Integrating Patient-Generated Health Data into Orthopaedic Care: A Qualitative Study on Early Adopter Experiences with Clinical Software

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Abstract

Background: Patient-Generated Health Data (PGHD) has been recognized as a potential tool in transforming healthcare from clinician-centered to more patient-centered approaches. This transformation is driven by the potential of PGHD to provide deeper insights into patients' conditions, facilitate personalized care, improve patient quality of life, reduce inefficiencies in data collection, and empower patients. Yet, actual implementation within clinical settings is still at early stages, and therefore impacts on clinical care remain limited.

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Results: The study identified several benefits of integrating PGHD into orthopaedic care, including improved patient education, enhanced communication and assessment, and increased patient motivation and adherence. However, several challenges were also noted, such as increased clinician workload, questionable data utility, lack of patient centricity, and inability to tailor software to clinical contexts. Suggested opportunities included improving dashboard design, personalizing physiotherapy, and using collected data for improving clinical care.

Conclusions: The integration of PGHD into orthopaedic care shows promise, largely in areas suggested by literature. However, significant challenges remain. Future research should focus on addressing solvable challenges such as improving software user interface design and functionality, while embracing the possibility that some challenges lack clear solutions and will likely require careful balancing of design tensions. The findings highlight the need for ongoing development and refinement of PGHD-inclusive systems to better support clinical practice and patient outcomes.

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Keywords

Patient-Generated Health Data (PGHD); Orthopaedic Care; Digital Health; Remote Monitoring; Patient-Centered Care; Clinician Workload; Patient Engagement; Health Informatics.

I. Introduction

There are frequent calls within academic literature and popular media to transform healthcare

systems from the traditional “clinician-centred” model to a more “patient-centred” approach, an approach characterised by shared clinical decision-making and increased patient autonomy (Grover et al., 2022) while also helping to reduce costs through coordinated and accessible personalised services (Natalie Dickson, 2024). An important and often asserted mechanism for this transition is increasing the use of Patient Generated Health Data (PGHD) within clinical care, information collected by individuals (and informal carers) on their treatment records, symptoms, biometric data, and lifestyle preferences (Omoloja & Vundavalli, 2021). Use of PGHD has been promoted for variously: providing deeper insight into a patient’s condition (Cohen et al., 2016); facilitating personalization of care (West et al., 2018); improving patient quality of life (Jim et al., 2020); reducing inefficiencies and insufficiencies in data collected solely at clinical visits (Basch & Abernethy, 2011); reducing retrospective recall bias (Yoo & De Choudhury, 2019); and empowering patients by helping them to understand their progress (Caldeira et al., 2021).

Using PGHD has become increasingly feasible as technologies for self-tracking of health and wellness data have become affordable and culturally acceptable to consumers (Lai et al., 2017). The ease of data collection for patients and ubiquity of these devices are informally influencing clinical interactions as patients increasingly present their self-collected data during clinical visits (West et al., 2018), and recent studies suggest that clinicians are increasingly open to using PGHD at least as supplementary data within clinical workflows (Guardado et al., 2024).

Despite the potential benefits, there remains extensive known barriers to implementing PGHD within clinical care. For example, (West et al., 2018) identified the nature of the data (structure, completeness, reliability, lack of context, relevance), selective disclosure, clinician suspicions of underlying patient psychiatric disorders, insufficient clinician time, insufficient clinician expertise, clinician overload, interoperability, and negative impacts to workflow. Other notable barriers include clinician reluctance to assume responsibility for motivating patients to collect data (Cohen et al., 2016); clinician concerns that reliance on PGHD could exacerbate health disparities (Jim et al., 2020); negative impacts on patient-clinician relationships (Lordon et al., 2020); and resistance to change within clinical culture (Basch & Abernethy, 2011). Given such diverse challenges, it is perhaps unsurprising that formal integration of PGHD within clinical practice remains limited (Giordanengo et al., 2019). Therefore, there remains a lack of knowledge on diverse PGHD-related topics such as how to use PGHD to improve healthcare outcomes (Omoloja & Vundavalli, 2021), impact on patient–clinician communication within surgical domains (Lordon et al., 2020), best practices to incorporate into clinical workflows (Tiase et al., 2021), and impacts in supporting clinical practice (Guardado et al., 2024).

This study sought to understand work practices, acceptance of digital tools, and attitudes toward PGHD to gain insights that could provide guidance for designing PGHD-inclusive orthopaedic software systems. To this end we conducted interviews with surgeons and physiotherapists who were members of an “early adopter” orthopaedic unit that had: a) been given the opportunity to use an early release of industry produced patient journey software that offered various tools for interacting with patients and their data, and b) participated over several years in the development and deployment of a novel device to enable orthopaedic patients to self-collect pain data (Price et al., 2018). Focussing on this context foregrounds real-world exposure and engagement with PGHD, with the reported experiences helping to fill current gaps in knowledge in the clinical use of PGHD, guiding future research on the use of this data in a clinical context.

Background

Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are common elective surgeries for older adults, where an original joint damaged by arthritis or trauma is replaced with metal and plastic implants. Due to high cumulative expenses resulting from this increasingly common procedure, TKA/THA operations are an important target for optimising care (Yu et al., 2015). To this end, fast-

track programs which seek to reduce patient time in-hospital, have become standard, successfully reducing costly hospital stays without impairing outcomes or increasing re-admissions (Petersen et al., 2020). However, despite the successes of this approach, there remain opportunities for improvement that could potentially be supported with increased use of PGHD. For example, TKA/THA patients frequently have risk factors which can be related to readmission (e.g., obesity, cardiovascular disease, diabetes, lifestyle factors) (Yu et al., 2015). Yet, current clinical systems often fail to consider what occurs outside the boundaries of the healthcare system (Batalden et al., 2016). This lack of vital information about patients' co-morbidities and lifestyle, can hinder timely decisions about surgical scheduling and personalising patient care, and there is also an urgent need to increase proactive care to enhance patient satisfaction, promote long-term recovery, and reduce unnecessary hospital stays. Given the importance of events occurring outside of the clinical setting for improving outcomes, the importance of engaging patients in collaborative care, and the potential for non-clinical data to inform policies that could improve outcomes, TKA/THA appears a promising domain for increased PGHD integration.

PGHD and THA/TKA

As mentioned in the introduction, the adoption and affordability of wearable devices has increased the feasibility of integrating PGHD into THA/TKA care, and there have been numerous studies exploring potential benefits and limitations. (Toogood et al., 2016) used ankle-worn Fitbit step counters to track daily steps in post-total hip arthroplasty (THA) patients. They found this method feasible and found that by differentiating activity levels based on factors like age, BMI, surgical approach, and discharge destination, it might be possible to identify slower recovery cases that could benefit from interventions. However, other studies cautioned that while tracking was technically feasible, the resulting data had practical limitations. For example, (Crizer et al., 2017) studied using step counts to monitor preoperative and postoperative recovery, but found a weak correlation with patient-reported outcomes. The authors suggested that combining objective measures like step counts with patient-reported outcomes would provide a more comprehensive assessment. Similarly, (Bendich et al., 2019) examined data from wearable sensors worn by patients both pre- and post-total joint surgery. They reported that alterations in sensor data six weeks post-surgery correlated closely with patients' reported improvements in well-being; however, the raw sensor data didn't directly correspond with patients' self-reported feelings, suggesting that to effectively predict post-surgery outcomes using sensors, it's essential to analyse how the data evolves over time rather than solely focusing on absolute values. These papers highlight that it is not sufficient to aggregate and report data to clinicians, but rather that meaningful interpretation and context are essential. We found numerous papers that applied tracking devices to support patient monitoring outside the clinical environment. However, we found little research on orthopaedic clinicians' reflections on the use of PGHD and more specifically their experiences with PGHD inclusive clinical software. In addition, relatively few studies on PGHD integration have examined the use of patient-generated data from the clinician’s rather than the patient perspective (West et al., 2018), which is important as clinician engagement has previously been recognised as a significant challenge for integrating patient self-reporting systems into clinical practice (Basch & Abernethy, 2011). This paper aims to fill these gaps through exploring clinician’s real-world experiences with the benefits and challenges of integrating PGHD into TKA/THA workflows, and through analysis identifying opportunities to improve these systems.

Methods

We chose to interview two essential and complementary clinical roles in the TKA/THA domain; orthopaedic surgeons who are central to the procedure (Walters et al., 2012) and physiotherapists whose work has been shown to improve post-surgical recovery (Coulter et al., 2013). Our team was composed of HCI

professionals and clinicians (Cheng et al., 2015) and a change management specialist who conducted the interviews. Our research was also guided by a socio-technical systems design (STSD) approach that seeks to dynamically balance human, social, organisational, and technical requirements, recognizing that software addressing interdependent systems often fail by not recognising the social and organizational complexity of the deployed environment (Baxter & Sommerville, 2011). Our research group has been collaborating with clinicians within this group since 2016 on the use of tracking devices to assess compliance (Kelly et al., 2021), research and design of a tangible devices for patient pain logging (B. A. Price et al., 2018), (L. Price et al., 2024), (Pearce et al., 2023). In addition, members of this unit are participating in early testing of "mymobility", an industry produced orthopaedic-care software platform which integrates diverse PGHD from Apple Watch and iPhone into clinical dashboards. These interviews were conducted from June to July 2022, a period when due to the pandemic, many typically in-person services had been replaced with app-based communication which by necessity gave clinicians additional exposure to using health relevant data collected by patients. Drawing on our ongoing relationship with the orthopaedic centre at Milton Keynes University Hospital, we used snowball sampling to recruit 4 orthopaedic surgeons (1 female, 3 male) and 5 physiotherapists (4 female, 1 male). All had previous experience with TKA/THA procedures, with experience ranging from 1.5-25 years. Clinicians had varying levels of exposure working with PGHD at MKUH. In the reporting on interviews S1-4 will be used for Surgeons, and P1-5 for Physiotherapists. Participants were assured anonymity, and ethics clearance was granted through the university ethics board. Preconditions for participation were professional capability in either of the two selected clinical roles, experience with TKA/THA, and spoken English. All participants were employed in these roles in the UK. Prior to interview, participants received an email confirmation of the time and date, as well as receiving copy of the questions, and a consent form that was returned by email. Participation was voluntary, and all participants were informed of their right to withdraw at any time. The interviews lasted from 30-60 min. and were conducted by the same member of the research team (LP). Participants were offered either face-to-face or online interviews to accommodate their clinical schedules. The interviewees' responses were anonymised according to ethics committee procedure. Each institution's data protection policy was adhered to ensuring that data was confidentially stored.

TABLE 1 DEMOGRAPHICS OF PARTICIPANTS

Participant	Age	Gender	Ethnicity	Role	Experience (Yrs.)
Surgeon 1	56	M	S. Asian	Associated specialist	25
Surgeon 2	46	M	S. Asian	Consultant orthopaedic surgeon	25
Surgeon 3	-45	M	S. Asian	Trauma and orthopaedic consultant, hip and knee.	25
Surgeon 4	53	F	White	Consultant Orthopaedic and Trauma Surgeon	15
Physio 1	25	F	White	Rotational physiotherapist	1.5
Physio 2	56	F	White	Senior team lead physio in trauma and orthopaedics	32
Physio 3	46	F	White	Physiotherapist on Trauma and Orthopaedics	12
Physio 4	29	M	White	Musculoskeletal and orthopaedic outreach physiotherapist	4
Physio 5	32	F	White	Specialist MSK physiotherapist	3

Questions were based on our literature review and previous experience researching the requirements and design of digital systems. The interview questions were piloted and iterated with an advising senior orthopaedic surgeon and a physiotherapist. The questions for the semi-structured interviews were structured within four sections: 1) Current work practices, 2) Use of digital tools, 3) Experiences with PGHD, 4) Experiences with mymobility software platform. For the last set of questions, participants were provided with anonymised screen shots of PGHD from the mymobility app for their reference (see Fig. 1-3).

mymobility Software

mymobility (*mymobility | Zimmer Biomet*, n.d.) is a digital care management platform tailored for orthopaedic patients, supporting a variety of procedures through care plans for knee, hip, shoulder, and spine surgeries. This platform seeks to facilitate communication and data sharing between patients and healthcare providers throughout the surgical process. Key features include:

- Patient Engagement and Compliance: The app seeks to foster patients' engagement in their surgical journey by providing educational materials, procedural information, and personalised exercise plans
- Data Monitoring and Insights: Through automated remote monitoring with Apple Watch and iPhone and patient-reported outcomes, the app tracks patient progress, allowing patients and clinicians dashboards to view collected data.
- Care Team Management: Through a unified platform for digital care management and telemedicine, the app seeks to support communication and coordination among patients and care team members.

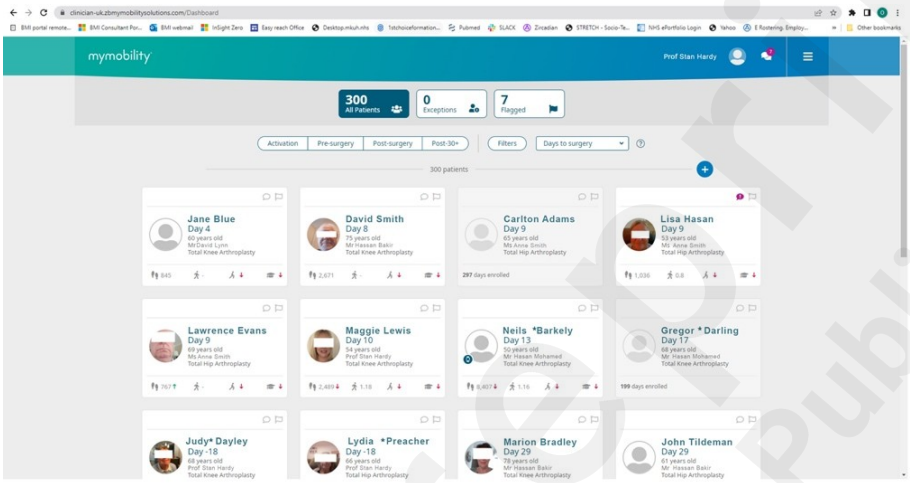

FIG. 1 PATIENT OVERVIEW

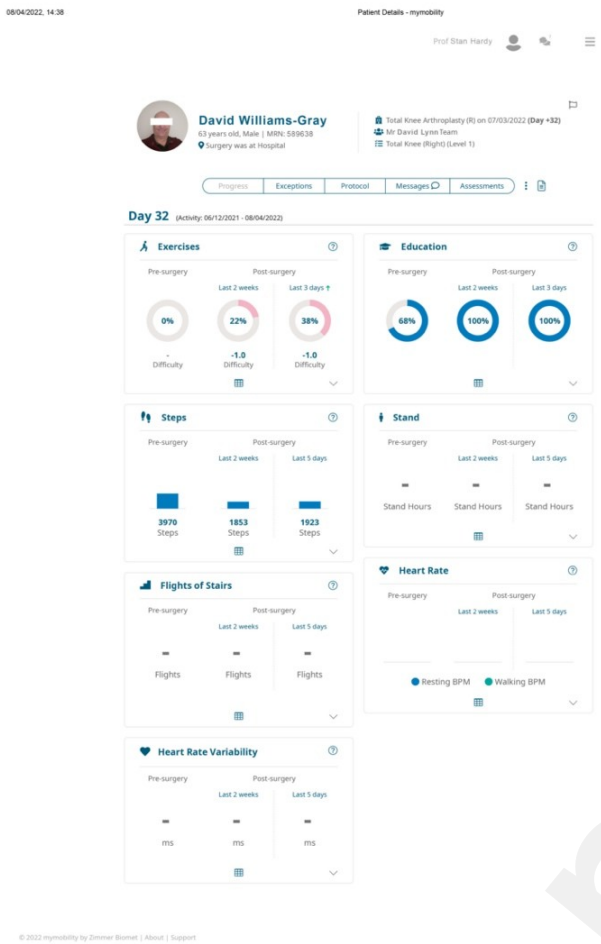

FIG. 2 PATIENT PROGRESS

Data Analysis

The anonymised transcribed interviews were analysed using a reflexive thematic analysis approach. The analysis focused on understanding meaning within specific contexts and acknowledging that data analysis involves storytelling, interpretation, and creation rather than uncovering an absolute truth hidden within the data (Braun & Clarke, 2019). We conducted our analysis with a realist framing, which *"reports experiences, meanings and the reality of participants"* with an inductive approach that attempts to conduct the analysis without the use of a pre-existing theory or model (Braun & Clarke, 2006). As per (Braun & Clarke, 2006) we used an iterative process of *familiarization, generating initial codes, searching for themes, reviewing themes, defining, and naming*. Analysis was conducted with NViVo software (NVivo qualitative data analysis Software; QRR International Pty Ltd., Version 12). The interviews were audio recorded and transcribed. The answers were then collected in subcategories using open coding. Finally, similar open codes were grouped together and discussed in frequent subsidiary meetings with team members. While not all software functions within mymobility platform are exclusively PGHD related (education and messaging), and as the software integrates PGHD as a core functionality that can influence these interactions, and as our approach was not sufficiently fine-grained to distinguish between the impact and interactions of each of the features, we report on clinician reflections on these aspects as well.

Results

Benefits

The mymobility app demonstrated benefits in patient information and education, communication and assessment, and patient motivation and adherence (see Fig. 1). Participants noted that the app reduced staff workload by providing pre-operative information and exercise plans, ensuring patients were well-prepared for surgery. Remote monitoring capabilities offered insights into patient activities and adherence, aiding clinical decisions and interventions. Additionally, features like reminders and goal setting improved patient adherence to clinical protocols.

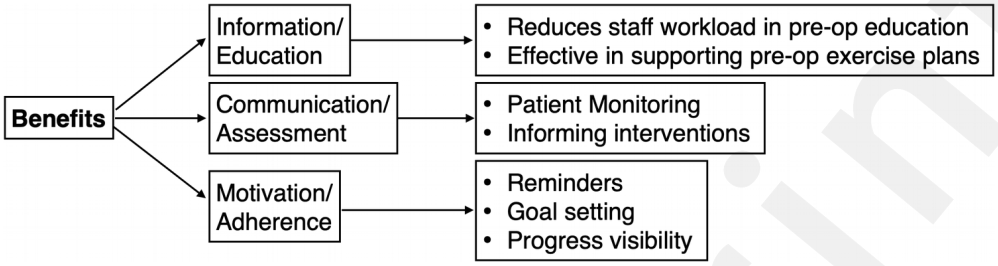

FIG. 3 BENEFITS

Information/Education

Participants were positive about the software reducing staff workload in pre-op education. P3 noted *"…they… get all the information…we normally spend a lot of time going through with them. And so…they have an idea of what they're getting themselves into."* And P5 added *"…the benefit of the mymobility app at the moment they do get that patient information [and] patient education…which I think a lot of them find very beneficial."* The app was also effective in supporting pre-op exercise plans. P4 noted that *"…the protocol-based rehab is absolutely fine prior to the operation."* And S1 added *"… it streamlines and gives them information and they can do and understand the exercises."*

Communication and Assessment

The ability to monitor patients remotely through the app was valued by the clinicians as well. As P1 noted, *"…pre-op... what they're already doing in the community… the number of steps that they're doing, that's really helpful to see…what their routine's already like. How active they are pre-op will influence their speed of recovery after op…"* Similarly, P4 noted *"...seeing what exercises they're doing …and how well they're adhering to it and how difficult the exercises are."* S3 was particularly impressed by the scope of the information *"… the mymobility app is brilliant. It's even monitoring how many steps you're taking, how you're doing stairs, it's even doing your gait analysis…the data we're capturing, it's unbelievable."* The ability to objectively monitor patients was also valued for giving insights into recovery. P3 noted, *"…you can see that he's improving over the last, so, obviously pre-surgery but obviously less post-surgery, which is to be expected. But as long as he's starting to improve."* And P5 added, *"… showing the weight between the right and the left leg that [is] quite beneficial to give us a bit more of a guide as to how much load they're put in through they're operated limb versus their non operated limb."* S1 was also positive about how the software could support overviews, *"I do like the initial dashboard which shows all my patients. So, then I can select a pre-surgery or post- region and then focus on one [at a] time [or] one small group. And then can look into …overall progress as well as their different activities which are included in in their data."*

Such information could also help to inform interventions, as S1 noted, *"…it gives us enough*

information so we can see that progress is satisfactory. And if they have any concern or we have any concern, then we can be in touch much quicker." And P3 observed how being able to track exercise could help to inform physiotherapeutic practice *"…I can see what exercises they have been doing, or what exercises they were prescribed by the physio, [and] whether or not they were doing them...I can see what has been tried, or what was advised for them to do before. And I can either reiterate that advice, or we can maybe try a different approach…"* Importantly, S1 noted how this monitoring over time could help with surgical prioritisation *"… we have picked up the patients whose mobility has significantly deteriorated…and then we go through the app, what they're doing and what they're able to do and we are able to assess that …and they need to be prioritised as far as the timing of surgery is concerned."*

Patient Motivation/Adherence

The app also provided features which could help motivate patients to adhere to clinician recommendations. Reminders were noted as beneficial with P4 observing *"…they seem to adhere a lot better to it when the phone pings at them and tells them to do it."* And S1 adding *"…but they do need multiple reminders, but with the app they have a constant source."* Goal setting was also valued as a feature for adherence to clinical protocols with S1 noting, *"I think setting the goals… included in the app is a very good, nice incentive for the patient, so they should know what will be expected..."* Similarly, the tracking capabilities in the app were valued for helping to make progress more visible, with P3 sharing *"It's really nice to be able to say, "But look how you were here." Because it's easy to forget, isn't it, when you're six months into your rehab, and you still feel that you're not progressing how you want to be, you actually forget quite how bad you were at the start."*

Challenges/Weaknesses

Despite benefits noted in previous section, there were also many noted shortcomings, which draw attention to the ongoing challenges in designing and implementing PGHD inclusive software. In the following sections we discuss ways in which the software was reported to often increase clinician workload, data utility was often questionable, was ill suited for patient needs, and the software lacked the flexibility to be tailored to clinical workflows (see Fig. 2).

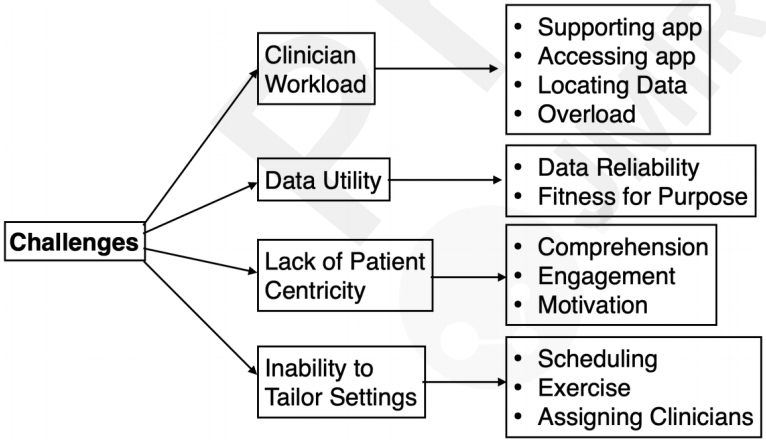

FIG. 4 REPORTED CHALLENGES

Clinician workload/time

The clinicians reported that the app increased their workload by introducing new responsibilities. P4 noted that the app could require support, noting *"…we do get a lot of messages saying how do I get the step count to work."* Accessing the app also introduced a barrier to clinician use with P5 noting on having to use additional apps *"…it's too difficult to log on to lots of different things…"* And S2 similarly noted, *"It's not particularly easy to access…You have to remember to log into it, look at the*

information." And P5 added *"…as much as that information is very beneficial, realistically in outpatient setting… to be able to log on to the app and get all that information is probably not realistic. And which is probably why we've not used it as much as we should have done."* The fragmentation of data was also noted as a barrier, with P2 observing, *"[it] take(s) a while to find the bits of information because they're all in various different places."* In addition, the large amounts of data within the interface could cognitively overwhelm clinicians both in quantity and lack of clarity, with S2 observing of the interface, *"Too much information and not quite sure what the information it is giving me is... I don't even know what double support percentage means. I'm not sure what scanned means, I'm not sure what the education means."* Or, as P1 noted *"It's a lot of data."*

Utility

Beyond the workload associated with accessing and comprehending data, there were also numerous challenges with applying the data to inform clinical practice. The reliability of the data was questioned, with P4 noting, *"I can't make a judgment based on something that I don't know if that's valid… if it says someone's not…walking or… they're walking a lot less... That could just mean they didn't have their phone in their pocket."* The data itself can also be insufficient to support patient assessment, as P2 noted *"…You have to look at the patient, you can't just look at the data."* The data itself was viewed as having limited value without in-depth context lacking in counts. P4 pointed out that steps count show only a limited view as, *"…it …doesn't tell you much about how they're walking… if someone's doing 3000 steps, but they're limping really badly and they're pain levels are really high, that's not particularly useful for us other than saying you're doing too much."* P4 continued, *"I won't log on to my mobility, see what their exercise record has been, and then base everything off that. I'll just ask them which of the exercises are difficult…it's a lot quicker and easier and you get a better answer that way."* Several clinicians also expressed that it was unclear how collected data could be used. P1 pointed out, *"And then once you've got the data what are you going to do with it?"* S2 noted, *"… it's more of a providing information rather than a collecting and analysing information…"* And P4 concluded that the data within the app *"…from a therapy point of view…it doesn't change our practice in any way, and it almost makes it longer…"*

Lack of Patient Centricity

The clinicians noted another challenge was that the software failed to adequately address patient needs and limitations. P5 observed *"…one of the biggest challenges (with PGHD) is…everyone's understanding of exactly what's being asked of them and how they measure that accurately."* Engaging patients can also pose significant challenges as P1 explained, *"…you get a lot of patients that are from care homes and perhaps they've got cognitive impairments, so they don't understand why you're there… sometimes they can't even remember why they've been admitted... trying to get them onboard with what you're trying to do. It can be quite challenging."* So, engaging this patient group with the responsibility of engaging with the software poses distinct challenges. As S4 notes, *"…they're…given access to mymobility…some of them don't engage…a lot of the patients we see here are also quite frail, quite elderly, it's a struggle to manage their everyday things, it's a struggle to manage all of their medications and everything else. I think it may just be one too many things for them to manage."* Some clinicians also brought up concerns that countdowns or metrics within the app could discourage pre-op preparation. P3 explained how the same data could impact different patients, *"...if they see they've slipped back a bit it might motivate someone to do more. In other cases, if they see they're slipping back, then it's that defeat. It's, "Well, it's not working anyway, so what's the point?"* Similarly, S4 noted that the countdown to the operation could *"…demotivate the patients because they think, "Oh, I've waited for a year, it's never going to happen. What's the point in doing these exercises? What's the point of me doing that?"*

Inability to tailor to patient journey

Another noted challenge lay in the software lacking adequate flexibility to reflect actual workflow needs. The inability to change the countdowns to reflect the actual status. P3: *"…the lady I've got on the ward this morning said her app is now telling her it's 52 days to her surgery. And she's like, "I've just had it." But it hasn't updated, so now she can't access the post-op programme..."* Lack of ability to personalise the exercise program was also noted as a significant challenge with P4 explaining that *"…preoperatively it's really good and the information is really good all the way through. But from a physio side of things post-op, we can't adjust the exercises."* P5 clarified that *"… there's only two programs of exercises and our patients are so varied that some of them exercises are too easy for certain patients, some of them are difficult for certain patients, and there's no specific way of them being able to change them or tailor them for them patients."* P4 continued explaining that due to the inability to tailor exercise programs *"... we'll just use a different (app), which is obviously not great because there may still (get) pinged by mymobility all the time to do their exercises…."*, which causes patients to *"… just delete the app because we tell them not to use it for the exercises."* Another noted deficiency was in their being insufficient consideration of the role of different stakeholders in the patient journey. P5 noted that *"…there's no way of us kind of assigning ourselves to that patient on the app…there's one physio generally that that checks all of the kind of messages, but they don't then necessarily know what physio that patients under or whether they're still under physio care."* And S4 stated, *"…they enter the data, but... I don't see them while they're on the waiting list, so I don't necessarily see what they're doing..."*

Opportunities for Improvement

As well as the benefits and shortcoming noted in the previous section, our analysis suggests several opportunities for enhancing future systems in dashboard design, personalization of physiotherapy, and clinical service improvement. Participants suggested making dashboards more intuitive and informative, with real-time notifications and interest in adding additional data such as heart rate and pain levels. They also emphasized the need for trend identification in patient data to better track progress over time. Personalizing physiotherapy was highlighted as crucial, with tailored exercises based on individual weaknesses and goals, especially post-operation. Lastly, the potential of PGHD to improve clinical care and surgical prioritization was recognized, suggesting that more detailed and personalised patient data might enhance treatment outcomes and resource management (see Fig. 3).

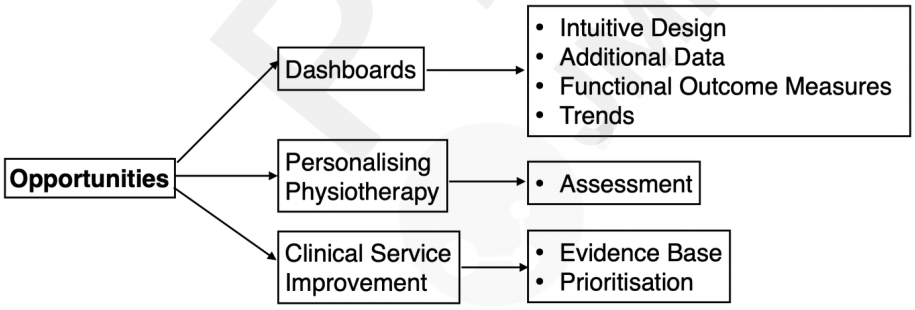

FIG. 5 OPPORTUNITIES

DASHBOARD DESIGN

There were several requests to make dashboard design and interactions more convenient. S2 reflected, *"It would be nice to have…a dashboard on the side of my screen here saying, "These are your patients, this is how they're doing." That would be useful...I've got a Google notification saying something happen in the news. Why can't I have them for my patients?"* And S3 asked for design elements that could draw attention to important details, *"...do you know what their daily steps have really gone up, or actually this patient's mobility has really gone down, something's not right here." I think the colour codes might help."*

There were also requests for additional data that might provide better overviews, with P1 noting, *"I*

definitely like seeing things like their heart rate." Pain data inclusion was requested by P4 who explained, *"Pain is usually the really big indicator…that we use…in that first six-week period..."* P5 emphasised that along with pain data it was important to understand the context in which it was occurring, *"… we need to know is how they're pain levels are, how they've got on with the exercises and kind of their progressive progression of their walking aids as well. And I really need to know more about kind of what movement they've got, whether they're walking equally or whether they're needing a walking aid…are they limping?"*

The importance of Functional Outcome Measures were also emphasised, with P4 desiring *"… their daily functions…how they're managing with getting washed and dressed…"* P3 emphasised the importance of these everyday activities, *"… patients that are coming through that have waited so long for their surgery, they're…quite limited in what they're able to achieve. So even some of the more basic stuff…Getting up from a chair, getting on and off the bed."* In addition, P3 asked for, *"… things like getting in and out of the car…How are they managing, are they driving again yet…. if they're able to use public transport, doing the shopping...it's all about their ability to get on with daily life, and characterised in terms of activities…contextualising it…"*

Trend visualisation was another functionality that clinicians noted could add substantial value to collected data. S4 noted, *"…those patient function scores...I think those are more important in terms of trend than absolute, because if you take somebody who's using a wheelchair, if they're walking around with two crutches and doing much better, their absolute PROM score will be low, but actually their benefit will be high…"* And P3 added, *"Particularly when they're coming back at six months, or even, like, twelve months. No one's seen them for six months, so if the patient was recording [mobility] and then you had access to that, you could really see how they'd been progressing over the last six months."* P5 explained about trends, *"… if somebody had something charted in front of them, they could see how well they've done, if they progressed…if they've regressed or something's gone wrong, you can kind of see the point in which that that's deteriorated."*

Personalising Physiotherapy

Clinicians noted the importance of personalising physiotherapy. Assessing patients is important as P5 states, *"…I give different exercises to most of my patients depending on where their weakness is, where their limitation in movement is and also depending on what their goals are."* Adding, *"I really need to know more about kind of what movement they've got, whether they're walking equally or whether they're needing a walking aid."* These custom modifications are particularly important post-operation as P4 explains, *"…the protocol-based rehab is absolutely fine prior to the operation…After the operation, so much depends on what changes…and what the patient actually presents as…everyone's different…"*

Clinical Service Improvement

PGHD could also be used to augmenting the evidence base to improve clinical care. S1 explained, *"...once we have enough data, we can look into what are the things which work for most of the patients, what are the concerns... most of the patients have or the actual limitations, and we can target those patients specifically if we know they're going to have a problem with communication...or actual physical rehabilitation."* S4 noted how such data could help to inform surgical practice *"Again, as a pragmatist, I think how would that change my practice in a sense that if the patients are all getting stiff afterwards, is that because I'm putting their knees too tight?"* Another area is in surgical prioritisation, with S1 noting, *"...if their mobility is decreasing quite rapidly, that's again a very important piece of information because...so we [can] try to get them in and have their operation quicker..."* And S4 stating, *"If we were able to adjust our waiting list according to how a patient deteriorates and acts, if we are able to have a resource where we can manage, "This person's wound's wrong, or they're going off their legs," and we can see them quickly from there, then that would be fantastic."*

Discussion

In this section we discuss the benefits, challenges, and opportunities raised through our analysis. First, we examine the software's potential to streamline patient education, improve communication, and enhance motivation. We then explore the hurdles of increased clinician workload, data trust issues, and patient engagement variability. We finally discuss emergent tensions and propose further research to help resolve ongoing challenges.

Benefits

The interviews suggested that the mymobility software with PGHD integration could offer meaningful benefits in the orthopaedic care setting. Structured education plans and essential information were appreciated for reducing staff workload and helping patients to prepare for operations. The communication and data sharing functions were useful for monitoring patients and in some cases helping to inform interventions. The use of reminders, goal setting, and the ability for patients to view progress over time were noted as showing promise for motivating patients to follow pre- and post-op care plans. Perhaps most promising for asserting the value of PGHD integration was S1 noting that there were specific cases where the shared data had provided evidence for prioritising care. However, it is important to note that app-based education and pre-operative physiotherapy support, some of the more successful noted aspects of the app, do not necessarily require PGHD integration. It remains for further research to determine if PGHD could help with further personalisation, for example with support for co-morbidities (Jansson et al., 2020), and if in these cases benefits would outweigh operational challenges. P4 noted that the great variance in post-operative outcomes require in depth knowledge of the patient's abilities and progress, which could potentially be supported by greater PGHD integration, though the interviewees expressed concerns that this was more reliably and with less effort accomplished through in-person contact (P4, P2). It is noteworthy and promising that many of the of the potential benefits of PGHD cited in the literature review were to at least some degree reflected in these interviews and in some cases delivered by the software. As per (Cohen et al., 2016) PGHD did help to provide insights; per (West et al., 2018) it did help to facilitate care personalisation; and as per (Caldeira et al., 2021) the collected data showed promise in motivating and engaging patients. While these benefits might not be universally reported by all clinicians, the responses suggest that this software is making strides in delivering the promised benefits of PGHD integration and this study provides some empirical evidence that it is viable to

integrate PGHD within orthopaedic clinical practice.

Challenges

Despite the noted benefits, Clinicians reported many barriers to integrating PGHD within clinical care, often echoing the known barriers cited in our review. Particularly problematic were the many ways the app could increase clinician workload, from requiring time to support patients in using the app (P4), interacting with the platform (S2), and locating and making use of data (P5). Potential benefits of the platform were also complicated by the clinicians continued reluctance to trust the validity of PGHD (P4) and challenges in applying data to decision making (P2). Furthermore, clinician expressed concern that need for patients to participate with this approach was unsuitable for many of their patients, echoing (Jim et al., 2020) which noted that use of PGHD in treatment could increase care disparities. The interviews also highlighted the challenges in tailoring software to reflect individual need, such as the selection of post-op exercises, or the assigning of clinicians. While the noted interface design shortcomings are likely correctable, the inability to overcome the larger barriers cited within the review are concerning given the resources likely invested in this software's design and development. In addition, defining the requirements for the many configurations needed to adequately address personalisation of the patient journey likely remains a stubborn problem (Tunis et al., 2024). This is especially vital, as clinicians noted how this inability to properly reflect individual patient journey can easily lead to software rejection. Similarly, this leads to another broader question as to how many features should be included within PGHD systems, given how single deficiencies area such as improper notifications can lead to product abandonment.

Opportunities

Clinicians suggested many realisable and relatively standard suggestions for improving product usability, such as making interface terms easier to understand, expanded use of colour coding, and indications of how patient progress deviates from norms or expectations. There were also calls for increasing convenience through new features such as notifications of important events and streamlining sign-ins, as well as potentially integrating additional data sources like heart rate, range of movement, pain levels, gait patterns and increased integration of functional outcome measures to support a more holistic understanding of patients' needs. Such suggestions appear relatively straightforward and reflect established design practices and features within other products. However, other suggestions such as automated exercise adaption to individual patient need might pose greater challenges, given that the clinicians emphasised the importance of human interaction in making these adjustments. And while the use of PGHD for clinical service improvement appears especially promising, it might require a standardisation and trust in PGHD which might still be culturally lacking at this time.

Design Tensions for Further Research

The software demonstrated capacity to deliver value to clinical care and many of the noted design deficiencies and suggested improvements are likely amenable to improvement through established iterative human-centred/ co-design techniques. Other deficiencies relate to broader societal concerns, which are outside of the ability of software systems to address. In this section we identify key areas for further research that consist of trade-offs or tensions that might imply conflicting requirements, which cannot be "solved" but rather require design decisions that recognise that trade-offs are inherent. While not necessarily novel, their persistence in this software after significant industry investment suggests that software design alone is insufficient to drive PGHD into the mainstream.

Leveraging Bigger Data vs. Burdening clinicians

Participants were impressed with the range of available data presented within the mymobility app and even suggested adding additional data. However, they also noted that expansive data could be overwhelming, could increase workload, and that they were often unsure of how to apply such data to their practice. RQ: *How can PGHD dashboards be designed to decrease clinician workload? How can system deliver the right data at the right time to the right clinical role?*

Standardization vs. Personalization in Clinical Practice

While standardized protocols and data collection methods are necessary for consistency and reliability, clinicians emphasized the importance of personalised care, particularly in post-operative physiotherapy, where individual patient needs vary significantly. RQ: *How can PGHD systems balance the need for standardized data collection and protocols with the flexibility required to personalize patient care effectively?*

Comprehensive vs. Targeted Software

Study participants related challenges resulting from accessing information and functionalities from multiple systems, which could support the need for a single comprehensive approach. Yet, participants also noted how one inappropriate feature could lead to system rejection. RQs: *What is the appropriate balance in number of features to include within PGHD inclusive orthopaedic software? How should this be determined?*

Adaptive vs. Static Design Approaches

It is recognised that healthcare is complex with outcomes emerging from multiple interacting systems needing frequent adaption to shifting contexts (Greenhalgh, 2018). This creates a tension between the validation needed to gain regulatory approval for clinical software systems, and the dynamic requirements within clinical contexts. RQ: *How can clinical software systems be designed that can be validated yet are sufficiently adaptable to variable workflows, preferences, and evolving needs?*

Limitations

This study has several limitations. The small sample size and focus on a single NHS unit limit the generalizability of the findings. Recruitment methods using snowball sampling and existing professional relationships may introduce selection bias, and the reliance on self-reported data could affect accuracy due to recall bias or socially desirable responses. Additionally, the varying levels of technological familiarity among clinicians and the unique circumstances of the COVID-19 pandemic, which increased reliance on digital tools, may have influenced the results. Future research should address these limitations by including a larger, more diverse sample across multiple healthcare settings and ideally employing random sampling methods to better capture the evolving nature of PGHD integration in clinical practice.

Conclusion

This study sought to close gaps in knowledge about the real-world application of PGHD integrative software within orthopaedic practice. To this end surgeons and physiotherapists were interviewed to learn more about their experiences and suggestions for improvement. The findings suggest that the mymobility software delivered some meaningful benefits. Structured education plans and the providing of essential information were praised for reducing staff workload and helping patients prepare for operations. The communication and data-sharing functions showed promise for monitoring patients and informing interventions. Additionally, reminders, goal setting, and progress-tracking features showed capacity to motivate patients to adhere to pre- and post-op care plans. Notably, the integration of PGHD helped prioritize care in specific cases, indicating its potential in enhancing clinical decision-making. While some benefits, such as app-based education and pre-op physiotherapy support, do not necessarily require PGHD integration, the software still aligns with literature-reviewed benefits, providing insights, facilitating personalised care, and motivating patients. While there remained a clear need for further interface and interaction design, the software appears to be making strides in delivering on the promised benefits of PGHD within a clinical context.

However, many of the known barriers to PGHD integration remain unresolved. Clinicians reported

challenges such as the app increasing their workload by requiring time to support patients in using the app, interacting with the platform, and locating and making use of data. Potential benefits were further hampered by clinicians' reluctance to trust the validity of PGHD and challenges in applying data to decision-making. Additionally, the patient participation required for a PGHD approach posed significant challenges, especially for those who are elderly or have cognitive impairments. In addition, future research is required to help find ways of addressing trade-offs or tensions that might not be “solvable” but rather require carefully considered design decisions. Future research and development should focus on finding methods of addressing these balances to increase usability, utility, and adoption.

Acknowledgements

Conflicts of Interest

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