Int J Cardiovasc Sci. 2024; 37:e20230085

ORIGINAL ARTICLE

Development and Implementation of a Computerized Decision Support System for Screening Hypertension and Diabetes in a Resource-Constrained Region

Laura Defensor Ribeiro de Melo,[1] Antonio Luiz Pinho Ribeiro,[1,2] João Antonio de Queiroz Oliveira,[1] Junia Xavier Maia,[1] Thábata Queiroz Vivas de Sá,[1] Vânia Soares de Oliveira e Almeida Pinto,[3] Marcia Maria Oliveira Lima,[3] Patrick Wander Enlich,[3] Leonardo Bonisson Ribeiro,[1] Christiane Correa Rodrigues Cimini,[3] Milena Soriano Marcolino[1,2]

Medical Shool and Telehealth Center, University Hospital, Universidade Federal de Minas Gerais,[1] Belo Horizonte, MG – Brazil
Instituto de Avaliação de Tecnologias em Saúde,[2] Porto Alegre, RS – Brazil
Mucuri Medical School, Universidade Federal dos Vales do Jequitinhonha e Mucuri,[3] Teófilo Otoni, MG – Brazil

Abstract

Abstract

Background: Strategies aimed at improving the diagnosis and treatment of cardiovascular diseases (CVD) are of utmost importance. Clinical decision support systems (CDSS) are guided by updated guidelines and may be capable of benefiting screening and early diagnosis initiatives in remote regions.

Objective: To develop a CDSS for screening hypertension and diabetes mellitus (DM), as well as to assess its feasibility and usability in the context of a primary care setting in a resource-constrained region.

Methods: This research focused on the strategy of screening hypertension and DM based on CDSS. A software was developed and implemented in 10 municipalities in the Northeast of the state of Minas Gerais, Brazil, from April 2017 to October 2018. Patients of 30 to 69 years of age were attended by primary care practitioners using the software. A Likert-scale questionnaire with 15 questions to assess usability (System Usability Scale) and satisfaction was applied to the professionals at the end of study. Groups were compared by applying the chi-squared test for categorical variables. Statistical significance was considered as $p < 0.05$.

Results: In the field study, 13,775 individuals were assessed; 185 patients were diagnosed with hypertension; 35 were diagnosed with DM, and 5 were diagnosed with both diseases. For the usability and satisfaction assessment, 258 healthcare professionals participated. Fifty-one percent considered their prior knowledge for the use of technologies to be good; 53.7% reported a desire to use the application frequently, and 78.4% would recommend the platform.

Conclusion: The implementation of a CDSS developed to assist in the screening of hypertension and DM was feasible in the context of a primary care setting in a resource-constrained region, with good user satisfaction.

Keywords: Hypertension; Diabetes Mellitus; Telemedicine; Mass Screening; Clinical Decision Support Systems.

Introduction

Cardiovascular diseases (CVD) are the main cause of death worldwide, which is a major concern for governmental leaders, research institutes, and health professionals alike. Hypertension and diabetes mellitus (DM) are recognized as major modifiable risk factors for CVD, and understanding the contribution of these risk factors to disease burden has motivated a wide range of studies and health promotion strategies.[1,2]

Around 1 in 10 individuals aged 20 to 79 in the world has diabetes, a total of approximately 537 million people. It is estimated that, by 2045, this number will increase to 784 million. The majority of cases are in developing countries, where the greatest increase in rates is expected in the coming

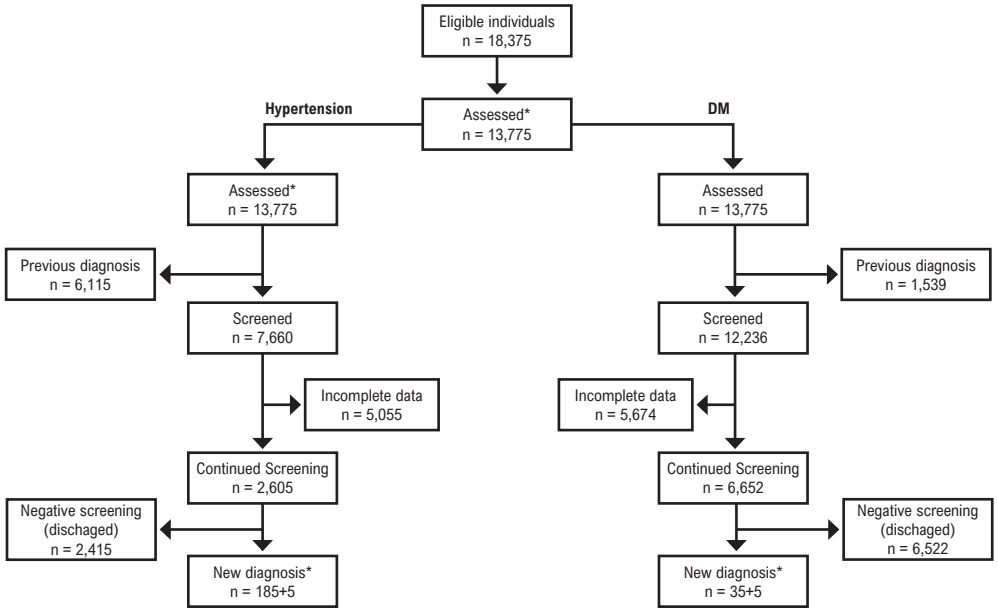
Mailing Address: Laura Defensor Ribeiro de Melo
Hospital das Clínicas, Universidade Federal de Minas Gerais. Avenida Professor Alfredo Balena, 190. Postal code: 30130-100. Belo Horizonte, MG – Brazil
E-mail: lauradefensorribeiro@hotmail.com
Editor responsible for the review: Ricardo Mourilhe-Rocha

DOI: https://doi.org/10.36660/ijcs.20230085

Manuscript received June 10, 2023; revised manuscript May 17, 2024; accepted May 23, 2024.

Central Illustration: Development and Implementation of a Computerized Decision Support System for Screening Hypertension and Diabetes in a Resource-Constrained Region

INTERNATIONAL JOURNAL OF Cardiovascular SCIENCES



Int J Cardiovasc Sci. 2024; 37:e20230085

*Flows for hypertension and DM screening. *The initial total number of individuals assessed includes those who followed the two flows concurrently (n = 1,203 individuals). Thus, the new diagnosis includes those patients who were screened for both disease (n = 5). DM: diabetes mellitus.*

decades.[3] A comprehensive study conducted in the capital cities of 27 Brazilian federative units revealed that 24.5% of adults received a medical diagnosis of hypertension, while 7.4% were diagnosed with DM. The prevalence of these conditions rose with age and declined with higher educational attainment.[4]

Screening and immediate treatment for DM tend to confer health benefits.[5] Individuals with DM should undergo a comprehensive assessment, including CVD risk, renal function, determination of body mass index (BMI), and measurement of HbA1c levels before establishing a patient care plan.[6] Management involves not only improving glycemic levels, but also decreasing CVD risk and early intervention in complications, such as diabetic foot, kidney failure, non-traumatic amputations, diabetic neuropathy, and diabetic retinopathy.[7,8] In this context, it is important to provide professionals with knowledge and resources that affect the quality of treatment and the clinical outcomes, as when dealing with optimal cardiovascular medical therapy in patients with DM and acute myocardial infarction.[9]

Similarly, hypertension screening and early diagnosis enable the reduction of the incidence of cardiovascular events, such as myocardial infarction, stroke, and heart failure.[10] Despite the practical recognition of this practice, studies aimed specifically at screening and the importance of early diagnosis in specific age groups are still restricted.[11]

It is estimated that at least three quarters of the world's deaths from CVDs are from low- and middle-income countries.[11] Often, these nations do not have the benefits of consistent and integrated primary healthcare (PHC) programs or access to specialized medical services. Additionally, low education levels may be associated with increased exposure to CVD risk factors in those countries.[11,12]

In Brazil, a middle-income country, diagnosis and management of these diseases are a challenge, considering the continental proportions of the country and the fact that the public health system has structural and financial limitations.[13] Brazilian primary care encompasses prevention, promotion, treatment, and rehabilitation of the most prevalent diseases, along with palliative care and health surveillance.[1] Considering the significant rise of CVD as a leading cause of death between 1990 and 2019,[14] it is crucial to research strategies that organize the management of chronic diseases, such as hypertension and DM, to enhance public health.

In this context, telehealth interventions such as teleconsultations,[15] telediagnosis,[16] and clinical decision support systems (CDSS)[17] have been consolidated as important tools to strengthen PHC assistance and

to improve access to specialized care, including support provided to the disease screening process and management.[18] Furthermore, these interventions may help improve the self-assessment of health for populations residing in remote regions, since aspects related to health access and coverage are recognized as components of poor self-assessment of health.[19]

CDSS work as electronic systems (digital, mobile, or wireless technology) aiming to aid in clinical decision-making, using personalized characteristics and clinical information to create patient-specific recommendations and advice for healthcare professionals.[18,20,21]

Therefore, the purpose of this study was to develop and implement a CDSS for screening for hypertension and DM in primary care in a resource-constrained region, as well as to assess the feasibility and usability of this strategy. Our hypothesis was that implementing a CDSS for screening hypertension and DM in primary care would be viable in low-income regions, and its application would be beneficial within this context.

Methods

Study design

This study is a subproject of the multicenter HealthRise Project, launched in 2014 as a 5-year global effort to improve screening, diagnosis, management, and control of hypertension and diabetes, as described elsewhere.[22] The HealthRise Project seeks to implement strategies to reduce early mortality from chronic noncommunicable diseases. Underserved populations were selected in 4 countries (Brazil, India, South Africa, and the United States), and interventions were adapted to local needs and resources. The project was developed with specific models for each region, respecting the common objectives of favoring the diagnosis of hypertension and diabetes, in addition to improving management measures and integrated care between the community and the local health service.[23] Specific microregions of the states of Minas Gerais and Bahia, namely, the region of Teófilo Otoni in Minas Gerais and the city of Vitória da Conquista in Bahia, were selected for program action implementation, after identifying barriers and gaps in the detection of CVD in those localities.[22]

The project was implemented in the Vale do Mucuri region, in the Northeast of the state Minas Gerais, Brazil (Figure 1). This region was chosen by the Brazilian Ministry of Health, as it aggregates municipalities with the lowest human development indexes (HDI) in Minas Gerais.[24] The city of Teófilo Otoni has the highest HDI in the microregion (0.701), although this is below the state average (0.810). The microregion has an illiteracy rate of 21.0%, which reaches around 40% when considering only the adult population, and an average of 8.4 years of formal education.[25]

Software development and implementation steps

The study was conducted in the following steps, adapted from the recommendations of the Medical Research Council framework:[26] (1) needs assessment; (2) software development and validation; and (3) software implementation .[27,28]

Step 1 – Regional needs assessment

The population of the Vale do Mucuri lives far from technological centers, has less access to specialized health services, and suffers from poor conditions of treatment follow-up.[29] Extensive needs assessment research to investigate the gaps of care related to the diagnosis and management of hypertension and diabetes was conducted by the *Instituto de Métricas e Avaliação em Saúde* (Institute for Health Metrics and Evaluation) in Brazil, specifically for this project, as previously reported,[23,30] considering a literature review on hypertension and DM management and secondary data from two cities that are socioeconomically similar to the regions included in the HealthRise Project.

Step 2 – Software development and validation

The software was designed by a multidisciplinary team, composed of health and information technology professionals, in the following three stages: (1) pre-prototype; (2) software development; and (3) software validation. During tests and training stages, some items were improved according to users' requests, and the errors were corrected. Details of each stage are shown in the Supplemental Materials.

Step 3 – Software implementation

The field study included 34 primary care units (PCU) in 10 municipalities: Ataleia, Catuji, Crisólita, Frei Gaspar, Itaipé, Ladainha, Novo Oriente de Minas, Ouro Verde de Minas, Setubinha, and Teófilo Otoni. The criteria for selection of the municipalities were: HDI lower than 0.6 and a population of less than 20,000 inhabitants, with the

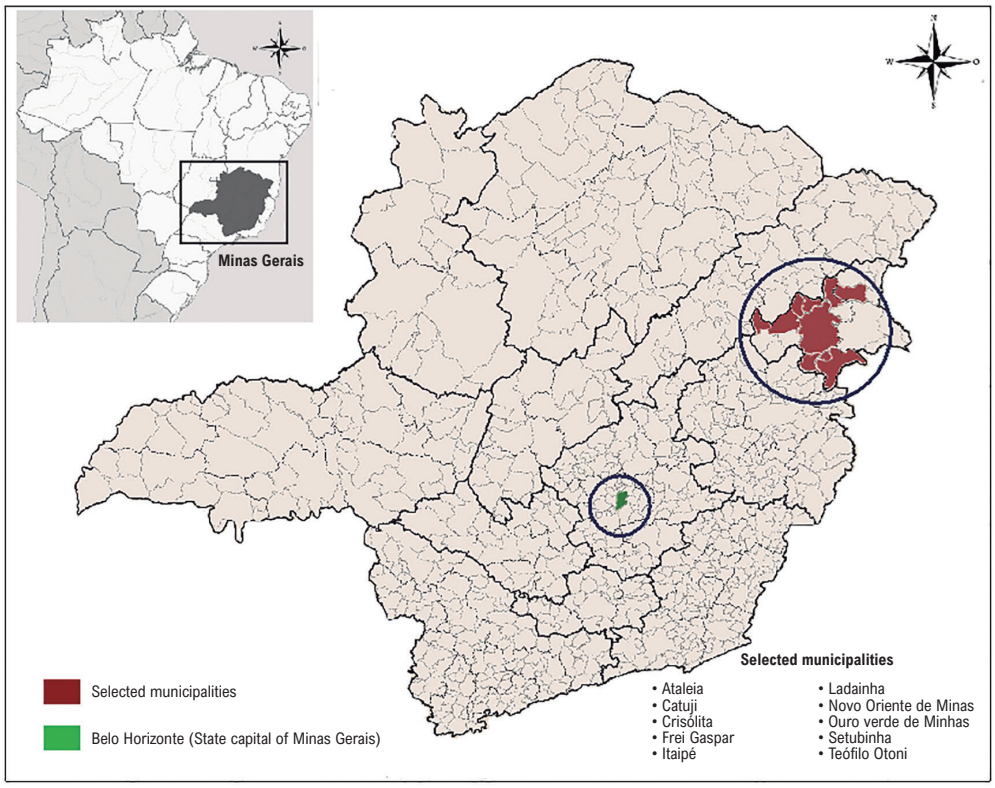


Figure 1 – Intervention area shown in a map of the state of Minas Gerais in Brazil.

exception of Teófilo Otoni, which was included because it was the location of the Medical School of *Universidade Federal dos Vales do Jequitinhonha e Mucuri*. The Brazilian Ministry of Health selected the Vale do Mucuri region for the field study, and the project coordinators established the criteria for inclusion of the municipalities.

Healthcare professionals participated in in-person and online training activities about the software and hypertension and DM screening. The research team developed a training plan for each category of professionals in health units (Supplemental Materials Table 1).

Each participant received a tablet with the screening app previously installed and configured in a fictional environment. The content was organized according to the professional category focused on in the practical software application. Participants had the opportunity to execute functions designated to each profile during the training. An electronic manual was available for all users and managers, providing detailed step-by-step instructions on correct app usage.

Field study and data collection

Patients were invited to participate in the screening program through information on PCUs, a campaign on local radio stations, dissemination by means of cars with loudspeakers, and directly by community health workers (CHW) in home visits.

The field study started in April 2017, through health fairs in the selected municipalities. The screening was conducted at the PCUs, through nursing consultations, when the same CDSS could be accessed via web and used to induct the patient in the flow. CHW visits and referral for PCU screening were performed until October 2018.

Target population

The target population included individuals of both sexes, aged 30 to 69 years, who were local residents of one of the 10 selected municipalities. Exclusion criteria were the coexistence of serious illness that limited life expectancy to less than 1 year; severe cognitive deficit; patients who were bedridden or unable to attend appointments at the PCUs;

and individuals who refused to participate. In addition, individuals with a previous diagnosis of hypertension were excluded from the screening for this condition, but kept for DM screening and individuals with a previous diagnosis of DM were excluded from the screening for this condition, but kept for screening for hypertension.

Diagnosis criteria for hypertension and DM are detailed in Supplemental Materials Table 2.

This study used a convenience sample; thus, a prespecified sample size was not calculated. All patients who met the aforementioned inclusion and exclusion criteria for hypertension screening and consented to take part in the study were screened for hypertension. For DM screening, all individuals with age ≥ 45 years, who had high or moderate cardiovascular risk or BMI ≥ 25 were screened, according to national and international guidelines, which consider being "Latino" as a risk factor for DM.[31]

Flow outline

The screening could be started in two different scenarios: in health fairs or at PCUs. During the health fairs, participating health professionals used a tablet with the CDSS installed. CHWs also used the software during household visits, and they could forward the patient to continue screening at a PCU, if necessary, or discharge the patient with lifestyle change recommendations. Considering these two ways to access patients, measurements of blood pressure, weight, height, and capillary glucose were performed.

As shown in Figure 2, patients with a prior diagnosis of hypertension or DM were directly referred for follow-up on control flow, with a doctor's appointment scheduled in 7 to 14 days. For both hypertension and DM screening, the patients answered a questionnaire about clinical conditions and had their measurements recorded, including weight,

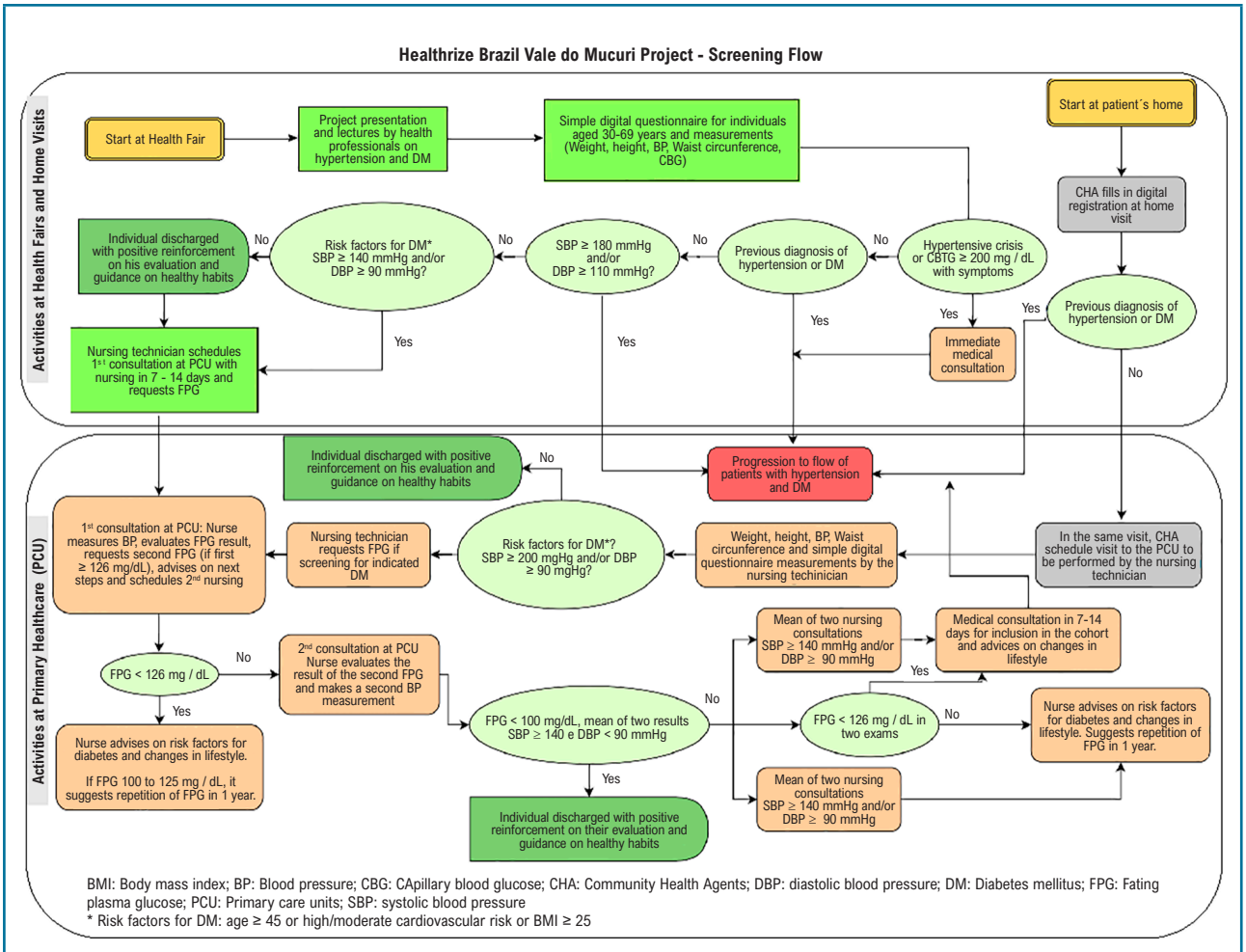


Figure 2 – Screening flow for hypertension and DM used at HealthRise Brazil Vale do Mucuri Project.

height, blood pressure, waist circumference, and capillary blood glucose. Details of each flow are shown in the Supplemental Materials.

Step 4 – Usability assessment

Usability and level of satisfaction related to the use of the application were assessed through a questionnaire, applied to the users of the tracking platform by the local coordinators at the end of screening phase in all participating cities. The questionnaire was organized into the following sections: (1) identification, (2) professional categorization, and (3) questions about satisfaction and usability. Basic information was obtained in the first part regarding city and professional position in the PHC team. Questions about sex, age, time worked as a PHC professional, and previous knowledge for use of information and communication technologies were gathered in the second part. To assess usability, the System Usability Scale was used, which is a validated usability questionnaire. This is based on a reverse score question Likert-scale questionnaire with 10 questions.[27,32] For satisfaction assessment, there were 5 Likert-scale questions developed specifically for the study, with options ranging from "totally agree" to "totally disagree" (Figure 3).

Statistical analysis

Data were described as absolute and relative frequencies for counts, and median and interquartile range (IQR) for continuous variables, as no continuous variables presented a normal distribution, when assessed by the Kolmogorov-Smirnov test. The data on patients who were assessed and excluded were compared using the chi-squared test for categorical variables. Among those included, comparisons were made across different professional categories using the chi-squared test for categorical variables.

Statistical tests were conducted with an alpha level of 0.05 in two-sided tests, considering p values < 0.05 as statistically significant. Data were processed and analyzed using IBM SPSS Statistics for Windows software (Version 21.0. Armonk, NY: IBM Corp.).

Results

Development and implementation

Software development was successful in the following screens: personal identification, questionnaire, measurements, and suggestions for decision-making or an alert screen (Supplemental Materials Figure 1).

In the field study, 18,375 patients were eligible for screening, with a median of 48 years of age (interquartile range [IQR] 39 to 57), 57.5% women; 13,775 patients were screened, with a median of 49 years of age (IQR 40 to 58), 59.7% women; 4,600 did not meet the requirements for assessment (i.e., did not sign informed consent, did not have both questionnaire and measurements taken, or both), with a median of 44 years of age (IQR 37 to 55), 50.8% female (Table 1).

Analysis of the patient flow is detailed in the Central Illustration. Of the 13,775 individuals who were assessed for hypertension, 6,115 (44.4%) presented a prior diagnosis. Thus, 7,660 participants with a properly answered questionnaire and registered measurements were included in the hypertension screening flow. Of those, 2,415 (31.5%) were screened negative and discharged with advice; 5,055 (66.0%) individuals did not complete the screening; and 185 (1.3%) new cases were diagnosed. Of the 13,775 individuals who were assessed for DM screening, 1,539 (11.2%) individuals presented a prior diagnosis. Therefore, 12,236 were screened. Following each step, 6,522 (53.3%) were screened negative and thus discharged; 5,674 (46.4%) were lost to follow-up; and a total of 35 (0.3%) new cases were diagnosed.

At the end of the screening, 185 patients were diagnosed with hypertension and 35 with DM, while 5 individuals were diagnosed with both hypertension and DM, totaling 225 new cases from the screening activities. The 225 new cases represent 1.6% of the initially screened population (13,775). It is important to highlight that 7,324 patients followed both flows (hypertension and DM) during part or all of the screening period. These data represent the success of the screening strategy in identifying, in a large group, those who were unaware of the diagnosis of hypertension, DM, or both, the most prevalent risk factors for CVD. Once diagnosed, these patients were properly referred for follow-up.

Usability assessment

In total, 258 healthcare professionals used the application, all of whom answered the questionnaire, with a median of 33 years of age (IQR 29 to 39), 74.5% women. Of those, 71.7% were CHWs; 14.7% were nurses; 4.6% were physicians, and 10.4% corresponded to other categories (nursing technician and allied health professionals). The number of participants per town ranged from 12 (Ataleia)

A. Professional Characterization
1. Gender: ( )M ( )F
2. Sex:
3. How long have you been working as a primary health care provessional?
4. How long have you consider your knowledge to use information and comunication technologies suck as computers, internet, tablet palm, smartphone before the start of this project?

Excellent | Good | Satisfactory | Below Satisfactory | Poor | I do not know how to answer

B. Usability and Satisfaction

Questions	Possible Answers				
	5. I totally agree	4. I agree	3. Indifferent	2. I disagree	I totally disagree
1. I think that i would like to use this system often					
2. I think that the app is unnecessarily complex					
3. I think that the system is easy to use					
4. I think that technical support is necessary to use this app					
5. I think that the various app functions were well integrated					
6. I think that were a lot of inconsistencies in this app					
7. I think that most people would learn to use the app quickly					
8. I thought the app complicated to use					
9. I felt very confident using the app					
10. I need to learn a number of things before i could continue using the app					
11. I felt comfortable using the app					
12. I easily found the information I needed					
13. The app interface (screen appearance) is pleasant					
14. The organization of information on the screen is clear					
15. I would recommend the app to an acquaintance					

Figure 3 – Usability and Satisfaction Questionnaire

to 44 (Ladainha). Participants' characteristics are shown in Table 2. There was a statistically significant difference among professionals regarding sex with a lower proportion of women among physicians (45.4%). About 52% considered their prior knowledge of the use of technologies to be good, while 19.2% considered it to be excellent, and 53.7% reported a desire to use the application frequently. There was no statistical difference among professionals about self-reported knowledge in information technology.

With regard to the questionnaire, 85.3% of the participants agreed that the application was easy to use; 81.8% considered the interface pleasant, and 78.4% would recommend the platform to a colleague (Table 3). Answers by categories are presented in detail in Supplemental Materials Table 3.

Discussion

We hypothesized that the implementation of a CDSS for screening hypertension and DM in primary care would be feasible in low-income regions, and its application would be beneficial within this context. This study developed a CDSS

Table 1 – Characteristics of the population*

	Eligible (n = 18,375)	Assessed (n = 13,775)	Excluded (n = 4,600)	p value
Sex				
Women	10,561 (57.5)	8,223 (59.7)	2,338 (50.8)	< 0.001
Education level				
Illiterate	2,842 (15.5)	2,062 (15.0)	780 (17.0)	0.001
Complete elementary school (8 years)	1,324 (7.2)	999 (7.2)	325 (7.1)	< 0.001
Incomplete elementary school (1 to 8 years)	8,877 (48.3)	6,572 (47.7)	2,305 (50.1)	0.005
Complete high school	2,714 (14.8)	2,121 (15,4)	593 (12.9)	< 0.001
Incomplete high school	1,455 (7.9)	1,129 (8.2)	326 (7.1)	0.016
Complete higher education	897 (4.9)	689 (5.0)	208 (4.5)	< 0.001
Incomplete higher education	183 (1.0)	137 (1.0)	46 (1.0)	< 0.001
Postgraduate	83 (0.4)	66 (0.5)	17 (0.4)	< 0.001
Family income				
No income	2.315 (12.6)	1,720 (12.5)	595 (12.9)	< 0.001
Up to 1 minimum wage	8,739 (47.6)	6,678 (48.5)	2,061 (44.8)	< 0.001
1 to 2 times minimum wage	4,843 (26.4)	3,787 (27.5)	1,056 (23.0)	< 0.001
2 to 4 times minimum wage	1,197 (6.2)	908 (6.5)	289 (6.3)	< 0.001
4 to 10 times minimum wage	125 (0.7)	96 (0.7)	29 (0.6)	< 0.001
10 to 20 times minimum wage	9 (0.05)	5 (0.04)	4 (0.1)	< 0.001
Unknown	1.147 (6.2)	581 (4.2)	566 (12.3)	< 0.001

** Absolute and percentage (%)*

Table 2 – Healthcare professionals' characteristics (%)

Variables	CHWs (n = 184)	Nurses (n = 37)	Physicians (n = 11)	Other health professionals (n = 26)	Total (n = 258)	p value
Sex						
Women	135 (73.3%)	29 (78.3%)	5 (45.4%)	23 (88.4%)	193 (74.8%)	0.047
Self-reported knowledge in information technology						
Excellent	34 (18.5%)	6 (16.2%)	4 (36.3%)	5 (19.2%)	49 (19%)	0.360
Good	90 (48.9%)	24 (64.8%)	5 (45.4%)	13 (50%)	132 (52.3%)	
Satisfactory	50 (27.2%)	7 (18.1%)	2 (18.2%)	6 (23%)	65 (25.2%)	
Below satisfactory/poor	10 (5.4%)	-	-	1 (3.8%)	11 (4.3%)	
Did not answer	-	-	-	1 (3.8%)	1 (0.4%)	

CHW: community health workers

Table 3 – Usability and satisfaction questionnaire (n = 258)

Questions	Totally agree (%)	Agree (%)	Indifferent (%)	Disagree (%)	Totally disagree (%)	Median score (IQR)
1. I think that I would like to use this system frequently	28.6	53.7	12.4	4.2	-	4 (4-5)
2. I found the system unnecessarily complex	1.9	9.7	12	58.7	14.3	2 (2-2)
3. I thought the system was easy to use	22	63.3	4.6	6.2	-	4 (4-4)
4. I think that I would need the support of a technical person to be able to use this system	8.1	28.2	14.3	40.2	5	3 (2-4)
5. I found the various functions in this system to be well integrated	13.9	58.7	10.8	13.1	0.4	4(3.5-4)
6. I thought there was too much inconsistency in this system	6.2	24.3	16.2	43.2	4.2	2 (2-4)
7. I would imagine that most people would learn to use this system very quickly	12	57.1	8.9	17	1.2	4 (3-4)
8. I found the system very cumbersome to use	1.9	8.9	9.7	63.3	12.7	2 (2-2)
9. I felt very confident using the system	15.8	57.9	14.7	7.7	0.4	4 (4-4)
10. I needed to learn a lot of things before I could get going with this system	3.9	27	10.4	48.3	8.1	2 (2-4)
11. I felt comfortable using the app	19.3	61	11.6	5.8	0.8	4 (4-4)
12. I easily found the information I needed	16.2	62.9	8.1	9,7	0.8	4 (4-4)
13. The app interface (screen design) is pleasant	13.1	68.7	10	5	-	4 (4-4)
14. The organization of information on the screen is clear	15.8	69.5	8.1	4.2	0.8	4 (4-4)
15. I would recommend the app to a colleague	14.7	63.7	10.4	8.9	1.2	4 (4-4)

IQR: interquartile range.
Ranging from 1 (totally disagree) to 5 (totally agree).

for the aforementioned purposes, implemented it in underserved municipalities in Vale do Mucuri, Minas Gerais, and confirmed our hypothesis. The software exhibited good performance for utilization, and the majority of healthcare professionals who participated in the study expressed their intent to recommend its use in a primary care setting.

Despite efforts and recent improvement in the treatment of hypertension and DM, CVDs remain the world's leading cause of morbidity and premature mortality, bearing important socioeconomic implications.[2,7,33,34] This justifies continuous search for modern tools for the identification and management of risk factors for CVDs. Awareness about the disease is a favorable factor for better control performance, even though it cannot be taken as an isolated determinant for successful treatment adherence, since negative attitudes toward dealing with DM, with cognitive manifestations that influence decision-making when facing a situation, may impair the ability to self-care. A study conducted in the Northeast Region of Brazil, in which 93.8% of patients with DM had a negative attitude towards coping with the disease, highlighted a negative and inversely proportional relationship between coping and adherence to physical activity and foot care.[35] Additionally, depressive symptoms affected 24.3% of the population in this study.[35] Given their recurring and significant impact on patient outcomes, e-health technologies have gained recognition for the treatment of depression, anxiety, and emotional distress in patients with DM.[36]

In Brazil, a study carried out with public servants to identify CVD and DM (ELSA-Brazil) showed that 80.2% of the population with high blood pressure was aware of their disease, a percentage close to that observed in Canada (82.6%).[37] However, due to the high illiteracy rates in the included municipalities, the needs assessment showed that a lower proportion of the patients with hypertension and DM were aware of the disease. Considering this context, screening programs are a favorable tool to enable early diagnosis and increase the estimate of treatment success.

Understanding the unique characteristics of a population, such as lifestyle behaviors, enables the development of more effective interventions for at-risk subgroups.[38] In the Vale do Mucuri region, it is important to account for the impact of social determinants of health when organizing the care strategy for chronic diseases, especially hypertension and DM. In this selected patient sample, the economic characteristics of the municipalities, with commerce and subsistence agriculture as the main sources of local income, bring these communities' lifestyle closer to that of rural workers. Nogueira et al. analyzed the profile of the most prevalent diseases and dietary characteristics in agricultural and non-agricultural workers and observed that agricultural workers exhibit even greater fragility of fruit and vegetable intake, along with lower rates of leisure time physical activity. These factors, associated with distances from PCUs and inflexible scheduling, position small Brazilian municipalities as strategic locations for the development of new initiatives and projects that can expand the screening and management of CVD.[19]

In the present study, 18,375 patients were assessed over a period of 17 months in the primary care setting (April 2017 to September 2018). The study showed that the software was applicable in that context, and it highlights the relevance of health fair activities and active search by CHWs through patient household visits, instead of waiting for these individuals to go to the health unit. The active search of such at-risk individuals was possible because the screening app was installed in tablets, which allowed for instant data inclusion. In this way, mobility capacity is one type of evidence highlighted in surveys that correlate technological strategies in healthcare services. Mobile programs have been associated with a reduction in user training time, achieving adequate proficiency in screening, and a minimization of human error when using workflow tools and systems.[39,40]

In total, 7,660 patients were screened for hypertension and 12,236 for DM, using a strategy carried out in an integrative field study between community activities at health events and individualized activities at PCUs, facilitated by using the CDSS. This scenario demonstrates the legitimacy of the CDSS as an auxiliary measure in PHC. Furthermore, the software's screening strategy combines clinical information with physical examination data, a superior screening resource when compared to traditional strategies in the diagnosis of DM, for example.[41] These devices integrate web applications or electronic health to a decision center based on updated information. They can be easily accessed and administered using desktops, tablets, and smartphones. Among the advantages in using CDSS, Sutton et al. points out the greater adherence to guidelines, cost reduction in the management of certain comorbidities, suggestion of differential diagnoses, integration of diagnostic resources (laboratory, pathology, imaging), and better patient data records.[42] It is interesting to note that computerized strategies can link initiatives to screening and managing complications, as a neural network-based method to stratify people at risk for developing diabetic foot, better directing the approach by the healthcare professional.[43]

It is important to highlight the low specificity of the criteria to refer patients for DM screening. Among 6,562 patients who completed screening for DM, according to the American Diabetes Association criteria,[7] 40 new cases were identified (0.6%). This result highlights the importance of logistics and economic conditions, since the diagnosis requires evaluations at separate time points and is based on specific laboratory results and resources that may not be always available in an area with limited health access. Throughout the study, as the primary care teams realized such low specificity, they decided to focus their efforts on the management of patients who were already diagnosed with hypertension and DM, which became another factor for the high number of patients lost to follow-up.

Another important finding is the level of approval and user acceptance when handling the application, even though some users had limited experience with electronic health records before the implementation of the application. The training strategy was designed in order to put into practice tasks that should be performed by each professional category, respecting

individualized understanding. The needs assessment and the training meetings were essential to understand the reality of the PCUs, to anticipate the difficulties that professionals could face when handling the application, and to make accurate adjustments in the application.

Despite the profusion of applications and platforms currently aimed at a health area, more than 95% have not been tested for feasibility or were assessed only in a particular stage of the development process.[27,44] In the present study, usability was assessed using a validated questionnaire, which demonstrated positive assessment by the users: "I think that the system is easy to use" was the choice for 85.3% of the participants, and "I felt very confident using the app" received a positive answer from 73.7% of the participants. Questions were also added to analyze satisfaction with the app.[32] It was considered a pleasant platform (81.8% of the evaluations agreed or totally agreed) and recommendable to new users (78.4%). This tool's applicability in PHC can be reinforced by its good execution during screening.

Another relevant analysis is understanding task shifting strategy as an approach to deal with the rising incidence of CVD, recognizing healthcare staff shortages, especially in regions with a low development index. Screening in those remote municipalities was a medical-centered task, and doctors did not have enough time for that activity during their work routine. The decision-making support provided by the software made this possible, which was essential to reaching a larger number of patients. Task shifting practice is already known in critical regions that have to deal with high-impact diseases.[45] The present study included the active involvement of CHWs and nurses in screening activities, acting in strategic positions from the stage of patient reception to the completion of the study at the PCU, each one with a specific role in the screening flow.[46-48]

Limitations

This study used a convenience sample. Although we were able to reach a large number of people, some volunteers did not complete the screening.

For the usability assessment, only an indirect analysis was performed, using a questionnaire. Complementation of this information could have benefited from a direct usability analysis through the observation of each user when manipulating the platform and/or a qualitative approach. It is also important to consider that we applied a Likert-scale questionnaire, in which answer choices varied from "totally disagree," "disagree," "indifferent," "agree," to "totally agree." This may generate doubts, because these concepts may not be as clear to the participant as they are to the researcher.[8]

Additionally, we must point out the limitations of the application highlighted by the users. About 11.6% of the respondents said that the application is unnecessarily complicated to use, and 36.3% stated that some type of technical support would be necessary to start using the platform. This impression is probably a reflection of the low level of knowledge to deal with technology that some professionals had at the beginning of the study. Answers from 30.5% of the users indicated inconsistencies within the tool, motivating a systematic checking of the decision-making support structure. These inconsistencies led to corrections in the fields of data entry and insertion of limits to prevent data with small errors from being recognized as conditions in the decision tree. Due to the decision support system integrating two flows (screening for hypertension and diabetes), there were difficulties in combining the decision reasoning between the flows, especially in the first step (initial approach), which resulted in the need for multiple adjustments to the decision tree. Those rates indicate that there is a possibility for improving the tool and eliminating errors, so that it can be even easier and more practical to use, approaching the reality of this population's technological knowledge.

Lessons and strengths

Significant insights gleaned from the study should be acknowledged. An integrated and multidisciplinary framework, based on available evidence and tailored to the specific target population, proved instrumental in the successful deployment of digital tools. Another relevant aspect was recognizing the needs and characteristics of the project's development region, enabling effective education of the population about the strategy's significance and its far-reaching impacts. This approach facilitated enhanced participation in the screening process, fostering the concept of self-care, which is pivotal for diagnosis and subsequent control measures.

Furthermore, it is worth noting the feasibility of this strategy as a complementary component of the public health system, with the potential to yield benefits in screening large-scale populations. The observed applicability during the implementation phase and

the positive user experience support the notion that utilizing CDSS for screening can be adapted for other regions. Thus, we realize how technology can extend its benefits to the realm of healthcare, even in challenging circumstances and remote areas where healthcare access may be constrained by geographical, social, and administrative barriers.

Conclusion

This study showed that the implementation of a CDSS to support the screening of hypertension and DM in the context of primary care in a resource-constrained area was feasible, with good user satisfaction. The positive screening in the study was modest, as only 33.94% of the screened individuals actually completed all phases for hypertension and 53.58% for DM, most likely due to logistic limitations and impaired comprehension among patients, especially those from a population with high levels of illiteracy. A low specificity of the American Diabetes Association criteria to refer patients for DM screening was also observed. Further studies aimed at assessing the costs of using CDSS for screening, as well as the clinical impact of using these applications, are still needed .

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, statistical analysis, obtaining financing, writing of the manuscript, critical revision of the manuscript for intellectual content: Melo LDR, Ribeiro ALP, Oliveira JAQ, Maia JX, Sá TQV, Pinto VSAO, Lima MMO, Enlich PW, Ribeiro LB, Cimini CCR, Marcolino MS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

This study was funded by Medtronic Foundation.

MSM was supported in part by CNPq [grant number 310561/2021–3].

ALPR was supported in part by CNPq (grant numbers 465518/2014-1, 310790/2021-2, 409604/2022-4 e 445011/2023-8) and FAPEMIG (RED 00192-23).

The funding body played no role in the design of the study, developing the software, and collection, analysis and interpretation of data, and in writing the manuscript.

Study Association

This article is part of the thesis of master submitted by Laura Defensor Ribeiro de Melo, from *Universidade Federal de Minas Gerais*.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee on Animal Experiments of the *Universidade Federal dos Vales do Jequitinhonha e Mucuri* under the protocol number 2.006.761.

References

1. Brasil. Ministério da Saúde. Cardiovascular Health Strategy: Instruction for Professionals and Managers of Primary Health Care. Brasília: Ministério da Saúde; 2022.
2. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990-2010: A Systematic Analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2224-60. doi: 10.1016/S0140-6736(12)61766-8.
3. International Diabetes Federation. IDF Diabetes Atlas [Internet]. Brussels: International Diabetes Federation; 2021 [cited 2023 Sep 24]. Available from: https://www.diabetesatlas.org.
4. Brasil. Ministério da Saúde. Vigitel Brazil 2019: Surveillance of Risk and Protective Factors for Chronic Diseases by Telephone Survey. Brasília: Ministério da Saúde; 2020.
5. Herman WH, Ye W, Griffin SJ, Simmons RK, Davies MJ, Khunti K, et al. Early Detection and Treatment of Type 2 Diabetes Reduce Cardiovascular Morbidity and Mortality: A Simulation of the Results of the Anglo-Danish-Dutch Study of Intensive Treatment in People With Screen-Detected Diabetes in Primary Care (ADDITION-Europe). Diabetes Care. 2015;38(8):1449-55. doi: 10.2337/dc14-2459.
6. Bertoluci MC, Silva WS Jr, Valente F, Araujo LR, Lyra R, Castro JJ, et al. 2023 UPDATE: Luso-Brazilian Evidence-based Guideline for the Management of Antidiabetic Therapy in Type 2 Diabetes. Diabetol Metab Syndr. 2023;15(1):160. doi: 10.1186/s13098-023-01121-x.
7. American Diabetes Association. Standards of Care in Diabetes-2023 Abridged for Primary Care Providers. Clin Diabetes. 2022;41(1):4-31. doi: 10.2337/cd23-as01.
8. Palma CCSSV, Lopes PM, Bomfim AS, Gomes MB. Pragmatic Clinic-based Investigation of Echocardiogram Parameters in Asymptomatic Patients with Type 2 Diabetes in Routine Clinical Practice and its Association with Suggestive Coronary Artery Disease: A Pilot Study. Diabetol Metab Syndr. 2023;15(1):162. doi: 10.1186/s13098-023-01128-4.
9. Zhang D, Gao H, Song X, Raposeiras-Roubín S, Abu-Assi E, Henriques JPS, et al. Optimal Medical Therapy Improves Outcomes in Patients with

Diabetes Mellitus and Acute Myocardial Infarction. Diabetes Res Clin Pract. 2023;203:110833. doi: 10.1016/j.diabres.2023.1108333.

10. Siu AL. Screening for High Blood Pressure in Adults: U.S. Preventive Services Task Force Recommendation Statement. Ann Intern Med. 2015;163(10):778-86. doi: 10.7326/M15-2223.

11. Zhu KF, Wang YM, Zhu JZ, Zhou QY, Wang NF. National Prevalence of Coronary Heart Disease and its Relationship with Human Development Index: A Systematic Review. Eur J Prev Cardiol. 2016;23(5):530-43. doi: 10.1177/2047487315587402.

12. van Lenthe FJ, Gevers E, Joung IM, Bosma H, Mackenbach JP. Material and Behavioral Factors in the Explanation of Educational Differences in Incidence of Acute Myocardial Infarction: The Globe Study. Ann Epidemiol. 2002;12(8):535-42. doi: 10.1016/s1047-2797(01)00279-4.

13. Paim J, Travassos C, Almeida C, Bahia L, Macinko J. The Brazilian Health System: History, Advances, and Challenges. Lancet. 2011;377(9779):1778-97. doi: 10.1016/S0140-6736(11)60054-8.

14. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global Burden of Cardiovascular Diseases and Risk Factors, 1990-2019: Update From the GBD 2019 Study. J Am Coll Cardiol. 2020;76(25):2982-3021. doi: 10.1016/j.jacc.2020.11.010.

15. Alkmim MB, Marcolino MS, Figueira RM, Sousa L, Nunes MS, Cardoso CS, et al. Factors Associated with the Use of a Teleconsultation System in Brazilian Primary Care. Telemed J E Health. 2015;21(6):473-83. doi: 10.1089/tmj.2014.0112.

16. Alkmim MB, Silva CBG, Figueira RM, Santos DVV, Ribeiro LB, Paixão MC, et al. Brazilian National Service of Telediagnosis in Electrocardiography. Stud Health Technol Inform. 2019;264:1635-6. doi: 10.3233/SHTI190571.

17. Bryan C, Boren SA. The Use and Effectiveness of Electronic Clinical Decision Support Tools in the Ambulatory/Primary Care Setting: A Systematic Review of the Literature. Inform Prim Care. 2008;16(2):79-91. doi: 10.14236/jhi.v16i2.679.

18. World Health Organization. Monitoring and Evaluating Digital Health Interventions: A Practical Guide to Conducting Research and Assessment. Geneva: World Health Organization; 2016.

19. Nogueira FAM, Damacena GN, Souza PRB Jr, Szcwarcwald CL. Self-reported Morbidities and Lifestyles of Agricultural and Non-agricultural Workers in Brazil: A Comparative Analysis Between 2013 and 2019. Cien Saude Colet. 2023;28(7):1971. doi: 10.1590/1413-81232023287.15922022.

20. Castillo RS, Kelemen A. Considerations for a Successful Clinical Decision Support System. Comput Inform Nurs. 2013;31(7):319-26. doi: 10.1097/NXN.0b013e3182997a9c.

21. Lobach D, Sanders GD, Bright TJ, Wong A, Dhurjati R, Bristow E, et al. Enabling Health Care Decision Making Through Clinical Decision Support and Knowledge Management. Evid Rep Technol Assess (Full Rep). 2012;(203):1-784.

22. Flor LS, Wilson S, Bhatt P, Bryant M, Burnett A, Camarda JN, et al. Community-based Interventions for Detection and Management of Diabetes and Hypertension in Underserved Communities: A Mixed-methods Evaluation in Brazil, India, South Africa and the USA. BMJ Glob Health. 2020;5(6):e001959. doi: 10.1136/bmjgh-2019-001959.

23. Medtronic Foundation. HealthRise Final Report: Expanding Access to Chronic Disease Care through Community Approaches in Four Countries. Sydney: Medtronic Foundation; 2019.

24. Instituto de Pesquisa Econômica Aplicada. Programa das Nações Unidas para o Desenvolvimento. Desenvolvimento Humano nas Macrorregiões Brasileiras. Brasília: Instituto de Pesquisa Econômica Aplicada; 2016.

25. Malachias I, Leles FAG, Pinto MAS. Plano Diretor de Regionalização da Saúde de Minas Gerais. Belo Horizonte: Secretaria de Estado de Saúde de Minas Gerais; 2010.

26. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. Developing and Evaluating Complex Interventions: The New Medical Research Council Guidance. BMJ. 2008;337:a1655. doi: 10.1136/bmj.a1655.

27. Cho H, Yen PY, Dowding D, Merrill JA, Schnall R. A multi-level Usability Evaluation of Mobile Health Applications: A Case Study. J Biomed Inform. 2018;86:79-89. doi: 10.1016/j.jbi.2018.08.012.

28. Yen PY, Bakken S. Review of Health Information Technology Usability Study Methodologies. J Am Med Inform Assoc. 2012;19(3):413-22. doi: 10.1136/amiajnl-2010-000020.

29. Magalhães SCM, Lima SC. Cenário da Rede de Saúde no Norte de Minas Gerais. Hygeia. 2012;8(15):245-58. doi: 10.14393/Hygeia819880.

30. Marcolino MS, Oliveira JAQ, Cimini CCR, Maia JX, Pinto VSOA, Sá TQV, et al. Development and Implementation of a Decision Support System to Improve Control of Hypertension and Diabetes in a Resource-Constrained Area in Brazil: Mixed Methods Study. J Med Internet Res. 2021;23(1):e18872. doi: 10.2196/18872.

31. American Diabetes Association Professional Practice Committee. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes-2022. Diabetes Care. 2022;45(Suppl 1):17-38.

32. Brooke J. SUS: A Quick and Dirty Usability Scale. In: Jordan PW, Thomas B, McClelland IL, Weerdmeester B (editors). London: CRC Press; 1996.

33. GBD 2017 Causes of Death Collaborators. Global, Regional, and National Age-sex-specific Mortality for 282 Causes of Death in 195 Countries and Territories, 1980-2017: A Systematic Analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392(10159):1736-88. doi: 10.1016/S0140-6736(18)32203-7.

34. Khan T, Yang J, Wozniak G. Trends in Medical Expenditures Prior to Diabetes Diagnosis: The Early Burden of Diabetes. Popul Health Manag. 2021;24(1):46-51. doi: 10.1089/pop.2019.0143.

35. Frazão MCLO, Viana LRC, Ferreira GRS, Pimenta CJL, Silva CRRD, Madruga KMA, et al. Correlation Between Symptoms of Depression, Attitude, and Self-care in Elderly with Type 2 Diabetes. Rev Bras Enferm. 2023;76(3):e20220741. doi: 10.1590/0034-7167-2022-0741.

36. Franquez RT, Moura MDG, McClung DCF, Barberato-Filho S, Lopes LC, Silva MT, et al. E-Health Technologies for Treatment of Depression, Anxiety and Emotional Distress in Person with Diabetes Mellitus: A Systematic Review and Meta-analysis. Diabetes Res Clin Pract. 2023;203:110854. doi: 10.1016/j.diabres.2023.110854.

37. Chor D, Ribeiro ALP, Carvalho MS, Duncan BB, Lotufo PA, Nobre AA, et al. Prevalence, Awareness, Treatment and Influence of Socioeconomic Variables on Control of High Blood Pressure: Results of the ELSA-Brasil Study. PLoS One. 2015;10(6):e0127382. doi: 10.1371/journal.pone.0127382.

38. Peres GB, Nucci LB, Andrade ALM, Enes CC. Lifestyle Behaviors and Associated Factors Among Individuals with Diabetes in Brazil: A Latent Class Analysis Approach. Cien Saude Colet. 2023;28(7):1983-92. doi: 10.1590/1413-81232023287.05622022.

39. Braun R, Catalani C, Wimbush J, Israelski D. Community Health Workers and Mobile Technology: A Systematic Review of the Literature. PLoS One. 2013;8(6):e65772. doi: 10.1371/journal.pone.0065772.

40. Surka S, Edirippulige S, Steyn K, Gaziano T, Puoane T, Levitt N. Evaluating the Use of Mobile Phone Technology to Enhance Cardiovascular Disease Screening by Community Health Workers. Int J Med Inform. 2014;83(9):648-54. doi: 10.1016/j.ijmedinf.2014.06.008.

41. Bracco PA, Schmidt MI, Vigo A, Mill JG, Vidigal PG, Barreto SM, et al. Optimizing Strategies to Identify High Risk of Developing Type 2 Diabetes. Front Endocrinol (Lausanne). 2023;14:1166147. doi: 10.3389/fendo.2023.1166147.

42. Sutton RT, Pincock D, Baumgart DC, Sadowski DC, Fedorak RN, Kroeker KI. An Overview of Clinical Decision Support Systems: Benefits, Risks, and Strategies for Success. NPJ Digit Med. 2020;3:17. doi: 10.1038/s41746-020-0221-y.

43. Ferreira ACBH, Ferreira DD, Barbosa BHG, Oliveira UA, Padua EA, Chiarini FO, et al. Neural Network-based Method to Stratify People at Risk for Developing Diabetic Foot: A Support System for Health Professionals. PLoS One. 2023;18(7):e0288466. doi: 10.1371/journal.pone.0288466.

44. Roess A. The Promise, Growth, and Reality of Mobile Health - Another Data-free Zone. N Engl J Med. 2017;377(21):2010-1. doi: 10.1056/NEJMp1713180.

45. World Health Organization. Task Shifting: Rational Redistribution of Tasks Among Health Workforce Teams: Global Recommendations and Guidelines. Geneva: World Health Organization; 2007.

46. Brasil. Ministério da Saúde. Caderno de Atenção Primária: Rastreamento. Brasília: Ministério da Saúde; 2010.

47. Castro MC, Massuda A, Almeida G, Menezes-Filho NA, Andrade MV, Noronha KVMA, et al. Brazil's Unified Health System: The First 30 Years and Prospects for the Future. Lancet. 2019;394(10195):345-56. doi: 10.1016/S0140-6736(19)31243-7.

48. World Health Organization. Strengthening Primary Health Care Through Community Health Workers: Investment Case and Financing Recommendations. Geneva: World Health Organization; 2015.

*Supplemental Materials

For additional information, please click here.