Estimating adult HIV prevalence in the UK in 2003: the direct method of estimation

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Table 3 is available on our website.

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Background: Estimates of the total number of prevalent HIV infections attributable to the major routes of infection make an important contribution to public health policy, as they are used for planning services.

Methods: In the UK, estimates were derived through the "direct method" which estimated the total number of diagnosed and undiagnosed HIV infections in the population. The direct method has been improved over a number of years since first used in 1994, as further data became available such as the inclusion of newly available behavioural survey data both from the National Survey of Sexual Attitudes and Lifestyles (Natsal 2000) and community surveys of men who have sex with men (MSM). These data were used to re-estimate numbers of people unaware of their infection and provided ethnic breakdowns within behavioural categories. The total population was divided into 10 mutually exclusive behavioural categories relevant to HIV risk in the UK—for example, MSM and injecting drug users. Estimates of the population size within each group were derived from Natsal 2000 and National Statistics mid-year population estimates. The total number of undiagnosed HIV infections was calculated by multiplying the undiagnosed HIV prevalence for each group, derived from the Unlinked Anonymous HIV Prevalence Monitoring Programme surveys (UAPMP), by the population size. These estimates were then added to the prevalent diagnosed HIV infections within each group derived from the national census of diagnosed HIV infections, the Survey of Prevalent HIV Infections Diagnosed (SOPHID). The estimates were then adjusted to include all adults in the UK. Because undiagnosed HIV prevalence estimates were not available for each of the behavioural categories, the UAPMP prevalence estimates were adjusted using available data to provide the best estimates for each group.

Results: It is estimated that 53 000 individuals are infected with HIV in the UK in 2003, of whom 27% were unaware of their infection. Of the total of 53 000, an estimated 26 000 were among heterosexually infected and 24 500 among MSM.

Conclusion: The direct method uses an explicit framework and data from different components of the HIV surveillance system to estimate HIV prevalence in the UK, allowing for a comprehensive picture of the epidemic.

Estimates of the total number of prevalent HIV infections attributable to the major routes of infection make an important contribution to public health policy. They can be used for the planning of healthcare services and for contributing to estimates of the future numbers with severe HIV infection used for planning health promotion programmes.¹ It is difficult to assess the extent of undiagnosed HIV infection in the population as the motivation behind testing is complex and individuals may be influenced by a range of behavioural and policy factors.² This challenge has led to the development of surveillance methods, which are based on the understanding of the problem associated with estimating HIV prevalence and the availability of data in the UK. The unlinked anonymous (UA) methodology approach based on specimens routinely gathered for other reasons is particularly useful in contributing to the surveillance of HIV infection in the subgroups of the population regardless of their HIV testing behaviour. UA testing allows the measurement of HIV prevalence both clinically diagnosed and undiagnosed.^{3,4}

Estimates of prevalent HIV infections have been calculated using a "direct method" previously in the UK. Population estimates derived from the National Survey of Sexual Attitudes and Lifestyles (Natsal) were combined with prevalence data from the Unlinked Anonymous HIV Prevalence Monitoring Programme (UAPMP) to produce estimates of the numbers of adults infected and alive in the population, through a series of assumptions based on

available data. The method was first developed in 1994,⁵ and further developed in 1997⁶ to use a combination of data from different sources and estimate prevalent undiagnosed infections.

A working group in the UK was recently convened to develop the estimation method focusing on the potential source of error around the necessary assumptions. This paper presents an extension of the previous methods to include evidence based adjustments using newly available data such as the inclusion of newly available behavioural survey data both from Natsal 2000 and community surveys of gay men. The methodology takes account of differences in HIV prevalence between subgroups within the major behavioural categories.

METHODS

The direct method estimates the total number of adults aged 16 years or more infected with HIV in the population. The method is based on the principle of combining the total of the diagnosed HIV infections in the UK with estimates of the total undiagnosed prevalent infections. The number of prevalent diagnosed HIV infections for each major behavioural category in the UK were taken to be the number of

Abbreviations: HAART, highly active antiretroviral therapy; IDU, injecting drug user; MSM, men who have sex with men; Natsal, National Survey of Sexual Attitudes and Lifestyles; SOPHID, Survey of Prevalent HIV Infections Diagnosed; UAPMP, Unlinked Anonymous HIV Prevalence Monitoring Programme.

reported infections from the national Survey of Prevalent HIV Infections Diagnosed (SOPHID) (box 1), adjusted for under-reporting and for failure to access services in a given year.⁷ The total number of undiagnosed infections can be expressed in terms of the age and region specific undiagnosed infections in different behavioural categories through the expression

$$\sum_{g=1}^G \sum_{r=1}^R \sum_{i=1}^I \rho_{irg} \pi_{irg}^U N_{ir}$$

where ρ_{irg} represents the size (as a proportion of the total population) of the subpopulation in behavioural category g , age group i , and region r ; π_{irg}^U indicates the corresponding prevalence of undiagnosed infection; and N_{ir} is the population in age group i in region r .

In order to estimate this number, the total population was divided into 10 hierarchical ($G = 10$), mutually exclusive behavioural categories relevant to HIV risk (for example, MSM, injecting drug users (IDU), heterosexuals attending STD clinics). Estimates of the population size for each behavioural category g , in the i th age groups ($I = 3$; $i = 1$: 16–24 years; $i = 2$: 25–34 years; $i = 3$: 35–44 years) and the r th region ($R = 3$; $r = 1$: inner London; $r = 2$: outer London; $r = 3$: rest of Britain) were derived using the proportion of people with these characteristics from Natsal 2000 (box 1)¹² and Census 2001 mid-year population estimates N .¹⁴ The number of HIV positive people with undiagnosed infection in each subpopulation was then estimated by multiplying the

size of each subpopulation by the corresponding estimate of π_{irg}^U (see below).

The behavioural categories and undiagnosed prevalence π_{irg}^U definitions are summarised in table 1 and detailed below. The UA surveys represent four groups: MSM and heterosexuals attending STD clinics, IDUs attending specialist centres, and the general heterosexual population measured through the survey of pregnant women. The number of diagnosed HIV positive individuals within each category from SOPHID, were excluded from the behavioural category population. Estimates of π_{irg}^U ($i = 1, 2, 3$; $r = 1, 2, 3$; $g = 1, \dots, 10$) were derived by adjusting the undiagnosed HIV prevalence obtained from the UAPMP (box 1).¹⁵ The adjustments made to the UAPMP undiagnosed prevalence are detailed in table 1. The estimated population size for inner and outer London were adjusted for cross boundary flow from area of residence for STD clinic attendance, as population data were collected by residence and undiagnosed HIV prevalence data by area of STD clinic. This age specific adjustment was calculated using diagnosed HIV infections in each behavioural category from SOPHID, comparing area of residence with area of treatment.

The resulting estimates of the number of undiagnosed HIV infections were finally added to the number of diagnosed HIV infections from SOPHID producing an estimate of total prevalent HIV infections within each behavioural category. As the undiagnosed estimates were only for adults aged 16–44 in Britain, they were then scaled up to include all adults in the UK.

Estimating undiagnosed HIV prevalence by behavioural categories

Men who have sex with men

The population sizes for three behavioural categories of MSM were calculated using the proportion of men with the following behavioural characteristics from Natsal 2000 and census mid-year population estimates, stratified by area and age group ρ_{rgi} (table 1). These were:

- current MSM; defined as men who have had any genital contact with a man in the past five years, and divided according to
 - current MSM who attended an STD clinic in the past five years
 - current MSM who did not attend an STD clinic in the past five years
- past MSM; defined as men who have had a male sexual partner more than five years ago but not in the past five years (table 1). However as this definition also includes MSM at low risk of HIV infection, the population group definition was confined to include only those men who had anal sex with a man more than five years ago.

The undiagnosed prevalence estimate was derived from the UAPMP survey of 15 STD clinics surveyed in England and Wales, and 11 in Scotland. This prevalence π_{irMSM}^U was adjusted first for geographic coverage, and secondly to produce specific prevalence estimates derived for three behavioural categories of MSM $\pi_{irMSM-STD}^U$, $\pi_{irMSM-nonSTD}^U$, $\pi_{irPAST-MSM}^U$ which represent varying levels of HIV risk (table 1).

Each adjusted undiagnosed prevalence estimate π_{irMSM}^U was multiplied by the estimated population sizes of MSM $\rho_{irMSM} N_{irmen}$.

Geographic adjustments

The majority of the UAPMP STD survey clinics in Greater London are in inner London. Given the greatly increased

Box 1 Data sources for direct method of estimation

Survey of prevalent HIV infections diagnosed (SOPHID)⁷

SOPHID is an annual census of all individuals with diagnosed HIV infections seen for treatment and care in the past year in England, Wales, and Northern Ireland. HIV positive individuals in Scotland are monitored through CD4 count surveillance. The numbers of prevalent diagnosed HIV infected individuals in Scotland were provided by the Health Protection, Scotland.

Unlinked anonymous HIV prevalence monitoring programme (UAPMP)^{8–11}

A national UAPMP has been ongoing since 1990. UA testing relies on the availability of residual specimens, collected for clinical testing for other reasons. These specimens are included in surveys and tested for HIV antibodies, following anonymising and unlinking from all identifiers. A number of surveys are carried out as part of the programme. These are in subpopulations collecting blood specimens including STD clinic attendees and pregnant women. Oral fluid samples were also collected through voluntary anonymous surveys of injecting drug users, and community surveys of MSM.

National survey of sexual attitudes and lifestyles (Natsal 2000)^{12 13}

Natsal 2000 is a stratified probability sample survey of the general population of 11 161 men and women aged 16–44 years resident in Britain. Further details have been published elsewhere. The study was undertaken between 1999 and 2001 and the response rate was 65.4%. Participants were interviewed using a combination of computer assisted face-to-face interview and computer assisted self-interview for collecting more sensitive questions and included a range of questions on sexual practices, behaviours, and attitudes.

Table 1 Hierarchical behavioural categories* and undiagnosed HIV prevalence definitions of the population of undiagnosed HIV infected individuals in the UK in 2003

	Behavioural categories	ρ_g definition	π_{ig}^U source	π_{ig}^U definition	Adjustment made to UAPMP undiagnosed prevalence	Source of adjustments
g1	Current MSM, STD clinic attendees	Men reporting a male sexual partner in the past five years who have been to an STD clinic in the past five years	UAPMP STD clinic survey	HIV prevalence among MSM attending STD clinic not clinically diagnosed	1.0 0.29	SOPHID, ⁷ ratio of inner: outer London population rate of diagnosed HIV cases ONS, ¹⁴ ratio of urban: rural population rate
			Inner London Outer London		0.78	
			Rest of Britain			
g2	Current MSM not STD clinic attendees	Men reporting a male sexual partner in the past five years who have not been to an STD clinic in the last five years	UAPMP STD clinic survey	HIV prevalence among MSM attending STD clinic not clinically diagnosed adjusted for differential risk for HIV of non-STD attendees (derived from the ratio of prevalence in STD attendees compared to non-attendees; Dodds <i>et al</i> ¹¹ and the ratio of the proportion of STD attendees who have ever had an STI to non-STD attendees, Johnson <i>et al</i> ¹²)	0.79	Dodds <i>et al</i> 2004 ¹¹ ratio of undiagnosed prevalence in STD attenders in last year compared to non-STD attenders Dodds <i>et al</i> 2004, (as above) + SOPHID, ratio of inner: outer population rate of diagnosed HIV cases Johnson <i>et al</i> , ¹² ratio of proportion who have ever had an STI of non-STD attenders in the past 5 years to men who have attended in the past 5 years + ONS, ratio urban: rural population rate UA IDU survey, ¹⁵ proportion of HIV infections undiagnosed
			Inner London		0.79*0.29	
			Outer London		0.40*0.78	
			Rest of Britain			
g3a	Current male IDU	Men reporting injecting drugs in the last five years where not a current MSM	UAPMP IDU survey	HIV prevalence among men attending specialist centres for IDU, not clinically diagnosed	0.32	UA IDU survey, proportion of HIV infections undiagnosed
g3b	Current female IDU	Women reporting injecting drugs in the last five years	UAPMP IDU survey	HIV prevalence among women attending specialist centres for IDU not clinically diagnosed	0.32	
g4	Past MSM	Men reporting a male anal sexual partner more than five years ago, no male sexual partner in the past five years and not a current IDU	UAPMP STD clinic survey	HIV prevalence among men not clinically diagnosed adjusted for differential risk for HIV of men not had sex with a man for more than 5 years (derived from the number of lifetime sexual partners of current MSM compared to past MSM, and the odds of having a previous STI by numbers of partners; Fenton <i>et al</i> ¹⁶)	0.1	Fenton <i>et al</i> 2005, ¹⁶ Natsal 2000, odds of previous STI with 10+ lifetime partners compared to one sexual partner
g5a	Past male IDU	Men reporting injecting drugs but who last injected more than five years ago where not a current MSM and not a past MSM	UAPMP IDU survey	HIV prevalence among men attending specialist centres for IDU who last injected more than five years ago, not clinically diagnosed	0.03	UA IDU survey, proportion of HIV infections undiagnosed

Table 1 Continued

Behavioural categories	p_g definition	π_{ig}^U source	π_{ig}^U definition	Adjustment made to UAPMP undiagnosed prevalence	Source of adjustments
g5b Past female IDU	Women reporting injecting drugs but who last injected more than five years ago	UAPMP IDU survey	HIV prevalence among women attending specialist centres for IDU who last injected more than five years ago not clinically diagnosed.	0.03	UA IDU survey, proportion of HIV infections undiagnosed
g6a Current heterosexual males, STD clinic attendees, black African	Men, non-virgin, reporting STD clinic attendance in past five years and never IDU and never had a same sex partner, of black-African ethnicity	UAPMP STD clinic survey of men born in sub-Saharan Africa	HIV prevalence among men born in sub-Saharan Africa attending STD clinics, not clinically diagnosed		
		Inner London Outer London		1.0 0.51	SOPHID, ratio of inner:outer London population rate of diagnosed HIV cases ONS, ratio urban:rural population rate
		Rest of Britain		0.78	
g7a Current heterosexual males, STD clinic attendees, not black African	Men, non-virgin, reporting STD clinic attendance in past five years, never IDU, who have never had a same sex partner and not of black-African ethnicity	UAPMP STD clinic survey of men not born in sub-Saharan Africa	HIV prevalence among men not born in sub-Saharan Africa attending STD clinics, not clinically diagnosed.		
		Inner London Outer London		1.0 0.51	SOPHID, ratio of inner:outer London population rate of diagnosed HIV cases ONS, ratio urban:rural population rate
		Rest of Britain		0.78	
g6b Current heterosexual females, STD clinic attendees, black African	Women, non-virgin, reporting STD clinic attendance in past five years but never IDU, of black-African ethnicity	UAPMP STD clinic survey of women born in sub-Saharan Africa	HIV prevalence among women born in sub-Saharan Africa attending STD clinics and not clinically diagnosed		
		Inner London Outer London		1.0 0.51	SOPHID, ratio of inner:outer London population rate of diagnosed HIV cases ONS, ratio urban:rural population rate
		Rest of Britain		0.78	
g7b Current heterosexual females, STD clinic attendees, not black African	Women, non-virgin, reporting STD clinic attendance in past five years but never IDU, not of black-African ethnicity	UAPMP STD clinic survey of women not born in sub-Saharan Africa	HIV prevalence among women not born in sub-Saharan Africa attending STD clinics and not clinically diagnosed		
		Inner London Outer London		1.0 0.51	SOPHID, ratio of inner:outer London population rate of diagnosed HIV cases ONS, ratio urban:rural population rate
		Rest of Britain		0.78	
g8a Lower risk heterosexual males, black African	All men, non-virgins, and are not in any of the above categories, of black-African ethnicity	UAPMP DBS survey of women born in sub-Saharan Africa	HIV prevalence of pregnant women born in sub-Saharan Africa (adjusted for fertility (Nicoll <i>et al</i> ⁷ & Cliffe <i>et al</i> ⁸), known positives, and overlap with STD attendance and IDU (Johnson <i>et al</i> ²))		
		Inner London		0.68*0.8/1.03	UA DBS survey, ¹⁵ undiagnosed proportion prenatal + Natsal 2000, overlap of IDUs and STD attendance + Nicoll <i>et al</i> 1998, ¹⁷ relative inclusion ratio (fertility adjustment)
		Outer London		0.68*0.8/1.03	
		Rest of Britain		0.65*0.8/0.8	

Table 1 Continued

Behavioural categories	p_g definition	π_{irg}^U source	π_{irg}^U definition	Adjustment made to UAPMP undiagnosed prevalence	Source of adjustments
g9a Medium risk heterosexual males, not black African	All men, non-virgins, attended an STD clinic more than 5 years ago and are not in any of the above categories and not of black-African ethnicity	UAPMP DBS survey of women not born in sub-Saharan Africa	HIV prevalence of pregnant women not born in sub-Saharan Africa (adjusted for fertility ^{17 18} known positives, and overlap with STD attendance and IDU ¹² and proportion of STD clinic attendance more than 5 years ago (Gilbart <i>et al</i> ¹⁹))		
		Inner London		0.68*0.8/1.03*0.33	UA DBS survey, ¹⁵ undiagnosed proportion prenatal + Natsal 2000, overlap of IDUs and STD attendance + Nicoll <i>et al</i> 1998, ¹⁷ relative inclusion ratio (fertility adjustment) + Gilbart <i>et al</i> 2006, ¹⁹ proportion attended an STD clinic more than 5 years ago
		Outer London		0.68*0.8/1.03*0.33	
		Rest of Britain		0.65*0.8/0.8*0.33	
g10a Lower risk heterosexual males, not black African	All men non-virgins and are not in any of the above categories and not of black-African ethnicity	UAPMP DBS survey of women not born in sub-Saharan Africa	HIV prevalence of pregnant women not born in sub-Saharan Africa (adjusted for fertility ^{17 18} known positives, and overlap with STD attendance and IDU ¹² and proportion never attended an STD clinic ¹⁹)		
		Inner London		0.64*0.8/1.03*0.67	UA DBS survey, ¹⁵ undiagnosed proportion prenatal + Natsal 2000, overlap of IDUs and STD attendance + Nicoll <i>et al</i> 1998, ¹⁷ relative inclusion ratio (fertility adjustment) + Gilbart <i>et al</i> 2006, ¹⁹ proportion never attended an STD clinic
		Outer London		0.64*0.8/1.03*0.67	
		Rest of Britain		1.00*0.8/0.8*0.67	
g8b Lower risk heterosexual females, black African	All women, non-virgins, and are not in any of the above behavioural categories, of black-African ethnicity	UAPMP DBS survey of women born in sub-Saharan Africa	HIV prevalence of pregnant women born in sub-Saharan Africa (adjusted for fertility, known positives, and overlap with STD attendance and IDU)		
		Inner London		0.61*0.8/1.03	UA DBS survey, undiagnosed proportion pre-natal + Natsal 2000, overlap of IDU and STD attendance + Nicoll <i>et al</i> 1998, relative inclusion ratio (fertility adjustment)
		Outer London		0.61*0.8/1.03	
		Rest of Britain		1.00*0.8/0.8	
g9b Medium risk heterosexual females, not black African	All women, non-virgins, who attended an STD clinic more than 5 years ago and are not in any of the above behavioural categories and not of black-African ethnicity	UAPMP DBS survey of women not born in sub-Saharan Africa	HIV prevalence of pregnant women not born in sub-Saharan Africa (adjusted for fertility, known positives, and overlap with STD attendance and IDU and proportion of STD clinic attendance more than 5 years ago)		
		Inner London		0.64*0.8/1.03*0.33	UA DBS survey, undiagnosed proportion prenatal + Natsal 2000, overlap of IDU and STD attendance + Nicoll <i>et al</i> 1998, relative inclusion ratio (fertility adjustment)
		Outer London		0.64*0.8/1.03*0.33	
		Rest of Britain		1.00*0.8/0.8*0.33	

Table 1 Continued

Behavioural categories	p_g definition	π_{irg}^U source	π_{irg}^U definition	Adjustment made to UAPMP undiagnosed prevalence	Source of adjustments
g10b Lower risk heterosexual females, not black African	All women, non-virgins, and are not in any of the above behavioural categories, not of black-African ethnicity	UAPMP DBS survey of women not born in sub-Saharan Africa	HIV prevalence of pregnant women not born in sub-Saharan Africa (adjusted for fertility, known positives, and overlap with STD attendance and IDU and proportion who never attended an STD clinic)		+ Gilbert <i>et al</i> 2006, proportion attended an STD clinic more than 5 years ago UA DBS survey, undiagnosed proportion prenatal
		Inner London		0.64*0.8/1.03*0.67	+ Natsal 2000, overlap of IDU and STD attendance
		Outer London		0.64*0.8/1.03*0.67	+ Nicoll <i>et al</i> 1998, relative inclusion ratio (fertility adjustment)
		Rest of Britain		1.00*0.8/0.8*0.67	+ Gilbert <i>et al</i> 2006, proportion never attended an STD clinic

*All groups are mutually exclusive.

incidence of HIV in inner London, using this undiagnosed HIV prevalence for the population attending STD clinics for all of London would lead to an overestimate of undiagnosed HIV prevalence in outer London. An adjustment factor was calculated using the ratio of the rate per 1000 population of diagnosed HIV infection in MSM in inner London compared to outer London. This assumes that the ratio of the diagnosed population rate receiving treatment in inner compared to outer London will be similar to the ratio of undiagnosed infections resident in inner London compared to outer London. Outside London the UAPMP STD clinics surveyed were in urban areas, and so to adjust the prevalence used for all of the rest of Britain, the ratio of the HIV diagnosed rate per 1000 population in urban compared to rural was used to adjust the total UAPMP undiagnosed HIV prevalence.

Behavioural category adjustments

The UAPMP undiagnosed HIV prevalence estimates π_{irMSM}^U were also adjusted for the different levels of HIV risk within the three behavioural categories of MSM (table 1). Current MSM who had not attended an STD clinic in the past five years would be expected to have a lower undiagnosed HIV prevalence than men that had attended.¹¹ To derive an undiagnosed HIV prevalence for this group, data from two behavioural surveys were used. The ratio of the difference in HIV prevalence between MSM who had not been to an STD clinic in the past year, and MSM who had, obtained from a community recruited sample of MSM for London,¹¹ was used as an adjustment to the undiagnosed HIV prevalence for London (table 1). The ratio of the proportion of men who had ever had a sexually transmitted infection (STI) but had not attended an STD clinic in the past five years, compared to men who had attended in the past five years derived from Natsal 2000 was used to adjust the prevalence for the rest of Britain (table 1). To determine the adjustment to be made to the undiagnosed HIV prevalence estimate for the past MSM category, the lifetime numbers of sexual partners of men in this behavioural category were compared to the lifetime numbers of sexual partners for current MSM using Natsal 2000. The majority of past MSM (83%) had one or two lifetime male partners compared to only 26% of current MSM, and none of the past MSM had five or more lifetime

partners. Risk of an STI is very strongly associated with the number of sexual partners in the past five years. Natsal 2000¹⁶ found the adjusted odds ratio of having a previous STI in men ranged from 7 with 5–9 partners to 18 with ≥ 10 partners. Using this as guidance, the UAPMP undiagnosed HIV prevalence was reduced to one tenth, reflecting the lifetime numbers of sexual partners in the past MSM behavioural category (table 1).

Injecting drug users

The population sizes for two categories of IDUs were calculated using the proportion of men and women with the following behavioural characteristics and census mid-year population estimates. These were stratified by area and age group (table 1) excluding individuals already assigned to previous categories. These were:

- current IDUs; defined as men and women who had injected drugs in the past five years.
- past IDUs; defined as men and women who had injected drugs more than five years ago.

These were then multiplied by an adjusted undiagnosed HIV prevalence π_{irIDU}^U derived from the UAPMP IDU survey (table 1).

Adjustments to undiagnosed prevalence estimates in IDU

The HIV prevalence estimate from the UAPMP survey of IDUs attending services was used for current IDU, adjusted for the overall proportion of infections diagnosed collected in the UAPMP. The same HIV prevalence estimate was used for past IDU, although it was assumed that a greater proportion of infections would be diagnosed than in current IDU.

Heterosexual men and women

The population size for five behavioural categories of heterosexual men and women were calculated using the proportion of individuals p_{irg} with the following behavioural characteristics (from Natsal 2000) and census mid-year population estimates N_{ir} , stratified by area and age group (table 1), excluding those already assigned to the above

categories. These were heterosexual men and women; defined as individuals who ever had sex and had:

- attended an STD clinic in the past five years, with African ethnicity.
- attended an STD clinic in the past five years, not with African ethnicity
- not attended an STD clinic in the past five years, with African ethnicity
- not attended an STD clinic in the past five years, not with African ethnicity.

Adjustments to the undiagnosed prevalence estimates in heterosexuals

The UAPMP STD undiagnosed HIV prevalence (age, area, gender, and country of birth African/non-African specific) was used for all heterosexuals who had attended an STD clinic in the past five years. The undiagnosed HIV prevalence from the UAPMP surveys of pregnant women (by African/non-African ethnicity) was used for all other heterosexuals who had not attended an STD clinic in the past five years (table 1). The undiagnosed HIV prevalence π_{irg}^U was calculated through adjustment of the UAPMP prevalence by the proportion of HIV infections in pregnant women that were diagnosed during antenatal care and were undiagnosed before pregnancy. In the UK all pregnant women are offered and recommended an HIV test and it is estimated that 92% are diagnosed before giving birth. The π_{irg}^U was also adjusted to account for the differential fertility and HIV prevalence of African women, and for the differential fertility of HIV positive women—that is, the relative inclusion ratio within the UAPMP pregnant women survey, making the π_{irg}^U more representative of all heterosexual women using an adjustment previously derived.¹⁷ The π_{irg}^U was finally adjusted for the overlap between categories, assuming that a proportion of the HIV positive pregnant women will also be STD clinic attendees or IDU, thus reducing the prevalence by these proportions (table 1). However the overlap between HIV positive pregnant women and STD clinic attendance is likely to be higher than the overlap among HIV negative women.¹⁹ Within the low risk heterosexuals, the low risk who were not African and not an STD clinic attendee in past five years were further divided into

- no STD clinic attendance in past five years but did attend more than five years ago and not African ethnicity

- never attended an STD clinic and not African ethnicity.

The denominator was divided according to STD clinic attendance more than five years ago and the undiagnosed HIV prevalence was further adjusted to account for the proportion of HIV infected heterosexuals with no major risk that reported STD clinic attendance.¹⁹

Blood factors

It was assumed that all HIV infections transmitted through blood or blood products were diagnosed and so no estimates of undiagnosed HIV infections were calculated.

Statistical adjustments

HIV prevalence estimates from the UAPMP surveys were adjusted using logistic regression analysis in STATA 7.0 fitting trends to the various datasets. Smoothed estimates of behaviours from Natsal 2000 were used, derived by predicting from a multinomial logistic regression model with main effects for age group and region.

Scaling up to all adults in the UK

Natsal 2000 sampled adults aged 16–44 years in Britain and thus the undiagnosed estimate was generated for these age groups and for Britain only. Numbers of undiagnosed infections for Northern Ireland were estimated using exposure group specific factors which assumed that the ratio of undiagnosed cases in Northern Ireland to the rest of Britain was the same as the ratio of diagnosed from SOPHID and the number of additional undiagnosed infections these proportions made were added to the total undiagnosed.²⁰ In order to estimate total prevalent infections for the adult population aged 16 years and over, the estimates were scaled up. The prevalent diagnosed HIV infections in the UK aged over 44 years were added to the diagnosed HIV infections. The proportion undiagnosed in the UK aged over 44 years was assumed to be the same as the proportion of all newly diagnosed HIV infections aged over 44 years at diagnosis and the number of additional undiagnosed infections these proportions made were added to the total undiagnosed.

The application of pregnant women data to all men and women assumes HIV infected women have an equal probability of becoming pregnant as uninfected women and that there is no differential fertility between people at high and low risk of HIV infection. As this is unlikely to be the case, especially in the UK where underlying fertility is low and HIV infection is high in subgroups with high fertility,¹⁸

Table 2 Estimates of prevalent HIV infections among adults in the United Kingdom at the end of 2003

Exposure category	Number diagnosed*	Number undiagnosed†	Total
Sex between men	18 100	6400 (26%)	24 500
Injecting drug use			
Males and females	1400	400 (22%)	1800
Heterosexuals			
Male	6700	4200 (39%)	10 900
African	4100	2000	6100
Non-African	2600	2200	4800
Female	11 800	3300 (22%)	15 100
African subtotal	8700	1400	10 100
Non-African subtotal	3100	1900	5000
Total	18 500	7500 (29%)	26 000
Blood products‡			
Males and females	700	0	700
Grand total	38 700	14 300 (27%)	53 000

*Numbers diagnosed were obtained from SOPHID and Health Protection, Scotland, adjusted for underreporting and failure to access services.

†Numbers undiagnosed for Northern Ireland derived by using exposure specific factors.

‡It was assumed that all cases infected through blood and blood products were diagnosed.

π_{irg}^U were adjusted to account for differential fertility effects.¹⁷

Estimates of prevalent HIV infections in the UK

At the end of 2003 an estimated 53 000 adults aged over 16 were living with HIV in the UK, 27% of whom were unaware of their infection (table 2). In 2003, just under half (46%) of the HIV infections in adults were in MSM. Of MSM, 26% were unaware of their infection, accounting for 45% of the estimated 14 300 undiagnosed prevalent infections. An estimated 26 000 adults who had acquired their infection through heterosexual sex were living in the UK in 2003, and 29% of these were unaware of their infection. The highest proportion of undiagnosed infection was in this category, with 22% of female and 39% of male heterosexuals unaware of their infection. Black-African men and women accounted for 62% of the total prevalent infections in heterosexuals and 45% of the undiagnosed heterosexual infections. There were an estimated 1800 IDUs living with HIV infection in 2003, of whom 22% were unaware of their infection. It was assumed that the number of undiagnosed HIV infections acquired through blood and blood product treatment was very low.

DISCUSSION

The direct method produces estimates of HIV infections in a relatively simple method where all assumptions and adjustments are made explicit. There are a number of biases and limitations inherent in the methodology. A number of assumptions were made when adjusting the UAPMP undiagnosed prevalence to apply to each behavioural category. These included assumptions about place of STI treatment and differential risk of being diagnosed with an STI being similar to HIV treatment and risk.

The method also assumed that the UAPMP STD clinics provided a representative sample from which to obtain a national undiagnosed HIV prevalence. It was also assumed that the undiagnosed HIV prevalence measured through STD clinics in the previous year was representative of the population that had attended an STD clinic in the past 5 years. This was likely to overestimate the number of current undiagnosed HIV infections. It was also assumed that the HIV prevalence in IDUs attending drug services was representative of all IDU. The estimates of undiagnosed infections in low risk heterosexuals are based on the undiagnosed HIV prevalence in pregnant women. This assumes that pregnant women are representative of the general population, and that the prevalence for low risk heterosexual men will be the same as low risk heterosexual women. The undiagnosed prevalence for low risk heterosexuals was calculated from the prenatal diagnosis rate, as this would be less influenced by antenatal screening and thus more representative of the undiagnosed proportion of the general population. As the population is very large (for the non-African population) these estimates are highly sensitive to the adjustments made to the undiagnosed prevalence and this is likely to have the greatest uncertainty.

There is no similar method for children. Information on the number of HIV infected pregnant women, whose infection was diagnosed (prior to or as part of their antenatal care) and known to their consultant obstetrician is based on the national survey of HIV in pregnancy coordinated by the Institute of Child Health (London) through the Royal College of Obstetricians and Gynaecologists. These reports were aligned with the overall prevalence estimates for HIV in pregnant women by geographical area to produce estimates of the proportion of women giving birth who were diagnosed before attending antenatal clinics, whose diagnosis was made through antenatal testing, and who remained undiagnosed at

delivery. To calculate an estimated number of babies based on observed surveillance data a vertical transmission rate of 2.2% is applied to the number of births to women diagnosed before birth and a vertical transmission rate of 26.5% was applied to the number of births to women remaining undiagnosed, derived from the UAPMP.²¹

The direct method has been used internationally in many countries previously.^{22–24} Unlinked anonymous surveys within the populations of interest are necessary to determine the undiagnosed HIV prevalence in the population groups. While named HIV surveillance can provide an estimate of the numbers of diagnosed HIV infections, the use of the SOPHID system of tracking all individuals accessing care annually allows the assessment of current individuals living with diagnosed HIV infection. Thus the estimation method just estimates undiagnosed HIV infections. The benefit of this methodology is that survival changes due to highly active antiretroviral therapy (HAART) do not influence or bias the estimation method due to differential inclusion in UAPMP, as these are only included in the diagnosed cases. Increasing HAART coverage affects the overall proportion of HIV infections that are undiagnosed, as the proportion of all HIV infections that are diagnosed has increased with increasing survival in people living with diagnosed HIV infection.

In the early 1990s, a study in London of a large and diverse sample of prostitutes found that they had a low prevalence of infection with HIV and high levels of use of condoms in commercial sex. There was a significant risk of other sexually transmitted infections associated with prostitutes' non-commercial sexual relationships, in which unprotected sex is common.²⁵ This previously established low risk from STI and HIV was found to have been maintained through high condom use in a nine year follow up of the sex workers from this initial study.²⁶ Thus unlike other developed countries, sex workers do not constitute a behavioural category within the UK direct method, they will be included within those individuals that attend STD clinics.

The enhanced direct method has provided evidence based adjustments to produce national estimates of prevalence. The incorporation of data from surveillance data and other complementary sources has strengthened the interpretation of these data. The advantage of this method is that all adjustments to the prevalence are clear and these adjustments can be updated and improved as more data become available. Further work is being carried out to improve the assumptions and prevalence estimates for this population.²⁷ A more mathematical approach has been developed that allows the quantification of the uncertainty within the estimates and allows a range to be produced for the estimates.

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AUTHORS' CONTRIBUTIONS

CMG was the lead author of the paper and chaired the project group. SC, AC, CHM, DDeA, KF, BE, AJ, and ONG were members of the project group, contributed to the development of the method, and contributed to the writing of the paper.

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