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Research Article

Simplifying Orthopedic Patient Education: A ChatGPT-Based Readability Analysis

Mendel Shloush[1a], Klaudia Greer[1b], Jonathan Brutti[1c], Brayden Tolman[1d], Jacob Rosenthal[1e], Rafael Aldaya Bourricaudy[2f], Marcia Varella, M.D.[1g], Fernando Aran, M.D.[1h]

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a Mendel Shloush is a fourth-year medical student at FIU Herbert Wertheim College of Medicine in Miami, Florida. Originally from New York City, he relocated to Miami approximately six years ago.

Mendel developed a passion for orthopaedic surgery following his own experience with an orthopaedic injury, which inspired his interest in the field. His research interests include unplanned excisions of soft tissue sarcomas and patient education initiatives aimed at improving patient understanding and outcomes.

He aspires to contribute to the orthopaedic surgery community through meaningful research, high-quality patient care, and ongoing efforts to advance the field.

Conflicts of Interest Statement for Mendel Shloush

b Klaudia Greer earned her degree in Exercise Physiology from Florida State University and is expected to receive her M.D. from the Florida International University Herbert Wertheim College of Medicine in 2027.

Connect with Klaudia Greer on LinkedIn

Conflicts of Interest Statement for Klaudia Greer

c Jonathan Brutti studied biological sciences at Florida International University (FIU) and graduated in 2021. Jonathan is expected to receive his medical degree from the FIU Herbert Wertheim College of Medicine in 2027.

Connect with Jonathan Brutti on LinkedIn

Conflicts of Interest Statement for Jonathan Brutti

d Brayden Tolman is a 4th year medical student at Florida International University Herbert Wertheim College of Medicine in Miami, FL.

Conflicts of Interest Statement for Brayden Tolman

e Jacob Rosenthal is a rising fourth-year medical student at Florida International University's Herbert Wertheim College of Medicine. His professional interests include Internal Medicine and advancing access to preventive health screening for underserved communities. Outside of medicine, he enjoys running and cooking in his free time.

Conflicts of Interest Statement for Jacob Rosenthal

f Rafael Aldaya Bourricaudy is a fourth-year medical student at the University of Florida College of Medicine, pursuing distinctions in Business and Innovation in Medicine as well as Honors in Research. Originally from Holguín, Cuba, he completed his undergraduate education at Florida International University Honors College, graduating summa cum laude with a degree in Biology and Natural and Applied Sciences.

His academic interests center on urology, health literacy, artificial intelligence in medicine, and surgical innovation. Rafael has contributed to multiple research projects within the University of Florida Department of Urology, with presentations at national meetings including the American Urological Association Annual Meeting, the World Congress of Endourology, and the Southeastern Section of the AUA. His work has focused on improving the accessibility of patient education and addressing disparities in urologic care among Hispanic populations.

Beyond research, he serves as President of the Latino Medical Student Association chapter at the University of Florida College of Medicine and is actively involved in mentorship, advocacy, and community outreach initiatives serving underserved populations across Florida.

He plans to pursue a career in academic urology.

Conflicts of Interest Statement for Rafael Aldaya Bourricaudy

g Dr. Marcia Varella is a pediatrician, neonatology fellow, and clinical epidemiologist. She teaches epidemiology and evidence-based medicine concepts and serves as a content and methodological mentor to research projects of medical students in various fields.

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Conflicts of Interest Statement for Dr. Marcia Varella

h Fernando S. Aran, M.D., is a board-certified orthopaedic surgeon specializing in lower extremity surgery, from the hip to the foot.

He completed his orthopaedic surgery residency at Wake Forest Baptist Health Center in Winston-Salem, North Carolina. Following residency, he pursued advanced fellowship training in Foot and Ankle Surgery at Duke University in Durham, North Carolina, where he trained in the management of complex foot and ankle pathology under leaders in the field.

Dr. Aran's clinical focus is the treatment of lower extremity conditions. His practice includes fracture care of the entire lower extremity, joint replacement, and reconstructive surgery. He is particularly interested in complex cases and values achieving optimal patient outcomes through surgical care.

[1] College of Medicine, Florida International University, [2] College of medicine, University of Florida

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Background

Health literacy plays a crucial role in patient decision-making. National guidelines from the NIH and AMA recommend that patient education materials (PEMs) be written at or below a 6th-grade reading level.

Materials and Methods

Four common foot and ankle conditions were studied: bunions, diabetic foot ulcers, broken ankles, and arthritis of the big toe. Each condition was searched on Google, and the first ten non-sponsored, non-academic websites were selected. Readability was assessed using Readable.com for grade level, Flesch-Kincaid Grade Level, and Flesch Reading Ease, both before and after prompting ChatGPT to "translate the following to a 6th-grade reading level." Paired t-tests and chi-square tests were used for statistical analysis in Stata v17.

Results

Before ChatGPT revision, 55% of websites received an "A" grade. The mean Flesch-Kincaid Grade Level was 7.69 (95% CI: 7.12–8.25), and the mean Flesch Reading Ease was 62.01 (95% CI: 58.65–65.37). After ChatGPT revision, the proportion of "A" grades rose to 85% (p=0.008). The average Flesch-Kincaid level dropped to 5.75 (95% CI: 5.18–6.31, p<0.001), and the Flesch Reading Ease score improved to 74.93 (p<0.001). Significant readability improvements were observed across all pathologies.

Conclusion

Online PEMs related to foot and ankle conditions often exceed recommended readability standards. ChatGPT revisions significantly improved readability scores, suggesting its potential as a tool to enhance patient comprehension.

INTRODUCTION

Health literacy is very important for patients to make educated decisions about their care. Yet, before the 1960s, doctors were largely in charge of healthcare decisions, and patient education was not considered of major value (Hoving et al. 2010). Over time, this idea has changed, especially since the advent of the internet, making medical information very easy to obtain. It is estimated that over 80% of people search health information online (Pew Research Center 2009). In the case of orthopedic care, half of patients research their condition before their first appointment (Krempec et al. 2003).

Good health-related education helps patients adhere to their treatment (Gold and McClung 2006) and feel better about their care (Abbott 1998). Therefore, online materials that are accurate and easy to read are necessary. Readability of the online content is important to ensure patients understand the information that they are reading (Cheng et al. 2022; Nattam et al. 2023; Kaundinya et al. 2023). While most U.S. adults read at an eighth-grade level, many possess lower literacy levels (Doak et al. 1998). Therefore, the National Institute of Health (NIH) and American Medical Association (AMA) recommend that patient education materials (PEMs) should be written at a sixth-grade level or below (Cotugna et al. 2005). However, PEMs, especially for orthopedics, are often far above that level (Badarudeen and Sabharwal 2008; Yi et al. 2017; Para et al. 2021).

Injuries to the ankle are very common. Ankle sprains alone affect about 2 million people annually in the U.S. (Waterman et al. 2010). Among the various pathologies, bunions affect 37.1% of older adults in some communities

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(Dunn et al. 2004); diabetic foot ulcers have a global prevalence of 6.3%, peaking at 13% in North America (Zhang et al. 2017); lower leg fractures, including broken ankles, ranked among the top three most common fracture sites in 2019 (GBD 2019 Fracture Collaborators 2021); and big toe arthritis is the second most referred condition after bunions in foot and ankle clinics (Howard et al. 2014). Prevention of foot and ankle conditions through patient education on proper shoes (Cheever et al. 2026) and exercises (Zecher and Leach 1995) could reduce disease burden. However, a study published in 2008 found that only 20.3% of the American Orthopaedic Foot & Ankle Society (AOFAS) website materials met the recommended readability level, averaging 8.3 (Bluman et al. 2009). A more recent study based on data from articles on the American Society for Surgery of the Hand website from 2020 also reported between 9th to 12th grade levels (Zhang et al. 2022). Thus, readability for foot and ankle PEMs has been of concern.

AI tools, like ChatGPT, have been employed to simplify complex texts (Malik P et al. 2019). Yet, its role in foot and ankle PEMs is scarce. This study initially assessed the readability of PEMs for four common foot and ankle issues, and tested if ChatGPT could adjust readability to a sixth-grade level, while keeping the information accurate, ultimately providing alternative strategies to improve the readability and accessibility of orthopedic patient education materials.

MATERIALS AND METHODS

STUDY DESIGN

This quasi-experimental, before-and-after study assesses the readability of foot and ankle patient education materials (PEMs) and evaluates whether ChatGPT could improve them to recommended reading levels without compromising content integrity. In Phase 1, baseline readability of the original PEMs was estimated; in Phase 2, ChatGPT-generated versions were analyzed and compared to the original readability scores to assess potential improvements.

SELECTION OF CONDITIONS

Common foot and ankle conditions that are prevalent in the general population and frequently managed both surgically and conservatively by orthopedic surgeons were included: bunions, diabetic foot ulcers, broken ankles, and arthritis of the big toe. Given their frequency, clear and accessible online information is essential for patient understanding of their condition.

DATA COLLECTION AND MEASUREMENTS

For each of the four conditions, a Google search was performed using lay search terms (e.g., "bunion") to simulate typical patient behavior. Medical jargon (e.g., "hallux valgus") was avoided. The first ten PEM results were selected, as most users do not go beyond the first page (Urman and Makhortykh 2023). We excluded PEMs from sponsored links, academic articles, and duplicates. The PEM text on the website was copied into Microsoft Word, with images and ads removed, then uploaded to Readable.com to estimate readability through 1) Grade Level, 2) Flesch-Kincaid Grade Level, and 3) Flesch Reading Ease Score. Grade Level is a Readable.com summary metric that incorporates results from multiple validated readability formulas. Higher grade level scores indicate greater reading difficulty that is more appropriate for advanced readers. The Flesch-Kincaid Grade Level is a specific, validated formula developed for the U.S. military that estimates the U.S. school grade required to comprehend the text. Both metrics express reading level as an approximate school grade. The Flesch Reading Ease Score is a distinct scale ranging from 0 to 100, with higher scores indicating easier reading. All three tools assess readability based on sentence length and word complexity, and have been shown to have high reproducibility and strong correlation with other readability scales (Williamson and Martin 2010).

CHATGPT INTERVENTION

After baseline readability was assessed, each PEM was input into ChatGPT with the prompt: "translate the following to a 6th-grade reading level," aligning with NIH and AMA guidelines (Kirchner et al. 2023). The output was then uploaded to Readable.com, and the same three readability metrics were collected.

STATISTICAL ANALYSIS

Statistical analyses were performed using Stata v. 17 (StataCorp. 2021. Stata: Release 17. Statistical Software). Differences in pre- and post-intervention for categorical variables (e.g., Grade Level) were analyzed with Pearson chi-square tests, and continuous variables (e.g., Flesch-Kincaid Grade Level, Reading Ease Score) were analyzed with paired t-tests and pairwise mean comparisons. Corresponding 95% confidence intervals (CI) were calculated. For each outcome, regression models were used to examine the influence of variables such as website type and condition, including both intervention status (pre-/post-ChatGPT) and categorical predictors. Significance was set at $p < 0.05$ for all statistical tests. Finally, a board-certified foot and ankle surgeon reviewed the ChatGPT-generated summaries and found them to be consistent, appropriate, and more accessible due to reduced jargon and shorter length.

RESULTS

The data was analyzed according to Readability Grade, Kincaid Level, and Flesch Ease in pre-GPT vs. post-GPT conditions.

GRADE

Grade A increased from 55% (N=22) in the original PEM to 85% (N=34) after "ChatGPT" intervention; Grade B decreased from 35% (N=14) to 15% (N=6); Grade C decreased from 10% (N=4) to 0% (N=0) (p=0.008 for difference in percentages in grade pre- vs post-intervention). The relative risk (RR) of achieving Grade A following the ChatGPT inter-

vention was 1.5 (95% CI: 1.1-2.1) with a risk difference of 30% (95% CI: 11-49%).

When analyses were condition-specific, results revealed a significant improvement in the number of PEM with Grade A for "Broken Ankle", from 4 to 10 (Pearson chi-squared=8.571, p=0.003). However, no significant differences were observed for the other conditions.

KINCAID LEVEL

The overall mean Kincaid level for all conditions combined was 7.6 (95% CI: 7.1-8.2) and it significantly decreased to 5.75 (95% CI: 5.2-6.3) post-GPT intervention. Regression analysis for Kincaid level demonstrated a mean average score decrease by 1.94 (p<0.001).

Similar trends in Kincaid level scores were observed for PEM related to Bunion, Broken Ankle, and Arthritis, with differences in Kincaid averaging -1.9 points (95% CI: -2.9 to -0.9, p=0.001), -2.9 (95% CI: -4.3 to -1.6, p<0.001), and -1.5 (95% CI: -3.0 to -0.10, p=0.037), respectively. No differences pre-post ChatGPT intervention were found for PEM in Diabetic Foot.

FLESCH EASE SCORES

The overall mean difference in pre-GPT and post-GPT Flesch Ease scores was 62.0 (95% CI: 58.7–65.4) and 74.9 (95% CI: 71.6–78.3), respectively. The mean difference was +12.9 (95% CI: 8.17-17.7, p<0.001) with the greatest improvement seen in the "Broken Ankle" condition (+18.0, p<0.001).

Condition-specific analyses showed significant improvement for all conditions, except "Arthritis." "Bunion" increased by 13.0 (95% CI: 7.7–18.4, p<0.001), "Diabetic Foot" increased by 12.5 (95% CI: 0.9–24.0, p=0.036), "Broken Ankle" increased by 18.0 (95% CI: 10.7–25.1, p<0.001), and "Arthritis" increased by 8.2 (95% CI: -0.5 to 17.0, p=0.064).

DISCUSSION

Foot and ankle conditions such as diabetic foot ulcers, arthritis of the big toe, bunions, and broken ankles often require complex medical terminology, making it difficult for patients to fully understand their diagnosis and treatment options. Our research demonstrates that readability can be significantly improved in patient education materials (PEMs) for these conditions, reinforcing prior studies that emphasize the need for clearer online orthopedic medical content to ensure broader accessibility (Karimi et al. 2023; Marshall et al. 2019). Our findings showed that ChatGPT intervention resulted in significant improvements in website content by increasing the Readability Grade and Flesch Ease score, while also decreasing the Flesch Kincaid level. Statistically significant differences were observed in all three of these categories, with similar trends across most conditions. The "broken ankle" condition had the most pronounced effects, with significant differences in all metrics. This category had the greatest mean increase in Flesch Ease score, and it was the only condition to show a significant improvement to Grade A. "Bunion" was the next condition to show the most ChatGPT-mediated improvements, lacking only a significant difference in readability grade improvement. While positive trends were observed in the "diabetic foot" and "arthritis" groups, these condition-specific analyses were based on relatively small samples of 10 materials per condition. Therefore, the lack of statistical significance may represent either true heterogeneity in ChatGPT performance across conditions or insufficient statistical power to detect smaller readability improvements.

This study reinforces prior research emphasizing the importance of improving the readability of online patient education materials (PEMs) to meet health literacy standards. Studies have consistently shown that most PEMs exceed the NIH-recommended sixth-grade reading level, especially in pediatric orthopedics and orthopedic trauma, making them difficult for many patients to understand (Thomas et al. 2023; Ghanem et al. 2024). Many patients turn to the internet for health information, yet the complexity of medical language can create barriers to understanding. Recent studies have shown that simplifying medical content can bring it closer to the NIH-recommended sixth-grade reading level, making it easier for a wider audience to comprehend (Kirchner et al. 2023; Rouhi et al. 2023; Shnaekel et al. 2018). Our findings support these conclusions, showing that revisions can greatly enhance the readability of PEMs related to foot and ankle conditions. A survey found that 76% of foot and ankle patients search for medical information online, yet 66% of patients question the credibility of the sources they find (Rosenbaum et al. 2023). Because patient comprehension is key to making informed medical decisions, our study focused on improving the clarity of commonly searched PEMs. By analyzing readability scores, such as the Flesch-Kincaid reading level, we observed a significant reduction in complexity across all tested materials.

Our results revealed that simplifying medical language led to a measurable improvement in readability, bringing PEMs closer to recommended reading levels while preserving medical accuracy. On average, revisions resulted in higher readability, as measured by Flesch Ease scores, while maintaining the integrity of key medical concepts. Furthermore, a board-certified foot and ankle surgeon reviewed the ChatGPT-generated summaries and found them to be consistent, appropriate, and more accessible due to the reduced use of jargon and shorter length. While some clinical nuances, such as distinctions between bunion subtypes or the omission of conditions like bunionettes, were lost, these were considered acceptable trade-offs that improved clarity for the average reader.

This study did not evaluate whether patient comprehension was enhanced for the AI-modified PEMs, leaving an important gap in understanding the practical impact on health literacy. Furthermore, readability formulas such as Flesch-Kincaid Grade Level and Flesch Reading Ease primarily assess sentence length and word complexity rather than clinical accuracy, medical actionability, or patient interpretability. In addition, each condition-specific subgroup analysis included only 10 patient education materials, which likely limited statistical power to detect smaller

differences between pre- and post-intervention readability outcomes. As a result, some non-significant findings may reflect insufficient power rather than a true absence of effect. While Flesch-Kincaid and Flesch Ease scores are widely accepted readability measures, incorporating alternative metrics could strengthen the validity and robustness of the study's methodology. Additionally, the complexity of highly technical topics may limit ChatGPT's capacity to simplify content effectively, emphasizing the need for tailored prompts and further refinement of AI models, particularly in areas such as medical pathologies and surgical procedures. These areas may not be sufficiently explained by the current state of generative AI models, and whether improvements in readability are generalizable in those cases remains to be tested.

Additionally, generative AI systems such as ChatGPT carry a recognized risk of inaccuracies and hallucinated medical content. Although a board-certified foot and ankle surgeon reviewed the revised materials and found them appropriate, validation by a single reviewer is insufficient to support widespread patient-facing implementation.

Previous research has shown that AI-based tools have the potential to address these readability challenges. For instance, Kirchner et al. demonstrated that ChatGPT can simplify medical language while retaining key information (Kirchner et al. 2023). Additionally, studies in orthopedics have highlighted persistent difficulties in improving the readability of PEMs due to the technical nature of the content. Trehan et al. demonstrated these challenges in the context of rotator cuff injury education (Trehan et al. 2024), and Patel et al. found similar issues in PEMs for osteoarthritis (Patel et al. 2023). Our findings add to this discussion by showing that foot and ankle PEMs, conditions frequently researched online by patients (Rosenbaum et al. 2023), also suffer from similar readability limitations.

The broader orthopedic literature further emphasizes the need for improved readability across various conditions (Badarudeen and Sabharwal 2010). Eltorai et al. and Doinn et al. both identified that many orthopedic PEMs do not meet readability recommendations, reinforcing the widespread nature of this problem (Eltorai et al. 2015; Doinn et al. 2020).

In conclusion, our results demonstrate that the implementation of generative AI tools such as ChatGPT can improve the readability of foot and ankle PEMs. ChatGPT shows significant promise in assisting healthcare providers and medical educators in enhancing the readability of online information for the public. Online PEMs can integrate ChatGPT to meet health literacy standards, potentially broadening access to reliable health information. Future research should expand ChatGPT's application to other orthopedic conditions and assess its impact on patient comprehension and health outcomes. By bridging the gap between medical language complexity and patient literacy, ChatGPT may serve as a transformative tool in improving health communication and patient empowerment.

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