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Android Mobile Informatics Application for some Hereditary Diseases and Disorders (AMAHD): A complementary framework for medical practitioners and patients

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ABSTRACT

Hereditary diseases and disorders constitute a public health problem. Many people in rural communities of developing countries of the world are particularly ignorant about the cause, modes of transmissions and the treatment plans for such diseases. In some cases, some people lack essential knowledge between common and rare hereditary diseases.

It is therefore appropriate and essential to develop a mobile application that will act as an educative resource and a good knowledge base for common and rare hereditary diseases.

The aim of this research is to develop **AMAHD** (**A**ndroid **M**obile Informatics **A**pplication for some **H**ereditary **D**iseases and **D**isorders).

The **objectives** of this research are to create an android mobile application that will act as a reference point and provide useful information about various hereditary diseases to medical personnel and professionals; provide additional educational resource to biological and bioinformatics researchers in different higher institutions; and provide a pedagogical, diagnostic and complementary foundational learning tool for African research students in biosciences, bioinformatics, and all other categories of students that currently engage in multidisciplinary research in the aspect of hereditary diseases.

Essential data was sourced from relevant literature. We developed AMAHD through an integration of programming languages in Java and XML (Extended Markup Language). SQLite was used to implement the database. We developed a **L**ogical **D**isjunction **R**ule-based **A**lgorithm (**LDRA**) for the AMAHD's diagnosis module.

A comparative analysis between existing commercial hereditary mobile applications and AMAHD was conducted and the results presented. A world-wide online survey (spanning Africa, Asia, Europe, America and Australia) was conducted to sample the opinion of individuals across the globe on the classification of hereditary diseases as either rare or common, within their respective regions. In addition, an evaluation of AMAHD on the offline platform was conducted by administering paper questionnaires and asking users direct questions about how they respectively rate the performance of AMAHD based on certain evaluation criteria. Furthermore, a separate evaluation of AMAHD was conducted using online survey monkey. Finally, a comparative analysis between the results obtained from the online evaluation and offline evaluation of AMAHD was conducted and presented.

The results of the surveymonkey online questionnaire revealed that: 58.49% of the participants agreed that AMAHD can be used to diagnose users ailments based on the hereditary disease symptoms they supplied to the mobile application; 13.21% disagreed, while 28.30% of the participants were indifferent. 71.7% of the participants agreed that AMAHD can act as a complementary resource for supplementary healthcare support; 5.66% disagreed, while 22.64% of the participants were indifferent. 88.46% of the participants agreed that AMAHD can be particularly supportive to developing countries where there is less awareness of the deadly effects on hereditary diseases; 1.92% disagreed, while 9.62% were indifferent. Finally, 86.79% of the participants agreed that AMAHD can be useful as an android health application, 13.21% disagreed.

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1. Introduction

Heredity diseases are diseases inherited by offspring from their respective parents. Such diseases are transmitted from parents to offspring. There are thousands of hereditary diseases among humans; some are common whereas some are not. The most disturbing thing about these diseases is that scientists are still trying to decipher the appropriate cure to them. A genetic disorder connotes an illness that results from one or more abnormalities in the human genome. Genetic disorders can cause hereditary diseases or it can result from mutations in DNA. Thus, when defective genes are inherited from parents, or when such defective genes are dominant, hereditary diseases are the outcome. There are currently about 4000 hereditary diseases and disorders; more are still being discovered [1].

A large proportion of deaths in West Africa are traceable to hereditary diseases. This is a public health problem. Inaccessibility to information and knowledge about hereditary diseases and disorders, especially in remote settings of the African continent constitutes another problem. Professor Ibrahim Gambari, Under Secretary-General, Special Adviser to the Secretary General of the United Nations, lamented that: "On Health and Education", he said, "the level of immunization of Children against dangerous childhood diseases, in the South-East is 44.6% immunization coverage, but the North-West has 3.7% and the North-East 3.6%." These childhood diseases span hereditary diseases and disorders [2]. In some situations, medical practitioners who are not knowledgeable, diagnose the wrong disease and prescribe the wrong medications.

The level of ignorance about hereditary diseases and disorders, the lack of comprehensive knowledge about its mode and medium of transmission from one generation to another, is of deep concern, especially among inhabitants of developing African countries. For instance, sickle cell anemia affects many people across different continents of the world [3–4]. Thus, it is expedient that the knowledge of hereditary diseases be made readily available to rural community dwellers in African regions through a mobile informatics approach. These are inhabitants that can read, write and knowledgeable about the use of mobile devices.

With the current trend of software development, focus is gradually shifting rapidly from the web based applications to the mobile platform, in order to foster portability and ease of access to these applications. The aim of this research is to develop **AMAHD** (**A**ndroid **M**obile Informatics **A**pplication for some **H**ereditary **D**iseases and **D**isorders). This will act as a complementary framework for medical practitioners, patients and inhabitants of communities within Africa and other developing continents of the world. The mobile application will help to provide detailed information about hereditary diseases, their symptoms, corresponding causes, and how they can be prevented or treated. It can also serve as a mini-diagnostic tool.

The incidences of genetic diseases between developed and developing countries differ. For instance, in Japan, they do not have high incidence of sickle cell anemia compared to African countries [5]. Different locations have different types of genetic/hereditary diseases and disorders mostly associated with them.

The **objectives** of this research are to:

- Create an android mobile application that will act as a reference point and provide useful information about various hereditary diseases to medical personnel and professionals
- Provide additional educational resource to biological and bioinformatics researchers in different higher institutions
- Provide a pedagogical and complementary foundational learning tool for African research students in biosciences, bioinformatics, and all other categories of students that currently engage in multidisciplinary research in the aspect of hereditary diseases.

The major reason for developing an android mobile informatics application is due to the wide acceptability and usage of android mobile applications. In 2012, according to a web design company based in Dubai [6], it was estimated that 80% of the world population now has a mobile phone, out of which only 1.08 billion are smart phones users. Based on the data compiled on smart phone user's statistics and facts, the android Smartphone platform has the highest market share of 46.9%. This growth is being driven by strong demand for low-cost Smartphone across major regions such as China, India and Africa. Based on these facts, an android mobile application was the most suitable platform for the implementation of AMAHD.

AMAHD contains information on different hereditary diseases and provides easy access to such information. It especially provides the information to curious individuals in order to sensitize them on the negative effects of these diseases. It also acts as a source of information and awareness to persons living with common hereditary diseases and disorders. It further acts as a complementary platform for medical practitioners, those ignorant of hereditary diseases and bioinformaticians in the areas of providing a comprehensive repository of knowledge.

2. Related works

Two separate reviews were conducted in this study. The first was the scholarly literature review while the second was the commercial application review.

2.1. Literature review

We searched for mobile application-related literature for prevalent hereditary diseases between 2003 and 2015 on the following academic indexing systems and databases: IEEE Explore, Science Direct, Scopus, PubMed and Web of Knowledge. Some of the prevalent hereditary diseases were sourced from the WHO Global Burden of Disease Report of 2004 [7]. From the search, we discovered that scholarly literature on mobile applications that dealt with diagnosis and treatments of hereditary diseases were relatively few. So we decided to focus on the review of commercially available hereditary-disease mobile applications.

2.2. Review of existing commercial mobile applications

From existing literature, we reviewed commercial mobile applications (from 2003 to 2013) that have been applied to some hereditary diseases or are still being applied to hereditary diseases from the application stores of different Smartphone brands [8,9], such as Google Playstore of Google Android [10], Apple itunes of Apple [25], BlackBerry World of BlackBerry [26] and Windows Phone Apps+Games Store of Microsoft [27]. The selected hereditary diseases are migraine [11], low vision [12], sickle cell disease [13], depression [14–16], asthma [17–20] and diabetes [21–24]. From a previous study conducted by Martinez Perez and colleagues [30], we were able to extract the tabulated statistical data for hereditary-related commercial mobile applications (See Table 1) with information about mobile applications and the corresponding stores where they were gotten from. After collating the list of hereditary-disease related mobile applications, we conducted a simple comparative analysis between existing mobile applications presented by Martínez-Pérez and colleagues [30] and AMAHD presented by us. This comparison is depicted in Table 2.

Table 1
Results of the hereditary-disease related commercial mobile apps review by Borja Martínez-Pérez and colleagues from 2003 to 2013 Source: (Martínez-Pérez et al. [30]).

Commercial site	Anemia	Migeraine	Low vision	Asthma	Diabetes	Diabetes mellitus	Depression
Google Play	7/74	57/201	33/43	44/226	> 1000	19/67	> 1000
Itunes	7/21	46/102	30/46	57/124	605	17/21	419
Blackberry	0/0	5/6	0/0	6/7	33	0/0	13
Windows	0/0	4/8	1/1	4/14	81	2/3	69
Nokia Ovis Store	0/0	0/0	–	1/2	40	15/40	35
Total	14	112	64	112	> 1759	53	> 1536

Table 2
Comparative analysis between AMAHD and some selected existing hereditary disease mobile application.

S/N	NAME	Condition	Rating	Class	Internet requirement	Clinical/ Non-clinical	Data Visualization
1	AMAHD	Generic (both rare and common hereditary diseases)		Educational Informative Assistive	Yes	Both	Text and photo
2	SickleSAM (not commercial)	Anemia		Tracking	No	Clinical	Graph
3	MD Series:	Anemia free	4.9	Educational	No	Both	Text
4	iBMM (not commercial)	Migraine		Educational Guideline Monitoring	Yes	Both	Video, text and graph
5	My Headache Log Pro	Migraine	4.1	Monitoring	Yes (Emails)	Both	Text and graph
6	VizWiz	Low Vision	4.5	Assistive	Yes	Non Clinical	Photos, text and audio
7	EZReader Theme Pack	Low Vision	4.4	Assistive	No	Non Clinical	Text and audio
8	m. Carat	Asthma		Assistive Monitoring	Yes	Non Clinical	Graph, text and picture
9	SIGN Asthma Patient Guide	Asthma	4.9	Informative Guidelines	Yes	Non Clinical	Text and pictures
10	Type 1 diabetes Friend: Alcohol Guide	Diabetes Mellitus		Educational Informative	Yes	Non Clinical	Text and photos
11	On Track Diabetes	Diabetes Mellitus	4.5	Monitoring	Yes (Emails)	Both	Text and graphs
12	VirtualClinic – The Get Happy Program	Depression		Educational Guidelines	Unknown	Non Clinical	Pictures, comic and text
13	Positive thinking	Depression	4.3	Treatment	Yes	Non Clinical	Text

Other studies, related to android mobile application development, have been conducted in the past. For instance, Arnhold et. al. [28], conducted an extensive systematic review and expert-based usability evaluation on android and iOS mobile applications for diabetes patients. In total, they analyzed 656 apps. Their review and evaluation results revealed that 355 (representing 54.1%) of the total mobile apps performed just one function, while 348 (representing 53.0%) performed documentation function. From their findings, they discovered that the most prominent and dominant mobile app language was English with 560 apps (representing 85.4% of the total mobile apps). Patients were mostly the users of the apps with 630 (representing 96.0%) of the total app users. Results also showed that most people (representing 53.7%), tended towards using free mobile apps.

Another mobile application known as MyFactor was developed by BioRx. MyFactor app was actually designed to help hemophilia patients manage their health conditions and interact with relevant healthcare team [29]. MyFactor mobile app was found to be effective because of its features such as; quick log infusions, ability to track bleeding episodes, capability to allow viewing and sharing reports of infusion and bleed history, scheduling infusion reminders, and updating past bleeds or infusions.

2.3. Existing research on mobile health for disease diagnosis and management

There are many existing research on the application of mobile health for disease diagnosis and management. In this section, we reviewed some of them. A review was recently conducted by Jutel and Lupton [61] to describe different diagnosis applications and highlight their impact on diagnosis process. A new app has been developed by some researchers in the University of Cambridge. The purpose of the app is to help monitor disease conditions for patients and doctors [62]. It has the capability of accurately measuring color-based test, which can be applied at home, hospital settings, and remote locations. It can also facilitate effective real-time transfer of patient medical data to medical practitioners. Some researchers have applied mobile systems in diabetes management [63]. In another study, a mobile application for diagnosing preeclampsia was developed to help people living in settings with limited resources [64]. Arsand and colleagues developed another mobile application to help people living with type 2 diabetes to management the disease [65]. Harris and colleagues designed a mobile diabetes management system by focusing on glycemic control in patients living with diabetes [66]. Lee and colleagues developed a mobile application game for dietary control of human body weight [67]. Kulkarnia and Ozturk developed (mPHASiS), a mobile patient information system which acts as a complementary tool to caregivers and can be integrated into a hospital information system for managing chronic diseases of affected patients [68]. Mattila and colleagues developed a wellness management mobile application [69]. The mobile application's concept focused on Cognitive-behavioral therapy(CBT). Logan and colleagues applied mobile phones to the management of the hypertension in hypertensive patients [70].

3. Materials and methods

3.1. Overview of AMAHD

AMAHD can be used by medical practitioners, medical students in training, patients, and bioinformaticians working in the area of genetics. It provides comprehensive information about hereditary diseases. The application consists of the **view disease menu**, **symptoms menu** and the **close buttons menu**. Within the application, the classifications of hereditary diseases were presented as either rare or common. We classified the hereditary diseases into common or rare hereditary diseases, based on the survey results we were able to collate from online survey participants from Africa, Australia, Europe, America, and Asia. These participants classified the hereditary diseases based on their understanding of the frequency of occurrence of such diseases in their respective regions. This informed our decision of classifying such hereditary diseases and disorders as either common or rare in AMAHD (See Figs. 3–16).

The first section of AMAHD consists of the rare hereditary diseases. Among the rare hereditary diseases, as highlighted in our android mobile application, are: dysplasia, thrombosis, pernicious Anemia, Parkinson's, methemoglobinemia, Leigh's, compormelic, amongst others. The section of AMAHD consists of the common hereditary diseases. Among some of the common hereditary diseases are: sickle cell, albinism, diabetes, color blindness, baldness, among others. The information about each hereditary disease provides description about the causes and possible treatments that can be applied to address such diseases (See Figs. 17 and 18).

The third section of AMAHD is the internet search option. The purpose of this section is to provide access to hereditary diseases that have not been listed in AMAHD. This allows any user to quickly search for information about hereditary diseases by connecting to the internet through AMAHD's graphical user interface. If the hereditary disease exists, then it displays information about it, but if not, it does not display. The result obtained here is dependent upon the availability of internet connectivity.

The fourth section of AMAHD is the symptoms section. We anticipated incorporating artificial intelligence into AMAHD in future versions. Therefore, this section is still at the developmental stage. However, in future versions of AMAHD, we hope to complete the symptoms section. The symptom section prompts the user to key-in up to four different symptoms and through a "Logical Disjunction Rule-based algorithm", AMAHD can suggest the likely hereditary disease(s) (See Figs. 23 and 24), that has the symptoms that such users have provided. However, if the hereditary diseases with such symptoms do not exist in AMAHD's database, AMAHD specifically states that the symptom does not exist in the database (See Figs. 19–22).

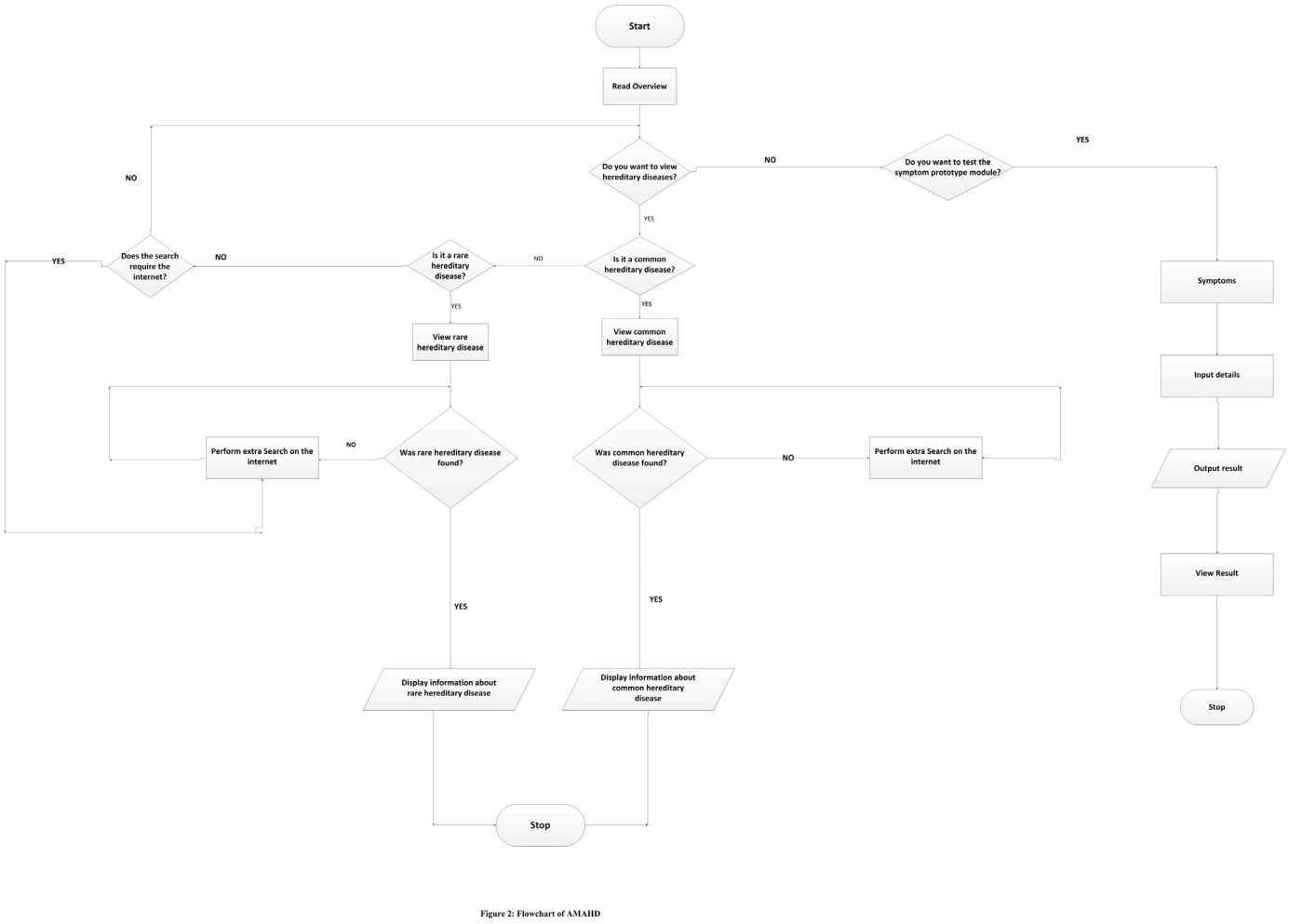


Figure 2: Flowchart of AMAHD

Fig. 1. Flowchart of AMAHD illustrating the various processes within AMAHD.

3.2. System architecture

The architecture of AMAHD consists of three (3) major layers namely: (i) the presentation layer (ii) the application layer and (iii) the data layer. This architecture helps to depict how the mobile application works and behaves. According to Kruchten and colleagues [31–33], software architecture of a system encompasses the composition of the structural and behavioral elements of the system. The functionalities that AMAHD provides are: viewing, entering and searching for information on hereditary diseases. AMAHD gets its data from a local database and the internet.

3.3. Implementation

Eclipse Integrated Development Environment (Eclipse IDE) was used for developing AMAHD. An integration of Java and XML

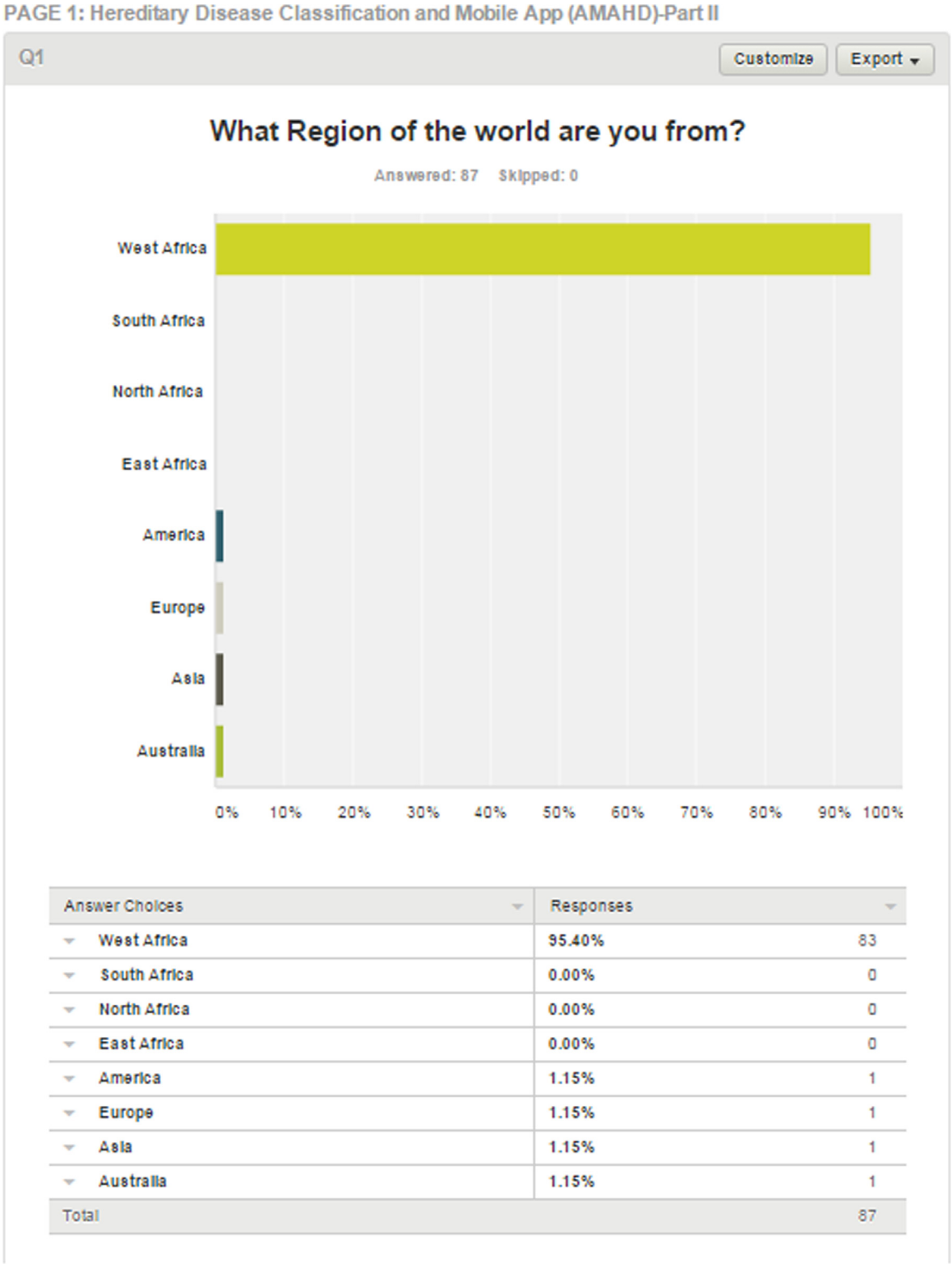


Fig. 2. Overview of AMAHD illustrating the various sections within AMAHD – view disease, symptoms and close.

(Extended Markup Language) programming languages were used to implement AMAHD. Android java source code was used to create the application. XML was used for designing the structure of the interface. SQLite was used for the database aspect of the android application. A logical deductive reasoning algorithm was developed and used to implement the symptoms section (See Section 3.3.2). BlueStacks App Player was used to emulate and simulate AMAHD on windows 7 and 8 operating systems. The implementation of AMAHD can also be viewed on the AMAHD flowchart as shown in Fig. 1. The flowchart begins with the overview section. It progresses by leading users to either view common diseases or rare diseases. If diseases are found, it displays information about such hereditary diseases. If not found, it provides opportunity for the users to search for the hereditary diseases. On the second front, if users are interested in keying symptoms, then AMAHD uses a logical rule-based algorithm as specified in Section 3.3.2 (See Listing 1), to infer the possible hereditary disease whose symptoms have been keyed into the application.

3.3.1. Implementation details of AMAHD

Java programming language was used for implementing the presentation for each type of hereditary disease included in AMAHD. They are then linked up with information about them on the database or on the internet. For the implementation of the database in AMAHD, these have been specified in the code listings. Few of the code listings for it can be viewed in the appendix section. However, a comprehensive list of all the codes for AMAHD can be made available upon request from the corresponding author.

3.3.2. Algorithm

A logical deduction mechanism was built into AMAHD by developing a logical disjunction-based algorithm that allows a user to enter up to four symptoms. AMAHD uses this algorithm to compare these symptoms with an existing database that has a list of hereditary diseases, with corresponding sets of possible symptoms. AMAHD now uses the algorithm to search through the database to select corresponding hereditary diseases that have such symptoms as entered by the user of the mobile application. The algorithm is based on the principle of logical disjunction and it is valid. For this reason, we have named our algorithm a "**Logical Disjunction Rule-based Algorithm**" (**LDRA**). The algorithm applies logical reasoning based on the principles of logical disjunction, by providing a set of possible hereditary diseases, whose symptoms are in common with the symptoms keyed in by the user into AMAHD (See Figs. 19–22) and (Figs. 23–24). The concept of 2 to the power of n (2^n) has many applications in computer science [47–49]. We adopted the concept of 2 to the power of n (2^n) for the current number of symptoms that the algorithm can accommodate. Here, $n=2$, thus we have $2^2=4$. We hope to build and implement a more robust version of this algorithm in the order of $2^8, 2^{16}, 2^{24}, 2^{30}, \ldots\ldots 2^{1024} \ldots, 2^{74,207,281}$ in future multi-lingual version of AMAHD. The last value of $2^{74,207,281}=300,376,418,084,606,182,052,986,\ldots\ldots\ldots\ldots$, 498, 687, 010, 073, 391, 086, 436,352. This final value has more than 22 million digits [50–53]. The (**LDRA**) algorithm is depicted as shown in Listing 1.

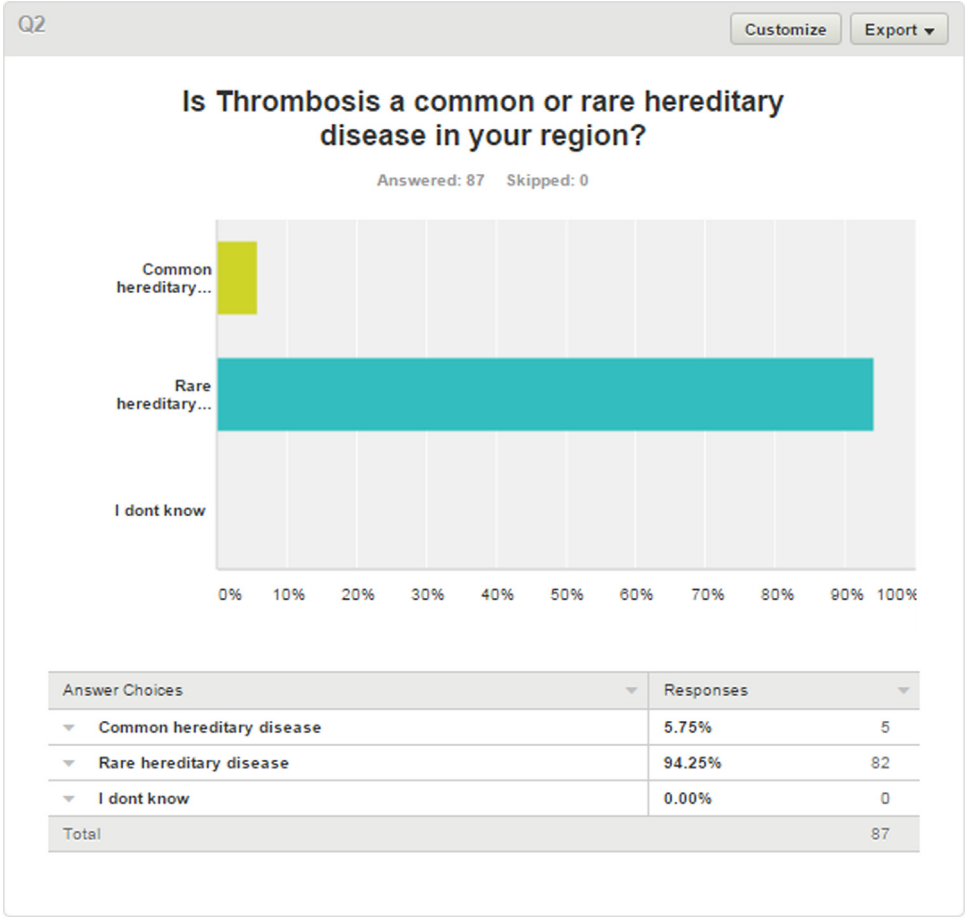


Fig. 3. Regions of the world that participated in the classification of some selected hereditary diseases and disorders. Some selected hereditary diseases and disorders were presented to participants to classify as either rare or common within their respective regions. Participants from Africa, America, Europe, Asia and Australia took part in the classification, with majority from West Africa.

Listing 1. Logical Disjunction Rule-based Algorithm (LDRA).

Begin
Enter symptom1, symptom2, symptom3, symptom4
Search for hereditary disease in the disease database having at least one of these symptoms
If (symptom1 or symptom2 or symptom3 or symptom4 is present) in the hereditary disease database
OR
If all the symptoms are found in any of the hereditary diseases and disorders,
then output hereditary_disease1/disorder1,
hereditary_disease2/disorder2,
hereditary_disease3/disorder3
hereditary_disease4/disorder4
that contains any of the symptoms searched for
Else
Output The hereditary diseases for these symptoms NOT found
End

From the knowledge of **Set Theory in Discrete Structures and Discrete Mathematics**,

If n=number of symptoms entered, then the number of possible outputs will be 2^n possible outputs. **Deductive reasoning** (which is also referred to as logical deduction or top-down logic), is a reasoning procedure from one or more statements (premises) to arrive at a logically sure conclusion. Thus, deductive reasoning creates a bridge that links premises to conclusions [54–57]. We adopted the knowledge of deductive reasoning in this algorithm.

From the knowledge of **logical reasoning and logical disjunction** [58,59], if $n=2$, then the truth table will generate $2^2=4$ possible outputs. However, if $n=3$, then the truth table is capable of generating $2^3=8$ possible outputs. If $n=4$, then the truth table is capable of generating $2^4=16$ possible outputs. For a **set A** with n elements, the cardinality of 2^A is 2^n. This is in fact the reason for

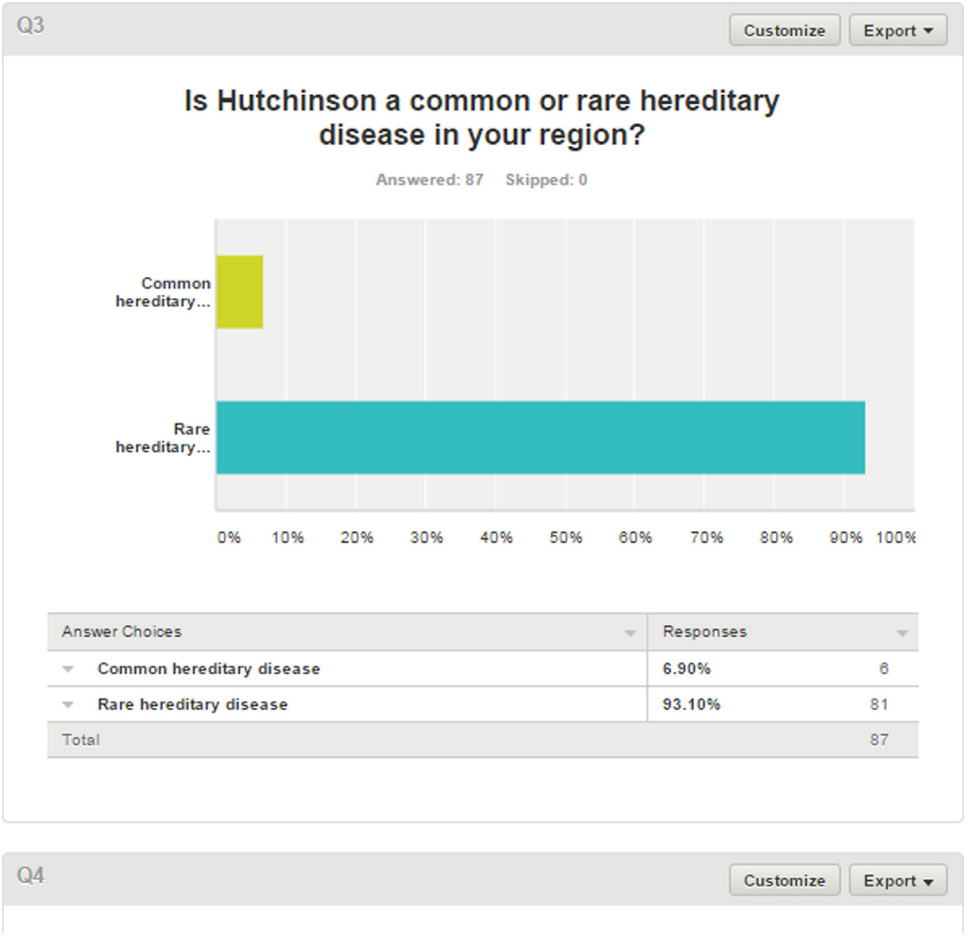


Fig. 4. Depiction of the percentages of those that classified Thrombosis as either a rare or a common hereditary disease/disorder. The results of the survey showed that majority classified Thrombosis as a rare hereditary disease/disorder in their respective regions than others.

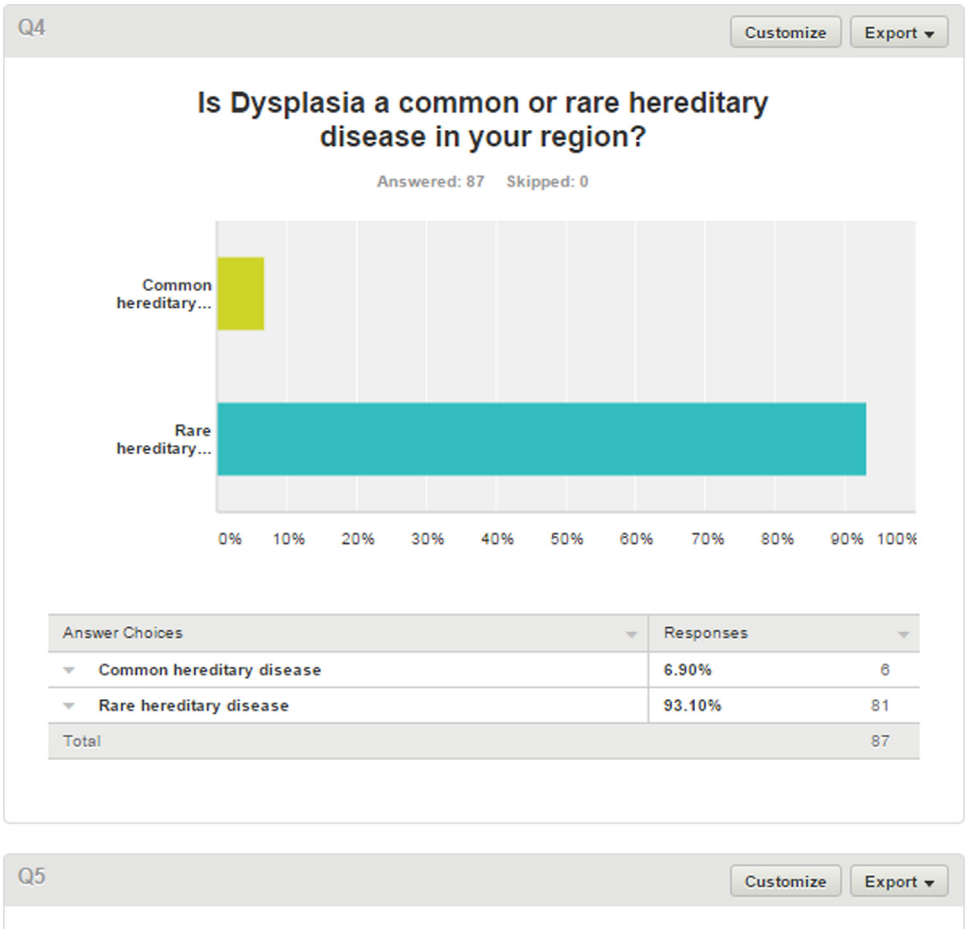


Fig. 5. Depiction of the percentages of those that classified Hutchinson as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Hutchinson as a rare hereditary disease/disorder in their respective regions.

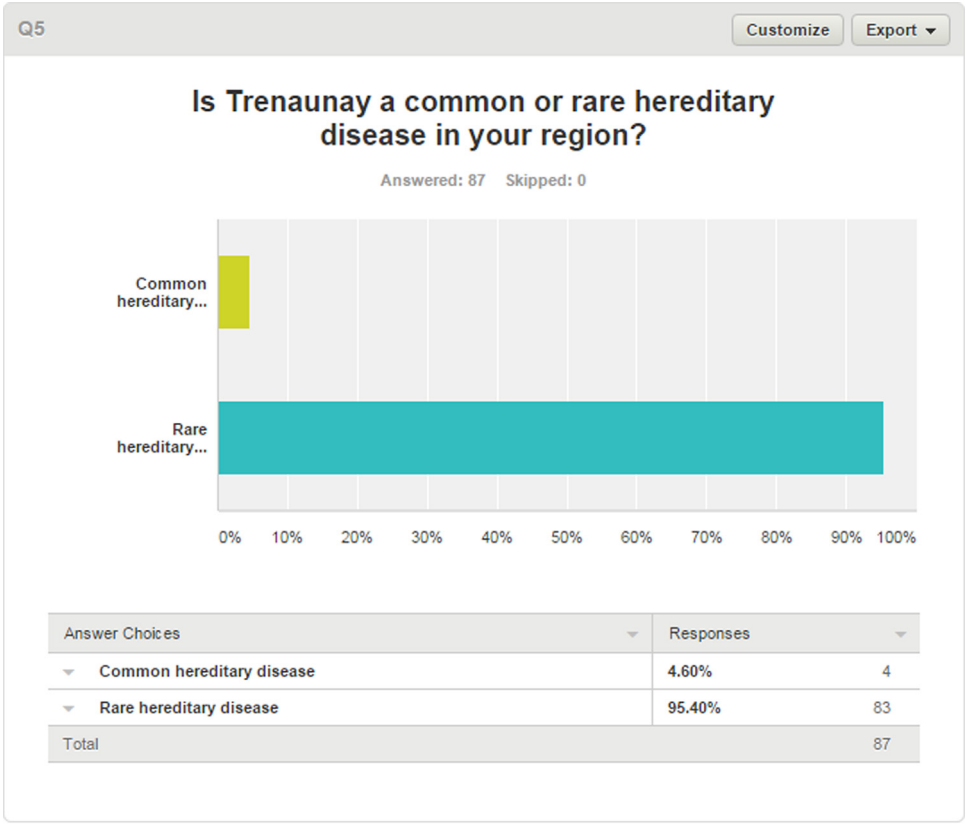


Fig. 6. Depiction of the percentages of those that classified Dysplasia as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Dysplasia as a rare hereditary disease/disorder in their respective regions.

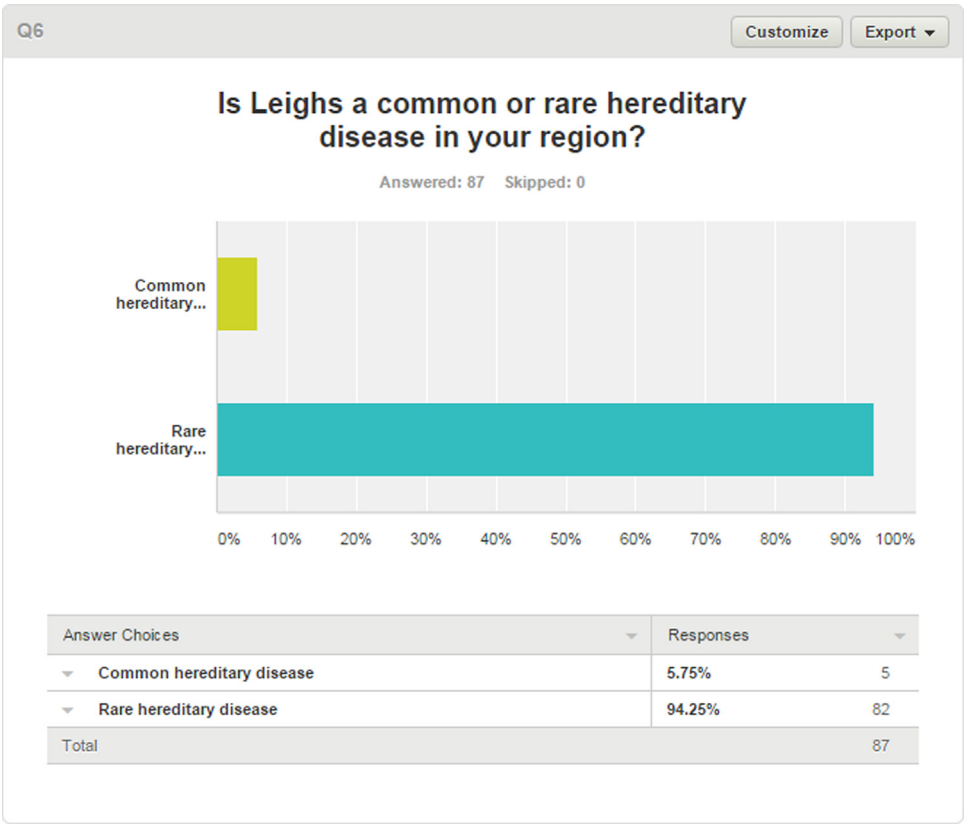


Fig. 7. Depiction of the percentages of those that classified Trenaunay as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Trenaunay as a rare hereditary disease/disorder in their respective regions.

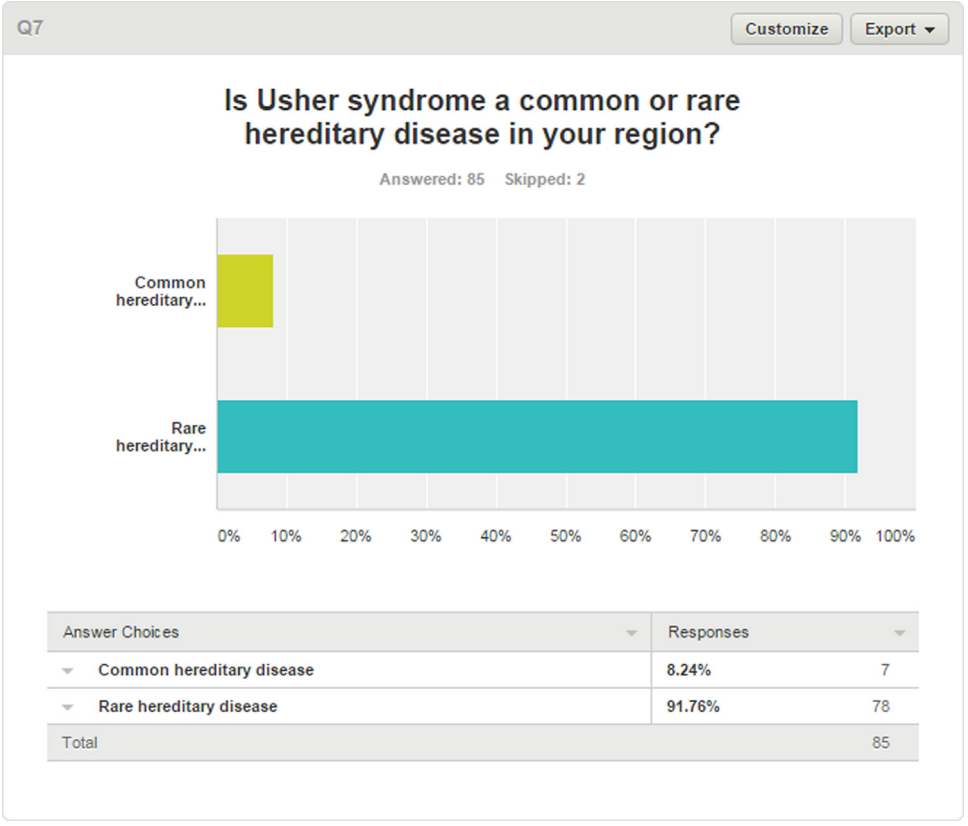


Fig. 8. Depiction of the percentages of those that classified Leighs as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Leighs as a rare hereditary disease/disorder in their respective regions.

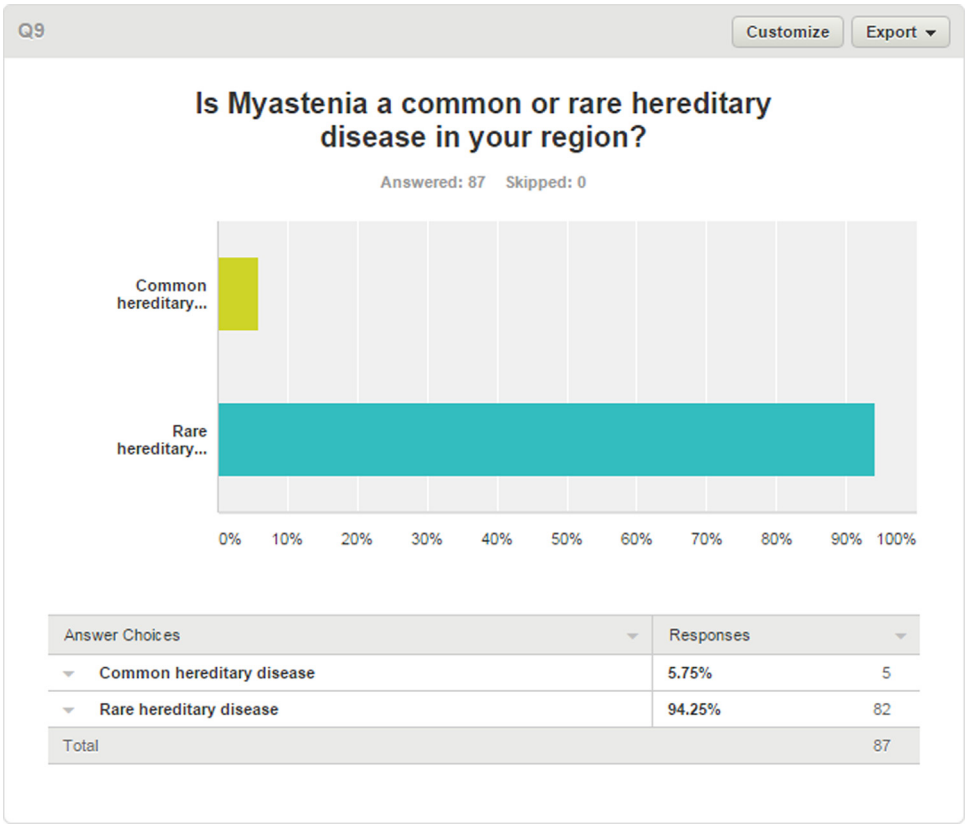


Fig. 9. Depiction of the percentages of those that classified Usher syndrome as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Usher syndrome as a rare hereditary disease/disorder in their respective regions.

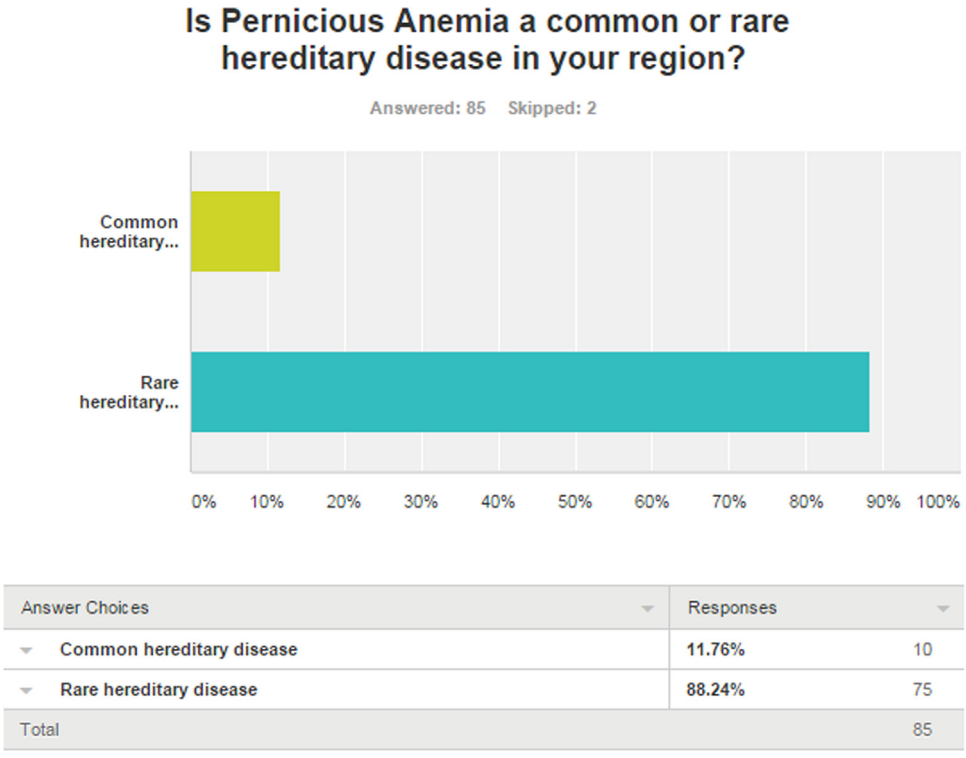


Fig. 10. Depiction of the percentages of those that classified Myastenia as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Myastenia as a rare hereditary disease/disorder in their respective regions.

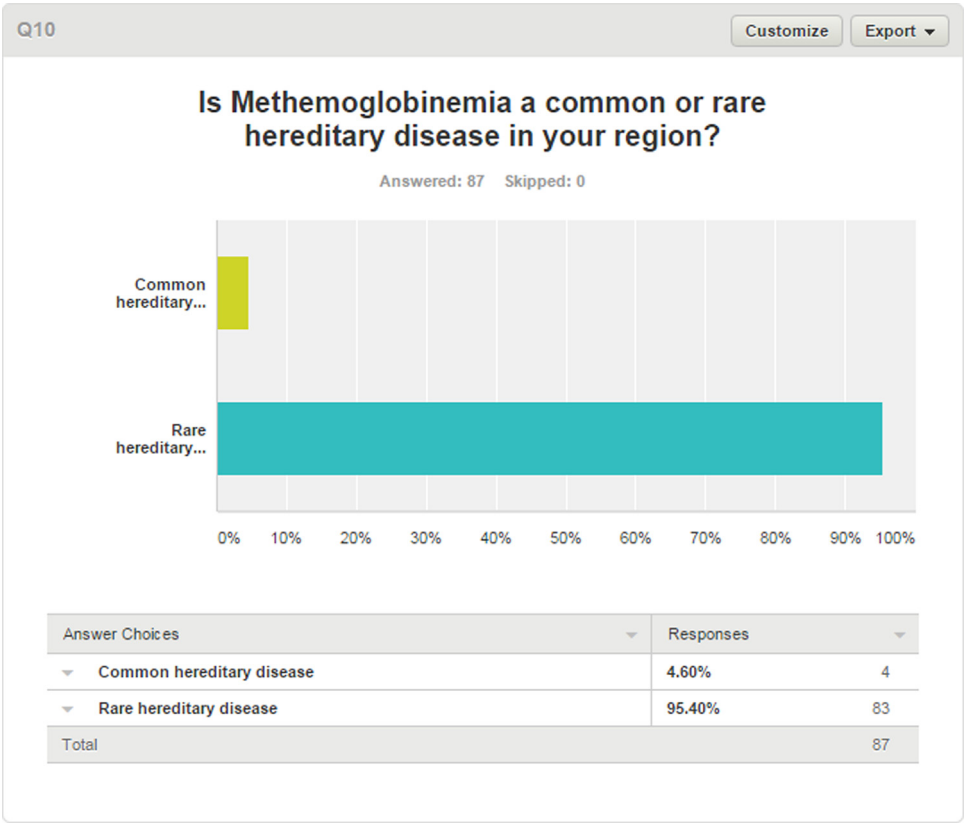


Fig. 11. Depiction of the percentages of those that classified Pernicious Anemia as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Pernicious Anemia as a rare hereditary disease/disorder in their respective regions.

the power set notation. Back to our proposed algorithm (LDRA), the principle of operation is similar to deductive logical reasoning. We developed this algorithm based on the principle of logical deduction, logical disjunction to be specific. We now married this principle to logic programming.

We have some assumptions here. They are:

- An hereditary disease may have more than one symptoms
- An hereditary disease may share more than one symptom in common with another hereditary diseases.

However, if $n=4$, then the logical truth table is capable of generating $2^4=16$ possible outputs. This particular condition is in perfect correlation and depiction with our proposed algorithm.

Here, we have the truth table highlighted in Table 4.4. There are 16 possible outcomes here.

The following propositions hold about the premises P, Q, R and S:

P is True – if symptom 1 exists in the hereditary disease database. If it does not exist, then P is false.

Q is True – if symptom 2 exists in the hereditary disease database. If it does not exist, then Q is false.

R is True – if symptom 3 exists in the hereditary disease database. If it does not exist, then R is false.

S is True – if symptom 4 exists in the hereditary disease database. If it does not exist, then S is false.

The following logical conclusions are valid after applying the principle of logical disjunction for the premises P, Q, R and S.

- **Remark 1** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 exists in the disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value implies that it returned a set of possible hereditary diseases which have all of the four symptoms within the hereditary disease database or share all the four symptoms in common within the hereditary database. According to the rule of logical disjunction, this is logically valid. In fact, in logic, this is referred to as the truth-preserving validity [60]. In logic, an argument is valid if and only if the truth of its premises entails or results into the truth of its conclusion.
- **Remark 2** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 DOES NOT exist in the disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value implies that it returned a set of possible hereditary diseases which have all of the three symptoms within the hereditary disease database or share all the three symptoms in common within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 3** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 DOES NOT exist in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value implies that it returned a

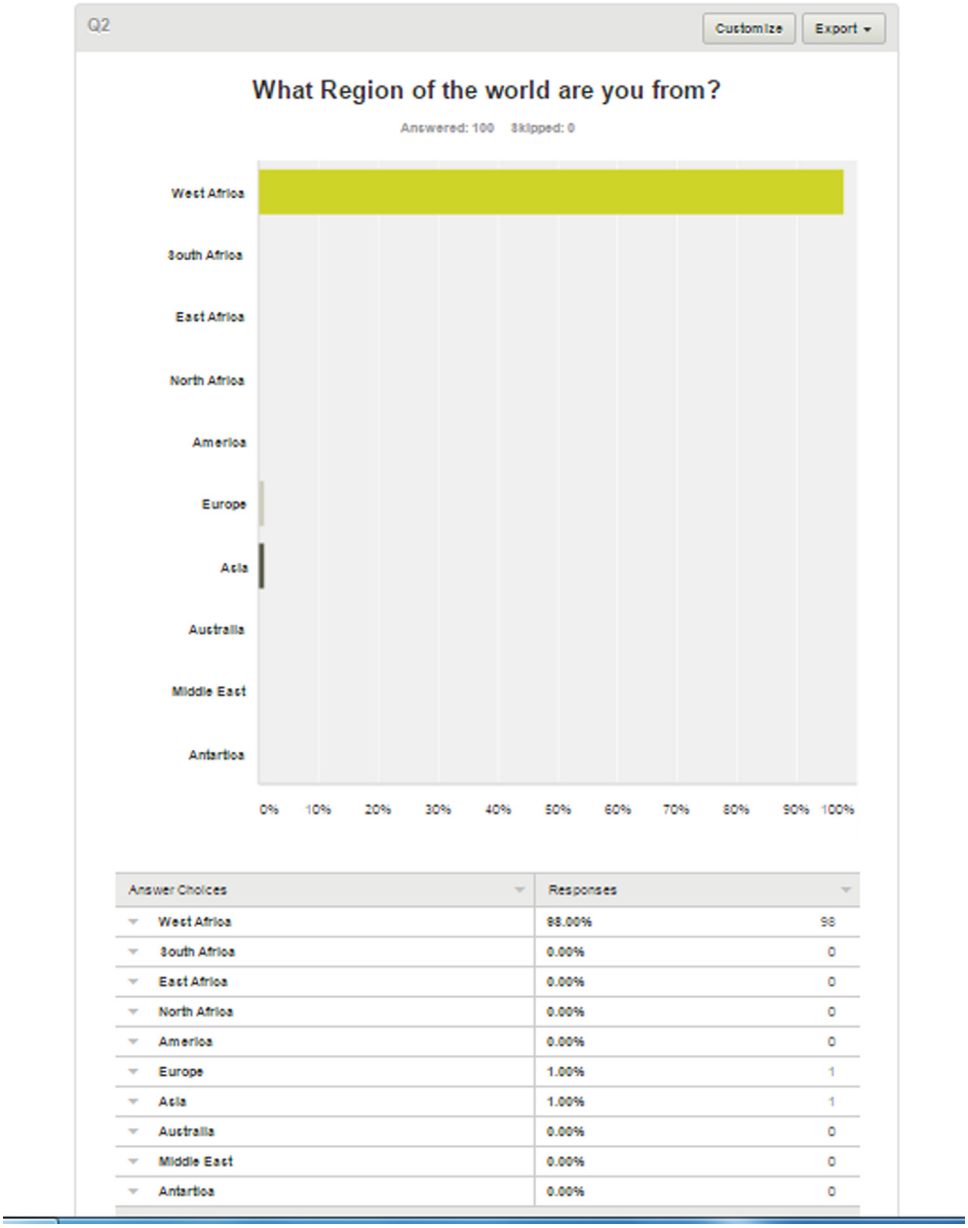


Fig. 12. Depiction of the percentages of those that classified Methemoglobinemia as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Methemoglobinemia as a rare hereditary disease/disorder in their respective regions.

set of possible hereditary diseases which have all of the three symptoms within the hereditary disease database or share all the three symptoms in common within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.

- **Remark 4** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 DOES NOT exist in the hereditary disease database or if symptom 4 DOES NOT exist in the hereditary disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value implies that it returned a set of possible hereditary diseases which have all of the two symptoms within the hereditary disease database or share all the two symptoms in common within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 5** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value implies that it returned a set of possible hereditary diseases which have all of the three symptoms within the hereditary disease database or share all the three symptoms in common within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 6** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 DOES NOT exist in the hereditary disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least one of the symptoms within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.

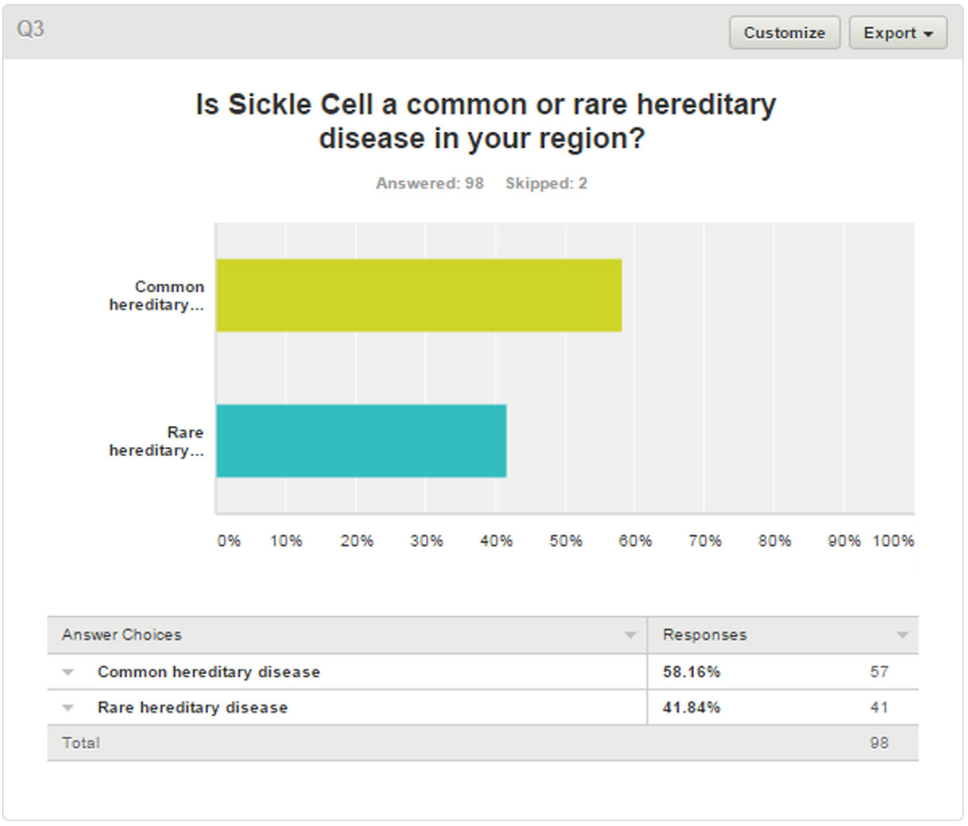


Fig. 13. Further Regions of the world that participated in the classification of some selected hereditary diseases and disorders. Some selected hereditary diseases and disorders were presented to participants to classify as either rare or common within their respective regions. Participants from Africa, Europe, and Asia took part in the classification, with majority from West Africa.

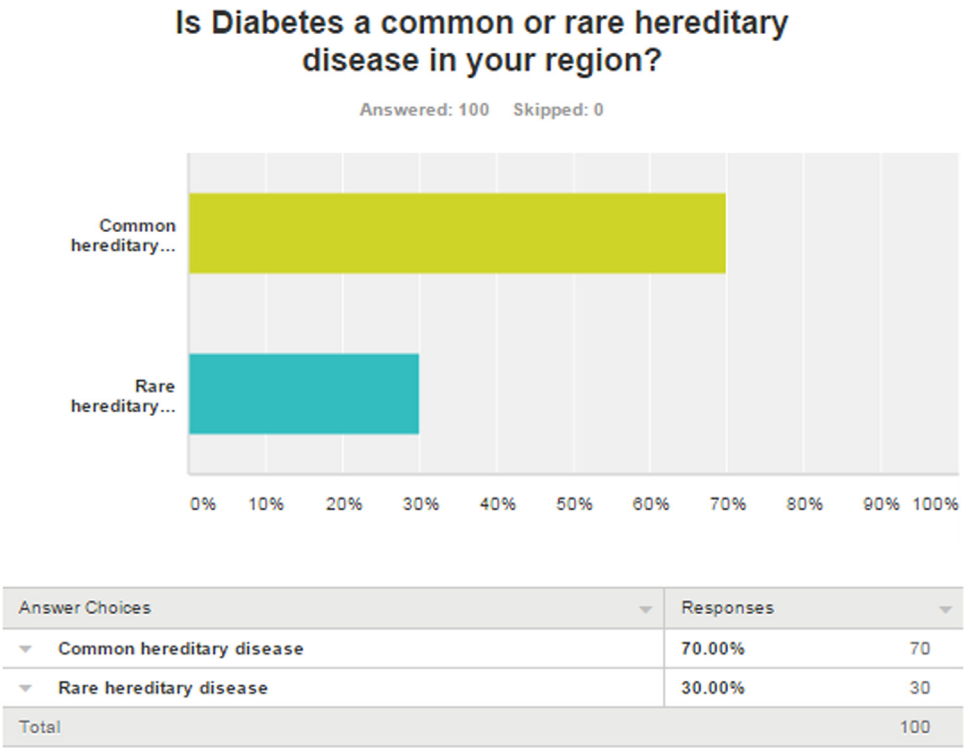
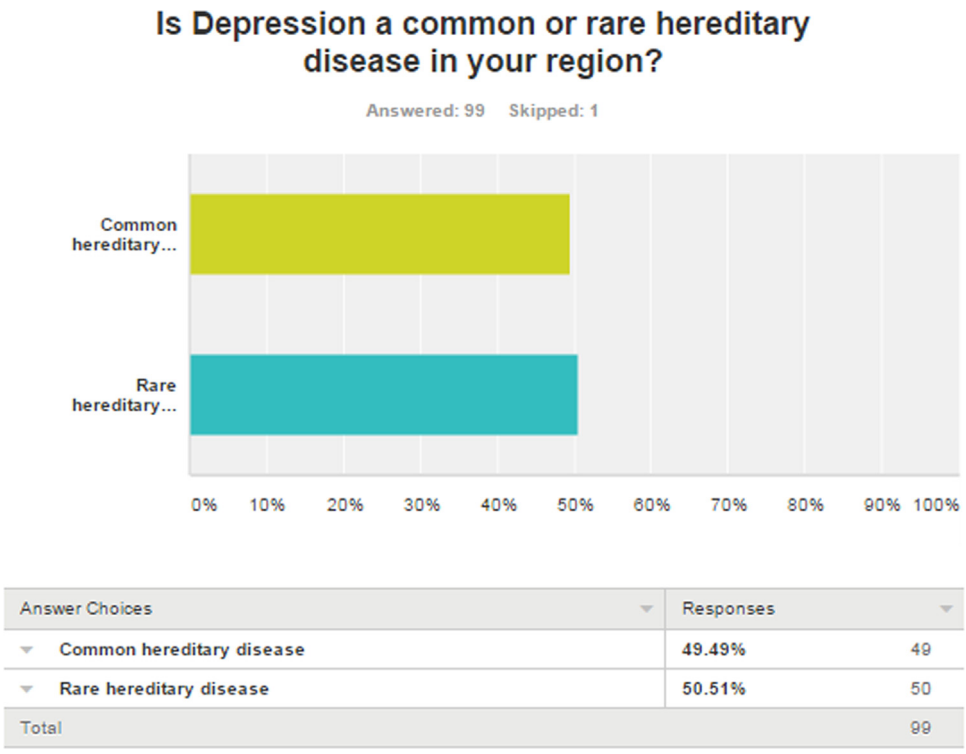


Fig. 14. Depiction of the percentages of those that classified Sickle Cell as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Sickle Cell as a common hereditary disease/disorder in their respective regions.



Answer Choices	Responses	
Common hereditary disease	49.49%	49
Rare hereditary disease	50.51%	50
Total		99

Fig. 15. Depiction of the percentages of those that classified Diabetes as either a rare or a common hereditary disease/disorder. The results of the survey showed that more people classified Diabetes as a common hereditary disease/disorder in their respective regions.

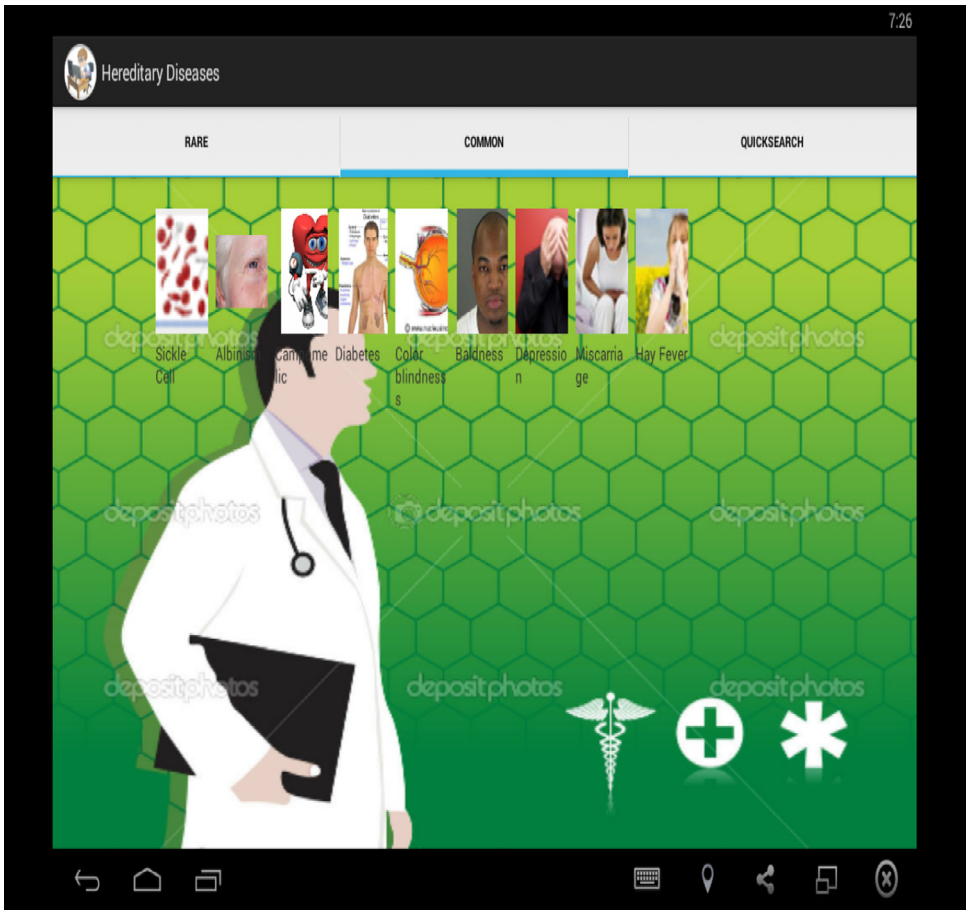


Fig. 16. Depiction of the percentages of those that classified Depression as either a rare or a common hereditary disease/disorder. The results of the survey showed that approximately equal number of people classified Depression as a common and rare hereditary disease/disorder in their respective regions.

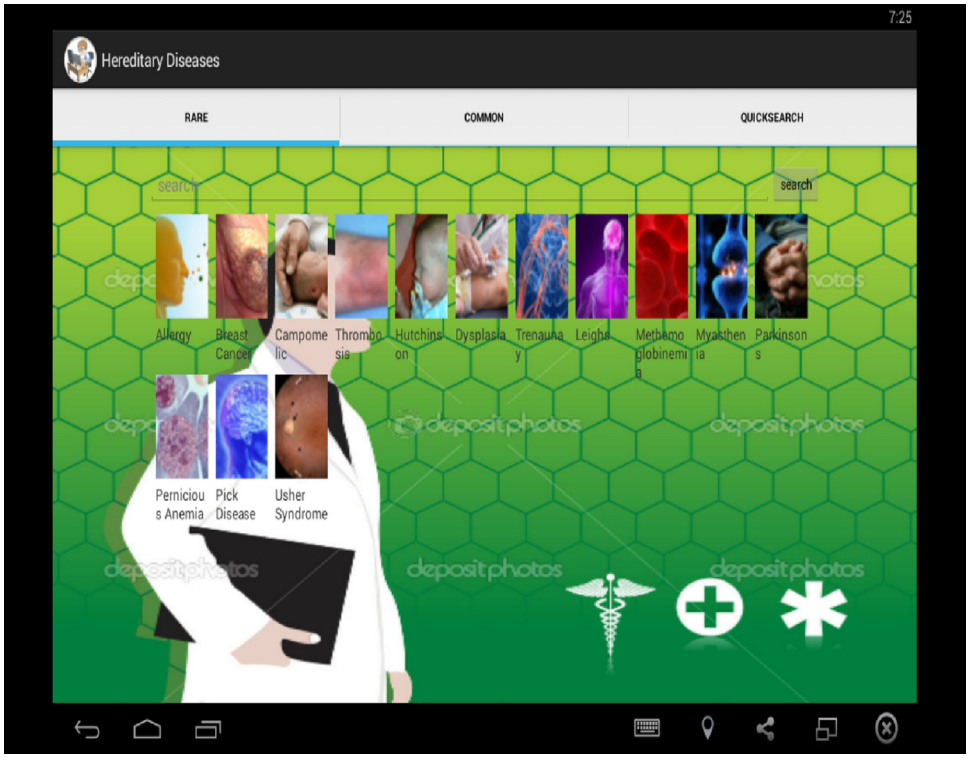


Fig. 17. Depiction of an overview of AMAHD highlighting section for common hereditary diseases. An overview of AMAHD showing the section for common hereditary diseases and disorders.

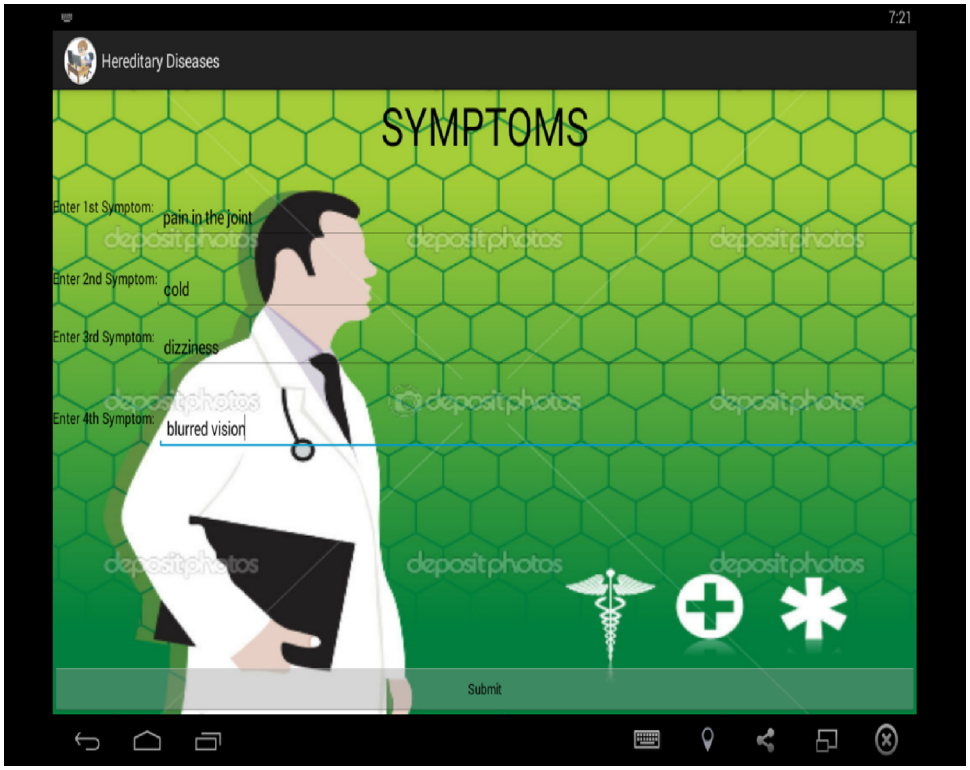


Fig. 18. Depiction of an overview of AMAHD highlighting section for rare hereditary diseases. An overview of AMAHD showing the section for rare hereditary diseases and disorders.

- **Remark 7** implies that if symptom 1 exists in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 DOES NOT exist in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*) (See Table 4.4). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.

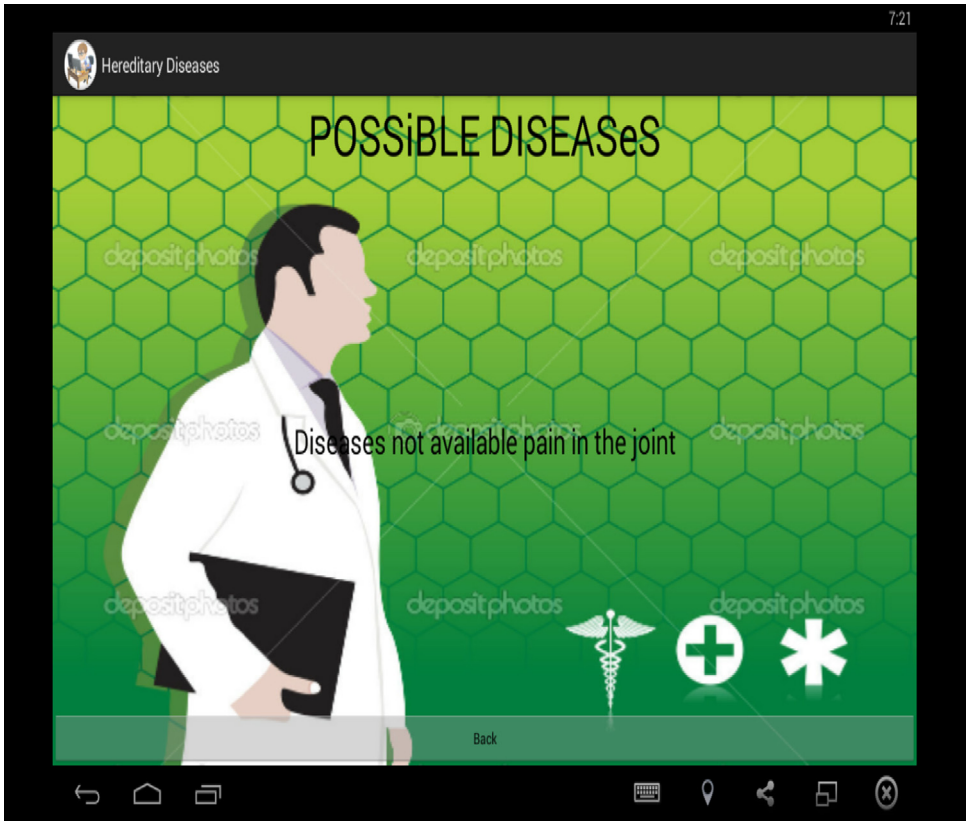


Fig. 19. Symptoms entered into AMAHD. The four (4) separate symptoms entered into AMAHD for this segment include: pain in the joint, cold, dizziness, and blurred vision. AMAHD uses a logical disjunction rule-based algorithm to process these symptoms.

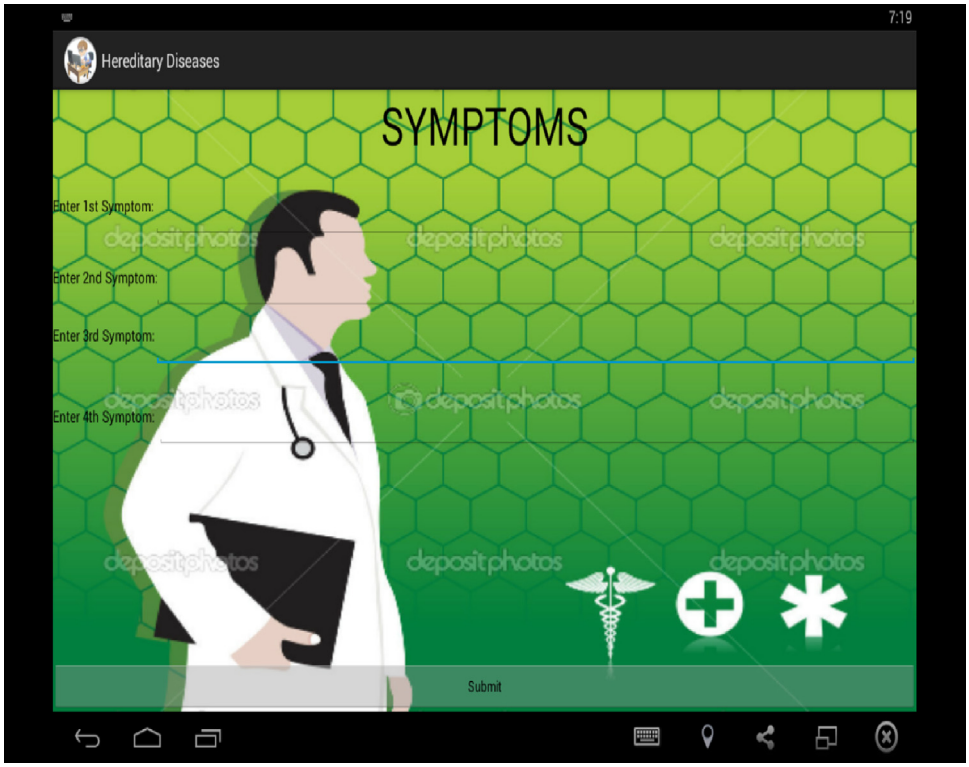


Fig. 20. AMAHD predicting no possible hereditary disease(s)/disorder(s). Here AMAHD returned no result because the logical disjunction rule-based algorithm found no symptom, (as entered by the user), in common with the hereditary disease database.

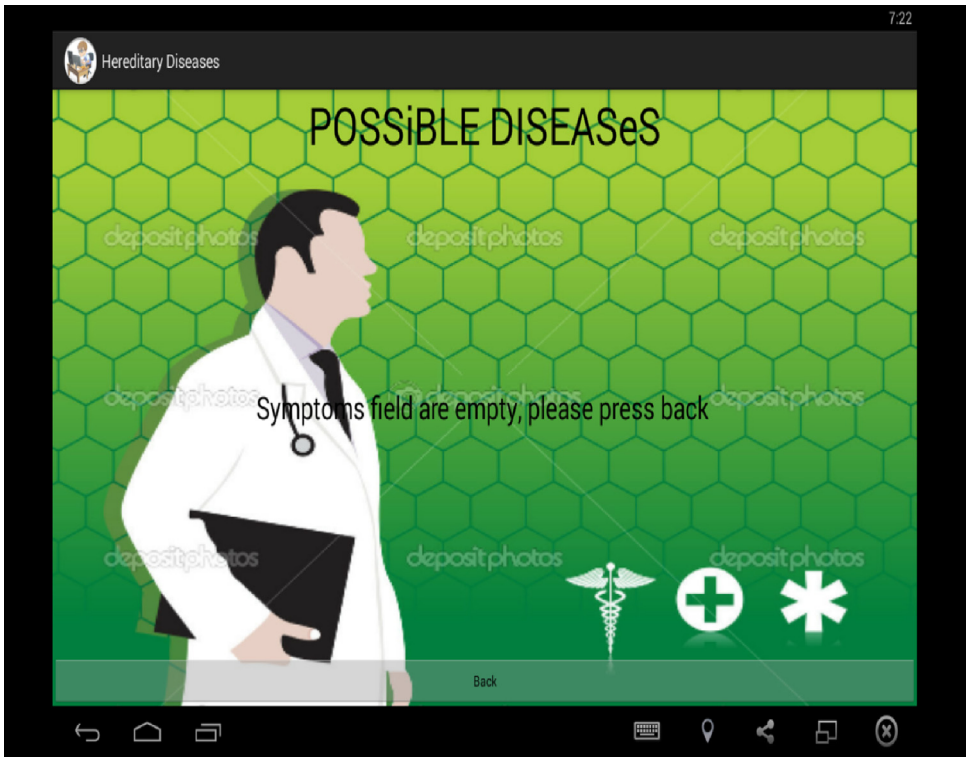


Fig. 21. AMAHD's symptom section revealing that symptom section was empty. This symptom section of AMAHD reveals that no symptom was entered.

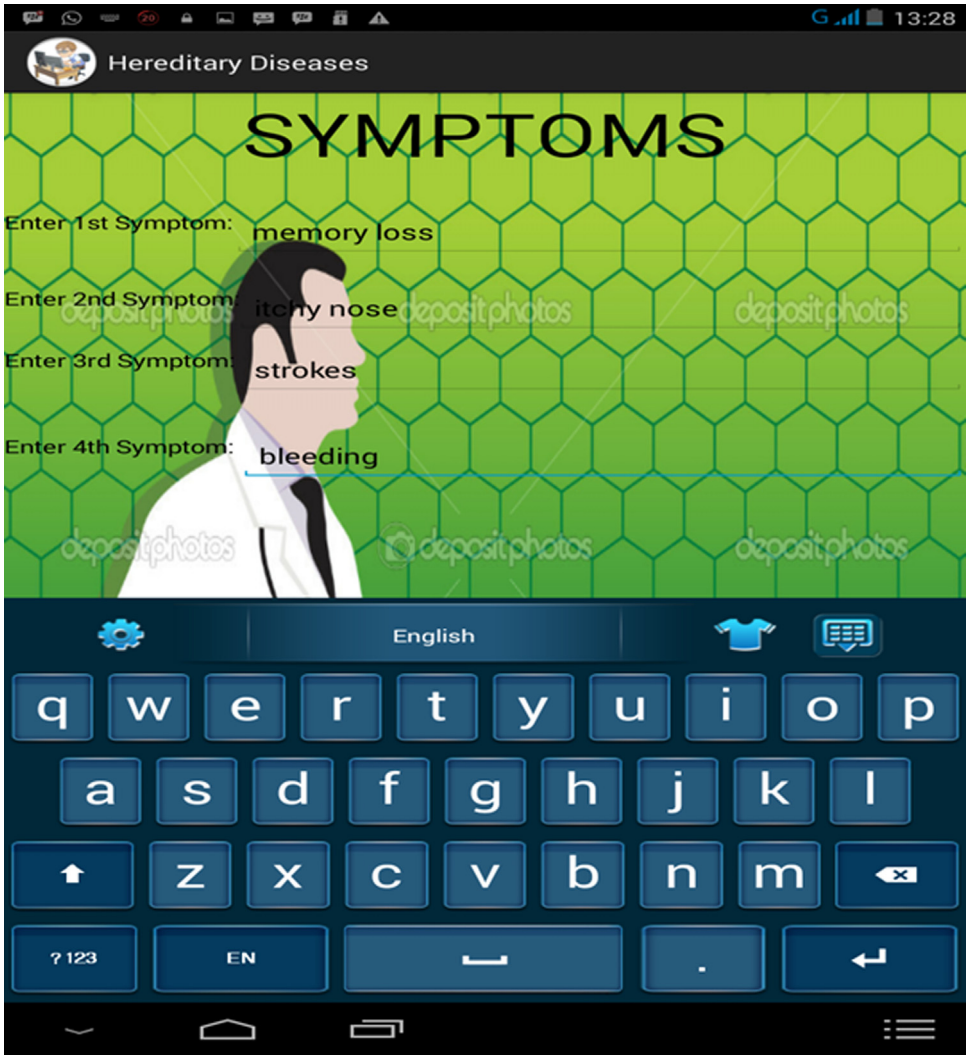


Fig. 22. AMAHD's section revealing that no symptom was entered. The symptom section of AMAHD displayed that no symptom was entered, thus no result to display possible hereditary diseases/disorders.

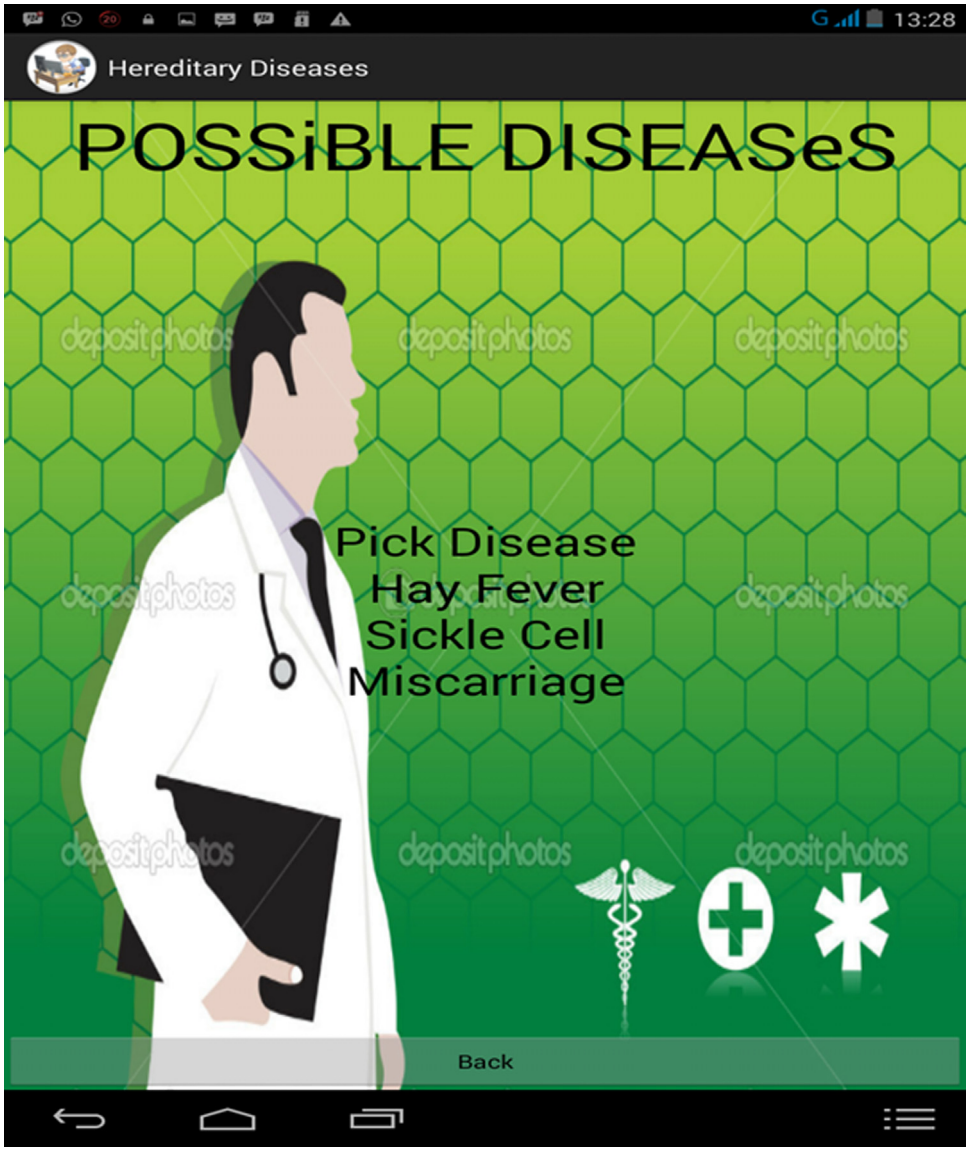


Fig. 23. Extra symptoms entered into AMAHD. The four (4) separate symptoms entered into AMAHD for this segment include: memory loss, itchy nose, strokes and bleeding. AMAHD uses a logical disjunction rule-based algorithm to process these symptoms.

- **Remark 8,** (See Table 4.4), implies that if symptom 1 exists in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 DOES NOT exist in the hereditary disease database or if symptom 4 DOES NOT exist in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 9,** (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 10,** (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 DOES NOT exist in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 11,** (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 DOES NOT exist in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.

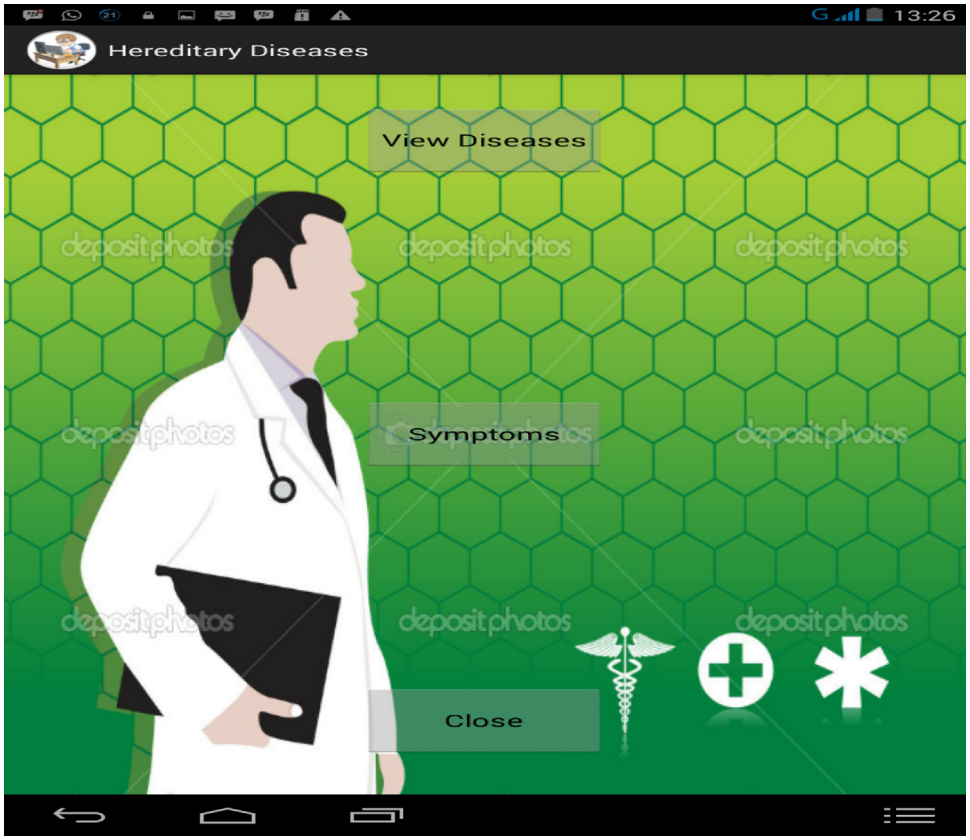


Fig. 24. Predicted possible hereditary diseases/disorders. The four (4) possible hereditary diseases/disorders predicted by the logical disjunction rule-based algorithm within AMAHD. The four possible hereditary diseases/disorders are: Pick disease, Hay fever, Sickle Cell, and Miscarriage.

- **Remark 12,** (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 exists in the hereditary disease database, or if symptom 3 DOES NOT exist in the hereditary disease database or if symptom 4 DOES NOT exist in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 13**, (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 14,** (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 exists in the hereditary disease database or if symptom 4 DOES NOT exist in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 15,** (See Table 4.4), implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 DOES NOT exists in the hereditary disease database or if symptom 4 exists in the hereditary disease database, then it still returns a truth value of (*T*). Returning this truth value is logical and this implies that it returned a set of possible hereditary diseases which have at least two of the symptoms are within the hereditary disease database. According to the principle of logical disjunction, this is logically valid.
- **Remark 16** implies that if symptom 1 DOES NOT exist in the hereditary disease database or if symptom 2 DOES NOT exist in the hereditary disease database, or if symptom 3 DOES NOT exist, or if symptom 4 DOES NOT exist in the hereditary disease database, then it returns a false value (*F*). This is when our proposed algorithm will select the ELSE part of the implementation and will not return anything as the output Or it produces the message **"The hereditary diseases for these symptoms NOT found",** if four (4) symptoms were originally entered, and they do NOT all exist in the hereditary disease database. According to the principle of logical disjunction, this is logically valid. In fact, it is referred to as the false-preserving validity [60].

For a truth-preserving validity, the interpretation under which all variables are assigned a truth value of 'true' produces a truth value of 'true' [60].

Table 3
Analysis of features between AMAHD and some selected existing hereditary disease mobile applications.

S/N	NAME	Context awareness	Therapist intervention	Interraction with users	Frequency	Interface	Public
1	**AMAHD**	User	Yes	Yes	Continuous	Simple intuitive	General
2	SickleSAM (Not commercial)	User	Yes	No	Continuous	Simple	School Children
3	MD Series:	No	–	No	Occasional	Not intuitive	Anemia Specialist
4	iBMM (not commercial)	No	Yes	No	Frequency of Migraine attacks	Not intuitive	General
5	My Headache Log Pro	Preferences Location	Possible	No	Frequency of Migraine attacks	Complex	General
6	VizWiz	Location	No	Yes	Frequent	Simple	General
7	EZReader Theme	Language	No	No	Need for arises	Basic	General
8	m. Carat	User Preferences Language	No	No	Constant	Complex	General
9	SIGN Asthma Patient Guide	NO	No Guidelines	No	Occasionally	Basic	General
10	Type 1 diabetes Friend: Alcohol Guide	No	No	No	Occasional	Simple	Young people
11	On Track Diabetes	Preferences	Possible	No	Several times	Normal	General
12	VirtualClinic – The Get Happy Program	Unknown	No	No	Regular	Simple	General
13	Positive thinking	Preferences	No	No	Regular	Simple	General

Table 4.1
Interpretation of criteria used for AMAHD's performance evaluation.

S/N	Evaluation criteria	Interpretation
1	**Ability**	This criterion checks whether AMAHD has the ability to identify or diagnose users ailments based on the symptoms they have supplied to the mobile app.
2	**Data validation 1**	This criterion helps to check whether AMAHD accepts appropriate data type for each field.
3	**Data validation 2**	This criterion helps to ascertain if AMAHD prompts error message whenever wrong data is supplied or when important input fields are omitted.
4	**Sufficiency**	This criterion helps users to check if AMAHD is sufficiently robust.
5	**Security**	This criterion is profitable in ascertaining whether AMAHD possesses adequate access control (security).
6	**Intension of use**	This criterion is profitable in ascertaining whether AMAHD will act as a complementary resource for supplementary healthcare support.
7	**Ease of use**	This Ease of Use criterion helps to check if AMAHD is generally simple to explore without any difficulty.
8	**Satisfaction**	This criterion helps to ascertain if users are actually satisfied with the services and operations provided by AMAHD.
9	**Supportiveness**	This criterion checks if AMAHD will be particularly supportive to developing countries with high rates of unawareness of the deadly effects on hereditary diseases.
10	**Usefulness**	This criterion helps to check if AMAHD would be useful as a mobile android health application.

Table 4.2
Demography on Off-line Paper questionnaire performance evaluation of AMAHD.

Participants	Numbers	Types of participants [profession]	Age [Bracket]	Gender [M=MALE & F=FEMALE]
Medical Professionals	60	Doctors – 40	30–60	M=30 F=10
		Nurses – 20	25–40	M= 2 F=18
Researchers	30	University researchers	30–50	M=25 F=5
Community inhabitants	70	Inhabitants of sub-urban areas with android devices (other diverse professions)	16–20	M=6 F=6
			30–50	M=36 F=4
			50–60	M=9 F=9
Students	40	Medical Students – 15	23–27	M= 10 F=5
		Other students – 25	18–24	M=15 F=10
Total	200			

Table 4.3
Comparison between offline paper-based survey and online survey monkey performance evaluation survey.

	Criteria for performance evaluation	Survey type	Percentage of participants in **Agreement**	Percentage of participants in **Disagreement**	Percentage of participants that were **indifferent**
1.	Ability	Offline survey	72.5%	21.5%	6%
		Survey monkey	58.49%	13.21%	28.30%
2.	Data validation1	Offline survey	69%	14.5%	16.5%
		Survey monkey	58.49%	3.78%	37.74%
3.	Data validation2	Offline survey	37.5%	22%	40.5%
		Survey monkey	47.17%	11.32%	41.51%
4.	Sufficiency [robustness]	Offline survey	62.5%	11.5%	26%
		Survey monkey	52.83%	15.09%	32.08%
5.	Security	Offline survey	65.5%	10%	24.5%
		Survey monkey	64.15%	7.55%	28.30%
6.	Intention of use	Offline survey	79.5%	7%	13.5%
		Survey monkey	71.7%	5.66%	22.64%
7.	Ease of use	Offline survey	67.5%	20.5%	12%
		Survey monkey	73.58%	3.78%	22.64%
8.	Satisfaction	Offline survey	73.5%	11%	15.5%
		Survey monkey	64.15%	5.66%	30.19%
9.	Supportiveness	Offline survey	81%	5.5%	13.5%
		Survey monkey	88.46%	1.92%	9.62%
10.	Usefulness	Offline survey	73%	12%	15%
		Survey monkey	86.79%	13.21%	0%

Table 4.4
Possible outcomes of the Logical disjunction rule-based algorithm truth table.

P	Q	R	S	PVQ	RVS	(PVQ) V (RVS)	Remarks
T	T	T	T	T	T	T	Remark 1
T	T	T	F	T	T	T	Remark 2
T	T	F	T	T	T	T	Remark 3
T	T	F	F	T	F	T	Remark 4
T	F	T	T	T	T	T	Remark 5
T	F	T	F	T	T	T	Remark 6
T	F	F	T	T	T	T	Remark 7
T	F	F	F	T	F	T	Remark 8
F	T	T	T	T	T	T	Remark 9
F	T	T	F	T	T	T	Remark 10

Table 4.4 (*continued*)

P	Q	R	S	PVQ	RVS	(PVQ) V (RVS)	Remarks
F	T	F	T	T	T	T	Remark 11
F	T	F	F	T	F	T	Remark 12
F	F	T	T	F	T	T	Remark 13
F	F	T	F	F	T	T	Remark 14
F	F	F	T	F	T	T	Remark 15
F	F	F	F	F	F	F	Remark 16

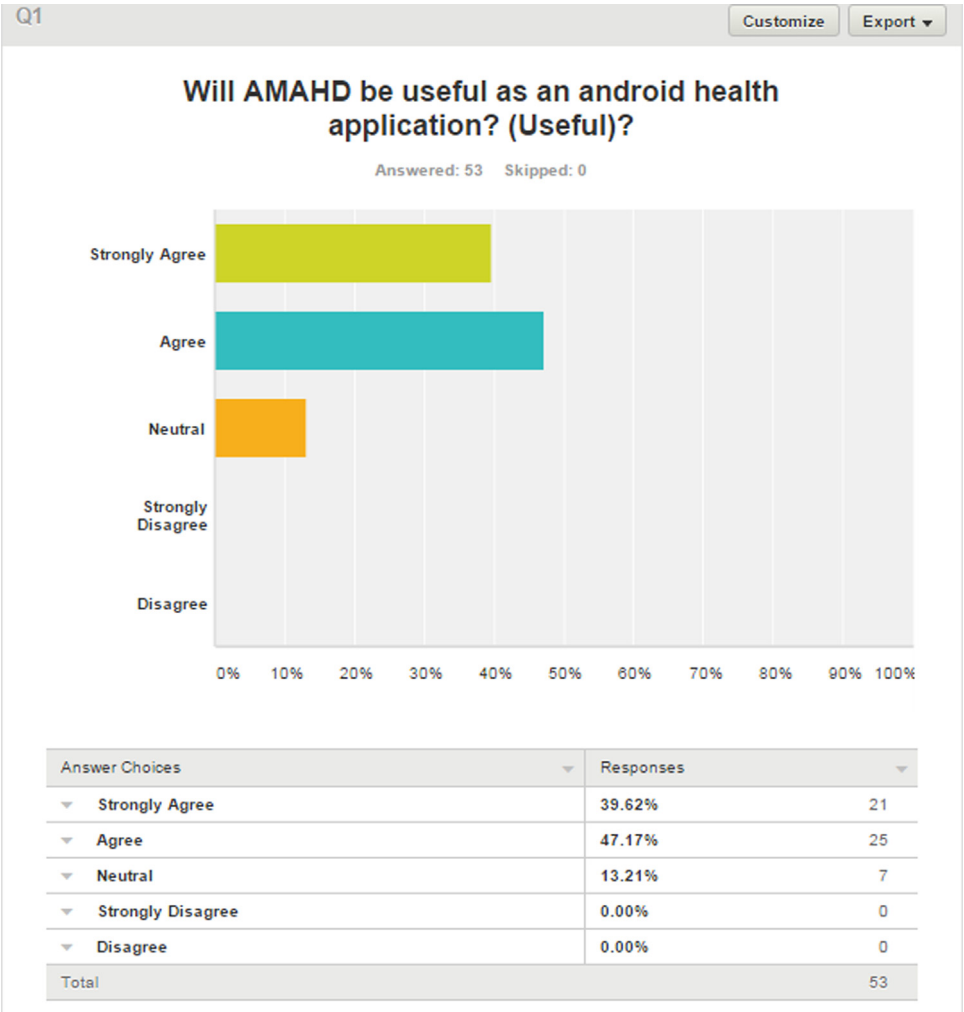


Fig. 25. Evaluation results to show the usefulness of AMAHD. Depiction of survey results to check if AMAHD will be useful as an android mobile health application.

For a false-preserving validity, the interpretation under which all variables are assigned a truth value of 'false' produces a truth value of 'false' [60].

Looking critically at the Table 4.4, Remark 1 has a truth-preserving validity; it is valid and sound. Remarks 2–15 are valid. Remark 16 has a false-preserving validity [60].

4. Results

4.1. Summary of findings

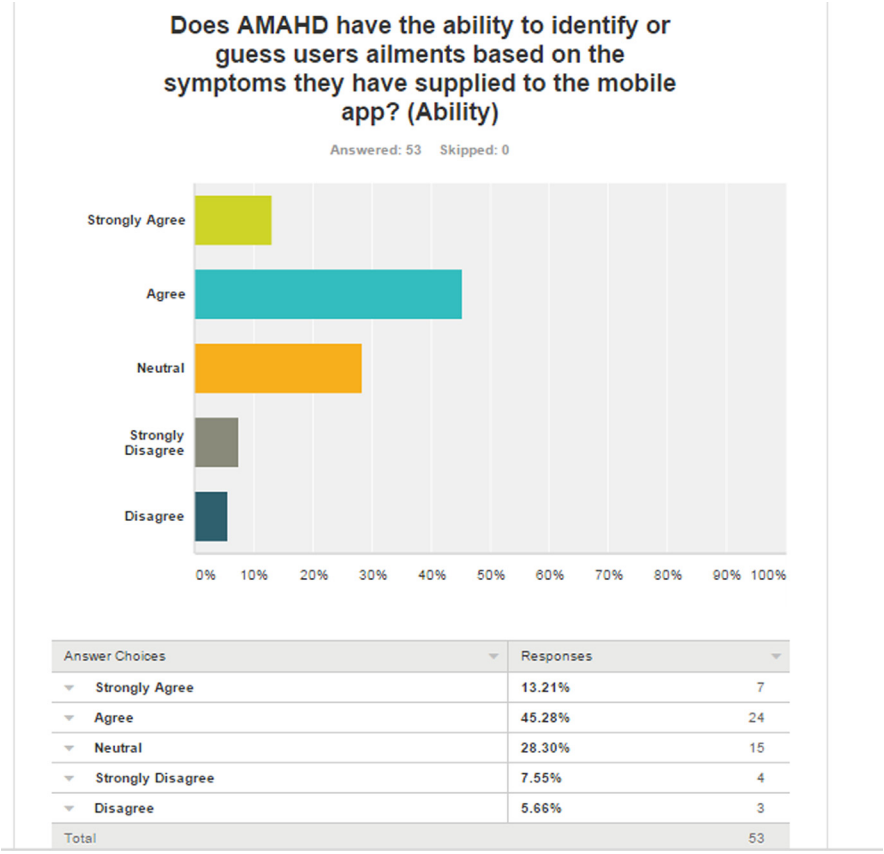
AMAHD can be downloaded from Google Play through the link: https://play.google.com/store/apps/details?id=com.manish.customnew&hl=fil

First, we present the results showing the classification of hereditary diseases as either common or rare hereditary diseases.

In the first phase of this survey, 87 people participated in classifying the hereditary diseases as either common or rare. Furthermore, in the second phase of the survey, 100 people participated in classifying the hereditary diseases as either a common type or a rare type within their respective regions. These results can be seen as shown in Figs. 3–16.

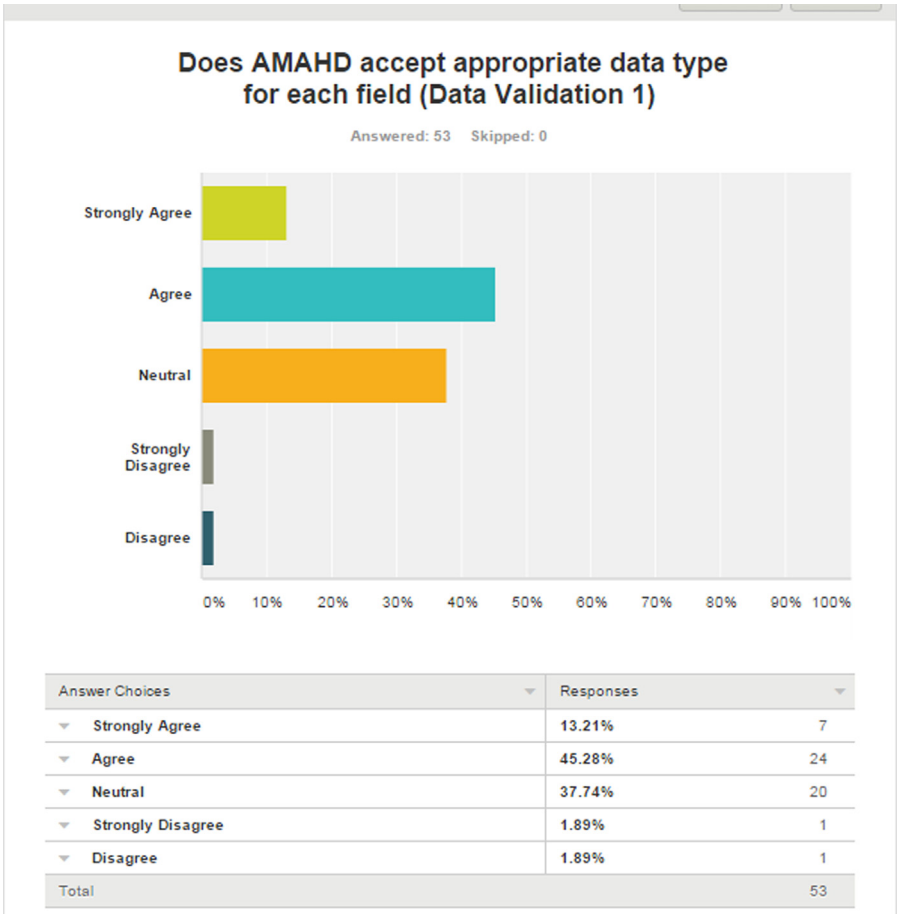
Second, we present the results showing the comparative analysis between AMAHD and other selected existing hereditary-disease mobile applications. These can be found in Tables 2 and 3.

Third, Figs. 3, 35 and 36 shows the various snapshots of the graphical user interfaces of AMAHD. Fig. 3 is an overview of the graphical user interface of AMAHD; this figure presents information about the view disease menu, symptoms menu and the close button menu. Fig. 35 shows the view diseases section. This section provides users with the opportunity to view information about hereditary diseases specifically under the rare category. Three categories exist namely: the rare, the common and the quick



Answer Choices	Responses	
Strongly Agree	13.21%	7
Agree	45.28%	24
Neutral	28.30%	15
Strongly Disagree	7.55%	4
Disagree	5.66%	3
Total		53

Fig. 26. Evaluation results to show the ability of AMAHD. Depiction of survey results to check if AMAHD has the ability to identify or diagnose user ailments based on symptoms entered by respective patients.



Answer Choices	Responses	
Strongly Agree	13.21%	7
Agree	45.28%	24
Neutral	37.74%	20
Strongly Disagree	1.89%	1
Disagree	1.89%	1
Total		53

Fig. 27. Evaluation results to show AMAHD's data validation 1 quality. Depiction of survey results to check if AMAHD can accept the appropriate data type for each field.

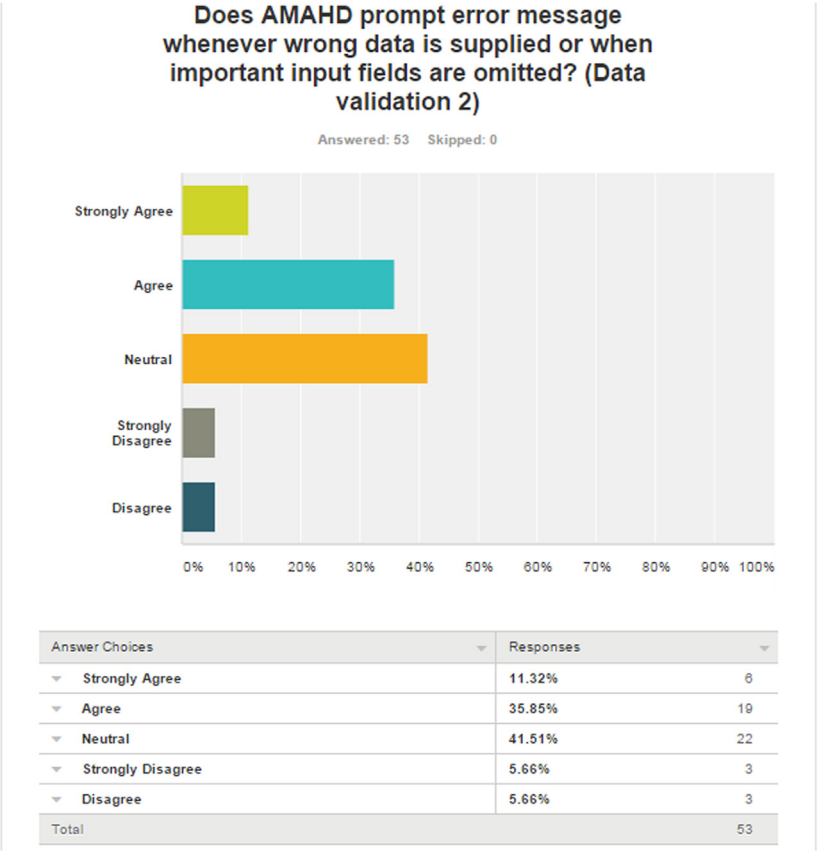


Fig. 28. Evaluation results to show AMAHD's data validation 2 quality. Depiction of survey results to check if AMAHD prompts error message whenever wrong data is supplied or when important input fields are omitted.

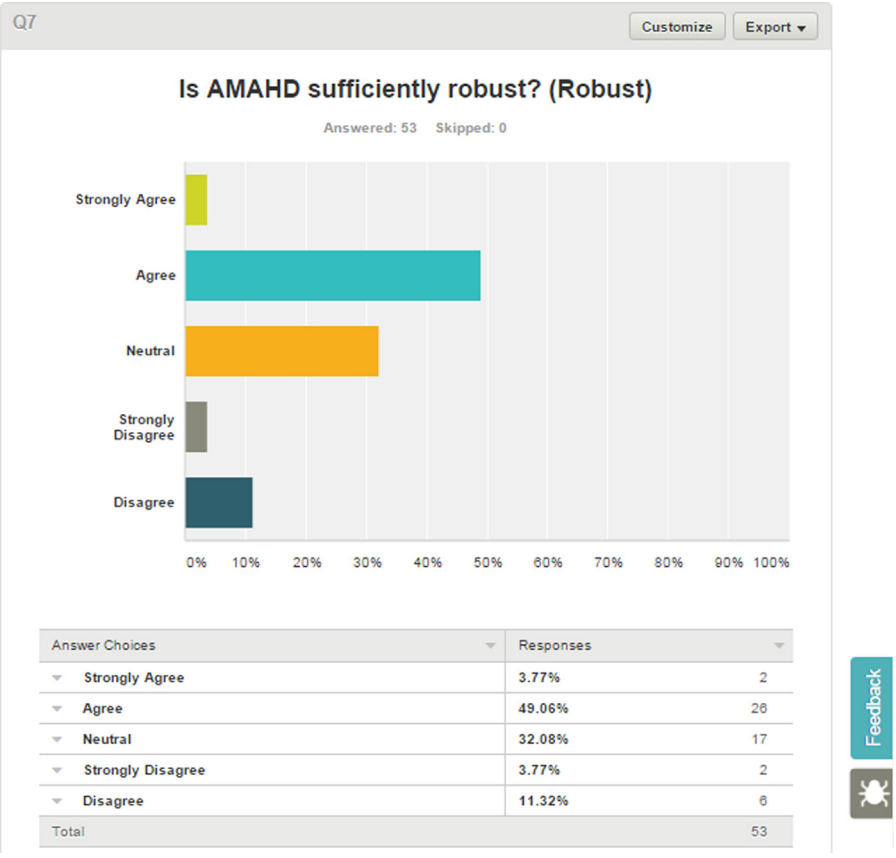


Fig. 29. Evaluation results to show AMAHD's robustness (sufficiency) quality. Depiction of survey results to check if AMAHD is sufficiently robust.

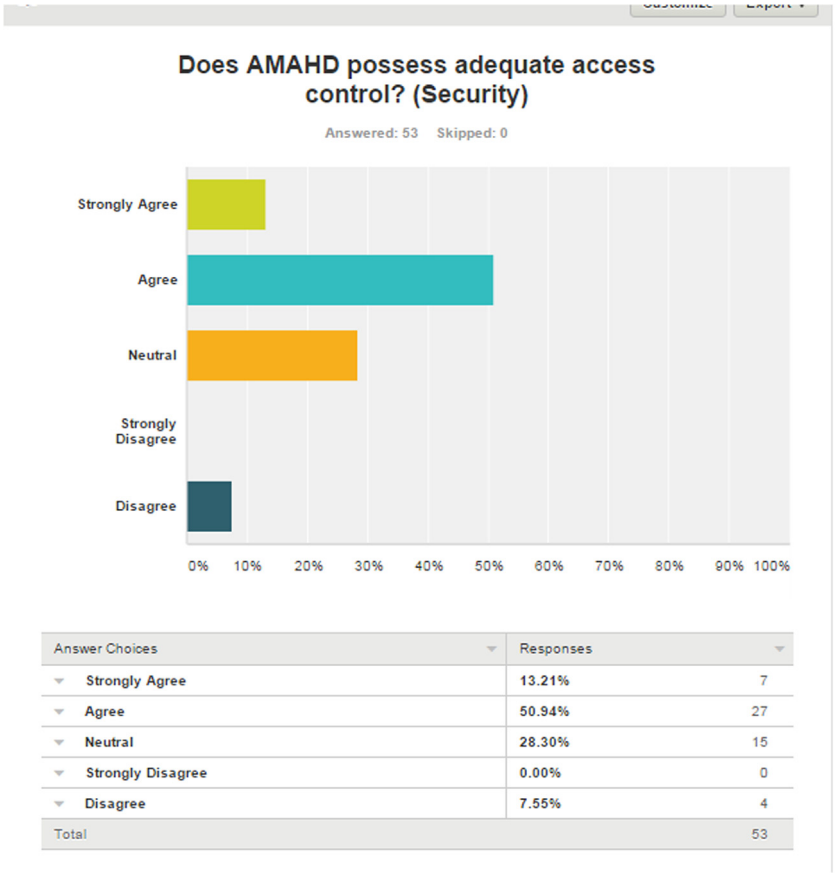


Fig. 30. Evaluation results to show AMAHD's security quality. Depiction of survey results to check if AMAHD possesses adequate access control.

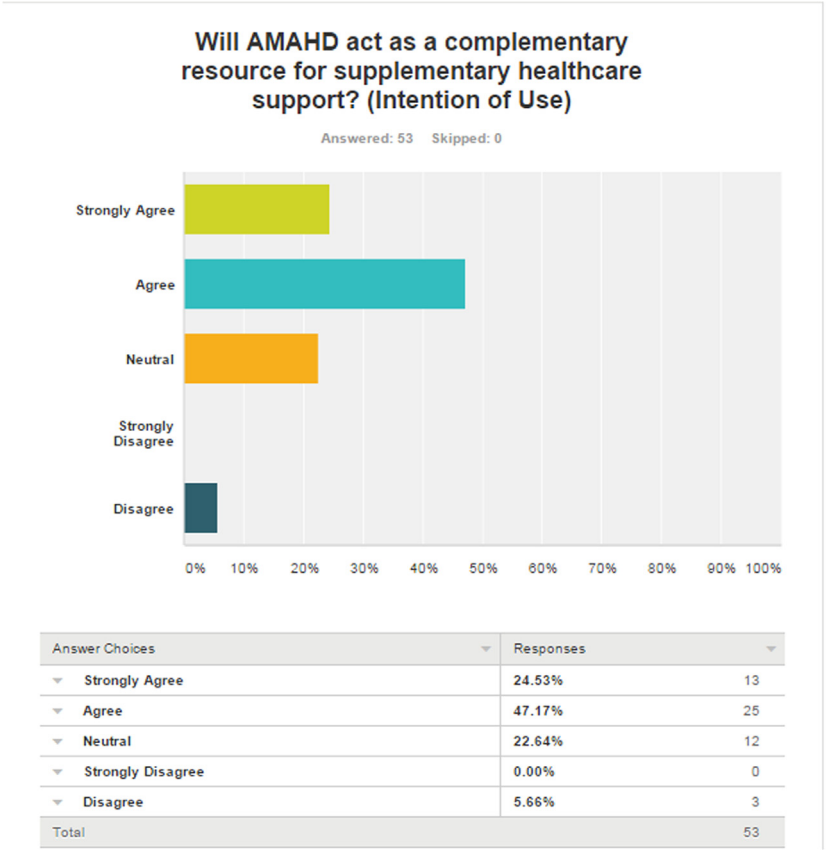


Fig. 31. Evaluation results to show AMAHD's quality of intention of use. Depiction of evaluation results to check if AMAHD will act as a complementary resource for supplementary healthcare support.

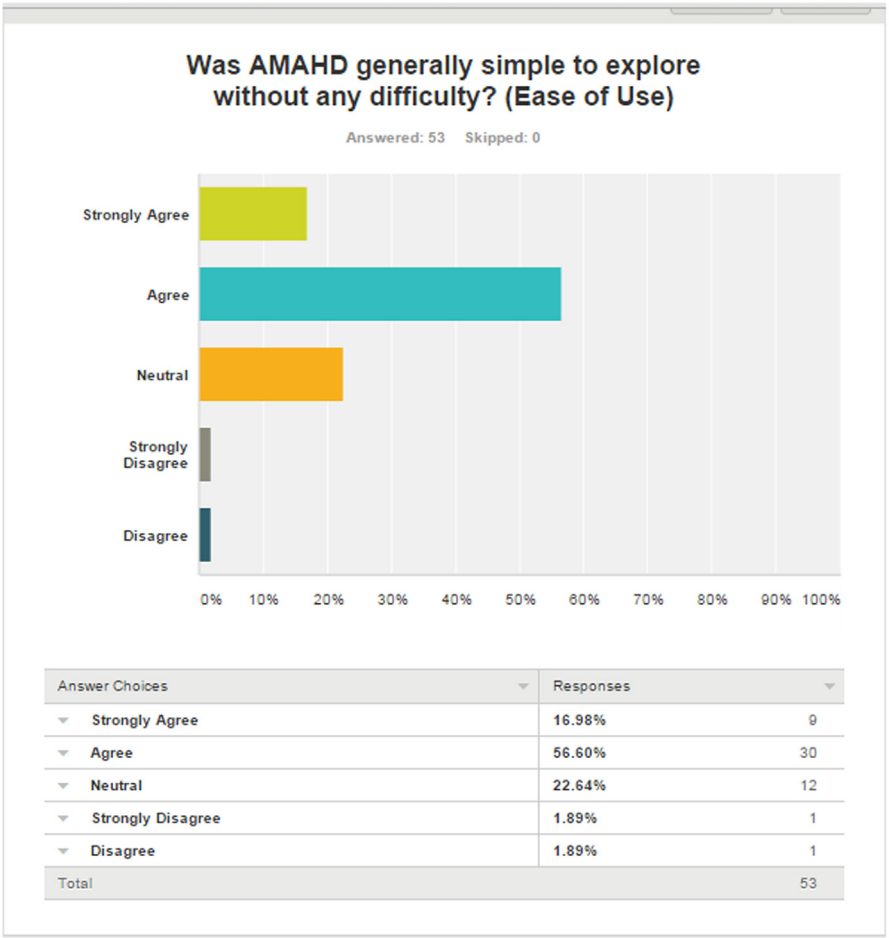


Fig. 32. Evaluation results to show if AMAHD's Ease of Use quality. Depiction of evaluation results to check if AMAHD will be simple to explore without experiencing any difficulty.

search. Fig. 36 provides useful information about common hereditary diseases.

Fourth, in order to evaluate the performance of AMAHD, some usability criteria were adopted. Some of these criteria have successfully been applied in previous studies. In the works conducted by Bertoa and Vallecillo; Bertoa and colleagues; Jah; Seffah and colleagues, some of these evaluation criteria were used [34–37]. A comprehensive offline and online user-evaluation of the performance of AMAHD was conducted, by administering questionnaires to medical professionals, researchers, community inhabitants, and students. This was done by manually providing them with AMAHD. AMAHD was also installed on their various mobile devices and laptops. Figs. 25–34 show the survey monkey online performance evaluation results. See also the Excel Sheet (Updated Evaluation analysis.xls), for the offline paper performance evaluation of AMAHD. Table 4.1 shows the criteria used for the performance evaluation.

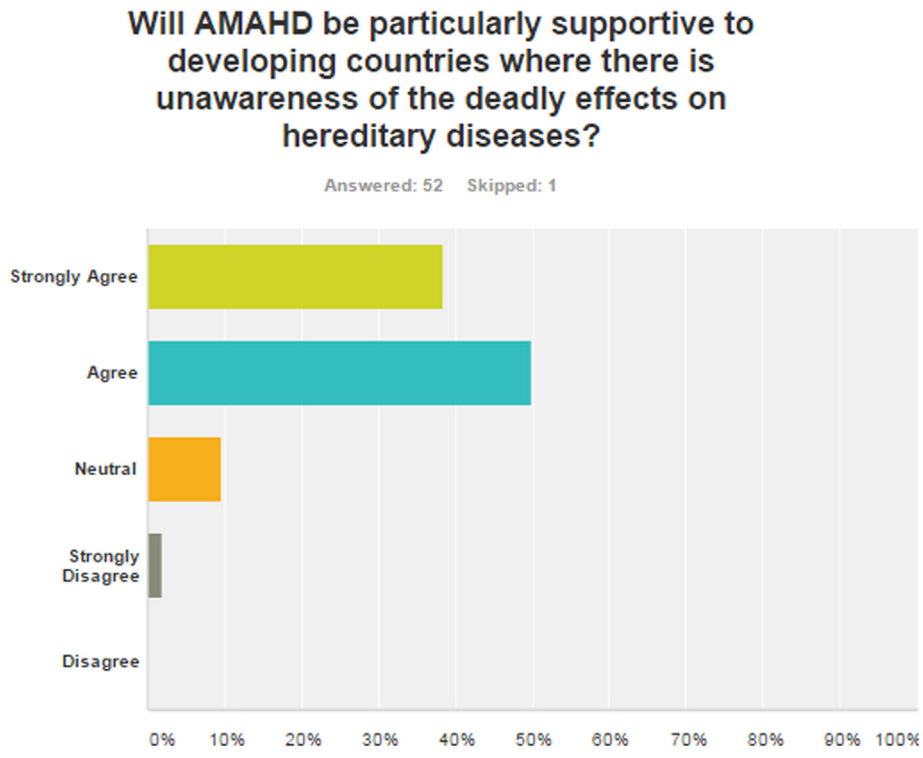
Finally; Table 4.3 shows the results of the comparative analysis between the offline paper survey and the online survey monkey survey.

4.2. Demographic Information about users that participated in the paper [Off-line] performance evaluation of AMAHD

Participants of the offline survey were mostly from south-western Nigerian States and their demography has been depicted in Table 4.2 (See also the Excel Sheet Updated Evaluation analysis.xls).

The results of the offline questionnaire papers administered during AMAHD's performance evaluation revealed that: 72.5%of the participants agreed that AMAHD had the ability to diagnose and guess users ailments based on the hereditary disease symptoms they keyed into AMAHD; 21.5% disagreed, while 6% of the participants were indifferent. In the criterion of data validation1, 69% of the participants agreed that AMAHD accepted appropriate data type for each field within the mobile application, 14.5% disagreed, 16.5% were indifferent. In the criterion of data validation2, 37.5% of the participants agreed that AMAHD prompted error messages whenever they supplied wrong data or when they omitted important input fields, 22% disagreed, while 40.5% were indifferent. On the criterion of sufficiency, 62.5% of the participants agreed that AMAHD was sufficiently robust. 11.5% disagreed, while 26% were indifferent. On the criterion of security, 65.5% of the participants agreed that AMAHD possessed adequate access control, while 10% disagreed and 24.5% of the participants were indifferent.

79.5% of the participants agreed that AMAHD can act as a complementary resource for supplementary healthcare support, 7% disagreed, while 13.5% were indifferent. 67.5% agreed that AMAHD was generally simple to explore without any difficulty, 20.5% disagreed, while 12% were indifferent. 73.5% of the participants agreed that they were satisfied with the services and operations provided by AMAHD, 11% disagreed, while 15.5% were indifferent. On the criteria of support, 81% of the participants agreed that AMAHD will be particularly supportive to developing countries where there is less awareness of the deadly effects of hereditary diseases, 5.5% disagreed, while 13.5% were indifferent. Finally, 73% of the participants agreed that AMAHD will be useful



Answer Choices	Responses	
Strongly Agree	38.46%	20
Agree	50.00%	26
Neutral	9.62%	5
Strongly Disagree	1.92%	1
Disagree	0.00%	0
Total		52

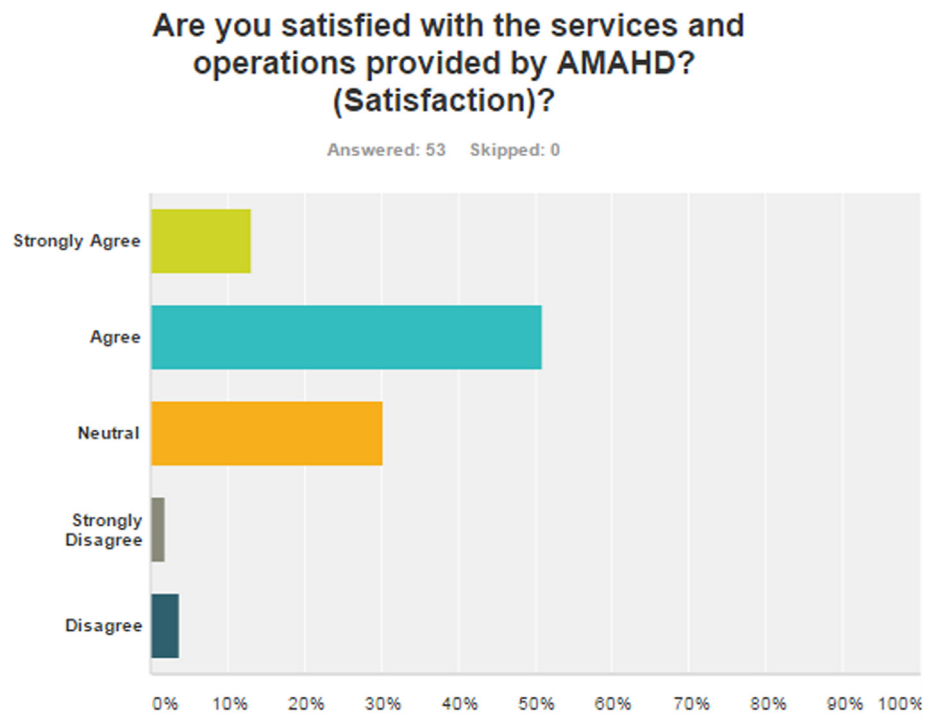
Fig. 33. Evaluation results to show AMAHD's quality of satisfaction. Depiction of evaluation results to check if users were satisfied with the services offered by AMAHD.

as an android mobile health application, 12% disagreed, while 15% were indifferent.

4.3. Information about the users that participated in the online survey monkey evaluation

About 100 participants participated in the general online survey monkey questionnaire on hereditary disease classification and AMAHD evaluation. 53 of these participants participated in the performance evaluation of AMAHD and they are from the following regions of the world: West Africa, America, Asia, Europe and Australia, with the majority from West African countries. The graphical charts of the results are displayed in Figs. 25–34.

The results of the online survey monkey questionnaire administered during AMAHD performance evaluation with 53 participants, revealed that: 58.49% of the participants agreed that AMAHD had the ability to diagnose and guess users ailments based on the hereditary disease symptoms they keyed into AMAHD, 13.21% disagreed, while 28.30% were indifferent. On the criteria of data validation1, 58.49% of the participants agreed that AMAHD accepted appropriate data type for each field within the mobile application, 3.78% disagreed, 37.74% were indifferent. On the criteria of data validation2, 47.17% of the participants agreed that AMAHD prompted error messages whenever wrong data was supplied or when important input fields were omitted by them, 11.32% disagreed, while 41.51% were indifferent. 52.83% of the participants agreed that AMAHD was sufficiently robust, 15.09% disagreed, while 32.08% were indifferent. On the aspect of security, in terms of possessing adequate access control, 64.15% of the participants agreed that AMAHD possessed adequate access control, while 7.55% disagreed and 28.30% were indifferent. 71.7% of the participants agreed that AMAHD can act as a complementary resource for supplementary healthcare support, 5.66% disagreed, while 22.64% were indifferent. On the ease of use criterion of AMAHD, 73.58% of the participants agreed that AMAHD was generally simple to explore without any difficulty, 3.78% disagreed, while 22.64% were indifferent. On the criterion of satisfaction, 64.15% of the participants agreed that they were satisfied the services and operations provided by AMAHD, 5.66% disagreed, while 30.19% were indifferent. 88.46% of the participants agreed that AMAHD will be particularly supportive to developing countries where there is less awareness of the deadly effects of hereditary diseases, 1.92% disagreed, while 9.62% were indifferent. Finally, 86.79% of the participants agreed that AMAHD will be useful as an android mobile health application, while 13.21% disagreed (Fig. 25).



Answer Choices	Responses	
Strongly Agree	13.21%	7
Agree	50.94%	27
Neutral	30.19%	16
Strongly Disagree	1.89%	1
Disagree	3.77%	2
Total		53

Fig. 34. Evaluation results to show AMAHD's quality of supportiveness. Depiction of evaluation results to check if AMAHD will be particularly supportive to inhabitants of developing countries where some of such inhabitants are less aware about the deadly effects of such diseases.

5. Discussion

5.1. Comparative analysis of AMAHD with other hereditary disease mobile applications

It is interesting to note that AMAHD has a generic nature which is quite different from other twelve hereditary-disease mobile applications. This is evident in the table of comparative analysis as depicted in Table 2 and Table 3. The purpose of AMAHD is for educative and informative purposes. Thus, AMAHD is dual purpose unlike other mobile applications which are of singular purpose. AMAHD needs internet connectivity to function like the four other mobile applications in Table 2. In situations where hereditary diseases searched for do not exist in AMAHD, if there is internet connectivity, users can connect to the internet through AMAHD. AMAHD can be used both for clinical and non-clinical purposes. Similar to the other twelve mobile applications in Table 2, AMAHD displays its results by text and data visualization.

In comparison with twelve other hereditary-disease mobile applications, AMAHD is a mobile application that can be used by different categories of people. Unlike other mobile applications that are complex and non-intuitive, AMAHD has a simple and intuitive interface (See Table 3). AMAHD has a continuous usage as compared with other hereditary disease-related mobile applications, because it can be used as an educative tool for biomedical students and bioinformatics researchers specializing in genetics. Thus, it is a rich resource that can provide complementary framework to those in the biological sciences and biomedical profession.

AMAHD can be used as a complementary resource by medical professionals, and it can also be used by inquisitive individuals seeking knowledge about common and rare hereditary diseases. AMAHD interacts with users by prompting them to keyin symptoms and displays results to them. From the list in Table 3, only VizWiz and AMAHD can interact with users. AMAHD was perceived by users as a useful, supportive and complementary android mobile application for hereditary diseases and disorders. Many agreed that AMAHD was easy to use.

AMAHD has the capability to provide easily accessible information to rural community dwellers through their various android devices. It is a rich knowledge base that can provide information about hereditary diseases to Africans and residents of other developing countries around the world.

AMAHD can be operated on android mobile devices; it can also be operated and viewed on laptops by first installing a mobile

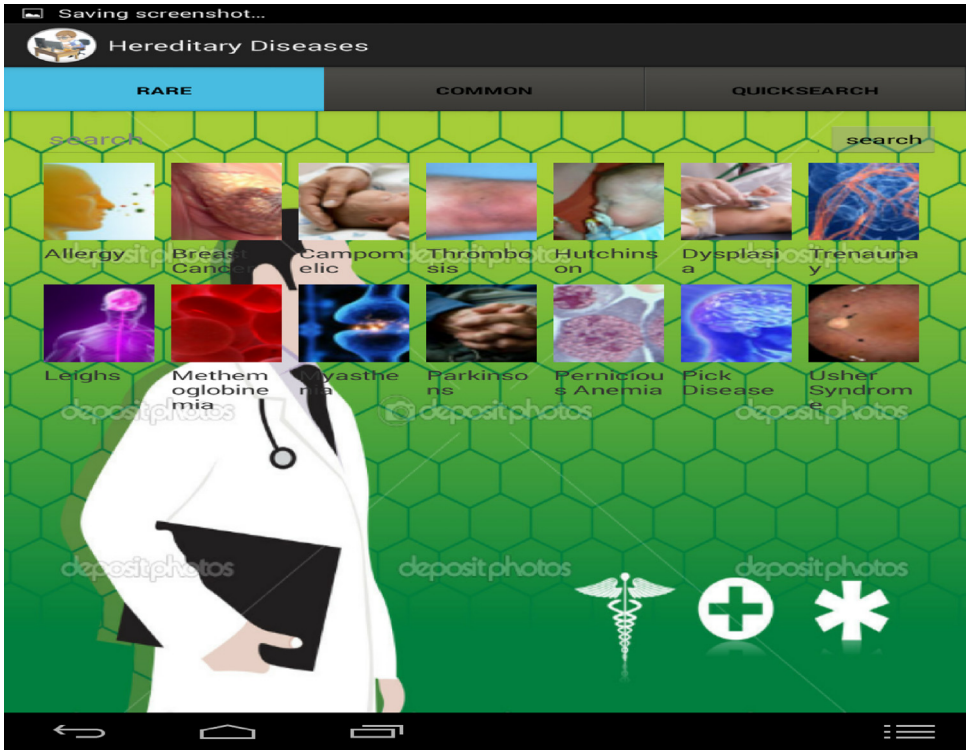


Fig. 35. Overview of Rare Hereditary Diseases within AMAHD.

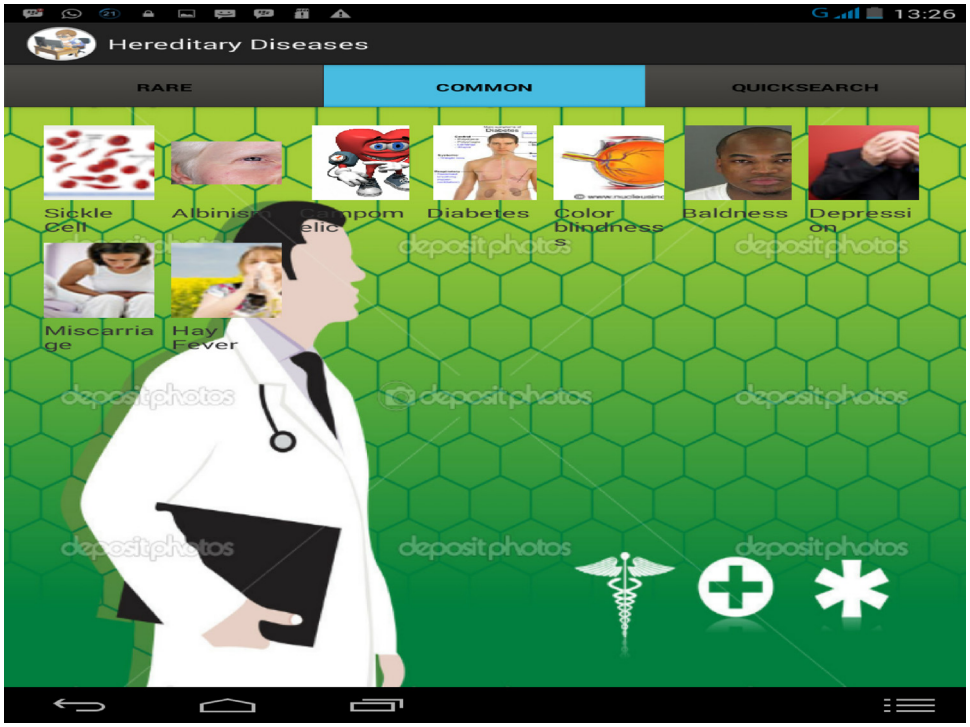


Fig. 36. Overview of Common Hereditary Diseases within AMAHD.

application viewer known as the Blue Stacks Thin Installer.exe application.

5.2. Impact on public health

Development and implementation of AMAHD can help discover hidden information about common and rare hereditary diseases. This will help translate into a positive knowledge revolution in the aspect of public health. This has the tendency of promoting healthy living habits among individuals.

Second, AMAHD provides a platform to educate and promote the use of health-related resources on mobile and hand-held devices. Public health outcomes become impressive as a result of communities that benefit and get impacted by the mobile application.

5.3. Impact on economy/socio-economy

A healthy nation is a great and prosperous nation. The AMAHD application, when put to use by many communities in African countries, and other developing nations of the world, can help promote health of citizens; this will in turn have positive impact on the economy of such nations.

5.4. Comparative analysis between the offline paper survey results and the online survey monkey survey results

Comparison between the offline paper survey and the online survey monkey evaluation of AMAHD, revealed that in terms of supportiveness, intention of use, security, ease of use, satisfaction, and usefulness; the participants in the two separate surveys were in agreement. The percentages of their agreement were of close proximity (See Table 4.3). However, they had varying range of disagreements, probably due to the scope of coverage. The first survey was conducted among the inhabitants of southwest Nigeria, while the second survey was conducted among inhabitants of West African countries, America, Asian countries, and European countries. Majority of the respondents were from West African countries.

5.5. The contribution of m-health applications to healthcare quality and cost containment

The contributions of mobile health (mhealth) applications to enhancing healthcare quality and guaranteeing cost containment in the healthcare sector cannot be underestimated. Mhealth applications provide good health literacy about hereditary diseases that majority are ignorant of [38]. Health literacy, in turn, helps to improve general public awareness, thus improving public health and reducing the amount spent on seeking for healthcare services.

Mobile health applications can be used to provide support for the Chronic Care Model. This, in turn, supports self-management and team-based care for patients living with different types of chronic diseases [39]; for instance, automated text messaging can help provide support for patients living with diabetes.

Mhealth applications have also been found useful and resourceful in treatment monitoring and the curbing of the spread of infectious diseases, such as malaria [40]. Emergency healthcare process automation can be achieved with mobile health technology [41].

Mhealth applications that have sensors, diagnostic and predictive functions can help ensure cost containment [42,43]. They can help patients monitor their health status and send real-time readings of patients' health conditions to specialist hospitals. They can help patients to drastically reduce the cost of consultation and diagnosis. They can also assist patients in avoiding the payment of consultation fee in seeing a medical doctor, while health applications that have drug prescriptions and recommender systems have saved patients the trouble of running around looking for an authentic pharmacist.

Some mhealth applications can help enhance the quality of infectious disease research [44–46]. This can be achieved by applying such mhealth-related applications to the fields of computational biology and bioinformatics of infectious diseases. In summary, mhealth applications have numerous benefits.

6. Conclusion

The adoption and application of computational knowledge from mobile informatics, computer programming and knowledge base domains, to develop an android mobile application on hereditary diseases and disorders, is a distinctive contribution to this study.

We have successfully implemented an android mobile application (AMAHD) that will benefit the scientific research community. We conducted experiments which helped us to successfully classify some hereditary diseases as either common or rare; information about these have been incorporated into our mobile application.

To some extent, we were also able to integrate artificial intelligence ("Logical Disjunction Rule-based Algorithm" (LDRA)), into AMAHD in order to identify symptoms and associate them with potential hereditary diseases.

The mobile application will help sensitize and complement the efforts of biomedical, medical and bioinformatics researchers working in the research areas of heredity and genetics.

Based on the results obtained from the performance evaluation conducted, AMAHD has proven to be a valuable resource to the research enterprise in the battle against hereditary diseases and disorders. For institutions, communities and researchers interested in adopting AMAHD, the mobile application is freely available online.

Future work on AMAHD will involve the incorporation of more hereditary diseases into the database, incorporation of a voice-enabled interactive facility, and a complete implementation of a predictive algorithm into the symptoms section of the mobile application. Extended work can also be done, by integrating text alerts into AMAHD, which will help a hereditary disease patient alert a medical doctor for immediate attention and care. We hope to further enhance the performance of AMAHD by further refining the computational methods adopted at developing the mobile application.

Contributorship statement

Olugbenga Oluwagbemi conceived the research project. Olugbenga also contributed to the design and development of AMAHD, as well as the experimental aspects detailing the implementation of AMAHD. AMAHD's algorithm (Logical Disjunction Rule-based Algorithm (LDRA)) was developed by Olugbenga, based on the concepts of logical disjunction, deductive reasoning, set theory and discrete structures. He also developed the architecture of the internal components of the software, the acquisition, analysis and interpretation of the data, and drafting of the manuscript. Olugbenga also provided guidance to the implementation of the algorithm in AMAHD.

Folakemi Oluwagbemi contributed to the design, analysis of AMAHD, interpretation of the data, and drafting of the manuscript.

Chisom Ughamadu contributed to the development of AMAHD's implementation and preliminary analysis and interpretation of data.

Conflict of interest

None declared.

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granting us permission to make use of some of the tables and data from their earlier publication. We thank Olaoluwa Duro-Bello and an anonymous individual that helped with the English grammar corrections of this manuscript. Finally, we want to thank all the numerous participants in the offline paper questionnaire and online survey monkey questionnaire.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.imu.2016.03.001.

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