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ORIGINAL

Features, gamification and user ratings of dengue and arbovirus apps in Latin American App Store storefronts

Funciones, gamificación y valoraciones de aplicaciones sobre dengue y arbovirosis en tiendas de aplicaciones de América Latina

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ABSTRACT

Introduction: Dengue, chikungunya and Zika impose a recurrent burden in Latin America, and mobile apps are used for education, clinical support and vector surveillance. The functions, game elements and ratings of these apps in regional storefronts had not been described. Methods: A cross-sectional content analysis of app-store listings was carried out with the public iTunes Search API in eight Latin American storefronts, using 22 search terms. Apps first released in 2012 to 2024 whose purpose centred on dengue, chikungunya, Zika, Aedes or arboviruses were included. Developer sector, six public-health functions and game elements were coded from the listing text, and ratings were taken from the storefronts. Exact 95% confidence intervals and Fisher tests were used, with exploratory intent. Results: The searches returned 3,908 listings, from which 18 apps were eligible. Education and information was the most frequent function (12 apps; 66.7%), followed by surveillance and mapping (6; 33.3%). A game was the delivery format of 2 apps (11.1%), and one app combined points, a ranking and challenges. Ratings existed for 11 apps and totalled 39 across storefronts. No association among sector, functions, game format and ratings reached $p < 0.05$. Conclusions: The shelf of dengue and arbovirus apps was small, free of charge, mainly informational and sparsely gamified, and user ratings were too few to indicate quality. Listing text should be complemented with direct app evaluation.

Keywords: dengue; mobile applications; gamification; Aedes; Latin America; health promotion.

RESUMEN

Introducción: El dengue, el chikungunya y el Zika imponen una carga recurrente en América Latina, y las aplicaciones móviles se emplean para educación, apoyo clínico y vigilancia de vectores. No se habían descrito sus funciones, elementos de juego ni valoraciones en las tiendas regionales. Métodos: Análisis de contenido transversal de fichas de tiendas de aplicaciones obtenidas con la API pública de búsqueda de iTunes en ocho tiendas latinoamericanas (22 términos). Se incluyeron aplicaciones lanzadas entre 2012 y 2024 centradas en dengue, chikungunya, Zika, Aedes o arbovirus. El sector del desarrollador, seis funciones de salud pública y los elementos de juego se codificaron desde el texto de la ficha; las valoraciones se tomaron de las tiendas. Se usaron intervalos de confianza exactos del 95 % y pruebas de Fisher, con intención exploratoria. Resultados: Las búsquedas devolvieron 3908 fichas, de las cuales 18 aplicaciones fueron elegibles. La educación fue la función más frecuente (12 aplicaciones; 66,7%), seguida de la vigilancia y el mapeo (6; 33,3%). Un juego fue el formato de 2 aplicaciones (11,1%), y una combinó puntos, clasificación y desafíos. 11 aplicaciones tuvieron valoraciones, 39 en total. Ninguna asociación entre sector, funciones, formato de juego y valoraciones alcanzó $p < 0,05$. Conclusiones: La oferta fue pequeña, gratuita, principalmente informativa y poco gamificada, y las valoraciones fueron demasiado escasas para indicar calidad. La ficha debe complementarse con la evaluación directa de las aplicaciones.

Palabras clave: dengue; aplicaciones móviles; ludificación; Aedes; América Latina; promoción de la salud.

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INTRODUCTION

Dengue is a mosquito-borne viral infection with a distribution that covers most of the tropics, and one model-based estimate placed the number of infections at 390 million per year.(1) The Global Burden of Disease analyses recorded a rise in incident cases and deaths between 1990 and 2017,(2) and the upward trend continued in the estimates up to 2019.(3) In Latin America the 2024 season was exceptional: Brazil reported 1,978,372 suspected cases by epidemiological week 11,(4) and the first 15 weeks of 2024 showed an average increase of 600% in new cases across the region compared with the same weeks of 2023.(5) Dengue now circulates with chikungunya and Zika, whose emergence changed the age profile of dengue in Brazil (6) and was recorded in the provinces of Ecuador.(7) The three arboviruses can present a similar clinical picture, which complicates diagnosis and case management.(8)

Mobile phones were incorporated into the control of these diseases as tools for surveillance, prevention, diagnosis and communication. A scoping review of 36 studies from twenty countries identified mobile applications as the most frequent phone-based service, with 18 studies.(9)A review of digital health interventions in dengue surveillance grouped them into 13 categories, among which mobile applications ranked fourth.(10)Regional analyses described the potential of mobile health in Peru and in the Region of the Americas.(11,12) Citizen science apps added a participatory route: the photographs and reports submitted through Mosquito Alert, validated by experts, gave early warning of the Asian tiger mosquito invasion in Spain.(13)

Two further constructs shape how such apps are designed and how they are judged. Gamification, the use of game-design elements in non-game contexts, is applied to motivate behaviour; a review of 819 studies found points, badges and leaderboards to be its most common implementations, with health and education among the leading contexts.(14) The empirical evidence on health outcomes was positive in 59% and mixed in 41% of 19 papers,(15) and only 4% of 1,680 health apps screened in the app stores included gamification.(16) The second construct is the app-store listing as a data source. App store analysis exploits descriptions, prices and ratings to characterise software,(17) and it has been applied to cardiac arrhythmia apps,(18) nutrition apps in Spain (19) and workers' health apps in Brazil.(20) Star ratings alone, however, do not measure app quality,(21) and users in different countries, Brazil and Mexico among them, differ in how they adopt and choose apps,(22) which makes the storefront a reasonable unit for a regional description.

In this study the offer of dengue and arbovirus apps was therefore treated as a construct with four dimensions: availability and provenance, public-health functions, gamification and user ratings. Educational games for dengue have been reported as research prototypes and trials,(23,24) but the apps that a Latin American user can actually find in the storefronts have not been inventoried. The objective was to describe the provenance, public-health functions, gamification elements and user ratings of dengue, chikungunya, Zika and Aedes apps first released between 2012 and 2024 and listed in eight Latin American App Store storefronts.

METHODS

Design, data source and eligibility

A cross-sectional content analysis of app-store listings was carried out, reported according to the STROBE items that apply to a study without participants. The listings were retrieved from the public iTunes Search API(25)for the storefronts of Brazil, Mexico, Colombia, Argentina, Peru, Chile, Paraguay and Ecuador, with the software entity and up to 200 results per query. Each record supplied the app name, description, store genres, first-release date, date of the current version, price, seller name, supported languages, and the average rating and number of ratings of the storefront that was queried. Twenty-two search terms in English, Spanish and Portuguese were used in each storefront (176 queries): dengue, chikungunya, zika, aedes, aedes aegypti, mosquito, arbovirus, arbovirosis, arbovirose, arboviroses, mosquito bite, foco mosquito, criadero mosquito, agente de endemias, vigilancia vectorial, combate ao mosquito, dengue zero, sintomas dengue, vector control, fumigacion, jogo dengue and juego dengue. The terms combined the disease names, the vector, and Spanish and Portuguese expressions chosen to capture reporting, field-agent and game-oriented listings. The data are the snapshot available from the public API.

The scope was defined by four decisions. The unit of analysis was the app, identified by its store identifier, and an app listed in several storefronts was counted once. The Latin American setting was defined by availability in the eight storefronts and not by the country of the developer.

Only the iOS store was covered, because it offers an open search interface (the iTunes Search API) and the Android store has no equivalent public interface. Apps were eligible when their name or description named dengue, chikungunya, Zika, Aedes or arboviruses (in any of the three languages), the first-release year fell between 2012 and 2024, and the declared purpose centred on the disease or its vector. Listings in which the term appeared only as one topic or feature of a multipurpose product, or as a false match, were excluded, and the reason was recorded for each decision.

The screening, the coding described below and the assignment of sector were performed by a language model (Claude, Anthropic) following written rules and a script that can be run again. They have not been verified by independent human coders, and the authors should confirm them.

Availability and provenance

The first-release year was grouped into three periods (2012 to 2016, 2017 to 2020, 2021 to 2024). The developer was classified from the seller name and the listing text as public sector (a ministry, a state or municipal government, a municipal data-processing company or a national health institute), research or non-profit project (a listing that described a research centre or a social technology project), international health agency (an app presented as official by the World Health Organization), or private company or individual in all other cases. Regional content was defined as an explicit tie of the listing to a Latin American country or institution. Storefront coverage was the number of the eight storefronts in which the app appeared. The search yield was recorded as the number of search terms and storefronts that retrieved each app. Price, the store genre and whether the current version was later than the first-release year were also recorded. Each variable was summarised as n (%) with an exact Clopper-Pearson 95% confidence interval (CI), and the length of the listing text as median and interquartile range (IQR).

Public-health functions

Six functions were defined: education and information; symptom checking and clinical guidance; breeding-site reporting; surveillance and mapping of cases or mosquito observations; support to vector-control field operations (inspection records, verification of brigade workers, treatment tracking); and mosquito identification. The audience, professionals or field agents versus the general public, was coded separately. Education and information required a statement that the app informs, teaches or provides references, news, videos or guides. Symptom checking and clinical guidance required that the app classified risk, listed warning signs, gave clinical management recommendations or advised when to seek care. Breeding-site reporting required that users could report breeding sites or foci of the vector. Surveillance and mapping required reporting or mapping of cases, mosquito observations or georeferenced records. Support to field operations required records of inspections, planning or tracking of treatments, or verification of brigade workers, and identification required classification of mosquitoes from images or learning to recognise species. A function was coded as present only when the name, description or store genre stated it, and each code was stored with a verbatim evidence fragment that the script verified against the listing. Absence of a function meant that it was not stated, not that the app lacked it. Functions were summarised as n (%) with exact CI and as the number of functions per app (median and IQR).

Gamification

Gamification was operationalised as a game being the delivery format (store genre of games, or a listing that describes the app as a game) and as the presence of seven game-design elements: points or scores, badges or achievements, levels or stages, rankings, challenges or missions, narrative or role-play, and explicit playful framing. The list follows the elements most often reported in gamification research.(14,16) Social, community or citizen-science participation was recorded separately because it is a participation feature and not a game-design element. Points were counted when the listing stated a reward by points or a score; challenges when the user had to complete tasks, including verification tasks proposed to other users; and narrative when the listing named a protagonist, a role assumed by the player or an adventure. The analysis consisted of n (%) with exact CI, and an overall indicator of any game format or game-design element.

User ratings

For each app, the average rating and the number of ratings of every storefront were obtained from the same listing records. Ratings were summed across storefronts, and the mean rating of each app was weighted by the number of ratings in each storefront. The rating fields reflect

the storefront in which each app was queried, and a rating given in one storefront does not enter another. Apps without ratings were counted separately. The Mobile App Rating Scale(21)was not applied because the apps were not installed and used. The ratings were summarised as the median and IQR of the number of ratings and of the app-level mean rating, and as the pooled mean weighted by the number of ratings.

Relations among dimensions

The associations of developer sector with symptom checking, breeding-site reporting and having any rating, of game format with the education function, and of regional content with sector were tested with the Fisher exact test. Spearman correlations were computed between the release year and the number of functions, and between the number of ratings and the mean rating. Odds ratios were not computed because several cells were zero, and the counts in each group are reported instead. The significance level was 0.05 (two-sided). With 18 apps the analysis had low power, no correction for multiplicity was applied, and the results are exploratory.

RESULTS

Availability and provenance

The 176 queries returned 3,908 listings, which collapsed into 551 unique apps. A total of 47 apps named dengue, chikungunya, Zika, Aedes or arboviruses; 1 was first released before 2012 and 24 after 2024. Of the 22 apps within the window, 4 were excluded as multipurpose products or false matches, and 18 apps were analysed.

Within the dimension of provenance, 8 apps (44.4%) were first released in 2017 to 2020, 7 in 2021 to 2024 and 3 in 2012 to 2016 (Table 1, Figure 1). Private companies or individuals developed 10 apps (55.6%; 95% CI 30.8-78.5), the public sector 5 (27.8%; 95% CI 9.7-53.5), research or non-profit projects 2 and an international health agency 1.

Table 1. Availability and provenance of dengue and arbovirus apps listed in Latin American storefronts.

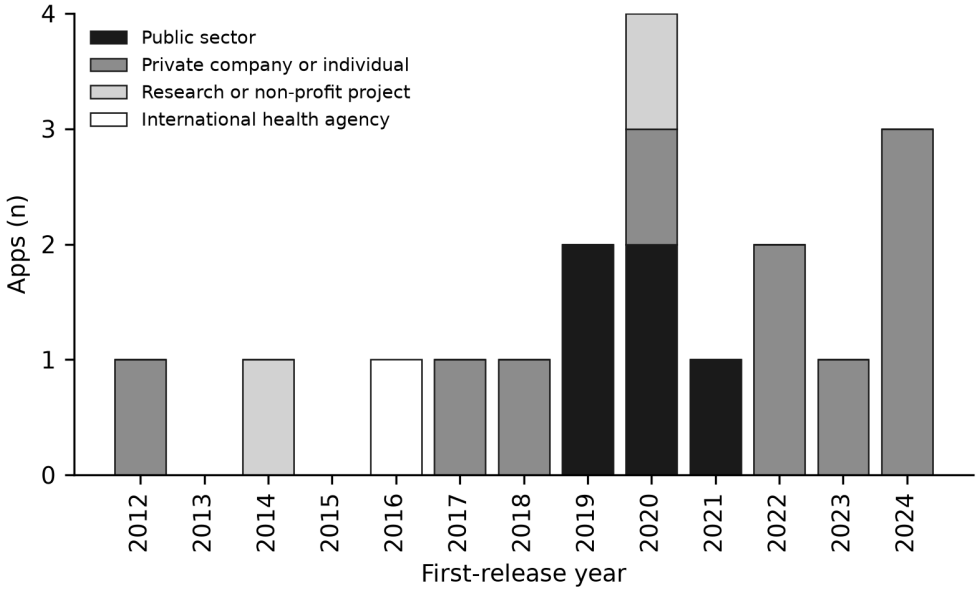
Characteristic	n	%	95% CI
First release 2012-2016	3	16.7	3.6-41.4
First release 2017-2020	8	44.4	21.5-69.2
First release 2021-2024	7	38.9	17.3-64.3
Developer: Public sector	5	27.8	9.7-53.5
Developer: Private company or individual	10	55.6	30.8-78.5
Developer: Research or non-profit project	2	11.1	1.4-34.7
Developer: International health agency	1	5.6	0.1-27.3
Content tied to a Latin American country or institution	12	66.7	41.0-86.7
Listed in all eight storefronts	11	61.1	35.7-82.7
Listed in a single storefront	6	33.3	13.3-59.0
Free of charge	18	100.0	81.5-100.0
Current version later than the first-release year	11	61.1	35.7-82.7
Store genre includes games	2	11.1	1.4-34.7

Note: CI = confidence interval (exact Clopper-Pearson). Percentages refer to 18 apps.

Regional content, defined as a tie to a Latin American country or institution, characterised 12 apps (66.7%; 95% CI 41.0-86.7). A total of 11 apps (61.1%; 95% CI 35.7-82.7) were listed in all eight storefronts, 6 in a single storefront, and the mean number of storefronts per app was 5.3. All 18 apps were free of charge. The term dengue retrieved 14 apps, 6 apps were retrieved by a single term, and 1 app appeared only under the term mosquito. The Brazilian storefront listed 16 apps, and the other 2 were found only in the Mexican and Peruvian storefronts. The median length of the listing text was 487 characters (IQR 355 to 722).

In relation to provenance within this dimension, the 5 public sector apps came from municipalities(3), a state government (1) and a national institute(1), and all of them were first released in 2019 or later.

Figure 1. First-release year of the included apps by developer sector.



Note: Each bar counts the apps first released in that year (n = 18).

Public-health functions

Education and information was stated by 12 apps (66.7%; 95% CI 41.0-86.7), surveillance and mapping by 6 (33.3%; 95% CI 13.3-59.0), and symptom checking and clinical guidance by 5 (27.8%; 95% CI 9.7-53.5). Breeding-site reporting was recorded in 5 apps, vector-control field operations in 3 and mosquito identification in 2 (Table 2).

For this variable, the median number of functions per app was 1.5 (IQR 1.0 to 2.75), with a maximum of 4. A total of 5 apps presented three or more functions, 1 listing stated none, and 6 apps (33.3%; 95% CI 13.3-59.0) were addressed to health professionals or field agents. Dengue was named in 11 listings, Zika or chikungunya in 5, and Aedes without a disease name in 6. No listing cited the Pan American Health Organization or the ARCA case database (0 listings).

As to this component, the maximum number of functions was reached by 2 apps, Mosquito Alert and sinDengue. In relation to the other dimensions, the associations of functions with sector and with game format are reported in the last subsection.

Table 2. Public-health functions offered by dengue and arbovirus apps.

Public-health function	n	%	95% CI
Education and information	12	66.7	41.0-86.7
Symptom checking and clinical guidance	5	27.8	9.7-53.5
Breeding-site reporting	5	27.8	9.7-53.5
Surveillance and case or mosquito mapping	6	33.3	13.3-59.0
Vector-control field operations	3	16.7	3.6-41.4
Mosquito identification	2	11.1	1.4-34.7
Addressed to health professionals or field agents	6	33.3	13.3-59.0

Note: CI = confidence interval (exact Clopper-Pearson). Functions are not mutually exclusive. Percentages refer to 18 apps.

Gamification

A game was the delivery format of 2 apps (11.1%; 95% CI 1.4-34.7), and 2 were also in the games genre. Challenges and narrative or role-play were each recorded in 2 apps, and points, a ranking and explicit playful framing in 1 app. Badges and levels were not stated in any listing (Table 3).

Table 3. Game formats and game-design elements stated in the app listings.

Game feature	n	%	95% CI
Game as the delivery format	2	11.1	1.4-34.7
Points or scores	1	5.6	0.1-27.3
Badges, trophies or achievements	0	0.0	0.0-18.5
Levels or stages	0	0.0	0.0-18.5
Rankings or leaderboards	1	5.6	0.1-27.3
Challenges or missions	2	11.1	1.4-34.7
Narrative, character or role-play	2	11.1	1.4-34.7
Explicit playful framing	1	5.6	0.1-27.3
Social, community or citizen-science participation	3	16.7	3.6-41.4
Points, badges, levels or rankings (any)	1	5.6	0.1-27.3
Any game format or game-design element (excluding participation features)	3	16.7	3.6-41.4

Note: CI = confidence interval (exact Clopper-Pearson). Elements are not mutually exclusive. Percentages refer to 18 apps.

For this variable, 3 apps (16.7%; 95% CI 3.6-41.4) presented a game format or at least one game-design element. Participation features were stated by 3 apps (16.7%; 95% CI 3.6-41.4).

As to this component, points, a ranking, challenges and playful framing co-occurred in one app, CLIC, which was not listed as a game. Neither of the 2 game-format apps stated points or a ranking.

User ratings

At least one rating was recorded for 11 apps (61.1%; 95% CI 35.7-82.7), and 7 apps had none. The ratings summed 39, with a median of 3 ratings per rated app (IQR 2.5 to 5.0) and a maximum of 7 (Table 4).

The median app-level mean rating was 5.0 (IQR 4.3 to 5.0; range 3.4 to 5.0), and 9 rated apps had a mean of 4.0 or higher. The pooled mean weighted by the number of ratings was 4.4.

Within this component, 4 of the 11 rated apps had five or more ratings. In relation to storefronts, 9 rated apps had ratings in the Brazilian storefront, 1 in the Mexican and 1 in the Peruvian storefront.

Table 4. User ratings recorded for the eleven rated apps.

App	Ratings (n)	Mean rating (1-5)	Storefronts with ratings (n)
DENGUE - Manejo Clínico - Adulto e Criança	7	4.7	1
Combate à Dengue	5	5.0	1
Flyttr Go	5	3.4	1
Udi Sem Dengue	5	3.4	1
sinDengue	4	5.0	1
Combate Aedes 2018	3	4.3	1
Dengue ONQOY	3	4.3	1
Sampa Saúde - Prefeitura SP	3	5.0	1
Mosquito Alert	2	5.0	2
CLIC	1	5.0	1
Combate a Dengue	1	5.0	1

Note: Ratings are summed across storefronts and the mean rating is weighted by the number of ratings in each storefront. Seven apps had no ratings and are not shown.

Relations among dimensions

Symptom checking was stated by 3/5 public sector apps and 2/13 of the other apps (Fisher p = 0.099), and breeding-site reporting by 2/5 and 3/13 (p = 0.583). The education function was stated by 2/2 game-format apps and 10/16 of the other apps (p = 0.529) (Table 5).

Table 5. Exploratory associations among developer sector, functions, game format and ratings.

Association	Estimate or counts	p
Breeding-site reporting: public sector versus other developers	2/5 vs 3/13	0.583
Symptom checking: public sector versus other developers	3/5 vs 2/13	0.099
Education function: game format versus other formats	2/2 vs 10/16	0.529
Public sector developer: Latin American versus international content	5/12 vs 0/6	0.114
Release year and number of functions (Spearman rho)	rho = -0.31	0.209
Number of ratings and mean rating, rated apps (Spearman rho)	rho = -0.50	0.114
Any rating: public sector versus other developers	4/5 vs 7/13	0.596

Note: Counts are events over total in the first group versus the second group (Fisher exact test); rho = Spearman correlation coefficient. No correction for multiplicity was applied.

Table 6. Inventory of the apps included in the analysis.

App	Release year	Developer	Storefronts (n)	Functions (n)	Game format	Ratings (n)
DENGUE - Manejo Clínico - Adulto e Criança	2012	Private company or individual	8	2	No	7
Mosquito Alert	2014	Research or non-profit project	8	4	No	2
WHO Zika App	2016	International health agency	8	1	No	0
Combate Aedes 2018	2017	Private company or individual	8	1	No	3
MosquitoTracker	2018	Private company or individual	8	2	No	0
Sampa Saúde - Prefeitura SP	2019	Public sector	8	1	No	3
Goiânia Contra o Aedes	2019	Public sector	1	1	No	0
Udi Sem Dengue	2020	Public sector	1	3	No	5
Mozzify	2020	Private company or individual	8	3	No	0
CLIC	2020	Research or non-profit project	2	3	No	1
sinDengue	2020	Public sector	1	4	No	4
Dengue ONQOY	2021	Public sector	1	2	No	3
Contra Dengue 2 Na Cidade	2022	Private company or individual	8	1	Yes	0
Flyttr Go	2022	Private company or individual	1	1	No	5
Combate à Dengue	2023	Private company or individual	1	1	Yes	5
Combate a Dengue	2024	Private company or individual	8	1	No	1
moSquITo	2024	Private company or individual	8	0	No	0
MozWatch	2024	Private company or individual	8	2	No	0

Note: Functions (n) counts the functions coded among the six listed in Table 2. Ratings (n) is the sum across storefronts.

Public sector developers accounted for 5/12 of the apps with Latin American content and 0/6 of the apps with international content (p = 0.114). Any rating was recorded for 4/5 public sector apps and 7/13 of the other apps (p = 0.596).

The release year was not associated with the number of functions (Spearman rho = −0.31; p = 0.209). Among the rated apps, the number of ratings was not associated with the mean rating (rho = −0.50; p = 0.114). None of the seven associations reached the 0.05 level. The inventory of the apps, with sector, release year, functions, game format and ratings, is given in Table 6.

DISCUSSION

The objective was to describe the provenance, public-health functions, gamification elements and user ratings of dengue and arbovirus apps in eight Latin American storefronts. The snapshot of 3,908 listings yielded 18 eligible apps that were free, mostly informational, rarely gamified and thinly rated. The discussion follows the order of the dimensions and closes with a joint reading.

For provenance, the eligible apps were a small fraction of the listings retrieved, and the same pattern appears in other app-store inventories. Only ten of 3,449 workers' health apps found in the Brazilian stores were eligible,(20)as were 42 of 1,460 nutrition apps in Spain,(19)and 435 of 31,564 apps in the medical category of a German store dealt with cardiac arrhythmias.(18)The public sector apps were all released from 2019 and came from municipalities, a state and a national institute, which fits a model in which local agencies commission tools for their own campaigns, as with AedesMap, an app that records dengue, Zika and chikungunya cases and Aedes aegypti foci with the cooperation of the population and health agents.(26) Several apps listed in the Latin American storefronts were developed elsewhere: Mozzify was evaluated among participants in the Philippines,(27)and Mosquito Alert was designed and promoted in Europe.(28)App users differ across countries in their needs and in the reasons for choosing or abandoning an app,(22)so the presence of an app in a storefront does not show that it was built for the regional user.

The release years can be read against the epidemiological sequence of the region. The only app from an international health agency, the WHO Zika App, was first released in 1, after Zika emerged in Brazil in 2015 and caused outbreaks across Latin America.(6)Three further apps were first released in 2024, the year in which dengue cases rose by an average of 600% across the region(5) and Brazil reported almost two million suspected cases in the first eleven weeks.(4)A cross-sectional snapshot cannot show whether releases followed outbreaks, and releases may equally reflect the availability of development tools or of municipal budgets. The data do show that the apps first released in 2024 came from private companies or individuals and not from health agencies.

For the functions, the predominance of education and information agrees with the use of mobile phones for prevention and communication documented in the scoping review of arboviral control,(9)whereas the review of dengue surveillance found that geographic information systems and machine learning were used more often than mobile applications.(10)Education was stated in a higher share of the dengue apps than in the nutrition apps of Spain, where nutrition education appeared in 38%.(19)Pregnancy apps, by contrast, offered 49 distinct functionalities,(29)a diversity that the dengue apps did not approach, since the median was 1.5 functions per app. Dengue, chikungunya and Zika co-circulate and can be clinically similar,(7,8) yet only 5 listings named Zika or chikungunya, and the coverage of the three viruses within a single app is therefore the exception.

The reporting of breeding sites and mosquito observations had its best-documented counterpart in citizen science, where expert-validated reports produced accurate early warning,(13) recruitment depended on promotion activities,(28)participants reported learning gains(30)and deep learning was developed to identify tiger mosquitoes in citizen photographs.(31)Only one of the present apps described expert validation of submitted photographs. The data that such reporting could supply have uses beyond a single municipality: a simulation study in Colombia combined the probability of mosquito presence with human mobility to analyse the severity of Zika epidemics,(32)and case data for the three arboviruses in the Americas were gathered in the ARCA database.(33)No listing referred to that database or to the Pan American Health Organization, so the apps appear to operate as separate tools and not as nodes of a regional information system.

The symptom-checking function deserves caution. A prototype expert system for diseases transmitted by Aedes aegypti reached a sensitivity of 91% but a specificity of 63%,(34)and none of the listings analysed here reported a validation of its guidance, as was also the case for arrhythmia apps whose descriptions did not give enough information on intended use and quality.(18)Two of the apps with clinical guidance were issued or distributed in connection with national health authorities, but the listings did not cite the regional guideline for the diagnosis and treatment of

the three arboviruses.(8)Messaging services outside the stores can also serve prevention, since a WhatsApp intervention in Colombia improved knowledge and practices about arboviral diseases,(35)and such channels are invisible to a store inventory.

For gamification, the finding that 3 of 18 apps presented a game format or a game-design element is consistent with the low prevalence of gamification in health apps in general, 4% of those screened in a previous review.(16)The elements that research reports most often, points, badges and leaderboards,(14)appeared only in CLIC, and none of the apps stated badges or levels. The combination in CLIC of rewards, a ranking and peer challenges resembles the archetype of competition and collaboration described for gamified health apps.(36)The academic literature on dengue games is larger than the store offer found here: a cooperative serious board game against Aedes aegypti was validated with a standard questionnaire,(23)a randomised trial in Singapore found a greater change in daily dengue-prevention practice with a serious game than with a website,(24) knowledge was higher after playing an Aedes serious game in a test with two groups of users,(37) and game apps were reported in classrooms of Brazil.(38,39) Further prototypes were designed with augmented and virtual reality or aimed at dengue prevention.(40,41) That contrast suggests that much of the gamified work has not reached the storefronts, although the search terms and the single store used here cannot confirm it.

The evidence on effects remains uneven, with positive results in 59% and mixed results in 41% of the papers reviewed,(15)and the field has been mapped in a meta-review of 53 systematic reviews(42)and in a review of gaming elements and challenges in healthcare.(43)A model of five gamification principles was tested with 133 trained raters on 17 digital health interventions,(44)a procedure that could be applied to dengue apps once the apps are installed. A regulatory consideration also applies: of 69 gamified health apps assessed against the European medical device regulation, 31 (44.9%) were judged likely or potentially non-compliant,(45)which matters for any gamified symptom checker.

For the ratings, the sparse records limit any reading of quality. The number of ratings per app was at most 7, whereas the nutrition study used a threshold of more than 500 reviews, a filter that would have excluded every dengue app in this analysis.(19)Star ratings do not substitute for structured assessment: when the Mobile App Rating Scale was applied, workers' health apps in Brazil obtained a mean of 3.15,(20) epilepsy apps in India 3.5(46)and Mozzify more than 4.(27)The pooled mean of 4.4 found here comes from a different instrument and from a handful of users, and the figures cannot be compared. In the Blackberry store, rating and popularity were correlated and free apps were rated higher than paid apps,(47)but all the apps studied here were free, so that contrast could not be examined. A previous review found no correlation between the number of behaviour change techniques in gamified apps and user ratings,(16)and the relation between rating count and mean rating observed here was not distinguishable from zero (rho = −0.50).

Among the associations across dimensions, none reached the 0.05 level, and the contrast between public sector developers and symptom checking (3/5 versus 2/13) is compatible with both no difference and a moderate one given the sample. Read together, the four dimensions describe a small, free and informational set of apps in which citizen reporting, clinical guidance and field-operation tools coexist with a few international apps, gamification is concentrated in a handful of listings, and user feedback is too sparse to guide a user or an agency.

The yield of the search is itself a result. The term dengue retrieved 14 of 18 apps, one app appeared only under the generic term mosquito, and the Brazilian storefront listed 16 apps, so that the 2 apps from Mexico and Peru would have been missed by a search restricted to Brazil. Because municipal and national apps may be listed in a single storefront, regional inventories need more than one storefront and more than the disease name, in the same way that the arrhythmia inventory required a read-out of a whole store category before filtering by search terms.(18)The audience shows a related contrast: 6 apps (33.3%) addressed health professionals or field agents, compared with 55.9% of the arrhythmia apps intended for healthcare professionals,(18)a difference that fits a field in which community participation is part of vector control.(48)

Several limitations apply. Only the iOS store was covered, and the Android store, which may hold a different offer, was not; quality scores differed between iOS and Android apps in an inventory of epilepsy apps,(46)so replication with Android listings using the terms and rules reported here would test that gap. The search interface returns at most 200 results per query and matching relied on named diseases, so apps that describe mosquito control without those words were missed; complementary queries by store category would reduce that loss. The functions and game elements were coded from the listing text and not from use of the apps, which may understate what an app does; installing the apps and rating them with the Mobile App Rating Scale by two raters would settle that point. Screening and coding were done by a single coder, a language model, without

independent verification, so a second human coder and an agreement statistic are needed. The ratings were few and confined mainly to the Brazilian storefront, and a snapshot cannot show apps withdrawn before it was taken, so a repeated archive of listings would address survivorship. With 18 apps the confidence intervals were wide and the tests were exploratory.

The findings have practical implications. Health agencies that commission apps could publish in the listing the intended use, the audience and the evidence behind clinical guidance, since none of the listings reported a validation. Developers could add reporting, validation and feedback features of the kind that citizen science apps already use and could declare their game elements explicitly. Researchers who build serious games for dengue could submit them to the stores and record ratings and usage, so that the effects reported in trials can be linked to apps that users find, and co-creation with communities, proposed as an approach to dengue vector control, offers a route to that link.(48)

CONCLUSIONS

The dengue and arbovirus apps listed in the Latin American storefronts were free, recent and developed mainly by private companies or individuals, with public sector apps concentrated in municipal, state and national campaigns of three countries.

Education and information was the most frequent public-health function, and symptom checking, breeding-site reporting, surveillance, field-operation support and mosquito identification were each stated by a smaller group of apps.

A game format or game-design elements were stated by a small group of apps, and one app combined points, a ranking and challenges.

User ratings were available for part of the apps and were too few to indicate quality.

No association among developer sector, functions, game format and ratings could be established with the available sample.

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