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**Prevalence of HIV at the Kokoyo informal gold mining site:
What lies behind the glitter of gold with regard to HIV
epidemics in Mali? A community-based approach (The
ANRS-12339 Sanu Gundo cross-sectional survey)**



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3 **Prevalence of HIV at the Kokoyo informal gold mining site: What lies behind the glitter of gold with**
4 **regard to HIV epidemics in Mali? A community-based approach (The ANRS-12339 Sanu Gundo**
5 **cross-sectional survey)**
6

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27 Viral Hepatitis (ANRS) grant ANRS-12339 Sanu Gundo.
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30
31 **Abstract**
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33 **Objectives:** The aim of this article was to estimate HIV prevalence and the factors associated with
34 HIV seropositivity using data from the Sanu Gundo cross-sectional survey conducted at the informal
35 artisanal small-scale gold mining (IASGM) site of Kokoyo in Mali. Our main hypothesis was that HIV
36 prevalence is higher in the context of IASGM than in the whole country.
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40 **Settings:** The ANRS-12339 Sanu Gundo survey was conducted in December 2015 at Kokoyo, one of
41 the largest IASGM sites in Mali with a population oscillating between 6 000 and 10 000 people. the
42 Malian NGO ARCAD-SIDA, organized prevention activities, proposed rapid tests for HIV and invited
43 people to take part in the survey. HIV prevalence was calculated for the sample, and for the different
44 groups according to the type of activity in IASGM. A Probit logistic regression was implemented to
45 estimate the characteristics associated with HIV seropositivity.
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50 **Participants:** 224 respondents: 37.5% were gold-diggers, 33% retail traders, 6.7% *tombolomas* (i.e.
51 traditional guards), 9% female sex-workers, while 14% reported another activity (mainly street
52 vendors).
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56 **Primary and secondary outcome measures:** HIV prevalence and HIV prevalence according groups
57 defined by their activity in the Kokoyo IASGM.
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3 **Results:** HIV prevalence was 8% 98%CI[7.7%-8.3%], which is much higher than the 2015 national
4 prevalence of 1.3% (UNAIDS). Probability of HIV seropositivity was 7.8% (p=0.037) higher for female
5 non sex-workers than for any other category, and this probability increased significantly with age.
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8 **Conclusions:** Our results demonstrate the importance of focusing on different categories of workers
9 and the necessity to conduct further similar research on other Malian IASGM sites, in order to
10 account for structural and geographical heterogeneity. Integrated policy-making should pay special
11 attention to infectious diseases among populations in IASGM zones. Bringing information/prevention
12 activities closer to people working in gold-bearing zones is an urgent public health action.
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16 **Strengths and limitations of this study**

- 17 - This is the first study conducted in an informal and artisanal small-scale gold mining site in
18 Mali involving all people directly or indirectly involved in informal mining activities.
- 19 - This study was conducted under the community-based framework, the survey design and
20 research questions were elaborated with representatives of the informal mine of Kokoyo.
- 21 - The highest prevalence was found among female not sex-workers (13%) pointing out the
22 importance of focusing on other less studied populations.
- 23 - There was an important proportion of participants in the survey that had never had a HIV
24 test highlighting the importance of “proximity health services”
- 25 - The cross-sectional design of the Sanu Gundo survey did not enable us to analyse changes
26 over time concerning different aspects, such as living and working conditions, seasonal
27 mobility, and sexual behaviour
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38 **Introduction**

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40 The poverty-driven activities and demographic conditions in the world’s informal artisanal small-scale
41 gold mining (IASGM) sector contribute to its vulnerability to infectious diseases including HIV. This
42 disease is recognized as one of the main public health issues in this sector, and potentially concerns
43 close to 15 million people involved in IASGM activities across 70 countries ¹. Despite the high-risk of
44 transmission ^{2,3}, and sustaining the spread of the disease ^{4,5}, very little is known about HIV epidemics
45 in IASGM sites. Existing HIV literature on people working and living in gold mining sites mainly
46 focuses on behavioural aspects, such as prevention ⁶, attitudes towards voluntary counselling and
47 testing ^{7,8}, the link between alcohol consumption and HIV ⁹, and the role of gender in the response to
48 HIV ^{3,10,11}. Furthermore, most studies have either been conducted among workers in industrial gold
49 mines or in mining communities near gold-bearing zones which are not exclusively related to the
50 IASGM sector. This is also the case for the few studies examining HIV prevalence: in South Africa in
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3 the last decade was approximately 25%^{3,12,13}, 22.3% for a group of Mozambican gold miners in 2012,
4 and 4.5% and 6.4% for Guinea in 2001 and 2007, respectively¹⁴. We found only one study concerning
5 an IASGM site, in the Amazon region of Guyana, where HIV prevalence was 6.5%¹⁵. In addition, these
6 studies principally focus on gold miners themselves and/or other presupposed at risk groups (e.g.
7 female sex-workers), with little attention given to other categories of potentially high-risk people
8 such as gold diggers (i.e. miners working in the informal sector), street vendors, and women who are
9 not sex-workers, playing an important role in transmission and/or mobility of HIV. Indeed, focusing
10 only on gold miners may divert the attention from these other high-risk groups², as demonstrated by
11 Clift *et al.*¹⁶ in a community near two industrial gold-mines in Tanzania, where HIV prevalence was
12 lower in mine workers (6%) than in men and women living at the mines but not directly involved in
13 mining (respectively, 16% and 18%).

20
21 Gold mining is one of the cornerstones of the Malian economy, representing almost 70% of the
22 country's total exports and 8% of the GDP in 2013¹⁷⁻¹⁹. Between 200 000 and 400 000 persons are
23 estimated to be directly concerned by IASGM activities^{20,21}. Despite the economic importance of the
24 sector, little attention has been paid to health, demonstrated by the poor medical services provided
25 in these sites^{22,23} and the increasing demand for health, especially concerning HIV. The high
26 prevalence observed in some key-populations provides a picture of the situation people may face in
27 these sites. A demographic and health survey (EDSMV) conducted in Mali in 2012 showed that HIV
28 prevalence among female sex-workers (24.2%), female street vendors (3.7%), and truckers (2.7%)
29 was clearly higher than the national prevalence of approximately 1.2% in the same year. A few
30 reports on IASGM in Mali have highlighted the urgent need to include the health dimension in
31 economic-based research programs, especially concerning HIV. Community activities must be
32 integrated into these programs as a tool to obtaining a greater understanding of the heterogeneity of
33 IASGM, the functioning of this informal labour market^{2,24}, and the impact of IASGM sector on the
34 transmission and spread of infectious diseases.

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45 In this context, we conducted the ANRS-12339 Sanu Gundo survey of the IASGM site at Kokoyo in
46 Mali's Koulikoro region in December 2015, using a community-based research approach. The
47 objective of this article was to estimate HIV prevalence - using the Sanu Gundo survey - for different
48 groups present at Kokoyo, and the factors associated with HIV seropositivity.

51 **Methods**

52 ***The survey and population***

56 The ANRS-12339 Sanu Gundo survey was conducted in December 2015 at Kokoyo (during 2 weeks),
57 one of the largest IASGM sites in Mali with a population oscillating between 6 000 and 10 000
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3 people, depending on the season (rainy/dry). In collaboration with the Chamber of Mines and the
4 Mines Ministry, this site was chosen given its geographical location implying a great deal of
5 heterogeneity as people not only come from other Malian regions, but also from other neighbouring
6 countries (Burkina Faso, Guinea, Nigeria, and Niger).
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10 The study started with conversations about global health topics with a focus on HIV/STI prevention
11 conducted by ARCAD-SIDA. Participants in the conversations were informed about the community-
12 based services provided by the mobile ARCAD-SIDA unit including the provision of a medical check-up
13 and essential medicines including those for treating STI. Furthermore, ARCAD-SIDA proposed rapid
14 tests for HIV and invited people to take part in the survey. Eligibility criteria included: 1) aged at least
15 18 years; 2) able to speak French, Bambara, or English; and 3) able to provide written consent.
16 Persons under the effects of alcohol and/or drugs were excluded. The convenience sample is formed
17 by 224 participants that were randomly included in the study.
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21 The *quantitative survey* consisted in a brief face-to-face questionnaire administered by trained
22 investigators who collected information about the following: 1) sociodemographic/socioeconomic
23 characteristics; 2) type of activity and mobility between sites; 3) HIV awareness, assessed with the
24 following questions: have you heard about HIV? Have you ever been tested for HIV before today? Do
25 you know your HIV status?; and 4) risky behaviours: alcohol and drugs consumption, sexual self-
26 definition, type(s) and frequency of intercourse. The *qualitative survey* organized the participants
27 into 5 activity-specific focus groups with semi-structured discussions about prevention and access to
28 care for HIV/STI: Malian gold-diggers, Non-Malian gold-diggers, female sex-workers, female non sex-
29 workers, and people guaranteeing the organizational functioning at the gold mine site (*damantiguis*
30 and *tombolomas*). All procedures and documents used were validated by both French (CCTIRS
31 N°15.917) and Malian (N°2015/65/CE/FMPOS) ethics committees.
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42 **Statistical analyses**

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44 The sample was described and HIV prevalence calculated for the overall sample, and for the different
45 groups according to the type of activity in the gold mining site. A Probit logistic regression was
46 implemented to estimate the characteristics associated with the probability of HIV seropositivity. All
47 statistical analyses were conducted using R software²⁵.
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51 **Results**

52 **Sample characteristics**

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54 The quantitative survey was conducted on convenience sample of 224 participants interested in
55 prevention and medical activities provides by ARCAD-SIDA (Table 1): 101 women (45.1%) and 123
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men (54.9%). There was a significant difference in average age between both genders: 25 and 29 years old ($p < 0.001$), respectively. With respect to participants' main residence, 133 (59.4%) declared they lived in Mali: 28.5% in Kokoyo (i.e. autochthonous) and 71.5% from different cities (i.e. non-autochthonous) including Danga (the nearest) and Timbuktu (the farthest). The remaining 91 participants (40.6%) declared another country as their principal place of residence. Concerning marital status, 158 participants (70.5% of participants) declared they were married or lived in a couple. Among them, 50.6% lived with their spouse in Kokoyo and the remaining 49.4% were geographically single. Indeed, 72.1% of the 86 married/in a couple males who did not live with their spouse in Kokoyo declared living with another partner at the site, whereas the proportion of geographically single women was only 22.2% among the sample's 72 married/in a couple females, and none of them declared having another partner at the site. Socio-economic difficulties were observed in terms of education level, with 49.1% of the 224 participants reporting they had never been to school. Among the others, 27.7% and 9.8% had, respectively, a primary and secondary school educational level, 12.1% had a Koranic educational background, and 1.3% declared having post-secondary school education. With respect to their activity in Kokoyo, among the 224 respondents 37.5% were gold-diggers, 33% retail traders, 6.7% *tombolomas*, 9% female sex-workers, while 14% reported another activity (mainly street vendors). Approximately half of the sample comprised people living under the poverty threshold of 1.9 US\$ per day: 49.3% compared with 49.1% in the general Malian population (2009)²⁶. Finally, 11.6% reported mobility between IASGM sites, and declared that Kokoyo was not the first IASGM site where they worked.

Table 1. Sample characteristics (n=224)

	n (%)
Gender	
Male	123 (54.9)
Female	101 (45.1)
Age: mean(sd)	27.5 (8.3)
Main residence country	
Mali	133 (59.4)
Other countries	91 (40.6)
Marital status	
Married or living in a couple	158 (70.5)
Single, divorced, widowed	66 (29.5)

Educational level

Never been to school	110 (49.1)
Primary	62 (27.7)
Secondary	22 (9.8)
Koranic	27 (12.1)
Post-secondary	3 (1.3)

Category of participant

Gold-diggers	84 (37.5)
Retail traders	74 (33.0)
Tombolomas	15 (6.7)
Female sex-workers	20 (8.9)
Other activities (mainly street vendors)	31 (13.8)

Under the poverty threshold (1.9 US\$ per day)

Yes	110 (49.1)
No	114 (50.9)

Have worked in other IASGM before Kokoyo

Yes	26 (11.6)
No	198 (88.4)

HIV prevalence and new diagnoses

Seventeen new HIV-positive cases were found with the ARCAD-SIDA testing, among those tested at the time of the survey, and 1 HIV-positive case was self-reported. Overall, HIV prevalence was 8%, which is much higher than the 2015 national prevalence of 1.3% (UNAIDS)²⁷. HIV prevalence was higher in women than in men, respectively, 10.4 and 5.9%. In terms of the 5 different categories studied, the highest HIV prevalence was in women who were not sex-workers (13%). Although lower than in women not sex-workers, prevalence in female sex-workers was higher (3.7%) at the Kokoyo site than the national prevalence for sex-workers. Prevalence in both non-Malian and Malian male gold-diggers was high, respectively, 7.7% and 6.5% whereas prevalence in males other than gold diggers was 6.4%. No HIV-positive case was observed in traditional guards.

The quantitative survey showed that 63.4% participants (142 out of 224) had never had a HIV test. Of these, 7 (4.9%) - 5 women and 2 men - tested positive for HIV using ARCAD-SIDA's test. This corresponded to 38.9% of the total 18 (11 women and 7 men) HIV seropositive participants observed, (or 45.5% (5/11) of total HIV women and 28.6% (2/7) of total HIV men). Among the 5 HIV positive cases for women 1 was a sand washer, 1 was female sex-worker and 3 were street vendors.

Among the 2 HIV positive cases for men 1 was a non-Malian gold digger and 1 was a male street vendor.

Factors associated to HIV seropositivity

Multivariate probit regression was implemented to estimate the factors associated with HIV seropositivity among the 224 participants in the quantitative survey (Table 2). Estimates show that the probability of HIV seropositivity was 7.8% ($p=0.037$) higher for female non sex-workers than for any other category, and this probability increased significantly with age. Indeed, the probability of HIV seropositivity - with respect to the youngest participants (aged between 18 and 21 years) – was 14.1% ($p=0.034$), 14.2% ($p=0.036$) and 16.1% ($p=0.021$) higher for participants aged 22-26 years, 27-29 years, and 30+ years, respectively. Finally, a 10.9% lower probability of HIV seropositivity was observed in participants who perceived their health status as good (versus poor).

Table 2. Factors associated with HIV seropositivity (n=224)

Covariates	Marginal Effects ¹ (dF/dX)	Coefficient	95% CI	
			Inf.	Sup.
Intercept		0.089	0.024	0.238
Category of participant				
Ref : Malian gold diggers and <i>tombolomas</i>				
Women sex-workers	0.019	1.161	0.350	3.105
Women non sex-workers	0.078	1.857	1.043	3.399
Non-Malian gold diggers	-0.010	0.926	0.239	2.658
Age²				
Ref: 18 to 21 years				
22 to 26	0.141	3.055	1.204	10.388
27 to 30	0.142	3.089	1.193	10.671
30+	0.161	3.593	1.325	12.902
Self-perceived health status				
Good health status	-0.109	0.422	0.232	0.736
Ref: Poor health status				
Weekly earnings³				
Earnings ≤ median	0.036	1.330	0.774	2.322
Ref: Earnings > median				

¹ Is the change in the probability given the change in each independent continuous variable and reports the discrete change in the probability for dichotomous variables.

² Age categories' cut-offs correspond to quartiles.

³ The median weekly earning is 14 500 FCFA (25 US\$). This variable was used to account for the socioeconomic status of participants.

Main findings of the qualitative survey

Five focus groups were carried out over 28 participants according to gender and professional status: 6 *tombolomas*, 6 Malian male gold diggers, 5 non-Malian male gold diggers, 5 women sex-workers and 6 women non sex-workers. The first discourse identified refers to sexual practices, especially non-systematic condom use, women sex-workers charging extra for condomless sexual intercourse, and the undisclosed use of female condoms. Participants attributed these practices to the following factors: the place where sexual intercourse took place: bars *versus* the street; the nationality/ethnicity of female sex-workers: Malians and Guineans were seen as more “flexible” than Nigerians (considered as “strict”) with regards to condom use; and the nature of the relationship between men and women: trustful relationships (considered “safer”) than strictly commercial-sex relationships (considered “risky”). The second discourse identified referred to health services access, with the main barrier being the long distances. Other barriers evoked were the high price of medicines, the lack of specialists and other health care providers, as well as the poor number and quality of HIV/STI information/prevention programmes described as the main reasons why participants resorted to traditional medicine.

Discussion

This is the first study conducted in an informal and artisanal small-scale gold mining site in Mali which investigates HIV not only in those directly involved in informal mining (i.e. gold diggers), but also in other populations with a related activity at the site. The aims of the present article emerged from the need for the authorities of the IASGM site at Kokoyo to characterize the population living there, and to provide community-based prevention and HIV testing as part of the health care services offered.

The low education level observed and the high proportion of participants living with revenues below the 1.9 US\$ poverty-line threshold, confirmed the poverty-driven characteristic of IASGM sites reported in the literature concerning other countries with large gold-bearing zones^{22,28}. The fluctuation of the population suggests large-scale cyclical migration of workers (i.e. they stay for a period, go back home, and the next season they return either to the same or to another mine), and as Rees et al. suggested, they are often separated from their family (i.e. geographically single)¹². This is confirmed by our results where 71.5% of Malian participants came from other regions of Mali (non-autochthonous), and 40.6% of the total sample were not Malian. Moreover, geographically single individuals accounted for 49.4% of the 158 participants who reported being married or living in

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3 a couple. This “bridge population” cohabits with other high-risk groups in the IASGM site at Kokoyo
4 representing potential source for the sustained spread of infectious diseases - including HIV - at the
5 site, and at their home ^{4,5}. Indeed, being single (geographically or not) is associated with risky
6 behaviours, given the freedom from social norms and the economic difficulties that prevail in IASGM
7 sites ². Furthermore, working conditions and the inherent related dangers which male gold diggers
8 are confronted with, have also been identified as factors related to an increase in risky behaviours
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15 This is the first time that HIV prevalence has been estimated in an IASGM site in Mali. We found a HIV
16 prevalence of 8% in the 224 participants in our study, which is much higher than the Malian national
17 prevalence of 1.3% estimated in 2015, this is in line with the 7% estimated for the IASGM site of
18 Tenkoto in the Kédougou region of Senegal ³¹. In addition, HIV prevalence varied for the different
19 categories studied, ranging between 3.6% for female sex-workers to 13% for both women gold
20 diggers and women street vendors. The latter value is in line with the 13% estimated for street
21 vendors in Burkina Faso, although that value was not specific to IASGM sites ³². Our estimates not
22 only reflect the results from the few qualitative studies performed to date which suggest high
23 prevalence of HIV in IASGM sites, but also highlight that accounting for other categories of people
24 than simply those directly involved in mining, other “less classic” groups are seen to be at higher risk
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33 The acceptability of HIV testing by participants observed in this study demonstrated not only that the
34 community-based dimension is crucial to conduct this kind of research ^{2,7}, but that it is also useful for
35 the provision of prevention and HIV testing to this population. This is one of the main contributions
36 of our analysis, and highlights the large demand-supply gap for health care services in Kokoyo.
37 Indeed, the nearest Rural Health Community Centre (CSCOM, *Centre de Santé Communautaire*) does
38 not provide either prevention or testing for HIV, and the only two centres of voluntary testing in the
39 Koulikoro region are far from gold-bearing zones, especially the IASGM site of Kokoyo. This
40 community-based research identified a large number of new HIV positive cases, and this is another
41 important contribution of the study. Most specifically, 38% among the 18 HIV positive participants in
42 the quantitative survey corresponded to new diagnoses using ARCAD-SIDA’s rapid tests. Women
43 were mostly concerned (5 out of 11 positive cases in women were new diagnoses), especially street
44 vendors. Although ARCAD-SIDA referred all 18 HIV positive participants to the nearest regional
45 hospitals (CSREF) in order to link them to care, the emerging question is whether or not these
46 participants subsequently initiated and adhered to antiretroviral treatment given the distance of
47 more than 100km between Kokoyo and Kangaba city where the CSREF is located. Unfortunately, we
48 have no information about lost-to-follow-up rates in people living with HIV in the context of IASGM
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3 sites, but presumably these rates are high given that HIV is not of primary concern to people in
4 IASGM sites, as suggested by Campbell³. This certainly seems to be the situation in Kokoyo, where
5 the large majority of study participants aware of HIV (over 90%) had never previously gone for a test
6 (63.4%). Multivariate analyses pointed out female non sex-workers, the eldest participants, and
7 those with poor self-perceived health status as the three sub-populations most associated with HIV
8 seropositivity.
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12 Some limitations should be acknowledged. First, the study sample is not representative of the whole
13 population in IASGM sites in Mali. However, our results seemed to reflect those in the literature.
14 Second, the cross-sectional design of the Sanu Gundo survey did not enable us to analyse changes
15 over time concerning different aspects, such as living and working conditions, seasonal mobility, and
16 sexual behaviour. Furthermore, although the participants who tested positive for HIV during the
17 study were referred to the regional hospital, the design of the survey did not allow us collect
18 subsequent information, either concerning linkage-to-care or antiretroviral treatment initiation.
19 Finally, there is a possibility of selection bias, as the sample was drawn from the healthcare
20 conversation audience organized by ARCAD-SIDA. This selection bias would reflect an audience
21 mainly comprising individuals interested in prevention and to some extent, worried by health issues,
22 especially HIV. One would expect that any future study whose design were to attract participants
23 other than those already interested in health care, would result in higher HIV prevalence being
24 measured and would accentuate the precarious characteristics already described by our survey at
25 Kokoyo. Despite these limitations, our study contributes to the existing literature by creating a
26 knowledge base which could be a useful first step for the development of suitable surveys and
27 interventions.
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40 **Conclusion**

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42 The results of this study demonstrate the importance of focusing on different categories of workers
43 and the necessity to conduct further similar research on other Malian IASGM sites, in order to
44 account for structural and geographical heterogeneity. The present article contributes to the
45 literature by reopening the debate about the impact of Health issues on IASGM activities, especially
46 HIV issues, in a context where the sustained spread of this disease could not only harm efforts in the
47 fight against AIDS, but also have important negative consequences in one of the main cornerstones
48 of the Malian economy. Integrated policy-making should pay special attention to infectious diseases
49 among populations in IASGM zones. Bringing information/prevention activities closer to people
50 working in gold-bearing zones is an urgent public health action.
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Authors contribution

LST designed and led the study and wrote the first draft of the report. LST, MSM, BS and BDK designed the analysis. LST, HB and FD analysed the data. MM and MB oversaw data management. All authors critically reviewed and approved the manuscript.

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38 **Competing statement: Authors declare no conflict of interest**

39
40 **Data sharing statement:**

41
42 Full dataset and statistical code available from the corresponding author at luis.sagaon-teyssier@inserm.fr. The
43
44 presented data are anonymized and risk of identification is null.
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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	NA
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	4
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7
		(b) Report category boundaries when continuous variables were categorized	7
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

**Prevalence of HIV at the Kokoyo informal gold mining site:
What lies behind the glitter of gold with regard to HIV
epidemics in Mali? A community-based approach (The
ANRS-12339 Sanu Gundo cross-sectional survey)**

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3 **Prevalence of HIV at the Kokoyo informal gold mining site: What lies behind the glitter of gold with**
4 **regard to HIV epidemics in Mali? A community-based approach (The ANRS-12339 Sanu Gundo**
5 **cross-sectional survey)**
6

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26
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28

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30 Viral Hepatitis (ANRS) grant ANRS-12339 Sanu Gundo.
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33
34 **Abstract**
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36 **Objectives:** The aim of this article was to estimate HIV prevalence and the factors associated with
37 HIV seropositivity in the population living and working at the informal artisanal small-scale gold
38 mining (IASGM) site of Kokoyo in Mali, using data from the Sanu Gundo cross-sectional survey. Our
39 main hypothesis was that HIV prevalence is higher in the context of IASGM than in the country as a
40 whole.
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45 **Settings:** The ANRS-12339 Sanu Gundo survey was conducted in December 2015 at Kokoyo, one of
46 the largest IASGM sites in Mali (between 6 000 and 10 000 people). The quantitative survey consisted
47 in face-to-face administration of questionnaires. Five focus groups were conducted for the
48 qualitative survey. HIV prevalence was calculated for the sample, and for the different sub-groups
49 within the sample, according to the type of activity performed in IASGM. A Probit logistic regression
50 was implemented to estimate the characteristics associated with HIV seropositivity.
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3 **Participants:** 224 respondents: 37.5% were gold-diggers, 33% retail traders, 6.7% *tombolomas* (i.e.
4 traditional guards), and 9% female sex-workers. The remaining 13.8% reported another activity
5 (mainly street vending).
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8 **Primary and secondary outcome measures:** HIV prevalence and HIV prevalence according to sub-
9 group, as defined by their activity at the Kokoyo IASGM.
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11 **Results:** HIV prevalence for the total sample was 8% 95%CI[7.7%-8.3%], which is much higher than
12 the 2015 national prevalence of 1.3% (UNAIDS). The probability of HIV seropositivity was 7.8%
13 (p=0.037) higher for female non sex-workers than for any other category, and this probability
14 increased significantly with age. Qualitative data revealed the non-systematic use of condoms with
15 sex-workers; and long distance from health services was the main barrier to accessing care.
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18 **Conclusions:** Integrated policy-making should pay special attention to infectious diseases among
19 populations in IASGM zones. Bringing information/prevention activities closer to people working in
20 gold-mining zones is an urgent public health action.
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22 **Strengths and limitations of this study**

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29 - This is the first study conducted in an informal and artisanal small-scale gold mining site in
30 Mali including all of the people directly or indirectly involved in the site's activities.
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32 - This study was implemented using a community-based research approach, the survey design
33 and research questions being developed in collaboration with representatives of the mine of
34 Kokoyo.
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36 - The highest HIV prevalence was found among female non sex-workers (13%), which
37 highlights the importance of focusing on high-risk less-studied populations.
38
39 - A large proportion of participants in the survey had never had a HIV test, which highlights the
40 importance of "close proximity health services"
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42 - The cross-sectional design of the Sanu Gundo survey did not enable us to analyse changes
43 over time concerning several socio-economic and behavioural aspects, such as living and
44 working conditions, seasonal mobility, or sexual behaviour
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49 **Introduction**

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51 The poverty-driven activities and demographic conditions in the world's informal artisanal small-scale
52 gold mining (IASGM) sector contribute to its vulnerability to infectious diseases including HIV. This
53 disease is recognized as one of the main public health issues in this sector, and potentially concerns
54 almost 15 million people involved in IASGM activities across 70 countries ¹. Despite the high risk of
55 transmission ^{2,3}, and sustained spread of the disease ^{4,5}, very little is known about HIV epidemics in
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3 IASGM sites. Existing HIV literature on people working and living in gold mining sites mainly focuses
4 on behavioural aspects, such as prevention⁶, attitudes towards voluntary counselling and testing^{7,8},
5 the link between alcohol consumption and HIV⁹, and the role of gender in the fight against HIV^{3,10,11}.
6 Furthermore, most studies have either been conducted among workers in industrial gold mines or in
7 mining communities near gold-bearing zones which are not exclusively related to the IASGM sector.
8 This is also the case of the few studies examining HIV prevalence, which in South Africa in the last
9 decade was measured at approximately 25%^{3,12,13}, at 22.3% for a group of Mozambican gold miners
10 in 2012, and at 4.5% and 6.4% for Guinea in 2001 and 2007, respectively¹⁴. We found only one study
11 concerning an IASGM site, specifically in the Amazon region of Guyana. HIV prevalence there was
12 6.5%¹⁵. In addition, these studies principally focus on gold miners themselves and/or other
13 presupposed most-at-risk groups (e.g. female sex-workers), with little attention given to other
14 categories of potentially high-risk people such as gold diggers (i.e. miners working in the informal
15 sector), women who are not sex-workers, and street vendors, all of whom play an important role in
16 the transmission and/or mobility of HIV. Indeed, focusing only on gold miners and not including these
17 other high-risk groups may be detrimental to the fight against HIV², as demonstrated by Clift *et al.*¹⁶
18 in a community near two industrial gold-mines in Tanzania, where HIV prevalence was lower in mine
19 workers (6%) than in men and women living at the mines but not directly involved in mining
20 (respectively, 16% and 18%).
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32 Gold mining is one of the cornerstones of the Malian economy, representing almost 70% of the
33 country's total exports and 8% of the GDP in 2013¹⁷⁻¹⁹. Between 200 000 and 400 000 persons are
34 estimated to be directly concerned by IASGM activities^{20,21}. Despite the economic importance of the
35 sector, little attention has been paid to health, as demonstrated by both the poor medical services
36 provided in these sites^{22,23} and the increasing demand for health, especially concerning HIV. The high
37 prevalence observed in some key populations provides a picture of the situation people may face in
38 these sites. A demographic and health survey (EDSMV) conducted in Mali in 2012 showed that HIV
39 prevalence among female sex-workers (24.2%), female street vendors (3.7%), and truckers (2.7%)
40 was much higher than the national prevalence of approximately 1.2% in the same year. Different
41 reports on IASGM in Mali have highlighted the urgent need to include the health dimension in
42 economic-based research programs, especially concerning HIV. Community-based activities (e.g.,
43 prevention, screening, counselling etc.) could help do this as they could help provide a greater
44 understanding of the heterogeneity of IASGM, the functioning of this informal labour market^{2,24}, and
45 the impact of IASGM sector on the transmission and spread of infectious diseases.
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55 We conducted the ANRS-12339 Sanu Gundo survey of the IASGM site at Kokoyo in Mali's Koulikoro
56 region in December 2015, using a community-based research approach. The objective of this article
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3 was to estimate HIV prevalence - using the Sanu Gundo survey – in different groups present at
4 Kokoyo, and the factors associated with HIV seropositivity.
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7 **Methods**

8 ***Settings and design***

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11 The ANRS-12339 Sanu Gundo survey was conducted in December 2015 at Kokoyo (for 2 weeks), one
12 of the largest IASGM sites in Mali with a population oscillating between 6 000 and 10 000 people,
13 depending on the season (rainy/dry). In collaboration with the Chamber of Mines and the Mines
14 Ministry, this site was chosen for its geographical location because of the great deal of cultural
15 heterogeneity there. People come not only from other Malian regions, but also from neighbouring
16 countries (Burkina Faso, Guinea, Nigeria, and Niger).
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22 The study started with conversations about global health topics with a focus on HIV/STI prevention
23 which were facilitated by ARCAD-SIDA members. Participants in the conversations were informed
24 about the community-based services provided by the mobile ARCAD-SIDA unit, including the
25 provision of a medical check-up and essential medicines including those for treating STI.
26 Furthermore, ARCAD-SIDA proposed rapid tests for HIV and invited people to take part in the survey.
27 For HIV screening, ARCAD-SIDA follows the Malian Ministry of Health recommendations using
28 Determine® rapid tests, and ImmunoComb® II for confirmation. ARCAD-SIDA provided counselling
29 about the importance of being treated to participants testing HIV positive, and referred them to
30 regional health care centres (Centre de Santé de Référence, CSREF) for blood assessment and
31 inclusion in treatment and follow-up programmes.
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39 Participants in the conversations were then invited to participate in the qualitative and quantitative
40 surveys (they could choose either or both) which formed the basis for the ANRS-12339 Sanu Gundo
41 survey. Community-based agents sent those interested to the Malian team of researchers, who in
42 turn provided detailed information about the content of the survey, its main objectives, and the
43 advantages/risks of participating in this kind of survey. Survey participants provided written formal
44 consent to participate in the survey(s) by signing a letter of consent. All procedures and documents
45 used were validated by both French (CCTIRS N°15.917) and Malian (N°2015/65/CE/FMPOS) ethics
46 committees.
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51 ***Participants***

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3 Eligibility criteria included: i) aged 18 years or older; ii) able to speak French, Bambara, or English; iii)
4 able to provide written consent to participate. Persons under the effects of alcohol and/or drugs
5 were excluded. For the *quantitative survey*, 224 participants constituted the convenience sample. In
6 order to reduce any potential over-representation and under-representation sampling bias, ARCAD-
7 SIDA activities were conducted every day at different time slots and locations at the site in order to
8 adapt participant recruitment to the work schedule of the different categories of people living there.
9 To those who agreed to participate in the survey(s), a brief face-to-face questionnaire was
10 administered by trained investigators who collected information about the following : i)
11 sociodemographic and socioeconomic characteristics: age (continuous variable), gender, marital
12 status, country of residence, educational level, and weekly earnings (dichotomized at the median of
13 14 500 FCFA, approximately 24.26 US\$) ; ii) type of activity and mobility between sites; iii) HIV
14 awareness, assessed with the following questions: “Have you heard about HIV?” “Have you ever
15 been tested for HIV before today?”, “Do you know your HIV status?”; iv) risky behaviours: alcohol
16 and drugs consumption, sexual self-definition, type(s) and frequency of intercourse; v) perceived
17 health status, assessed with the following question: “How do you consider your state of health
18 today?”, with possible answers including “very poor”, “poor”, “moderate”, “good”, and “very good”.
19 This variable was equal to 1 for those perceiving their health was good or very good, and 0 for those
20 perceiving they had poor or very poor health. For the *qualitative survey*, purposive sampling was
21 implemented. This seemed to be the most suitable sampling method as the main objective of the
22 qualitative survey was to collect information about prevention and access to care for HIV/STI among
23 specific groups. The sample size for each group was fixed between 5 and 8 survey participants in
24 order to ensure diversity among them. Five activity-specific focus groups were organized: Malian
25 gold-diggers, Non-Malian gold-diggers, female sex-workers, female non sex-workers, and people
26 guaranteeing the organizational functioning at the gold mine site (*damantiguis* and *tombolomas*).
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45 **Statistical analyses**

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47 The sample was described and HIV prevalence calculated both for the overall sample, and for the
48 different sub-groups listed above (i.e., according to the type of activity in the gold mining site). A
49 Probit logistic regression was implemented to estimate the characteristics associated with the
50 probability of HIV seropositivity. Given the nature of the normal distribution assumption of the error
51 term in the Probit estimation, coefficients are not affected by the presence of extreme values in
52 independent variables. Furthermore, Probit regression allows the computation of marginal effects
53 that are more flexible and more informative than odd-ratios^{25,26} which tend to be larger in the
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presence of rare events and are in any case preferred for small samples²⁷. Marginal effects, dF/dX , are interpreted as instantaneous rates of change: for a dichotomous explanatory variable, a marginal effect shows how predicted probabilities change when the variable changes from 0 to 1. All statistical analyses were performed using R software²⁸.

Results

Sample characteristics

The quantitative survey was conducted on a convenience sample of 224 participants interested in prevention and medical activities provided by ARCAD-SIDA (Table 1): 101 women (45.1%) and 123 men (54.9%). There was a significant difference in average age between both genders: 25 and 29 years old respectively. With respect to participants' main residence, 133 (59.4%) declared they lived in Mali: 28.5% in Kokoyo (i.e. autochthonous) and 71.5% from different cities (i.e. non-autochthonous) including Danga (the nearest) and Timbuktu (the farthest). The remaining 91 participants (40.6%) declared another country as their principal place of residence. With respect to marital status, 158 participants (70.5% of the whole sample) declared they were married or lived in a couple. Among them, 50.6% lived with their spouse in Kokoyo and the remaining 49.4% were geographically single. Of the 86 married/in a couple males who did not live with their spouse in Kokoyo 72.1% declared living with another partner at the site. Conversely, the proportion of geographically single women was only 22.2% among the sample's 72 married/in-a-couple females, and none declared having another partner at the site. Socio-economic difficulties were observed in terms of educational level, with 49.1% of the 224 participants reporting they had never been to school. Among the others, 27.7% and 9.8% had, respectively, a primary and secondary school educational level, 12.1% had a Koranic educational background, and 1.3% declared having post-secondary school education. With respect to their activity in Kokoyo, among the 224 respondents 37.5% were gold-diggers, 33% retail traders, 6.7% *tombolomas*, 9% female sex-workers, while 14% reported another activity (mainly street vending). Approximately half of the sample comprised people living under the poverty threshold of 1.9 US\$ per day: 49.3% compared with 49.1% in the general Malian population (2009)²⁹. Finally, 11.6% reported mobility between IASGM sites, and declared that Kokoyo was not the first IASGM site where they had worked.

Table 1. Sample characteristics of participants living in the informal artisanal small-scale gold mining site (IASGM) of Kokoyo in Mali (n=224)

Variables	n (%)
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Gender		
	Male	123 (54.9)
	Female	101 (45.1)
Age²		
	Ref: 18 to 21 years	57 (25.4)
	22 to 26	60 (26.8)
	27 to 30	53 (23.7)
	30+	54 (24.1)
Main residence country		
	Mali	133 (59.4)
	Other countries	91 (40.6)
Marital status		
	Married or living in a couple	158 (70.5)
	Single, divorced, widowed	66 (29.5)
Educational level		
	Never been to school	110 (49.1)
	Primary	62 (27.7)
	Secondary	22 (9.8)
	Koranic	27 (12.1)
	Post-secondary	3 (1.3)
Category of participant		
	Malian gold-diggers, tombolomas, and other malian workers	130 (58)
	Women sex-workers	27 (12,1)
	Women non sex-workers	54 (24,1)
	Non-malian gold diggers	13 (5,8)
Self-perceived health status		
	Good health status	133 (59,4)
	Ref: Poor health status	91 (40,6)
Weekly earnings³		
	Earnings ≤ median	112 (50)
	Ref: Earnings > median	112 (50)
Have worked in other IASGM before Kokoyo		
	Yes	26 (11.6)
	No	198 (88.4)

HIV prevalence and new diagnoses

Seventeen new HIV-positive cases were found with the ARCAD-SIDA testing, among those tested at the time of the survey, and 1 HIV-positive case was self-reported. Overall, HIV prevalence was 8% 95%CI[4.5%, 11.6%]. HIV prevalence was higher in women than in men, respectively, 10.4 95%CI[4.5%, 16.2%] and 5.9% 95%CI[1.7%, 6.5%]. In terms of the 5 different categories studied, the highest HIV prevalence was in women who were not sex-workers (13% 95%CI[5.4%, 20.3%]). Although lower than in the latter group, the prevalence in female sex-workers was still higher (3.7% 95%CI[-3.5%, 10.9%]) at the Kokoyo site than the national prevalence for sex-workers (irrespective of gender). Prevalence in both non-Malian and Malian male gold-diggers was high, respectively, 7.7% 95%CI[-7.4%, 22.8%] (90%CI[-4.9%, 20.4%]) and 6.5% 95%CI[-0.7%, 13.7%] (90%CI[0.5%, 12.6%]), whereas prevalence in males other than gold diggers was 6.4% 95%CI[-0.7%, 13.5%] (90%CI[0.5%, 12.3%]). No HIV-positive case was observed in traditional guards (*tombolomas*).

The quantitative survey showed that 63.4% participants (142 out of 224) had never had a HIV test. Of these, 7 (4.9%) - 5 women and 2 men - tested positive for HIV using ARCAD-SIDA's test. This corresponded to 38.9% of the total 18 (11 women and 7 men) HIV seropositive participants observed, (or 45.5% (5/11) of total HIV women and 28.6% (2/7) of total HIV men). Among the 5 HIV positive cases for women, 1 was a sand washer, 1 was a female sex-worker and 3 were street vendors. Among the 2 HIV positive cases for men, 1 was a non-Malian gold digger and 1 a male street vendor.

Factors associated to HIV seropositivity

A multivariate probit regression was implemented to estimate the factors associated with HIV seropositivity among the 224 participants in the quantitative survey (Table 2). Estimates show that the probability of HIV seropositivity was 7.8% ($p=0.037$) higher for female non sex-workers than for any other category, and this probability increased significantly with age. Indeed, the probability of HIV seropositivity - with respect to the youngest participants (aged between 18 and 21 years) - was 14.1% ($p=0.034$), 14.2% ($p=0.036$) and 16.1% ($p=0.021$) higher for participants aged 22-26 years, 27-29 years, and 30+ years, respectively. Finally, a 10.9% lower probability of HIV seropositivity was observed in participants who perceived their health status as good (versus poor).

Table 2. Factors associated with HIV seropositivity among participants living in the informal artisanal small-scale gold mining site (IASGM) of Kokoyo in Mali (n=224)

Covariates	Marginal Effects ¹ (dF/dX)	Coefficient	95% CI		P-value
			Inf.	Sup.	
Intercept		-2.413	-3.716	-1.431	<0.001
Category of participant					
Ref : Malian gold diggers and <i>tombolomas</i>	Ref.	Ref.			
Women sex-workers	0.019	0.151	-1.048	1.134	0.780
Women non sex-workers	0.078	0.624	0.046	1.231	0.036
Non-Malian gold diggers	-0.010	-0.057	-1.423	1.015	0.924
Age²					
Ref: 18 to 21 years	Ref.	Ref.			
22 to 26	0.141	1.105	0.175	2.332	0.036
27 to 30	0.142	1.115	0.162	2.358	0.039
30+	0.161	1.268	0.271	2.548	0.022
Self-perceived health status					
Good health status	-0.109	-0.862	-1.459	-0.307	0.003
Ref: Poor health status	Ref.	Ref.			
Weekly earnings³					
Earnings ≤ median	0.036	0.282	-0.261	0.840	0.310
Ref: Earnings > median	Ref.	Ref.			

¹ Is the change in the probability given the discrete change for dichotomous variables.

² Age categories' cut-offs correspond to quartiles.

³ The median weekly earning is 14 500 FCFA (25 US\$). This variable was used to account for the socioeconomic status of participants.

Main findings of the qualitative survey

Five focus groups were carried out over 28 participants according to gender and professional status: 6 *tombolomas*, 6 Malian male gold diggers, 5 non-Malian male gold diggers, 5 female sex-workers and 6 women non sex-workers. Among the discourses identified, one referred to sexual practices, especially non-systematic condom use, women sex-workers charging extra for condomless sexual intercourse, and the undisclosed use of condoms by women. Participants attributed these practices to the following factors: i) the place where sexual intercourse took place: bars *versus* the street; ii) the nationality/ethnicity of female sex-workers: Malians and Guineans were seen as more “flexible” than Nigerians (considered as “strict”) with regards to condom use; and iii) the nature of the relationship between men and women: trustful relationships (considered “safer”) than strictly

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3 commercial-sex relationships (considered “risky”). Another discourse identified referred to health
4 services access, with the main barrier being the long distances involved. Other barriers mentioned
5 were the high price of medicines, the lack of specialists and other health care providers, as well as
6 the low number and poor quality of HIV/STI information/prevention programmes described. These
7 barriers were also the main reasons why participants resorted to traditional medicine.
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11 Discussion

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14 This is the first study conducted in an informal and artisanal small-scale gold mining site in Mali which
15 investigates HIV not only in those directly involved in informal mining (i.e. gold diggers), but also in
16 other populations with a related activity. The aims of this article were drawn up specifically to
17 respond to the need for the authorities of the IASGM site at Kokoyo to characterize the population
18 living there, and to provide community-based prevention and HIV testing as part of the health care
19 services offered.
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26 The low educational level observed and the high proportion of participants living with revenues
27 below the 1.9 US\$ poverty-line threshold, reflects the high level of poverty reported in the literature
28 concerning IASGM sites in other countries with large gold-bearing zones^{22,30}. The fluctuation of the
29 population at Kokoyo suggests large-scale cyclical migration of workers (i.e. they stay for a period, go
30 back home, and the next season they return either to the same mine or to another). Rees et al.
31 suggested they such workers are often separated from their family (i.e. geographically single)¹²,
32 something confirmed by our results where 71.5% of Malian participants came from other regions of
33 Mali (non-autochthonous), and 40.6% of the total sample were not Malian. Moreover, geographically
34 single individuals accounted for 49.4% of the 158 participants who reported being married or living in
35 a couple. This “bridge population” cohabits with other high-risk groups in the IASGM site at Kokoyo,
36 representing a potential source for the continued spread of infectious diseases - including HIV - at
37 the site, and at their home^{4,5}. Indeed, being single (geographically or not) is associated with risky
38 behaviours, given the freedom from social norms and the economic difficulties that prevail in IASGM
39 sites². Furthermore, working conditions and the inherent related dangers which male gold diggers
40 are confronted with, have also been identified as factors related to an increase in risky behaviours
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This is the first time that HIV prevalence has been estimated in an IASGM site in Mali. We found a
prevalence of 8% in the 224 participants in our study, which is much higher than the Malian national
prevalence of 1.3% estimated in 2015³², but is in line with the 7% estimated for the IASGM site of
Tenkoto in the Kédougou region of Senegal³³. In addition, HIV prevalence varied for the different

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3 categories studied, ranging between 3.6% for female sex-workers to 13% for both women gold
4 diggers and women street vendors. The latter value is in line with the 13% estimated for street
5 vendors in Burkina Faso, although that value was not specific to IASGM sites³⁴. Our estimates not
6 only reflect the results from the few qualitative studies performed to date which suggest high
7 prevalence of HIV in IASGM sites, but also highlight that “less classic” groups (i.e. those not directly
8 involved in mining) are at higher risk². The different HIV prevalence rates found across groups may
9 reflect the lack of prevention programs adapted to key populations other than sex-workers in Mali.
10 Most of the efforts in the fight against HIV/AIDS in Mali are concentrated on female sex-workers and
11 men having sex with other men (MSM), who are identified as the most vulnerable groups. This could
12 explain - at least in part - the low prevalence rate among female sex-workers in Kokoyo IASGM and
13 the higher prevalence among other groups, including female non-sex workers and gold-diggers.
14 Indeed participants from these two categories expressed during the focus groups that prevention
15 campaigns are mostly directed at female sex-workers, who seem to be more informed about the risk
16 of HIV contamination and about prevention tools.
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26 The acceptability of HIV testing by participants observed in this study demonstrated not only that the
27 community-based dimension is crucial to conduct this kind of research^{2,7}, but that it is also useful for
28 the provision of prevention and HIV testing to this population. Of the 236 persons invited to test for
29 HIV, only 5% refused. This is one of the main contributions of our analysis, and highlights the large
30 demand-supply gap for health care services in Kokoyo. Indeed, the nearest Rural Health Community
31 Centre (CSCOM, *Centre de Santé Communautaire*) does not provide either prevention or testing for
32 HIV, and the only two centres of voluntary testing in the Koulikoro region are far from gold-bearing
33 zones, especially the IASGM site of Kokoyo. This community-based research identified a large
34 number of new HIV positive cases, and this is another important contribution of the study. More
35 specifically, 38% of the 18 HIV-positive participants in the quantitative survey were newly diagnosed
36 using ARCAD-SIDA's rapid tests. Five out of 11 positive cases in women were new diagnoses,
37 especially female street vendors. Although ARCAD-SIDA referred all 18 HIV positive participants to
38 the nearest regional hospitals (CSREF) in order to link them to care, the emerging question is whether
39 or not these participants subsequently initiated and adhered to antiretroviral treatment given the
40 distance of more than 100km between Kokoyo and Kangaba city where the CSREF is located.
41 Unfortunately, we have no information about lost-to-follow-up rates in people living with HIV in the
42 context of IASGM sites, but presumably these rates are high given that HIV is not of primary concern
43 to people in IASGM sites, as suggested by Campbell³. This certainly seems to be the situation in
44 Kokoyo, where the large majority of study participants aware of HIV (over 90%) had never previously
45 gone for a test (63.4%). Multivariate analyses indicated that female non sex-workers, the eldest
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3 participants, and those with poor self-perceived health status were the three sub-populations most
4 associated with HIV seropositivity.
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7 Some limitations should be acknowledged. First, the study sample is not representative of the whole
8 population in IASGM sites in Mali. However, our results reflect those in the literature. Second, the
9 cross-sectional design of the Sanu Gundo survey did not enable us to analyse changes over time
10 concerning different aspects, such as living and working conditions, seasonal mobility, and sexual
11 behaviour. Furthermore, although the participants who tested positive for HIV during the study were
12 referred to the regional hospital, the design of the survey did not allow us collect subsequent
13 information, either concerning linkage-to-care or antiretroviral treatment initiation. Finally, there is a
14 possibility of selection bias, as the sample was drawn from the healthcare conversation audience
15 organized by ARCAD-SIDA. Nevertheless, any selection bias would reflect an audience mainly
16 comprising individuals interested in prevention and to some extent, worried about health issues,
17 especially HIV. One would expect that any future study whose design were to attract participants
18 other than those already interested in health care, would result in higher HIV prevalence being
19 measured and would accentuate the precarious characteristics already described by our survey at
20 Kokoyo. Despite these limitations, our study contributes to the existing literature by creating a
21 knowledge base which could be a useful first step for the development of suitable surveys and
22 interventions.
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33 **Conclusion**

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35 The results of this study demonstrate the importance of focusing on different categories of workers
36 and the necessity to conduct further similar research on other Malian IASGM sites, in order to
37 account for structural and geographical heterogeneity. The present article contributes to the
38 literature by reopening the debate about the impact of health issues on IASGM activities, especially
39 HIV issues, in a context where the sustained spread of this disease could not only harm efforts in the
40 fight against AIDS, but also have important negative consequences on one of the main cornerstones
41 of the Malian economy. Integrated policy-making should pay special attention to infectious diseases
42 among populations in IASGM zones. Bringing information/prevention activities closer to people
43 working in gold-bearing zones is an urgent public health action.
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53 **Authors' contribution**

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3 LST designed and led the study and wrote the first draft of the report. LST, MSM, BS and BDK
4 designed the analysis. LST, HB and FD analysed the data. MM and MB oversaw data management. All
5 authors critically reviewed and approved the manuscript.
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11 12 13 References

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38 **Competing statement: Authors declare no conflict of interest**

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40 **Data sharing statement:**

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42 Full dataset and statistical code available from the corresponding author luis.sagaon-teyssier@inserm.fr The
43 presented data are anonymized and risk of identification is null.
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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	NA
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	4
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7
		(b) Report category boundaries when continuous variables were categorized	7
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

**Prevalence of HIV at the Kokoyo informal gold mining site:
What lies behind the glitter of gold with regard to HIV
epidemics in Mali? A community-based approach (The
ANRS-12339 Sanu Gundo cross-sectional survey)**

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3 **Prevalence of HIV at the Kokoyo informal gold mining site: What lies behind the glitter of gold with**
4 **regard to HIV epidemics in Mali? A community-based approach (The ANRS-12339 Sanu Gundo**
5 **cross-sectional survey)**
6

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30 Viral Hepatitis (ANRS) grant ANRS-12339 Sanu Gundo.
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34 **Abstract**

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36 **Objectives:** The aim of this article was to estimate HIV prevalence and the factors associated with
37 HIV seropositivity in the population living and working at the informal artisanal small-scale gold
38 mining (IASGM) site of Kokoyo in Mali, using data from the Sanu Gundo survey. Our main hypothesis
39 was that HIV prevalence is higher in the context of IASGM than in the country as a whole.
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43 **Design:** The ANRS-12339 Sanu Gundo was a cross-sectional survey conducted in December 2015. The
44 quantitative survey consisted in face-to-face administration of questionnaires. Five focus groups
45 were conducted for the qualitative survey. HIV prevalence was calculated for the sample, and
46 according to the type of activity performed in IASGM.
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50 **Settings:** The informal artisanal small-scale gold mining site of Kokoyo, one of the largest sites in Mali
51 (between 6000 and 1000 people).
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54 **Participants:** 224 respondents: 37.5% were gold-diggers, 33% retail traders, 6.7% *tombolomas* (i.e.
55 traditional guards), and 9% female sex-workers. The remaining 13.8% reported another activity
56 (mainly street vending).
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3 **Primary and secondary outcome measures:** HIV prevalence and HIV prevalence according to sub-
4 group, as defined by their activity at the Kokoyo IASGM. A Probit logistic regression was
5 implemented to estimate the characteristics associated with HIV seropositivity.
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8 **Results:** HIV prevalence for the total sample was 8% 95%CI[7.7%-8.3%], which is much higher than
9 the 2015 national prevalence of 1.3% (UNAIDS). The probability of HIV seropositivity was 7.8%
10 (p=0.037) higher for female non sex-workers than for any other category, and this probability
11 increased significantly with age. Qualitative data revealed the non-systematic use of condoms with
12 sex-workers; and long distance from health services was the main barrier to accessing care.
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15 **Conclusions:** Integrated policy-making should pay special attention to infectious diseases among
16 populations in IASGM zones. Bringing information/prevention activities closer to people working in
17 gold-mining zones is an urgent public health action.
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20 **Strengths and limitations of this study**

- 21 - This is the first study conducted in an informal and artisanal small-scale gold mining site in
22 Mali including all of the people directly or indirectly involved in the site's activities.
- 23 - This study was implemented using a community-based research approach, the survey design
24 and research questions being developed in collaboration with representatives of the mine of
25 Kokoyo.
- 26 - The highest HIV prevalence was found among female non sex-workers (13%), which
27 highlights the importance of focusing on high-risk less-studied populations.
- 28 - A large proportion of participants in the survey had never had a HIV test, which highlights the
29 importance of "close proximity health services"
- 30 - The cross-sectional design of the Sanu Gundo survey did not enable us to analyse changes
31 over time concerning several socio-economic and behavioural aspects, such as living and
32 working conditions, seasonal mobility, or sexual behaviour

33 **Introduction**

34 The poverty-driven activities and demographic conditions in the world's informal artisanal small-scale
35 gold mining (IASGM) sector contribute to its vulnerability to infectious diseases including HIV. This
36 disease is recognized as one of the main public health issues in this sector, and potentially concerns
37 almost 15 million people involved in IASGM activities across 70 countries¹. Despite the high risk of
38 transmission^{2,3}, and sustained spread of the disease^{4,5}, very little is known about HIV epidemics in
39 IASGM sites. Existing HIV literature on people working and living in gold mining sites mainly focuses
40 on behavioural aspects, such as prevention⁶, attitudes towards voluntary counselling and testing^{7,8},
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3 the link between alcohol consumption and HIV⁹, and the role of gender in the fight against HIV^{3,10,11}.
4 Furthermore, most studies have either been conducted among workers in industrial gold mines or in
5 mining communities near gold-bearing zones which are not exclusively related to the IASGM sector.
6 This is also the case of the few studies examining HIV prevalence, which in South Africa in the last
7 decade was measured at approximately 25%^{3,12,13}, at 22.3% for a group of Mozambican gold miners
8 in 2012, and at 4.5% and 6.4% for Guinea in 2001 and 2007, respectively¹⁴. We found only one study
9 concerning an IASGM site, specifically in the Amazon region of Guyana. HIV prevalence there was
10 6.5%¹⁵. In addition, these studies principally focus on gold miners themselves and/or other
11 presupposed most-at-risk groups (e.g. female sex-workers), with little attention given to other
12 categories of potentially high-risk people such as gold diggers (i.e. miners working in the informal
13 sector), women who are not sex-workers, and street vendors, all of whom play an important role in
14 the transmission and/or mobility of HIV. Indeed, focusing only on gold miners and not including these
15 other high-risk groups may be detrimental to the fight against HIV², as demonstrated by Clift *et al.*¹⁶
16 in a community near two industrial gold-mines in Tanzania, where HIV prevalence was lower in mine
17 workers (6%) than in men and women living at the mines but not directly involved in mining
18 (respectively, 16% and 18%).
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21 Gold mining is one of the cornerstones of the Malian economy, representing almost 70% of the
22 country's total exports and 8% of the GDP in 2013¹⁷⁻¹⁹. Between 200 000 and 400 000 persons are
23 estimated to be directly concerned by IASGM activities^{20,21}. Despite the economic importance of the
24 sector, little attention has been paid to health, as demonstrated by both the poor medical services
25 provided in these sites^{22,23} and the increasing demand for health, especially concerning HIV. The high
26 prevalence observed in some key populations provides a picture of the situation people may face in
27 these sites. A demographic and health survey (EDSMV) conducted in Mali in 2012 showed that HIV
28 prevalence among female sex-workers (24.2%), female street vendors (3.7%), and truckers (2.7%)
29 was much higher than the national prevalence of approximately 1.2% in the same year. Different
30 reports on IASGM in Mali have highlighted the urgent need to include the health dimension in
31 economic-based research programs, especially concerning HIV. Community-based activities (e.g.,
32 prevention, screening, counselling etc.) could help do this as they could help provide a greater
33 understanding of the heterogeneity of IASGM, the functioning of this informal labour market^{2,24}, and
34 the impact of IASGM sector on the transmission and spread of infectious diseases.
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37 We conducted the ANRS-12339 Sanu Gundo survey of the IASGM site at Kokoyo in Mali's Koulikoro
38 region in December 2015, using a community-based research approach. The objective of this article
39 was to estimate HIV prevalence - using the Sanu Gundo survey - in different groups present at
40 Kokoyo, and the factors associated with HIV seropositivity.
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Methods

Design and settings

The ANRS-12339 Sanu Gundo cross-sectional survey was conducted in December 2015 at Kokoyo (for 2 weeks), one of the largest IASGM sites in Mali with a population oscillating between 6 000 and 10 000 people, depending on the season (rainy/dry). In collaboration with the Chamber of Mines and the Mines Ministry, this site was chosen for its geographical location because of the great deal of cultural heterogeneity there. People come not only from other Malian regions, but also from neighbouring countries (Burkina Faso, Guinea, Nigeria, and Niger). All procedures and documents used were validated by both French (CCTIRS N°15.917) and Malian (N°2015/65/CE/FMPOS) ethics committees.

The study started with conversations about global health topics with a focus on HIV/STI prevention which were facilitated by ARCAD-SIDA members. Participants in the conversations were informed about the community-based services provided by the mobile ARCAD-SIDA unit, including the provision of a medical check-up and essential medicines including those for treating STI. Furthermore, ARCAD-SIDA proposed rapid tests for HIV and invited people to take part in the survey. For HIV screening, ARCAD-SIDA follows the Malian Ministry of Health recommendations using Determine® rapid tests, and ImmunoComb® II for confirmation. ARCAD-SIDA provided counselling about the importance of being treated to participants testing HIV positive, and referred them to regional health care centres (Centre de Santé de Référence, CSREF) for blood assessment and inclusion in treatment and follow-up programmes.

Participants in the conversations were then invited to participate in the qualitative and quantitative surveys (they could choose either or both) which formed the basis for the ANRS-12339 Sanu Gundo survey. Community-based agents sent those interested to the Malian team of researchers, who in turn provided detailed information about the content of the survey, its main objectives, and the advantages/risks of participating in this kind of survey. Survey participants provided written formal consent to participate in the survey(s) by signing a letter of consent.

Participants

Eligibility criteria included: i) aged 18 years or older; ii) able to speak French, Bambara, or English; iii) able to provide written consent to participate. Persons under the effects of alcohol and/or drugs

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3 were excluded. For the *quantitative survey*, 224 participants constituted the convenience sample. In
4 order to reduce any potential over-representation and under-representation sampling bias, ARCAD-
5 SIDA activities were conducted every day at different time slots and locations at the site in order to
6 adapt participant recruitment to the work schedule of the different categories of people living there.
7 To those who agreed to participate in the survey(s), a brief face-to-face questionnaire was
8 administered by trained investigators who collected information about the following : i)
9 sociodemographic and socioeconomic characteristics: age (continuous variable), gender, marital
10 status, country of residence, educational level, and weekly earnings (dichotomized at the median of
11 14 500 FCFA, approximately 24.26 US\$) ; ii) type of activity and mobility between sites; iii) HIV
12 awareness, assessed with the following questions: “Have you heard about HIV?” “Have you ever
13 been tested for HIV before today?”, “Do you know your HIV status?”; iv) risky behaviours: alcohol
14 and drugs consumption, sexual self-definition, type(s) and frequency of intercourse; v) perceived
15 health status, assessed with the following question: “How do you consider your state of health
16 today?”, with possible answers including “very poor”, “poor”, “moderate”, “good”, and “very good”.
17 This variable was equal to 1 for those perceiving their health was good or very good, and 0 for those
18 perceiving they had poor or very poor health. For the *qualitative survey*, purposive sampling was
19 implemented. This seemed to be the most suitable sampling method as the main objective of the
20 qualitative survey was to collect information about prevention and access to care for HIV/STI among
21 specific groups. The sample size for each group was fixed between 5 and 8 survey participants in
22 order to ensure diversity among them. Five activity-specific focus groups were organized: Malian
23 gold-diggers, Non-Malian gold-diggers, female sex-workers, female non sex-workers, and people
24 guaranteeing the organizational functioning at the gold mine site (*damantiguis* and *tombolomas*).
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42 **Statistical analyses**

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44 The sample was described and HIV prevalence calculated both for the overall sample, and for the
45 different sub-groups listed above (i.e., according to the type of activity in the gold mining site). A
46 Probit logistic regression was implemented to estimate the characteristics associated with the
47 probability of HIV seropositivity. Given the nature of the normal distribution assumption of the error
48 term in the Probit estimation, coefficients are not affected by the presence of extreme values in
49 independent variables. Furthermore, Probit regression allows the computation of marginal effects
50 that are more flexible and more informative than odd-ratios^{25,26} which tend to be larger in the
51 presence of rare events and are in any case preferred for small samples²⁷. Marginal effects, dF/dX ,
52 are interpreted as instantaneous rates of change: for a dichotomous explanatory variable, a marginal
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3 effect shows how predicted probabilities change when the variable changes from 0 to 1. All statistical
4 analyses were performed using R software²⁸.
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8 9 ***Qualitative data analysis***

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11 Focus groups were audio-recorded and transcribed. The principle of thematic encoding developed by
12 Flick²⁹ for the analysis of interviews was applied as for other studies with focus groups³⁰. Therefore,
13 thematic and pragmatic dimensions were combined into a dialogical unit to highlight patterns
14 specific to the different groups. Lexical analysis was carried out using both Alceste and MAXQDA
15 software. The different dimensions were cross-classified to generate new insights about the
16 organisation of the data (i.e. how common themes are linked together, specific interactions intra-
17 and inter-groups, etc.).
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25 26 **Results**

27 28 ***Sample characteristics***

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30 The quantitative survey was conducted on a convenience sample of 224 participants interested in
31 prevention and medical activities provided by ARCAD-SIDA (Table 1): 101 women (45.1%) and 123
32 men (54.9%). There was a significant difference in average age between both genders: 25 and 29
33 years old respectively. With respect to participants' main residence, 133 (59.4%) declared they lived
34 in Mali: 28.5% in Kokoyo (i.e. autochthonous) and 71.5% from different cities (i.e. non-
35 autochthonous) including Danga (the nearest) and Timbuktu (the farthest). The remaining 91
36 participants (40.6%) declared another country as their principal place of residence. With respect to
37 marital status, 158 participants (70.5% of the whole sample) declared they were married or lived in a
38 couple. Among them, 50.6% lived with their spouse in Kokoyo and the remaining 49.4% were
39 geographically single. Of the 86 married/in a couple males who did not live with their spouse in
40 Kokoyo 72.1% declared living with another partner at the site. Conversely, the proportion of
41 geographically single women was only 22.2% among the sample's 72 married/in-a-couple females,
42 and none declared having another partner at the site. Socio-economic difficulties were observed in
43 terms of educational level, with 49.1% of the 224 participants reporting they had never been to
44 school. Among the others, 27.7% and 9.8% had, respectively, a primary and secondary school
45 educational level, 12.1% had a Koranic educational background, and 1.3% declared having post-
46 secondary school education. With respect to their activity in Kokoyo, among the 224 respondents
47 37.5% were gold-diggers, 33% retail traders, 6.7% *tombolomas*, 9% female sex-workers, while 14%
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reported another activity (mainly street vending). Approximately half of the sample comprised people living under the poverty threshold of 1.9 US\$ per day: 49.3% compared with 49.1% in the general Malian population (2009)³¹. Finally, 11.6% reported mobility between IASGM sites, and declared that Kokoyo was not the first IASGM site where they had worked.

Table 1. Sample characteristics of participants living in the informal artisanal small-scale gold mining site (IASGM) of Kokoyo in Mali (n=224)

Variables	n (%)
Gender	
Male	123 (54.9)
Female	101 (45.1)
Age²	
Ref: 18 to 21 years	57 (25.4)
22 to 26	60 (26.8)
27 to 30	53 (23.7)
30+	54 (24.1)
Main residence country	
Mali	133 (59.4)
Other countries	91 (40.6)
Marital status	
Married or living in a couple	158 (70.5)
Single, divorced, widowed	66 (29.5)
Educational level	
Never been to school	110 (49.1)
Primary	62 (27.7)
Secondary	22 (9.8)
Koranic	27 (12.1)
Post-secondary	3 (1.3)
Category of participant	
Malian gold-diggers, tombolomas, and other malian workers	130 (58)
Women sex-workers	27 (12,1)
Women non sex-workers	54 (24,1)
Non-malian gold diggers	13 (5,8)
Self-perceived health status	

Good health status 133 (59,4)
 Ref: Poor health status 91 (40,6)

Weekly earnings³

Earnings ≤ median 112 (50)
 Ref: Earnings > median 112 (50)

Have worked in other IASGM before Kokoyo

Yes 26 (11.6)
 No 198 (88.4)

HIV prevalence and new diagnoses

Seventeen new HIV-positive cases were found with the ARCAD-SIDA testing, among those tested at the time of the survey, and 1 HIV-positive case was self-reported. Overall, HIV prevalence was 8% 95%CI[4.5%, 11.6%]. HIV prevalence was higher in women than in men, respectively, 10.4 95%CI[4.5%, 16.2%] and 5.9% 95%CI[1.7%, 6.5%]. In terms of the 5 different categories studied, the highest HIV prevalence was in women who were not sex-workers (13% 95%CI[5.4%, 20.3%]). Although lower than in the latter group, the prevalence in female sex-workers was still higher (3.7% 95%CI[-3.5%, 10.9%]) at the Kokoyo site than the national prevalence for sex-workers (irrespective of gender). Prevalence in both non-Malian and Malian male gold-diggers was high, respectively, 7.7% 95%CI[-7.4%, 22.8%] (90%CI[-4.9%, 20.4%]) and 6.5% 95%CI[-0.7%, 13.7%] (90%CI[0.5%, 12.6%]), whereas prevalence in males other than gold diggers was 6.4% 95%CI[-0.7%, 13.5%] (90%CI[0.5%, 12.3%]). No HIV-positive case was observed in traditional guards (*tombolomas*).

The quantitative survey showed that 63.4% participants (142 out of 224) had never had a HIV test. Of these, 7 (4.9%) - 5 women and 2 men - tested positive for HIV using ARCAD-SIDA's test. This corresponded to 38.9% of the total 18 (11 women and 7 men) HIV seropositive participants observed, (or 45.5% (5/11) of total HIV women and 28.6% (2/7) of total HIV men). Among the 5 HIV positive cases for women, 1 was a sand washer, 1 was a female sex-worker and 3 were street vendors. Among the 2 HIV positive cases for men, 1 was a non-Malian gold digger and 1 a male street vendor.

Factors associated to HIV seropositivity

A multivariate probit regression was implemented to estimate the factors associated with HIV seropositivity among the 224 participants in the quantitative survey (Table 2). Estimates show that

the probability of HIV seropositivity was 7.8% ($p=0.037$) higher for female non sex-workers than for any other category, and this probability increased significantly with age. Indeed, the probability of HIV seropositivity - with respect to the youngest participants (aged between 18 and 21 years) – was 14.1% ($p=0.034$), 14.2% ($p=0.036$) and 16.1% ($p=0.021$) higher for participants aged 22-26 years, 27-29 years, and 30+ years, respectively. Finally, a 10.9% lower probability of HIV seropositivity was observed in participants who perceived their health status as good (versus poor).

Table 2. Factors associated with HIV seropositivity among participants living in the informal artisanal small-scale gold mining site (IASGM) of Kokoyo in Mali (n=224)

Covariates	Marginal Effects ¹ (dF/dX)	Coefficient	95% CI		P-value
			Inf.	Sup.	
Intercept		-2.413	-3.716	-1.431	<0.001
Category of participant					
Ref : Malian gold diggers and <i>tombolomas</i>	Ref.	Ref.			
Women sex-workers	0.019	0.151	-1.048	1.134	0.780
Women non sex-workers	0.078	0.624	0.046	1.231	0.036
Non-Malian gold diggers	-0.010	-0.057	-1.423	1.015	0.924
Age²					
Ref: 18 to 21 years	Ref.	Ref.			
22 to 26	0.141	1.105	0.175	2.332	0.036
27 to 30	0.142	1.115	0.162	2.358	0.039
30+	0.161	1.268	0.271	2.548	0.022
Self-perceived health status					
Good health status	-0.109	-0.862	-1.459	-0.307	0.003
Ref: Poor health status	Ref.	Ref.			
Weekly earnings³					
Earnings \leq median	0.036	0.282	-0.261	0.840	0.310
Ref: Earnings > median	Ref.	Ref.			

¹ Is the change in the probability given the discrete change for dichotomous variables.

² Age categories' cut-offs correspond to quartiles.

³ The median weekly earning is 14 500 FCFA (25 US\$). This variable was used to account for the socioeconomic status of participants.

Main findings of the qualitative survey

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3 Five focus groups were carried out over 28 participants according to gender and professional status:
4 6 *tombolomas*, 6 Malian male gold diggers, 5 non-Malian male gold diggers, 5 female sex-workers
5 and 6 women non sex-workers. Among the discourses identified, one referred to sexual practices,
6 especially non-systematic condom use, women sex-workers charging extra for condomless sexual
7 intercourse, and the undisclosed use of condoms by women. Participants attributed these practices
8 to the following factors: i) the place where sexual intercourse took place: bars *versus* the street; ii)
9 the nationality/ethnicity of female sex-workers: Malians and Guineans were seen as more “flexible”
10 than Nigerians (considered as “strict”) with regards to condom use; and iii) the nature of the
11 relationship between men and women: trustful relationships (considered “safer”) than strictly
12 commercial-sex relationships (considered “risky”). Another discourse identified referred to health
13 services access, with the main barrier being the long distances involved. Other barriers mentioned
14 were the high price of medicines, the lack of specialists and other health care providers, as well as
15 the low number and poor quality of HIV/STI information/prevention programmes described. These
16 barriers were also the main reasons why participants resorted to traditional medicine.
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28 Discussion

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30 This is the first study conducted in an informal and artisanal small-scale gold mining site in Mali which
31 investigates HIV not only in those directly involved in informal mining (i.e. gold diggers), but also in
32 other populations with a related activity. The aims of this article were drawn up specifically to
33 respond to the need for the authorities of the IASGM site at Kokoyo to characterize the population
34 living there, and to provide community-based prevention and HIV testing as part of the health care
35 services offered.
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40 The low educational level observed and the high proportion of participants living with revenues
41 below the 1.9 US\$ poverty-line threshold, reflects the high level of poverty reported in the literature
42 concerning IASGM sites in other countries with large gold-bearing zones^{22,32}. The fluctuation of the
43 population at Kokoyo suggests large-scale cyclical migration of workers (i.e. they stay for a period, go
44 back home, and the next season they return either to the same mine or to another). Rees et al.
45 suggested they such workers are often separated from their family (i.e. geographically single)¹²,
46 something confirmed by our results where 71.5% of Malian participants came from other regions of
47 Mali (non-autochthonous), and 40.6% of the total sample were not Malian. Moreover, geographically
48 single individuals accounted for 49.4% of the 158 participants who reported being married or living in
49 a couple. This “bridge population” cohabits with other high-risk groups in the IASGM site at Kokoyo,
50 representing a potential source for the continued spread of infectious diseases - including HIV - at
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3 the site, and at their home ^{4,5}. Indeed, being single (geographically or not) is associated with risky
4 behaviours, given the freedom from social norms and the economic difficulties that prevail in IASGM
5 sites ². Furthermore, working conditions and the inherent related dangers which male gold diggers
6 are confronted with, have also been identified as factors related to an increase in risky behaviours
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9 ^{3,33}.

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11 This is the first time that HIV prevalence has been estimated in an IASGM site in Mali. We found a
12 prevalence of 8% in the 224 participants in our study, which is much higher than the Malian national
13 prevalence of 1.3% estimated in 2015³⁴, but is in line with the 7% estimated for the IASGM site of
14 Tenkoto in the Kédougou region of Senegal ³⁵. In addition, HIV prevalence varied for the different
15 categories studied, ranging between 3.6% for female sex-workers to 13% for both women gold
16 diggers and women street vendors. The latter value is in line with the 13% estimated for street
17 vendors in Burkina Faso, although that value was not specific to IASGM sites ³⁶. Our estimates not
18 only reflect the results from the few qualitative studies performed to date which suggest high
19 prevalence of HIV in IASGM sites, but also highlight that “less classic” groups (i.e. those not directly
20 involved in mining) are at higher risk ². The different HIV prevalence rates found across groups may
21 reflect the lack of prevention programs adapted to key populations other than sex-workers in Mali.
22 Most of the efforts in the fight against HIV/AIDS in Mali are concentrated on female sex-workers and
23 men having sex with other men (MSM), who are identified as the most vulnerable groups. This could
24 explain - at least in part - the low prevalence rate among female sex-workers in Kokoyo IASGM and
25 the higher prevalence among other groups, including female non-sex workers and gold-diggers.
26 Indeed participants from these two categories expressed during the focus groups that prevention
27 campaigns are mostly directed at female sex-workers, who seem to be more informed about the risk
28 of HIV contamination and about prevention tools.

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30 The acceptability of HIV testing by participants observed in this study demonstrated not only that the
31 community-based dimension is crucial to conduct this kind of research ^{2,7}, but that it is also useful for
32 the provision of prevention and HIV testing to this population. Of the 236 persons invited to test for
33 HIV, only 5% refused. This is one of the main contributions of our analysis, and highlights the large
34 demand-supply gap for health care services in Kokoyo. Indeed, the nearest Rural Health Community
35 Centre (CSCOM, *Centre de Santé Communautaire*) does not provide either prevention or testing for
36 HIV, and the only two centres of voluntary testing in the Koulikoro region are far from gold-bearing
37 zones, especially the IASGM site of Kokoyo. This community-based research identified a large
38 number of new HIV positive cases, and this is another important contribution of the study. More
39 specifically, 38% of the 18 HIV-positive participants in the quantitative survey were newly diagnosed
40 using ARCAD-SIDA's rapid tests. Five out of 11 positive cases in women were new diagnoses,
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3 especially female street vendors. Although ARCAD-SIDA referred all 18 HIV positive participants to
4 the nearest regional hospitals (CSREF) in order to link them to care, the emerging question is whether
5 or not these participants subsequently initiated and adhered to antiretroviral treatment given the
6 distance of more than 100km between Kokoyo and Kangaba city where the CSREF is located.
7 Unfortunately, we have no information about lost-to-follow-up rates in people living with HIV in the
8 context of IASGM sites, but presumably these rates are high given that HIV is not of primary concern
9 to people in IASGM sites, as suggested by Campbell ³. This certainly seems to be the situation in
10 Kokoyo, where the large majority of study participants aware of HIV (over 90%) had never previously
11 gone for a test (63.4%). Multivariate analyses indicated that female non sex-workers, the eldest
12 participants, and those with poor self-perceived health status were the three sub-populations most
13 associated with HIV seropositivity.
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21 Some limitations should be acknowledged. First, the study sample is not representative of the whole
22 population in IASGM sites in Mali. However, our results reflect those in the literature. Second, the
23 cross-sectional design of the Sanu Gundo survey did not enable us to analyse changes over time
24 concerning different aspects, such as living and working conditions, seasonal mobility, and sexual
25 behaviour. Furthermore, although the participants who tested positive for HIV during the study were
26 referred to the regional hospital, the design of the survey did not allow us collect subsequent
27 information, either concerning linkage-to-care or antiretroviral treatment initiation. Finally, there is a
28 possibility of selection bias, as the sample was drawn from the healthcare conversation audience
29 organized by ARCAD-SIDA. Nevertheless, any selection bias would reflect an audience mainly
30 comprising individuals interested in prevention and to some extent, worried about health issues,
31 especially HIV. One would expect that any future study whose design were to attract participants
32 other than those already interested in health care, would result in higher HIV prevalence being
33 measured and would accentuate the precarious characteristics already described by our survey at
34 Kokoyo. Despite these limitations, our study contributes to the existing literature by creating a
35 knowledge base which could be a useful first step for the development of suitable surveys and
36 interventions.
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48 **Conclusion**

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50 The results of this study demonstrate the importance of focusing on different categories of workers
51 and the necessity to conduct further similar research on other Malian IASGM sites, in order to
52 account for structural and geographical heterogeneity. The present article contributes to the
53 literature by reopening the debate about the impact of health issues on IASGM activities, especially
54 HIV issues, in a context where the sustained spread of this disease could not only harm efforts in the
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3 fight against AIDS, but also have important negative consequences on one of the main cornerstones
4 of the Malian economy. Integrated policy-making should pay special attention to infectious diseases
5 among populations in IASGM zones. Bringing information/prevention activities closer to people
6 working in gold-bearing zones is an urgent public health action.
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10 11 12 **Authors' contribution**

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14 LST designed and led the study and wrote the first draft of the report. LST, MSM, BS and BDK
15 designed the analysis. LST, HB and FD analysed the data. MM and MB oversaw data management. All
16 authors critically reviewed and approved the manuscript.
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56 **Competing statement: Authors declare no conflict of interest**

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58 **Data sharing statement:**
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3 Full dataset and statistical code available from the corresponding author luis.sagaon-teyssier@inserm.fr The
4 presented data are anonymized and risk of identification is null.
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For peer review only

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	NA
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	4
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7
		(b) Report category boundaries when continuous variables were categorized	7
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.