
overall ES, we multiplied each lnPR by its weight, summed the
weighted lnPR across samples, and then divided by the sum of
the weights. In presenting the results, the aggregated lnPR was
converted back to the PR by exponential function. 1−PR was
then derived, along with a 95% confidence interval (CI).

Sensitivity analyses examined the effect of outliers by
comparing the aggregated ES with estimates obtained after
iterations using k−1 findings (k = number of independent
samples). In other words, we removed a finding and calculated
the aggregated ES. We then replaced that finding, removed
another, and repeated the process. Stratified analyses were also
conducted to examine whether ESs differed by type of
comparison (between-group vs. within-subject) and gender of
participants (men vs. women).

Adjustment for HIV Serostatus of Sex Partners
The meta-analysis was conducted with and without
applying an adjustment factor to primary studies that assessed
self-reported sexual behavior with any partner.5–10,12,14 Data on
the prevalence of UAV with any partner may bias the meta-
analysis, because some people who know they are HIV+ only
have unprotected sex with partners perceived to be HIV+,20–22
The adjustment factor focused the analysis on behavior with
partners at risk for infection.

The adjustment was applied to the prevalence data of
HIV+ aware participants (or prevalence during the postnoti-
fication period) before conducting the meta-analysis. The
adjustment was not applied to the HIV+ unaware group (or
prenotification period) under the reasonable assumption that
unawareness leaves risky behavior patterns unaltered and that
persons who are unaware of their infection are not likely to be
having unprotected sex only with HIV+ partners. Accordingly,
we assume that some of their sexual activity is with persons at
risk for infection.

The empirically derived adjustment factor was calcu-
lated with data from 6 US studies conducted from 1995
to 2001 (J. L. Richardson, S. Stoyanoff, J. Milam, et al,
unpublished data, 1999)22–26 different from those in the meta-
analysis. The participants in the “adjustment studies” were all
aware of their HIV+ status and were recruited at a variety of

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locations (eg, HIV clinics, AIDS service organizations, bars, clubs). The adjustment studies contained data on self-reported UAV with any partners and with partners reported to be HIV+. The behavioral window varied (eg, past 3 months, last 2 sexual encounters). Half of the studies used self-administered surveys, and the other half used face-to-face interviews.

For each adjustment study, we first calculated the percentage of participants who engaged in UAV with any partner (factor “A”). Next, participants who engaged in those risk behaviors only with partners reported to be HIV+ were removed from the numerator. The percentage was then recalculated using all participants in the denominator to estimate the prevalence of UAV with partners at risk for infection (factor “B”). Dividing this “at-risk prevalence” (B) by the “any partner prevalence” (A) and then subtracting from 1 (ie, 1−B/A) yields the percentage reduction in the prevalence of UAV with at-risk partners relative to any partner. Calculations were performed for 3 groups to identify appropriate adjustment indices for the samples in the meta-analysis: men who have sex with men (MSM; 5 samples), men in general (4 samples that pooled MSM and heterosexual men), and women (3 samples).

The adjustment index was calculated as the unweighted average of the reductions across studies within each group. The unweighted average minimizes the influence of sample size and methodologic factors that may affect behavioral assessment. The unweighted average reduction was 43% (range: 27.3%–52.5%) for MSM, 47.5% (range: 42.0%–51.8%) for men in general, and 45.1% (range: 38.9%–56.0%) for women. These indices were applied only to studies that assessed UAV with any partner. For example, HIV+ aware MSM’s prevalence of UAV with any partner was reduced 43% to derive an estimated prevalence of UAV with at-risk partners. The adjustment factor was not applied to studies that assessed behavior with at-risk partners (study by Colfax et al,11 SHAS phase 2 data set), nor it was applied to “casual partners” (HERS data set), because many of those casual partners were probably at risk. Sensitivity analyses examined whether there were any changes in the meta-analytic results when the adjustment index was calculated as a weighted average (ie, applying an inverse variance weight to each adjustment study before averaging).

RESULTS

Eleven independent findings from 1988 through 2003 were included in the meta-analysis. Six were between-group comparisons, and 5 were within-subject comparisons. Table 1 presents the characteristics of the studies and the unadjusted findings. Every study showed that the prevalence of UAV was lower in the HIV+ aware group (or postnotification period) compared with the HIV+ unaware group (or prenotification period).

Two sets of results of the random-effects models are presented in Table 2: findings based on the unadjusted data and findings based on data adjusted to focus on at-risk sex partners. The combined ES for all 11 findings in the unadjusted model indicates that the prevalence of UAV was an average of 53% (95% CI: 45%–60%) lower in HIV+ aware persons relative to HIV+ unaware persons. The reduction was 68% (95% CI: 59%–76%) in the adjusted model (k = 11). Each of these reductions differed significantly from 0 (Z > 25, P < 0.001). In both models, the reduction was significantly larger in the between-group findings (k = 6) compared with the within-subject findings (k = 5) (unadjusted model: 7(1)2 = 38.71, P < 0.0001; adjusted model: 7(1)2 = 8.32, P < 0.01). The ESs of the men and women did not differ significantly in either model (unadjusted: 7(1)2 = 0.18, P > 0.50; adjusted: 7(1)2 = 2.47, P > 0.10).

Sensitivity Analyses

Sensitivity analyses indicated that no individual finding appreciably affected the overall (k = 11) or between-group (k = 6) ES in the two models. The ESs were affected less than ±3% (eg, absolute change from 68% to 70% reduction in the prevalence of UAV) with any single finding removed. For the unadjusted and adjusted models, the within-group ES (k = 5) changed no more than ±5% and the men’s ES (k = 7) changed no more than ±4%. There was slightly more instability in the women’s aggregated findings. The ES changed no more than ±4% in the women’s unadjusted model but changed up to 8% in the adjusted model. For example, the ES was reduced nearly 8% in the adjusted model when the SHAS phase 1 finding was removed and was increased 4% in the adjusted model when the SHAS phase 2 finding was removed. These individual findings (especially the SHAS phase 1 finding) were heavily weighted in the aggregated analysis because of large sample sizes. In summary, the overall models (k = 11) showed a high level of stability. The stability decreased only slightly when analyses were performed separately for between-group and within-subject comparisons. The stability of the men’s data exceeded the stability of the women’s data in the adjusted model.

Finally, we examined the effect of using a weighted (as opposed to an unweighted) average of the adjustment studies that focused the analysis on at-risk sex partners. The meta-analytic findings were virtually identical when using these 2 methods (absolute difference of 1% in the estimated ESs).

DISCUSSION

Our meta-analysis shows that the prevalence of high-risk sexual behavior is markedly lower in HIV+ persons aware of their seropositive status than in HIV+ persons unaware of their status. The findings of studies conducted in the United States from 1988 through 2003 were highly consistent despite methodologic differences among the investigations. A highly similar picture emerges from studies that examined STD acquisition rates between HIV-infected aware and unaware persons.27–30 These studies were not included in the meta-analysis because of the qualitatively different nature of the outcome variable and the fact that the partner serostatus adjustment could not validly be applied to those studies. Of persons presenting at an STD clinic in New Orleans (1989–1991) with a first-time diagnosis of gonorrhea, new gonorrhea diagnoses were 50% lower during 2 to 3 years of follow-up in persons aware relative to unaware that they were HIV+.27 In an STD clinic in Miami in 1988 through 1989, the percentage with a
## TABLE 1. Summary of Findings From Primary Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of Comparison</th>
<th>Sample</th>
<th>Outcome Measure and Findings</th>
<th>Reduction (%) in Prevalence of UAV in HIV+ Aware Relative to HIV+ Unaware Persons (or after vs. before HIV+ notification)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McCusker et al9</td>
<td>Between-group</td>
<td>HIV+ homosexual men recruited at a health clinic in Boston who reported engaging in unprotected anal intercourse on the initial survey (1986–1987) before getting HIV test results</td>
<td>Questionnaire self-administered at 12 months after initial survey. Percentage reporting occurrence of unprotected insertive anal intercourse with any partners in previous 6 months (among those who reported unprotected anal activity on initial survey).</td>
<td></td>
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<td></td>
<td></td>
<td>12 months later: 15 HIV+ unaware; 36 HIV+ aware</td>
<td>HIV+ unaware: 80% with any partner. HIV+ aware: 33% with any partner.</td>
<td>59%</td>
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<tr>
<td></td>
<td></td>
<td>203 HIV+ unaware; 31 HIV+ aware for 6 months or more</td>
<td>HIV+ unaware: 37% with any partner. HIV+ aware: 13% with any partner.</td>
<td>65%</td>
</tr>
<tr>
<td>SHAS14</td>
<td>Between-group</td>
<td>HIV+ men and women surveyed in 12 cities or states in the United States from January 1995 to December 2000 (SHAS phase 1)</td>
<td>Interviewer-administered questionnaire. The recall window for sexual behavior was the past 12 months. Assessment of anal intercourse did not distinguish between insertive or receptive positions. Data were not available on the perceived HIV status of sex partners. We calculated the percentage reporting occurrence of UAV with any partners in the past 12 months.</td>
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<td></td>
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<td>169 HIV+ men who learned status &lt;1 month before survey (unaware); 6934 HIV+ men who learned status 13+ months before survey (aware)</td>
<td>Men: HIV+ unaware: 68% with any partner. HIV+ aware: 25% with any partner.</td>
<td>63%</td>
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<td></td>
<td>67 HIV+ women who learned status &lt;1 month before survey (unaware); 2249 HIV+ women who learned status 13+ months before survey (aware)</td>
<td>Women: HIV+ unaware: 81% with any partner. HIV+ aware: 33% with any partner.</td>
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<tr>
<td>SHAS15</td>
<td>Between-group</td>
<td>HIV+ men and women surveyed in 19 cities or states in the United States from May 2000 to December 2003 (SHAS phase 2). Participants in SHAS phase 2 did not participate in SHAS phase 1 described previously.</td>
<td>Interviewer-administered questionnaire. Measured sexual behavior in most recent sexual encounter with steady and/or other partner. Anal intercourse distinguished between insertive and receptive positions. Data on the perceived HIV status of partners were available. We calculated the percentage of men reporting UAV with an at-risk partner (ie, HIV+ or unknown serostatus partner) and the percentage of women reporting UAV with an at-risk partner.</td>
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<tr>
<td></td>
<td></td>
<td>334 HIV+ unaware; 2335 HIV+ aware</td>
<td>Men: 334 HIV+ unaware: 39% with at-risk partner. HIV+ aware: 16% with at-risk partner.</td>
<td>59%</td>
</tr>
<tr>
<td></td>
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<td>106 HIV+ unaware; 883 HIV+ aware</td>
<td>Women: 106 HIV+ unaware: 63% with at-risk partner. HIV+ aware: 28% with at-risk partner.</td>
<td>56%</td>
</tr>
<tr>
<td>Cleary et al8</td>
<td>Within-subject</td>
<td>153 HIV+ male and 43 HIV+ female blood donors from New York who gave blood between 1986 and 1988</td>
<td>Self-administered questionnaire. Percentage reporting occurrence of UAV or oral sex with any partners in the 7 days before notified HIV+ and in the 7–14 days after notification.</td>
<td></td>
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<td></td>
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<td></td>
<td>Men: Before: 68% with any partner. After: 40% with any partner.</td>
<td>41%</td>
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<td></td>
<td></td>
<td></td>
<td>Women: Before: 58% with any partner. After: 38% with any partner.</td>
<td>34%</td>
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</table>
newly diagnosed STD declined 11% in the 6 months after they learned they had HIV infection compared with the 6 months before their HIV+ diagnosis.29 STD studies conducted in other countries show even stronger findings. Of HIV+ persons presenting at a genitourinary clinic in London in 1994, the prevalence of diagnosed STDs was 73% lower in the year after HIV diagnosis than in the year before.29 Finally, of HIV+ women presenting at prenatal and pediatric clinics in Rwanda (1988–1989), the prevalence of clinically diagnosed gonorrhea was 54% lower in the year after than the year before HIV diagnosis.30

In our analysis, the between-group and within-subject comparisons demonstrated significant reductions in self-reported UAV, although the reduction was higher in the between-group design. One explanation is that a group of HIV+ aware persons may differ from a group of HIV+ unaware persons on other variables associated with unsafe sex, potentially accentuating the difference between the groups. For example, on average, people who are unaware they are infected with HIV are likely to be younger than people who are aware they are HIV+.31 The prevalence of unsafe sex has been found to be higher among younger than older MSM.31,32

Another issue concerns whether behavior change in HIV+ aware persons is maintained over time. Additional analysis of the SHAS phase 2 data set showed that the prevalence of UAV in the most recent encounter with an at-risk partner was remarkably similar among subgroups of HIV+ aware men who differed in length of time they knew they were HIV+ (range: 1–24 months [17%], 25–48 months [16%], 49–72 months [17%], 73–96 months [14%], and >96 months [13%]). The prevalence was 39% in HIV+ unaware men. A highly similar pattern was seen in HIV+ aware women in SHAS phase 2 and in men and women in SHAS phase 1. One other study not included in the meta-analysis because it assessed sexual behavior of HIV+ aware persons but not HIV+ unaware persons did not confirm this pattern. The prevalence of UAV was higher in persons aware of their infection for 5 or more years compared with those diagnosed more recently.33 These mixed results make it difficult to reach conclusions at this time about the stability of behavior change after being diagnosed HIV+. This issue merits attention in future research.

Our meta-analytic findings must be viewed within the context of the methodologic limitations of the primary studies. First, the studies used self-reported sexual behavior. Self-reports are open to socially desirable responding, and some HIV+ aware persons may underreport unprotected sex with at-risk partners.34 US studies of HIV serodiscordant homosexual35 and heterosexual36 couples demonstrate high levels of agreement (approximately 90%) between couple members in self-reports of condom use, however. We were not able to gauge the level of partner agreement in the studies analyzed.
TABLE 2. Effect Sizes of the Random-Effects Models

<table>
<thead>
<tr>
<th>ES: Reduction (%) in Prevalence of UAV in HIV+ Aware Relative to HIV+ Unaware Persons and 95% CIs</th>
<th>Model Based on Unadjusted Data From Primary Studies</th>
<th>Model Based on Adjusted Data From Primary Studies*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All findings pooled (k = 11)</td>
<td>53 (45, 60)</td>
<td>68 (59, 76)</td>
</tr>
<tr>
<td>Between-group comparison (k = 6)</td>
<td>60 (58, 63)</td>
<td>72 (59, 80)</td>
</tr>
<tr>
<td>Within-subjects comparison (k = 5)</td>
<td>37 (27, 46)</td>
<td>64 (57, 71)</td>
</tr>
<tr>
<td>Male participants (k = 7)</td>
<td>53 (40, 63)</td>
<td>70 (58, 79)</td>
</tr>
<tr>
<td>Female participants (k = 4)</td>
<td>55 (48, 62)</td>
<td>66 (44, 80)</td>
</tr>
</tbody>
</table>

All ESs are significantly different from zero (p < 0.01) based on Z test.

*For primary studies that measured sexual behavior with any partners, the data from the HIV+ aware group (or the postnotification period) were adjusted to focus on partners at risk for HIV infection (see Methods section). The adjustment was applied to 7 of 11 findings (4 of 6 between-group findings and 3 of 5 within-subject findings; 5 of 7 for male subjects and 2 of 4 for female subjects).

k indicates number of findings entered into the meta-analysis.

here. Second, we were not able to examine the number of sex partners placed at risk by HIV+ aware and HIV+ unaware persons, because those data were not available in the literature. The difference between these groups in the prevalence of UAV may not necessarily reflect the magnitude of difference in the number of sex partners placed at risk. Our analysis, however, provides a starting point for a more refined model when additional data become available. Third, the difference in the prevalence of UAV between HIV+ aware and HIV+ unaware persons may not reflect differences in HIV transmission rates between groups. Actual transmission depends on a host of biologic factors. For example, transmission risk is increased when an individual who is the source of exposure is in the primary HIV infection stage,37 has a high viral load,4,38 or has an STD.38,39 These factors would elevate transmission risk more from HIV+ unaware than HIV+ aware persons, because unaware persons as a group are more likely to be in the primary infection stage, to have a higher viral load because they are not in medical care, and to have an STD.27–30

Our findings reinforce the need for a multidimensional approach to HIV prevention.1 Resources and efforts are needed to make HIV testing opportunities more accessible (eg, rapid tests) and to reduce barriers to testing so that infected persons learn their status. Public health campaigns targeting young MSM, especially young MSM of color, are urgently needed, because many of these men are unaware they are infected.40 Promising but underused methods for reaching such persons include offering HIV testing routinely in all health care settings in high HIV prevalence areas5; offering testing at venues that attract high-risk persons; adding HIV testing capacity to all effective educational outreach and risk reduction interventions41; and gaining the cooperation of current HIV+ aware persons to reach members of their sexual and social networks for HIV testing, counseling, and care if needed.52

Clearly, HIV counseling and testing alone are not enough to control the HIV epidemic. Behavioral interventions for people aware they are infected and for those at high risk for HIV are needed. Those interventions may reduce sexual risk behavior by as much as 30% to 40%.41–45 For those aware that they are HIV+, the challenge is to find settings and approaches for delivering prevention programs to this population over time. The HIV clinic is an ideal setting for offering prevention messages and counseling to HIV+ persons and for integrating prevention with routine medical care.46 Such counseling from HIV providers has been shown to be efficacious in reducing unprotected intercourse in HIV+ patients.44 Other promising interventions have been delivered by HIV+ peers in community settings.47 Assisting HIV+ people to establish social networks that encourage risk reduction and provide social support for seeking medical care and adhering to treatment regimens has also shown promise in demonstration projects.48 Together, these approaches may contribute to more rapid control of the HIV epidemic in the United States and elsewhere.

ACKNOWLEDGMENTS

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REFERENCES


36. Marks G, Burris S, Peterman TA. Reducing sexual transmission of HIV among HIV-infected persons. The other within-subject studies did not 452
provide individual level data to calculate the before and after correlations, so we imputed values based on the MACS ($r = 0.49$) and HERS ($r = 0.20$). The MACS value was used for the subgroup of men in the studies by Cleary et al\textsuperscript{8} and Colfax et al.\textsuperscript{11} The HERS value was used for the subgroup of women in the study by Cleary et al.\textsuperscript{8}

We performed a sensitivity analysis to examine how much the aggregated PRs and CIs changed when these correlation values were increased or decreased by 0.20 correlation units of the original imputed values (ie, the MACS value was changed by ±0.20, the HERS value was changed by ±0.20). This ±0.20 represents a reasonable boundary for capturing the correlation between before and after behavior in the population. The aggregated PR changed half of 1% or less in each direction, and the width of the CIs increased or decreased only 4 units (percentage points) from the original. Thus, the imputation did not unduly affect the results.