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Factors influencing the download of mobile health apps: Content review-led regression analysis

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ABSTRACT

Objectives: The objective of this study was twofold: classifying diabetes smartphone apps using content review, and identifying the factors that influence the app download through regression analysis.
Methods: From Google Play Store, a total of 5557 apps that matched the search criteria 'diabetes' were identified and extracted using a structured sheet. Purposeful sampling technique and selection criteria were applied to identify 500 apps, and content review was done to characterize the apps. Multiple regression analysis was employed to find the association between app download and app characteristics.
Results: Content analysis revealed that 464 out of the 500 apps (92.8%) were free. The most common app features were monitoring and tracking (39%), treatment information (23%) and nutrition (18%). Two-thirds of the apps were intended for patients. The most common business models were advertising (34%), freemium (20%), and razor-and-blade (19%). Regression results explained the preference for apps that provide nutrition function and monitoring capabilities. As per the study results, factors that boost application download include: high ratings, frequent updating, long standing market presence, and those offered by US companies.
Conclusions: Content review highlights the various self-management capabilities offered by diabetes apps. This study adds to the extant literature on mobile application classification by introducing the business model dimension.

Introduction

Health care costs are increasing consistently and exponentially across the world [1]. Global increase in the incidence of chronic diseases has been accompanied by a simultaneous rise in the total health care expenses [2]. Diabetes, a chronic health condition, has disproportionately affected people in both developing and developed nations [3]. In 2014, 422 million people were diagnosed with diabetes worldwide [3]; by 2035, this number is estimated to spike to 592 million [4]. The American Diabetes Association [5] has reported that diabetes is the most expensive chronic condition in the United States today. To reduce the cost of diabetes care, the patients must take charge of disease management themselves. Self-management is crucial for people with diabetes [6–8]. Prevention of diabetes related health issues necessitates the continuous monitoring and constant engagement of patients. Advancements in information and communication technology (ICT) [9] coupled with the rapid growth of smartphones facilitate self-management of diabetes through mobile health apps. Mobile health (mHealth) is the provision of health care and other health-related services via portable mobile devices [9,10]. Recent studies [11–13] confirm that use of mobile apps has improved the health condition of patients with diabetes.

Currently, there are thousands of diabetes management apps available in the app stores. There is a growing interest among researchers to review the diabetes apps. Prior reviews on diabetes apps focused on four major themes: classification [6,8,14–24], evaluation of usability [6,14,19,22], self-management [6,8,15,18,22], and comparison of app features with clinical guidelines [21,23]. These reviews update the researchers and practitioners about new features added over a period of time and also trace the evolution of diabetes mobile apps. Classification schemes used in the earlier reviews organized the apps on the basis of functional features, type of diabetes, and language. The prior reviews [15,17,19,22] also considered only the commercialization aspect (paid versus free) of the app. Now, the business model, defined as "the heuristic logic that connects technical potential with the realization of economic value" [25] is gaining traction in the health domain. However, business model classifications are not available for diabetes apps.

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Very few studies have quantitatively explored the functions of the diabetes apps. Arnhold et al., [19] used multiple regression analysis to study the relationship between usability and app functions. They found that usability is positively correlated with recipe suggestion and communication function. A recent review of clinical management literature and apps for type-1 diabetes mellitus by Martinez-Millana et al. [49] found that self-monitoring, communication, education, and gamification functionalities of apps benefit patients; they concluded that very few apps in the market offer a wide range of features for self-management. This study calls for research on acceptability and usability to explore the features impacting the self-management of diabetes. The number of downloads indicates the popularity [47] and consumer acceptance of the mobile apps [48]. Other indicators for popularity and acceptance include ratings and app reviews by patient groups [50].

The aim of this study was to conduct content review of diabetes mobile apps from Google Play Store in order to classify the apps based on their features, target audience, and business models; further, the study aimed to carry out multiple regression analysis to identify the attributes leading to the download of the diabetes apps.

Methods

Study design

This study design involved a content review to classify diabetes mobile apps in Google Play Store followed by regression analysis to identify the factors influencing the app download. This study reviewed Google Play Store apps designed for diabetes management. As of 2016, Android was the largest platform with 84.8% of the smartphone market share [26].

Data collection

By March 2018, Google Play Store contained 3.8 million apps [27]. On April 17, 2018, the authors did a search using the keyword "diabetes" on the Google Play Store, a digital app platform for the Android operating system. App market platform 42matters [28] was used for downloading diabetes apps data.

Selection criteria

The keyword "diabetes" was searched in the title, apart from short description and description fields of the apps. Details of 5557 apps that matched the search criteria were downloaded. Basic app details such as app name, description, screenshot, rating, downloads, developer's classification, date of creation, and date of last update were downloaded and extracted in a Microsoft Excel sheet. We (researchers KG and GS) independently screened the apps based on the selection criteria, and purposefully sampled 500 apps that met the inclusion criteria. The selection process described in Fig. 1 was implemented in a structured Microsoft Excel sheet.

Inclusion criteria

- Apps belonging to Google Play Store
- Descriptions written in English language
- Titles and descriptions of the apps pertaining to diabetes or diabetes related conditions

Exclusion criteria

- Descriptions written in languages other than English
- Duplicate apps from the Google Play Store
- Titles and descriptions not related to diabetes

Data coding

Characteristics of the diabetes apps were heterogonous in nature [49]. There were no standard frameworks available to classify the mHealth apps for diabetes. The coding scheme for this study was adopted from the existing literature: Classification of a diabetes app by its main feature and classification by audiences were adopted from [6,20]; classification by organization type was adopted from [44]; classification by diabetes type was included from [24], and application origin was adopted from [17]. This study has considered the most common types of diabetes - type 1, type 2, gestational diabetes and prediabetes. We developed a coding scheme for the business model based on the review of the literature [27–32] on business model typology. The coding scheme has been reviewed by 3 experts with significant experience in developing and executing the business models.

We did the initial coding scheme for the content analysis together, by reviewing the contents of the first 75 apps (15%, 75/500) in the sample. Subsequently, using the coding scheme of Table 1, the first reviewer (GK) manually codified the entire sample. The second reviewer (GS) analyzed the codified information from a random sample of 100 apps (20%, 100/500). For each category, inter-rater reliability was assessed using Cohen's kappa. Disagreements on coding schemes were resolved by consensus. The app categories were coded manually after analyzing the app descriptions, screenshots, and information obtained from developer websites. The detailed coding scheme for each category is presented in Table 1.

Statistical analysis

Classification of apps using content analysis has been presented with mean and frequencies. Multiple regression analysis was performed to study the association between the dependent variable 'downloads' and the 31 independent variables. Download range was obtained from Google Play Store. As the number of downloads was normally distributed, mean was considered as download. The independent variables were included from the app market data and content review. The regression model is presented in Fig. 3. Regression analysis was performed using SPSS version 22.

Regression model construction

To satisfy the linearity assumptions of the regression model, instead of downloads, 'Log (downloads)' was considered as a dependent variable. The regression model included 31 independent variables (8 from Google Play Store, 23 from content review). Of the 8 variables included from Google Play Store, "medical" and "health & fitness" were obtained from developer's classification of the apps. The variable "updated apps" checked whether the app was updated or not since its creation. Variable "ratings" was measured on a 5-point scale, "months since creation" checked how old the app was in months, and "months since last update" checked as to when an app was last updated. Step-wise procedure in multiple regressions was used to model apps download. The conceptual model (Fig. 3) explains the data type and source of the explanatory and response variables.

Sample size and power analysis

To perform multiple regression analysis, the minimum sample size should be at least 15 observations for each variable [51], with the minimum of 50 observations [52]. This translated to 465 observations (31×15) in our case. The number of apps considered in this study was 500, which was sufficient to perform the multiple regression analysis.

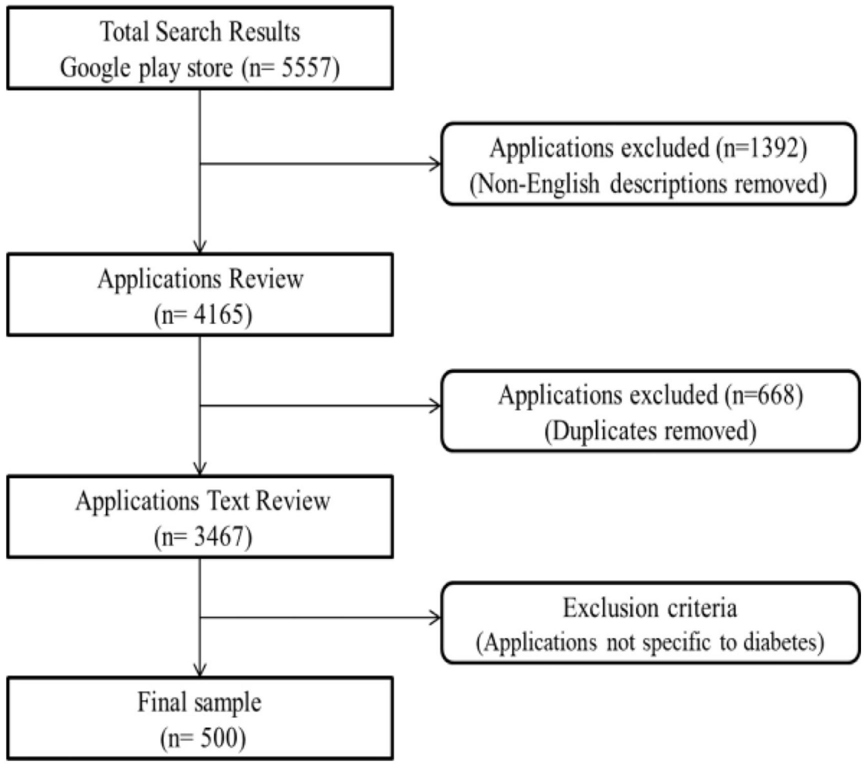

Fig. 1. Flow chart of the app selection process.

Table 1
Coding scheme for classification.

Category	Description of coding logic
Application features	Primary purpose and feature of diabetes apps
Monitoring and tracking	Tools to monitor blood glucose, blood pressure, insulin dosage, BMI, medication and exercise
Information	Information about disease and treatment options
Nutrition	Recipe suggestion, cookbook, and diet planning
Disease management	Information and practical tools to deal with medical and behavioral aspects of diabetes
Event	Information about the conference, congress, meetings, and, scientific sessions that focus on diabetes-related issues
Detection and prevention	Tools to diagnose diabetes before it occurs (detection), and tools to avoid it (prevention)
Others	Fundraising and appointment booking
Organization type	Organizations that develop mobile apps for diabetes
App development	Individual developers and organizations that develop apps for various categories such as medical, games, etc.
Health technology	Organizations that develop technology-based devices, vaccines, and systems for diabetes management
Health app development	Individuals and organizations that develop apps only for medical category
Health care	Hospitals, research institutes, and other health care agencies that provide health care services
Government	Apps floated by government agencies and departments (i.e., IT department)
Others	Universities, journals, and health publishers
Target audience	Primary target audience for apps
Patients	Intended for people with diabetes
General	Intended for the general public
Health care professionals	Intended for professionals who provide health care services
Diabetes type	App types categorized as type 1, type 2, gestational diabetes, prediabetes, and others
Generic	Type independent, designed to be used by all types of diabetes
Type 1	Designed specifically for type 1 diabetes
Type 2	Designed specifically for type 2 diabetes
Gestational Diabetes	Designed for gestational diabetes developed during pregnancy
Prediabetes	Designed for people with high blood sugar but not high enough to have type 2 diabetes
Business model	Business logic that connects technical potential with economic value [25]
Advertising	Apps are provided free of cost. mHealth provider offers advertising services via mobile apps [29,30]
Freemium	The free basic version of the apps with optional premium version offering enhanced features [31,32]
Razor and blade	"Pricing razors inexpensively, but aggressively marking up on the consumables" [31,33], (i.e., Glucometer and associated monitoring apps are given at lower price with a high mark up on Glucometer strips)
Free	Apps to generate high traffic as a source of revenue [32,30,34]
Subscription	Involves collecting subscription fee; pay-per-use model [31,29,30,34]
Voluntary service provider	Users access the tools provided via mobile apps and pay the provider on a voluntary basis (i.e., apps by NGOs) [35,30]
Application origin	Country of origin for diabetes apps

A post hoc power analysis was conducted using the software G*Power 3.1.9.4 [53] to confirm whether the number of apps selected provide sufficient power to detect medium effects. For the sample size 500 with (medium effect size = 0.15, $\alpha = 0.05$, number of predictors = 31), the statistical power was calculated as 0.99. Cohen [54] recommended a power value of 0.8 to achieve statistical significance. With the power value of 0.99, the sample size was adequate for regression analysis.

Results

Classification

Database search in 42matters [22] using application programming interface (API) yielded 5557 apps. With the elimination of non-English and duplicate apps, 3467 unique apps were identified. From this, a final sample of 500 apps that specifically address diabetes-related issues were selected for the purpose of classification (Fig. 1). Inter-rater reliability of the apps between the two researchers was determined using Cohen's kappa and found to be acceptable with 0.87.

Features and purpose

Monitoring and tracking: Monitoring and tracking (39%, 195/500) emerged as the largest category (Fig. 2A). Monitoring apps provided functionality to monitor and track blood glucose, insulin level, blood pressure, medication, weight, BMI, etc. Apps in this category also provided trend analysis, data visualization and enabled sharing of monitoring data with care takers and doctors when abnormal trends were observed.

Information and communication: This category included apps that provided information about the disease and treatment, alternative treatment information (Ayurveda, Acupressure, Siddha, etc.), clinical outcomes and latest updates to health care professionals, online certification and education to patients and health care professionals, forums and platforms for patients and health care professionals to interact and share information, diabetic news, magazines, books, and journals. 23.2% (116/500) of the apps were classified under information and communication.

Nutrition: Many apps (18.2%, 91/500) in this category provided food recipes for diabetic patients, and information about the foods that diabetic patients can eat or should avoid. Apps in this category were used to calculate the amount of carbohydrates in various food items.

Disease management: These apps (7%, 35/500) provided the range of functionalities needed to deal with medical and behavioral aspects of diabetes. Functionalities under this category included combination of monitoring and tracking, nutrition, and information. Diabetes management programs offered via mobile apps were also classified under disease management.

Promote an event: These apps (6.4%, 32/500) promoted events such as conferences and meetings of various diabetes forums.

Detection and prevention: Functionalities provided by detection and prevention apps (4.8%, 24/500) included symptoms, risk assessment questionnaires, calculation of the risk score that predicts the chances of developing diabetes; as well as food items, diet, and exercises that help to prevent diabetes.

Organization type

Individuals and application development: Individuals and application development organizations (Fig. 2B) was the top category (36.8%, 184/500). App development companies offer diverse apps ranging from health care apps to gaming apps. The reliability of clinical information provided through the apps developed by app development companies was questionable. The majority of the organizations in this category were start-ups and small and medium-sized enterprises (SMEs).

Health technology: Diagnostic equipment companies (glucose monitoring systems, insulin injection providers, etc.) and digital diabetes management service providers were classified under health technology organizations (22.2%, 111/500).

Health app development: Companies developing health apps (21.8%, 109/500) focused mainly on the design and development of apps for the health care domain. These organizations had expertise in developing apps for health care, but it was not clear whether health care professionals were involved in the app development process.

Health care organizations: Health care organizations (14%, 70/500) included hospitals, health care associations (ADA, Japan diabetic society, etc.), and pharmaceutical companies, which directly provided health care services.

Government: Government institutions offered 2.8% (14/500) of the apps aimed at providing diabetes education, awareness, and management functionalities.

App audience

Two-thirds of the apps (66.4%, 332/500)) were designed exclusively for patients with diabetes (Fig. 2E). Nearly one-third of the apps (29.6%, 148/500)) were preventive apps designed to be used by both diabetic patients and the public in general. Hence, 96% of the diabetes apps were available for diabetic patients. A small number of apps (4%, 20/500)) were designed for health care professionals.

Diabetes type

The majority of the apps (91.8%, 459/500)) were common to all types of diabetes (Fig. 2D). Merely 2% (9/500) of the apps were designed exclusively for type 1 diabetic patients, and 6% (30/500) of the apps were available for type 2 diabetic patients. Of the 500 apps reviewed, only 2 apps were available for patients of gestational diabetes (Habits: Gestational Diabetes App, and Deal with Gestational Diabetes during Pregnancy App) and prediabetes (Prediabetes Disease, and How to Maintain Normal Blood Sugar).

Business model

Commercialization of apps was ascertained by the number of free and paid apps (See Fig. 2F). Most of the apps (92.8%, 464/500)) were offered free of cost. Price of the paid apps ranged from 0.99$ to 60$. The average price of the paid apps was calculated as 11.2$. After reviewing the app data set, the apps were categorized by business model (Fig. 2C).

The *Advertising* model emerged as the predominantly adopted business model (34.4%, 172/500) among the diabetes app providers. Companies leveraging this business model provided the apps free of cost but they use these mobile apps to publish advertisements. The providers generate revenue by acting as a broadcaster of advertisements.

The *Freemium* [17] business model was adopted by 20.2% (101/500) of the apps, which leveraged this business model by providing basic apps for free, but the users have to make "in-app purchases" to avail the premium services delivered through these apps. Revenue was generated by in-app purchases.

The *Razor-and-blade* business model was adopted by 18.6% (93/500) of the apps. In this model, the basic version is given free or at a low cost, but the consumables are sold at higher prices. Glucose meters or insulin pumps are sold at cheap cost along with

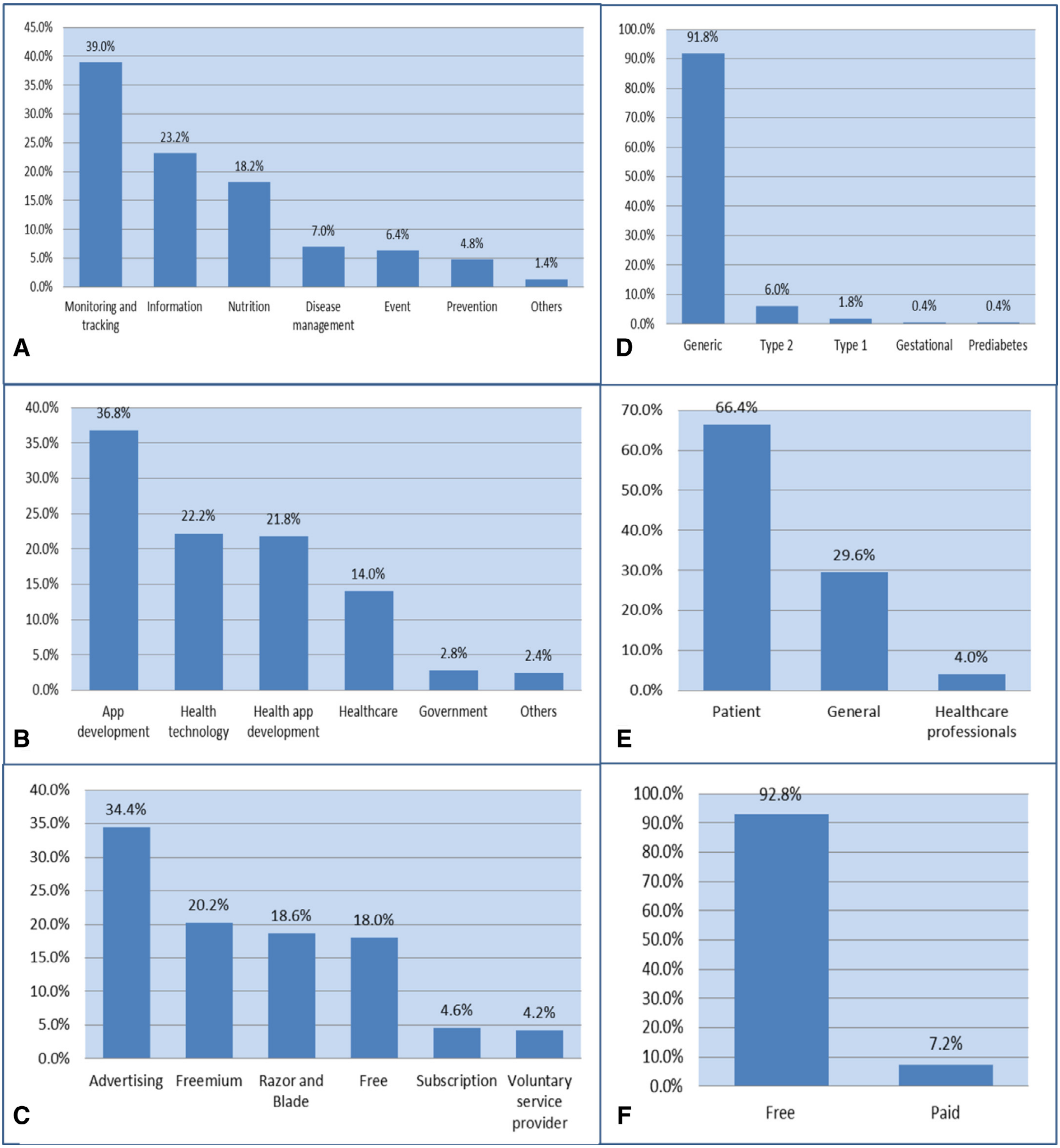

Fig. 2. Classification by (A) feature, (B) organization type, (C) business models, (D) type, (E) users, (F) commercialization.

free access to monitoring apps. Providers generate revenue through the sale of consumables such as glucometer strips and insulin injections.

The *Free* business models are gaining popularity among e-business [35] and mHealth. This model has been adopted by 18% (90/500) of the diabetes apps. By providing the apps free of cost, the provider tries to generate high traffic toward these apps. This helps the providers to promote and gain popularity of their brand name, products, and services.

The *Subscription* model adopted by 4.6% (23/500) of the apps involves the upfront payment of the fee to gain access to the diabetes apps. This model was largely adopted by apps that provided advanced monitoring and tracking capabilities.

The *Voluntary contributor* model was adopted by 4.2% (21/500) of the apps. This model is primarily adopted by apps providing advanced monitoring and tracking capabilities. NGOs and government organizations that use the voluntary contributor model earn money through the voluntary contributions made by people.

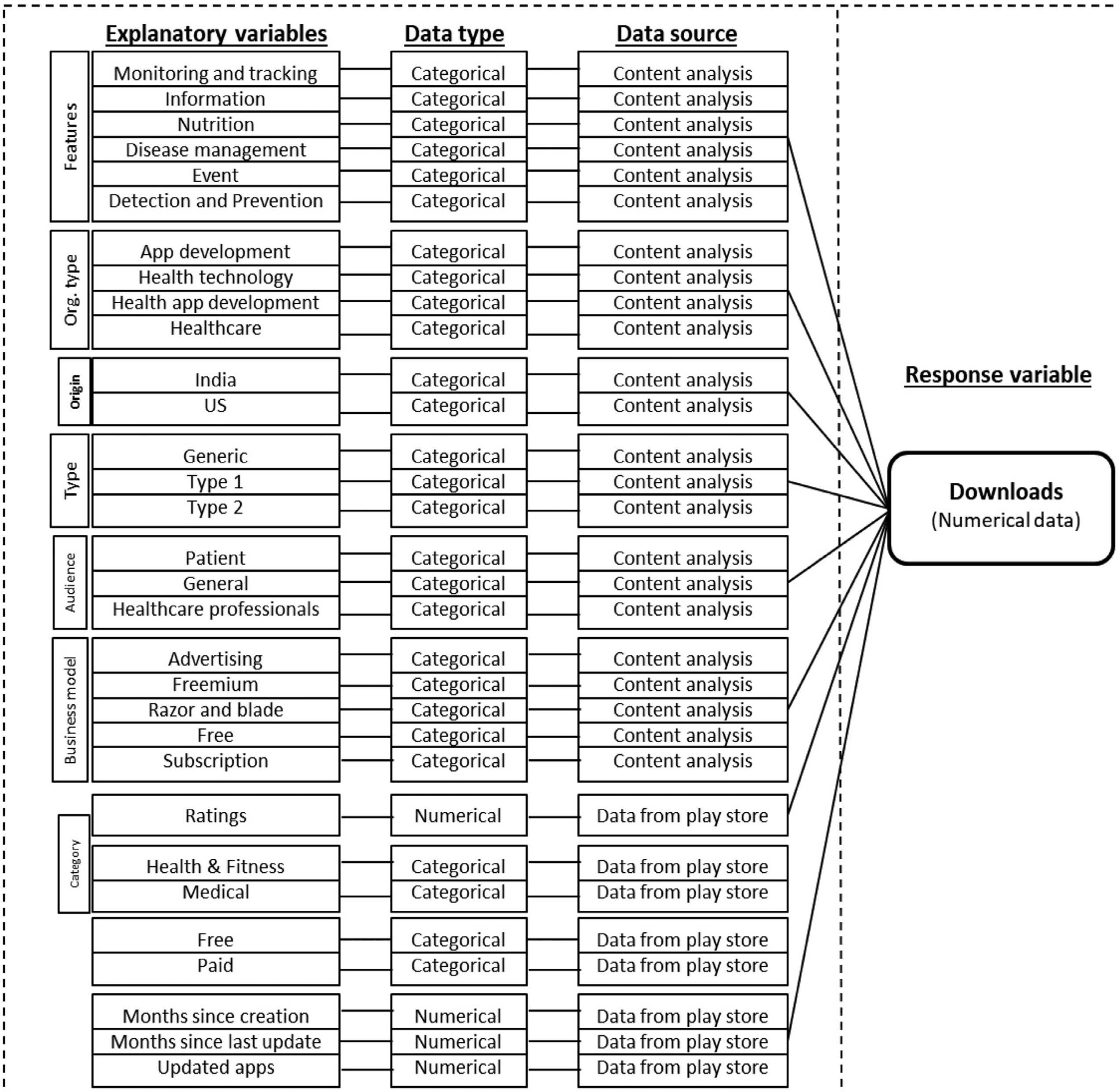

Fig. 3. Conceptual model for multiple regression.

Application origin (country)

Countries of origin for apps were found by reviewing the Google Play Store webpage and application developer's website. Country details were obtained for 79% (395/500) of the apps. Table 2 shows the share of apps by the top 10 countries.

Among the countries listed in the Table 2, India at 23.6% (118/500), and United States at 21.4% (107/500), accounted for more than 20% of the total apps. Application search being performed from India might be the reason for the maximum number of apps from India. China too had good number of apps, but many of them were not part of this analysis as the descriptions were not available in English.

Table 2
Classification by country.

Country	Applications, n, (%)
India	118 (23.6%)
US	107 (21.4%)
Switzerland	39 (7.8%)
UK	22 (4.4%)
Taiwan	9 (1.8%)
Germany	9 (1.8%)
Canada	7 (1.4%)
France	6, (1.2%)
Australia	5 (1%)
Japan	5 (1%)

Regression result

Regression analysis was performed to explain the association between the app downloads and the characteristics of the diabetes apps. The results of the multiple regression analysis indicated that 10 variables (see Table 3) explained 51.8% of the variance ($R^2 = 0.518$, $F(1489) = 4.610$, $p < 0.05$). From the t-statistics, it was observed that all the 10 variables were significant.

Table 3
Result of regression analysis.

Summary of the regression analysis results					
Variable	Coefficient	SE coefficient	*t*-value	*p*-value	VIF
(Constant)	1.393	.116	11.964	.000	
Rating	.235	.022	10.697	.000	1.156
Months since creation	.032	.003	12.637	.000	2.013
Months since last update	−0.016	.003	−5.643	.000	1.949
Paid	−1.199	.148	−8.077	.000	1.246
Patient	.309	.081	3.806	.000	1.247
Nutrition	.381	.099	3.848	.000	1.234
Razor and blade	.218	.103	2.115	.035	1.360
Free model	−0.246	.098	−2.517	.012	1.190
US	.222	.088	2.511	.012	1.109
Detection and prevention	−0.364	.170	−2.147	.032	1.115
R^2	0.518				

Overall, the model is found to be significant in explaining the app download.

Discussion

Systematic review

This study reviewed a large number ($n = 500$) of diabetes apps available in Google Play Store. The range of services offered by the diabetes apps included: monitoring, dietary management, remote consultation, diabetes education, detection, prevention, and communication.

More than a third of the diabetes apps offer the “monitoring and tracking” function. This highlights the importance of continuous monitoring [36,37] and the self-monitoring capability offered through these apps.

This study is a pioneering effort to objectively classify the diabetes apps based on business models. Our business model classification showed the emergent business models and revenue streams tapped by the mHealth service providers. Analysis showed that advertising, freemium, razor and blade, and free business models were widely perceived (91.2) as successful models by diabetes mHealth service providers.

Applications by app development organizations indicate the lack of involvement of qualified health care personnel in the development of the apps [38,39]. The rapid increase in the numbers of the mobile apps raises concerns regarding data safety and security [40,41], which necessitates the need for a robust framework [42] for mobile apps.

Regression output and interpretation

Ours was the first study to have quantitatively modeled the diabetes mobile apps download.

The variable ‘rating’ had a positive coefficient. Rating has been used by Google Play Store for measuring the quality of the apps [43]. The results of this study indicate that apps which received a higher rating from the users will lead to greater number of downloads. Variable “nutrition” had positive coefficient. Among the various functions, apps offering tools for “nutrition management” for patients with diabetes attract more downloads. Positive coefficient for “month since creation” and negative coefficient for “month since last update” reflect the users’ preference to download long-standing apps and those apps that were regularly updated with latest content. Apps maintained by developers lacked the involvement of healthcare professionals [38,39]. At the same time, apps maintained by healthcare professionals were not updated leading to outdated information [44]. This necessitates the continuous collaboration between the app developers and healthcare professionals to keep the apps updated with the latest content.

A strong preference for free diabetes apps was reflected by the highest negative coefficient for the “paid” apps. Among the business models, “razor and blade” and the “free” models found to be significant. Positive coefficient for the razor and blade model reflects the users’ preference to download the apps linked to glucometers and insulin pumps. This provides evidence for the diabetic patients’ preference for the diabetes mHealth app’s self-management capabilities. Variable “patient” had a positive coefficient. This shows that the apps intended for patients with diabetes are widely accepted as compared to those apps meant for the general public. Variable “US” had a positive coefficient. This implies that keeping all other parameters constant if the app is developed by companies or developers based in US, they are likely to have more downloads. This indicates that the US firms are perceived as significant providers of mHealth services and regression results provides the evidence for the adoption of diabetes apps that were originating from the US. This corroborates with the finding [55] that the US offers the best market conditions for mobile health solutions.

Practical implications

Content review performed in this study extends the literature by classifying the apps by business model. Our analysis also shows the increasing tendency among the people with diabetes to use the self-management capabilities delivered through the diabetes mHealth apps. Multiple regression analysis provided insights into the factors influencing the successful adoption of diabetes apps.

This study has major implications for various stakeholders in the mHealth ecosystem. Firstly, the implications of this study are of high relevance to the decision makers and developers of mHealth apps for diabetes. This study improves the understanding of factors that will influence the download of diabetes apps. Incorporating these aspects into the design and development of mHealth apps will lead to the development of successful of apps for diabetes. Secondly, this classification will empower the patients with diabetes to understand the features available in the diabetes apps and select the apps that address their personal requirements. A large percentage of the apps were designed for health monitoring, treatment information, and nutrition tracking. Information apps will increase the understanding of diabetes. Feedback from the monitoring apps improves the communication between the patients and clinicians. Most importantly, this study will have the following implications for healthcare practitioners: Estimates from prior studies [45,46] suggest that diabetes treatment adherence was in the range of 23–77%. Classifications from this study can help the healthcare practitioners to recommend the diabetes apps to patients to improve the treatment adherence. Care providers have to exercise substantial caution when recommending insulin dosage calculator apps without testing [18]. Apps targeted at healthcare professionals enable them to get updated with the latest clinical practice guidelines (e.g. Diabetes Canada Guidelines app), and prepare them for the diabetes certification also (e.g. Certified Diabetes Educator app).

Limitation

One of the limitations of this study is that classifications and recommendations are based on the experience of the two researchers primarily involved in this study. Classifications of the apps were done using objective criteria coupled with the researchers' experience with mHealth apps. This study relied on app store description, screenshot, and website details for classification and analysis. The scope of this study did not include the actual download of the mobile app. There can be discrepancies between the app description and actual functionalities available in the app. However, app store details are the only information available for the users to install an app. App download may not strictly be an indicator of user acceptance because download does not always guarantee regular use. The android app market provides only the download range, which makes a thorough download analysis impossible. The other two limitations of our study are based on inclusion criteria. One, this study considered only Google Play Store apps; apps from other stores (iTunes store, etc.) were not under the scope of this study; the second being that apps with non-English descriptions were not considered for this study.

Conclusion

This study reviewed the apps using content review and regression analysis. Content review added value substantially by providing classifications for diabetes mobile apps. App classification will empower the patients with diabetes to understand the features available in the diabetes apps. Classifications from this study can help clinicians to recommend the diabetes apps to patients to improve the treatment adherence. Regression analysis has provided valuable insights for practitioners by stipulating the attributes that should be present in the apps for maximizing downloads. From the result of our multiple regression analysis, we have developed the following five-point strategy for developing successful Android diabetes mobile apps:

- Apps for people with diabetes should provide monitoring capabilities and nutrition, features.
- Apps should be offered free of cost.
- Apps should be up to date with regular updates on diabetes prevention and treatment.
- Organizations looking to outsource the app development can collaborate with organizations from the United States.
- Business models such as the razor and blade model should be adopted for generating sustainable revenue streams.

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