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ORIGINAL ARTICLE

Effect of an ecosystem-centered community participation programme on the incidence of dengue. A field randomized, controlled trial

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Abstract

Objectives The purpose of this study is to analyse the effect of a community participation programme based on the ecosystem model on the incidence of dengue in urban communities.

Methods A randomized controlled field trial was conducted in the state of Colima, Mexico. The intervention consisted of a community participation programme focused on the ecosystem; simultaneously, the control groups were communities that only received the usual official prevention programs. The incidence of dengue was estimated in people of both groups due to the appearance of de novo IgM antibodies during the follow-up period.

Results The incidence of dengue in the intervened group was 2.58%/month (n=818) and in control group 2.26%/month (n =994), with a risk ratio of 1.14 (95% CI 0.89–1.45) and a PAF of 0.06 (95% CI −0.056 to 0.16). The *A. aegypti* larval density (Breteau Index) was reduced in the treated group.

Conclusions The implementation of a community participation programme in the cities of Colima, Mexico, showed a slightly counterproductive effect on the incidence of dengue. This happened even with a reduction in the *A. aegypti* index.

Keywords Dengue · Ecosystemic · Community participation · *Aedes aegypti* · Breteau index · Colima, Mexico

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Introduction

Dengue is the vector-borne viral disease of greatest impact worldwide due to its constant expansion in affected countries and the development of increasingly more aggressive forms of the disease (Gyawali and Taylor-Robinson 2016; Murgue 2010). Given that there are still no effective antiviral medications and that the use of vaccines has not yet been globally accepted (Villar et al. 2015), the main strategy for dengue containment continues to be based on the reduction in populations of the mosquito *Aedes aegypti* (Linnaeus). These strategies are based on the spatial application of insecticides in the form of ultra-low volume (ULV) spraying or the placement of larvicidal products in water-holding receptacles. On the other hand, community participation has been presented as a basic element in any attempt to reduce the impact of dengue (WHO 2009). However, programmes based on community participation have not had the desired results in the incidence of dengue (Carvalho et al. 2017). Although some encouraging results have been reported in terms of the reduction in *A. aegypti* populations, larvae and pupae (Espinoza-Gómez et al. 2002), the actual incidence of dengue has not declined but has shown an increase. Some explanations for these discordant results have been attributed to the following weaknesses: (1) Almost all studies evaluate only the population of the larvae of the vector and not the final effect, which is infection by the virus. (2) The analysis of the incidence of dengue is based on the appearance of clinical cases reported by the medical care units that place these patients in relation to their homes and not where they spend most of the day. (3) With respect to community intervention, the type of strategy employed is not clearly specified, and the concept is very heterogeneous. (4) In very few cases are suitable control groups studied (Al-Muhandis and Hunter 2011). Despite these known inaccuracies, many authors insist that the starting point for dengue control is to promote community participation, not only through information programmes but also with a change in attitudes and practices through the greater empowerment and social cohesion of the groups involved through programmes with an ecosystem approach, as has been observed in Cuba and Colombia (Bonet et al. 2007; Quintero et al. 2009). When evaluating the real effectiveness of community intervention programmes, it is necessary to perform studies that apply to populations that share the same risk of contact with the vector, with controls matched in time and space and that measure dengue infection as an exit event during follow-up. This can be accomplished through the detection of antibodies in selected cohorts of people and not just by passively counting new clinical cases or calculating entomological indices (Sarti et al. 2016).

In the present study, a community trial was conducted in the urban zones of the state of Colima, Mexico, which has been the site of two important dengue epidemics in the last 15 years. The objective of our study was to evaluate the effectiveness of a community participation campaign with an ecosystemic approach on the incidence of dengue infections, estimated from the detection of antibodies in the studied subjects.

Methods

Studied population

The state of Colima is located on the west coast of Mexico (19° 31′–18° 41′ N; 103° 29′–104° 41′ W), with a population of 711,235 inhabitants according to the National Institute of Geographic Statistics and Information of the state (Spanish abbreviation: INEGI) (INEGI 2005) with an area of 5625 km^2. Its predominating climate is hot and humid, with rains in the summer and a mean annual temperature of 28 °C. The study was conducted within 30 blocks of houses randomly selected through simple randomization in the three most important cities of the state of Colima: the urban zone of Colima and Villa de Álvarez, with 294,137 inhabitants; Manzanillo, with 161,420 inhabitants; and Tecomán, with 112,726 inhabitants. These blocks are areas of approximately ½ hectare, which is considered to be the typical area of *A. aegypti* activity. Each block included an average of 75 buildings, including housing, public and commercial buildings. These areas belong to basic geostatistical areas (BGA) with similar population, economic income and educational levels that correspond to a low/middle level according to the INEGI (INEGI, 2005).

Study design

A controlled, randomized community trial was conducted. The dependent variable or exit event was the incidence of dengue as determined by the presence of IgM and/or IgG de novo anti-dengue antibodies in the studied subjects, and the independent variable was the intervention with an ecosystem-centred community participation programme. Approximately 45 inhabitants in each block were selected. The assignment of individuals to the intervention was performed by blocks through simple randomization. The inclusion criteria of the subjects were permanently residing on the assigned block during the entire study and staying on it for at least 8 h during the daytime; being older than 6 months of age; not having any chronic disease or infection at the beginning of the study; and being seronegative for anti-dengue antibodies. Individuals who showed the presence of IgG or IgM antibodies or who had questionable results in the reference sample, changed their address, or no longer wished to participate in the study were excluded.

Data collection

A baseline capillary blood sample was taken to identify IgG and IgM anti-dengue antibodies through the rapid Dengue-Duo (PanBio®) immunochromatographic test, following the manufacturer's instructions. At the 6-month follow-up, a new blood sample was taken, and the subjects were asked if they had presented with fever or symptoms suggestive of dengue during that period. For internal validation, 80 positive and 110 negative samples from the two groups were sent to the Institute of Diagnosis and Epidemiologic Reference of the Health Department in Mexico City (INDRE [Spanish acronym]) to confirm or rule out the presence of antibodies through MAC-ELISA, with the technique suggested by the manufacturer of the EIA Light Diagnostics Kit®, Chemicon Intl., Inc. Temecula, CA, USA. In some of the cases that were detected during the febrile phase, NS1 antigen identification was performed.

Reverse transcriptase coupled to the polymerase chain reaction test with a universal primer (Lanciotti et al. 2018) was carried out for those who were positive to later perform sequencing and determine serotypes.

Community participation programme

The intervention consisted of the application of an ecosystem-centred community participation programme in accordance with the guidelines defined by Lebel for Ecohealth (Lebel 2004) and subsequently applied in Havana, Cuba (Bonet et al. 2007), as well as with the recommendations of the WHO for the community management of dengue (WHO 2009). The ecosystem approach involved the integration of a multidisciplinary team that worked closely with local leaders, policymakers and other stakeholders to form focal groups to design a sustainable programme of knowledge-based actions adapted to the needs and particular uses in each location (Lisitza and Wolbring 2018). This strategy was reinforced by replicating actions utilized in 2001 during a community participation programme for the control of *A. aegypti* in Colima (Espinoza-Gómez et al. 2002), such as contact with the local leaders and official representatives of each neighbourhood. Such focal groups had meetings with leaders and experts to identify the importance of dengue in the framework of health priorities in each block based on the basal diagnosis of dengue prevalence and larval indices at each block. The prioritization of problems inherent to each community was addressed according to the model proposed by Sanoff (2000). After a discussion of the problems, the group defined strategies to prevent dengue. Those strategies were tailored to each block according to the beliefs and uses unique to each location. In addition, environmental management with local authorities (for example, to improve garbage collection or the water supply or eliminate large water containers) was encouraged. The programme consisted of the integration of a multidisciplinary work team that organized the conformation of focal groups in each block or neighbourhood that included local leaders and residents of the zone, with the participation of representatives of the municipal authority and local health department committees. Through these groups, the problems inherent in each community were addressed, prioritizing them according to the model proposed by Sanoff (2000).

Dengue was identified by the community itself in an environmental, social, and demographic context, and ideas were discussed in regard to the best manner of its control depending on the characteristics and resources of each zone. The programme was centred on two aspects: (1) the elimination of *A. aegypti* breeding grounds and (2) personal protection from mosquito bites and opportune identification of dengue. These tasks were complemented with house-to-house promotional activities as well as with the use of sociodramas, photo novels, and printed promotional material and demonstrative practices (Espinoza-Gómez et al. 2002; Bonet et al. 2007). We consider communities as the geographical spaces where people share the risk of being bitten by *A. aegypti* during the daytime independent of their familiar or friendship ties. The members of the families involved and the people who live in the same building (schools, stores, etc.) within the blocks that participated in the programme were considered treated. In the control blocks, the only promotion activity was the one usually carried out by the Department of Health through the "Patio Limpio" programme (clean backyard) and the systematic use of spatial fumigation or larvicidal (Temephos) use in water containers performed by the field workers of the Secretary of Health. In these blocks, the follow-up was similar to that in the intervention group. To reduce a possible mixture of the treatment effects among blocks, we selected only the people who remain almost all day in the block and tried to exclude people with constant mobility throughout the city (taxi drivers, travelling merchants, etc.); in addition, the distance between the treated and control blocks was higher than 500 m, but the follow-up was similar to that in the intervention group. To validate the participation of individuals in the community programme, an entomologic survey was carried out to determine the larval indices in the homes or buildings corresponding to each study group. In particular, the Breteau Index (BI) per block was calculated before and after the intervention. The study began in May 2009 and ended in January 2011. To analyse the possible effects of other intervening variables on the final result, the sex and age of the participants were taken into account. All the studied blocks were treated with spatial fumigations performed according to the Norma Oficial Mexicana for vector control by the Secretary of Health (Norma Oficial Mexicana 2014). The fumigations were carried out with permethrin combined with Esbiol and ButoxiPiperonile at 100 ml per hectare with ULV at 10 m of a diameter of the droplet with London Fog® equipment in raids of 3 to 4 days. Therefore, this was not considered a confounding variable.

Statistical analysis

The sample size was calculated based on a crude incidence of dengue in the control group of 1.7% per month/person in accordance with previous studies in Colima (Espinoza-Gómez et al. 2003) and with an expected reduction of up to 25% (d=0.45) after the intervention. Incidence was estimated according to the time of exposure per individual, dividing the number of positive individuals by the total number of sampled individuals and the number of months of observation (Greenland 1984). Univariate logistic regression analysis was used to compare the incidence rates between groups and to calculate the correlation coefficient. In each case, the rate ratio and its respective confidence interval were calculated. The population attributable fraction (PAF) was calculated by means of the formula PAF= [P(D)−ΣC P(D) C,E–) P(C)]/P(D) and the confidence intervals with ln (1− PAF)±z1-α/2 {Var [ln (1−PAF)]}. With respect to multiple correlations, a multivariate analysis with an unconditional logistic regression was used, and a Bonferroni's adjustment was made to establish the significance of *p*.

To assess the BI as infectious pressure, we designed the following formula: Let *C i* be the effect of the reduction in infectious pressure in group *i* due to some strategy *i*, 〚0≤ C〛 *i*≤1. Regardless of the strategy, the infection pressure is proportional to the number of mosquitoes in group *i*, *M_i*.

$$x_i \propto C_i M_i N_i,$$

where *N_i* is the total number of persons in the group where strategy *i* was tested. The incidence in group *i* is proportional to the product of the number of mosquitoes and the number of susceptible individuals in location *i* (-mass-action law).

Since *M_i* is proportional to the BI in group *i*, *B_i*, it turns out that

$$\frac{x_i}{N_i} \propto C_i B_i$$

That is,

$$\frac{\frac{x_1}{N_1}}{\frac{x_2}{N_2}} \approx \frac{C_1 B_1}{C_2 B_2}$$

In the previous expression, *C* 1/C 2 is the ratio of the relative reductions in strategies 1 and 2. This is:

$$\frac{C_1}{C_2} \approx \frac{x_1 B_2 / N_1}{x_2 B_1 / N_2}$$

The incidence analysis was performed individually considering a per protocol test.

Results

Crude incidence

In the baseline sample, 2650 persons were surveyed, of whom 1812 concluded the 6-month follow-up. The causes of exclusion were as follows: basal IgG or IgM antibodies to dengue were present (64 cases in control and 61 in treated blocks), 140 persons were reluctant to go on in the control group and 225 in the intervened blocks, and 162 in control and 186 in treated blocks changed their address.

Table 1 Incidence of dengue in 6 months according to the demographic variables and community participation in the cities of Colima, Villa de Álvarez, Tecoman and Manzanillo, Colima, Mexico from May 2009 to January 2011

Variable	Positive/total cases	Incidence cases/100 persons per month	Odds ratio (Confidence interval 95%)
Male	95/710	2.23	
Female	167/1102	2.52	1.15 (0.87–1.51)
Age			
<3 years	7/124	0.94	
4–9	25/164	2.54	
10–19	77/449	2.85	
20–29	36/276	1.93	
30–39	31/234	2.21	
40–49	27/229	1.96	
50–59	23/130	2.94	
60–69	15/105	2.38	
70 or older	21/101	3.46	1.6 (0.97–2.63)
Community participation	127/818	2.53	1.15 (0.89–1.51)[a]
Control	135/994	2.26	

[a]Estimated rate ratio = 0.85 (0.65 −1.11), population attributable fraction: 0.08 (0.18 to −0.05)

Table 1 shows the demographic characteristics of the people ultimately involved in the whole study. The total crude incidence was 262/1812 (14.46%) in 6 months, that is, 2.41 (95% CI 1.92–4.0)/100 persons/month.

Effect of the intervention

The incidence in the intervention group (127/818=15.52%) was slightly but not significantly higher than that in the control group (135/994=13.58%), with a risk ratio of 1.14 (95% CI 0.89–1.45) and a PAF of 0.06 (95% CI −0.056 to 0.16). Table 1 shows the analysis of the confounding variables of sex and age on the appearance of new cases. Sex and age did not show an effect on incidence. In general, the effect of the community participation programme was not significant even after adjusting for age and sex through multiple logistic regression analysis.

Entomologic survey

Upon analysing the changes in the larval indices of *A. aegypti* as an indicator of intervention adherence, the BI was observed to increase in the control group from 5.83 to 7.42 in 175 houses studied, whereas in 109 houses corresponding to the intervention group, the index was reduced from 12.8 to 7.33 as a result of the proactive actions

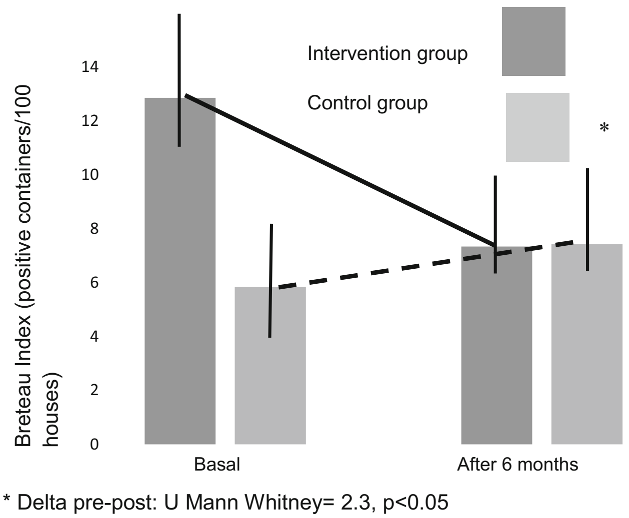

Fig. 1 *Aedes aegypti* Breteau Index in the intervened and control blocks of Colima, Villa de Álvarez, Tecoman and Manzanillo, Colima, Mexico from May 2009 to October 2010. At the beginning of the study and after 6 months

regarding the elimination of hidden water receptacles, garbage collection, etc., not done in the control group. The difference between the basal and postintervention BI in the control and intervention groups is depicted in Fig. 1.

Regarding the estimation of the pressure of BI to dengue infection using the aforementioned formula and considering 1 as the strategy with community participation and 2 as the control group, we have:

$x_1 = 127, x_2 = 135, B_1 = 12.8, B_2 = 5.83, N_1 = 818,$
$N_2 = 994$ thus:

$$\frac{C_1}{C_2} \approx 0.5206$$

In this case, it is safe to set $C_2=1$, that is, no reduction in vector pressure in the control group; then, the effort of the people in the participation group reduced the pressure of the vector upon the community to 48%. This means that in the treated communities, the real incidence could have reached 19.6%, but the preventive actions reduced it to the observed 15.2%.

Internal validation

The tests for detecting IgG and IgM through MAC-ELISA performed at the INDRE of the National Ministry of Health on a subsample of 190 serums showed that the rapid test used in the study had a 91% sensitivity (95% CI 88.5–95.2) and a 94% specificity (95% CI 89.1–97.8) for IgG and a 89.2% sensitivity (95% CI 86.4–92.1) and a 92% specificity (95% CI 91.7–94.8) for IgM. These data are consistent with the recent validation of rapid tests for the detection of dengue infections (Blacksell et al. 2006). The molecular biology test carried out on 4 of the studied patients showed the presence of serotype 1 from strains DENV-1/MX/BID-V3664/2006 (GenBank #GQ868499) and DENV-1/MX/BID-V3744/2008 (GenBank #GQ868529), coinciding with that found by the INDRE in patients with dengue attended at medical units in Colima. Of the 278 positive cases of dengue infection, 34 showed a clinical picture suggestive of dengue, of which only 10 were evaluated and confirmed by the official health authorities.

Discussion

The estimated incidence of dengue infection during the study period was 2.41 per 100 persons/month, which is approximately double the interepidemic transmission rate in Colima (Espinoza-Gómez et al. 2003). It is quite probable that the introduction of a new serotype in the region, such as DENV 1, has triggered such high attack rates. During the study period, the Ministry of Health reported 4994 cases. The most relevant finding of the study is the lack of a reduction in the incidence of dengue in association with the community participation programme. Instead, it seems that this intervention produced a paradoxical increase in the number of incident cases in relation to that in the control group. At first glance, this could suggest that the campaign was not carried out properly or that the population did not follow it. However, the notable reduction in larval indices in relation to those in the control group, similar to what was previously observed in Colima in 2000 (Espinoza-Gómez et al. 2002), implies that people participated in activities to eliminate *A. aegypti* breeding sites. The reduction in BI in the intervened group of up to 48% compared to that in the control blocks, in theory, could have protected the residents of the treated blocks in the same proportion so that the current incidence could have hindered the occurrence of figures even higher than those in the control group. Nevertheless, some authors have noted that dengue transmission does not depend only on larval *A. aegypti* density, as there are many other environmental factors involved (Cromwell et al. 2017). Since environmental factors, such as climate, rain precipitation, urbanization, public services and vegetation index values, as well as age, sex, mobility, socioeconomic status and scholarship, were controlled, it is possible to assume that these factors did not influence the results. On the other hand, as the adult population of *A. aegypti* does not correlate with the larval indices, it is possible that adult mosquitoes easily invade places where larval populations have decreased, which could be associated with a greater transmission of dengue despite relatively low larval populations. In the same way, other entomologic variables, such as the pupal index or number of adults per house, are currently proposed as more suitable entomologic indices for the risk of dengue (Parra et al. 2018; Cromwell et al. 2017). These different points of view deserve particular analysis in ad hoc studies of the correlation between dengue incidence and the different entomologic parameters. Regardless, the community-based programme used by us failed to obtain a desirable reduction in the incidence of dengue. These results differ from those of another similar study performed in Mexico, in which the authors found a significant reduction in dengue transmission with a community-based programme (Andersson et al. 2015). A possible explanation for these differences is that we used a community concept based on geographical boundaries and not a community defined by the householders themselves. We confined a completely dissimilar group of people in the same space, and this could have influenced our results in the sense of discrepancies among the inhabitants of the blocks related to political or family conflicts between them. For example, we found anecdotal cases of reluctance to cooperate among neighbours in the intervened blocks due to political differences. Furthermore, some subjects in the control group applied strategies to eliminate the larvae taken from relatives living in the treated blocks. This inevitable cross-mixing of behaviours could have ultimately influenced the results. The programme likely exacerbated weak social cohesion, the fragmentation of family groups and political polarization at the local level, which contributed to the failure to prevent dengue. Such iatrogenic effects have been observed in other preventive activities focused on specific groups, for example, in programmes to stop alcoholism and smoking (Chudley et al. 2002). This phenomenon could be attributed to the unwillingness to follow generalized vertical measures for health promotion and people preferring family councils.

In any case, it is necessary to carry out a more critical review of the way in which community participation programmes are designed and operated. These programmes are not as economical as they seem since they represent a large consumption of work hours as well as complicated logistics for their implementation (Bouzid et al. 2016).

Limitations

A limitation of the study is the relatively low specificity and sensitivity of the rapid immunochromatographic tests for the diagnosis of dengue; however, as discussed above, for epidemiological purposes, these techniques have adequate specificity and sensitivity (Blacksell et al. 2006). Another limitation is the lack of more extensive and continuous entomological sampling in the study areas, particularly with respect to the sampling of adult mosquitoes that are directly involved in the transmission of dengue. Finally, it is necessary to add a qualitative in-depth survey to explore the main reasons for the seemingly greater risk behaviours in people participating in community programmes.

Conclusions

Community participation programmes demand a critical review for their implementation, at least in countries with limited educational levels, little social cohesion, and lax legislation, as is the case in almost all of Latin America. Such programmes should be contrasted with several concepts of community and with massive vertical actions in each area endemic for dengue. In contrast, in countries with a much more equitable society, higher educational level and stricter systems of control, as is the case in Cuba, community participation campaigns can show much more encouraging effects (Quintero et al. 2009).

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Authors' contributions OANS: Advisor upon work with children and adolescents, work at schools, the contribution of ideas. MDCR: Fieldwork, coordination of focal groups, qualitative data collection. YTR: Fieldwork, advisory in community participation, the contribution of ideas, linkage with the Institute of Tropical Medicine in La Havana, Cuba. HODL: Advisor in community participation activities, the contribution of ideas. IDE: Support in the laboratory work and contribution of ideas. CMHS: Analysis of data, work at schools, advisor in design and preparation of the draft. FEG: Design, original idea, resource management, writing of the draft. All authors have approved the final article.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Each participant signed a statement of informed consent for minimal intervention studies in accordance with the stipulations of the Norma Oficial Mexicana for health research. In the case of children, parents sign was collected. The study was approved by the institutional bioethics and research committee of the Department of Health of the State of Colima (Number 05/2007), following the Helsinki's 1964 Declaration.

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