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Public Views on Managing Benign Prostatic Hyperplasia-Related Voiding Dysfunction: Potential Applications of Digital Therapeutic

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Purpose: This study aims to explore the potential of digital therapeutics in managing voiding dysfunction associated with benign prostatic hyperplasia (BPH). To achieve this, we collected and analyzed news and community data from major Korean platforms to assess the trends in media and community discussions and examine how digital therapeutics can contribute to personalized care and support self-management for patients with BPH-related voiding dysfunction.

Methods: Data was collected over a 3-year period from October 2021 to September 2024 using the keywords ‘prostate’, ‘urinary’ and ‘treatment’. Key terms and patterns were then identified through word frequency analysis, TF-IDF (term frequency-inverse document frequency) analysis, and N-gram analysis to examine the potential applicability of digital therapeutics in this area.

Results: The news data primarily focused on expert-oriented medical information related to the treatment, surgical options, and diagnosis of BPH. In contrast, community data centered on discussions about everyday symptoms and solutions, such as urinary issues and self-care tips. This suggests that patients are particularly interested in practical problem-solving and self-management strategies.

Conclusions: This study suggests that digital therapeutics can empower patients with BPH to self-manage their urinary disorders through personalized management tools. Future research can be done to focus on empirically examining the clinical validity and practical applicability of digital therapeutics for BPH through clinical trials.

Keywords: Benign prostatic hyperplasia; Voiding dysfunction; Digital therapeutics; Healthcare software; Personalized medicine; Patient care


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INTRODUCTION

Benign prostatic hyperplasia (BPH) is prevalent among middle-


aged and older men and often causes voiding dysfunction and lower urinary tract symptoms (LUTS) [1]. Traditional treatments, such as medications and surgery, are effective in reliev-

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ing symptoms but have limitations in ongoing management.

With recent advances in digital healthcare, digital therapeutics are gaining traction in the management of voiding dysfunction. In particular, digital health technologies including virtual healthcare systems and data analytics, has seen accelerated adoption due to the coronavirus disease 2019 pandemic's shift toward contactless healthcare [2]. Since 2020, in-person consultations have dropped by over 50%, while remote consultations, such as phone consultations, have more than tripled [3], highlighting both the need and potential for digital health solutions. In this regard, digital therapeutics could play a critical role in supporting long-term health management through personalized treatment and real-time monitoring, particularly for chronic conditions like BPH, continuous tracking is essential.

Along with the growth of the digital therapeutics and digital therapeutic device market, various innovations are emerging. For example, Seoul National University Bundang Hospital's 'proudP' app measures urinary rate without needing a physical device [4], and Konkuk University's 'MediLight' wearable device provides bladder monitoring for neurogenic bladder patients [5]. In addition, ongoing research is underway to develop algorithms that monitor urination according based on patient posture changes [6].

This study aims to explore public discussions around managing BPH-related voiding dysfunction and assess the potential of digital therapeutics. We collected and analyzed news and community data from major Korean platforms over the last 3 years, from October 2021 to September 2024. The main keywords used for the study were 'BPH,' 'urinary,' and 'treatment.' Text mining techniques were applied to these datasets to identify patients' daily concerns, requirements, and sentiments. Our findings suggests that digital therapeutics hold promise as a personalized, continuous solution for managing voiding dysfunction in BPH patients.

Theoretical Background

Pathologic basis of voiding dysfunction with BPH

BPH, the most common urinary disease, leads to the growth of prostate tissue, specifically epithelial and stromal cells. This tissue expansion compresses the urethra, leading to increased resistance to urine flow from the bladder and ultimately causing LUTS [7].

These symptoms include difficulty urinating (voiding dysfunction), incomplete bladder emptying, frequent urination, nocturia, and urinary incontinence, all of which substantially impact

quality of life [8]. The prevalence of BPH rises markedly after the age of 40, with more than half of men in their 60s and over 90% of men in their 80s likely to experience the conditions [9].

Recent studies have shown that BPH is closely linked to inflammatory responses, not just prostate enlargement. The activation of inflammatory cytokines (interleukin-6, tumor necrosis factor- α , etc.) is more pronounced in BPH patients, and as the inflammatory process progresses, prostate proliferation accelerates, compressing the urethra and exacerbating voiding dysfunction [10].

Treatment and management of voiding dysfunction due to BPH

The primary treatment for BPH-induced voiding dysfunction includes medication and surgical treatment. Medications, primarily α -blockers and 5 α -reductase inhibitors, work by relaxing prostatic smooth muscle or reducing the size of the prostate to relieve urination symptoms [11]. Although these medications are effective initially, side effects from long-term use and resistance may limit their continued effectiveness [12].

If medications prove ineffective or present severe side effects, surgical options are recommended. Common surgical procedures include transurethral resection of the prostate and holmium laser enucleation of the prostate, both of which remove prostate tissue to relieve urethral obstruction and improve urinary function [13]. Although these treatments are effective, BPH is a chronic condition that requires ongoing management even after surgical intervention. As a result, there is growing interest in digital therapeutics and urinary management software as complementary solutions.

Concept and development of digital therapeutics

Digital therapeutics encompass a wide range of technologies, including software, mobile apps, web platforms, games, virtual and augmented reality devices, artificial intelligence, and metaverse platforms [14]. These tools can be customized based on therapeutic goals and effectiveness. Given the chronic nature of BPH, digital therapeutics are well-suited to support continuous monitoring and reduce the daily management burden on patients. By allowing real-time symptom tracking and health monitoring, digital therapeutics empower healthcare providers to offer personalized treatment strategies. This is expected to maximize treatment and care effectiveness and empower patients to actively manage their health.

A recent German clinical trial demonstrated that app-based treatment for patients with voiding dysfunction led to notable

improvements in symptom relief and quality of life compared to standard treatment [15]. The app-based approach was also found to be safe, with no side effects, indicating that digital therapies may be an effective alternative for managing voiding disorders.

In addition, the rapid expansion of the digital therapeutics market has spurred efforts from hospitals, universities, research institutions, and companies to develop customized devices for patients. For example, Seoul National University Bundang Hospital developed the ‘proudP’ app, which measures urine flow rate using a smartphone [4]. It was developed to eliminate the need for a physical device and streamline the essential diagnostic process for BPH. Professor also, Eunkyung Park at Sunchunhyang University is working on a device and algorithm that uses peripheral nerve stimulation to alleviate voiding dysfunction [16]. It represents a novel digital approach to improve urinary symptoms to stimulate the patient’s nerves. Professor Aram Kim of Konkuk University has developed the ‘MEDiLight’ wearable bladder monitoring device for patients with neurogenic bladder, which attaches to the lower abdomen and monitors bladder urine levels so that users can manage urination schedules through their smartphone [17]. This innovation aims to enhance the quality of life for patients and caregivers who face urination dysfunction challenges due to neurological conditions [17].

These advances in digital therapies and devices are shaping a future where patients have increased access to personalized self-management tools, and enabled safer, more convenient man-

agement of urination disorders and supporting proactive health maintenance.

MATERIALS AND METHODS

Research Design

In this study, we applied text mining techniques to convert unstructured textual data into structured information [18]. To streamline data collection and analysis, we used the Textom platform (www.textom.com) to gather news and community data. Then, frequency analysis and term frequency-inverse document frequency (TF-IDF) and N-gram analysis were used to analyze the main keywords and topics related to ‘voiding dysfunction due to prostate enlargement.’ The data analysis followed a 3-step procedure, as shown in Fig. 1: (1) data collection, (2) data preprocessing, and (3) data analysis [19].

Data Collection and Refinement

In this study, data was collected from October 1, 2021 to September 30, 2024, using the keywords ‘BPH,’ ‘urine,’ and ‘treatment.’ News data was sourced from NAVER, Daum, and Google News, while community data was gathered from platforms such as NAVER Cafe, NAVER Knowledge, Daum Cafe, and Facebook. The scope of collection includes title, body content, and URLs, resulting in a total of 5.23 MB for news data and 3.16 MB for community data.

‘BPH,’ ‘urination,’ and ‘treatment’ were chosen based on com-

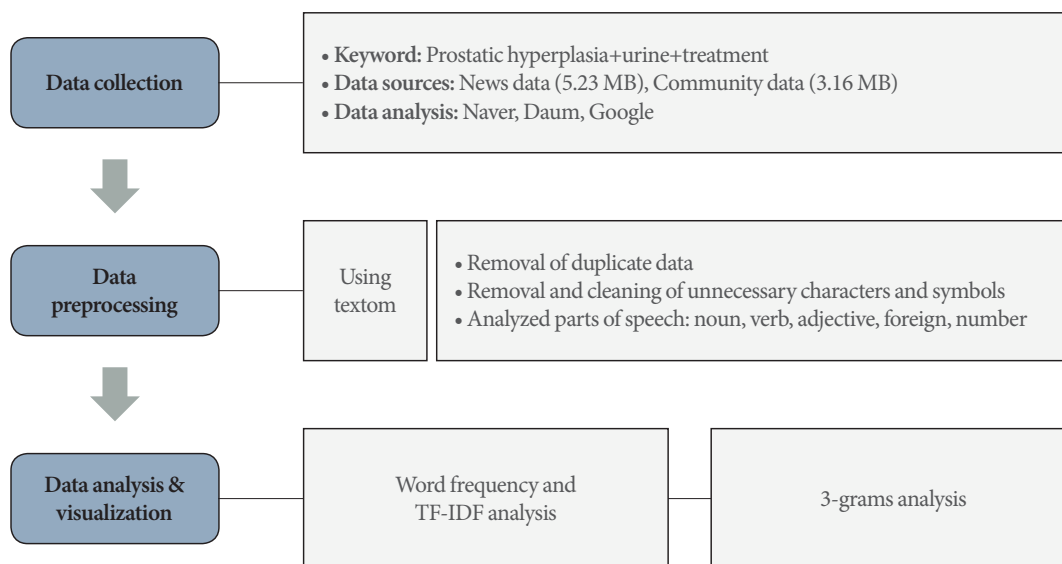


Fig. 1. Entire data analysis procedure. TF-IDF, term frequency-inverse document frequency.

mon expressions found in community discussions. The phrase ‘difficulty urinating’ was more frequently used than the technical term ‘voiding dysfunction.’ In addition, ‘urine’ was more commonly referenced than ‘pee’ and ‘treatment’ more than ‘management.’ In particular, the keyword ‘treatment’ was chosen to become an ideal keyword as it encompasses broader topics relevant to voiding dysfunction and potential digital therapeutics applications.

For data analysis, the morphological analysis tool MeCab was used, and data preprocessing included cleaning the text by removing extraneous characters and symbols and eliminating duplicates. Deduplication was performed by removing exact duplicates based on selected columns. Analyzed parts of speech included nouns, verbs, adjectives, foreign words, and numbers.

Analysis Methods

Word frequency and TF-IDF analysis

Word frequency analysis is a technique that identifies frequently used words within a text and is utilized to identify the main topics or keywords within a document [20]. In this study, we conducted a word frequency analysis to efficiently extract key themes and quickly identify prominent topics and issues within the news and community data.

TF-IDF analysis is a method that combines the frequency of occurrence of a particular word in a document (TF) with the inverse of how often the word appears in the entire document (IDF) to assess the relative importance of the word [21]. It compensates for the limitations of word frequency and is effective in identifying important words within a document. In this

Table 1. Top 10 keywords according to frequency and TF-IDF analysis in the news

Rank	Keyword	Frequency	Keyword	TF-IDF
1	Prostate	3,461	Test	1072.381349418
2	Hyperplasia	2,420	Bladder	862.02647583746
3	Urine	2,186	Surgery	850.37059743982
4	Treatment	1,863	Symptom	810.09678983545
5	Symptom	1,046	Medications	755.31980573139
6	Bladder	781	Urination	738.76358311795
7	Urination	625	Prostate Cancer	736.61557170769
8	Male	598	Disease	731.30122336637
9	Surgery	596	Male	689.62146750145
10	Test	584	Patient	681.70050151977

TF-IDF, term frequency-inverse document frequency.

study, we used TF-IDF analysis to identify the most important words related to “BPH+urine+treatment” and compared the keywords in news and community data to pinpoint the central themes of each dataset. This approach allowed us to highlight the main keywords emphasized in each dataset, which we then used to further explore the applicability of digital therapeutics.

N-gram analysis

N-gram analysis is a natural language processing technique that analyzes combinations of consecutive words to identify frequent patterns in text, and is used to identify associations between words and predict words that are likely to follow when a particular word occurs in text data [22]. In this study, we used 3-gram analysis to examine word association patterns in depth. We identified the top 20 3-grams to clarify key patterns and themes, highlighting meaningful relationships within the data.

RESULTS

Word Frequency and TF-IDF Analysis Results

The word frequency and TF-IDF analysis identified 4,371 unique words in the news data and 9,078 unique words in the community data. The top 10 keywords for each dataset are shown in Tables 1 and 2.

The highest-ranked keywords in the TF-IDF analysis of the news data include ‘test’ (1,072.38), ‘bladder’ (862.03), ‘surgery’ (850.37), ‘symptoms’ (810.10), and ‘medication’ (755.32). These results indicate that news articles primarily focus on medical procedures and treatment related to BPH. Keywords like ‘test’

Table 2. Top 10 keywords according to frequency and TF-IDF analysis in the communities

Rank	Keyword	Frequency	Keyword	TF-IDF
1	Prostate	9,797	Test	3339.5052636928
2	Urine	6,867	Surgery	2964.5949663533
3	Hyperplasia	6,234	Urology	2492.1697499373
4	Treatment	6,132	Symptom	2437.7628145508
5	Symptom	3,962	Prostatitis	2256.5357081427
6	Surgery	2,539	Bladder	2194.160204598
7	Test	2,379	Male	2050.3535018134
8	Urology	1,980	medications	1927.6185871597
9	Male	1,681	Disease	1905.8021039036
10	Bladder	1,671	Cause	1804.2091836966

TF-IDF, term frequency-inverse document frequency.

and ‘surgery’ highlight the emphasis on diagnostic and treatment procedures, while ‘medication’ suggests a focus on pharmaceutical interventions as part of BPH management.

In the community data, top keywords from TF-IDF analysis were ‘test’ (3,339.51), ‘surgery’ (2,964.59), ‘urology’ (2,492.17), ‘symptoms’ (2,437.76), and ‘prostatitis’ (2,256.54). Although terms such as ‘tests’ and ‘surgery’ are frequently mentioned, they related more to shared experiences of discomfort and medical visits than to clinical descriptions of procedures. In particular, the terms such as ‘virility,’ ‘premature ejaculation,’ and ‘erectile dysfunction’ in the top 100 in the community data reflects anxiety and concern about potential sexual dysfunction due to BPH and voiding dysfunction. References to specific locations such as ‘Pyeongtaek’ and ‘Ilsan,’ suggest that users are exchanging information on hospital experiences and recommendations for reliable BPH care providers.

These findings underscore distinct differences in the content of news and community discussions. While news sources provide objective, specialized medical information, community forums address personal experiences, practical solutions, and management tips. This suggests an opportunity to develop an information approach that combines objective and professional medical information from news sources with lifestyle practices frequently discussed in communities to support symptom management.

N-gram Analysis Results

The 3-gram analysis yielded a total of 36,586-word combinations in the news data and 116,467 in the community data. The top 20 most frequent keywords are shown in Fig. 2.

The top 100 most frequent word combinations in the news data include terms like ‘prostate cancer treatment,’ ‘prostate cancer diagnosis,’ ‘medication surgery,’ ‘prostate-specific antigen (PSA),’ ‘digital rectal examination,’ ‘transurethral resection of the prostate,’ and ‘prostate ultrasound.’ These combinations indicate that news articles are largely focused on medical information and treatment procedures for managing voiding dysfunction related to an enlarged prostate. Frequent references to ‘diagnosis’ and ‘treatment’ emphasize the importance of care and intervention for BPH and voiding dysfunction. In addition, the use of terms such as ‘treatment,’ ‘medication,’ and ‘surgery’ indicates a focus on providing objective information about the management and treatment of voiding dysfunction. The prominence of these terms in news articles reflects an intention to emphasize the need for prevention and proper management of voiding dysfunction and to communicate to the public the importance of regular screening and early treatment.

In contrast, the top 100 most frequent word combinations in the community data include phrases like ‘virility food virility pills,’ ‘prostate enlargement urine,’ ‘urologist,’ ‘suspected prostate enlargement,’ ‘online urology virility,’ ‘urine blockage urinary

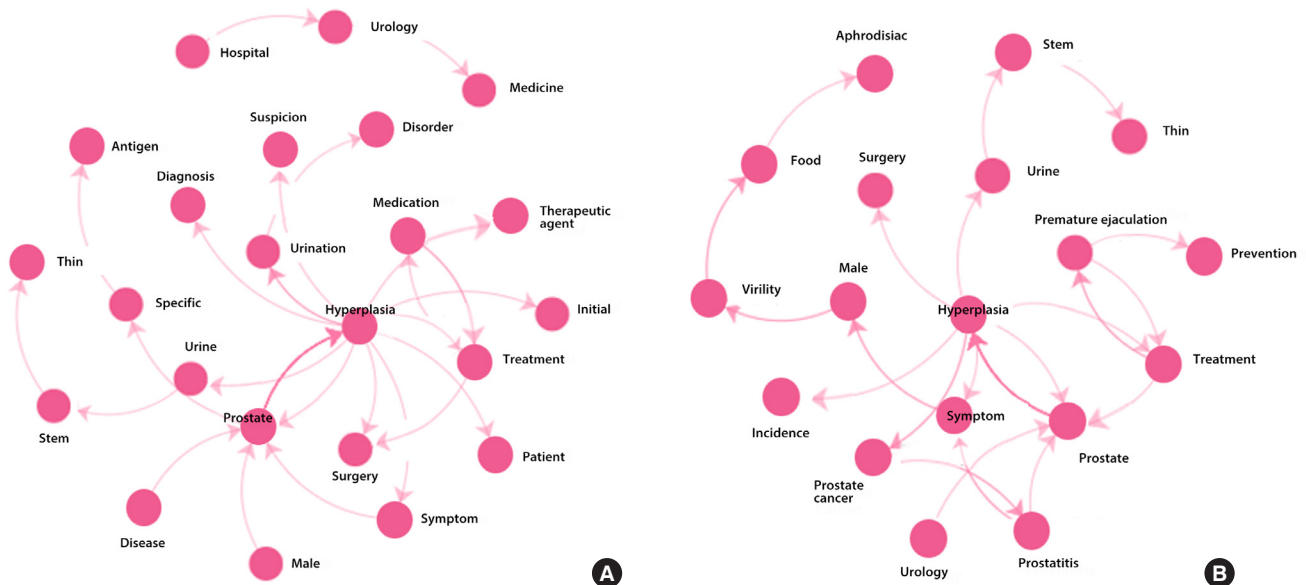


Fig. 2. Three-gram news data visualization (A), community data visualization (B).

retention,' 'male menopause symptoms,' and 'pain when urinating.' While common terms like 'treatment' and 'symptoms' appear in both news and community data, the community is distinctly focused on everyday symptoms and discomforts of BPH. Words like 'virility,' 'food,' 'urine,' and 'premature ejaculation' reflect community concerns about the impact of BPH on daily life and physical health, particularly sexual health and function.

Community discussions also include experiences with doctor visits and advice on managing BPH symptoms independently. Keywords such as 'virility,' 'menopause,' and 'care' suggest that community members seek information on sexual health and lifestyle improvements. This provides an opportunity for digital therapeutics to support patients by offering validated advice on sexual health care, nutrition, exercise, and stress management. By addressing these practical concerns, digital therapeutics can empower individuals with daily self-management practices, helping to improve their quality of life and reduce symptoms associated with BPH.

DISCUSSION

This study explored the potential of digital therapeutics in managing voiding dysfunction associated with BPH. News and community data from October 2021 to September 2024 were collected and analyzed using 3-gram, word frequency, and TF-IDF methods to gauge public awareness and interest.

The results showed that news sources focused on specialized medical information related to voiding dysfunction diagnosis and treatment, with keywords like 'test,' 'surgery,' and 'medication' appearing frequently. This likely reflects an intention to educate the public on the importance of early detection and treatment of voiding dysfunction due to prostate enlargement. In contrast, the community data highlighted terms like 'weak urine stream' and 'urinary retention,' suggesting that the real impact of urinary dysfunction on physical function and quality of life is widely felt by the public. These findings have several implications and future directions to get suggested when digital therapeutics are applied in BPH.

First, digital therapeutics should incorporate objective diagnostic and treatment information from news data as a core feature, complemented by daily symptom management and lifestyle modification insights frequently discussed in the community. This combination will enable the public to engage in effective self-management by providing practical lifestyle interventions — such as hydration, exercise, and dietary guidance —

that can be applied to manage urination disorders.

Second, given the frequent mentions of hospital visits and the need for face-to-face consultations in the community data, integrating virtual care and self-monitoring capabilities into digital therapeutics could be highly effective. This approach would empower users to monitor their health status in real-time and manage them more safely and efficiently with remote expert consultations available as needed.

Third, digital therapeutics need to be designed as personalized self-management tools, drawing on community discussions around sexual health and menopausal symptom relief. This approach would facilitate the integration of tailored lifestyle interventions such as stress management techniques, nutritional information, exercise tips, and more into daily routines, thereby enhancing self-management and contributing to overall health improvement.

Since the data was drawn from specific platforms, it may not fully capture public perception. Furthermore, the study's quantitative text analysis approach limits its ability to explore the deeper perceptions of the illness. To address these limitations, future research can be done to broaden data collection to include a wider range of platforms and incorporate qualitative analysis to gain deeper insights into the public's lived experiences and emotional responses. Additionally, clinical studies can be conducted on patients with voiding dysfunction to validate the effectiveness of digital therapeutics in supporting personalized management and improving treatment outcomes.

AUTHOR CONTRIBUTION STATEMENT

- Conceptualization: *SJL, JMP, JYK*
- Data curation: *SJL, JMP, JYK*
- Formal analysis: *SJL, JMP, JYK*
- Funding acquisition: *JYK*
- Methodology: *SJL, JMP, JYK*
- Project administration: *JYK*
- Visualization: *SJL, JMP, JYK*
- Writing - original draft: *SJL*
- Writing - review & editing: *SJL, JMP, JYK*

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