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Description of apps targeting stroke patients: A review of apps store

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Abstract

Background: As a principal cause of mortality and disability worldwide, stroke imposes considerable burdens on society and effects on the lives of patients, families, and communities. Owing to their growing global popularity, health-related applications (apps) offer a promising approach to stroke management but show a knowledge gap regarding mobile apps for stroke survivors.

Methods: This review was conducted across the Android and iOS app stores in September–December 2022 to identify and describe all apps targeting stroke survivors. Apps were included if they were designed for stroke management and contained at least one of the following components: medication taking, risk management, blood pressure management, and stroke rehabilitation. Apps were excluded if they were unrelated to health, not in Chinese or English, or the targeted users were healthcare professionals. The included apps were downloaded, and their functionalities were investigated.

Results: The initial search yielded 402 apps, with 115 eligible after title and description screening. Some apps were later excluded due to duplicates, registration problems, or installation failures. In total, 83 apps were included for full review and evaluated by three independent reviewers. Educational information was the most common function (36.1%), followed by rehabilitation guidance (34.9%), communication with healthcare providers (HCPs), and others (28.9%). The majority of these apps (50.6%) had only one functionality. A minority had contributions from an HCP or patients.

Conclusion: With the widespread accessibility and availability of smartphone apps across the mHealth landscape, an increasing number of apps targeting stroke survivors are being released. One of the most important findings is that the majority of the apps were not specifically geared toward older adults. Many of the currently available apps lack healthcare professionals' and patients' involvement in their development, and most offer limited functionality, thus requiring further attention to the development of customized apps.

Keywords

Stroke, smartphone, mobile application, telemedicine

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Introduction

Globally, stroke is regarded as the second leading cause of death and the third leading cause of death and disability combined (as expressed by disability-adjusted life-years lost).[1] The results of a population-based cost analysis showed that the total cost of stroke across 32 European countries was €60 billion a year in 2017, with health care

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accounting for €27 billion (45%), representing 1.7% of health expenditure.[2] The growing burden of strokes on a global scale strongly suggests that current primary stroke and cardiovascular disease prevention strategies are either not used widely enough or are effective only to a limited extent.[3] Population aging, the ongoing high prevalence of risk factors (e.g. hypertension), and inadequate management further contribute to the increasing burden of strokes.[4] Previous studies have reported stroke survivors as having persistent unmet needs after hospitalization.[5,6] Based on estimates, four out of 10 stroke patients are discharged and sent home without services to support their long-term needs.[7]

Overwhelming evidence shows the use of mobile health (mHealth) as a promising solution for increasing access to healthcare.[8,9] Given the unprecedented spread of mobile technologies and advancements in their innovative capacity to address health priorities, the world is witnessing this new field of mHealth. mHealth is defined as "the use of mobile phones to provide patients and health-care workers with support to improve health."[10] An unprecedented impetus for the development of culturally sensitive mHealth has been created by the COVID-19 pandemic worldwide.[11] Not surprisingly, the number of mHealth applications (apps) developed and available to smartphone users has kept growing in recent years. mHealth apps provide a great opportunity to revamp healthcare delivery in resource-limited settings and simultaneously offer significant potential for effective management of chronic diseases and comorbidities.[12] Specifically, mHealth apps have the potential to support the long-term needs of stroke survivors.[13]

Although apps have paved the way for innovative intervention, a thorough review of apps demonstrates a concerning lack of both healthcare provider (HCP) involvement in app development and the evidence-based effectiveness of apps.[14] Santo et al.[15] systematically reviewed the apps available in the Australian iTunes store and in Google Play, concluding that despite the growing number of available apps, the majority did not have many of the desirable features. Therefore, the apps are considered low quality. The growth of mHealth apps for strokes has been exponential, yet little is known regarding the features of these apps. Corresponding to this situation, there is a need for evaluating these apps. To date, there are syntheses of existing evidence on the evaluation of apps for hypertension,[16] cancer,[17] medication adherence,[14] diabetes,[18] and COVID-19.[19] A previous study that aimed to provide an overview of the leading mHealth apps in mainland China found that the most common disease-specific apps focused primarily on diabetes, hypertension, and hepatitis management.[9]

A review investigating mHealth apps' support for stroke caregiving engagement found that most of the current stroke-related apps are intended for healthcare professionals.[20] To our knowledge, there is a dearth of literature regarding mobile apps for stroke survivors in particular despite the proliferation of stroke-related mobile apps in general.

In light of this gap, we conducted an updated and comprehensive systematic review of stroke mobile apps across two major commercial app stores. We seek to answer two research questions:

1. What are the current stroke apps' functions and medical professionals' involvement in the development of this field across major smartphone platforms?
2. What are the gaps in the field to guide the future development of stroke apps?

Methods

Study design

This study involved a review of apps targeting stroke survivors that are available in the two most popular app stores (Apple App Store and Google Play Store). A systematic review methodology, adhering to Preferred Reporting Items for Systematic Reviews and Meta-Analyses standards, was utilized.[21] The Quality and Risk of Bias Checklist for Studies that Review Smartphone Applications[22] was also used to ensure an adequate description of this app review's methods.

App identification

Search strategy. To identify the appropriate records for this review, an electronic search was conducted between September and December 2022 across the Android and iOS app stores. According to the data from Statista,[23] Android and iOS respectively accounted for nearly 70% and 25% of the mobile operating system market worldwide in January 2022. Google Play maintained its position as the leading app store, offering approximately 3.5 million apps available for download, while App Store was home to over 2.2 million apps, as of May 2021.[24] Due to the fact that Android and iOS are undoubtedly the most important app stores in which every developer aims to succeed, our search was limited to these stores.

A two-step approach, developed in collaboration with a librarian, was used to conduct our systematic search to ensure a comprehensive inquiry. In step 1, the following terms were used to search for stroke measurement apps across the app stores: "stroke prevention," "stroke risk," "stroke control," "stroke management," "stroke rehabilitation," "stroke," "brain attack," "intracranial hemorrhage," "subarachnoid hemorrhage," "cerebral infarction," and "stroke treatment." No limits were imposed on the app publication date. Apps in languages other than English or Chinese were excluded. Given that the indexing of apps varied greatly across the app stores, a calibration exercise was performed prior to the app selection in order to validate our ability to detect stroke management apps.

In step 2, each store was searched again using keyword strings by inputting multiple forms of stroke (e.g. “intracranial hemorrhage,” “subarachnoid hemorrhage,” “cerebral infarction,” and “brain attack”) in combination with the following terms: “care,” “prevention,” “risk,” and “neurology.” This two-step approach was utilized because of the different search methods between the app stores at the time of this review, with the search algorithm optimized for Apple and for Google Play by using single keywords and keyword strings, respectively.[22] Given that the indexing of apps varied greatly across the app stores, a calibration exercise was performed prior to the app selection in order to validate our ability to detect stroke management apps. Specifically, we tested our search criteria for the ability to detect a wide range of well-known apps that were available in the app stores for download.

Inclusion and exclusion criteria. We included the apps that met these criteria: (1) The description was written in English or Chinese, and “stroke” was directly included in the keywords or images accompanying the app description. (2) The app alluded to stroke management in the description (e.g. education, tracking, physical/mental health, symptom control, and medication taking). (3) The app was intended for those with a diagnosis of stroke in general rather than HCPs in particular. We included both paid and free apps in this study.

The apps were excluded if they met at least one of the following conditions: (1) It did not target stroke. (2) It was designed for entertainment rather than a medical purpose. (3) The app software did not function when downloaded or required identification (e.g. patient number/prescription access after download). (4) It was not designed for general use (e.g. it only provided services in one hospital or as part of a specific study).

Screening and selection of apps. All apps that were identified through the search and met the inclusion criteria, based on their titles and descriptions, were downloaded by the main researcher. Three reviewers conducted the eligibility screening. Two researchers independently analyzed each app, adapted to a Huawei Glory 9 (for the Android platform) or an iPhone 6S (for the iOS platform) smartphone. All discrepancies were resolved by a discussion among other investigators until consensus was achieved. All apps that met the criteria were run for at least one day if they met the criteria to gain access to all reminders or notifications that appeared. The researcher sometimes spent up to a week on running the apps to determine how health information (e.g. blood pressure) was graphically represented on the screen. The data on all included apps were charted.

Data abstraction

Overview. The data for each app came from the app repository overview and the developer’s website. For a number of apps with no website address, information was gleaned from testing alone. The abstracted data for all identified apps included the app’s name, developer, year of release, last update, the store where it is available, country of origin, involvement of healthcare professionals/patients, price and functions, availability of evidence pertaining to the app (either to its design and development or efficacy), and number of downloads.

The involvement of healthcare professionals and patients was defined as referring to any health professionals working on the app development as well as user involvement, which was included in the description on the app store. Thus, this included medical/healthcare professionals, pharmacists, behavior change specialists, physicians, and nurses.

Functionalities. The researcher categorized the app functionalities that were considered in this study according to the functionalities of stroke management that have been determined in previous studies about medical apps[9,12] and examined for effectiveness in scientific trials.[25,26] The categories were emergency information collection, risk assessment, reminders, educational information, self-monitoring of blood pressure/lipids/glucose, rehabilitation guidance, communication with HCPs and others, and psychological support.

Statistical analysis

The data were analyzed using IBM SPSS 26.0. Descriptive statistics were used to summarize the features available among all eligible apps. Proportions were also used to summarize the variables, including app functionalities, costs, and download numbers. The data were analyzed in January 2023.

Results

Summary of search results

The initial search for stroke-related mobile apps in App Store and Google Play generated a total of 316 and 86 apps, respectively. Figure1 displays the methodology used for identifying, screening, and selecting the apps’ matching criteria. After removing the duplicates, 202 apps remained for eligibility screening, and 115 (46 in Google Play and 69 in App Store) met the inclusion criteria for further download and evaluation. Subsequently, a total of 26 apps (14 in Google Play and 12 in App Store) failed in the download or registration (e.g. requiring specific identification access, such as hospital or primary care identification) or did not work properly after the download. Finally,

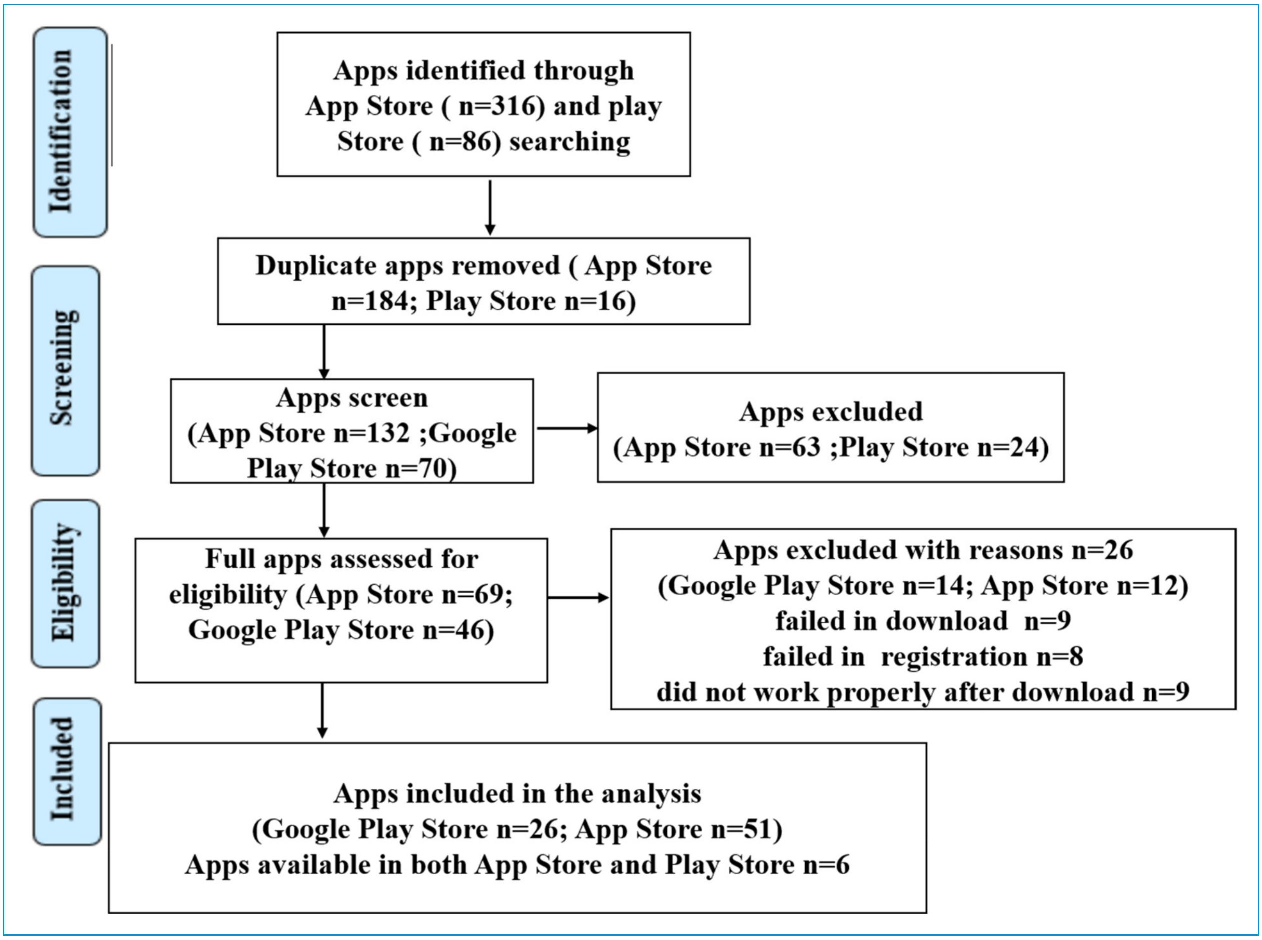

Figure1. Flow diagram of study methods.

83 apps (26 in Google Play, 51 in App Store, and 6 available in both) were formally selected for review.

Characteristics of the apps

Table1 lists the included apps and their characteristics. Of the 83 apps that met the selection criteria, six had both Android and iOS versions, 51 (61.4%) could run only on the iOS operating system, and 26 were only available in the Android market. Regarding the costs of the apps, 68 (81.9%) were free to download, nine had prices ranging from $1.99 to $249. In terms of the intended age group, the most common intended age group was not specified (67/83, 80.7%), there were 10 apps focused on adults, and no apps focused on older adults. Over one-third (32/83, 38.6%) of these apps released their latest version in 2022. The version dates of the reviewed apps ranged from December 12, 2014 to September 26, 2022. The numbers of downloads (available at Google Play) were as follows: <5000 group, 59.3% (19/32 apps); 5000–10,000 group, 9.4% (3/32); and >10,000 group, 31.3% (10/32). None of the apps from Apple had information on the number of downloads. The majority of the apps (67/83, 80.7%) in both repositories were provided by private enterprises. China and the United States offered 36.1% and 22.9% of the apps, respectively. Of the 83 apps, 50 (60.2%) were in English.

Healthcare providers/patient involvement in app development and evidence base

Based on the descriptions and websites (if available) of the 83 apps, the researcher determined if HCPs and patients were involved in the design and development processes. An involvement level, which was classified into systematic and ad-hoc categories, was created to differentiate the levels of HCP and patient involvement in app development. The main distinction between these two categories was whether there was direct participation during app development. For example, if an app involved stroke care experts in app development, then it can be regarded as a systematic HCP involvement. We found that of the 83 apps, 29 (34.9%) had contributions from an HCP or a medical/pharmaceutical organization during their development. Meanwhile, two out of 12 apps involved HCP in a systematic way. End users

Table1. Characteristics of included stroke apps.

Characteristics	Apple ($N=57$), *n* (%)	Android ($N=32$), *n* (%)
Number of downloads		
<5000 group	N/A[a]	19 (59.3%)
5000–10,000 group	N/A	3 (9.4%)
>10,000 group	N/A	10 (31.3%)
Cost of download (US$)[b]		
0.00	44(77.2%)	30 (93.7%)
0.00 < cost ≤ 5.00	6 (10.5%)	1(3.1%)
Cost > 5.00	7(12.3%)	1(3.1%)
Developer category		
Private enterprises	45(78.9%)	28(90.6%)
Public authorities or institutions	10(12.7%)	3(9.4%)
Individual	2(3.5%)	1(3.1%)
Intended age		
Not specified	45(78.9%)	28(87.5%)
Adults	12(21.1%)	4(12.5%)
Older adults	0(0.0%)	0(0.0%)
Language		
English	51(89.5%)	5(15.6%)
Chinese	6(10.5%)	27(84.4%)
Issuing country		
China	9 (15.8%)	27 (84.3%)
United States	23 (40.4%)	2 (6.3%)
England	3 (5.3%)	0 (0.0%)
Canada	1(1.8%)	1 (3.1%)
India	5(8.8%)	1 (3.1%)
South Africa	2 (2.4%)	1 (3.1%)

(continued)

Table1. Continued.

Characteristics	Apple ($N=57$), *n* (%)	Android ($N=32$), *n* (%)
Singapore	2(2.4%)	0(0.0%)
Germany	2(2.4%)	0(0.0%)
Australia	3 (5.3%)	0(0.0%)
Spain	1 (1.8%)	0(0.0%)
Ireland	1 (1.8%)	0(0.0%)
Brazil	1 (1.8%)	0(0.0%)
Netherlands	1 (1.8%)	0(0.0%)
New Zealand	1 (1.8%)	0(0.0%)
Portugal	1 (1.8%)	0(0.0%)
Denmark	1 (1.8%)	0(0.0%)

[a]N/A: not applicable.
[b]Once the users begins using the app, the app may ask for additional costs not included in the cost of download.

(e.g. stroke patients) were not involved in app development in a systematic way. Four apps involved patients' input in the design. Both HCP and patients were involved in the development of only one app yet in an ad-hoc way.

Apps' purpose and functionalities

All apps could be classified according to their functionalities, including emergency information collection, risk assessment, medication management, educational information, self-monitoring of blood pressure/lipids/glucose, rehabilitation guidance, communication with HCPs and others, and psychological support. Each app had at least one of these functionalities (**Multimedia Appendix 1**). Various functionalities were identified, as listed in Table2.

The most common functionality was educational information (30/83, 36.1%); the second was rehabilitation guidance (29/83, 34.9%). Educational content varied across apps. Most included basic educational information on an introduction to stroke, signs and symptoms, risk factors, stroke treatment, and prevention. Notably, a few apps included educational information on hypertension or information on dietary approaches to stop hypertension. Some apps focused on containing general information on diabetes or alternative treatments. Despite the majority of educational materials being text-based, several apps contained videos and images to depict their content.

Regarding rehabilitation guidance, apps encompassed four rehabilitation areas (physical function, language function, cognitive function, and risk factor reduction). Therapy apps, reminders, rehab videos, and rehab videos with reminders were four mobile app types that were identified. Each therapy app is aimed at promoting repetitive motion, often in the form of a game. Some apps claiming to help patients to obtain access to visual and auditory feedback on their excise by viewing the display on the screen of synchronous equipment, they did not report any evidence of their reliability and validity.

The third most common functionality was communication with HCPs and others (24/83, 28.9%). A majority of the included apps help the users to communicate with HCPs or friends through text messaging or chat. In addition, some apps facilitating patient–physician communication by allowing users to export their entered data over time directly to others via email and other apps such as "WeChat." Opportunities to manage medication, social support from peers with anxiety or worry, and features to actively set goals and identify stroke were found infrequently, and none of the apps contained the provision of automatic feedback, which was provided to users either by representing data in distinct color codes or through self-care messages and notifications to inform the user of whether Bp or other measurements have diverged from the average level.

As shown in Table3, the majority of the apps (42/83, 50.6%) included only one functionality, while a small number (16/83, 19.3%) included comprehensive (i.e. three or more) functionalities.

Table2. The frequency of functionalities across the included apps.

Functionality	Total number of apps, n (%)
Educational information	30 (36.1)
Rehabilitation guidance	29 (34.9)
Communication with HCPs and others	24 (28.9)
Risk assessment	19 (22.9)
Self-monitoring of blood pressure/ lipids/glucose	18 (21.7)
Emergency information collection	13 (15.7)
Medication management	7 (8.4)
Psychological support	6 (7.2)

HCPs: healthcare providers.

Table3. The frequency of functionalities across the included apps.

Number of functionalities	Total number of apps, n(%)
1	42 (50.6%)
2	25 (30.1%)
≥3	16 (19.3%)

Discussion

Principal findings

This study provides a snapshot of the stroke apps in the two most popular app stores—Google Play (Android) and Apple Store (iPhone). To our knowledge, this is the first study conducted to systematically and extensively review current apps developed to target stroke survivors, which are available in the two largest app repositories. We found that with the widespread accessibility and availability of smartphone apps, an increasing number of apps targeting stroke survivors had been released in recent years. Piran et al.[27] indicated that medical apps specifically supporting stroke survivors/caregivers could be developed and tested to ensure that the issues faced by these populations would be adequately addressed. In addition, Bonura et al.[28] concluded that the impacts of technologies and the improvements allowed by apps would become even more important in common and time-dependent diseases, such as stroke. In this scenario, further improvements may be provided by implementing apps in stroke management.

One of the most important findings of this present study was that the majority of the apps were not specifically geared for older adults. Undoubtedly, an app's target users can provide information about market opportunities and underlying market forces facing app developers.[9] Although there are plenty of devices and apps, they still need to be made more appropriate for older people.[29] Population aging, increased life expectancy, and the need for independent living should encourage the inclusion and involvement of elders in the contemporary IT society.[30] The literature highlights stroke as particularly common among the elderly.[31] It stands to reason that this demographic would potentially gain the most from stroke apps. To stay economically and socially independent, older generations are now digitally aware.[29] More recent evidence suggests that with an aging population, telehealth services are becoming more common to aid in independent living and health management among older adults with chronic conditions.[32] According to a recent study,[33] older people comprise an important user group, whose members are receptive to using technology and able to learn to interact with technology systems. Consequently, it is of great importance that developers design apps targeting the older age groups.

On a more encouraging note, the apps displayed a wide variety of functionalities, such as emergency information collection, risk assessment, medication management, educational information, self-monitoring of blood pressure/lipids/glucose, rehabilitation guidance, communication with HCPs and others, and psychological support. Our review showed that the majority of these apps had only one function, while the rest offered different combinations of functionalities. However, we also found a few apps with comprehensive functionalities. Apps incorporating more comprehensive functionalities are potentially more effective.[34] Interestingly, referring to app functionality, rehabilitation guidance was the second most common (29/83, 34.9%). Our findings further support the idea of Piran et al.,[27] who note that the majority of apps exist to specifically support stroke survivors/caregivers, primarily focusing on language and communication difficulties, and there is abundant room for further progress in developing and testing more apps that would encompass most stroke survivor/caregiver needs.

There are serious issues regarding HCPs' and stroke patients' lack of involvement in app development. App reviews focusing on other medical fields have reported similar findings.[35] This could potentially raise a serious issue, as the bewildering diversity of available apps has made it difficult for clinicians and the public to discern which apps are the safest or the most effective.

However, since there is no information on the extent to which HCPs and patients were engaged in app design, it seems impossible to describe their influence on the development of these apps. Although the involvement of HCPs and patients in app development does not necessarily guarantee app efficacy, it will likely avoid the spread of misleading information to the public and is suggestive of more reliable content and higher quality, which will encourage more user engagement. The need for user-centered principles in the design of mHealth apps to ensure acceptability and usability was highlighted in a recent review.[20] Thus, it is imperative for app developers to involve HCPs and patients in app development to ensure the development of high-quality stroke apps.

Future research

Based on the results of this review, two main potential areas for future research are recommended. First, despite the widespread availability of apps, researchers and commercial developers should be made aware of the requirements for creating appropriate apps for elderly stroke survivors since stroke is the second largest cause of death for persons older than 60 years.[36] Future efforts (and collaborations) should be made to properly design more apps targeting elderly stroke survivors that demonstrate scientific evidence of their effectiveness and usability to the public. Second, the importance of HCP and patient involvement in the creation of apps should be noted, as it helps enhance the clinical applicability of app content, as well as user satisfaction and acceptance. Collaboration among app developers, HCPs, and patients may open a new scale of possibilities in app development.

Limitations

This study has its own limitations that are worth considering. First, the review only included apps that were developed for English-speaking and Chinese-speaking users, excluding apps in other languages. However, since the apps on the two most common smartphone platforms were reviewed, the results offered a general picture of the present status of smartphone app stores in the field of stroke management. Moreover, the findings provided very broad characterizations of current app features meant for stroke, yet the content of educational information of the included apps was not checked to ensure that they were up to date and met medical standards and health literacy guidelines. Third, the determination of whether each app was developed with HCPs' and/or patients' involvement was totally based on developer websites and app descriptions, which cannot verify whether the information was correct. Further research assessing how their involvement would make a difference in app content and quality would help address this issue. Finally, because of the rapid production and release of new apps, we were unable to download and test the newest stroke apps.

Conclusions

To summarize, the present review demonstrates a shortage of apps targeting older adult stroke survivors. The results also demonstrate a concerning lack of HCP and patient involvement in app development. In this regard, close collaboration among app developers, HCPs, and patients is required when developing high-quality stroke apps.

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References

1. Feigin V L, Stark B A, Johnson CO, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet Neurol* 2021; 20: 795–820.
2. Luengo-Fernandez R, Violato M, Candio P, et al. Economic burden of stroke across Europe: a population-based cost analysis. *European Stroke* Jounal2020; 5: 17–25.
3. Owolabi M O, Thrift A G, Mahal A, et al. Primary stroke prevention worldwide: translating evidence into action. *Lancet Public Health* 2022; 7: e74–e85.
4. Wu S, Wu B O, Liu M, et al. Stroke in China: advances and challenges in epidemiology, prevention, and management. *The Lancet Neurol* 2019; 18: 394–405.
5. Burns S P, Schwartz J K, Scott S L, et al. Interdisciplinary approaches to facilitate return to driving and return to work in mild stroke: a position paper. *Arch Phys Med Rehabil* 2018; 99: 2378–2388.
6. Ullberg T, Zia E, Petersson J, et al. Doctor's follow-up after stroke in the south of Sweden: an observational study from the Swedish stroke register (Riksstroke). *European Stroke J*ournal2016; 1: 114–121.
7. Prvu Bettger J, McCoy L, Smith E E, et al. Contemporary trends and predictors of postacute service use and routine discharge home after stroke. *J Am Heart Assoc* 2015; 4:e001138.
8. Bakker D, Kazantzis N, ,Rickwood D, et al. Mental health smartphone apps: review and evidence-based recommendations for future developments. *JMIR Ment Health* 2016; 3: e4984.
9. Hsu J, Liu D, ,Yu YM, et al. The top Chinese mobile health apps: a systematic investigation. *J Med Internet Res* 2016; 18: e222.
10. Pandian J D, Gall S L, ,Kate M P, et al. Prevention of stroke: a global perspective. *The Lancet* 2018; 392: 1269–1278.
11. Giansanti D. The role of the mHealth in the fight against the COVID-19: successes and failures. *Healthcare (Basel)* 2021; 9:58.
12. Burns S P, Terblanche M, ,Perea J, et al. Mhealth intervention applications for adults living with the effects of stroke: a scoping review. *Arch Rehabil Res Clin Transl* 2021; 3: 100095.
13. Burns S P, Terblanche M, ,MacKinen A, et al. Smartphone and mHealth use after stroke: results from a pilot survey. *OTJR : Occupation, Participation and Health* 2022; 42: 127–136.
14. Ahmed I, Ahmad NS, ,Ali S, et al. Medication adherence apps: review and content analysis. *JMIR mHealth uHealth* 2018; 6: e6432.
15. Santo K, Richtering S S, ,Chalmers J, et al. Mobile phone apps to improve medication adherence: a systematic stepwise process to identify high-quality apps. *JMIR mHealth uHealth* 2016; 4: e6742.
16. Alessa T, Hawley M S, ,Hock E S, et al. Smartphone apps to support self-management of hypertension: review and content analysis. *JMIR mHealth uHealth* 2019; 7: e13645.
17. Charbonneau D H, Hightower S, ,Katz A, et al. Smartphone apps for cancer: a content analysis of the digital health marketplace. *Digit Health* 2020; 6: 2055207620905413.
18. Gong E, Zhang Z, ,Jin X, et al. Quality, functionality, and features of Chinese mobile apps for diabetes self-management: systematic search and evaluation of mobile apps. *JMIR mHealth uHealth* 2020; 8: e14836.
19. Ming L C, Untong N, ,Aliudin N A, et al. Mobile health apps on COVID-19 launched in the early days of the pandemic: content analysis and review. *JMIR mHealth uHealth* 2020; 8: e19796.
20. Lobo E H, Frolich A, ,Kensing F, et al. Mhealth applications to support caregiver needs and engagement during stroke recovery: a content review. *Res Nurs Health* 2021; 44: 213–225.
21. Moher D, Shamseer L, ,Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015; 4: 1-9.
22. Grundy Q H, Wang Z and ,Bero L A. Challenges in assessing mobile health app quality: a systematic review of prevalent and innovative methods. *Am J Prev Med* 2016; 51: 1051–1059.
23. Global mobile OS market share 2012-2022. CISION,https://www.prnewswire.com/news-releases/the-global-smart-meter-market-2012-2022-162288596.html(2022, accessed 19 March 2022)
24. Atha H. The ultimate list of app stores 2021.https:www.moveoapps.com/blog/list-of -app-stores/ (2021,accessed 29 May 2022)
25. Krishnamurthi R, Hale L, ,Barker-Collo S, et al. Mobile technology for primary stroke prevention: A proof-of-concept pilot randomized controlled trial. *Stroke* 2019; 50: 196–198.
26. Sarfo F S, Ulasavets U, ,Opare-Sem O K, et al. Telerehabilitation after stroke: an updated systematic review of the literature. *J Stroke Cerebrovasc Dis* 2018; 27: 2306–2318.

27. Piran P, Thomas J, ,Kunnakkat S, et al. Medical mobile applications for stroke survivors and caregivers. *J Stroke Cerebrovasc Dis* 2019; 28: 104318.
28. Bonura A, Motolese F, ,Capone F, et al. Smartphone app in stroke management: a narrative updated review. *J Stroke* 2022; 24: 323–334.
29. Klimova B and ,Maresova P. *Elderly people and their attitude towards mobile phones and their applications—a review study*. Advanced Multimedia and Ubiquitous Engineering1Feture Tech Mue;2016:31–36.
30. Iancu I and ,Iancu B. Designing mobile technology for elderly. A theoretical overview. *Technol Forecast Soc* 2020; 155: 119977.
31. Tsao C W, Aday A W, Almarzooq Z I, et al. Heart disease and stroke statistics-2022 update: a report from the American Heart Association. *Circulation* 2022; 145: e153–e639.
32. Ware P, Bartlett S J, ,Pare G, et al. Using eHealth technologies: interests, preferences, and concerns of older adults. *Interact J Med Res* 2017; 6: e4447.
33. Czaja S J. Usability of technology for older adults: where are we and where do we need to be. *J Usability Stud* 2019; 14: 61-64.
34. Alessa T, Abdi S, ,Hawley M S, et al. Mobile apps to support the self-management of hypertension: systematic review of effectiveness, usability, and user satisfaction. *JMIR mHealth uHealth* 2018; 6: e10723.
35. Xiao Q, Lu S, ,Wang Y, et al. Current status of cardiovascular disease-related smartphone apps downloadable in China. *Telemed J E Health* 2017; 23: 219–225.
36. Facts and figures about stroke. https://www.world-stroke.org/component/content/article/16-forpatients/84-facts-and-figures-about-stroke (accessed May 2023).