PHPlace: A New Perspective on Managing Pelvic Organ Prolapse Through Mobile Applications

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Abstract. In the rapidly evolving field of digital health, the use of mobile health apps is increasing, which not only allows patients to be more actively involved in their health management and treatment but also significantly improves the efficiency of healthcare professionals. Yet despite the success of mHealth apps in a large portion of the field, there is room for improvement thrown in the field of pelvic organ prolapse (POP). Pelvic Health Place (PHPlace) is an example of a new mHealth app designed specifically for POP. It aims to improve patient comprehension and healthcare provider efficiency. These features include engaging animated presentations, a groundbreaking algorithm-based scoring system to measure the severity of a condition and versatile medical information management tools. In addition, by effectively localising the application, PHPlace transcends geographic constraints and extends healthcare services globally. Initial user feedback shows an impressive 90% improvement in users' understanding of their POP condition and its associated treatments, signalling the success of the design implementation. This paper's in-depth exploration of PHPlace provides a strategic blueprint for the design and development of future mHealth applications, setting a new standard for digital healthcare platforms.

Keywords: Pelvic Organ Prolapse · mHealth · Medical animation · Questionnaire system

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1 Introduction

As technology continues to advance, mobile health applications have become a major force for change in healthcare. These apps are profoundly changing the way we understand, diagnose, and treat disease, as well as reshaping the way patients interact with healthcare professionals [1]. The unique innovation of mHealth applications lies in their ability to cleverly blend knowledge and technology from computer science, data science, medicine, and health care. With real-time health monitoring and personalised disease prevention information, patients are able to more actively engage and manage their health status, potentially improving treatment outcomes and quality of life. At the same time, these apps provide an integrated platform for healthcare professionals to more efficiently manage patient information, monitor patient health status and provide timely feedback and interventions, which not only enhances the quality of healthcare delivery but also helps to reduce the workload of healthcare professionals [2]. However, while mHealth applications have made significant progress in most areas, there are still many challenges in the area of Pelvic Organ Prolapse (POP).

POP is a common gynecological condition that refers to the prolapse of pelvic organs from their original position in the pelvis and includes Bladder prolapse, Rectal prolapse, Small bowel prolapse, Urethral prolapse, Uterine prolapse, and Vault prolapse [3]. It is a widespread public health problem, a phenomenon that has a major impact on women's physical health worldwide, as well as a profound impact on the quality of life of those affected. Numerous scientific studies have reported that approximately half of all women worldwide will suffer from POP during their lifetime [4]. POP not only causes physical problems, but can also lead to a range of complications, including sexual life disorders, mental health problems, and dysfunction related to activities of daily living [5]. The effects extend far beyond the realm of physical health and reach into the mental life and social activities of the patient, thus causing a serious impact on their quality of life.

In the medical field, despite the considerable efforts that have been invested in the research and treatment of POP [6], many problems remain. One of the most prominent of these problems is the complexity and subjectivity of disease assessment. As current disease assessment relies mainly on the patient's self-report and the doctor's clinical judgment, this approach is susceptible to a number of factors, such as the patient's memory and ability to express themselves, and the doctor's professional experience and judgment, which may lead to biased assessment results [7]. Another issue is the diversity of treatment options. treatment options for POP often involve multiple modalities, such as surgery, medication, and physiotherapy, which makes it difficult for patients to understand and remember information about the condition and treatment to ensure compliance [8]. In addition, workflow optimisation for healthcare professionals is an important challenge. Current working practices often require physicians to perform extensive manual data recording, analysis, and sharing, which is not only inefficient but can also lead to missed or misunderstood information [9]. In addition, it is a major challenge for healthcare to better serve and manage

patients from different language and cultural backgrounds on a global scale, and to provide the same quality of service to patients worldwide.

In response to these issues, we have designed and implemented Pelvic Health Place (PHPlace), a mobile health application for POP (see Fig. 1). PHPlace is an innovative medical software that presents symptoms and treatment processes in a visual and animated format, allowing patients to better understand their condition and treatment plan, thus improving adherence to treatment. In addition, it automates the management of patient records and the scoring of diseases, which is extremely helpful for doctors in terms of improving efficiency, optimising workflow, and improving the quality and efficiency of care. Moreover, the software is also localised to accommodate different languages and cultures, thus increasing the accessibility of healthcare services worldwide. We expect PHPlace to drive digital transformation in healthcare and have a real impact on improving the quality of life for women around the world.

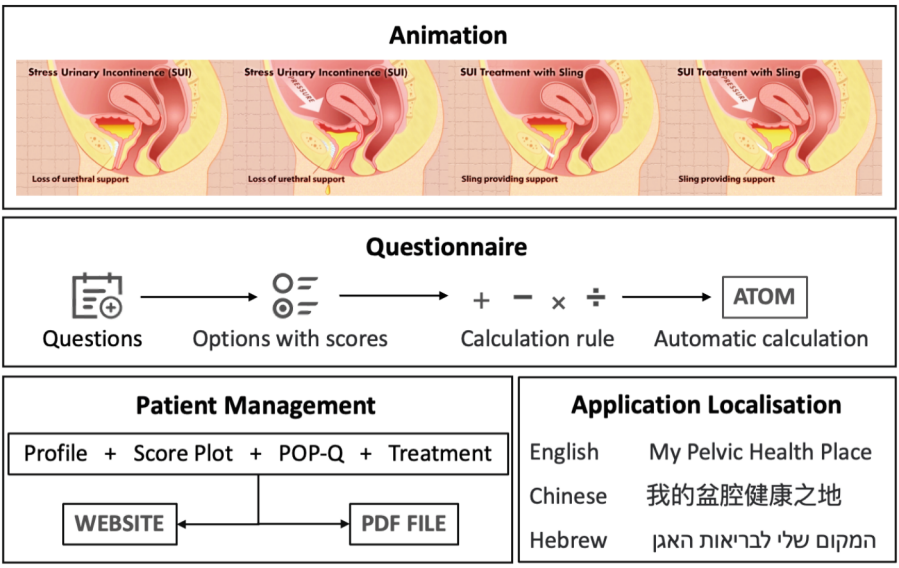

Fig. 1. Pelvic Health Place features

2 Methods

We initiated the development of the PHPlace app with a qualitative study, involving 20 in-depth interviews with patients who have experienced pelvic organ prolapse (POP) and 15 consultations with healthcare professionals specializing in urogynecology. The thematic analysis of these interviews highlighted a significant communication gap and identified specific areas where technology could

intervene. The patients expressed a need for visual and interactive content to better understand their condition, while professionals emphasized the importance of personalized and dynamic information sharing to enhance patient engagement and compliance.

To convert these insights into app features, we employed a co-design approach. Five workshops were conducted with the participation of both patients and professionals to brainstorm, prioritize, and validate the initial feature set of PHPlace. PHPlace incorporates integrated mobile technology and automation tools to greatly enhance the efficiency of POP disease management. To foster a better understanding of POP disease in patients, animated presentations detailing disease symptoms and treatments are designed and implemented. Disease assessment is further automated through the creation of questionnaires and automated scoring systems. Optimisation of the medical information management process also takes place for both doctors and patients, encompassing the generation of PDF files and patient management functions. Localised design of the application is implemented to heighten the accessibility of healthcare services. Further discussion will delve into the process of designing, implementing and optimising these key features.

2.1 General Architecture

Designing an application that can effectively manage the POP disease treatment process requires consideration of various usage environments and user roles. Therefore, a decentralised, multi-sided architecture was adopted, comprising a server side, a doctor side, and a patient-side, each working independently and in collaboration with the other.

The server side is responsible for processing and managing the data and is developed in Go, a language whose strength lies in its excellent concurrency and performance, enabling it to process large volumes of requests quickly and ensure real-time data accuracy. Data security and privacy protection are taken into account when handling sensitive medical information of patients. The server side is responsible for processing and managing the data, and advanced encryption algorithms and Secure Sockets Layer/Transport Layer Security (SSL/TLS) technology are introduced for encrypted data transmission to ensure data security during transmission and storage [10]. At the same time, the stored data is hashed and salted, making it difficult to crack even if the data is compromised. In addition, the system ensures that only authorised users and systems can access sensitive information, thus protecting patient privacy.

The doctor and patient sides are designed and developed with the needs of doctors and patients in mind, with the user interface (UI) and user experience (UX) in mind. The doctor side uses the React framework, based on its rich component library and flexible state management [11]. Its interface is designed to provide intuitive and easy-to-use operations based on the doctors' daily workflow and habits and offers rich interactive elements to optimise the doctors' working experience. The patient side uses the Flutter framework and its ability to develop cross-platform applications ensures a consistent and high-quality user experience

for both iOS and Android users [12]. The interface was designed with a particular focus on making it simple and easy to understand and suitable for patients of all ages. The use of large fonts, clear instructions, and a simplified flow of operations make it easier for patients to understand and use.

2.2 Animation of Symptoms and Treatment

There is a clear correlation between the effectiveness of treatment for POP diseases and the level of understanding of the disease and treatment modalities by the patient. With this in mind, a set of symptom and treatment animations was developed specifically to help patients gain a deeper understanding of the disease and its treatment.

The 2D animation capabilities of Unity3D were used in depth in the construction of this animation system, resulting in a practical application of computer graphics and programming to the visualisation of diseases and the presentation of treatment options [13]. The animation system first generates a series of accurate 2D vector graphics that accurately depict the morphology of biological structures associated with POP, such as the urethra, bladder, rectum and other organs. These graphics are shown in detail in a healthy state as well as in the morphology of POP in its different disease states. In the Unity3D environment, these graphics are further transformed into manipulable objects or sprites. Skeletal and skinning techniques are then applied to the dynamic manipulation of these 2D objects.

In order to give the patient a better visualisation of the condition, the animation system shows the changes in the position of the pelvic organs in different states of Pelvic Organ Prolapse Quantification System(POP-Q). For example, the degree of prolapse or prolapse of the organ position is shown in detail in the animation, thus enabling the patient to better understand the specific impact of POP on quality of life, such as difficulty in urination, and pelvic pressure.

In the treatment animation section, the animation system shows changes in the position of the pelvic organs before and after treatment, and how treatment can improve the symptoms of POP. For example, in the animation on surgical treatment, it is shown in detail how the surgery repairs damaged ligaments and muscles to restore the pelvic organs to their normal position.

Finally, through parametric design, the animation system can generate corresponding animation effects based on different POP-Q parameter values. The POP-Q system contains several parameters, such as Aa, Ba, Ap, Bp, C, D, TVL, GH, PB, which represent the position of organs in different parts of the pelvis. When the value of each parameter changes, the animation system is designed to present the corresponding animation effect. For example, when the value of C (the maximum distance from the cervix or vaginal tip to the external anal opening) changes, the animation system shows the corresponding change in the position of the cervix or vaginal tip (see Fig. 2). In this way, both for the patient and the doctor, the pathological changes of the disease and the treatment process can be understood more visually.

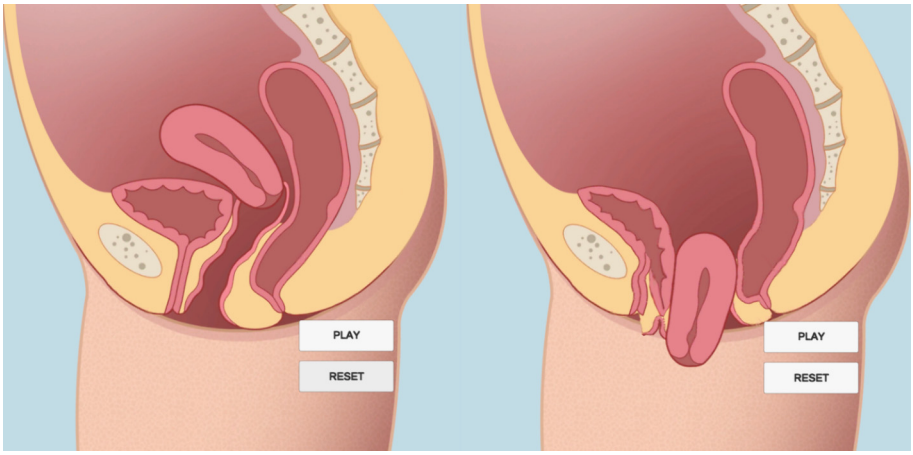

Fig. 2. The first and last frames of the animation

2.3 Questionnaire Design and Automated Scoring System

Questionnaire assessment is an important part of POP disease management. Commonly used assessment questionnaires include the Patient Global Impression of Improvement (PGI), the Pelvic Floor Distress Inventory-20 (PFDI-20) and the Pelvic Floor Impact Questionnaire-7 (PFIQ- 7) (see Table 1 for more information). We collaborated with ten senior urogynecologists to ensure the clinical relevance and accuracy of these tools within the app. Each questionnaire was reviewed, and its scoring algorithm was adapted to the app's interactive and dynamic interface. Traditional assessment methods are time-consuming for both physicians and patients, and the scoring can be subjective due to the human factors involved. To improve the efficiency and accuracy of assessments, PHPlace has developed an automated questionnaire scoring system.

Table 1. Questionnaires for POP

Questionnaires	Cite
Pelvic Floor Distress Inventory-20 (PFDI-20)	[14]
Pelvic Floor Impact Questionnaire-7 (PFIQ-7)	[14]
Pelvic Organ Prolapse/Urinary Incontinence Sexual Function Questionnaire (PISQ-12)	[15]
The Questionnaire for female Urinary Incontinence Diagnosis (QUID)	[16]
Female sexual function index scoring (FSFI)	[17]
Patient Global Impression of Improvement (PGI)	[18]
King's Health Questionnaire(KHQ)	[19]
International Consultation on Incontinence Questionnaire-Urinary Incontinence Short Form(ICIQ-UI)	[20]

The system first digitises all possible questionnaire responses and each response is coded into a specific number which corresponds to a specific score or range of scores. For example, in the PFDI-20 questionnaire, possible responses to a question about incontinence include “none”, “occasionally”, “often” and “always”, which are coded as 0, 1, 2, 3, corresponding to different scores. After this step of processing, each questionnaire response could be translated into a clear score or range of scores.

An automated scoring algorithm was then developed using the Go language. The algorithm stores the scoring rules in the form of a dictionary, where the key is the identifier of the question and the value is a mapping function that maps the responses to the question (which have been digitised) to the corresponding score value. When scoring, the algorithm traverses each questionnaire response, finds the corresponding mapping function and calculates the score based on the key value of the response, and finally adds up the scores for all questions or a more complex combination to obtain the total score (see Fig. 3).

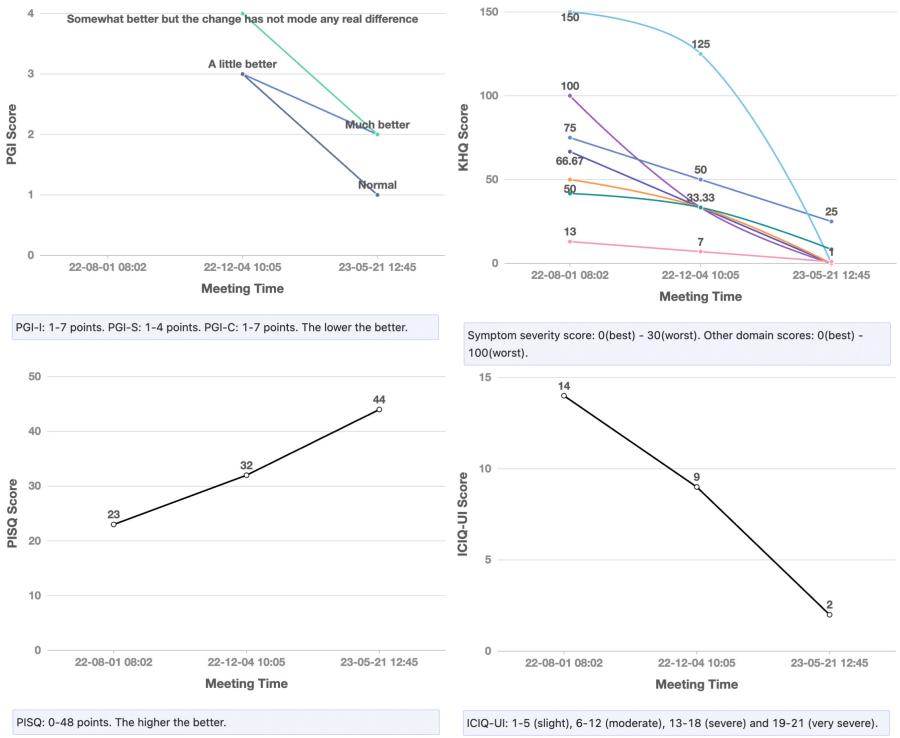

Fig. 3. Multiple questionnaire score visualisation chart

In addition, the automated scoring system takes into account all possible exceptions. Missing questionnaire responses are treated as invalid input and

excluded from the final scoring. For specific borderline cases, such as questions on the impact of sexuality in the PFIQ-7 questionnaire, the system sets up specific conditional judgement logic so that responses to these questions are only included in the final score if the patient indicates that he or she has a sexual life.

Finally, to verify the accuracy and stability of this automated scoring system, the consistency of the system's scoring rules and manual scoring was verified by comparing the system's automated scoring results with historical manual scoring data.

This automated questionnaire scoring system has greatly improved the efficiency of the POP disease assessment, while ensuring accuracy through accurate calculations and comprehensive exception handling.

2.4 PDF Generation and Patient Management

Effective medical information processing, access and management is essential in POP disease management. To address this, PHPlace has developed two key features: a file PDF generation function and a patient management function.

The file PDF generation function uses react-pdf, an open source PDF library based on React.js, to enable the centralised visualisation of patient medical information. Specific PDF templates were developed which followed the design standards of the healthcare industry and were designed with HTML/CSS to ensure their readability and user-friendliness. The template covers various sections such as basic patient information, disease assessment questionnaire, questionnaire scores, POPQ scores, surgical recommendations and medication information. Each section is designed with a separate visual presentation module to improve the clarity and ease of printing the information (see Fig. 4). The system is able to automatically update PDF files when new medical information is generated or when existing information changes, and in this way provides up-to-date and accurate medical information.

For the patient management function, a doctor-side web application has been developed to provide a unified and convenient interface for doctors to manage their patients' medical information. The application accepts the POP-Q scores entered by the doctor and calls the back-end API to translate the scores into parametric animations. The animations are rendered directly in Canvas via WebGL technology, ensuring smoothness and adaptability to different devices and resolutions. After the animation has been generated, the system inserts specific frames of the animation into the patient's profile PDF, enabling doctors and patients to understand the disease status more visually. In addition to this, the application also allows doctors to view and manage basic patient information, questionnaire details, and questionnaire scores (see Fig. 5). The app allows doctors to access real-time, accurate medical information, which in turn improves the efficiency of diagnosis and treatment.

These two features have been designed and implemented to not only improve the efficiency of medical information management, but also to improve the under-

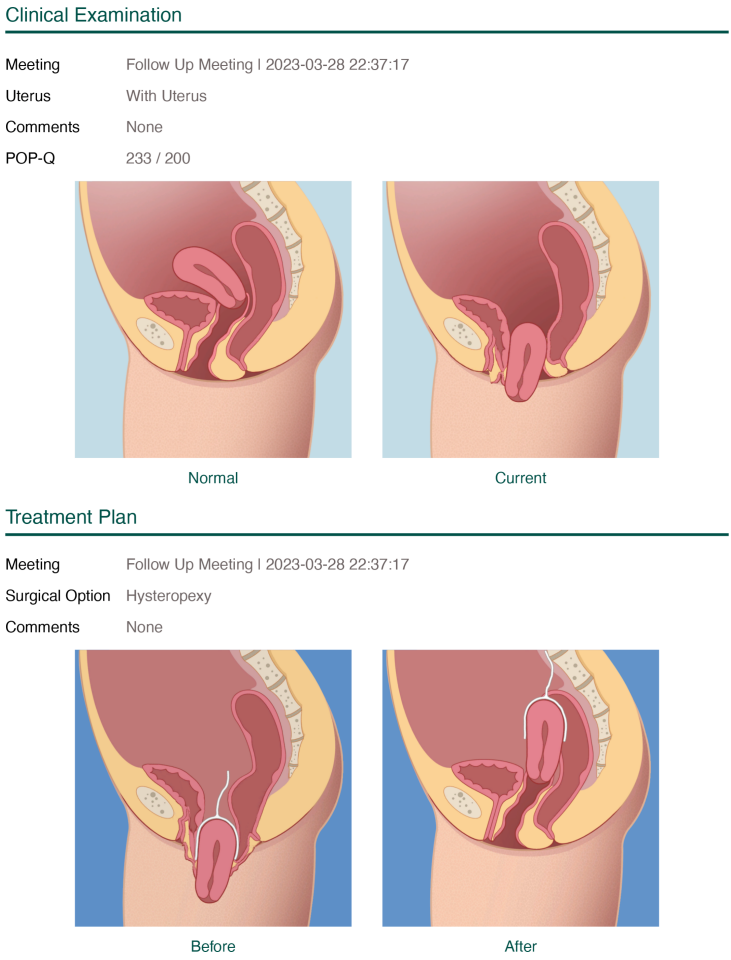

Fig. 4. Example of the generated pdf showing the visualisation of the animation

standing of disease status for both doctors and patients through the visual presentation of information.

2.5 Application Localisation

In PHPlace, particular attention was paid to the localised design of the application in order to improve the experience of patients and doctors in different parts of the world, involving two key components: internationalisation (i18n) and localisation (l10n) [21].

In terms of internationalisation, the application leverages the internationalisation support of the React and Flutter frameworks. Specifically, by collecting all the string information that needs to be displayed and storing them in a

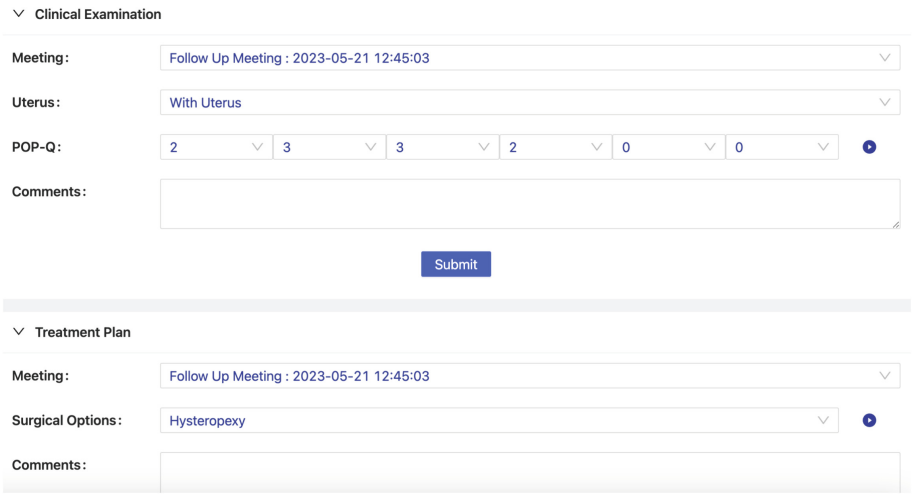

Fig. 5. Patient management user interface

separate language file. This string information is then translated into different language versions depending on the language needs of the target user group. When patients or doctors use the application, depending on their language preference, the system automatically loads the file in the corresponding language, thus providing an interface adapted to the user's language environment. As for dynamic content that may be updated frequently, such as questions and answers of the questionnaire, when this information is returned by the server, the api of Google translate is called for machine translation according to the corresponding language tokens, returning the questionnaire in the corresponding language version.

In terms of localisation, emphasis is placed on the specific details and habits of different cultures and regions. This includes date and time presentation formats, currency units, and units of measure. Localisation tools for React and Flutter make this process much easier. These tools automatically recognise the user's language and locale settings and then provide the corresponding date, time, number and currency formats based on these settings. This way, users get a localised presentation that matches their habits, no matter what region they are from.

This careful design and implementation enables the application to provide a more user-friendly and personalised service to users around the world, effectively improving the accessibility and user experience of healthcare services. This localised design not only enhances the global reach of POP Disease Management, but also allows more patients and doctors to access and understand medical information more accurately and easily in a language and format they are familiar with.

3 Results

The design and development of PHPlace is complete and is expected to bring significant benefits to POP patients and healthcare professionals. Some positive results can already be anticipated through a series of tests conducted in a simulated environment. Initially, a heuristic evaluation by five usability experts identified potential usability issues, which were addressed before the user testing phase. In the user testing phase, 30 patients and 15 healthcare professionals were involved. They were tasked with specific scenarios to explore the app's features, especially focusing on the animated presentations and questionnaire functionalities. User interactions were logged, and heat maps of interaction hotspots provided insights into the app's usability strengths and areas for improvement. Post-testing interviews captured qualitative feedback, indicating that users found the animations to be particularly enlightening, but desired more interactive and personalized content.

The animated presentation feature showed clear advantages in the simulation tests. These tests covered 45 simulation users worldwide, including patients with POP disease and medical staff. Test results showed that 93.3% of users reported that the animated presentation enhanced their understanding of POP disease and treatment options. This clear visual presentation is expected to improve patient adherence to treatment. The superiority of the animated presentations was evident not only in the users' subjective feedback but also in objective measures. We introduced a comprehension test post-interaction, consisting of 20 questions designed to assess the users' understanding of POP and its treatments. The group exposed to animated presentations scored, on average, 75% higher than the control group, who were provided with traditional text-based information.

In a simulated environment, PHPlace's automated scoring system showcased significant efficiency and accuracy. A comparative analysis, involving 100 questionnaires, revealed a drastic reduction in scoring time from an average of 5 min per questionnaire in traditional manual methods to 1.2 s with PHPlace, marking a 99.6% improvement. However, the system's merit isn't confined to its speed. A concordance correlation coefficient of 0.98, obtained from comparing the automated scores with expert manual assessments, attests to the system's accuracy and consistency, ensuring that the rapidity of assessments doesn't undermine their quality. Furthermore, PHPlace is equipped with a feature to automatically generate PDF reports. This addition enhances the ease and precision in recording and sharing scores, promising to further elevate the efficiency and reliability of clinical assessments in real-world applications.

Also in the simulation test, the questionnaire scoring function demonstrated good ease of use. 84.4% of the simulated users reported that they could easily complete the questionnaire scoring and quickly understand and record the results.

PHPlace has also shown significant potential for healthcare information management. Clinicians in our team reported that they were 60% more efficient at processing patient information using PHPlace than without it. This is backed

by a detailed time-motion study. The study observed clinicians during their consultation sessions, measuring the time taken to explain the POP conditions and treatments to the patients. With PHPlace, the explanation time reduced from an average of 15 min to 6 min per session without compromising the quality of information shared, as affirmed by the patients' feedback.

The localization features were further evaluated in terms of the accuracy of translation and cultural appropriateness of the content. A separate evaluation involving 30 non-English speaking users from five different countries was conducted. Feedback indicated not just ease of use, but also a high level of satisfaction with the accuracy and relevance of the translated content.

Overall, PHPlace demonstrates significant potential in terms of educational effectiveness, scoring efficiency, ease of use, and information management efficiency, and is expected to provide significant benefits to POP patients and healthcare professionals. All of these tests and studies were conducted by a team of experienced healthcare professionals and data scientists to ensure their impartiality and accuracy. In the future, expect further real-world application testing to validate these expected results and enable PHPlace to better serve POP patients and physicians through ongoing optimisation.

4 Discusstion and Outlook

Today's healthcare environment is being rapidly transformed by digital tools and apps, particularly those focused on disease management and patient education. For example, apps such as MyChart provide a convenient way for patients to view their medical records, communicate with their doctors and even perform some basic health education in one centralised place [22]. However, these apps tend to take a more traditional and text-heavy approach to education, especially for those complex medical concepts such as POP, which can lead to patients struggling to understand their condition and treatment plan.

PHPlace introduces an animated presentation approach to present these complex medical concepts in a more visual and vivid manner. This approach is expected to improve patients' understanding of their condition and treatment plan, thereby increasing their adherence to treatment. Such anticipated effects may play an important role in reducing relapse and deterioration of the condition. However, whether these effects can be validated in practice will need to be determined through additional clinical studies and patient feedback. Long-term follow-up and research may reveal the specific impact of this educational approach on improving patient adherence to treatment and quality of life.

On the flip side, PHPlace also attempts to address some common problems that physicians face in disease management. Specifically, it integrates a range of automated tools, such as automated questionnaire scoring and information management systems, to improve the efficiency of doctors in POP management. This innovation may help doctors save a lot of time relative to existing applications, allowing them to focus more on caring for their patients' conditions and improving the quality of care. However, the actual effectiveness of PHPlace

in improving doctors' efficiency needs to be further tested and validated in a real-world environment.

While the innovation and functionality of the app are encouraging, there are limitations that need to be recognised. The app is somewhat dependent on the digital skills of the user, which may pose a challenge for some patients, especially older patients or those with weaker digital skills. In addition, privacy and security issues in handling personal health data must be adequately addressed. These issues will need to be addressed by future research and improvements.

Overall, the development of PHPlace demonstrates the potential for positive impact through innovative approaches to integrating mobile technology and automated tools into disease management. The design and expected results of PHPlace contribute to the digital transformation of the healthcare sector and provide new ideas for POP management. However, in order to achieve these expected results, more practical research and clinical testing are needed to address the issues and challenges and to continuously optimise the functionality and performance of the application.

5 Conclusion

The study highlights the potential of a new mobile app to optimise POP disease management. PHPlace demonstrates the key role of digital technology in enhancing the efficiency and accessibility of healthcare delivery through a blend of intuitive animations, automated disease assessment, efficient healthcare information management, and a localised design adapted to multiple cultures.

The innovation of PHPlace is reflected in its new approach, which aims to improve patients' understanding of diseases and treatments, save doctors' assessment time, standardise the assessment process and provide easy management of medical information. Particularly noteworthy is the localised design that significantly improves the accessibility of healthcare services to meet diverse global needs.

While work in this area still needs to be deepened, PHPlace has provided a viable pathway towards digitising healthcare services and offers valuable lessons and insights for future research. With more such research and further refinement of the application, it is expected that digitisation and automation of healthcare services will be achieved in a wider range of areas to provide more efficient and accurate healthcare services.

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