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Mobile solution and chronic diseases: development and implementation of a mobile application and digital platform for collecting, analyzing data, monitoring and managing health care

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Abstract

Background Technological advances based on mobile health (mHealth), the field of digital health (eHealth) aimed at managing health services and care and their concomitant transformations, have become increasingly important in the 21st century. In this context, care for individuals diagnosed with Chronic Non-Communicable Diseases (CNCDs) deserves to be highlighted. The aim of this study is to present the creation, development and implementation of the Telehealth Center of the Federal University of Viçosa (NUTELES - UFV), for the monitoring and management of health care for individuals with Arterial Hypertension (AH) and/or Diabetes Mellitus (DM).

Methods This study, carried out in 2022 and 2023, involved 374 patients diagnosed with AH and/or DM in the health micro-region of Viçosa/MG, Brazil, comprising nine municipalities. The research aims to describe the creation, development and implementation of a software (NutelesApp) for the collection, storage, management and analysis of epidemiological research in public health, focusing specifically, on the monitoring and management of health care for individuals with AH and/or DM monitored by Primary Health Care (PHC). The parameters collected and analyzed were obtained through a questionnaire applied to patients, consisting of 70 questions, subdivided into 12 classes of questions. The epidemiological survey data was collected using mobile devices and analyzed using computer techniques based on statistical analysis. Once the field teams had completed their work, the files were transferred to servers for general analysis processing, using estimates of means, prevalence and respective standard errors, calculated using the Statistical Package for Social Science (SPSS) program, which takes into account the planning variables and includes the basic weights resulting from the sampling process. This study was approved by the Human Research Ethics Committee and registered, prior to recruitment, by the Brazilian Registry of Clinical Trials (ReBEC), ID: RBR-45hqzmf (Last approval date: 11/30/2022).

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Results The information obtained through data collection with subsequent exploratory analysis of epidemiological data using the NutelesApp software suggests that mobile applications intended for the purpose of monitoring and managing healthcare for people with AH and/or DM should address the variables necessary to support a process of understanding the health conditions and/or disease of the individual as a whole and provide short- and long-term learning. Regarding the results of the survey using the software, the variables of 374 people were analyzed. Majority are female (73.2%) and white (43.5%). Most patients are elderly (average 64 years), with blood pressure levels within the normal range for this population, BMI indicates overweight, AC increased risk for cardiovascular events and CC within the recommendation value. All biochemical parameters analyzed were above normal limits.

Conclusions The description of the creation and development of the software includes practical examples of its implementation, the results collected and its applicability in real scenarios, presenting determining criteria that can provide assertive and timely interventions for monitoring and managing the health and/or disease parameters of patients with HA and/or DM. In addition, the beneficial consequences of using this application will extend to health units and their respective management, improving the services provided by PHC and enhancing strategies and actions for health promotion and disease prevention.

Keywords Public health, Hypertension, Diabetes, Health monitoring, Healthcare management

Introduction

Chronic Non-Communicable Diseases (NCDs) are a global public health problem and are the main causes of mortality in the world [1, 2]. These include Arterial Hypertension (AH), which currently affects approximately 1.13 billion people worldwide, and Diabetes Mellitus (DM), which is estimated to increase from 537 million (in 2021) to 578 to 700 million between 2030 and 2045 [3–5].

The World Health Organization (WHO) estimates that the world's elderly population will double from 12 to 22% by 2050 [6]. In Brazil, the latest census carried out by the Brazilian Institute of Geography and Statistics in 2022 showed that the total number of people aged 65 or over in the country increased by 57.4% compared to 2010 [7]. Population ageing increases the risk of many chronic diseases, so monitoring and managing them is of paramount importance and represents a major challenge for public health worldwide [8].

It is known that both AH and DM are multifactorial diseases, many of which are modifiable, such as sedentary lifestyles, smoking, poor diet and behavioral influences such as non-adherence to drug treatment [5, 9]. To this end, some innovative, cost-effective and sustainable approaches, in line with the Sustainable Development Goals (SDGs), have been employed to reduce the negative influences on patients' health conditions and/or diseases and improve the management of their healthcare [10, 11].

In this sense, the WHO [12] advocates that Primary Health Care (PHC) should be placed at the center of efforts to improve the well-being of the population. This is because a strong and well-structured PHC reduces total health expenditure and is essential to achieve the SDGs related to universal health coverage. Therefore, in the same year, a project was proposed in Brazil that aims to identify innovative strategies to address the obstacles related to PHC, so that the country can achieve the SDG targets and strengthen health actions for people affected by NCDs [13]. One of the main conclusions of this proposal involved promoting the use of technologies oriented towards health promotion and prevention of diseases and illnesses through the use of Innovation and Communication Technologies (ICTs) [12]. With this, it is concluded that Brazil is on the right path to managing the chronic diseases that affect it, however, it is necessary to innovate its health practices to be in line with the goals proposed by the WHO and increasingly benefit the health services provided and, mainly, the health and well-being of the population.

In this scenario, technological advances based on mobile health (mHealth), the field of digital health (eHealth) with a focus on the management of health services and care and its concomitant transformations, have become increasingly important in the 21st century and received great encouragement from the WHO [11, 14]. eHealth can be used for many purposes and presents consistent results in studies already carried out, such as reducing the incidence of chronic diseases, increasing adherence to treatment, adequate screening and long-term and remote follow-up measures, through the implementation of adequate preventive and educational actions [14–18].

An important issue to be considered is the target audience for the technological applications that are created. As already mentioned, the elderly population is increasing exponentially [6, 7]. Linked to this, the risk of developing and complications of chronic diseases increases with aging. Although there is concern about the capacity and preference for using health technologies by the elderly, evidence shows that they have good interaction with educational environments developed within

the mobile application with information and guidance on the disease, which allows self-monitoring and management of their own health conditions [19–21]. A systematic review with meta-analysis focused on the use of mobile applications as a digital intervention for adults and the elderly, found that there was an improvement in the monitoring of these patients, with the intervention group, that is, those who used mobile health applications, having a reduction of 0.39% (CI 0.24–0.54) in the value of glycated hemoglobin (HbA1c) compared to the usual care group [22]. This evidence reinforces not only that the elderly can use this type of innovation, but also that it is possible to use these types of technology for the benefit of the population without harming their health and/or disease indicators.

It is also worth noting that this technological innovation in the health area does not replace the specialized workforce. However, there is evidence that digital health has advanced significantly and presents better results when compared to the approach traditionally used in health services [22, 23]. Therefore, these technological alternatives must be better studied, developed and implemented.

As demonstrated, although mHealth has made great progress, especially in recent years, more research on the creation, implementation and evaluation of mobile applications is needed to fill existing gaps, such as the implementation of mHealth in low- and middle-income countries; technologies with interfaces that allow continuous monitoring of data received in a systematic way; and educational programs to raise patients' awareness of the applications of digital health technology [24, 25].

We are aware of the existence of various software, programs and other innovative proposals with different objectives and aimed at different audiences. However, it is always necessary to consider the peculiarities of each population and their respective comorbidities. Therefore, research in this field must propose the development of new software that is, in fact, effective and efficient for the audience and service for which it is intended. This is why our research group identified the need to develop a Telehealth Center aimed at adults and elderly people diagnosed with AH and/or DM, specifically focused on monitoring and managing the health care of this population.

The aim of this study is therefore to describe the development and present the implementation of a new health technology application, the Telehealth Center of the Federal University of Viçosa (NUTELES - UFV), a software program designed to monitor and manage the health care of adult and elderly individuals with AH and/or DM assisted by Primary Health Care (PHC).

Materials and methods

In this section, we describe the methodology of the study, providing a theoretical basis and a description of the design and development of the technological application we developed, NUTELES-UFV, which comprises a mobile application (NutelesApp) and a digital platform (NutelesWeb).

The actions were carried out based on the targets set by the United Nations (UN) SDGs, especially those related to SDG 3, which includes ensuring a healthy life and well-being for all, and SDG 17, which aims to strengthen the means of implementation and revitalization of the global partnership for sustainable development.

Ethical considerations

This study was approved by the Human Research Ethics Committee of the Federal University of Viçosa (UFV), under opinion No. 4.475.901 and registered, prior to recruitment, by the Brazilian Registry of Clinical Trials (ReBEC), ID: RBR-45hqzmf (Last approval date: 11/30/2022). In accordance with Resolution No. 466/2012 of the National Health Council, which regulates research involving human beings, individuals were asked to sign an Informed Consent Form (ICF) in order to take part in the study, guaranteeing the confidentiality of the information and their anonymity.

Recruiting participants

A total of 374 adult and elderly participants were recruited from nine municipalities in the health micro-region of Viçosa, Minas Gerais, Brazil, which is part of the Zona da Mata region of the state of Minas Gerais, Brazil. In total, participants were recruited from 19 health units in the aforementioned micro-region.

In order to select the sample, the following inclusion criteria were considered: age over 18 years old; being followed up by PHC units and with a confirmed diagnosis of AH and/or DM. Patients with serious clinical conditions requiring specialized care, pregnant women and individuals with a history of alcohol and/or drug abuse, bedridden people or those using wheelchairs were excluded from the study.

Data collection and tools

The definition of the parameters collected and analyzed was established through an extensive literature review and consultation with specialists in the field. As a result, we drew up a questionnaire (Supplementary file 1). That was applied to the patients, consisting of 70 questions, subdivided into 12 classes of questions related to sociodemographic characteristics, behavioral factors, clinical and physical assessment, health care, eating habits, level of physical activity [26] and laboratory tests.

Table 1 shows the description of the questions in each class and their respective questions.

All these parameters were collected using a semi-structured questionnaire that was developed and pre-tested in a pilot study in a population and municipality with characteristics similar to those of the study in question, but which is not part of the sample studied.

In order to automate the process, data collection was carried out using a computer environment and application (NutelesApp) running on mobile electronic devices (Smartphones/Tablets/Computers), where the questionnaire was applied by previously trained and qualified researchers.

Intervention - NUTELES/UFV technological application

NUTELES-UFV, which includes NutelesWeb and NutelesApp, was created by researchers from the University Teaching Innovation Program (PRODUS), UFV's Health Planning and Management Studies Laboratory (LabPlanGest) and UFT's Database and Software Engineering Laboratory. The main objectives of the mobile application are to store sociodemographic and health data and information and to monitor modifiable parameters (behavioral factors, lifestyle habits, physical assessment, food consumption, laboratory tests) in the medium and long term. It also provides reliable information and guidance based on scientific evidence on NCDs, giving patients, families and professionals control over the content and access. In this way, care is integrated and health promotion and the prevention of illnesses and morbidities is provided and conducted in a viable and appropriate manner.

With this, NUTELES-UFV comprises a functional system that was presented to users in the early stages to obtain improvements, ideas and requirements for the final product, providing support for the needs and desires of users and health professionals, creating an environment conducive to behavioral changes and extracting the main aspects that the adults and elderly people in the study need and/or would like to have in a mobile application to support the treatment and monitoring of their comorbidity.

The NUTELES-UFV technological application includes: (1) architecture and computing environment, (2) data architecture, (3) functional and non-functional requirements of NUTELES-UFV, (4) navigation hierarchy and (5) interaction with the user through personal guidance and educational resources in the application.

Architecture of the NUTELES/UFV computing environment

The environment consists of a mobile application, developed for remote data collection in the field, and also a web-based information system for synchronizing and managing all the data collected in the field. The app and web application store the data collected in a centralized database. The management system can therefore be

Table 1 Classification of the questions in the questionnaire applied to patients

Class	Question description	Questions
Personal characteristics	Sociodemographic information, such as age, gender, race, occupation, income, living situation (all of which preserved the anonymity of the patients).	1–9
Housing situation	Information on whether the home is owned or not, whether it has internet access and what kind.	10–12
Clinical assessment	Information on existing comorbidities, namely: DM, AH, CKD, Peripheral Vascular Disease, heart disease, depression, anxiety, obesity, dyslipidemia and medication use.	13–24
Adverse events	Information on whether the patient has been affected by the SARS-CoV 2 virus and whether they have been hospitalized in the last year for any reason.	25–26
Target organ damage	Information on whether the patient has ever had a heart attack, stroke, diagnosis of hypertensive or diabetic retinopathy and/or diabetic neuropathy.	27–30
Family history of illness (father, mother, children and siblings)	Information on whether the patient has a father, mother, children and/or siblings who had/have DM, AH, CKD, heart disease, stroke, suffered a heart attack, dementia, anxiety, depression, obesity and/or dyslipidemia.	31–42
Clinical assessment	Current clinical signs and symptoms include changes in appetite, weight and urination, weakness, blurred vision, edema, dizziness, thirst, vomiting, diarrhea and lesions/pain in the lower limbs. Measurement of DBP, SBP and heart rate.	43–58
Physical examination	Measurement of anthropometric measurements such as weight, height, Body Mass Index (BMI), Abdominal Circumference (AC) and Calf Circumference (CC).	59–63
Risk factor assessment	Information on smoking, alcoholism, illicit drugs and protein supplementation.	64–67
Food consumption	Information on the consumption of foods such as raw salad, cooked vegetables, fresh fruit, beans, milk, fried snacks, sausages, sweet and savory cookies, soft drinks and coffee.	68 (QFA)
Physical activity	Information on the practice of moderate or vigorous physical activity and its frequency.	69 (IPAQ)
Laboratory evaluation	Information on biochemical tests of interest, such as: fasting glucose, glycated hemoglobin, uric acid, total cholesterol and fractions, calcium, phosphorus, sodium, potassium and complete blood count.	70

accessed via a web browser or via a mobile application initially available on Google Play. The architecture of the environment is shown in Fig. 1.

Figure 1 shows the components (modules) that make up the NUTELES-UFV computer architecture. The NutelesApp consists of the mobile version of the application, used to collect epidemiological data in the field. The application has three main actors: the system administrator, the health professional and the public served. The system administrator is responsible for registering health professionals, who in turn are able to register patients in the system. They also have the ability to create new users and survey questionnaires. The health professional, on the other hand, has the specific ability to register an action to collect information on patients, with the latter user filling in the form with their health information.

The application temporarily stores the data collected on the mobile device during field data collection activities and then synchronizes the collected field data with the application's central server, thus keeping the information up to date. NutelesApp has five modules:

- Registration module: comprises the collection of user data the first time the user accesses the system.
- Authentication module: guarantees restricted access to information by registering the user in the system for the purposes of identification and profile association (health professional and/or patient).
- Storage module: runs the routines for managing database transactions by controlling inserts, updates, deletes and queries in the database.
- Survey form module: presents and collects data from the patient survey.
- Visualization module: presents a mechanism for visualizing information.

The application requires an internet connection, since its database is in a remote repository. However, it has an access control mechanism to preserve access to the data collected and stored in the database. The application can be filled in by users and health professionals, who initially enter their personal details, such as their individual registration number, address, contact telephone number and which health unit they are linked to.

NUTELES data architecture

The main functions of the NutelesApp platform are health data collection, information analysis and visualization of patient data. The platform makes it possible to obtain more flexible data, as it allows healthcare professionals to be mobile when collecting it. In addition, the platform enables the application of inference mechanisms

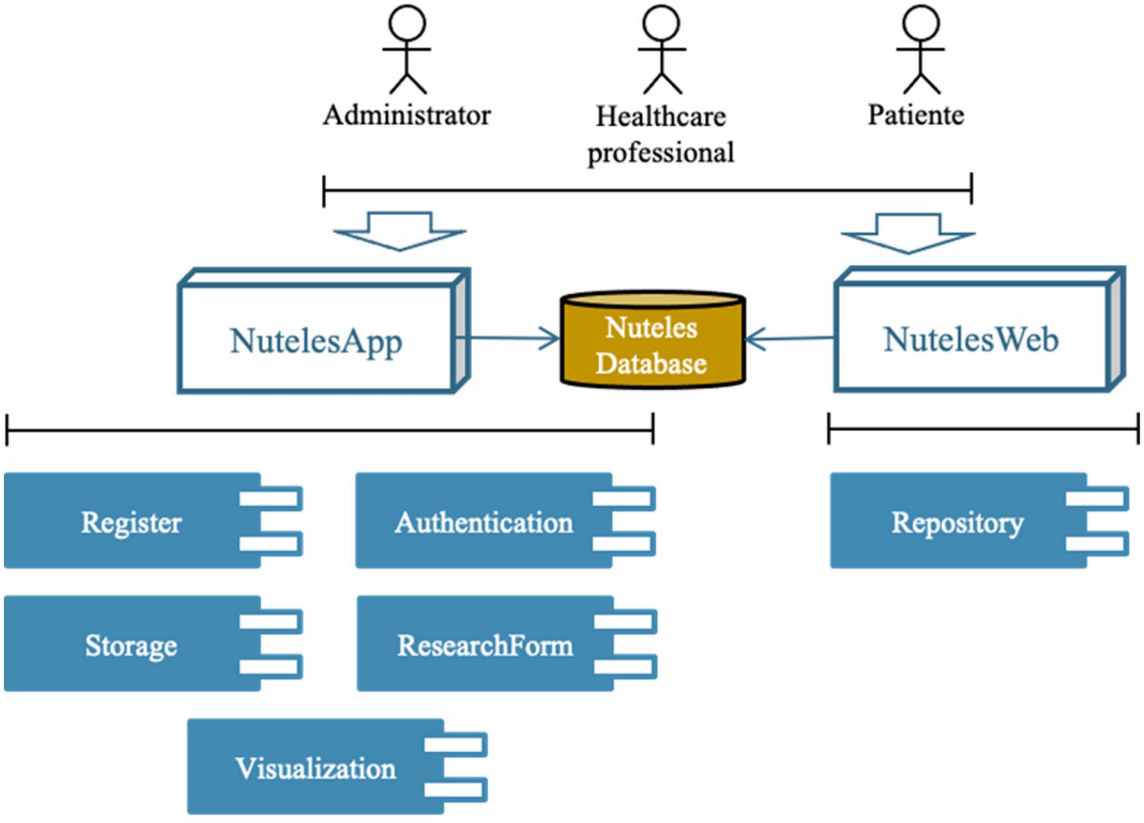

Fig. 1 Implementation design of the NUTELES computing environment. *Source* authors' own creation

for various tasks such as classification, grouping and scenario prediction. Finally, it facilitates the presentation of information in graphs and visualization mechanisms. However, all these potentialities are made possible by the quality of the data stored in the database.

Figure 2 shows the general organization of the classes of information stored in the database. The attributes recorded in the database were defined based on this class of information represented by the fields provided in the electronic data collection forms inserted into the NutelesApp platform. A data dictionary was developed to facilitate the sharing of the data structures developed in this work.

All the structures are filled in during the data collection process to form the epidemiological survey database. The processing of exploratory analyses, inferences and other studies will be carried out according to the data presented in this diagram. The model's starting point is the data structure of the strategy used to collect this data, which represents a broader set of activities in which health interventions and actions are carried out. These interventions are small training activities for users and professionals focused on health care, which together are incorporated into a larger strategy, which configures the long-term monitoring of patients.

For each intervention, it is necessary to register the patients and professionals who belong to the health units in each of the municipalities in the health micro-region of Viçosa, Minas Gerais, Brazil, where the research is being carried out. A characterization survey is carried out for each unit through meetings with the coordinators and managers. After this characterization, data on the patients and health professionals belonging to each of the units is recorded. It is important to note that the user's identifying information is not stored in the database in order to guarantee anonymity.

The patient data structure is the starting point for the epidemiological survey data. From this it is possible to fill in the questionnaire using the structure of the form, and associate it with the other parameters to be collected.

Functional and non-functional requirements of NUTELES-UFV

The use case diagram graphically describes the functionalities of an application. It is a functional requirement gathering tool that models the expected behavior of the system in an interaction with the user. Figure 3 gives an overview of the use cases for the NUTELES-UFV application, showing each of the actors (stakeholders) interacting with the respective functionalities they have access to.

The diagram shows two main actors interacting with NUTELES-UFV through its functionalities (ellipses). The first actor, called a healthcare professional, is responsible for registering the patient's identification and health information. Once the information has been registered, the results of the questionnaire can be printed, as described in the link<<extends>>with the analytical report. It is necessary for the health agent to fill in all the data on the clinical history, health analyses, sociodemographic data and information on COVID-19.

The second actor, called the patient, has access to the registration and health data collected by the healthcare professional, allowing them to be monitored. It should be noted that both actors must be authenticated in order to access the information recorded, both for reading and for recording information, the latter functionality being allowed only to the health professional.

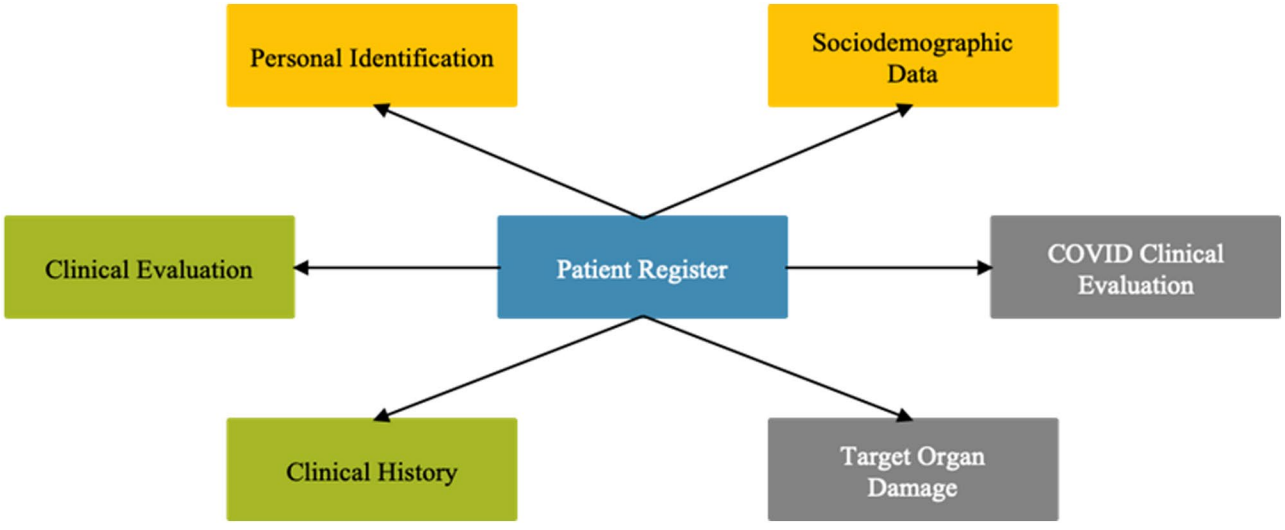

Fig. 2 Data structure for storing information collected via the NutelesApp mobile application from the NUTELES-UFV environment. *Source* authors' own creation

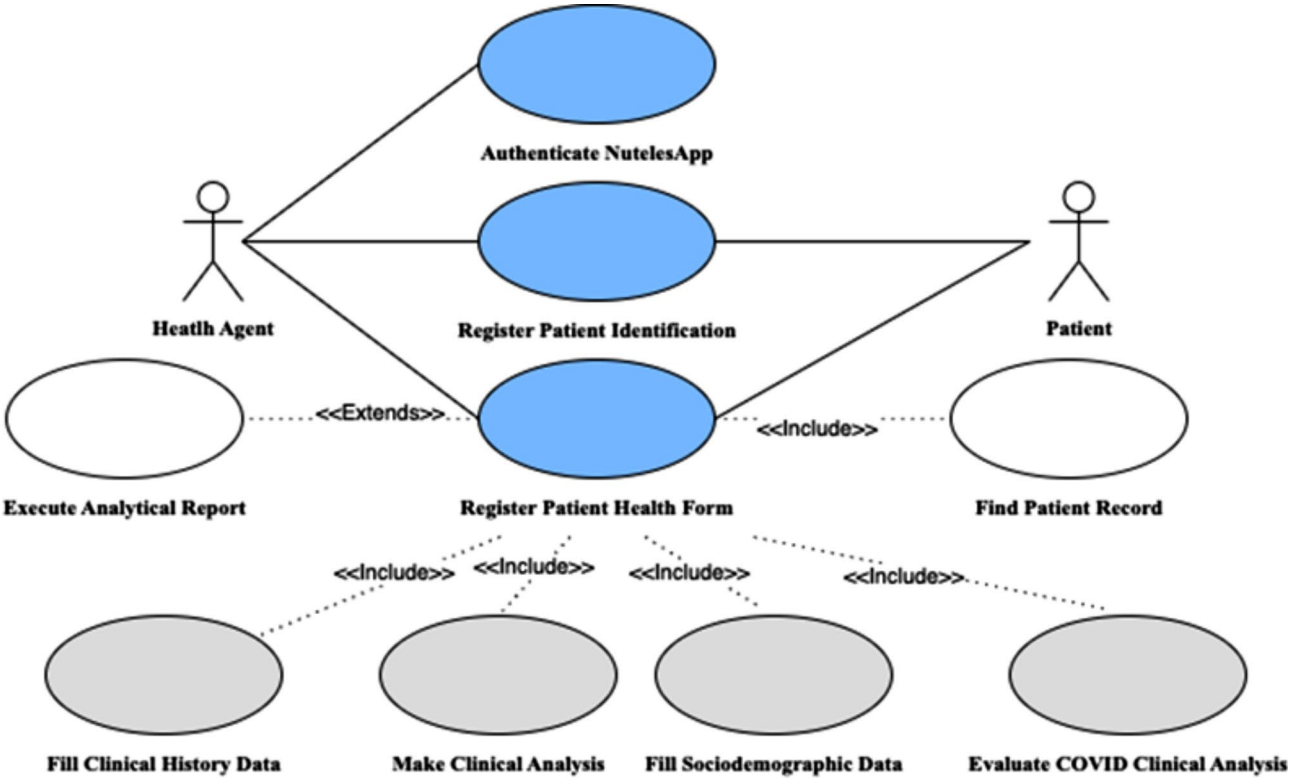

Fig. 3 Use case diagram with the functional requirements for building the NUTELES-UFV computing environment. *Source* authors' own creation

Navigation hierarchy

The user interaction interfaces of the NutelesApp application are organized as shown in Fig. 4. We will look at the access of a health professional so that they have an overview of the functionalities in the application. In this context, navigation begins with the application's presentation screen, which gives the user two access options, either to register again or to authenticate. The user can authenticate after registering.

Once authenticated, the home will be displayed with access options for registering the patient, viewing the user's profile and accessing the list of patients of that health professional user. Patient registration allows for the collection of registration data for the health professional responsible and the patient being assessed, information on the patient's lifestyle and information on the clinical assessment carried out, providing important information for health monitoring.

By filling in the information, it is possible to visualize the general picture of the patient's lifestyle and clinical assessment in an efficient and convenient way. This information makes it possible to carry out important analyses and draw inferences by classifying patients into groups previously defined by studies, grouping them by characteristics identified from the information recorded or even creating mechanisms to predict scenarios for carrying out interventions, whether they are more preventive or even reactive given the scenario identified.

User interfaces

The application's home screen displays the application's initial information, including the logo and the login form. To gain access to the application's features, the user must first register. The e-mail address and password that were previously registered are required for authentication and access to the application's work area. After filling in these fields and clicking on the "Login" button, the user will be redirected to another screen.

Data analysis

The epidemiological survey data was collected using mobile devices and analyzed using computer techniques based on statistical analysis. Once the field teams had completed their work, the files were transferred to servers for general analysis processing, using estimates of means, prevalence and respective standard errors, calculated using the Statistical Package for Social Science (SPSS) program, which takes into account the planning variables and includes the basic weights resulting from the sampling process.

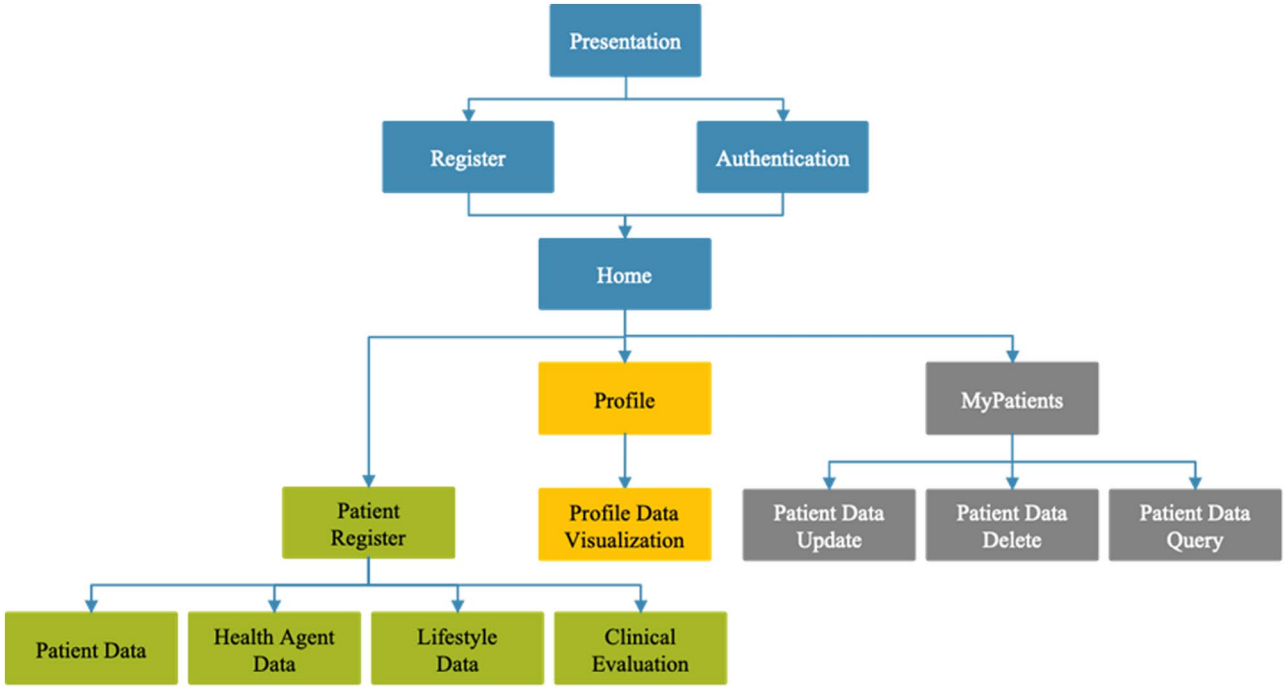

Fig. 4 Navigation hierarchy in the NutelesApp application. *Source* authors' own creation

Application results

The results are expressed in the mobile application for the collection and subsequent exploratory analysis of epidemiological data. The application adopts the Creative Commons Non-Commercial and Attribution License (BY-NC), allowing licensees to copy, distribute, display and perform the software, as well as develop derivative works from it, provided that licensees give credit to the authors and use applications for non-commercial purposes.

The information obtained through data collection with subsequent exploratory analysis of epidemiological data using the NutelesApp software suggests that mobile applications intended for the purpose of monitoring and managing health care for people with AH and/or DM should address the variables necessary to support a process of understanding the health conditions and/or disease of the individual as a whole and provide short- and long-term learning.

Furthermore, the description of the creation and development of the software includes practical examples of the results collected as well as their presentation in real scenarios. The digital application is both preventive and predictive, since it produces determining criteria for interventions aimed at monitoring the health parameters of individuals and, consequently, reducing the negative outcomes of the diseases studied and analyzing the needs for improving the services provided by PHC.

The following subsections present some of the functions and interfaces of mobile and web applications.

NutelesApp mobile application

Figure 5 shows that the registration screen contains mandatory fields for registering the user, such as: full name, individual registration, e-mail, telephone, address and password. Once these fields have been filled in, the user must click on the "Register" button. A dialog box will then appear informing the user that the registration has been successful, enabling them to use the application.

Once registered, the user simply has to follow the initial login steps to be directed to the application's home screen. If the user is an administrator, they will have access to various features, including viewing and editing patient information, creating new patients and the profile screen with their personal information. By pressing the plus (+) button, the user will be redirected to the patient registration screen, which is divided into various registration topics including: Personal Identification and Sociodemographic Data, Clinical Assessment and Lifestyle Habits.

The initial part of the registration form contains general registration fields for identifying the patient's location and contacts and the health unit in which they are located, allowing the identification of the health team and support from the geographical region. Figures 6 and 7 show the interface of the NutelesApp data collection mechanism, to be applied and filled in by researchers and/or health professionals.

The advantage of filling in the portal is that you can register directly in the NUTELES-UFV environment database, as all the information registered in the portal is

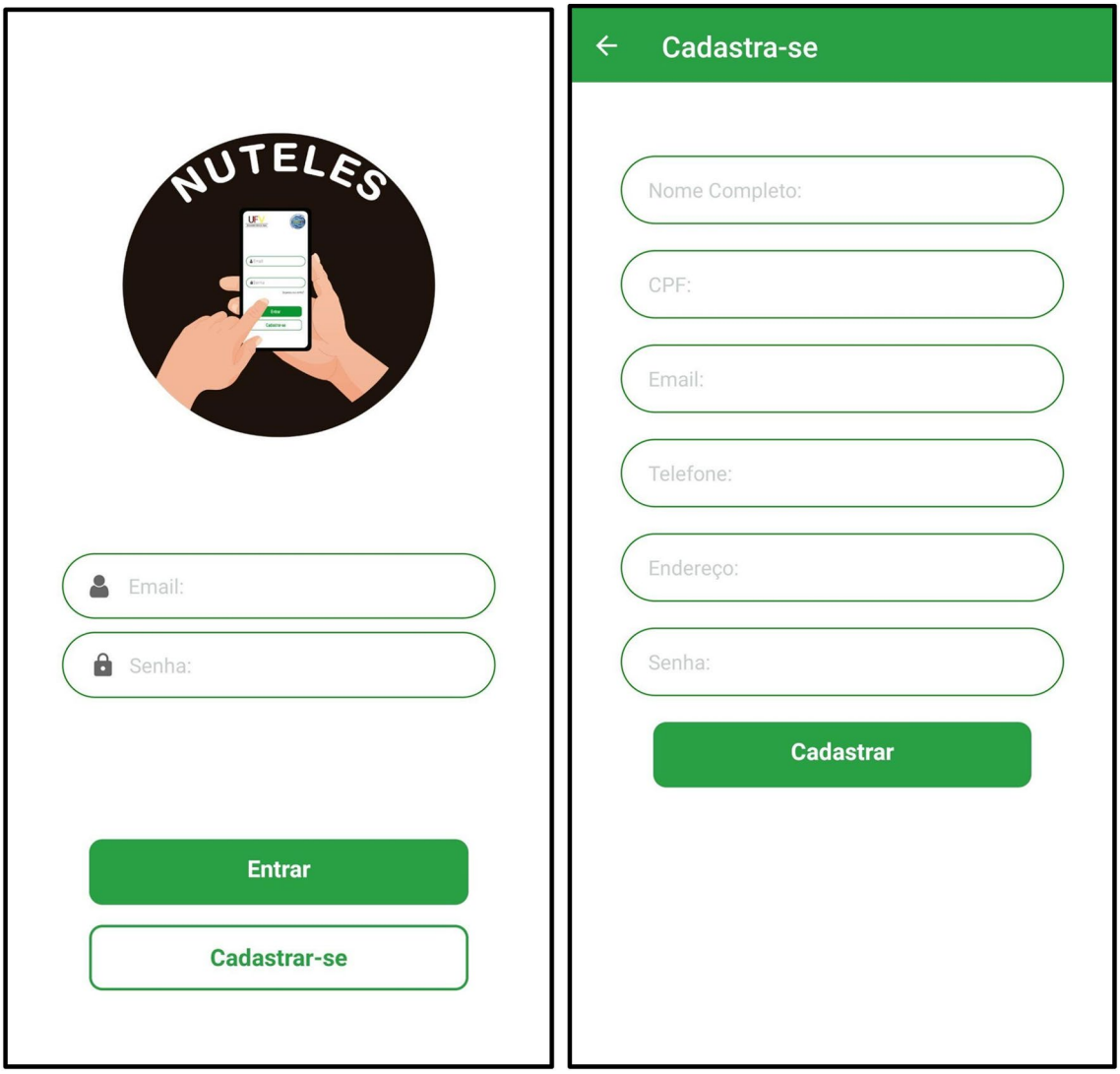

Fig. 5 Use case diagram with the functional requirements for building the NUTELES-UFV computing environment

stored directly in the database. In the case of the app, the information is registered on the mobile device for later transfer to the central database. The registration process becomes more efficient as the information registered will be duly stored electronically, in various information stores, in the local and central database and in backup systems, making it possible to efficiently retrieve information to carry out various processes. In addition, the information collected and recorded in databases allows for greater efficiency in processing analysis, which is important for carrying out statistics and decision-making.

Survey results

Data collection took place in two ways: (1) at the PHC health units in each of the nine municipalities in the Viçosa health microregion, Minas Gerais; (2) at the patients' homes. When, for some reason, the patient did not attend the unit, the researchers went to their homes to collect the data. It is worth noting that the health units are located close to the patients' homes.

In this first stage of data collection, the data were stored by researchers who were properly trained for this purpose. Later, in order to monitor the parameters that are subject to change, health professionals will be able to update them in the software, having been trained for this purpose. Patients will also be trained to make these updates when appropriate (especially those related to lifestyle habits). Those who have some limitation for this purpose will be advised by a family member/caregiver or another person who can help them.

It is worth noting that patients will only have access to data related to their own health, and it is impossible for any of them to have access to data other than their

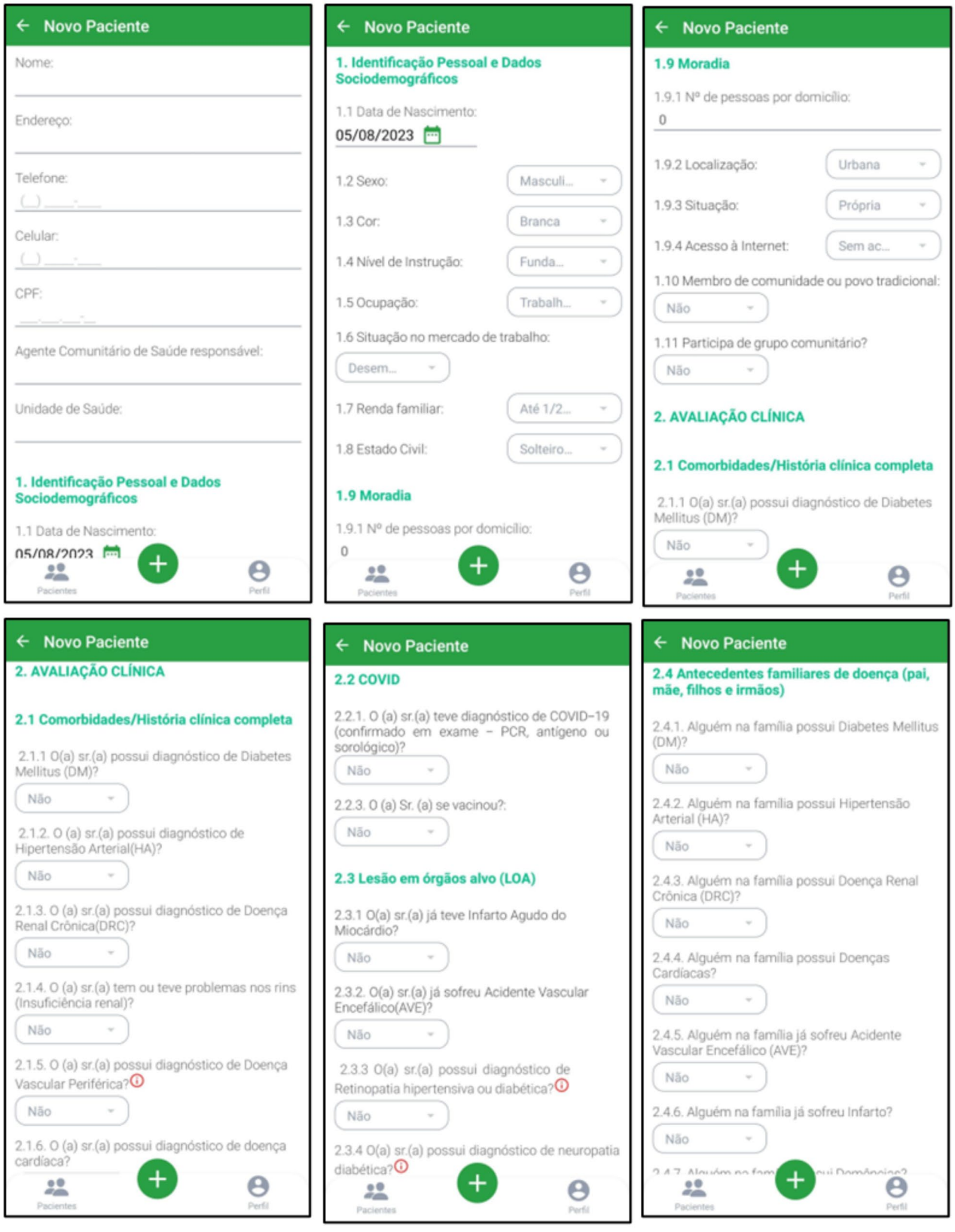

Fig. 6 General patient data collection and clinical assessment screens

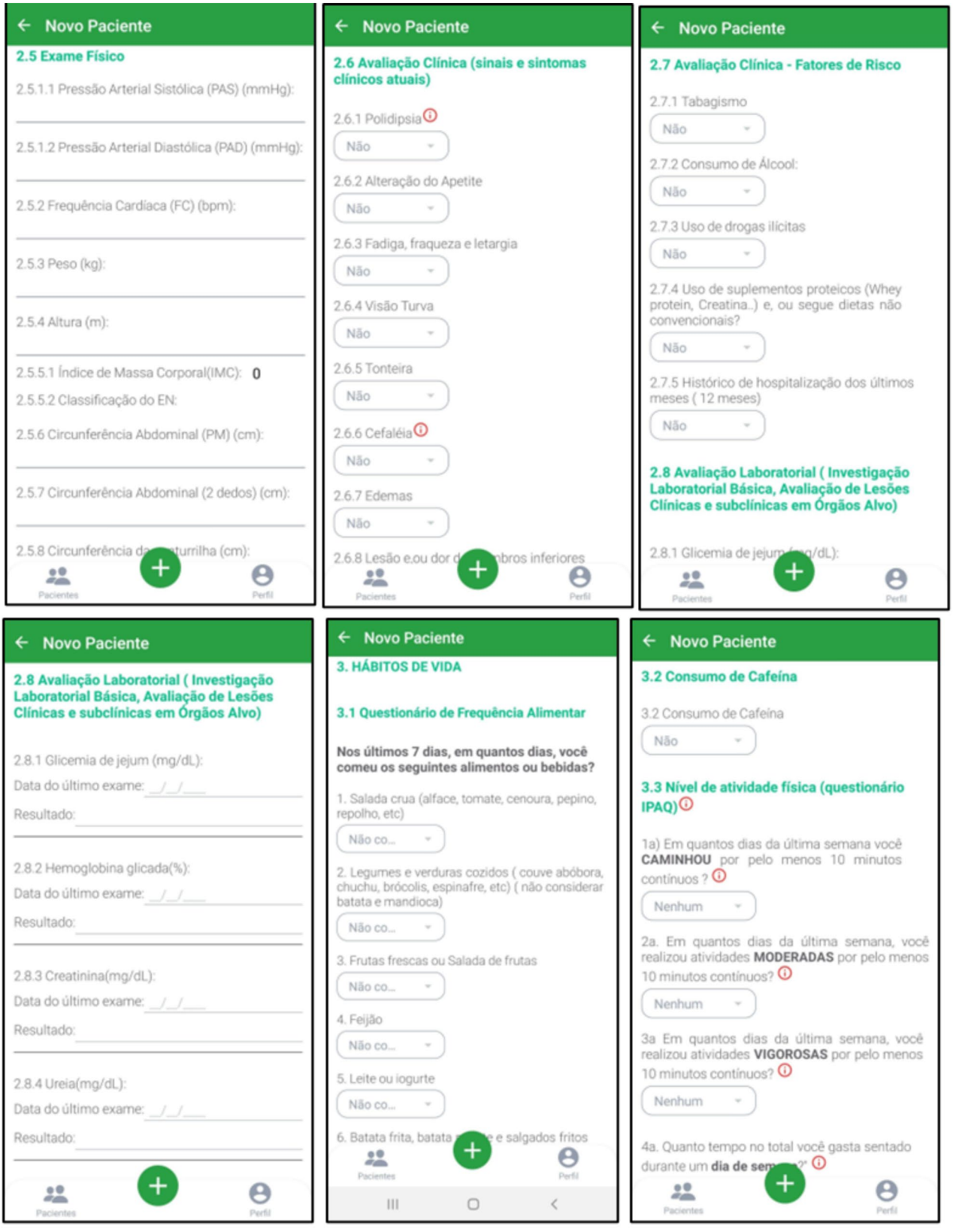

Fig. 7 Clinical assessment and lifestyle habits collection screens

own. To do this, registration and login to the system are required.

The frequency analysis of the baseline data and the profile of the patients registered on the platform are shown in Table 2. We have a total of 374 individuals and it can be seen that the majority are female (73.2%) and white (43.5%).

The average age was 64 years (±11.67), the average SBP was 128 mmHg (±19.40), the average DBP was 81 mmHg (±15.90) and the average heart rate was 76.94 (±34.19). With regard to anthropometric measurements, the average BMI was 29.84 mg/m² (±16.04), AC was 94.66 cm (±14.24) and CC was 35.52 cm (±5.05).

These figures show that the average age of the people is elderly, with blood pressure levels within the normal range for this population, BMI indicates overweight, AC increased risk for cardiovascular events and CC within the recommendation value.

As for the biochemical parameters, we have an average fasting blood glucose of 164.64 mg/dl (±78.63); glycated hemoglobin of 9.62 (±17.86); creatinine of 2.16 (±8.93); total cholesterol of 186.52 mg/dl (±40.17); HDL of 51.69 mg/dl (±16.68); triglycerides of 137.93 mg/dl (±76.20).

Table 2 Profile of patients with AH and/or DM in the Viçosa health micro-region, Minas Gerais, Brazil

Variables	*n*	%
Sex		
Male	100	26,8
Female	273	73,2
Color/race		
White	162	43,5
Black	94	25,3
Brown	110	29,6
Indigenous	0	0,0
Yellow	6	1,6
Level of education		
No education	49	13,2
Elementary school incomplete	190	51,1
Complete primary education	54	14,5
High school incomplete	17	4,6
Completed high school	45	12,1
Higher education incomplete	6	1,3
Complete university degree	11	3,0
Income		
No income	12	3,3
Up to ½ salary	19	5,1
+ from ½ to salary	100	27,1
+ 1 to 2 salaries	150	40,7
+ from 2 to 5 salaries	77	20,9
+ from 5 to 10 salaries	11	3,0
Marital status		
Single	34	9,6
Married	208	58,9
Separate	9	2,5
Divorced	30	8,5
Widowed	72	20,4
Internet access		
Yes	274	73,37
No	98	26,3

Figures 8 and 9 generated by the NutelesApp show the results of the exploratory analysis obtained by processing the patient questionnaires. The first figure shows the report with the percentage of patient participation in the survey by municipality in the health micro-region of Viçosa, Minas Gerais and Fig. 9 exemplifies the percentage of comorbidities worked on in the study.

Since this is a sample in which all participants already have a confirmed diagnosis of hypertension and/or DM, they are undergoing treatment to control the diseases and avoid negative outcomes. This treatment includes, among the modifiable factors that relate to lifestyle habits, drug treatment as well. However, although all patients have already been diagnosed with the diseases (AH and/or DM), not all of them undergo treatment in the appropriate way to control the comorbidity. This is why monitoring and managing the parameters that involve health care is so important, as this enables health professionals to identify where the treatment is failing and how to act in a way that does not harm the patient.

Discussion

In the present study, we provide a description of the development and implementation of a digital health solution (NUTELES-UFV), based on mHealth (NutelesApp), for individuals with NCDs, with an emphasis on AH and/or DM. The results of this research suggest that guidance on health conditions and/or disease, as well as patient management, monitoring and self-monitoring, can be provided through an mHealth intervention.

The software developed for collecting, storing and analyzing data from epidemiological research in public health provides, among other benefits, the replacement of paper with electronic forms, which has, among other features, the ability to exempt the researcher and/or health professional from manually transferring the collected data to a computer, since this process is done in an automated way and provides less chance of data transfer errors, generating more reliable, fast and secure information. Kelly et al. (2018) [27], Bonner et al. (2018) [28] and Brown et al. (2024) [29] emphasize that many outpatient services have insufficient resources to provide contact with health professionals at the frequency and intensity necessary to generate sustained long-term behavior change. This scenario places the patient in a position where their needs are not met and care is not sustainable even in the short term, as services become fragmented. This is why advances in digital health provide better health interventions in a unified manner to treat NCDs at their most complex levels, which can be more effective and improve access to health services provided [29].

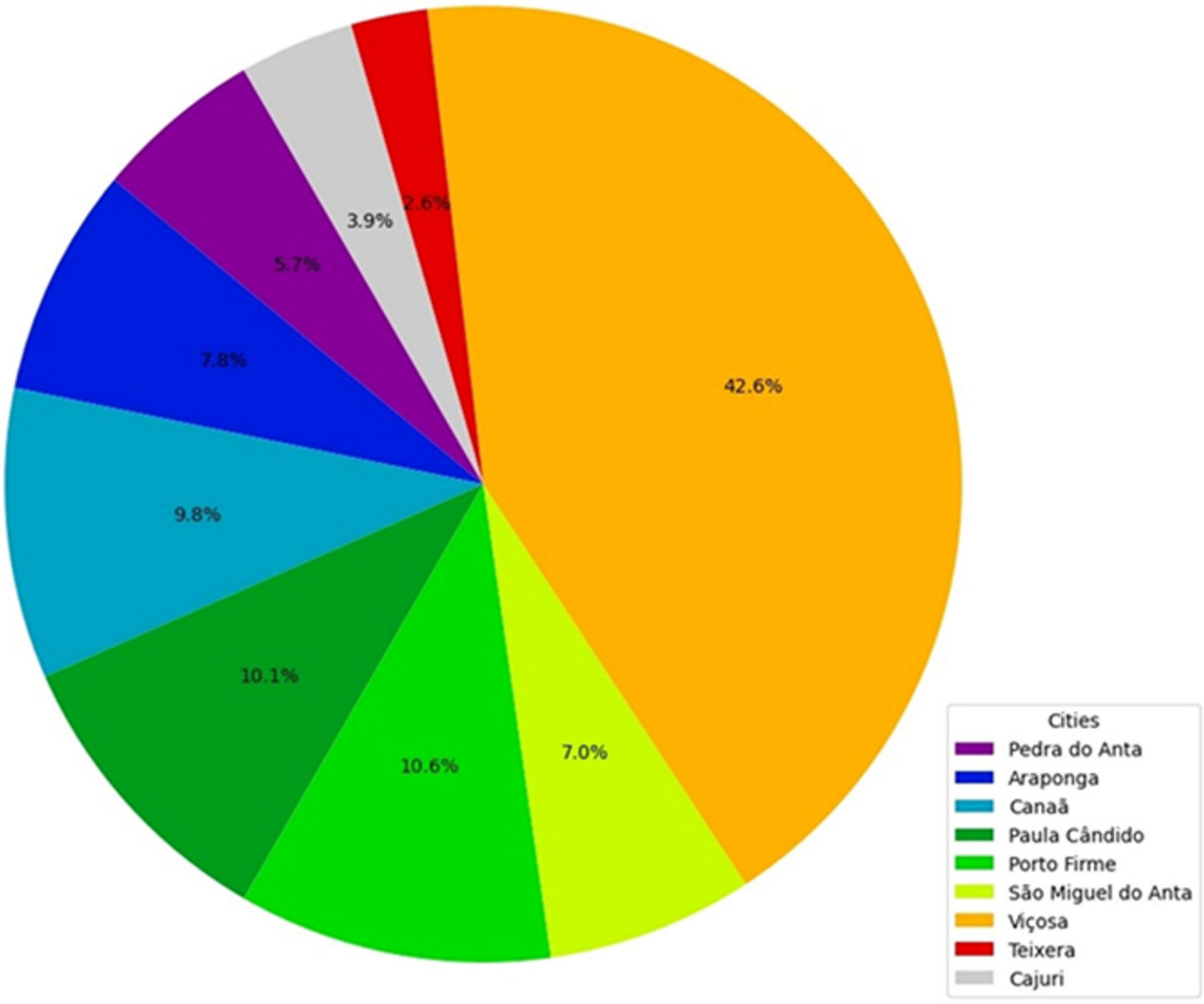

Fig. 8 Graph showing the percentage of patients in each municipality in the Viçosa healthmicro-region, Minas Gerais, Brazil. *Source* Authors' own creation

Given the range of applications and other digital health solutions, individuals may not know which one best applies to their reality or feel insecure about entering their health data. Therefore, our Telehealth Center advocates data privacy and single registration and login, which are some strategies that make users safer. A study carried out by Zhang et al. (2019) [30] identified that the main factors contributing to users not accepting mobile apps is precisely the fear of data privacy being exposed. Added to this is the possibility of an incorrect diagnosis being made (this happens when data is entered manually). These factors are directly related to the lack of intention to change behavior.

This choice of intervention by the patient is closely linked to engagement in its use, as highlighted by the findings of Brown et al. (2024) [29]. This finding is in line with the study by Clark et al. (2008) [31] and Delevry and Le (2019) [32], which address the direct effect of patient choice on health outcomes and the impact of this on behavioral changes, treatment adherence, self-monitoring and health management.

In fact, various digital solution methods/procedures have been developed over the last few decades with the aim of building technological tools that have been improving the performance of their users in the most diverse sectors of social life for the provision of effective and reliable health services and actions [11, 15, 16]. Added to this is the difficult epidemiological situation of COVID-19 and the emergency social distancing measures that have transformed health systems around the world. In addition, pandemics have triggered the widespread use of digital technologies among people who need constant monitoring of their health status [11, 33]. Therefore, digital health offers some advantages associated with virtual communication, low costs for the patient, time savings and reduced risk of infections.

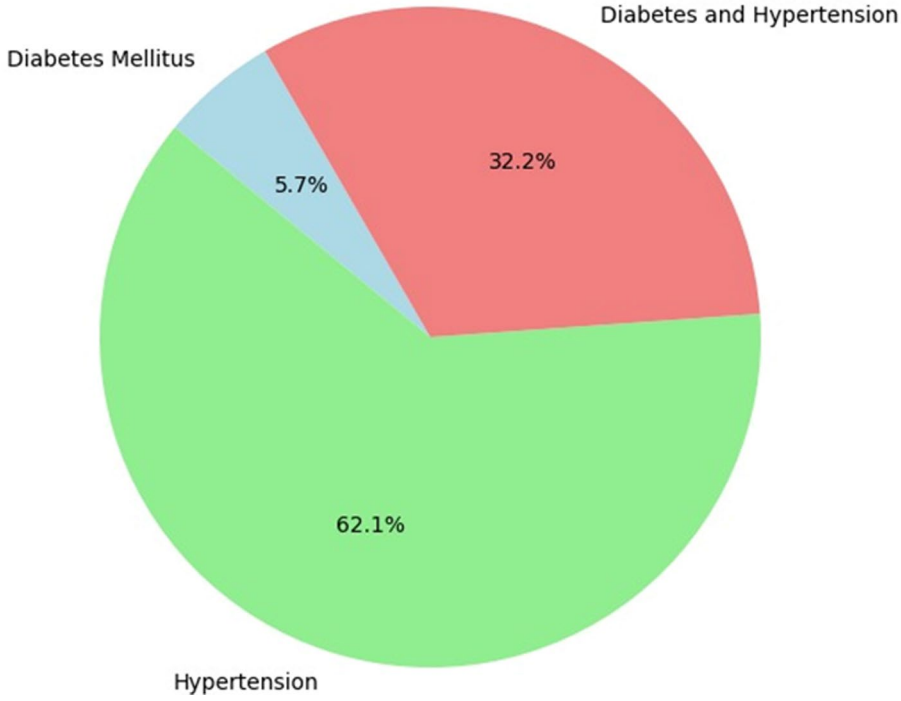

Fig. 9 Graph showing the percentage of patients diagnosed with AH, DM and both comorbidities. *Source* Authors' own creation

The use of technology, especially apps, is efficient, effective and considered successful for health care and assistance [22]. With regard to the treatment of chronic diseases and patient health education activities on disease monitoring, it reinforces adherence to treatment by facilitating the understanding of recommendations and being easily accessible [34].

Specifically in the treatment and monitoring of individuals with AH and/or DM, we highlight the findings of the systematic review with meta-analysis by Ferreira et al. (2023) [22], which showed the difference in treatment between people monitored traditionally and those monitored by mobile interventions in the improvement, management, self-monitoring, and monitoring of adult and elderly patients with hypertension and/or DM. The study by Faezi, Afshar, and Rahimi (2023) [35] aimed to identify the motivating and inhibiting factors that affect the use of health information technology in the treatment and management of AH. The findings indicate that paid applications and access to the internet and a smartphone are the main inhibiting factors, while the motivating factors address the greater frequency of patient monitoring, reduced treatment costs, and ease of data sharing. Similar inhibiting factors were found in the study by Van Den Heuvel et al. (2020) [36]. These studies address important aspects to be considered when thinking about what can improve patient adherence and use of technologies. These findings are in line with what is recommended by our Telehealth Center, where services will be offered free of charge with subsequent monitoring and management of health care for patients diagnosed with AH and/or DM.

Alessa, Hawley, and Witte (2021) [37] developed a study that aimed to identify the most appropriate AH application for the health system studied. They demonstrated that smartphone applications with comprehensive functionalities are potentially effective, and participants liked the reminder features for self-management activities the most. This was also the case for the Jeppesen and Ainsworth (2015) [38] study, which highlighted the importance of this strategy to maintain correct patient adherence. Reminders are advisable strategies, as they address the forgetfulness factor of patients, especially elderly patients. Faezi, Afshar, and Rahimi (2023) [35] advocate similar strategies when proposing the effect of cellphone intervention in reducing AH. No less important, Liu et al. (2023) [39] demonstrated that the mHealth application-based intervention potentially improved the health knowledge of patients diagnosed with AH and supported self-management with the adoption of healthier lifestyles, including medication adherence, low-salt diets and physical exercise, thus controlling blood pressure.

Similar results are found in the use of health technologies in the management of DM. A study by Baptista et al. (2020) [40] reported that patients felt motivated, comfortable, and confident using the mobile application. These results are in line with the findings of Faezi, Afshar, and Rahimi (2023) [35] when considering the motivating aspects that applications need to have to

ensure successful adherence to them. Burda et al. (2022) [41] demonstrated that the usability of a DM-focused self-management mobile application was promising, as participants felt motivated, capable, and had improvements in glucose levels and overall metabolic stability consistent with the use of the application. Other studies and analyses support these findings, such as the one by Sun et al. (2019) [42] with diabetic, Chinese and elderly patients who received glucometers that transmit data and received guidance on medication, diet and exercise through mHealth. After the intervention, the patients saw their glycated hemoglobin levels decrease. Important findings by different authors also indicate that elderly patients with DM interact well in an educational environment developed within a mobile application [43–47].

Other strategies have been devised and modified to improve patient adherence, but despite the obvious benefits of mobile applications in healthcare, there are a number of challenges and concerns regarding efficacy, safety and ethical issues that must be taken into account when developing applications and, especially, when evaluating their usability indicators with users [48].

In summary, although digital health technologies are widely used with proven effectiveness, more initiatives are needed for the development and implementation of innovative tools in the health sector, given that, as shown in the characterization of our study, the main modifiable parameters for the population with AH and/or DM are those that are highest. In this context, mobile interventions represent a substantial gain in monitoring and managing the health care of these patients, allowing longitudinal follow-up by health professionals as well as the patients themselves. Certainly, precursor strategies for improving this situation will prevent undesirable outcomes from comorbidities and, above all, will provide a significant improvement in the quality of life of these people.

Limitations, strengths and future work

Limitations include the relatively small sample size, due to the fact that the field research was conducted over 6 to 12 weeks, requiring careful monitoring of each participant. Also due to technical restrictions, so far, our system only works for Android systems, which limits access to those with IOS. However, these issues are already being taken into account, since the sample is already being expanded and the software will soon be available for IOS as well. Another limitation of our study is the fact that continuous monitoring and management of patients' health status requires time for repeated measurements to be collected, monitored, and analyzed for subsequent direct intervention with patients. Since this is a study describing the creation and development of software and the respective data collected and tabulated, our study presents only baseline data, making it impossible for us to perform continuous monitoring at this time. However, we emphasize that this monitoring is ongoing and will be portrayed in future studies by our research group.

One of the strengths of this work is the fact that, although there is currently free software that performs similar functions to NutelesApp, one of its main advantages is that it works as a tool that uses standardized forms, developed, tested and applied by Brazilian public health institutions, for which NutelesApp will be available free of charge. In addition, it is an application designed to collect data in the field, without necessarily needing to be connected to the World Wide Web (Internet), i.e. if it is impossible to connect to the Internet at the time of the approach to the patient, especially in more remote areas, the application temporarily stores the information collected in its own database for later transmission to a central database. This feature makes it possible to include remote and hard-to-reach areas, which are sometimes overlooked in location-based surveys.

Another strength of our software is the security of the data collected and stored. Through encryption, the data can only be recovered in full using a private access key, preventing data leaks in the event of an invasion of the security and privacy of the information.

Also noteworthy is the partnership between Brazilian public universities and the municipal and state health secretariats, which gives our mobile digital solution significant potential to impact the evaluation of health programs and policies at different levels of government. Equally important is the possibility of correlating the information obtained with the municipalities, states and health units where the research was carried out, with the possibility of expanding it to other regions of the country.

Further research needs to be carried out to refine and/or improve the performance of the system developed. As a planned expansion of our software, we would like to highlight the availability of more usable options for participants, such as options for viewing general guidance on their own state of health. However, there is already an option for patients to make suggestions for improving the application.

Also, as we saw in our study, data visualization is a key element in monitoring and self-monitoring technologies, as it allows us to learn and recognize trends, thus supporting behavioral change. With regard to monitoring technologies for the adult and elderly population, which represents the majority of our audience, data visualization is generally a resource used to represent goals and progress. However, there is a lack of guidelines on how to design specific visualizations for the elderly. In our study, we used a simple visualization.

Conclusions

Our main objective was to provide details of the development and implementation of a new technological application aimed at monitoring people with NCDs, especially AH and/or DM, and to better understand the needs of this population when using such tools. Patients reacted positively and it was possible to draw up a profile of this public, which will help us to make improvements to the application and other interfaces, such as an information portal for this same public for subsequent continuous monitoring,

Furthermore, the description of the creation and development of the software includes practical examples of its implementation, the results collected and its applicability in real scenarios, presenting determining criteria that can provide assertive and timely interventions for monitoring and managing the health and/or disease parameters of patients with HA and/or DM. The beneficial consequences of using this application will extend to health units and their respective management, improving the services provided by PHC and enhancing strategies and actions for health promotion and disease prevention.

The conclusions of this study also underline the importance of assertive mobile health interventions, in line with the SDGs and more comprehensive for people who already have NCDs, so that the comorbidity does not progress negatively in the long term. We hope that the knowledge gained in this study will be used to design new applications for patients and that they will be better adopted by adults and the elderly and thus ultimately help to promote active and healthy ageing.

Abbreviations

AH	Arterial Hypertension
DM	Diabetes Mellitus
mHealth	Mobile health
eHealth	Digital health
CNCDs	Chronic Non-Communicable Diseases
NUTELES-UFV	Telehealth Center of the Federal University of Viçosa
PHC	Primary Health Care
SPSS	Statistical Package for Social Science
ReBEC	Brazilian Registry of Clinical Trials
SDGs	Sustainable Development Goals

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-024-11505-y.

Supplementary Material 1

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Author contributions

E.S.F. contributed to the literature, designed the study, analyzed the dada and drafted the manuscript. J.P.T.J and M.A.D. collected and analyzed the data. G.D.C. contributed to the supervised the data analysis and revision of the manuscript; A.H.M.O. and G.M.B., software and supervises the data analysis and contributed to the revision of the manuscript; R.M.M.C. contributed to the designed the study, supervised the data analysis and contributed to the drafted and revision of the manuscript for final approval.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

The research project was approved by the Human Research Ethics Committee of UFV, under opinion no. 4.475.901 and registered, prior to recruitment, by the Brazilian Registry of Clinical Trials (ReBEC), ID: RBR-45hqzmf (Last approval date: 11/30/2022). Written informed consent to participate in the research was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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