A Smart Headache Record of Neurology Applications for Mobile Devices

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Abstract. In modern society, the migraine is a common disease. In order to improve accuracy of diagnosis, patients need to keep diaries logging headaches during periods of migraine treatment. Physicians can thereby make diagnoses and keep track of headache and migraine episodes through diary entries. Some hospitals may provide patients with paper diaries for recording purposes, though they are not easy to carry, nor are they convenient to save for patients with long-term problems. As a result, this study constructs a special mobile medical application (APP) prototype for migraines and cooperates with the Neurology Department of Taipei Veterans General Hospital, a Medical Center in Taiwan. The app can transform patients' headache diaries into electronic data and upload it to a database for future access and retrieval. Diary records are displayed not only on mobile platforms (e.g. smartphones, tablet computers), but also on user interfaces via the web. This can be used to help other research concerning migraines, which needs large amounts of collected headache data. Moreover, physicians can improve the efficiency of treatment and accuracy of diagnosis; they can use data that has been automatically processed by the diary app. The purpose of this study is to reduce the reading time of diaries, improve efficiency of diagnosis, solve problems with paper diaries (such as being difficult to keep, read, and transport, uploading headache diaries to databases, and providing data for analysis).

Keywords: headache diary, health information technology, migraine, mobile medical diagnosis

1   Introduction

In the current age of advanced information technology, people's lives are interconnected and people interact using technological devices. Researchers need to use computers to collect and store data, which is then used to research and verify medical queries and theories. Health Information Technology (HIT) can reduce mistakes in medication and diagnosis, help medical professionals obtain patient information in a timely manner, shorten wait times, and improve care quality and efficiency [1-3]. Importantly, electronic medical records can store patients' personal health records, including medical records, inspection reports, and medical images [4]. In addition, physicians can use the Internet to provide patients with diversified medical services, such as useful information concerning medicine and hospitals and advice on treatment options.

The International Headache Society (IHS) addressed the standard of diagnosis migraines and further defined migraines and what symptoms are associated with the disease. According to the study, a migraine is one of four major chronic diseases leading to disability; although migraines are not life-threatening, they can seriously affect patients' lives, work, and family status [5]. Migraines are not only caused by psychological factors, but also physiological diseases (for example, changes in brain chemicals) [6]. As

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different treatments are developed, physicians, for example, can use videos and telecommunications equipment to diagnosis and give advice to patients, collect data related to diagnosis results to send to patients, and determine effective and prompt treatments. To track the status of patients more clearly, physicians advise that patients become accustom to keeping a diary, recording the time of headache onset and duration, if there are any signs or symptoms before onset, and seizure frequency. In turn, diaries assist physicians diagnose patients and can be used as references for follow-up treatment. Physicians suggest that headache patients record their situations daily. Initially, patients recorded headache diaries on paper or specialized forms offered by hospitals. Physicians checked patient headache records when they returned for follow-up visits and used the records for diagnosis and treatment. However, physicians are required to spend a lot of time interpreting data from paper diaries and calculating frequency. Therefore, mistakes are made, such as miscalculations or errors in judgement. For patients, caring around a paper diary can prove burdensome. As a result, paper diaries may be forgotten and records prove inaccurate. This inaccuracy in diaries leads physicians to low accuracy of diagnosis and high rates of misdiagnosis.

The United States Food and Drug Administration (FDA) prepared a draft guideline for mobile medical apps in 2011. At that time, the latest version of the guidelines were used to regulate mobile medical apps and manufacturing companies of the app have issued updates to September 2013 [7]. Patients can replace paper diaries with a diary app and recorded headache data will be saved to a database. In the future, this database will be used for research and analysis. Most apps are used to assist relatively simple or otherwise tedious tasks in hospitals. This study concerns the development of a mobile medical app to solve the problems inherent in paper diaries. Headache data that needs to be entered into databases by people is transformed into digital data in the diary app; therefore, the large amount of headache data is analyzed through data mining and different algorithms, thereby making data collection quick and easy. Examples of such tasks are the online appointment number status inquiry system used at Taipei Veterans General Hospital, appointment reminder, pill reminder, and other systems. As of this study, no apps are used explicitly for treatment or diagnosis. Therefore, this study cooperated with the Neurology Department at Taipei Veterans General Hospital cooperated to assist in developing a mobile medical app to record patient headaches and assist physicians in tracking headaches experienced by patients and any prescription drug use. As shown in Fig. 1, the users of diary are divided into 3 parts: physicians, patients and other. Users who have some problems when they use paper diary. The problems of paper diary that they can be solved after users have used app. The objectives of this study are to reduce (1) time of reading diaries and improve efficiency and accuracy of diagnosis, (2) problems of paper diaries, (3) uploading headache diaries to databases, and (4) providing headache data for analysis.

	Before the implementing of app	After the implementing of app
Physicians	• Hard to read (Broken paper, illegible writing) • Counting days of headache (Errors in scoring)	• Installed in intelligent devices (Reading improved) • Counting Automatically (Accuracy of scoring) (Time of reading diary)
Patients	• Hard to carry (Broken paper, illegible writing, space occupied) • Waiting physicians for counting days of headache (Time wasting) (Errors in scoring)	• Installed in intelligent devices (Problems of reading improved and easy to carry) • Counting Automatically (Time of reading diary) (Accuracy of scoring)
Other	• Paper diaries are not kept easily	• Data of paper diaries are saved in database (Analyzed and researched) • Other analyses of research

Fig. 1. Comparison of headache diary

2 Migraines

Migraines are defined as headaches of great intensity that attack repeatedly [8]. This type of headache is usually described by patients as a throbbing headache with similarity to regular vascular pulsing. Most patients feel pain around the temple and eye range, but migraines often appear in the forehead, and at both sides, the top, and back of the head. Migraines are also known as 'sick headaches' because they are regularly accompanied by nausea and vomiting, while some patients may also experience restlessness, constipation and/or diarrhea, and feel scared toward noises and odd smells. Many people have headaches, but migraines are much stronger than other types of headaches. According to information provided by the travel and security assistance company International SOS, the methodology to distinguish a migraine from normal headaches is as follows: They must be serious enough to necessitate rest, induce vomiting, and cause discomfort at onset. If patients experience two or three of these, then there is a 90% likelihood of migraine.

Gender and age have no bearing on a person's chance to experience a migraine, and the time and frequency of a migraine is different for each person. However, according to statistics from the Taiwan Headache Society, the probability of women suffering from migraines is three times that of men; the reason may be related to a woman's hormonal cycle. Migraines may be induced by environmental and dietary factors. In terms of environment, tension may be caused by work environment, living in a high pressure environment, or being in a climate that is too cold or too hot. In respect to dietary concerns, about 15% of people find that certain foods can lead to migraines, such as chocolate, citrus, coffee, etc. [9]. Genetics can also play a role in migraines; there is a great chance for migraines to genetically pass from parents to their children. According to statistics, if one parent suffers from migraines, their children have a probability of 46% to develop migraines; if both parents suffer from migraines, the probability increases to 66%. However, genetics is just one more in a number of factors that contribute to migraines. Formerly, medical professionals considered migraines a problem of the blood vessels. However, today medical professionals believe that different brains will have different irritants leading to the release of excitatory substances, or that if the meningeal vascular is irritated then a series of pain reactions will be initiated [10]. IHS released its Standard of Migraine Diagnosis in 1988, containing clear descriptions of and a definition for migraine symptoms [11]. The standard divided migraines into seven types (Migraine without aura, Migraine with aura, Ophthalmologic migraine, Retinal migraine, May be a migraine prodromal or related symptom of childhood periodic syndrome, Complicated migraine, and Migraine that does not comply with the aforementioned diagnosis standards). Accompanying the seven migraine types were two migraine diagnosis standards, which are presented in Table 1 and discussed below: migraine without aura and migraine with aura.

Table 1. Standard of migraine with aura and migraine without aura diagnosis

Migraine without Aura	Migraine with Aura
A. Conforming from Type B to Type D at least 5 times	A. Conforming type
B. Headache continued 4-72 hours	B. At least three of the following four types:
C. Headache has at least two characteristics:	1. More than one time of symptom can be recovered from completely and the display portion of the cerebral cortex and/or functions of the brainstem are abnormal.
1. One-sided	
2. Pulsation	
3. Level of headache is medium or heavy (daily life is limited or prohibited)	2. Having at least one type of aura that appears gradually over four minutes or having more than two types of aura emerge.
4. Headache becomes harder when patients walk up and down a staircase or other similar daily task.	3. Auras don not continue for more than 60 minutes and if having more than one aura, the time is increased following the rate.
D. At least one type of situation alongside headache:	4. Headache emerges after emerging auras within 60 minutes (also before auras or in the same time with auras).
1. Nausea and/or vomiting	
2. Sensitive to sound and/or light	

The Migraine Disability Assessment Test (MIDAS) is used by physicians to check if a patient's life is influenced by migraines. MIDAS includes seven questions that are against headache days in 3 months of patients' life such as work, schoolwork, housekeeping, and social contact [12]. Questions 1 and 2 are

related to work and schoolwork. Question 1 asks about how many days patients cannot work and/or go to school because of migraines and question 2 how many days patients feel the effectiveness of their work and/or schoolwork is decreased by half or greater. The combined total of days for questions 1 and 2 cannot be greater than 90 days. Questions 3 and 4 are related to housekeeping. Question 3 concerns how many days patients cannot commence housework because of migraines and question 4 asks how many days patients feel their housekeeping ability is decreased by half or greater. The combined total of days for questions 3 and 4 cannot be greater than 90 days. Question 5 inquires as to how many days patients cannot join family gatherings, social functions, and/or leisure activities. The above-five questions are considered over a range of 0-270 days and added up to arrive at a MIDAS score. Question 6 is about how many days patients have experienced headaches over a three-month period and question 7 concerns the level of headache (0~10 points). These two questions are not included in the MIDAS point total. The total of MIDAS points has a method of classification: MIDAS $\leqq$ 5 is grade I and MIDAS between 6 to 10 is grade II, where headache level at grade I and II is slight; MIDAS between 11 to 20 is grade III, where the headache level is medium; MIDAS>21 is grade Ⅳ and the headache level is serious. This method of classification can help physicians establish a standard for diagnosis when treating patients for headaches.

Chronic migraines are defined by the FDA as headaches experience by patients that occur during at least 15 days per month and last four or more hours per day. Symptoms include pain, sensitivity to light and/or sound, sickness, and the worsening of patients' daily lives. An episodic migraine is a precursor to chronic migraines. In the beginning, the frequency of headaches in patients is less than two days per week, after which headaches increase in frequency (15 or more days per month). According to this standard, about 3% of patients per year have episodic migraines that evolve into chronic migraines. If patients want to use medication to continue what they consider normal daily activities, drug dependence can follow and is not uncommon. In addition to using medicine for treatment, patients can choose to make life adjustments, develop better or different habits, sleep adequately, and avoid work fatigue to improve headaches. Some patients may have special predisposing triggers, such as food, wine, or severe variance in temperature. These factors can be avoided through simple measures of restriction. Physicians suggest that patients record their headaches and symptoms whenever they occur. Fig. 2 is a headache diary provided by the Neurology Department of Taipei Veterans General Hospital. The content of the diary includes: intensity, symptoms, aura, headache duration in hours/days, preventive medications, how well acute treatment is working, and menstrual cycle. This recording device helps physicians diagnosis patients and make referrals. Physicians diagnose headaches according to the information recorded in patients' headache diaries and use the "preventive medications" and "acute treatment" sections, again filled out by patients, to modify medication as necessary. For chronic, repeating headaches, the treatment goal is to decrease headache frequency rate in accordance with the standard of Paroxysmal headaches and to determine preventive treatment.

3 The Conceptual Framework of the Diary App

When the diary app was constructed, we took real experiences from the hospital and communicated with front-line physicians and patients as references for the app. In early research, we held discussions with a neurology physician and recorded his requirements, which were used to design the research framework. Then, we referred to the paper headache diary used by the Neurology Department of Taipei Veterans General Hospital. After completion of the prototype diary app, we helped patients install the app and then explained how to use it during consultation hours. We continuously observed diary app behavior while in-use between physicians and patients. Problems related to functionality and usage were recorded during these periods. These records can be used in subsequent updates and revisions. After repeated testing, a complete diary app was constructed. During the entire research process, in order to evaluate whether the diary app was achieving the purpose of research or not, we used a questionnaire survey to check whether system achievements met expectations.

This study used Google questionnaires and paper questionnaires to collect patient information regarding behavior of the diary app and their reasoning for using cellphones. In the last part of the questionnaire, patients needed to fill out a one-month MIDAS questionnaire. We helped patients who met our conditions fill out the questionnaire during physician consultation hours. After collecting all necessary information, the available data was analyzed to evaluate the research purpose (whether the system improves diary reading time and accuracy of diagnosis) and the efficiency of the research. These

Headache Diary - VGH															

Date： _____ Y _____ M ID： _____ Name： _____

Intensity (0 = no headache, 1 = mild, 2 = moderate, 3 = severe)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Morning															
Afternoon															
Night															
Sleep															
If you have the following symptoms, please tick															
Nausea?															
Vomiting?															
Sensitive to light?															
Sensitive to sound?															
Throbbing?															
Unilateral onset?															
Worsened by physical activities?															
Aura before headache?															
Visual aura															
Other aura															
Headache duration hours/day?															
Preventive medications															
Acute treatment, working or not ? (0 = no, 1 = a little, 2 = effective, 3 = very effective)															
Menstrual period, please tick															

Fig. 2. Headache diary from the Taiwan headache society

results were also used to help with diary app modification. The main purpose of the diary app was for physicians to be able to clearly and easily view patient headache conditions. For this reason, we needed to observe how physicians read paper diaries and how patients record their headaches on paper diaries during consultation hours. According to observational results, physicians need to browse patients' paper diaries, look for the last date a patient came for consultation, and total the number of days patients experienced headaches. Additionally, physicians divided the number of days patients experienced between heavy, moderate, and mild headaches. Patients were diagnosed according to the frequency of different headache types. For example, patients need to have their prescriptions adjusted based on the number of headache days and the severity of headaches. In regards to female patients, physicians paid special attention to menstrual cycle, which affects the level and frequency of headaches. If patients have Restless Leg Syndrome (RLS), physicians also pay special attention to the frequency of RLS appearing and observe responses to treatment. The main development programming language for the app was JavaScript and it can be used on Android and iOS. Also, it can be easily used in conjunction with different programming languages such as PHP, JavaScript, etc.

Fig. 3 is the system framework for the diary app. Patients needed to use their intelligent portable devices to input daily headache diary entries; they can record their headaches anywhere at any time.

Physicians can check patients' headaches from their own intelligent portable devices and use headache data that is already calculated by the app as diagnostic references. Headache diaries are not only saved on patients' intelligent portable devices, but also uploaded to databases. These diaries are displayed using a web interface. If users want to read diaries on web interface, they need to log in. Patients can also use a web interface to add and edit their headache diary entries and save diaries added in the database, which can then be downloaded at a later date. Physicians are also able to log in to check patients' headache diaries and are not limited to patients' intelligent portable devices to check.
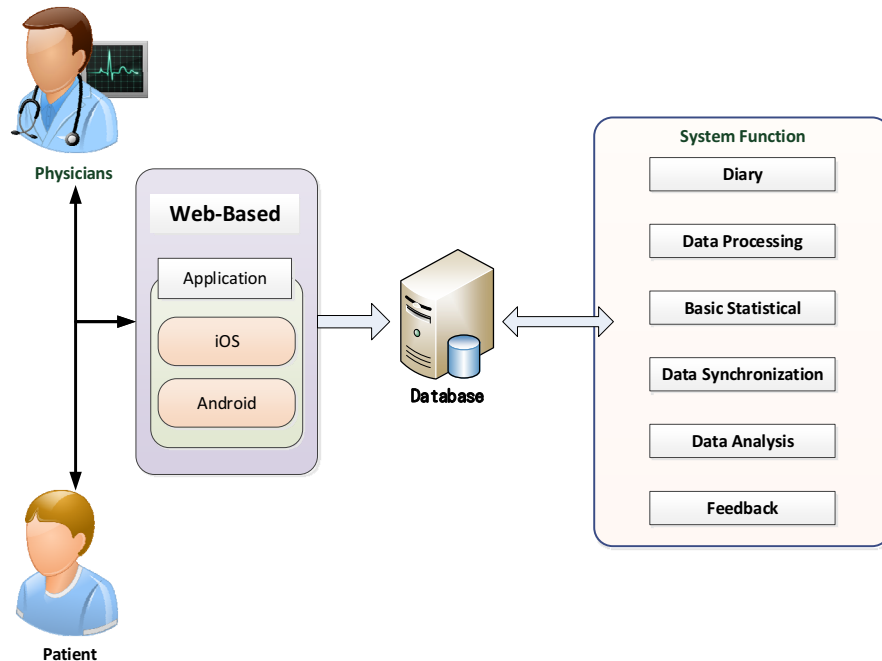
Fig. 3. The system framework

To prove whether the diary app achieved the research purpose of this study or not, we chose to use research questionnaires. The purposes of this study were to reduce time necessary to read diary entries, improve the efficiency and accuracy of diagnosis, solve problems related to paper diaries (e.g., not easy to keep, read, or carry outside), assist with headache diary database uploads and maintenance, and provide headache data for analysis. During the study, we expected to work with 100 participants at Taipei Veterans General Hospital. However, there was about a 10% wastage rate for participants, so we eventually decided to use 110 participants. We also collected data from participants at Taipei Municipal Gan-Dau Hospital. The first phase of this study was screening out patients who had never used a paper diary. The purpose of this screening was to make sure patients were able to compare usage experience between the diary app and paper diaries. If patients did not satisfy the above conditions, they were not considered for the list of participants.

4　System Implementation

Observations in this study were conducted during consultation hours. To streamline and refine the diary app, physicians were consulted and the app was tested for a long period of time. After testing, the system functions were divided into six parts: "diary," "profile settings," "drug management," "statistical analysis," "data synchronization," and "feedback." Main functions in "diary" were implemented as "new diary" and "edit diary"; users can use the "new diary" function to record headache events. The diary app recording format is the same as the paper diary, only digital. If users want to edit contents of the diary, they need just find the moment they want to edit, change the contents, and resave the entry. "Profile settings" is available for filling out basic user information, which needs to be completed for treatment purposes. This information is used for other system operations. The "drug management" section is where users manage their medication and is divided into two functions: "add drugs" and "delete drugs." "Statistical analysis" maintains user headache statistics. It can display information according to time

range, which is chosen by the user, and is used for statistical data of headache, menses or RLS, and counting days of relevant headache auras. Additionally, this section allows users to read statistical charts and forms populated by the diary app. "Data synchronization" is where the diary app synchronizes via web system in order to upload and update medical information from the user's intelligent portable device. "Feedback" is if users have any questions or comments about the diary app that can be submitted by e-mail.

4.1 New / Editing Diary

In Fig. 4, the design of the main user interface uses a calendar pattern so that users can check their headache conditions clearly and conveniently. Next, according to the four different headache levels and conditions, different colored indicators are displayed on the screen. Headache levels have four types: heavy, moderate, mild, and no headache, which are indicated by the colors red, yellow, green, and none, respectively. A red border surrounding a date indicates the date users last saw a physician and the current date is highlighted. If users want to record which date they last visited a physician, they need to select the option "saw a physician" in the "new diary" section. If users want to add a new diary entry, they can select any date on the calendar and enter information for that specific date.
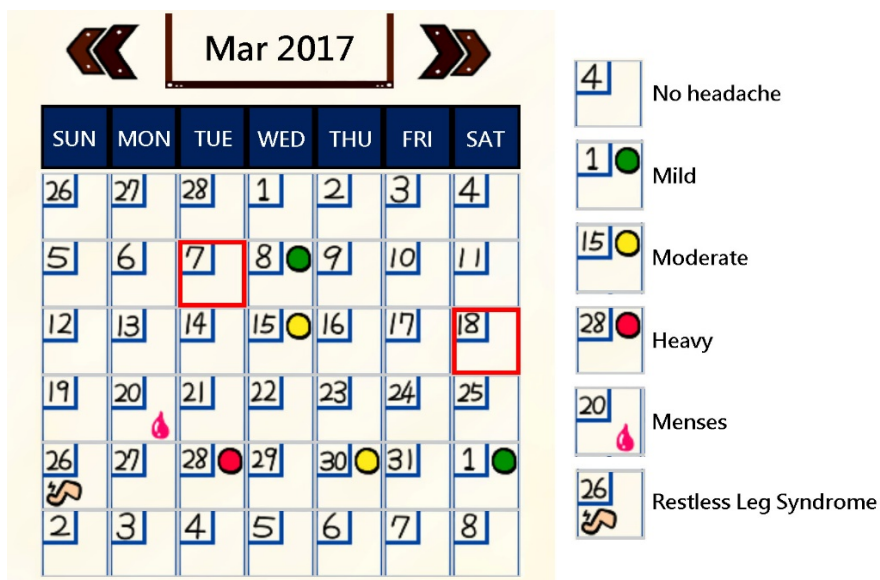
Fig. 4. User interface & light signals of headache levels

The headache record format is the same as that of a paper diary. The title is the chosen date and the following menu is divided into "level of headache," "record of seeing physicians," "symptoms and auras," "headache duration in hours/days," "medication record," and "menses and RLS." Users can select an items, which then unfolds allowing users to fill out a detailed list. "Record of seeing physicians" keeps track of physician visits at the Neurology Department in Taipei Veterans General Hospital and does not include when users see physicians at other hospitals or clinics. "Symptoms and auras" is the same content as a paper diary and the result of headache statistics can be found in "statistical analysis." "Headache duration in hours/days" is the approximate duration in hours and days of headaches experienced by users. "Medication record" is where users can record daily usage of prescription drugs. If users add more drugs, they can add the name of the drug(s), which will be displayed in "drug management." In addition, users need to fill in whether daily doses of drugs and painkillers are effective or not. "Menses and RLS" is used to record if either or both of these conditions appeared on a specific day.

4.2 Statistical Analysis

Different methods are used to display the entire statistical analysis for users' headache conditions, as shown in Fig. 5. When users enter this page, they need to choose "start day" and "end day"; headache data is then displayed according to this range of time. The contents of statistical analysis include: "start

time of time interval," "end time of time interval," "total days of headaches," "total weeks of headaches," "total number of data," "total time of headache," "average hours of headache," "days of heavy headaches," "days of moderate headaches," "days of mild headaches," "days of no headaches," "total days of heavy, moderate, and mild headaches," "total days of heavy and moderate headaches," "days of Migraines with Auras (MA)," "days of Migraines without Auras (MO)," "days of Probable Migraine (PM)," "days of other," and "days of headaches that are affected by menses and RLS." MA is the number of days users see a flash of light or part of their vision is obscured before a headache. MO is if users have concomitant symptoms like "sensitivity to light and sound" or "nausea and vomiting" during the period of headache and more than two items from the following: "headache is like a throbbing pulse," "headache is unilateral onset," and "headache is worsened by physical activities.". PM is if users have concomitant symptoms like "sensitivity to light and sound" or "nausea and vomiting" during the period of headache or more than two items from the following: "headache is like a throbbing pulse," "headache is unilateral onset," and "headache is worsened by physical activities.". In addition to the above conditions, days of headache are listed in the days of "Other." "Days of headaches that are affected by menses" is days of headaches from two days prior to menses to the third day of menses.
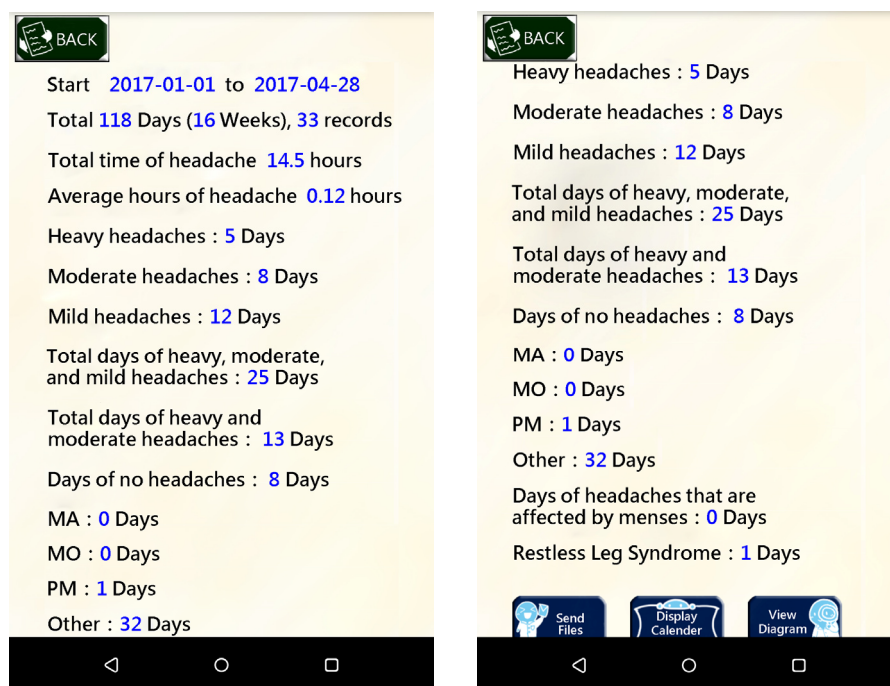

Fig. 5. Page of statistical analysis

Finally, users can use "upload data" to upload data to a web system so that diary entries are saved to a database. Users need to choose a range of time and then select "upload data." The diary app checks the network status first, after which the diary app displays two types of data that can be uploaded: "diary upload" and "drug upload." However, if registration records are not found, users first need to fill out basic registration information. Diary and drug records are listed according to the range of time chosen by the user. The app uses the "POST" function in hypertext transfer protocol (http) to upload diary and drug records to the web system. The diary app must check whether any errors, such as empty required fields, are present before the system uploads the next record. If the diary app displays an upload error, the system uses error message to notify users according to the content of the error. The user can see all records of diary entries, drug usage, and the list of user drugs in the web system after being uploaded.

4.3 Chart View

We designed two different charts to provide users with the ability to check their headache conditions in the diary app. These charts can help physicians access corresponding data on the page. The two chart types are "week chart" and "7-day chart". The "week chart" is shown in Fig. 6(a) and the time interval is a cycle that completes every seven days. Three different colored bars displayed on the horizontal bar

chart represent "days per week," "days of heavy, moderate, and mild headaches," and "days of heavy and mild headaches." This bar chart can display how weekly headache conditions improve or any reduction in duration after taking drugs and using other treatment methods. According to this data, physicians can diagnose patients, assign treatment, and determine if expected treatment results were met. The "week chart" divides the range of time from Monday to Sunday and respectively counts patient condition during each of the seven days. This chart has two display types: "range of time display" and "months display." The "range of time display" is shown in Fig. 6(b); the method of display is the same as described above. The "months display" shows all days where headaches were logged into the diary app and displays them by months and years. Users can choose any month they want to read. The main purpose of the "week chart" is to check headache condition from Monday to Sunday. Physicians can use this chart to diagnose whether a user's lifestyle may be leading to headaches and if changes to said lifestyle may lead to betterment of condition. For example, headache triggers may appear during work days and disappear during holidays.
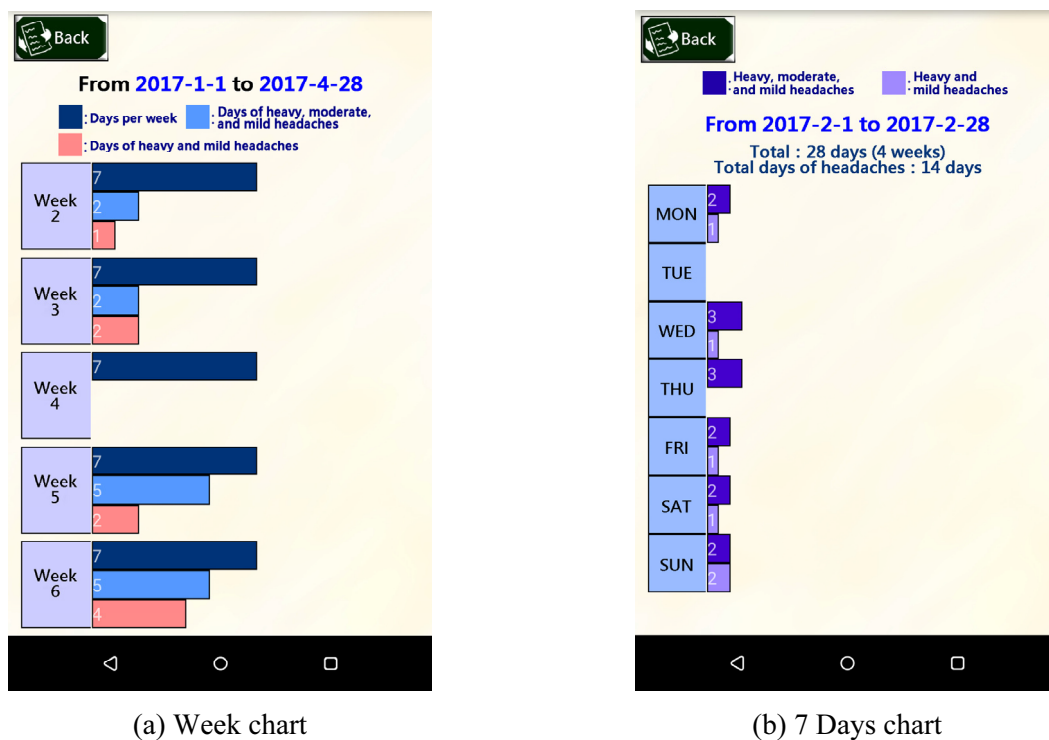
(a) Week chart	(b) 7 Days chart

Fig. 6.

5   Results of Usage Survey Investigation

In order to collect research data legally, we applied for and passed the research qualifications from the Institutional Review Board, Taipei Veterans General Hospital. We then collected data during the consultation hours of Dr. Wang at the Neurology Department, Taipei Veterans General Hospital and Taipei Municipal Gan-Dau Hospital. The requirement of participants was that they at some point used paper diaries. The purpose of this requirement was so participants could compare headache diaries in both paper and digital formats. We used consultation hours to ask patients about which diary format they were using and other relevant questions. According to the results of their responses, we estimated whether they fit the research purpose or not. After questionnaires were collected, we used SPSS to conduct descriptive statistics and inferential statistics according to the questionnaire data. The total number of effective questionnaires came to 126. About 25.4% of participants were men (32 persons) and 74.6% women (94 persons). The statistics of the sex ratio fit the sex-distribution discovered from this study (men to women being 1 to 3). In regards to age, the minimum age on questionnaires was 17 years old and the maximum was 65 years old with an average age of 42 years old. As shown in Fig. 7, a bar chart represents participants' ages with the minimum value being "under 20 years old" and the maximum

"above 60 years old"; the range of 20 years old to 60 years old was divided into four items, each comprising ten years. Based on this data, about 40% of participants were between 41 and 50 years old, meaning that the age of participants we collected is similar to the age of patients with headaches.
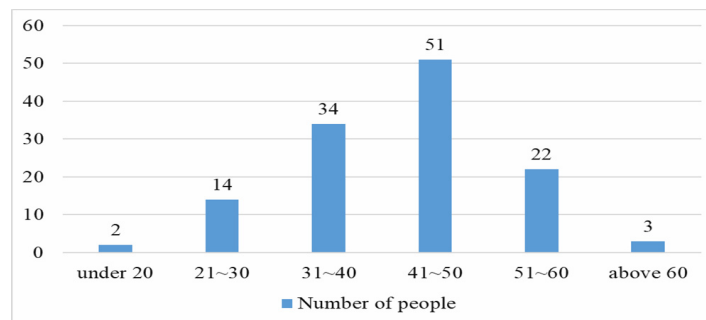
Fig. 7. Age Distribution of Participants

MIDAS is used to estimate the daily lives of patients who are affected or not affected by headaches. The results of these statistics are shown in Table 2.

Table 2. Descriptive statistics of MIDAS (One month)

	N	Minimum	Maximum	Mean	Std. Deviation
P4-1	126	0	8	.48	1.282
P4-2	126	0	20	3.39	4.610
P4-3	126	0	10	1.29	2.131
P4-4	126	0	31	4.17	5.345
P4-5	126	0	15	.99	2.057
P4-6	126	0	31	8.00	7.165
P4-7	126	0	10	5.27	2.049
P4-8	126	0	56	10.32	10.469
Valid N (listwise)	126				

Question P4-1 asked, "How many days were you unable to work or go to school because of headaches in the past month?"; minimum days were 0, maximum days were 8, and average days were 0.48±1.282. Question P4-2 asked, "During how many days has your work or study efficiency been reduced by half or more than half because of headaches in the past month (deducting days in question 4-1)?"; minimum days were 0, maximum days were 20, and average days were 3.39±4.61. Question P4-3 asked, "How many days were you prevented from doing housework because of headaches in the past month?"; minimum days were 0, maximum days were 10, and average days were 1.29±2.131. Question P4-4 asked, "How many days has your housework efficiency been reduced by half or more than half because of headaches in the past month (deducting days in question 4-3)?"; minimum days were 0, maximum days were 31, and average days were 4.17±5.345. Question P4-5 asked, "How many days were you unable to join social activities, family gatherings and/or leisure activities because of headaches in the past month?"; minimum days were 0, maximum days were 15, and average days were 0.99±2.057. Question P4-6 asked, "How many days did you experience headaches in the past month?"; minimum days were 0, maximum days were 31, and average days were 8±7.165. Question P4-7 asked, "How would you rate your headache level (0 = no headache, 10 = serious headache)?"; minimum level was 0, maximum level was 10, and average level was 5.27±2.049. Question P4-8 was the total MIDAS score, where the above five questions were added together; minimum points were 0, maximum points were 56, and average points were 10.32±10.469. According to the standard of classification in MIDAS, the average headache level of participants was grade IV (the total of MIDAS points for the past three months was greater than 21, so the total of MIDAS points for the past month was greater than around 7) and the level of headache was considered serious.

As shown in Table 3, about 46.8% of participants thought the accuracy of their headache diary entries was very high (80%-100%), about 40.5% of participants thought their headache diary entries were of high accuracy (60%-80%), and the remaining 12.7% of participants thought their headache diary entries were only of medium accuracy (40%-60%).

Table 3. Accuracy rating of recorded headache diaries as reported by participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Middle (40%~60%)	16	12.7	12.7	12.7
	High (60%~80%)	51	40.5	40.5	53.2
	Very High (80%~100%)	59	46.8	46.8	100.0
	Total	126	100.0	100.	

The statistics were a comparison between paper diaries and the diary app. The question was, "Is the diary app more convenient to use than a paper diary?" As shown in Table 4, about 91.1% participants thought that the diary app was much more convenient than paper diaries, about 6.5% of participants thought that the two were similar, and the remaining 2.4% of participants thought that the diary app was not more convenient to use than the paper diary.

Table 4. Rate participants thought the diary App was more convenient than paper diaries

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	3	2.4	2.4	2.4
	Similar	8	6.3	6.5	8.9
	Yes	113	89.7	91.1	100.0
	Total	124	98.4	100.0	
Missing	99	2	1.6		
Total		126	100.0		

The results of the analysis are shown in this portion where we used the MIDAS of participants and other questions to use inferential statistics according to different scales of data. We used a single factor ANOVA (analysis of variance) to compare total MIDAS scores for the following question: "Was the diary app convenient for recording headaches?" As shown in Table 5, the average MIDAS score was equal to 9.53 ± 9.538, where participants thought recording headaches on the diary app was convenient; the average MIDAS score for patients who believed that recording headaches on the diary app was inconvenient is equal to 24 ± 9.899. According to the above results, if the MIDAS scores of participants tend to be higher, they believe recording headaches on the diary app is more inconvenient. As shown in Table 6, the p-value is equal to 0.009 and means that the two groups of data have a significant result.

Table 5. Descriptive statistic of "MIDAS"

	N	Average	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Inconvenient	2	24.00	9.899	7.000	-64.94	112.94	17	31
No Effect	7	19.29	18.830	7.117	1.87	36.70	0	56
Convenient	116	9.53	9.538	.886	7.77	11.28	0	43
Total	125	10.30	10.510	.940	8.44	12.16	0	56

Table 6. The ANOVA of MIDAS

	SS	Df	MS	F	*p-value*
Between Group	1010.097	2	505.049	4.857	.009
Within Group	12686.351	122	103.986		
Total	13696.448	124			

6 Conclusion

This study develops a mobile medical app in cooperation with the Neurology Department of Taipei Veterans General Hospital. The diary app was tested during consultation hours and improved. Finally, we

completed the development of the diary app. The major purpose of this study is to (1) achieve a reduction in the time needed to read a diary and improve diagnosis efficiency; (2) improve the accuracy of diagnosis; (3) solve the problems of paper diaries being difficult to carry and maintain; (4) upload headache diaries to a database; and (5) provide headache data to be analyzed. According to the analysis results, physicians can use the function of "statistics analysis" from the diary app to determine the number of headache days and relative statistics of patients according to a range of chosen time. Therefore, errors in scoring improved and the accuracy of diagnosis by physicians increased. Next, according to analysis results of clinical records and questionnaires, the time applied to reading entries in the diary app by physicians was less than when reading paper diaries. Owing to the reduction in time applied to reading headache diary entries, the accuracy of diagnosis by physicians improved and they were able to spend time asking other questions about symptoms and provide more careful diagnoses.

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