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Digital Health Empowerment in Surgery: Exploring Total Hip Arthroplasty as a Model for Transformation

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Abstract. In the realm of modern healthcare, digital health solutions are poised to transform patient care, particularly in surgical interventions such as Total Hip Arthroplasty. Through a scoping review of 40 studies, this paper identifies six categories of digital interventions tailored for pre- and post-operative care in THA, spanning (Tele-)Rehabilitation, (Tele-)Monitoring and -Communication, Mobile Applications and Patient Portals, Digital Patient Assessment and Outcome Measurement, as well as Biomechanics and Robotics. These solutions, ranging from AI-driven communication tools to weight-shifting robot control systems, promise a more patient-centered, efficient, and accessible healthcare model. The paper concludes by advocating for continued exploration and development of digital health solutions to improve surgical outcomes and patient experiences across various medical contexts.

Keywords. Digital Health, Pre- and Post-habilitation, Surgery, Hip Arthroplasty

1. Introduction

In an era marked by rapid medical advancements, digital health solutions (DHS) offer promising prospects for transforming patient care, providing personalized, efficient, and accessible services [1]. As such, there is a growing imperative to explore the impact of DHS on various facets of healthcare delivery, including surgical interventions. Surgical procedures are pivotal moments in patient care, where precision, efficiency, and comprehensive pre- and post-operative management significantly affect outcomes.

Pre- and post-operative management for patients often involves pre- and post-habilitation programs, including education and exercise routines, to prepare them physically and mentally for surgery and aid in their recovery afterward. However, implementing these measures entails high costs and poses challenges due to constraints

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in both time and personnel resources [2]. Thus, DHS can offer a decisive contribution by providing effective and cost-friendly interventions. Yet, a comprehensive overview of DHS available for facilitating pre- and post-habilitation in patients undergoing total hip arthroplasty (THA) is lacking. Consequently, this paper, utilizing an explorative research design, aims to provide a comprehensive overview of DHS, which support the care provided to patients prior to and following surgery. THA is examined for two key reasons: it is one of the most prevalent elective surgeries, with about a million artificial hips implanted annually [3], and the advantages of pre- and post-habilitation in improving THA outcomes, like better functionality, make it significant for study [4].

2. Methods

To provide an overview of DHS, which have the potential to facilitate the care provided to surgical patients in pre- and post-habilitation, a scoping review, following the guidelines proposed by Peters et al. (2015) [5] was conducted. Since a scoping review identifies key concepts and research gaps within a field [5], it is the most suitable method for our research objective.

The search strategy comprised a scientific database search in PubMed in February 2024 using the following search term:

(artificial hip[Title] OR hip arthroplasty[Title] OR hip replacement[Title] OR hip prosthesis[Title]) AND (patient[Title]) AND (information[Title/Abstract] OR education[Title/Abstract] OR knowledge[Title/Abstract] OR training[Title/Abstract] OR physio*[Title/Abstract] OR rehab*[Title/Abstract] OR prehab*[Title/Abstract] OR exercise[Title/Abstract]).*

We filtered articles focusing on humans in English or German within the last 15 years. Two researchers independently screened 465 articles based on titles and abstracts. Eligible articles focused on THA, addressed pre- or post-habilitation, and involved digital interventions. After resolving discrepancies, 40 articles met the criteria. The search process is illustrated in **Figure 1**.

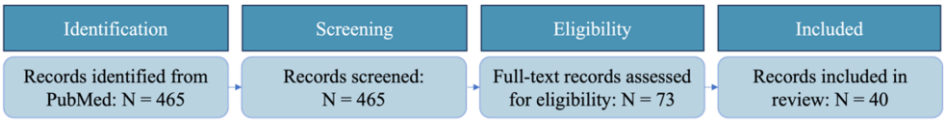

Figure 1. Scoping review process.

The categories of DHS presented in section 3 were formed in an inductive categorization process based on Mayring (2014) [6]. Therefore, initial categories were formed following the screening of the first 30 articles. Subsequent minor adjustments to the categories were collaboratively made by all authors after screening half of the articles.

3. Results

The scoping review results are outlined in the following section. Six categories of DHS were identified, each aimed at improving pre- and/or post-habilitation for THA patients. An overview, as well as the number of papers per category (indicated in brackets) can be

found in Figure 2. Five articles pertain to two categories and are therefore classified under both. Moreover, the utilization points of DHS along the patient pathway are illustrated. Due to page constraints, only selected articles will be cited, with a full list provided in Appendix A[2].

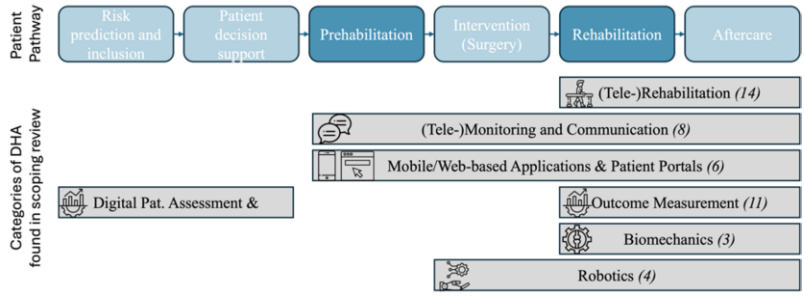

Figure 2. Categories of DHA and their application along the patient pathway.

(Tele-)Rehabilitation: Fourteen papers were found examining digital solutions for post-operative rehabilitation after THA, encompassing various delivery modes from traditional mobile and web applications to innovative approaches like serious gaming with health professional involvement. These interventions facilitate communication between healthcare providers and patients asynchronously (e.g., exercise prescription and performance monitoring via text messaging), synchronously (especially video consultations), and can complement on-site rehabilitation programs (e.g., virtual reality-enhanced therapy). It should be noted that of these papers, n = 4 papers have comprehensively reviewed the state-of-the-art identifying the technological needs for rehabilitation after THA [7], and demonstrating comparable or superior results to traditional rehabilitation programs [8].

(Tele-)Monitoring and -Communication: Employing delivery modes and technologies akin to those mentioned in the previous section, multiple studies (n = 8) explored the integration of digital tools in scenarios related to pre-surgery or spanning both pre- and post-surgery phases. This included the provision of video content delivered asynchronously (esp. details about the surgery or physical rehabilitation exercises) and real-time video consultations. Remarkably, one study delved into the effectiveness and reliability of generative AI (ChatGPT) in addressing common questions from patients before undergoing THA (i.e., the computer as intelligent communicator) (9).

Mobile/Web-Applications and Patient Portals: This included n = 2 papers describing patient-facing apps with a high degree of autonomy and low involvement of professionals (little to no asynchronous communication). These applications were used to guide, motivate, and remind patients to exercise, educate patients about surgery, self-management in everyday life, and evaluate outcomes. In contrast, n = 4 studies also described the asynchronous bidirectional communication with the health provider (e.g., in the case of complications) in addition to the mentioned functionalities and therefore may be considered as a type of patient portal.

[2] Appendix A is available via: https://datashare.tu-dresden.de/s/BczWoDy69NbqakZ

Digital Patient Assessment and Outcome Measurement: Several studies (n = 3) investigated machine learning approaches to assess the patient's postoperative risk, the length of stay or gait impairments. Additionally, two studies described sophisticated approaches including multimodal imaging and slice encoding to detect prosthesis failures or loss [10]. Further, six studies investigated digital tools like the Patient-Reported Outcomes Measurement Information System for post-THA outcome assessment, exploring correlations with traditional measures, and mental health scores [11]. The studies underscore the value of digital patient-reported measures in evaluating post-THA outcomes. Additionally, one underexplored aspect involves using analytical PROM reports to assist patients in making informed decisions about undergoing surgery [12].

Biomechanics: Three studies investigated the efficacy of biofeedback systems in facilitating the recovery of patients following THA. These systems offered instant feedback to patients throughout their rehabilitation process, resulting in better movement patterns, decreased pressure on the hips, and improved overall function and quality of life [13]. Utilizing methods such as mobile feedback training, sensorized systems, and foot-worn biomedical devices, these interventions demonstrated significant potential in enhancing post-THA rehabilitation outcomes.

Robotics: Studies (n = 4) in robotic-assisted techniques for THA demonstrate diverse advancements, comparing robot-assisted rehabilitation with conventional methods [14]. Robot control systems notably enhanced balance ability or demonstrated promising improvements in gait. The findings underscore the potential of robotics in optimizing both surgical and rehabilitation outcomes for THA patients, offering innovative avenues for enhancing postoperative recovery and functional restoration.

4. Discussion

The review highlights the extensive range of DHS for THA, from pre-operative education and planning tools to post-operative rehabilitation and monitoring systems, marking a significant move towards a more patient-centered, efficient, and accessible healthcare model. These solutions enable healthcare providers to deliver a more holistic and integrated approach to patient care, covering diverse phases of the patient pathway. Nonetheless, as we delve into this digital exploration, it's crucial to persistently evaluate the effectiveness, accessibility, and acceptance by patients of these technologies to ensure they fulfill the varied needs of the patient population. Moreover, the review emphasizes the potential of DHS to address multiple aspects of patient care in a cohesive and integrated way. Yet, further design research is essential to explore how to integrate and seamlessly combine various DHS, aiming for a comprehensive, unified and simultaneously cost-effective patient care across different healthcare settings. Currently, the findings indicate that existing DHS are highly dedicated and specific, demonstrating a notable lack of integration in their functional design.

The insights from THA suggest potential transferability to other elective surgical processes (e.g. knee arthroplasty), promising similar application areas. However, the success of adapting these solutions to different surgeries necessitates careful consideration of procedural differences, patient and professional needs, and clinical

evaluation. A limitation of our scoping review particularly lies in its descriptive character and unsuitability for identifying potential future application fields for DHS, especially concerning trends around artificial intelligence and advancements in sensor technology. Instead, the exploration of future developments and application possibilities should be conducted through qualitative surveys among technical experts and medical professionals to gain a deeper understanding of the expectations and opportunities in this rapidly evolving field.

5. Conclusions

Our study delves into the transformative potential of Digital Health Solutions (DHS) in surgery, particularly Total Hip Arthroplasty (THA). Through a comprehensive scoping review of 40 studies, we explored a diverse range of DHS, spanning from pre-operative education tools to post-operative rehabilitation and monitoring systems. This extensive array underscores the promising role of DHS in reshaping healthcare to be more patient-centered, efficient, and accessible. By presenting this overview, we aim to not only illuminate the current landscape of digital health innovations but also catalyze further research in developing and evaluating these solutions. Our hope is that this work stimulates broader exploration into how DHS can enhance surgical outcomes and healthcare delivery, ultimately improving patient experiences across medical fields.

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