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Mosquito-Borne Arboviruses in Brazil: Assessment of Apps Based on the Mobile Apps Rating Scale (MARS)

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Abstract

Background: In Brazil, the prevalence of arboviral diseases, such as dengue, Zika, and Chikungunya, transmitted mainly by mosquitos, has increased alarmingly. In recent years, numerous free mobile apps tackling this issue have become available for various purposes and users.

Objectives: This study aimed to systematically survey and evaluate these apps using the Mobile App Rating Scale (MARS).

Methods: The survey was performed on Google Play Store and sought to identify these apps adopting the descriptors “Chikungunya”, “Dengue” and “Zika”. The MARS scale was used by two researchers to evaluate the apps following their translation to Portuguese and subsequent validation. Student's T-test, Kappa statistics, and Cronbach's alpha coefficient were employed to evaluate the interobserver agreement and the reliability of the scale.

Results: Most apps (20 out of 29 or ~70%) were created to disseminate basic information about arboviral diseases to the population or for entertainment. There was an agreement between the two researchers for all parameters of the MARS scale, except for the engagement ($p=0.002$). The Cronbach's alpha coefficient indicated good reliability.

Conclusions: The use of the MARS scale has shown that most of the evaluated apps were developed to share information about arboviral diseases in an interactive way, but they do not necessarily have the purpose of influencing their users to change behaviours related to vector control or the prevention of arboviral diseases, which the authors feel would be a more appropriate aim for future app development.

Keywords: Mosquito-borne arboviruses, Mobile health (mhealth), mobile application, assessment

1. Introduction

In Brazil, the prevalence of diseases caused by arboviruses and transmitted by mosquitoes, such as dengue, Zika and Chikungunya, has increased alarmingly in recent years (Leta et al., 2018). Until September 2020, a total of 928,282 cases of dengue, with an incidence of 441.7 per 100,000 inhabitants, were registered by the Ministry of Health (Brazil, 2020; Santos et al., 2022). The traditional vector control programs, based on vertical methods to eliminate breeding sites with the use of insecticides, have failed due to the increase of resistant mosquito populations, the high level of adaptation of mosquitoes to urban environments and infrastructural problems in Brazilian cities (Lima-Camara, 2016; Donalisio et al., 2017; Lowe et al., 2018); (Donalisio et al., 2017).

One of the most effective control programs is community participation in monitoring mosquito breeding sites (Abel Mangueira et al., 2019; Costa et al., 2020; Santos et al., 2022). However, the existing programs do not effectively involve the population in the practices of elimination of these sites, leaving the community in the position of spectators (Abel Mangueira et al., 2019; Costa et al., 2020; Santos et al., 2022). Thus, health promotion and health education measures that transcend the dissemination of knowledge are necessary in order to boost the engagement of the population.

Recently, several studies have made efforts to elucidate the elaboration of educational materials for health promotion based on models of behaviour change, as well as the importance of using these theories for the involvement of the communities in health actions and for the adoption of individual protection behaviour (World Health Organization, 2012). One of the strategies that have been used to evaluate behaviour change involving communities and populations is the use of mobile learning and software applications (apps) for mobile devices (World Health Organization, 2012; McKay et al., 2018; Abel Mangueira et al., 2019). Available anywhere and at any time, these devices are very promising for the development of apps based on behaviour change theories to promote health education (Masterson Creber et al., 2016; Taj et al., 2019; Yang et al., 2015).

The rapid proliferation of smartphone apps has made it difficult - for their users as well as for health professionals and researchers - to define which ones have greater potential and quality (Stoyanov et al., 2015; Cummings et al., 2013). In 2014, there were more than 100,000 apps falling into the health, fitness, or medical categories, which doubled the market size of two and a half years previously (Xu & Liu, 2015). However, there is still a lack of evidence and methodological strategies to effectively evaluate the quality of the apps for health promotion, since the use of star ratings on Web pages is very subjective and based on unknown sources.

The Mobile App Rating Scale (MARS)

In 2015, Stoyanov and colleagues (2015) proposed a scale for the classification and the evaluation of the quality of these apps – the Mobile App Rating Scale (MARS) (Stoyanov et al., 2015). This scale has four sections, one of which is specific and modifiable to suit the application that is to be evaluated (Stoyanov et al., 2015). The items of the MARS scale are scored using a five-point Likert scale (1 inadequate, 2 poor, 3 acceptable, 4 good, and 5 excellent). The first section provides descriptive information about the apps. The second evaluates the objective quality of the application and it is organised into 19 items divided into four categories: engagement, functionality, aesthetics, and information quality. The third section contains four items that evaluate the overall subjective satisfaction of the user. The fourth section is an application-specific subscale that evaluates the perceived effect on knowledge, attitudes, the user's intentions regarding behaviour change, the search for help to promote change, and the likelihood of changing the identified target behaviours. The reliability of this scale was also examined, showing good results (Stoyanov et al., 2015). Recently, the MARS has been translated, validated, and adapted to be used in different countries and to be effective for rating apps built around health issues (Stoyanov et al., 2015; Terhorst et al., 2020; Martin Payo et al., 2019; Domnich et al., 2016; Messner et al., 2020).

2. Objectives

This study aimed to use the Mobile App Rating Scale (MARS) to systematically survey and evaluate the apps related to the issue of arboviral diseases that are available for different purposes and users in Brazil. To achieve this goal, the MARS scale was translated into Portuguese and validated before being used to assess the quality of these mobile applications.

3. Methods

The analysis of the apps for mobile devices was performed using the search terms "Chikungunya", "Dengue" and "Zika", referring to three of the main arboviral diseases transmitted by the *Aedes aegypti* mosquito. Preliminary screening was done based on the name and description of the app on Google Play Store, excluding apps that had fewer than 500 downloads, were duplicates (found using different search terms) or paid apps as well as those whose names were not associated with the search terms. After submitting the apps to the exclusion criteria, they were reviewed by team members and then downloaded for evaluation (Figure 1). The screening was based on the Android operating system and Google Play Store; since, in Brazil, more than 95% of the population uses the Android system. The screening was performed over the period of three months and a total of 29 Apps were selected to be evaluated.

After the screening phase, the MARS was translated from English into Portuguese and a pilot study was then performed to validate the tool. In this study, ten undergraduate biology students and four researchers (SS, RSM, VAA, IDF) performed the analysis of one of the apps identified in the screening phase using the translated scale. After addressing their critical comments regarding translation and other suggestions, the assessment was replicated with the final version of MARS. The Portuguese version of MARS can be obtained from the authors on request.

Before evaluating the 29 Apps, we followed the methodology suggested by Stoyanov and colleagues (2015). After watching training videos, three researchers used the Portuguese version of the scale to evaluate five apps not included in the final sample. Following this training phase, the 29 apps were independently analyzed by two of them (researchers A and B). The compiled data were analyzed with the R program. Numerical variables representing the scores were analyzed using the normality test (Shapiro-Wilk) and, considering that most of them had a normal distribution, the Student's T-test was performed to compare the means obtained by the two researchers ($p>0.5$).

The Kappa test was used to evaluate the interobserver agreement for binary categorical variables and for variables using the Likert scale. To interpret the results, we used the Landis and Koch (1977) table, which establishes values above 0.81 as almost perfect agreement; between 0.61 and 0.80 as strong agreement; from 0.41 to 0.60 as moderate agreement; from 0.21 to 0.40 as reasonable agreement; between 0 and 0.20, the agreement is weak and if it is zero, it is insignificant (20). To perform the comparative evaluation of the reliability of the MARS scale between the two observers, Cronbach's alpha coefficient was used. It varies from 0 to 1. Values above 0.7 indicate good reliability of the evaluated score questionnaire.

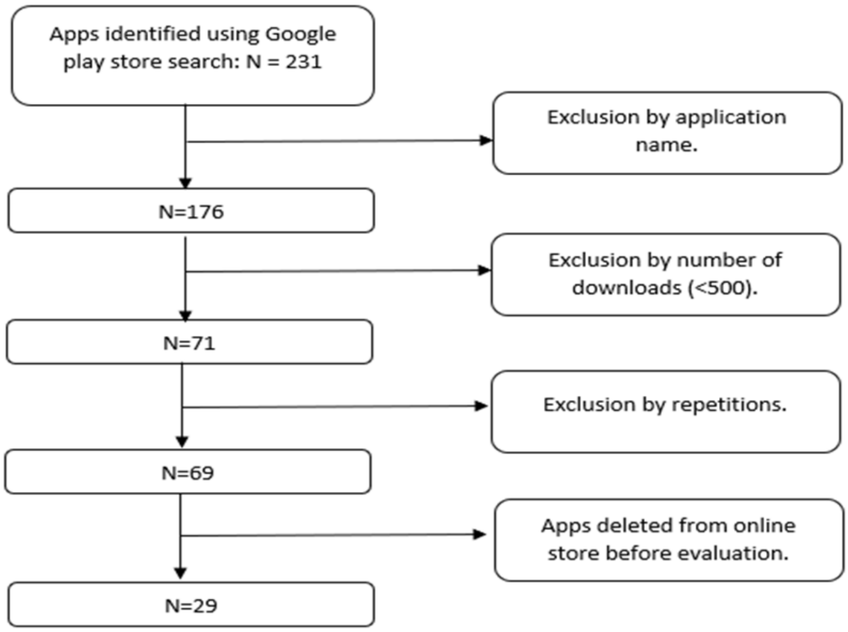

Figure 1. Flow chart of the selection of applications for mobile devises (apps) in Google Play Store

4. Results

Table 1 presents a brief description of the 29 apps selected for analysis. It was verified that only four apps (14%) were developed by the state or federal government with the purpose of disseminating information to the population, facilitating the identification of mosquito breeding sites or individuals affected by arboviral diseases. One of these apps, “Zika Zero”, was widely disseminated by media outlets, such as television and radio. Four other apps were designed by university researchers or non-governmental organizations to collect epidemiological data or to facilitate the georeferencing of cases of arboviral diseases or breeding grounds. Furthermore, the dissemination of updated scientific information was the focus of the application created by the World Health Organization (WHO).

Most apps (20 out of 29 or ~70%) were created by individual or professional developers to disseminate basic information to the population or for entertainment; several “smash the button” games were developed. Interestingly, one of the apps offered a sound frequency that was supposed to be insect repellent. In all, 23 of the 29 apps had the general population as their target audience; four targeted health workers, one was for basic education teachers and the final one was aimed at children.

Table 2 shows the scores obtained by the 29 apps, in each of the parameters of the MARS scale, comparatively analyzing the evaluations of researchers A and B. It was observed that eight of the 10 apps with the highest average score were well evaluated by both researchers, showing strong agreement. Although the scores attributed by the different evaluators were not identical, the ranking of the apps tended to be considerably similar. Using the MARS scale, the two apps with the highest scores were “Dengue”, developed to assist health professionals in the management of epidemiological information; and the “SP X Dengue” app, an educational game developed by São Paulo state government. There was also an agreement between the evaluation of the researchers regarding the two apps with the lowest quality score (Mosquito Attack and Dengue x Chik x Zika).

Table 1. Description of the 29 Brazilian applications for mobile devices (apps), selected using the search terms “Chikungunya”, “Dengue” and “Zika”, which are the names of three of the main arboviral diseases transmitted by the *Aedes aegypti* mosquito

Description of the applications					
Name	**Developer**	**Funding**	**Aim**	**Target Audience**	**Brief Description**
01-Dengue	Medtouch Software	Professional App Developer	Clinical management	Health workers	Diagnostic information, treatment and hospitalization criteria for arboviral diseases
02-SP X Dengue	PRODESP - SP	State Government	Educative game	General Population	Game
03-Zika Virus	AES	Individual App Developer	Share information	General Population	Basic information about Zika virus
04-Dengue Fever Disease	DroidClinic	Individual App Developer	Share information	General Population	Basic information about arboviral diseases
05-Sem Dengue	Colab S.A.	Start-up and government	Entomological surveillance	General Population	Publication of photos of mosquito breeding sites for management of surveillance services.
06-Dengue SC	CIASC	State Government	Entomological surveillance	General Population and Health Workers	Georeferencing of mosquito breeding sites
07-RS Contra Aedes – Agentes	Telessaúde UFRGS	University	Entomological surveillance	Health Workers	Georeferencing of mosquito breeding sites and tool developed to help the health workers responsible for vector control
08-WHO ZIKA APP	WHO	World Health Organization	Science diffusion	Researchers and Health Workers	Scientific information of arboviral diseases.
09-Zika vírus 3D Animação	SfondiAnimati 3D	Professional App Developer	Images and animations of virus	General Population	Images and animations related to arboviruses
10-Zika@SG	HosayStudios	Professional App Developer	Share information	General Population	Basic information about Zika virus
11-Ariê e Yuki contra mosquitos	Krafthaus Designers	Professional App Developer	Educative game	Children	Game
12-Anti Mosquito Simulation Lite	Gonsai	Professional App Developer	Repellent tool	General Population	Sound frequency that supposedly repels mosquitoes
13-MOSQUITO Alert	Movement EcologyLab	Non-governmental organization and university researchers	Entomological surveillance	General Population	Notification and sharing of information by the population that can be used by researchers

14-Alerta Dengue	IMA Informática S/A	State Government	Locate at-risk areas	General Population	GPS localization of at-risk areas
15-Esmagar mosquitos	DevgamesApps	Professional App Developer	Entertainment	General Population	Game “smash the button”
16-Extermina Dengue	PlayO Studio	Individual App Developer	Entertainment	General Population	Game “smash the button”
17-Dr. Chikungunya	SPT TOLIMA	Professional App Developer	Diagnostic tool	Health Workers	Diagnostic information, treatment and hospitalization criteria for arboviruses
18-Mapa da Dengue	Web Fantástico	Professional App Developer	Monitoring map for surveillance	General Population	GPS localization of at-risk areas
19-Ataque a Dengue	TG Studio	Individual App Developer	Educative game	General Population	Game (teaching how to locate breeding sites)
20-Zika VirusandMicrocephaly	Eric Brou	Individual App Developer	Notify about news	General Population	Daily news and information’s of Microcephalia and Zika virus
21-Kill Mosquito da Dengue	Dimar Luiz dos Santos	Individual App Developer	Entertainment	General Population	Game “smash the button”
22-Chikungunya' 1	HUNT GAMES	Professional App Developer	Entertainment	General Population	Game “smash the button”
23-Zika vírus-Minha Vida	Webedia	Non-governmental organization of journalists	Notify about news	General Population	Daily news and information’s of arboviruses
24-Zika Zero	HiroTanima	Federal Government	Engage in preventive campaigns	School teachers	Engagement of schools in vector control of arboviruses
25-Todos Contra a Dengue	Mauricio Jezierski	Individual App Developer	Share information	General Population	Basic information of arboviral diseases
26-Zika Dilma	Edson Silva	Individual App Developer	Entertainment	General Population	Game “smash the button” (comedy and satirizing).
27-Fight Dengue	Access Devices Asia Sdn. Bhd.	Professional App Developer	Entertainment	General Population	Game “smash the button”
28-Mosquito Attack	MagicX	Professional App Developer	Entertainment	General Population	Game “smash the button”
29-DengueXChikXZika	DVG	Non-governmental organization and university researchers	identify symptoms of arboviruses	General Population	Questionnaire to evaluate the probability of being infected by arbovirus

Table 2. Averages obtained by two evaluators (A and B) after the analysis of applications related to arboviral diseases for each of the sections evaluated using the "Mobile App Rating Scale (MARS)". (ENG – Engagement; FUN –Functionality; AES – Aesthetics; INF – Information; SCQ – Overall Score for Quality; SCS – Overall Score for Subjective Quality; BC – Score for Behavior Change section)

	Researcher A								Researcher B							
App	**ENG**	**FUN**	**AES**	**INF**	**SCQ**	**SCS**	**BC**	**Mean**	**ENG**	**FUN**	**AES**	**INF**	**SCQ**	**SCS**	**BC**	**Mean**
01-Dengue	3.00	4.50	3.33	4.00	3.71	3.25	4.16	**3.71**	4.40	4.75	5.00	4.60	4.69	3.75	4.66	**4.55**
02-SP X Dengue	3.80	4.25	3.33	3.66	3.76	3.25	4.16	**3.74**	3.80	4.25	4.33	4.00	4.10	3.75	5.00	**4.18**
03-Zika Vírus	1.40	3.00	1.00	1.75	1.79	1.00	1.00	**1.56**	3.00	4.50	4.66	4.50	4.17	3.50	4.00	**4.05**
04-Dengue Fever Diasease	3.00	3.50	2.33	3.40	3.05	2.25	3.50	**3.00**	3.80	3.75	5.00	3.33	3.97	3.25	4.66	**3.97**
05-Sem Dengue	3.80	3.50	3.33	3.50	3.53	2.50	3.33	**3.36**	3.40	3.50	4.66	4.40	3.99	3.50	3.66	**3.87**
06-Dengue SC	3.20	4.25	3.66	3.80	3.73	3.00	4.00	**3.66**	2.80	4.25	4.33	4.40	3.95	3.50	3.50	**3.82**
07-RS Contra Aedes - Agentes	3.60	4.25	3.33	4.00	3.80	3.50	4.16	**3.81**	2.40	5.00	4.00	3.66	3.77	2.25	4.00	**3.58**
08-WHO ZIKA APP	2.00	3.20	2.66	4.40	3.07	2.75	3.16	**3.03**	3.00	4.25	4.00	3.00	3.56	2.25	3.66	**3.39**
09-Zika vírus 3D Animação	2.20	3.25	1.66	1.50	2.15	1.00	1.00	**1.82**	2.80	4.00	3.66	4.60	3.77	2.50	2.16	**3.36**
10-Zika@SG	2.60	3.75	2.66	3.33	3.09	3.25	4.00	**3.24**	2.60	4.25	3.33	3.50	3.42	1.75	3.83	**3.24**
11-Ariê e Yuki contra mosquitos	3.80	4.50	4.00	3.33	3.90	2.50	3.33	**3.62**	3.00	4.25	4.66	3.50	3.85	1.75	1.33	**3.19**
12-Anti Mosquito Simulation Lite	2.80	3.75	2.33	3.00	2.97	2.50	2.16	**2.79**	2.20	4.25	2.66	4.16	3.32	2.25	2.66	**3.07**
13-MOSQUITO Alert	3.20	2.25	2.00	2.50	2.48	1.25	2.16	**2.26**	3.75	3.50	3.00	3.00	3.31	1.25	1.00	**2.69**
14-Alerta Dengue	3.20	3.75	3.33	2.80	3.27	1.75	3.00	**3.01**	2.20	4.00	2.66	2.75	2.90	1.75	2.00	**2.61**
15-Esmagar mosquitos	3.00	3.50	2.66	2.50	2.91	1.50	2.00	**2.58**	1.40	3.50	3.33	4.00	3.06	1.50	1.00	**2.54**
16-Extermina Dengue	3.00	3.25	2.33	2.00	2.64	1.50	2.16	**2.41**	2.40	3.75	2.66	2.80	2.65	1.25	1.66	**2.45**
17-Dr. Chikungunya	3.60	4.00	2.66	3.66	3.48	2.25	3.66	**3.33**	1.80	4.25	2.33	3.00	2.85	1.25	1.00	**2.35**
18-Mapa da Dengue	2.80	2.50	1.66	1.50	2.11	1.00	2.16	**1.96**	1.40	3.75	2.33	2.75	2.56	1.25	2.00	**2.29**
19-Ataque a Dengue	2.60	2.75	2.66	3.00	2.75	1.75	2.50	**2.57**	1.80	4.25	2.33	2.50	2.72	1.25	1.00	**2.26**
20-Zika VirusandMicrocephaly	2.80	3.25	2.00	2.60	2.66	1.50	2.83	**2.52**	1.80	3.50	1.00	3.50	2.45	1.75	1.66	**2.24**
21-Kill Mosquito da Dengue	3.20	3.75	2.66	2.00	2.90	2.00	2.16	**2.67**	1.80	3.00	2.00	2.60	2.35	1.25	2.50	**2.21**
22-Chikungunya' 1	3.20	4.00	3.00	2.00	3.05	2.00	2.16	**2.77**	1.40	3.25	2.33	2.75	2.43	1.00	1.00	**2.02**
23-Zika vírus-Minha Vida	3.20	4.25	3.00	3.40	3.46	2.50	3.83	**3.38**	1.80	3.75	1.33	2.50	2.35	1.25	1.00	**2.00**

24-Zika Zero	2.40	3.50	2.66	2.50	2.77	1.75	2.16	**2.53**	1.20	3.00	1.00	2.60	1.95	1.00	2.16	**1.84**
25-Todos Contra a Dengue	3.00	3.75	2.33	2.60	2.92	2.25	3.00	**2.84**	1.80	4.00	1.00	1.60	2.10	1.25	1.00	**1.82**
26-Zika Dilma	3.40	4.25	3.00	3.00	3.41	3.00	1.83	**3.13**	1.00	3.50	1.33	2.00	1.96	1.00	1.16	**1.71**
27-Fight Dengue	2.80	3.00	2.33	2.20	2.58	1.50	2.50	**2.42**	1.40	1.75	2.00	2.66	1.95	1.00	1.00	**1.68**
28-Mosquito Attack	3.00	3.00	2.00	2.00	2.50	1.50	2.00	**2.29**	1.40	1.00	2.66	1.75	1.70	1.00	1.00	**1.50**
29-DengueXChikXZika	2.00	3.75	2.66	2.40	2.70	1.25	1.00	**2.25**	1.40	1.50	1.00	1.50	1.35	1.00	1.00	**1.25**

Table 3. Comparison of the general means obtained by the different evaluators for each of the sections of the scale “Mobile App Rating Scale” using T-student test. (* p<0.05)

Section (Score)	**Appraiser**	**n**	**Mean**	**SD**	**p-value**
Engagement	A	29	2.95	0.57	*0.002
	B	29	2.31	0.92	
Functionality	A	29	3.59	0.59	0.73
	B	29	3.66	0.91	
Aesthetics	A	29	2.64	0.65	0.32
	B	29	2.92	1.31	
Quality of Information	A	29	2.84	0.79	0.15
	B	29	3.17	0.91	
Subjective Information	A	29	2.10	0.75	0.36
	B	29	1.90	0.96	
Average Quality of Information	A	29	3.00	0.54	0.99
	B	29	3.01	0.87	
Average Subjective Quality	A	29	2.10	0.75	0.36
	B	29	1.90	0.96	
Specific Medium - Change of Behavior	A	29	2.72	0.97	0.16
	B	29	2.28	1.36	

[Abbreviations: n – number; SD – Standard Deviation].

Table 3 shows the results of the t-student test comparing the mean scores attributed by the two researchers for each of the MARS parameters. It was found that there was an agreement between the evaluation of the researchers for all of these parameters, except for the engagement (p=0.002).

Table 4. Kappa statistics results for the variables with significant p-value

	Variable	Kappa	p-value
	APPLICATION FOCUS		
F1	Informative	0.65	0.00
F2	Entertainment	0.92	0.00
F3	Audio-visual	0.47	0.00
F4	Breeder's Denunciation	0.44	0.00
F5	Geolocation	0.90	0.00
3	AFFILIATIONS	0.40	0.00
	OBJECTIVE QUALITY		
6	ENTERTAINMENT	0.24	0.01
7	INTEREST	0.27	0.00
8	CUSTOMIZATION	0.20	0.05
14	GESTURAL DESIGN	0.22	0.03
18	PRECISION DESCRIPTION	0.23	0.03
19	GOALS	0.28	0.07
23	CREDIBILITY	0.42	0.00

By using a Likert-type scale with five response options for each of the items assessed on the MARS scale, Kappa statistics indicated that nine parameters had no significant p-value. Table 4 shows the interobserver agreement values of the variables in which the Kappa p-value was significant ($p<0.5$). It was verified that the Kappa values varied from 0.20 (customization) to 0.92 (application focus); three of 13 parameters had an almost perfect or strong agreement (above 0.61); three varied from 0.41 to 0.60, showing a moderate agreement; six varied from 0.21 to 0.40, being classified as reasonable agreement; and just one in thirteen had a Kappa value of 0.20, showing a weak agreement.

Finally, the internal consistency of the MARS was estimated using Cronbach's alpha coefficient and the results showed good reliability. A small difference between the results of the two evaluators was observed: 0.93 and 0.77 for researchers A and B, respectively (Table 5).

Table 5. Results of the reliability analysis of the MARS scale items, using the Cronbach's alpha coefficient. (Abreviattions: SD – standard deviation; CR – Correlation; CA1 – Cronbach Alfa if the it is deleted; Cr.Alpha – Cronbach Alfa)

	Researcher A					Researcher B				
Variables	**Mean**	**SD**	**Correlation**	**CA1**	**Cr. Alpha**	**Mean**	**SD**	**Correlation**	**CA1**	**Cr. alpha**
6. Entertainment	3.43	0.8	0.15	0.93	**0.93**	**3.2**	0.8	0.43	0.76	**0.77**
7. Interest	3.57	0.5	0.49	0.93		3.4	0.6	0.32	0.77	
8. Customization	2.71	0.8	0.09	0.94		1.4	0.9	0.87	0.73	
9. Interactivity	4	0.6	0.27	0.93		2	1	0.65	0.74	
10. Target Group	3.57	1.1	0.62	0.93		4.2	0.5	0.88	0.75	
11. Performance	3.71	0.8	0.87	0.92		4.4	0.6	-0.55	0.8	
12. Ease of use	3.71	0.8	0.87	0.92		4.6	0.6	-0.39	0.8	
13. Navigation	4.14	0.9	0.85	0.92		4.4	0.6	0.6	0.76	
14. Gestural Design	3	0.6	0.74	0.93		4	0.7	-0.24	0.8	
15. Layout	3.29	1	0.72	0.92		4	0.7	0.85	0.74	
16. Graphics	2.57	0.5	0.49	0.93		3.8	0.5	0.45	0.76	
17. Visual appeal	4	0.6	0.83	0.92		3.4	0.9	0.32	0.77	
18. Precision of description	2.57	0.8	0.82	0.92		4.4	0.6	-0.31	0.79	
19. Goals	3.57	0.5	0.35	0.93		3.8	0.8	0.28	0.77	
20. Quality of information	3.57	0.5	0.71	0.93		4.2	0.8	-0.09	0.79	
21. Quantity of information	3.86	0.9	0.84	0.92		3.4	1.5	0.05	0.81	
22. Visual information	3.57	0.8	0.52	0.93		3.4	1.3	0.25	0.78	
23. Credibility	2.71	1.1	0.77	0.92		3.6	0.9	0.95	0.72	
25. Would recommend the app	3.29	1.1	0.94	0.92		2.2	0.5	0.88	0.75	
26. How many times would you use	1.57	1	0.11	0.94		1.4	0.9	0.87	0.73	
27. Would you pay for this app	3.43	0.8	0.82	0.92		3.2	0.5	0.88	0.75	
28. Star rating	3.43	0.8	0.15	0.93		3.2	0.8	0.43	0.76	

5. Discussion

For the first time in Brazil, the MARS scale was translated and used to evaluate mobile apps. Most of the Brazilian apps were created by individual developers or companies, with little or no contribution from health professionals and organizations, and aimed to share information about arboviral diseases in an interactive way. However, they do not necessarily intend to influence their users to change behaviours related to vector control or the prevention of these diseases.

One of the issues identified in the present study was the screening process using search terms on the app store. Using the three selected descriptors (Dengue, Zika, and Chikungunya), the survey led to a great number of apps that had no direct connection to these arboviral diseases. In Brazil, the term "zika or zica" is used in common parlance to refer to bad luck and these words were extensively employed in this sense by developers on the app store.

Another issue was the durability or lifetime of the apps on the Google Play Store. Due to the challenges mentioned above, the screening of the apps was a lengthy process. In addition, many months were dedicated to the translation and validation of the Portuguese version of the MARS Scale as well as to the training of the researchers. During this process, several apps were excluded from Google Play Store. Given that most of the apps were developed by individual initiatives for entertainment purposes, this possibly occurred due to their financial limitations (Xu & Liu, 2015).

Most of the analysed apps were developed for the dissemination of information or entertainment purposes. A few excellent apps, such as the WHO ZIKA APP, fulfil their aim and manage to deliver high-quality information to health professionals and citizens. Some other apps, despite succeeding in providing information in an interactive way, do not necessarily intend to influence their users to change behaviours related to vector control or the prevention of arboviral diseases, which the authors feel could have huge benefits, especially amongst the more popular apps. Where this has been a specific aim of an app (or a project), the public health benefits are significant (Cummings et al., 2013). Moreover, the content made available on the apps was often not developed by health workers or organizations, meaning that conceptual mistakes, misconceptions or misunderstandings are possible or, indeed, inevitable (Cummings et al., 2013).

In the literature, many studies have addressed the contribution of behaviour change theories to the development of digital health technologies (Hartin et al., 2016; Wang et al., 2019; Glanz & Bishop, 2010). These theories, for example, have been successfully used to develop apps focusing on physical activities and weight loss (Yang et al., 2015). Despite this, the Brazilian apps analyzed in the present work did not adopt these theories to promote behaviour change in order to reduce the incidence of arboviral diseases.

This study corroborates previous findings demonstrating that the MARS scale is a reliable tool to identify high-quality apps (Stoyanov et al., 2015; Terhorst et al., 2020; Martin Payo et al., 2019; Domnich et al., 2016; Messner et al., 2020). For example, the "RS Contra Aedes - Agents" was classified as one of the five apps with the highest scores in the engagement section, general average score and subjective quality average. This app was developed by the Federal University of Rio Grande do Sul (UFRGS) in partnership with the State Department of Health. Targeting community health workers, endemic disease control agents and military officers, this app aims to help control and monitor home inspections for the elimination of mosquito breeding sites. The application is equipped with a geo-referencing system that provides real-time information to the health workers who are performing inspections and allows them to create reports, and record the date of the visit, address, type of property and location, that can feed the database of the Department of Health. The app also provides information about the diseases transmitted by the *Aedes aegypti* mosquito and its prevention, also offering advice for pregnant women to prevent congenital Zika syndrome. These features combine to make this app an exemplar of what the authors would like to see developers aim for: informative and instructive, but also adding to knowledge and supporting behavioural change.

This study also showed that most of the apps tackling public health issues available on the Google Play Store in Brazil were created by individual initiatives with little or no contribution and assistance from health services. Given the importance of the impact that these apps can have on public health by stimulating behaviour change, the authors support the creation of specific public policies to regulate, evaluate, and promote these apps. Additionally, efforts must be made to develop open-access repositories so that, over the years, a deeper analysis of the role of these apps in health promotion can be performed (Boulos et al., 2014). In the United Kingdom and in the United States, for example, there are already initiatives to create specific regulations and continuous assessment procedures for health-related apps. This kind of initiative needs to be globally discussed and better systematized in order to build common criteria for evaluating and regulating such apps (Iglezakis, 2020; Parker et al., 2017).

Carrillo et. al. (2021), in a literature review regarding the use of apps in the prevention of arboviruses, pointed out that few studies showed effective m-health interventions in terms of reducing vector density, either by changing population behaviour or as early warning indicators of outbreaks. The authors emphasize the need for the use of well-defined methodologies, such as randomized controlled trials or quasi-experimental designs, to assess the impact of using new technology. In the present work, it was not possible, with the use of the MARS scale, to evaluate the effectiveness of the use of the apps in relation to the purpose of reducing the prevalence of mosquito-borne arboviruses.

Regarding the reliability of the MARS scale, the findings of this study corroborate previous ones published by Stoyanov (Stoyanov et al., 2015; Taj et al., 2019; Terhorst et al., 2020). In terms of the limitations of the present study, although many researchers participated in the validation of the Portuguese version of the MARS scale, only two carried out the analysis of the 29 apps due to time restrictions and the need for training. In addition, it was not possible to replicate the study using the iOS operating system, because most of the apps analyzed in this work did not provide a version for this system.

6. Conclusions

The use of the internationally validated "Mobile Apps Rating Scale" can be effective to differentiate between mobile applications and place them on a continuum of usefulness. This study showed that most of the mobile apps investigated were developed to share information about arboviral diseases in an interactive way, but they do not necessarily intend to influence their users to change behaviours related to vector control or the prevention of these diseases. It is the authors' contention that this should be addressed in the development of future applications, supported by a specific national public policy. Effective information leading to behavioural change has the potential to unlock significant public health benefits over and above those of applications designed merely to inform at a basic level.

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Competing Interests Statement

The authors declare that they have no competing interests.

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