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## Predictors of antimalarial self-medication in illegal gold miners in French Guiana: a pathway towards artemisinin resistance.

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1 **Title:** Predictors of antimalarial self-medication in illegal gold miners in French Guiana: a  
2 pathway towards artemisinin resistance

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27

28 **Abstract** (255 words)

## 29 **Background**

30 Malaria is endemic in French Guiana (FG), South America. Despite the decrease of cases in the  
31 local population, illegal gold miners are very affected by malaria (22.3% of them carried  
32 *Plasmodium spp*). Self-medication seems to be very common but its modalities and associated  
33 factors have not been studied. The aim of this study was to evaluate parasite susceptibility to  
34 drugs and to document behaviours that could contribute to resistance selection.

## 35 **Method**

36 This multicentric cross-sectional study was conducted in resting sites along the Surinamese  
37 border. Participating gold miners working in French Guiana completed a questionnaire and  
38 provided a blood sample.

## 39 **Results**

40 From January to June 2015, 421 illegal gold miners were included. Most were Brazilian (93.8%),  
41 70.5% were male. During the most recent malaria attack, 45.5% reported having been tested for  
42 malaria and 52.4% self-medicated, mainly with artemisinin derivatives (90%). Being in FG  
43 during the last malaria attack was the main factor associated with self-medication (AOR=22.1).  
44 This suggests that access to malaria diagnosis in FG is particularly difficult for Brazilian illegal  
45 gold miners. Treatment adherence was better for persons who reported being tested. None of the  
46 32 samples with *P. falciparum* presented any mutation on the pfK13 gene, but one isolate showed  
47 a resistance profile to artemisinin derivatives *in vitro*.

## 48 **Conclusion**

49 The risk factors for the selection of resistance are well known and this study showed that they are  
50 present in French Guiana with persons who self-medicated with poor adherence. Interventions  
51 should be implemented among this specific population to avoid the emergence of artemisinin  
52 resistance.

53

54

55 **Text words count:** 3658 words

## 56 **Background**

57 Malaria is a major parasitic illness, with 198 million cases and 584,000 deaths in 2014,  
58 worldwide.<sup>1</sup> In French Guiana (FG), a French overseas territory located on the Guiana Shield in  
59 South America, malaria is endemic.<sup>2</sup> Great efforts have been deployed to control malaria in the  
60 region. In Suriname as in local villages in French Guiana, the number of cases decreased  
61 drastically.<sup>3,4</sup> But in this territory, mainly covered by Amazonian forest, the soil is rich in gold. In  
62 addition to the legal mining industry, 8 to 10 thousand illegal gold miners, mainly Brazilian,  
63 work in the forest.<sup>5</sup> They have difficult life conditions with poor hygiene and exhausting work  
64 which lead to poor health. Deforestation and still water pools favor mosquito proliferation,  
65 notably *Anopheles darlingi*, the main malaria vector. In 2015, in western French Guiana,  
66 molecular malaria diagnosis showed 22.3% of illegal gold miners carried *Plasmodium spp.*, 84%  
67 of whom were asymptomatic.<sup>6</sup> In 2014, in a gold mining site near Maripa Soula, 48.5% of gold  
68 miners were *Plasmodium spp.* positive by PCR.<sup>7</sup> This indicated that although malaria in local  
69 populations keeps decreasing, it remains hyperendemic in this specific population in French  
70 Guiana. Medical care is free in Health Centers but the remoteness of the mines and the fear of  
71 law enforcement hamper effective access to care for miners. A first study in this population in  
72 Suriname and French Guiana has shown that self-medication with artemisinin derivatives seemed  
73 to be very common, with poor treatment adherence.<sup>8</sup> But self-medication modes and factors  
74 associated with it have not been studied specifically in French Guiana despite access to care  
75 differences between those two countries. This frequent self-medication threatens the efficacy of  
76 artemisinin derivatives. In fact, the main known factors contributing to antimalarial drug  
77 resistance are: poor treatment adherence (quantity or treatment duration), poor quality of drugs  
78 and drug pressure with monotherapy.<sup>9,10</sup> Historically, antimalarial drug resistance emerged  
79 independently, in South-East Asia and in the Amazon region, as it happened for chloroquine

80 resistance in the 1960's.<sup>11,12</sup> The decrease of sensitivity to artemisinin derivatives appeared about  
81 10 years ago in South East Asia and now concerns five countries in the Mekong Region.<sup>13-15</sup> .  
82 The transborder context between Suriname, Brazil and French Guiana, with movements of  
83 precarious populations in remote areas, challenges malaria control in this area and is similar to  
84 the transborder context of the Mekong region.<sup>16</sup> Several parameters are used to characterize  
85 artemisinin resistance. *In vivo*, the persistence of parasites in the blood more than three days after  
86 treatment or a delayed parasite clearance time are indicators.<sup>17</sup> *In vitro*, the survival rate of ring-  
87 stage parasites that have been exposed for six hours to dihydroartemisinin is the best phenotyping  
88 method to identify a decreased parasite sensitivity to dihydroartemisinin.<sup>18</sup> Finally in 2013,  
89 certain mutations in the *pfk13* gene were shown to be associated with an increased parasite  
90 clearance time in isolates from South-East Asia.<sup>19</sup>

91  
92 The objectives of this study were to describe the behaviours of illegal gold miners working in  
93 French Guiana when they had a malaria attack; to evaluate factors associated with self-  
94 medication and with poor treatment adherence; and to characterize artemisinin sensitivity of the  
95 associated parasites.

96

## 97 **Methods**

98 A multicentric cross-sectional observational study was conducted in 2015 between January 1<sup>st</sup> and  
99 June 30<sup>th</sup>. As no sampling frame exists, illegal gold miners were recruited using convenience and  
100 snow-ball sampling on « resting sites », areas where they go for rest, supplies or medical care.  
101 These sites were spread along the Suriname-French Guiana border on the Maroni river.

102 Inclusion criteria were: working on a gold mining site in FG; being at the resting site for less than  
103 seven days; being over 18 years of age; and giving informed consent. A questionnaire collected  
104 socio-demographic data, knowledge, attitudes and practices (KAP) in gold miners concerning  
105 malaria. Poor adherence was considered if the person declared that there were remaining pills at  
106 the end of the last malaria treatment. Behaviour when having malaria referred to the last malaria  
107 episode only, to avoid memory bias. A rapid diagnostic test was performed on the field and  
108 malaria treatment was given if the test was positive. A 5 ml-blood sample was taken from each  
109 participant for further analysis and sent to the National Reference Center for Malaria for  
110 biological investigations. If the thin smear was positive for *Plasmodium falciparum*, parasites  
111 were phenotyped using the standard isotopic method and the ring survival assay (RSA).<sup>18-20</sup> DNA  
112 was extracted from 200µL of whole blood with the QIA amp<sup>®</sup> DNA kit (Qiagen). The *pfK13*  
113 gene was amplified and sequenced using the Sanger method.<sup>19</sup> Study size and bias assessment are  
114 described in reference<sup>6</sup>.

### 115 **Statistical analyses**

116 Data were analysed with Stata12 software (StataCorp<sup>®</sup> College Station, Texas). Data from the  
117 KAP study were analysed using Multiple Correspondence Analyses (MCA) in order to reduce the  
118 dimension of the variables. Ascending Hierarchical Classification (AHC) was used to define  
119 clusters with similar characteristics; individuals were grouped in clusters using variables selected  
120 from the MCA, namely those with higher weights on MCA. Bivariate analyses was done using  
121 Chi-Square tests or Student's t-test depending on the type of variable. Variables with a p-value <  
122 0.20 in bivariate analyses were included in a multivariate logistic regression to identify factors  
123 associated with self-medication and poor treatment adherence. A backward selection method was  
124 used to retain variables significant at a 0.05 level in the final multivariate model. The goodness of



125 fit of the logistical regression model was tested with the Hosmer and Lemeshow test. All  
126 statistical analyses used a 5% significance level.

## 127 **Ethics**

128 The study was approved by the Comité d'Evaluation Ethique de l'Inserm, Process n°14-187  
129 (IRB00003888 FWA00005831). The database was anonymized and declared to the Commission  
130 Nationale Informatique et Libertés. Patients were included after recording informed consent.

131

## 132 **Results**

### 133 **Study population**

134 From January to June 2015, 421 illegal gold miners were included in the study with a  
135 participation rate of 90.5%.<sup>6</sup> The mean age was 37.7 years (min-max=18-62) and 70.5% of  
136 participants were men. Most of them (93.8%) were born in Brazil and they worked in 67 different  
137 mining sites.

### 138 **Malaria knowledge and protection**

139 Malaria was mentioned in the top three health problems at mining sites by 84.8% of interviewed  
140 people. The mode of transmission was well known: 91.4% mentioned the mosquito but 3.3%  
141 mentioned living near dirty water or 3.3% in a dirty environment, or 1.6% drinking dirty water.

142 One hundred twenty eight (30.4%) considered that it was better to take treatment even if the  
143 malaria test was negative, 11.2% that treatment could be stopped when feeling better and 8.5%  
144 that malaria could be cured without treatment. Most (95.7%) thought that malaria kills. French  
145 malaria treatment was considered better than Surinamese treatment for 93% of them, and better

146 than Brazilian treatment for 84%. However, the three treatments are in fact the same: artemether-  
147 lumefantrine, labelled as Riamet® in France and Coartem® in Brazil or Suriname. The majority  
148 of interviewed people (85.5%) could mention three or more malaria symptoms.

149 Considering malaria protection, 18% declared protecting themselves from malaria always or  
150 often, but 54.8% never. The modes of protection were: mosquito nets (29%), mosquito repellents  
151 (21.6%), wearing long clothes (2.1%) and living far from dirty water (1.2%). However, only  
152 15.7% declared having slept under a mosquito net the last night at the mining camp, of which  
153 only 19.7% were insecticide-treated nets. The main reasons for not using a mosquito net were:  
154 did not have any (63.4%), uncomfortable (19.1%), destroyed by French Army (10.4%) (military  
155 operations against illegal gold mining aim at destroying all logistical supplies on mining camps),  
156 too constraining (7.9%), useless (5.6%) and would hamper flight in the event of a military raid in  
157 the camp (3.4%). Malaria chemoprophylaxis was used by 6.4% of people, mainly with Artecom®  
158 (dihydroartemisinin/piperaquine/trimethoprim + primaquine single dose).

### 159 **Past malaria history and behaviours**

160 The flow chart is presented figure 1. Forty five persons (10.7%) declared never having had  
161 malaria. They differed from the 376 people who declared a past history of malaria for sex (51%  
162 of male in persons who never had malaria versus 73% in person with a past history of malaria,  
163  $p=0.002$ ), age (31% more than 37 years versus 52%,  $p=0.009$ ) but the place of birth did not  
164 differ. Most participants (66.2%) declared having had more than seven malaria attacks, and  
165 24.2% three or less. The median time since the last malaria attack was two years [Interquartile  
166 range: 6 months - 6 years]. During the last malaria attack, 52.4% (N=197) self-medicated with  
167 antimalarial drugs, 45.5% (N=171) got tested for malaria, 1.3% (N=5) used medicinal plants and

168 0.8% (N=3) declared having done nothing, without statistical difference between groups for  
169 socio-demographic variables. When only considering people having had their last malaria attack  
170 less than two years ago, 66% took the whole treatment and 66.5% self-medicated, compared to  
171 86.7% and 39.3% for those who had malaria more than two years ago, respectively ( $p<0.001$  for  
172 both). Behaviour also varied with the place of the last malaria attack: 66% of self-medication if in  
173 French Guiana, 28% if in Suriname and 7% if in Brazil ( $p<0.001$ ).

#### 174 **Malaria testing**

175 For persons who got tested for malaria (N=171), the testing location depended on the country  
176 where the malaria attack occurred. If malaria occurred in Brazil (N=56) or Suriname (N=18),  
177 people got tested in these countries. But if malaria occurred in French Guiana (N=86), 47.7%  
178 went to Suriname to get tested (33 persons to a health center, 8 to Malaria Service Deliverers  
179 (MSD)), 37.2% to a French health center, and 12.8% went back to Brazil. The two other persons  
180 (2.3%) declared having been tested by Surinamese malaria service deliverers at a mining site in  
181 French Guiana. Easy accessibility was the main reason declared for choosing a place for malaria  
182 diagnosis and treatment (85.9%). Care was free for 87.7% of the surveyed miners. Treatment  
183 effectiveness was perceived to be good for 93.6% persons, and 90% declared having taken the  
184 complete treatment course.

#### 185 **Self-medication**

186 A majority of those who reported self-medication (N=197) bought antimalarial drugs directly on  
187 the mining site (80.7%), or got it from friends or family (6.1%). Ninety percent (178/197) of  
188 antimalarial drugs contained artemisinin derivatives, of which 93.8% were Artecom®. Most of  
189 the time (85.1%), the treatment was paid in gold, 1 to 3 grams, which is worth 30 to 90 USD.

190 Treatment effectiveness was considered to be good for 68% of the persons but insufficient for  
191 23.9%. One hundred and twenty persons (60.9%) declared having taken the whole treatment. The  
192 majority (93.4%) declared that self-medication was related to the distance of malaria testing  
193 structures. After multivariate analyses, the main variables significantly associated with self-  
194 medication were being in FG during the last malaria attack (adjusted odds-ratio (AOR)=22.1) and  
195 being born in Brazil (AOR=10.74) (Table 1).

### 196 **Factors associated with poor adherence**

197 Treatment adherence was statistically different between persons who got tested (N=154/171,  
198 90.1%) and those who self-medicated (N=120/197, 60.9%) ( $p<0.001$ ). The main factors  
199 associated with poor adherence were self-medication (AOR=6.03) and thinking that it is better to  
200 take a treatment even if the malaria test is negative (AOR=2) (Table 2).

### 201 **Multiple correspondence analyses**

202 Two-dimensional projection of the correspondence analyses showed malaria behaviours on the  
203 first axis, with the opposition between self-medication and malaria testing. The second axis  
204 describes malaria knowledge with on the positive coordinate inadequate malaria knowledge.  
205 Dimension 1 plus 2 displayed 81% of the variance. The smaller the distance between points, the  
206 stronger was their association. Thus, self-medication, poor adherence, more than four malaria  
207 attacks, and the last malaria attack in the past two years were associated, as well as the opposite  
208 modalities(Figure2).

209 Based on significant variables in the correspondence analyses, two clusters of persons were  
210 defined with ascending hierarchical classification. The first one regrouped people declaring a past  
211 history of three or less malaria attacks, the last one occurring more than two years ago, for which

212 they got tested and treated with a good adherence. They did not consider malaria as a major  
213 health problem. The second opposite cluster regrouped people declaring four or more malaria  
214 attacks, the last one more recently (less than two years ago), for which they self-medicated with a  
215 poor adherence. They considered malaria as a major health problem. Sociodemographic data did  
216 not differ between the two clusters (Table 3).

### 217 **The state of parasite sensitivity to artemisinin derivatives in French Guiana**

218 Among the 421 miners included, 94 were diagnosed positive by PCR for *Plasmodium spp*  
219 carriage including 55 *P. falciparum* cases (10 coinfecting with *P. vivax*). The other PCR were  
220 positive for *P. vivax* only (35/94), *P. malariae* (3/94) and *P. vivax* + *P. malariae* (1/94). Among  
221 these *P. falciparum* samples, the parasite density was sufficient for successful amplification and  
222 sequencing of the *pfk13* gene in 32 samples (58%). None of them revealed any mutation in the  
223 propeller part of the gene.

224 Six *P. falciparum* samples were successfully phenotyped using the RSA method. Five out of six  
225 exhibited a 0% survival rate. The last one exhibited a survival rate of 2.70% which is above the  
226 decreased sensitivity threshold of 1%. This result has not been confirmed by a second analyses  
227 (survival rate at 0%). However this isolate was also associated with an *in vitro* susceptibility  
228 (IC<sub>50</sub>) to artemether of 14.18 nM whereas the other values were between 1.35nM and 5.42nM.  
229 This value is considered to be higher than the decreased susceptibility threshold of 12 nM.  
230 Therefore, those two methods suggest at least a transient resistance profile for these parasites to  
231 artemisinin derivatives. These parasites were isolated from a 28 years old Brazilian man who  
232 took one pill of Artecom® four days before the sampling for malaria symptoms.

233

## 234 **Discussion**

### 235 **Study limitations**

236 Because sampling did not use probabilistic methods we cannot exclude recruitment biases.

237 Behaviour in case of malaria symptoms and adherence were analysed with a questionnaire, which

238 may lead to declaration bias (« correct answer » given to health professional) and memory bias.

239 Missing data (8 for adherence for example) could also contribute to bias the results.

### 240 **Frequent self-medication linked to difficult access to care in French Guiana**

241 This study showed that self-medication is very common in illegal gold miners working in FG:

242 53.7% resorted to self-medication for the last malaria episode. These results confirm previous

243 observations in a specific mining site in FG.<sup>7</sup>

244 The multivariate analyses shows that health-seeking behaviour depends on which country gold

245 miners worked in: being in FG during the last malaria attack was the main factor associated with

246 self-medication. This suggests that access to malaria diagnosis in FG is particularly difficult for

247 Brazilian gold miners compared to Brazil or Suriname. The main reason given by gold miners

248 was the remoteness of the mine from the health care centers (93.4% versus 64% in the

249 Surinamese survey) and we could also add the illegality of their activities and residency in

250 France. Currently, in Suriname, Malaria Service Deliverers procure free malaria diagnostic tests

251 and treatment everywhere on the Surinamese territory, even in gold mining areas, with the

252 program “Looking for Gold, Finding Malaria”.<sup>3,21</sup> In Suriname, 50% of gold miners declared

253 having used self-medication during the past 18 months in 2013, but these results included people

254 working in Suriname and in FG, without differentiation. Therefore, it was not representative of

255 the specific behaviour of gold miners in Suriname.<sup>8</sup> Thus, even if healthcare is free for everyone

256 in FG, in practice it is difficult to reach these healthcare structures for illegal gold miners who  
257 often live days away.

258 Self-medication was also linked to personal malaria history: the more people had experienced  
259 malaria, the more they were likely to self-treat themselves. This link could also be explained by a  
260 general behaviour which associates: disregarding health issues, not protecting themselves from  
261 malaria and not seeking medical care. We could assume that the acquired knowledge about  
262 treatment after the first malaria attack could facilitate self-medication for future malaria episodes.  
263 Malaria treatment misconceptions were also associated with self-medication. This emphasizes the  
264 necessity to reinforce public health messages for this specific population.

#### 265 **Self-medication is quasi-exclusively associated with ACT intake**

266 The majority of the drugs used in self-medication are artemisinin based combination therapies  
267 (ACT) (90%). This is concordant with what was observed in Suriname (96.1%).<sup>8</sup> Treatment was  
268 mainly Artecom®, produced by a Chinese firm, Tonghe Pharmaceutical Co.Ltd (Chongqing,  
269 China). This drug had good efficacy and tolerance in Africa and Asia.<sup>22,23</sup> However, Artecom®  
270 has some weaknesses: the dihydroartemisinin dose may vary; and there is no information on  
271 the dose of primaquine included on the Guiana Shield.<sup>24,25</sup> The information leaflet in a package of  
272 Artecom® bought in the forest during the study mentioned the regimen in English and French  
273 (two pills twice a day for two days), which is not understandable for most Brazilian miners.  
274 Finally, the package indicated “protect from light and keep in a dry and cool place”, which is  
275 probably not feasible in illegal gold mining sites in the Amazonian forest.

#### 276 **Malaria treatment adherence is better when it is cheap and delivered by health workers**

277 It is difficult to really evaluate adherence, generally based on self-reports or pill counts.<sup>26,27</sup> In  
278 this study, the question “did pills remain when you have stopped the treatment?” was used to  
279 allow comparison with the results from the Surinamese anthropological study<sup>8</sup> and because the  
280 packaging of drugs used in our region (in legal or illegal market) contains one complete  
281 treatment. A Brazilian study in the Amazon basin found a difference between self-reported non-  
282 adherence and pill counts (12.2% versus 21.8%).<sup>28</sup> But in Tanzania, the comparison of declared  
283 adherence with adherence estimated through “smart blister packs” (Coartem® tablets with  
284 microchip recording pills push out date and time) showed very similar results (64% of complete  
285 adherence versus 67%).<sup>29</sup> Studies assessing adherence refer to a current malaria attack. But in this  
286 study, the behaviour concerned the last malaria attack which occurred at a median of two years  
287 before. When the last malaria attack occurred long before, people were more likely to have  
288 declared getting tested and having taken the complete malaria treatment. This may reflect a  
289 memory bias the embellishment of reality towards the socially desirable answer. Malaria  
290 diagnosis and treatment adherence might have been overestimated. Self-medication and poor  
291 adherence could therefore be even more frequent than reported.<sup>30</sup>

292 Treatment adherence was significantly better when treatment was given after getting a malaria  
293 test (90.1% versus 60.9% if self-medication). This suggests that there was a real impact of getting  
294 tested and having malaria treatment with explanations from health workers. In the Surinamese  
295 study, the same results were found with 78.9% of the miners who declared having completed the  
296 treatment when given by a health worker compared to 40.2% when self-medicated.<sup>8</sup> In 2015, a  
297 meta-analyses observed a higher level of adherence to ACT in the public sector than in the retail  
298 sector (76% versus 45%).<sup>26</sup> This could be explained by the fact that in the public sector, ACTs  
299 are given for free with instructions by the health workers whereas informal drug stores dispense a  
300 presumptive malaria treatment without clear instructions. A study in Uganda in 2016 reinforced



301 this idea as it found no association between testing and treatment adherence as long as the  
302 treatment sent by shop vendors was associated with treatment information.<sup>31</sup> Beside the lack of  
303 treatment information, the high cost of the treatment on the black market is another factor leading  
304 to poor adherence. In fact, ACTs cost 1 to 3 grams of gold (25 to 90 USD), when miners gain  
305 about 10 to 15 grams per week.<sup>32</sup> Therefore, most people declared interrupting the treatment as  
306 soon as they felt better, and kept pills for the next malaria episode. Thus, the easy availability (for  
307 free or at a low price) and explanation from health workers might explain the association between  
308 malaria test and adherence.

309

### 310 **Putative emergence of artemisinin resistance in the parasite population of French Guiana**

311 This high level of self-medication raises the concern of selection for drug resistant parasites. In  
312 Guyana (formerly English Guiana), 5% of the isolates collected in 2010 carried the C580Y *pfK13*  
313 mutation.<sup>33</sup> Since then, no other mutations associated with artemisinin resistance in South East  
314 Asia have been observed on the Guiana Shield.<sup>34</sup> Phenotyping methods identified one putative  
315 resistant isolate with a survival rate above the threshold. However, this result was not confirmed  
316 despite the conformity of the quality control (Cambodian strains). Therefore we could speculate  
317 that these parasites exhibited a transient stage of resistance/tolerance that is not stable through  
318 time and not necessarily associated with mutations on the *pfK13* gene. This phenotype could have  
319 been lost during *in vitro* multiplication.<sup>35</sup> Therefore, resistance parameters to characterize parasite  
320 resistance to artemisinin in South America still need to be validated.

321 **Whether artemisinin resistance has already emerged or not, there is an urgent need for**  
322 **actions**

323 Malaria resistance is a threat for global health throughout the world.<sup>36</sup> The risk factors for  
324 selection of resistance are well known and this study showed that they are present in French  
325 Guiana with people who self-medicated themselves with poor adherence. In addition, the quality  
326 of the drug could be altered by living conditions and poor storage conditions. Parasite  
327 phenotyping suggested that the first step of resistance selection was reached with some parasites  
328 exhibiting transient stage on the path of resistance.

329 Therefore, it is urgent to address the problem based on the data provided by the scientific  
330 evidence (the present study as well as references 6–8). To limit self-medication and poor  
331 adherence, improving the access to diagnosis and free, or even cheap, medication delivered with  
332 instructions for use are required. Countering false beliefs is also required: one third of  
333 interviewed people thought that it was better to take a treatment even if the malaria test was  
334 negative and 6.4% used ACT as chemoprophylaxis. Beside treatment improvement, individual  
335 protection from vectors in these areas of high transmission is crucial and the distribution of  
336 insecticide-treated nets should be improved. Gold miners are easily accessible on resting sites and  
337 are concerned about their health. Public health interventions in cooperation with Suriname and  
338 Brazil should be considered to reduce malaria transmission and limit the risk of emergence of  
339 artemisinin resistance, which would have disastrous health and economic consequences well  
340 beyond French Guiana.<sup>36</sup>

341

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352

353 **Transparency declarations**

354 The authors declare that they have no competing interests.

355

356

357

358 **REFERENCES**

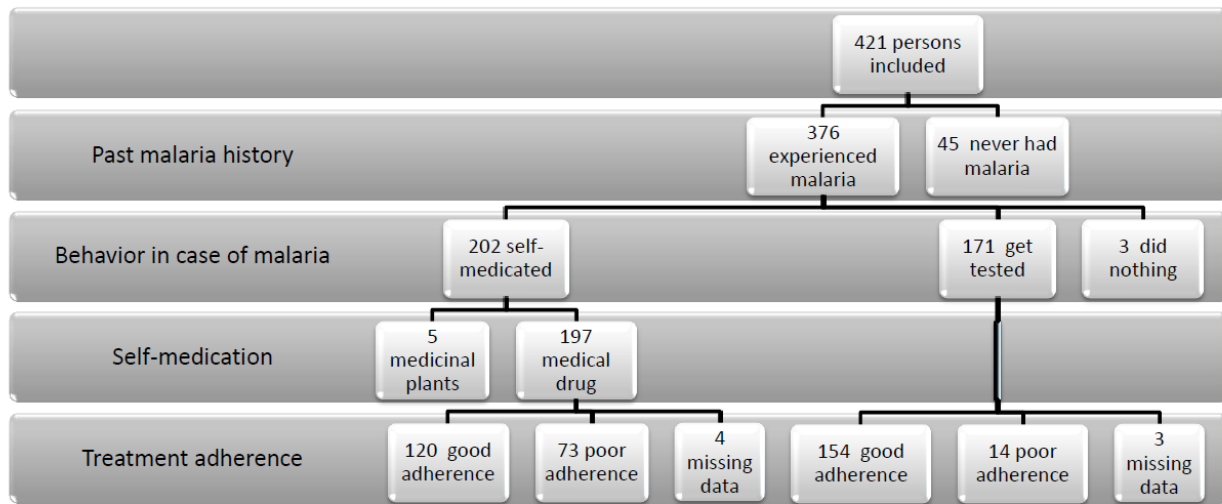
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447 **Figure 1: Flow chart of the study\***

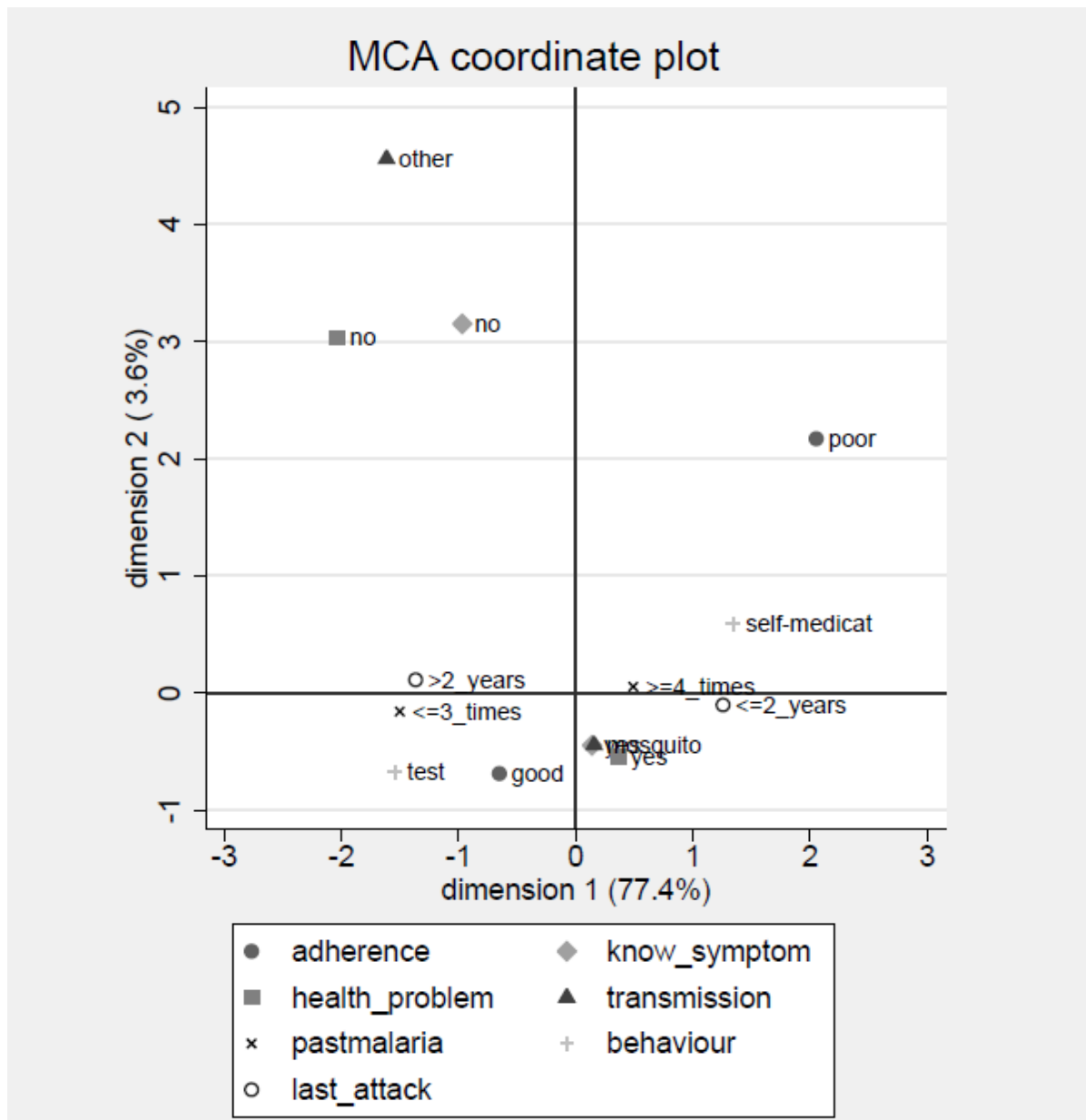


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449 \* In our region, free medication is given to all persons who are tested positive for malaria so getting tested  
450 for malaria and self-medication are mutually exclusive categories

451

452 Figure 2: Illegal gold miners behaviours towards malaria in French Guiana, analysed with Multiple  
453 Correspondence analyses



454



455 **Table 1: Logistic regression model for factors associated with self-medication in illegal gold miners working in French Guiana, 2015**  
 456 (n=202/N=373)

	Self-medication n/N (%)	Univariate analyses		Multivariate analyses <sup>a</sup>	
		OR [CI 95%]	<i>p</i> <sup>b</sup>	AOR [CI 95%]	<i>p</i> <sup>b</sup>
<b>Socio-demographic characteristics</b>					
<b>age<sup>c</sup></b>					
<= 38 years	98/178 (55.06)	1	<b>0.739</b>	1	<b>0.384</b>
> 38 years	104/195 (53.33)	0.99 [0.98-1.01]		0.99 [0.97-1.01]	
<b>sex<sup>c</sup></b>					
female	57/101 (56.44)	1	<b>0.59</b>	1	<b>0.770</b>
male	145/272 (53.31)	0.88 [0.56-1.40]		1.09 [0.61-1.96]	
<b>country of birth</b>					
other than Brazil	3/21 (14.29)	1	<b>&lt;0.001</b>	1	<b>&lt;0.001</b>
Brazil	199/352 (56.53)	7.8 [2.26-26.98]		10.74 [2.82-40.82]	
<b>countries of work the last three years<sup>d</sup></b>					
FG <sup>e</sup> and others	47/115 (40.87)	1	<b>&lt;0.001</b>	1	<b>0.016</b>
FG <sup>e</sup> only	155/258 (60.08)	2.18 [1.39-3.41]		2 [1.14-3.55]	
<b>Attitude and knowledge</b>					
<b>malaria is a major health problem<sup>f</sup></b>					
no	19/55 (34.55)	1	<b>0.001</b>		
yes	183/318 (57.55)	2.57 (1.41-4.67)			
<b>better to treat even if test negative<sup>g</sup></b>					
no	133/263 (50.57)	1	<b>0.031</b>	1	<b>0.039</b>
yes	69/110 (62.73)	1.64 [1.04-2.59]		1.82 [1.03-3.22]	
<b>malaria stays all life<sup>h</sup></b>					
no	148/287 (51.57)	1	<b>0.065</b>		
yes	54/86 (62.79)	1.58 [0.97-2.60]			
<b>cure without treatment<sup>i</sup></b>					
no	180/342 (52.63)	1	<b>0.046</b>	1	<b>0.036</b>
yes	22/31 (70.97)	2.2 [0.98-4.92]		3.19 [1.08-9.46]	
<b>protection against mosquitoes</b>					
sometimes/never	177/315 (56.19)	1	<b>0.066</b>		
always/often	25/58 (43.10)	0.59 [0.34-1.04]			
<b>Clinical data</b>					
<b>past history of malaria</b>					
<=3 malaria attacks	30/91 (32.97)	1	<b>&lt;0.001</b>	1	<b>0.005</b>
>= 4 malaria attacks	172/282 (60.99)	3.18 [1.93-5.23]		2.47 [1.31-4.64]	
<b>date of last malaria attack</b>					
<=2 years	130/194 (67.01)	1	<b>&lt;0.001</b>	1	<b>0.028</b>
> 2 years	72/179 (40.22)	0.97 [0.96-0.98]		0.98 [0.97-1)	
<b>place when last malaria attack</b>					

Brazil	4/60 (6.67)	1	<b>&lt;0.001</b>	1	
French Guiana	188/274 (68.61)	30.60 [10.75-87.11]		22.1 [7.39-66.04]	<b>&lt;0.001</b>
other	10/39 (25.64)	4.82 [1.39-16.74]		6.11 [1.60-23.4]	<b>0.008</b>
<b><i>Plasmodium spp. PCR</i></b>					
negative	162/286 (56.64)	1	<b>0.081</b>	1	<b>0.002</b>
positive	40/87 (45.98)	0.65 [0.40-1.05]		0.37 [0.20-0.68]	

a Hosmer-Lemeshow test:  $p=0,507$

b obtained from the likelihood ratio test

c age and sex were forced

d countries were people worked for gold mining the last three years

e French Guiana (FG)

f considering malaria as a major health problem on mining sites

<sup>g</sup> thinking that it is better to take a malaria treatment even if the malaria test is negative, just to be sure

h thinking that malaria stay the all life in the body

i thinking that malaria can be cure without treatment

458 Table 2: Factors associated with poor malaria treatment adherence in illegal gold miners working in French Guiana, 2015 (N=87/361)

	Poor adherence	Univariate analyses		Multivariate analyses <sup>a</sup>	
	n/N (%)	OR [CI 95%]	p <sup>b</sup>	AOR [CI 95%]	p <sup>b</sup>
<b>Socio-demographic characteristics</b>					
<b>sex<sup>c</sup></b>					
female	29/98 (29.59)	1	<b>0.142</b>	1	<b>0.184</b>
male	58/263 (22.05)	0.67 [0.40-1.14]		0.67 [0.37-1.21]	
<b>age<sup>c</sup></b>					
<= 38 years	52/172 (30.23)	1	<b>0.009</b>	1	<b>0.005</b>
> 38 years	35/189 (18.52)	0.52 [0.32-0.86]		0.97 [0.95-0.99]	
<b>work time in gold mining</b>					
<= 10 years	56/202 (27.72)	1	<b>0.068</b>		
> 10 years	31/159 (19.50)	0.99 [0.98-1.01]			
<b>Attitude and knowledge</b>					
<b>better treat even if test negative<sup>d</sup></b>					
no	51/256 (19.92)	1	<b>0.004</b>	1	<b>0.016</b>
yes	36/105 (34.29)	2.10 [1.26-3.48]		2 [1.14-3.51]	
<b>malaria kills<sup>e</sup></b>					
no	86/347 (24.78)	1	<b>0.089</b>		
yes	1/14 (7.14)	0.23 [0.03-1.81]			
<b>protection against mosquitos</b>					
sometimes/never	78/304 (25.66)	1	<b>0.097</b>		
always/often	9/57 (15.79)	0.54 [0.25-1.16]			
<b>Clinical data</b>					
<b>past history of malaria</b>					
<=3 malaria attack	16/89 (17.98]	1	<b>0.112</b>		
>= 4 malaria attack	71/272 (26.10)	1.61 [0.88-2.95]			
<b>date of last malaria attack</b>					

<=2 years	64/188 (34.04)	1	<0,001	1	0.003
> 2 years	23/173 (13.29)	0.96 [0.96-0.98]		0.98 [0.96-0.99]	
<b>health-seeking behaviour<sup>f</sup></b>					
get tested	14/168 (8.33)	1	<0.001	1	<0.001
self-medication	73/193 (37.82)	6.69 [3.60-12.43]		6.03 [3.15-11.54]	
<b>place when last malaria attack</b>					
Brazil	4/59 (6.78)	1	<0.001		
French Guiana	75/263 (28.52)	5.48 [1.92-15.67]			
other	8/39 (20.51)	3.54 [0.99-12.74]			

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a Hosmer-Lemeshow test: p=0,799

b obtained from the likelihood ratio test

c age and sexe were forced

<sup>d</sup> thinking that it is better to take a malaria treatment even if the malaria test is negative, just to be sure

e thinking that malaria can kill

f for the last malaria attack

460 Table 3: Two clusters of persons in Ascending Hierarchical Classification (N=361)\*

	Cluster 1 N=213 n (%)	Cluster 2 N=148 n (%)	p
<b>Variables included in ACH</b>			
<b>health-seeking behaviour</b>			
get tested	161 (75.6)	7 (4.7)	
self-medication	52 (24.4)	141 (95.3)	<0,001
<b>treatment adherence</b>			
good	206 (96.7)	68 (45.9)	
poor	7 (3.3)	80 (54.1)	<0,001
<b>date of last malaria attack</b>			
<=2 years	56 (26.3)	132 (89.2)	
> 2 years	157 (73.7)	16 (10.8)	<0,001
<b>malaria is a major health problem</b>			
no	44 (20.7)	11 (7.4)	<0,001
yes	169 (79.3)	137 (92.6)	
<b>transmission pathway</b>			
other	21 (9.9)	11 (7.4)	
mosquito	192 (90.1)	137 (92.6)	0,425
<b>past history of malaria</b>			
<=3 malaria attack	67 (31.5)	22 (14.9)	
>= 4 malaria attack	146 (68.5)	126 (85.1)	<0,001
<b>symptoms knowledge</b>			
no	28 (13.2)	17 (11.5)	
yes	185 (86.8)	131 (88.5)	0,639
<b>Socio-demographical data</b>			
<b>sex</b>			
female	50 (23.5)	48 (32.4)	
male	163 (76.5)	100 (67.6)	0,059
<b>age</b>			
<= 38 years	96 (45.1)	76 (51.4)	
> 38 years	117 (54.9)	72 (48.6)	0,239
<b>education</b>			
none/primary	113 (53.1)	69 (46.6)	
secondary/university	100 (46.9)	79 (53.4)	0,229
<b>time in gold mining</b>			
<=10 years	112 (52.6)	90 (60.8)	
> 10 years	101 (47.4)	58 (39.2)	0,121

461 \*N=120+73+154+14=361