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Digital technologies for bowel management: A scoping review

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Abstract

The use of digital technologies in managing bowel conditions has been a topic of interest among healthcare practitioners. The objectives of this paper were to provide information about the types of digital technologies that have been used for bowel management and the context of the studies; identify the gaps and challenges in digital technologies for bowel management and propose new methods and techniques for the application of digital technologies in bowel management. A scoping review was conducted following the principles of Preferred Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). A search was conducted on six academic databases. 1891 papers were retrieved from the initial search; however, 6 papers were included based on the inclusion and exclusion criteria. The findings suggest that published work focused mainly on a research context and with a narrow focus targeting sub-categories of bowel conditions and not implemented in the context of everyday use. The findings also illustrate the variety of early-stage developments focused on increasing support for severe bowel dysfunction, for example, through biofeedback to aid muscle control training, or the placement of artificial anal sphincters to increase rectal perception. However, technology to support bowel management for broader populations with less severe or variable symptoms appears limited. Future work would be to conduct empirical research in the application of advanced technologies such as on-organ sensors in managing bowel conditions.

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1. Introduction

Bowel conditions such as faecal incontinence, constipation, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), gastro-oesophageal reflux disease (GERD), diarrhoea and low anterior resection syndrome (LARS) can significantly reduce individual quality of life[1]. 6.5 million people in the UK are estimated to be living with a bowel condition[2]. In the United States, 24 to 45 million people suffer from IBS and approximately 3.1 million people suffer from IBD[3]. Bowel conditions present huge costs to healthcare, for example, in the UK, £168 million was spent on treating constipation in 2018 and 2019[4].

The focus of this scoping review is on conditions that affect people's ability to control and manage their bowels, for example, faecal incontinence. Faecal incontinence is a medical condition in which there is an uncontrolled release of faeces from the bowel[5]. Faecal incontinence affects 5% to 10% of adults in the UK and 8.3% of adults in the US[6-7].

Digital technologies are increasingly being used as a mechanism to increase self-management and in turn quality of life[8], as well as to decrease the burden on the National Health Service (NHS)[9]. Several studies have previously reviewed the literature on the use of digital technologies for bowel management, often with a specific focus. Yin et al.[10], for example, conducted a scoping review on the use of mobile technologies to support patients with IBS. Nyugen et al.[11] also conducted a systematic review on the use of mobile technologies, web applications and telemedical systems to support bowel care. However, there is a dearth of studies reviewing the literature on the use of digital technologies for conditions such as faecal incontinence, LARS, GERD and constipation. Additionally, the digital technology focus within these existing reviews does not cover the discussion on the use of sensors for bowel management. There is, therefore, value in a review that examines the use of a wide range of digital technologies such as sensors, web, mobile and internet technologies for managing bowel conditions.

The primary aim of this scoping review was to provide a review of the scope and range of digital technologies for managing bowel conditions such as faecal incontinence. The objectives were to offer insights into the varieties of digital technologies employed and the settings in which these studies were conducted and explore the effectiveness of digital technologies for managing bowel conditions.

1.1. Review approach

A scoping review methodology was utilised to identify the range of studies within the context of bowel management[12].

1.2. A review of previous systematic reviews on the use of digital technologies for bowel management

Majidova et al.[13] and Yin et al.[10] both reviewed the literature on digital health apps used in the context of IBD. While Yin et al.[10] focused on digital health apps, Majidova et al.[13] also explored the use of digital health and Artificial Intelligence (AI) tools in the context of treating, monitoring, diagnosing and in the prognosis of IBD. Both studies suggest that digital health tools such as mobile apps have been useful for managing IBD. However, they recommended more practical applications of these technologies outside the research domain. This suggests that more application of these technologies in clinical settings should be encouraged.

Web technologies have also been explored in the treatment of IBD. Stiles-Sheilds and Keefer[14], Jackson et al.[15] and Bernard et al.[16] conducted systematic reviews on the use of web technologies for managing IBD, specifically Crohn's disease and ulcerative colitis. These studies reported shortcomings such as not being able to determine the cost benefit of implementing web technologies to support IBD patients[15]; they also found that a wide range of information about IBD is not available on the internet[16]. It was also reported that web technologies had a positive impact on ulcerative colitis patients and further evidence is needed to show that mobile apps can improve self-management for IBD patients[15]. While Nguyen et al.[11] found that digital health technologies in IBD care reduced costs, the application of these technologies did not have any significant impact on the treatment of IBD patients.

Vega et al.[17] conducted a review of 14 mobile applications that provided educational information for faecal incontinence or allowed for symptom tracking, with assessment using an application scoring tool. The majority of applications included were bowel movement trackers (13 out of 14). Applications generally rated well for navigation

ease and subjective presentation but only three applications allowed for tracking of faecal incontinence episodes. Only one application included educational content specific to faecal incontinence. Data exportation capability was integral to 10 of the 14 applications. Vega at al. (2021) highlighted the likely risk of patients encountering inaccurate and irrelevant faecal incontinence information, which could impact self-management opportunities and health outcomes. Systematic reviews in the area of faecal incontinence have mostly focused on the clinical aspects and the use of non-digital technologies for treatment and management[18-20].

1.3. Defining digital technologies

For the purpose of this study, digital technologies refer to tools and applications that can "create, store, process, transmit and display information."[21]. As such, technologies that can perform these tasks in relation to faecal incontinence were included in the review.

2. Methods

A scoping review approach was applied in this study. The study followed the principles of Preferred Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)[22]. The inclusion and exclusion criteria are described as follows:

2.1. Inclusion criteria

- Studies describing the use of digital technologies for bowel management/care.
- Case studies as well as intervention studies were included.
- Studies published between 2010 and 2022.
- Studies reporting the use of digital technologies for bowel management.
- Peer-reviewed publications in journals and conferences.
- Studies utilising digital technologies as defined by Tulinayo et al.[21]

2.2. Exclusion criteria

- Studies published before the year 2010.
- Studies not published in English.
- Studies not focusing on bowel health intervention using digital technologies.
- Studies focusing on animal interventions.
- Patents were excluded.
- Studies focusing on the use of digital systems for training medical staff on faecal incontinence.
- Review papers.

2.3. Database Screening

Database searches were conducted in July 2022 on ACM, Web of Science, IEEE, Scopus, PubMed and CINAHL using search terms relating to bowel management and digital technologies published since 2010. Database results were exported to Refworks where duplicates were removed. The remaining results were exported to Microsoft Excel for screening.

2.4. Article selection

Two independent reviewers screened articles at an abstract level, with selected articles subsequently screened at full-text level. All screening was conducted based on the inclusion criteria outlined above. Before screening commenced, the two reviewers completed an inter-rater reliability check[23] of 100 articles (selected using a random number generator), with a resulting Kappa score of >90%.

2.5. Data Extraction

Data was extracted from all included records following full-text screening for study design, technology type, study characteristics, intervention detail and key outcomes.

2.6. Data Analysis

An appraisal of quality and risk of bias was conducted using the Mixed Methods Appraisal Tool (MMAT)[24] chosen for its application to diverse methodologies.

A narrative synthesis was conducted to provide an overview of developments and evidence in the bowel management field. Data analysis was conducted with the two main reviewers in consultation with the wider project team to draw on relevant and varied expertise.

3. Results

In total, 1891 studies were included in this study. 28 duplicate papers were removed. The remaining 1863 papers were screened based on the title and abstract relevance; 371 full text papers were examined in which 6 papers met the inclusion criteria. The articles included in the study are described in Table 1.

Table 1: Articles included in the study

Author	Year	Country	Study Design	Technology type	Study characteristics	Intervention description	Outcomes
Bartlett et al.[25]	2011	Australia	Randomised clinical study	Biofeedback	72 participants took part in the study which included 19 males.	37 participants took part in the randomly controlled study which included 12 males. The randomised group also participated in the clinical practices and were also involved in pelvic floor exercises.	There was no noticeable difference among the two groups that participated in the study. Although there was a significant decline in faecal incontinence among participants that attended the biofeedback sessions.
Bird et al.[26]	2022	United States	Descriptive evaluation	Bowel tracking system	6 students participated in the study and they were selected because they had gastrointenstinal (GI) problems and were being cared for by a GI specialist. 5 male and 1 female participant took part in the study	The study was conducted in one month in which movements in their bowels were recorded and later analysed. The study was conducted in two group homes. All participants completed the bowel movement tracking on the bowel tracking system.	While the authors acknowledged short comings in the design of the study, the findings showed that participants believed that the system could monitor bowel movements.
Carrara et al.[27]	2018	Not applicable	Experimental	Artificial Neural Network	Data was collected from 2 national multicentre trials. Data from 598 men were analysed.	An Artificial Neural Network model was used for the prediction and presentation of the graphical tool. 5 input variables were used.	A graphical tool based on an Artificial Neural Network model which can be used in medical practice to predict late faecal incontinence in patients who have undergone radio

							therapy of the prostrate.
Gregerson et al.[28]	2022	Not applicable	Feasibility study	Novel analysis including feasibility of wireless Fecobionics with new graphical user interface	30 participants, 20 male, 10 female healthy participants scoring low on feacal incontinence and constipation scales	Fecobionics device was inserted with the subject in left lateral position. The subject moved to the commode, where the bag was filled until urge to defecate sensation	The present study establishes the foundation for future use of Fecobionics for dyssynergia diagnostics and as a biofeedback tool, where patients based on the functional signatures visualized on the graphical user interface can learn to control and train the muscles to correct the neuromuscular dysfunction.
Kadam-Halani et al.[29]	2019	Not applicable	Assessment	Internet	The study used the DISCERN quality analysis tool and the JAMa benchmark criteria to search for 4 terms commonly used to find information for faecal incontinence.	N/A	Information on faecal incontinence on the internet is not enough.
Matsumoto et al.[30]	2020	Japan	Case study	Ultrasonic imaging to guide bowel management	Case study of 85-yr old man with prostate cancer and chronic constipation in a home care setting in Japan	Ultrasonic observations were performed by trained home health nurses using a hand-held system to guide bowel management	Ultrasonography improved bowel management in this patient with clinically severe chronic constipation.

3.1. Study characteristics

A total of 6 studies were included in the study. There were a variety of papers included in the review as shown in Figure 2.

3.2. Study design

Study design included experimental (1/6), randomised clinical study (1/6), descriptive evaluation (1/6), feasibility study, assessment (1/6) and case study (1/6).

3.3. Year of publication

One paper was published in 2011, 2018, 2019 and 2020. Two papers were published in 2022.

3.4. Technologies used

Artificial Neural Network (1/6), biofeedback (1/6), bowel tracking system (1/6), wireless fecobionics with new graphical user interface (1/6), Internet (1/6), Ultrasonic imaging to guide bowel management (1/6).

3.5. Countries

Some studies did not include the countries where the study was conducted (3/6). However, some studies were conducted in the United States (1/6), Australia (1/6) and Japan (1/6).

3.6. The effectiveness of digital technologies for managing incontinence

Studies showed an improvement in outcome. For example, Bartlett et al.[25] reported a decline in the frequency of faecal incontinence in participants who took part in the study where biofeedback assisted exercise was introduced to patients with faecal incontinence. An application was developed to track bowel movements among students. The study showed that the application allowed participants to record their bowel movements2[6]. AI techniques such as Artificial Neural Networks have been used to develop a graphical interface which can be used to predict faecal incontinence.[27]. The dataset was gathered from a clinical centre which focused on 598 males that had undergone radiotherapy of the prostate. Although the study was mainly experimental, clinical outcome was not explored as the application was not trialed in a clinical environment[27].

Gregerson et al.[28] conducted a study in which a fecobionics-simulated stool device was inserted with graphical interface measurements taken during defecation attempts. This successful proof-of-concept development lays the groundwork for future uses of fecobionics for dyssynergia diagnoses and as a biofeedback tool, where patients may learn to regulate and train their muscles to treat neuromuscular dysfunction based on functional signatures shown on the graphical user interface. The study proved that the concept of using a device to capture bowel function measurements can be used as biofeedback aid for muscular dysfunction training. However, technologies such as ultrasonic imaging have enabled bowel self-management improvements in a patient with severe constipation by providing greater information about stool status to guide actions and improve symptoms[30].

4. Discussion

To the best of the researchers' knowledge, this is the first study reviewing the scope and range of studies on the use of digital technologies for bowel condition management. As such, we distinguish our study from previous reviews which focused on using digital technologies to support other bowel conditions except faecal incontinence.

Our main finding is that the use of digital technologies has had positive outcomes in the majority of the studies. While there are studies on digital technologies for faecal incontinence, there is not much documentation of research in this domain. Furthermore, the studies reported were mostly around a research context and with a narrow focus targeting sub-categories of bowel conditions and not implemented in the context of everyday use. This is similar to other studies reviewing the application of digital technologies such as AI and machine learning in predicting, detecting and managing diseases[31]. They found that published studies focused on research based experiments in controlled environments rather than in the real world context. This calls for more research focused on exploring digital technologies in the context of healthcare after the implementation of digital health projects. The types of studies in the domain were mainly focused on studies within a controlled environment. This shows the need to carry out more research in a real world environment to test the effectiveness of digital technologies for faecal incontinence. This will provide data into real world evidence of the technologies and their impact on healthcare in the long run.

Digital technologies for faecal incontinence have been explored in a few countries such as the United States, Australia, and Japan. Although some studies did not report the countries where the study was conducted, it will be good to explore the findings of these studies in different countries and contexts to evaluate the generalisation of the technologies.

There was a study about bowel tracking, however, there was not much discussion about mobile apps, the Internet or web applications. The majority of the technologies explored focused on core engineering technologies such as ultrasound imaging[30], biofeedback[25] and wireless fecobiotics[28]. Although some studies highlighted mobile apps and the internet as tools for supporting faecal incontinence, it was reported that these technologies did not have enough information or adequate apps to support faecal incontinence. Furthermore, there was a dearth of studies focusing on the design and development of software based technologies. This calls for the need to co-design mobile apps for

patients with faecal incontinence and develop websites and applications that provide information about faecal incontinence.

Only six studies were included in this study with the majority published in the late 2010's and early 2020s. This shows that studies on the use of digital technologies for managing bowel conditions such as faecal incontinence are gradually taking momentum although not at a fast pace like other areas of health such as malaria and maternal health[32-33]. Two additional papers were excluded from this review during screening based on in-vivo animal–focused study design but which highlight broader research efforts to increase artificial anal sphincter technologies for patients with damaged sphincters. Zhou et al.[34] for example, found their pressure sensors replicated rectal perception and Ke et al.[35] incorporated biosensor feedback that increases the potential for restored continence. However, performance issues during the in-vitro experiments of both studies highlight a need for further testing and development.

This review illustrates the variety of early-stage developments focused on increasing support for severe bowel dysfunction, for example, through biofeedback to aid muscle control training, or the placement of artificial anal sphincters to increase rectal perception. However, technology to support bowel management for broader populations with less severe or variable symptoms appears limited. Matsumoto et al's[30] ultrasonic imaging case study demonstrates how real-time detailed stool status information has the potential to aid lifestyle modification and improve symptoms, suggesting this is an area worthy of future focus. However, quality assessment limitations demand caution and demonstrate the need for further research attention. There are novel technologies in the early testing and development stage focused on diagnosis and assessment[36] but not included in this study as they did not meet the inclusion criteria.

5. Conclusions and recommendations

In conclusion, the review provided the scope and range of studies on the use of digital technologies for bowel management, specifically for faecal incontinence. The findings suggest that exploratory studies have been carried out in this context and these studies have been conducted in very few countries.

Based on the search criteria, inclusion and exclusion criteria, relevant publications might have been excluded, hence a limitation of the study. Future work would be to conduct empirical research in the application of advanced technologies such as on-organ sensors in managing bowel conditions. On-organ sensors can further be linked to mobile apps using wireless connectivity such as Bluetooth thereby creating an ecosystem of digital health technologies[37,38]. Researchers working on the development of on-organ sensors can explore the concept of digital twins to support implantation of on-organ sensors in the bowel.

Future work should consider co-designing these technologies specifically with patients suffering from bowel conditions such as IBD, IBS, LARS or bowel incontinence. This would then lead to the development of a cross platform mobile apps which can then be adopted by users of different phone types.

There were no studies exploring how digital technologies connect patients and medical doctors or patients suffering from bowel conditions with other patients suffering from similar bowel conditions. In the future, digital technologies can try to tackle networking in this space.

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