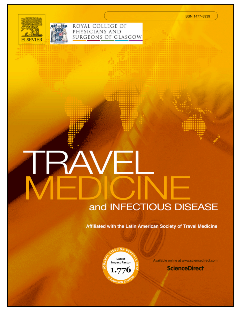
Accepted Manuscript



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PII: S1477-8939(17)30067-4

DOI: 10.1016/j.tmaid.2017.04.004

Reference: TMAID 1114

To appear in: *Travel Medicine and Infectious Disease*

Received Date: 3 February 2017

Revised Date: 18 April 2017

Accepted Date: 21 April 2017

Trend analysis of imported Malaria in London; observational study 2000 to 2014

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Key words (3-6 words not included in the title):

Imported malaria, non-endemic country, travellers, VFR

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Description of paper (100 characters)

Epidemiology of imported malaria in London over fifteen years

Abstract

Background

We describe trends of malaria in London (2000-2014) in order to identify preventive opportunities and we estimated the cost of malaria admissions (2009/2010-2014/2015).

Methods

We identified all cases of malaria, resident in London, reported to the reference laboratory and obtained hospital admissions from Hospital Episode Statistics.

Results

The rate of malaria decreased (19.4[2001]-9.1[2014] per 100,000). Males were over-represented (62%). Cases in older age groups increased overtime. The rate was highest amongst people of Black African ethnicity followed by Indian, Pakistani, Bangladeshi ethnicities combined (103.3 and 5.5 per 100,000, respectively). The primary reason for travel was visiting friends and relatives (VFR) in their country of origin (69%), mostly sub-Saharan Africa (92%). The proportion of cases in VFRs increased (32%[2000]-50%[2014]) and those taking chemoprophylaxis decreased (36%[2000]-14%[2014]). The overall case fatality rate was 0.3%. We estimated the average healthcare cost of malaria admissions to be just over £1 million per year.

Conclusion

Our study highlighted that people of Black African ethnicity, travelling to sub-Saharan Africa to visit friends and relatives in their country of origin remain the most affected with also a

decline in chemoprophylaxis use. Malaria awareness should focus on this group in order to have the biggest impact but may require new approaches.

1. Introduction

In 2015, approximately 214 million cases of malaria and an estimated 438,000 deaths were reported worldwide, with an estimated fall in incidence of 37% between 2000 to 2015 [1]. Africa remains the most affected continent, with approximately 90% of all malaria cases and 92% of malaria deaths (WHO).

The UK has the second highest number of imported cases in Europe, following France [2]. In the last five years half of all cases reported in the UK occurred in London. This is likely to be a reflection of the ethnic diversity of the London population and also their travelling habits. In 2001, it was estimated that 8% of the total UK population were born abroad. In 2014 the figure was over 14% and in London the estimate is above 36% [3].

More than half of malaria cases are individuals travelling to visit friends and relatives in their country of origin. Cases occur in visitors and new entrants to the UK from abroad, as well as individuals travelling abroad from the UK for holiday or business. Changes in travel patterns and migration, as well as changes in the global epidemiology of malaria are likely to have an impact on the number of imported cases. However, the risk of malaria can be reduced by taking bite prevention measures, such as the use of bed nets and mosquito repellents, as well as taking appropriate chemoprophylaxis [4].

Under the Health Protection (Notification) Regulations 2010 malaria is a notifiable disease [5] and all positive specimens should be sent to the Public Health England (PHE) Malaria Reference Laboratory (MRL) for confirmation. Each specimen should be accompanied by a surveillance questionnaire that collects basic demographics, travel history and whether chemoprophylaxis was taken or not [6].

We aimed to describe the basic epidemiology of malaria in London between 2000 and 2014 in order to identify vulnerable populations, as well as to provide a crude estimate of the cost of malaria admissions for the financial years 2009/2010 to 2014/2015. The situation in London may mirror the situation in other global cities in non-endemic countries and could provide valuable information for malaria prevention.

2. Methods

2.1 Malaria reference laboratory data

Data on malaria cases in the UK is collected by the PHE MRL housed at the London School of Hygiene & Tropical Medicine and managed by the PHE Travel and Migrant Health Section. This is the most complete dataset on malaria in the UK [7]. We conducted a cross-sectional study of the cases confirmed by the PHE MRL between 2000 and 2014 presumed to be resident within London.

From 2013 onwards, missing data was supplemented where available, using HPZone (HPZone TM Infact Shipley, Yorkshire) which is an online case management tool that it is used by the health protection teams in England. Individuals with malaria that were on HPZone but not on the MRL data were added into a final dataset.

The final dataset included information on: demographics (age, sex, ethnicity [only from 2004], postcode, and local authority, country of birth and country of usual residence), clinical information (date of onset), travel information (reason for travel, travel destination and duration of travel), microbiological data (*Plasmodium* species), and whether chemoprophylaxis was taken or not.

Cases were classified according to reason for travel when provided. When missing, country of usual residence was used instead to classify cases into "travelled abroad from the UK" or "foreign visitors". Where country of travel was missing, we used world region of travel.

2.2 Hospital episode statistics

Information on hospital admissions, length of stay by main speciality and age was obtained from the Hospital Episode Statistics© (HES). This is a secured data warehouse managed by the Health and Social Care Information Centre that contains details of all National Health Service (NHS) admissions in England [8]. This included all the finished admissions episodes in residents in London admitted to hospital between 2000 and 2014 that mentioned malaria in any of the diagnosis fields. Therefore, admissions do not represent the number of patients, as a person may have more than one admission within the study period.

2.3 Descriptive analysis

We calculated the incidence per year using midyear population estimates for 2014 from the Office for National Statistics (ONS) [9]. We mapped the rates for 2014 by local authority using ArcGIS© V.10.2 [10]. We presented the demographics, type of travel and *Plasmodium* species of all cases regardless of whether they were foreign visitors or London residents travelling abroad from the UK. We described the reason for travel, continent the case travelled to and the use of chemoprophylaxis only for cases that travelled abroad from the UK. We completed the descriptive analysis using Stata© V13.1 [11] and we presented the data in five year cohorts.

We allocated an Index of Mass Deprivation (IMD) 2015 to each case [12]. The English Indices of Deprivation 2015 are based on 37 separate indicators, organised across seven distinct domains of deprivation (income; employment; health deprivation and disability; education, skills and training; crime; barriers to housing and services; and living environment) which are combined, using appropriate weights, to calculate the IMD 2015 [12]. The score represents an overall measure of multiple deprivation experienced by people living in an area and is calculated for every Lower Super Output Area (LSOA). Every LSOA in England is ranked according to its level of deprivation relative to that of other areas. In order to allocate an IMD to the cases the postcode of residence was first geocoded to LSOA [13]; using ArcGIS© V.10.2. An IMD score quintile was then allocated to each LSOA within our dataset. We plotted in a map the deprivation scores by LSOA and local authority.

2.4 Cost analysis of hospital admissions for the financial years 2009/2010 to 2014/2015

The NHS national tariff payment system [14] for each financial year between 2009/2010 to 2014/2015 was used to estimate the crude cost of hospital admissions in London that had malaria mentioned in any of the diagnosis fields [Healthcare resource group (HRG) name, 'Malaria'; HRG code, WA08Z]. We calculated the average cost to the health care system per admission based on the number of admissions and the length of stay. We used the non-elective spell tariff and we calculated an average cost for the six year period by dividing the overall cost by the number of years in the study. Assuming that all admissions came through the Accidents & Emergencies (A&E) department we also applied the A&E tariff (Category 1 investigation with category 1-2 treatment) by calculating an average for the study period and applying it to each admission.

3. Results

3.1 Descriptive analysis of all malaria cases in London between 2010 and 2014

Between 2000 and 2014 a total of 15,473 cases of malaria were reported in London, whilst 25,222 cases were reported in the UK. Overall, since 2000, the number of cases of malaria in London decreased, by 39% in 2014 compared with 2000 (Figure 1, Table 1). The incidence rate in 2014 in London was 9.1 per 100,000, compared with 2.5 per 100,000 in the UK (Incidence rate ratio [IRR] 3.6, Confidence interval [CI] 3.3; 4.0, p <0.0001) (Figure 1). The rate of malaria in London decreased from 19.4 per 100,000 population in 2001, down to 9.1 per 100,000 population in 2014 (IRR 2.1, CI 1.9; 2.3, p <0.0001).

The median age of cases in 2000 and 2014 was 35 years (interquartile range [IQR], 24-46 years), and cases were predominantly male (62%). The median age of cases in 2000 was 30 years of age (interquartile range [IQR], 8-42 years) and 39 years of age (IQR 25-50 years) in 2014 (p <0.0001). A shift in age distribution of cases between 2000 and 2014 was observed, with an increase in cases occurring in 45-60 years and >60 years, and a decrease in cases aged <15 years, 15-29 years and 30-45 years (Table 1; Figure 2).

In 2014, 37% (291/779) of cases occurred in south London, with the highest rates observed in the following local authorities: Southwark, Lewisham and Greenwich (31/100,000, 24/100,000, 21/100,000 population respectively) (Figure 3). Regarding the deprivation score, cases between 2000 and 2014 in London were predominantly in the most deprived quintiles 1 and 2 (41% [4,262/1,0259] and 35% [3,610/10,259], respectively). In Figure 4 we have plotted the areas in London that are most deprived.

In London, the majority of malaria cases were due to *P. falciparum* (82%, 12,713/15,357), followed by *P. vivax* (10%, 1497/15,357). Almost all those infected with *P. falciparum* had visited sub-Saharan Africa (97%, 9927/10256), whilst those with *P. vivax* had predominantly visited the Indian sub-continent (77%, 877/1,141). We observed a strong seasonal trend, with the number of cases each year peaking during the summer months (July to September), coinciding with the UK summer holiday.

Ethnicity was routinely recorded for cases reported from 2004 onwards and was known for 92% of cases in London between 2004 and 2014. The majority of cases were of African ethnicity (82%, 7,722/9,399), with a further 10% (999/9,399) of Indian, Pakistani or Bangladeshi ethnicity (Table 1). The rate of malaria in 2014 in individuals of African ethnicity was 103.3 per 100,000, compared with 5.5 per 100,000 in individuals of Indian, Pakistani and Bangladeshi descent combined (IRR 18.6, CI 14.2, 24.9; p <0.0001).

The reason for travel was known for 57% (8,780) cases between 2000 and 2014. Of these, 69% (6,052) were individuals visiting friends and relatives (VFR), 20.2% (1,774) were foreign visitors, 6% (524) were travelling on holiday and 3% (301) were travelling for business. Among the cases for which the reason for travel was known, VFR represented the highest increase in proportion from 57% (415/726) in 2000 to 75% (395/525) in 2014 (p<0.0001) which represented a minimum decrease in the crude number of cases. When we used the five year averages presented in Table 2, the increase remained significant for VFR (80% in 2000-2004 to 90% in 2010-2014, p<0.0001). There was a significant decrease in the proportion of cases whose reason for travel was holidays (12% in 2000-2014 to 3.8% in 2010-2014, p<0.05), the people who travel for business remained stable (4.8% 2000-2004 to 4.9% 2010-2014, p>0.05).

3.2 Descriptive analysis of cases of malaria that travelled abroad, London 2000 to 2014

Out of the total number of cases reported in London between 2000 and 2014, 50% (7,728/15,473) travelled abroad (Table 2). The median duration of travel between 2005 and 2014 was 28 days (IQR, 14-42 days) (Table 2). A total of 6,404 (92%) reported travelling to sub-Saharan Africa, in particular Nigeria, and 394 (6%) reported travelling to the Indian sub-continent. Travel destination remained largely stable other than a slight increase in the number of cases travelling to the Indian sub-continent was observed.

Of those who travelled abroad from London, 23% of cases between 2000 and 2014 reported taking chemoprophylaxis (1,500/6,496). Amongst VFR, in 2000 the proportion who reported taking chemoprophylaxis was 36% (139/386) compared to 14% (44/312) in 2014 (p 0.005). Although it appears that the number of individuals taking chemoprophylaxis declined there is significant missing data and information regarding the appropriateness of chemoprophylaxis taken and whether individuals adhered to the regimen was unavailable.

3.3 Descriptive analysis of deaths due to malaria reported in London between 2000 and 2014

Since 2000, 44 deaths due to malaria were reported in London, with a case fatality rate (CFR) of 0.3% in all ages. Most of the malaria deaths (98%, 43/44) were infected with *P. falciparum* and one case was infected with *P. vivax*. The ages ranged between 6 and 70 years, with a median age of 47 years. Five deaths occurred in children under the age of 16, with no deaths in children under five years. Males and females were equally affected, with 48% of deaths in male cases. Most of the malaria deaths were in cases that had travelled abroad from the UK (81%, 30/37), with seven cases arriving in London (19%) either as visitors or new entrants. Only four individuals reported taking chemoprophylaxis. Out of the remaining individuals, 23 reported taking no prophylaxis and no information was available for 17.

3.4 Descriptive analysis of admissions between 2000 and 2014 and economic costing of admissions reported by HES for the financial years 2009/2010 to 2014/2015

A total of 13,916 malaria hospital admissions were reported by HES between 2000 and 2014 (Table 3). Overall, the total number of admissions fell between 2000 and 2014, and the average length of stay decreased (Table 3). The majority of admissions did not have a speciality listed. Admissions predominantly occurred in adults aged between 15 and 60 years, and the shift in age distribution is observed between 2000 and 2014, with an increase in admissions in older age groups (Table 3).

Between 2009/2010 and 2014/2015 the number of malaria admissions was over four and a half thousand. The average length of stay was two days. Overall, the crude estimate of cost was over £6 million and on average it was just over a £1 million per study year (Table 4)

4. Discussion

The results of this study are largely in accordance with previous findings for London [15] and with the national review of malaria [16]. This study showed that the rates of malaria in London have declined between 2000 and 2014. The reasons for the decline are unclear. Previous studies in the UK suggested a decline in malaria transmission in West Africa as a possible explanation [17]. In Amsterdam the decline in number of cases observed up until 2002 were attributed to a decrease in nonimmune patients [18]. However, this was followed by an increase in the Netherlands most notably since 2013 and mostly due to immigration of asylum seekers from the horn of Africa and among VFRs [19]. An increasing trend in malaria cases between 1973 and 2013 was also seen in the US, a country with a similar epidemiology to the UK where malaria affected mostly VFRs and travellers to Africa, specifically Nigeria [20]. Increases in the US were mostly attributed to inadequate use of appropriate prevention measures by travellers [20].

The epidemiological description of cases in London suggests that males were more likely to have malaria, with cases predominantly occurring in adults aged between 15 and 60 years, possibly reflecting UK travel patterns. The highest rates of malaria were among individuals of African descent followed by individuals of Indian, Pakistani and Bangladeshi descent combined. The majority of cases occurred in individuals travelling abroad from London, more specifically, travelling to visit friends and relatives in their country of origin. Although there was an overall downward trend, the proportion of cases amongst VFRs increased significantly during the study period although in absolute numbers they remained broadly similar. Within this group, the main region of travel was sub-Saharan Africa, and in particular Nigeria, Ghana and Sierra Leone.

The highest burden of disease was amongst residents of south east London, particularly in Southwark, Lewisham and Greenwich. The geographical distribution of cases in London is likely explained by the ethnic background of the different London boroughs. People of West African heritage tend to concentrate in certain London boroughs. Using the IMD score, the majority of cases were found to be resident in local authorities with high levels of deprivation (quintiles 1 and 2).

The number of cases peaked in July-September each year, in line with the UK school summer holiday when individuals are most likely to travel abroad. This also coincides with the high-transmission rainy season in West Africa. The majority of malaria cases were due to *P. falciparum*, and this reflects the fact that most cases travelled to sub-Saharan Africa.

In recent years there has been a shift in the age distribution of cases, with an increase in older age groups (45-60 years). This was observed in both notifications and inpatient admissions. One possible explanation is that older individuals are less susceptive to preventative messages if they have been born in a malaria endemic country and so may underestimate their risk compared with individuals born in the UK. In addition they are at higher risk of mortality. In support of this, the proportion of individuals born in endemic countries increased over the study period, particularly in people over 40 years old. However, completion rates for country of birth were poor (45%). Increases in visits abroad from 2000 to 2015 were observed in people over 65 years of age, but no apparent increases in trends were seen in age groups 45-54 and 55-64 suggesting that these groups are not necessarily travelling more. Further work on the reasons for this shift in age distribution is required to better understand it.

Only 15% of cases travelling abroad from London reported taking chemoprophylaxis. Furthermore, the proportion of cases that took appropriate chemoprophylaxis for the travel destination is likely to be lower. A study by Smith *et al* showed that use of chemoprophylaxis varied according to the geographical origin of the individual, with the lowest reported uptake in individuals from Africa and South Asia [21]. In addition, they reported that VFRs were less likely to report taking prophylaxis compared with other travellers. A number of different reasons for not taking chemoprophylaxis have been described, including cost, low perception of personal risk, failure to access the drugs prior to travel, lack of knowledge and scepticism over the efficacy of the drugs. However, other reasons include: feelings of competence amongst VFRs in their ability to self-manage the disease and that of doctors and other health care workers in their country of origin to diagnose and treat malaria appropriately. Also there was a perceived poor confidence in physicians in their country of residence to treat illnesses related to overseas travel, and malaria when returning [22–24]. Similar findings were shown in a study exploring adherence to malaria prevention guidelines by US residents of Nigerian origin [25]. Some studies looking into malaria perceptions and practices in VFRs suggest that the decisions about malaria prevention in this group are complex and that preventive measures based on a knowledge deficit approach e.g. raising awareness may not be sufficient to have an impact in behaviour [26]. One option is to provide subsidised malaria chemoprophylaxis to increase uptake, and the results of a modelling study suggests that this is a cost-effective policy for reducing imported malaria cases [27]. Conversely, a study undertaken in the UK evaluating this strategy failed to demonstrate an impact on malaria prevention. It also appears that the use of chemoprophylaxis has declined in this group but there was a high proportion of missing information on chemoprophylaxis so this should be interpreted with caution. The decline in the use of chemoprophylaxis could be further explored by looking at prescription data, as done by Guedes *et al* 2010 in Finland [29]. However, this could be challenging as a lot of them are likely to be private prescriptions. In addition, no information regarding bite prevention measures was available in this study. This is one of the key public health messages given to travellers and it would be of interest to evaluate this in the future.

The number of deaths due to malaria has remained stable since 2000, with a CFR of 0.3%. Previous studies have shown that the mortality risk is higher in elderly individuals and tourists [30,31]. However, due to the small number of deaths in this study, no trends could be observed.

The total number of admissions is lower compared with the total number of cases in the MRL dataset, as it only includes inpatients. Some hospitals do not routinely admit non-severe malaria. However this dataset may overestimate the number of inpatients as it does not differentiate between readmissions of the same patient.

The crude cost of malaria in London has declined as cases have reduced however it still represents just over a million pounds per year to the NHS in inpatient costs. However, these costs do not take into account other healthcare costs including outpatient, and non-healthcare community costs and costs to the individual and family so the actual cost may be more than this. As malaria is preventable, this is a cost that could be reduced. This highlights the importance of preventative messages and strategies that can specifically target the most affected groups in London.

5. Limitations

Firstly, in this study changes in travel behaviour of London residents have not been taken into account. Since 2000 there has been a 5.3% annual increase in individuals travelling to visit friends and relatives, resulting in an increasing potential for exposure [32]. Secondly, the number of cases of malaria reported here are likely to be an under-estimate of the true number of cases. A previous capture-recapture study estimated that only 62% of all cases in London were captured by the MRL, although completion rates are highest for *p. falciparum* malaria [33]. Thirdly, the completeness of the data is likely to have been improved from 2013 onwards [34]. However, it remains poor for some of the fields for the previous years. In addition other relevant information such as whether individuals followed bite prevention guidelines was not available.

When interpreting the cost estimates, there are a number of factors than need to be considered. Firstly, the costs were estimated using national prices, and therefore the costs for London may differ compare to the rest of the country. In addition, this is just an estimate of the cost, and true cost may vary, for example different tariffs other than the national tariff may have been used. Furthermore, we considered all patients to be non-elective, and this will over-estimate the cost for elective patients (although the number of elective patients for malaria is likely to be low). The A&E tariff applied to the admissions is likely to underestimate the cost for some of the cases as we only applied Category 1. Some admissions were likely to require a higher level of care while in A&E. Additionally, the cost of different specialties was not considered, for example intensive care is likely to be more costly, and therefore this may underestimate the overall cost. However, the number of patients in these specialities was low. Finally, HES data only includes NHS admissions so patients treated privately or cases that did not required admission to hospital are not included.

Despite these limitations the results are based on a large dataset over a 15 year period, which allows the possibility to observe trends, and changes over time.

6. Conclusion

Overall, the number of cases of malaria in London has declined since 2000. This is in line with a 37% decline in the global incidence of malaria in the same time period. The global decline is likely to be due to advances in malaria control in endemic countries [1]. Better control measures in endemic countries may have had an impact on the number of cases occurring in London [1]. This might be more important for VFRs who might benefit from improvements in control measures targeting the local population in endemic countries. However, it is unclear how this may actually occur and also it would not explain the increases seen in other places such as the US and the Netherlands or the fact that the overall decline of cases in VFRs in London has remain unchanged since 2000. VFRs, especially those travelling to Nigeria, remain the most affected with a significant decline in the proportion of VFRs using chemoprophylaxis. However, due to missing data this needs to be interpreted with caution.

In the majority of circumstances, malaria remains a preventable disease. Efforts should focus on ensuring that appropriate pre-travel advice is provided, including bite prevention, discussion around the benefits of chemoprophylaxis and prescription of appropriate chemoprophylaxis for the region of travel, particularly given the high costs demonstrated in this study as a result of malaria hospital admissions in London. The reasons for the fall in the use of chemoprophylaxis need to be better understood and may require the exploration of new strategies in order to reach this group and to increase awareness about malaria.

Acknowledgements

We are grateful to Nalini Iyanger for providing advice related to the costing part of the project and Robel Feleke for kindly providing the data on admissions from the Hospital Episode Statistics. We thank all the laboratories and clinicians who provide data to the PHE Malaria Reference Laboratory.

References

[1] WHO. World Malaria Report 2015. WHO; 2015.
[2] WHO Europe. Centralized Information System for Infectious Diseases (CISID): Malaria n.d. http://data.euro.who.int/cisid/ (accessed August 26, 2016).
[3] ONS. Local Area Migration Indicators, United Kingdom, Mid 2004 to Mid 2014 2014. http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-376617 (accessed December 15, 2015).
[4] Public Health England. Malaria prevention guidelines for travellers from the UK 2015 n.d. https://www.gov.uk/government/publications/malaria-prevention-guidelines-for-travellers-from-the-uk (accessed August 26, 2016).
[5] The Health Protection (Notification) Regulations 2010 n.d. http://www.legislation.gov.uk/uksi/2010/659/contents/made (accessed August 26, 2016).
[6] Malaria report form - Publications - GOV.UK n.d. https://www.gov.uk/government/publications/malaria-report-form (accessed November 10, 2016).
[7] Travel and Migrant Health Section. Malaria Imported Into the UK: 2015 Implications for those advising travellers. UK: Public Health England; n.d.

[8] Hospital Episode Statistics 2012. http://digital.nhs.uk/hes (accessed August 26, 2016).
[9] Office for National Statistics. Population estimates n.d. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates (accessed February 25, 2016).
[10] ESRI 2011. ArcGIS Desktop. CA; Environmental System Research Institute n.d.
[11] StataCorp. 2013. Statistical Software. College Station, TX: Stata Corp LP n.d.
[12] Department for Communities and Local Government. English indices of deprivation 2015 n.d. https://www.gov.uk/government/statistics/english-indices-of-deprivation-2015 (accessed August 26, 2016).
[13] Geography ONS. Super Output Area (SOA). Off Natl Stat 2011. http://webarchive.nationalarchives.gov.uk/content/20160105160709/http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/super-output-areas--soas-/index.html (accessed August 26, 2016).
[14] Monitor. NHS trusts: documents and guidance - NHS National Tariff Payment System n.d. https://www.gov.uk/government/collections/nhs-trusts-documents-and-guidance (accessed August 12, 2016).
[15] Public Health England. Malaria in London: Review of imported malaria cases. Data from 2000 and 2014. 2013.
[16] Malaria in the UK: annual report - Publications - GOV.UK n.d. https://www.gov.uk/government/publications/malaria-in-the-uk-annual-report (accessed December 15, 2015).
[17] Behrens RH, Carroll B, Smith V, Alexander N. Declining incidence of malaria imported into the UK from West Africa. Malar J 2008;7:235. doi:10.1186/1475-2875-7-235.
[18] Baas MC, Wetsteyn JCFM, van Gool T. Patterns of imported malaria at the academic medical center, Amsterdam, the Netherlands. J Travel Med 2006;13:2–7. doi:10.1111/j.1708-8305.2006.00003.x.
[19] de Gier B, Suryapranata FST, Croughs M, van Genderen PJJ, Keuter M, Visser LG, et al. Increase in imported malaria in the Netherlands in asylum seekers and VFR travellers. Malar J 2017;16:60. doi:10.1186/s12936-017-1711-5.
[20] Cullen KA. Malaria Surveillance — United States, 2013. MMWR Surveill Summ 2016;65. doi:10.15585/mmwr.ss6502a1.
[21] Smith AD, Bradley DJ, Smith V, Blaze M, Behrens RH, Chiodini PL, et al. Imported malaria and high risk groups: observational study using UK surveillance data 1987-2006. Bmj 2008;337.
[22] Pistone T, Guibert P, Gay F, Malvy D, Ezzedine K, Receveur MC, et al. Malaria risk perception, knowledge and prophylaxis practices among travellers of African ethnicity living in Paris and visiting their country of origin in sub-Saharan Africa. Trans R Soc Trop Med Hyg 2007;101:990–5. doi:10.1016/j.trstmh.2007.05.009.
[23] Neave PE, Behrens RH, Jones COH. “You’re losing your Ghanaianess”: understanding malaria decision-making among Africans visiting friends and relatives in the UK. Malar J 2014;13:287. doi:10.1186/1475-2875-13-287.
[24] Morgan DM, Figueroa-Muñoz JI. Barriers to Uptake and Adherence with Malaria Prophylaxis by the African Community in London, England: Focus Group Study. Ethn Health 2005;10:355–72. doi:10.1080/13557850500242035.
[25] Leonard L, VanLandingham M. Adherence to Travel Health Guidelines: The Experience of Nigerian Immigrants in Houston, Texas. J Immigr Health 2001;3:31–45. doi:10.1023/A:1026610602073.

[26] Behrens RH, Neave PE, Jones COH. Imported malaria among people who travel to visit friends and relatives: is current UK policy effective or does it need a strategic change? Malar J 2015;14:149. doi:10.1186/s12936-015-0666-7.
[27] Massad E, Behrens BC, Coutinho FAB, Behrens RH. Cost risk benefit analysis to support chemoprophylaxis policy for travellers to malaria endemic countries. Malar J 2011;10:130. doi:10.1186/1475-2875-10-130.
[28] Neave PE, Taylor S, Behrens RH. Does public subsidy of the cost of malaria chemoprophylaxis reduce imported malaria? A comparative policy analysis. Malar J 2013;12:238.
[29] Guedes S, Siikamäki H, Kantele A, Lyytikäinen O. Imported malaria in Finland 1995 to 2008: an overview of surveillance, travel trends, and antimalarial drug sales. J Travel Med 2010;17:400–404.
[30] Checkley AM, Smith A, Smith V, Blaze M, Bradley D, Chiodini PL, et al. Risk factors for mortality from imported falciparum malaria in the United Kingdom over 20 years: an observational study. Bmj 2012;344.
[31] Broderick C, Nadjm B, Smith V, Blaze M, Checkley A, Chiodini PL, et al. Clinical, geographical, and temporal risk factors associated with presentation and outcome of vivax malaria imported into the United Kingdom over 27 years: observational study. Bmj 2015;350:h1703.
[32] ONS. Reference table: Travel Trends - Section 1 Travel and Tourism, 1980 to 2014. Off Natl Stat 2015. http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Travel+and+Transport#tab-data-tables (accessed December 16, 2015).
[33] Cathcart SJ, Lawrence J, Grant A, Quinn D, Whitty CJM, Jones J, et al. Estimating unreported malaria cases in England: a capture–recapture study. Epidemiol Infect 2010;138:1052–1058.
[34] Public Health England. Malaria imported into the UK 2015: implications for those advising travellers n.d. https://www.gov.uk/government/publications/malaria-in-the-uk-annual-report (accessed August 26, 2016).

Table 1. Characteristics of cases of malaria reported by the Public Health England malaria reference laboratory, London 2000-2014

	2000-2004		2005-2009		2010-2014	
	n	%	n	%	n	%
Total	**6277**		**5065**		**4131**	
Age (years)	**6203**		**5021**		**4125**	
<15	976	15.7	620	12.3	343	8.3
15-29	1546	24.9	1225	24.4	959	23.2
30-44	2291	36.9	1663	33.1	1265	30.7
45-60	1022	16.5	1128	22.5	1200	29.1
>60	368	5.9	385	7.7	358	8.7
Sex	**5867**		**4872**		**4050**	
Male	3566	60.8	2976	61.1	2635	65.1
Country of birth	**2982**		**2193**		**1820**	
UK or non-endemic country	676	22.7	426	19.4	320	17.6
Malaria-endemic country	2306	77.3	1767	80.6	1500	82.4
Ethnicity*	**854**		**4655**		**6890**	
African	713	83.5	3639	84.6	3070	78.9
Indian/Pakistani/ Bangladeshi	84	9.8	397	8.5	518	13.3
Other	57	6.7	319	6.9	302	7.8
Plasmodium species	**6221**		**5037**		**4099**	
P. Falciparum	5218	83.9	4238	84.1	3257	79.5
P. Vivax	521	8.4	441	8.8	535	13.1
Other	482	7.8	358	7.1	307	7.5
Type of travel	**3490**		**3091**		**2970**	
Travelled abroad from the UK	2679	76.8	2490	80.6	2395	80.6
Foreign visitors	811	23.2	601	19.4	575	19.4
Deprivation quintile	**3358**		**3437**		**3464**	
1 (Most deprived)	1490	44.4	1443	42.0	1329	38.4
2	1134	33.8	1208	35.1	1268	36.6
3	477	14.2	540	15.7	559	16.1
4	184	5.5	174	5.1	229	6.6
5 (Least deprived)	73	2.2	72	2.1	79	2.3

*Only collected routinely from 2004 onwards

Table 2. Characteristics of cases reported by the malaria reference laboratory that travelled abroad, London 2000-2014

	2000-2004		2005-2009		2010-2014	
	n	%	n	%	n	%
Total (travelled abroad from the UK)	**2741**		**2551**		**2436**	
Duration of travel (median [IQR])†	-	-	28	14-42	28	16-42
Reason for travel	**2690**		**2267**		**2049**	
VFR	2173	80.8	2033	89.7	1846	90.1
Holiday	323	12.0	123	5.4	78	3.8
Business	128	4.8	73	3.2	100	4.9
Other	66	2.5	38	1.7	25	1.2
Continent of travel	**2646**		**2434**		**2331**	
Africa	2440	92.2	2235	91.8	2130	91.4
Indian sub-continent	122	4.6	145	6.0	145	6.8
Other	84	3.2	54	2.2	54	1.8
Chemoprophylaxis	**2315**		**1852**		**1739**	
Yes	730	31.5	358	19.3	287	16.5
No	1585	68.5	1494	80.8	1452	83.5

†Data for duration of travel for 2000-2004 was unavailable.

Table 3. Total admissions, average length of stay, treatment specialty and age of malaria admissions reported by the Hospital Episode Statistics, London 2000-2014

	2000-2004		**2005-2009**		**2010-2014**	
	n	**%**	**n**	**%**	**n**	**%**
Total number of admissions	**5351**		**4732**		**3833**	
Average length of stay	3.0		2.1		2.0	
Main Speciality						
Critical care medicine	0	0	37	0.8	33	0.9
Infectious diseases	1,073	20.1	364	7.7	239	6.2
Tropical medicine	0	0	146	3.1	103	2.7
Other	4,278	79.9	4,185	88.4	3,458	90.2
Age (years)						
<15	929	17.4	575	12.2	353	9.2
15-29	1255	23.5	1119	23.6	825	21.5
30-44	1957	36.6	1608	34.0	1205	31.4
45-60	852	15.9	1053	22.3	1127	29.4
>60	356	6.7	377	8.0	323	8.4

Table 4. Number of admissions, length of stay (in days) and overall cost and average cost per financial year of malaria admissions reported by the Hospital Episode Statistics, London 2009/10-2014/15

Financial year	**Number of admissions**	**Average length of stay (days)**	**Crude cost**	**Crude cost per financial year**
2009/10-2014/15	4,606	2.0	£6,330,793	£1,055,132

Figure 1. Total number of cases and rates per 100,000 population of malaria by year in London, 2000 -2014

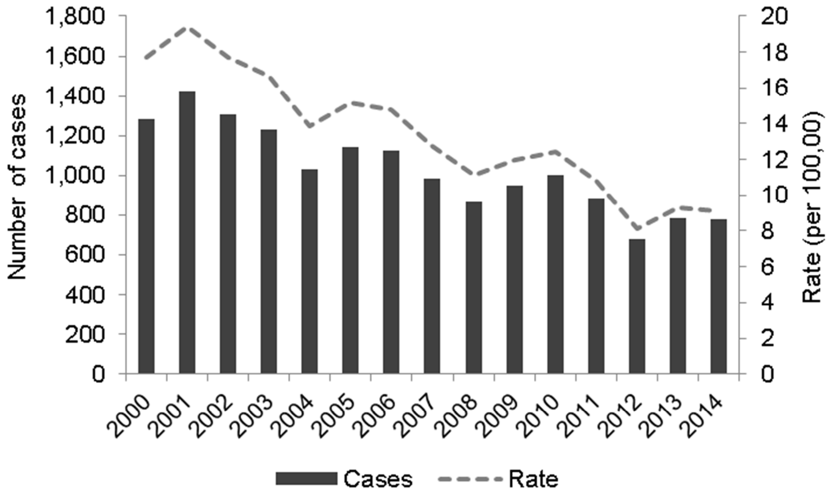


Figure 2. Age and sex distribution of malaria cases by five-year period, London 2000-2014

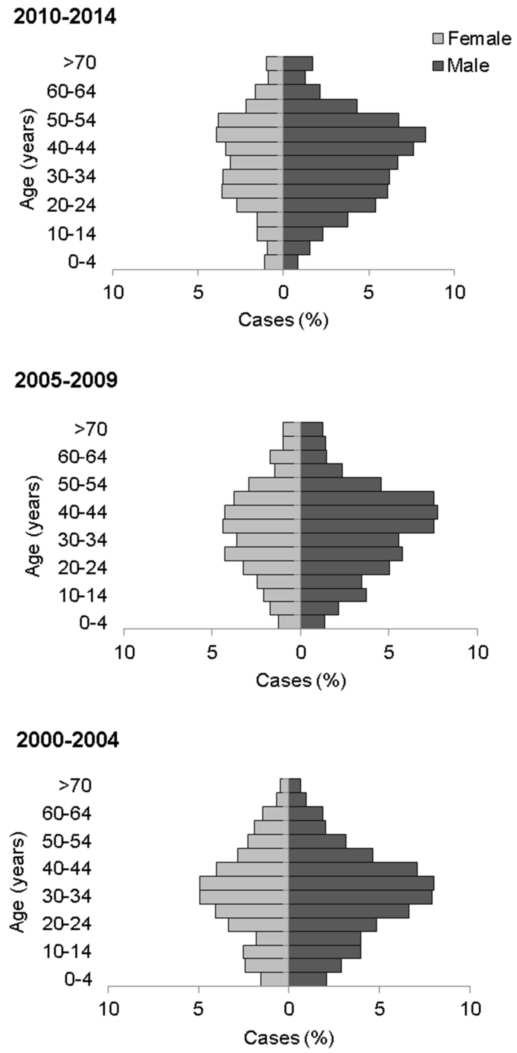
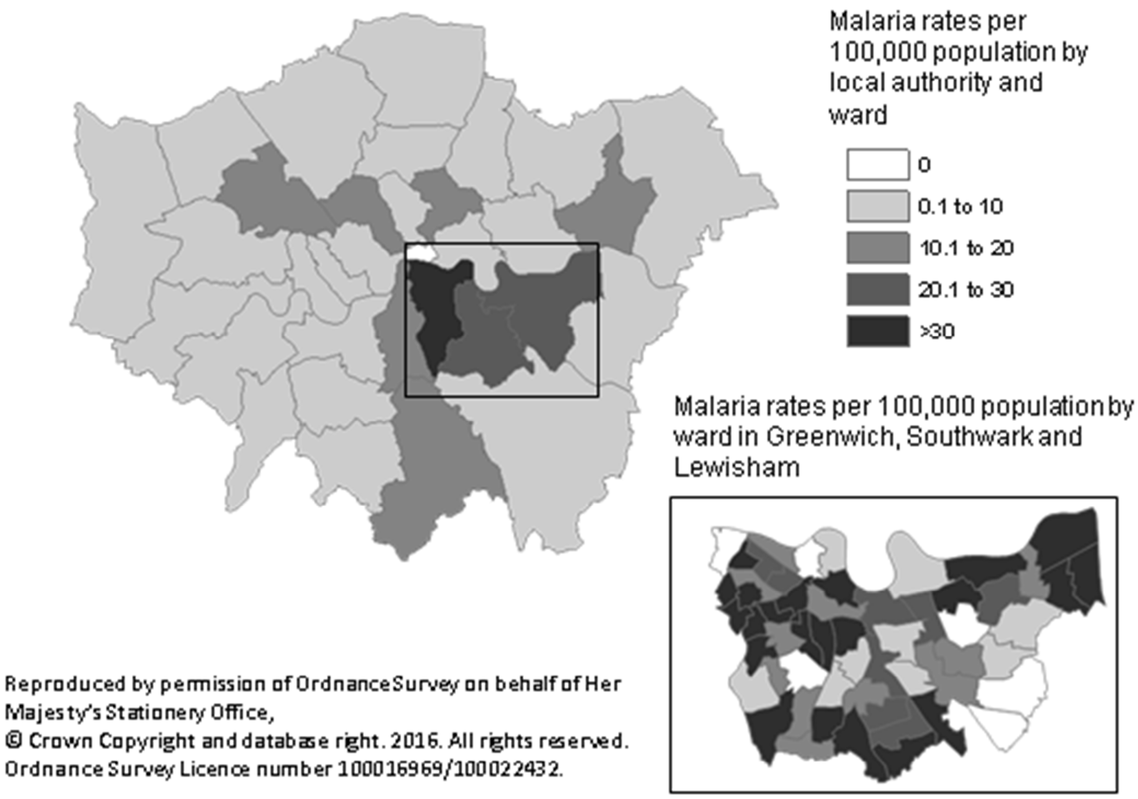


Figure 3. Malaria rates per 100,000 population by local authority of residence and by ward for the three local authorities with the highest rates (Southwark, Lewisham and Greenwich), London 2014



List of local authorities in London presented in order from the highest to the lowest rate of Malaria per 100,000 population in 2014 Southwark, Lewisham, Greenwich, Hackney, Barking and Dagenham, Camden, Croydon, Lambeth, Brent, Newham, Hammersmith and Fulham, Merton, Bexley, Enfield, Kensington and Chelsea, Hillingdon, Barnet, Wandsworth, Redbridge, Sutton, Haringey, Westminster, Islington, Waltham Forest, Harrow, Hounslow, Tower Hamlets, Ealing, Bromley, Havering, Richmond upon Thames, Kingston upon Thames and City of London

Figure 4. 2015 IMD scores by quintile, plotted by LSOA and local authority in London.