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Evaluating the Readability of Patient Education Materials for Anterior Vertebral Body Tethering, Distraction-Based Methods, and Posterior Spinal Fusion for the Treatment of Pediatric Spinal Deformity

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ABSTRACT

Background: The Internet is an important source of information for patients, but its effectiveness relies on the readability of its content. Patient education materials (PEMs) should be written at or below a sixth-grade reading level as outlined by agencies such as the American Medical Association. This study assessed PEMs' readability for the novel anterior vertebral body tethering (AVBT), distraction-based methods, and posterior spinal fusion (PSF) in treating pediatric spinal deformity.

Methods: An online search identified PEMs using the terms "anterior vertebral body tethering," "growing rods scoliosis," and "posterior spinal fusion pediatric scoliosis." We selected the first 20 general medical websites (GMWs) and 10 academic health institution websites (AHIWs) discussing each treatment (90 websites total). Readability tests for each webpage were conducted using Readability Studio software. Reading grade levels (RGLs), which correspond to the US grade at which one is expected to comprehend the text, were calculated for sources and independent *t* tests compared with RGLs between treatment types.

Results: The mean RGL was 12.1 ± 2.0. No articles were below a sixth-grade reading level, with only 2.2% at the sixth-grade reading level. AVBT articles had a higher RGL than distraction-based methods (12.7 ± 1.6 vs 11.9 ± 1.9, $P = 0.082$) and PSF (12.7 ± 1.6 vs 11.6 ± 2.3, $P = 0.032$). Materials for distraction-based methods and PSF were comparable (11.9 ± 1.9 vs 11.6 ± 2.3, $P = 0.566$). Among GMWs, AVBT materials had a higher RGL than distraction-based methods (12.9 ± 1.4 vs 12.1 ± 1.8, $P = 0.133$) and PSF (12.9 ± 1.4 vs 11.4 ± 2.4, $P = 0.016$).

Clinical Relevance: Patients' health literacy is important for shared decision-making. Assessing the readability of scoliosis treatment PEMs guides physicians when sharing resources and discussing treatment with patients.

Conclusion: Both GMWs and AHIWs exceed recommended RGLs, which may limit patient and parent understanding. Within GMWs, AVBT materials are written at a higher RGL than other treatments, which may hinder informed decision-making and patient outcomes. Efforts should be made to create online resources at the appropriate RGL. At the very least, patients and parents may be directed toward AHIWs; RGLs are more consistent.

Level of Evidence: 3.

Other and Special Categories

Keywords: AVBT, fusion, distraction, education, readability

INTRODUCTION

Scoliosis in skeletally immature patients remains a difficult condition to treat. Traditionally, a posterior spinal fusion (PSF) with maximum correction was the mainstay of surgical treatment, with the notion that a short and straight spine is preferred over a long, deformed one.[1] However, fusion surgery decreases motion through portions of the spine, limiting spinal mobility.[2,3] Furthermore, primary fusion at a young age is associated with high morbidity due to restricted thoracic growth and associated lung function, particularly in patients with early onset scoliosis, which includes all spinal deformities in children younger than 10 years.[4] The treatment paradigm has therefore shifted to focus on spine growth preservation techniques to preserve thoracic cavity, lung growth, and spine mobility.[5] Distraction-based constructs such as traditional growing rods, vertical expandable prosthetic titanium rib, and magnetically controlled growing rods have provided alternative approaches to primary fusion in skeletally immature patients; however, they are not without their own complications.[6–8] Newer compression-based techniques, such as anterior vertebral body tethering (AVBT), rely upon the Hueter-Volkmann principle[9] to correct scoliosis while maintaining flexibility and growth. A mechanical tether is adhered to the lateral vertebral body on the convex side. As the spine continues to grow, the convex side is compressed while the concave side is allowed to "catch up," further straightening the spine.[10–13]

When deciding between PSF, distraction-based methods, and AVBT, patients and families are increasingly turning to the plethora of online resources. Online health information is now one of the most valued resources to parents, with an estimated 98% having used the internet to search for information about their child's health.[14] The prevalence of online information, however, does not translate to patient or family comprehension. Several health care organizations such as the American Medical Association,[15] the Agency for Healthcare Research and Quality,[16] and the National Work Group in Cancer and Health[17] recommend that patient education materials (PEMs) be written at a sixth-grade reading level or lower, yet studies have shown that the reading level of PEMs is too advanced across numerous pediatric subspecialties.[18–21]

The effective dissemination of PEM at a reading level that is comprehensible to most patients and their families is essential to properly inform surgical candidates of the risks and benefits of the newer AVBT techniques as well as the other options available to them. While other studies have analyzed the readability of various surgical procedures in orthopedics,[22–27] to our knowledge, there are no studies that have compared the readability of scoliosis procedures such as PSF, distraction-based methods, and AVBT. The purpose of this study was to evaluate the readability of currently available online PEMs for AVBT in comparison to PSF and distraction-based methods to assess the ability of patients to make informed decisions regarding treatment options. We hypothesized that the readability of PEMs from readily accessible online resources is written, on average, at a higher-than-recommended reading level.

MATERIALS AND METHODS

Website Identification

In June 2021, Google searches were conducted to identify online PEMs using the terms "anterior vertebral body tethering," "growing rods scoliosis," and "posterior spinal fusion pediatric scoliosis." The first 20 general medical websites (GMWs) and 10 academic health institution websites (AHIWs) discussing AVBT, distraction-based methods, and PSF were included for each search term (90 websites total). An AHIW was defined as any website affiliated with a university or academic medical center (ie, a ".edu" website). A GMW was defined as any website that was not an AHIW but was intended to provide medical information. The authors of GMWs included individual physicians, surgical groups, health journals, and databases such as Wikipedia. Because the goal of this study is to determine readability of information accessible to patients, we focused on availability rather than authorship. We excluded websites not likely to be used by patients and parents such as online peer-reviewed journal articles.

Readability Analysis

The content of each webpage was copied, and the text was pasted into individual Microsoft Word documents. Text irrelevant to the article content was removed; this included text related to webpage navigation, dates, author names/affiliations, addresses, and telephone numbers. Tables, references, and website links were also removed to avoid their influence on the readability scores. Ten validated readability tests were conducted on each web page using the Readability Studio (Oleander Software Solutions Ltd.) software. The tests included the Bormuth Grade Placement, Coleman-Liau, Fry, Gunning Fog, Harris-Jacobson Wide Range Formula, Läsbarhetsindex, New Dale-Chall, Rate Index, Raygor Estimate, and Simple Measure of Gobbledygook (SMOG) index. Each of these tests report a reading grade level (RGL) that corresponds to the United States educational grade level at which one is expected to read and comprehend the text satisfactorily. A collective RGL was then determined for each article by averaging the RGLs from each test, as follows:

$$\frac{(BGP+CL+Fry+GF+HJ+LIX+NDC+RIX+Raygor\ Estimate+SMOG)}{10}$$

Statistical Methods

The percentage of articles with a collective RGL at or below the sixth-grade level was determined. Independent *t* tests were conducted to compare RGLs between treatment types. To investigate for a differential effect based on website category, we performed the same analysis following stratification by GMW vs AHIW. All analyses were 2-tailed, and statistical significance was set at a *P* value of <0.05. IBM SPSS Statistics version 27 (Armonk, NY) was used for the analysis.

Table 1. Articles collected per website category.

Website Category	No. of Articles (%)
General medical website	60 (66.7%)
Academic health institution website	30 (33.3%)
Total	90 (100%)

RESULTS

Website Readability

Ninety websites were analyzed after exclusion criteria were applied. Sixty websites (66.7%) were classified as GMWs and 30 websites (33.3%) as AHIWs (Table 1). The mean collective RGL was 12.1 ± 2.0 (range, 6.4–15.2; Figure 1). Based on collective RGL, no article (0%) was found to be written below the sixth-grade reading level, and 2 of the articles (2.2%) were found to be written at the sixth-grade reading level (Figure 2). Five articles (5.6%) were at or below the eighth-grade reading level. Thus, 94.4% of the articles had readability levels above the mean reading level of the adult United States population.[28] The mean collective RGL exceeded the sixth-grade level by an average of 5.1-grade levels and the eighth-grade level by an average of 3.1-grade levels.

Information regarding AVBT was written at a higher mean collective RGL when compared with distraction-based methods (12.7 ± 1.6 vs 11.9 ± 1.9, *P* = 0.082) and PSF (12.7 ± 1.6 vs 11.6 ± 2.3, *P* = 0.032; Table 2). Materials for distraction-based methods and PSF were written at comparable levels (11.9 ± 1.9 vs 11.6 ± 2.3, *P* = 0.566). Stratification by website type revealed that, within GMWs, AVBT materials were written at a higher RGL when compared with distraction-based methods (12.9 ± 1.4 vs 12.1 ± 1.8, *P* = 0.133) and PSF (12.9 ± 1.4 vs 11.4 ± 2.4, *P* = 0.016). Within AHIWs, however, there was no evidence of statistical difference in RGL between treatment types (12.2 ± 1.8 for AVBT vs 11.4 ± 2.1 for distraction-based methods, *P* = 0.364; 12.2 ± 1.8 for AVBT vs 12 ± 2 for PSF, *P* = 0.835).

Key linguistic units were assessed for each article (Figure 3). On average, articles consisted of 38% (range, 21.5–50.4) long words. There was a larger percentage of long words (38 ± 5.5) when compared with complex words (18.9 ± 4.9, *P* < 0.001), Fog hard words (17.5 ± 11.6, *P* < 0.001), Dale-Chall unfamiliar words (30.9 ± 7, *P* < 0.001), and overly long sentences (28.6 ± 16.2, *P* < 0.001). The mean longest sentence was 40.1 (range, 20–69) words.

DISCUSSION

AVBT has been recognized as a novel, minimally invasive technique that provides an alternative to distraction-based methods and PSF for the treatment of

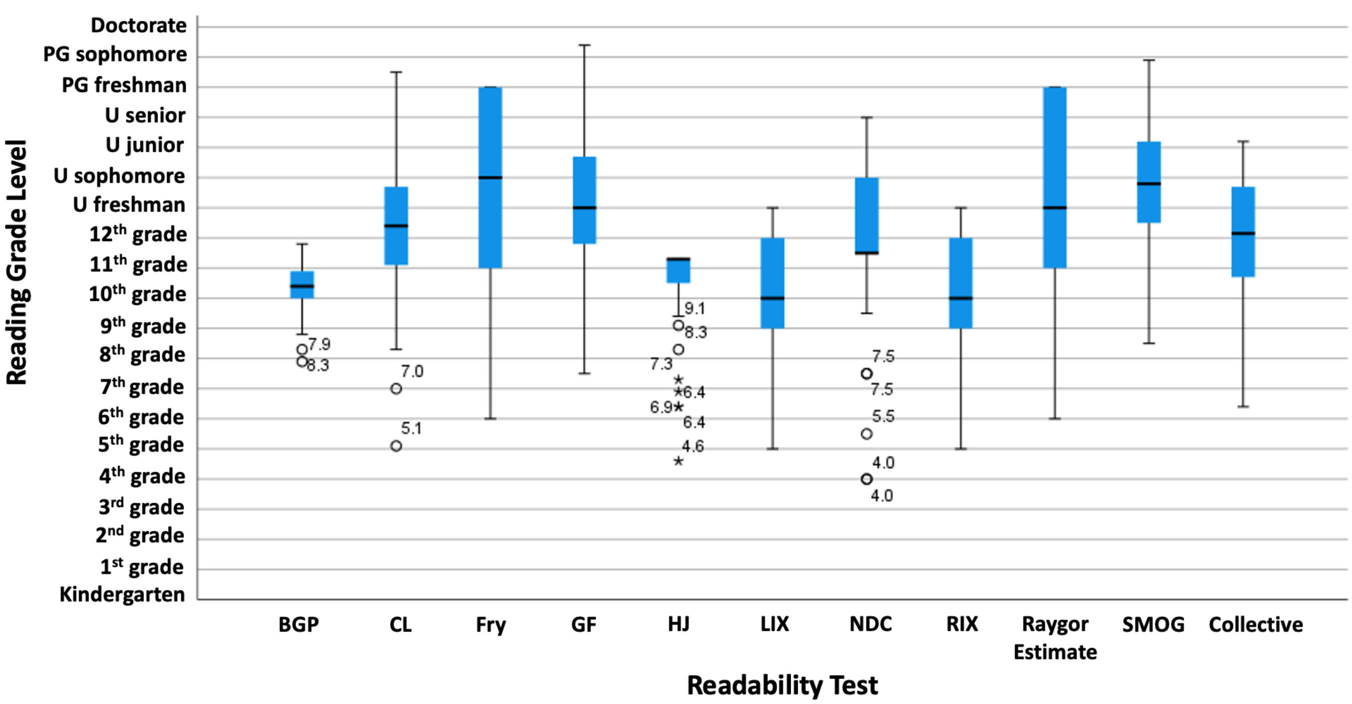

Figure 1. Reading grade level for each individual readability test; the box represents the interquartile range with the median represented by the horizontal line, while the whiskers represent the upper and lower quartiles; circles represent outliers. Abbreviations: BGP, Bormuth Grade Placement; CL, Coleman-Liau; GF, Gunning Fog; HJ, Harris-Jacobson Wide Range Formula; LIX, Läsbarhetsindex; NDC, New Dale-Chall; PG, postgraduate; RIX, rate index; SMOG, Simple Measure of Gobbledygook; U, university.

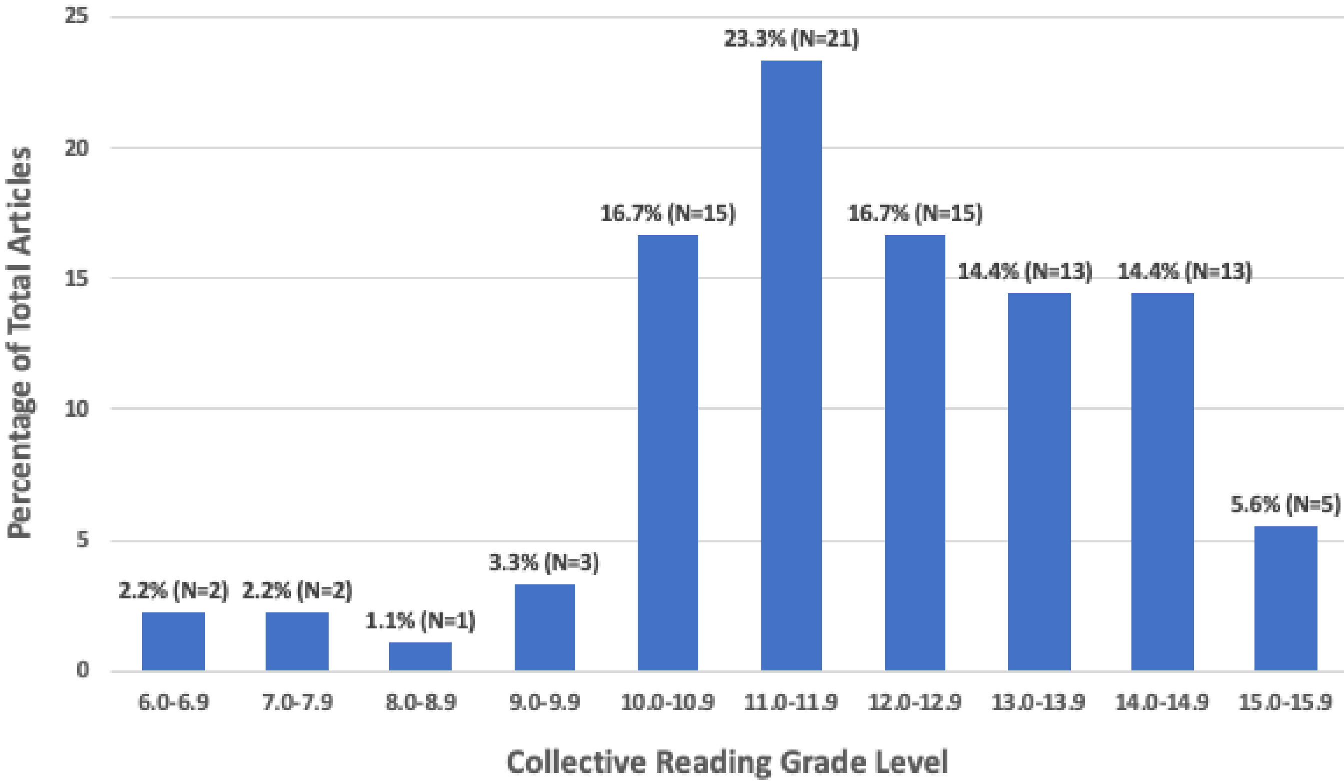

Figure 2. Percentage of articles at the various collective reading grade levels.

pediatric spinal deformity. As is true for any new procedure, the effective dissemination of PEM is essential for properly informing surgical candidates of the risks and benefits of AVBT compared with alternative treatment methods. While AVBT presents a viable option for some patients, its appropriateness varies among individual cases. Notably, the decision to pursue AVBT vs other modalities should be informed by a comprehensive understanding of the risks and benefits associated with each treatment method. To our knowledge, this is the first study to evaluate the readability of online PEMs related to AVBT in comparison to PSF and distraction-based methods.

The results of our study highlight that the vast majority of online PEM pertaining to AVBT, distraction-based methods, and PSF are written well above the recommended RGL. In fact, the overall mean RGL for the analyzed PEMs was that of a high school senior, nearly 6 grade levels above the national recommendations. Overall, AVBT was found to be written at a

Table 2. Individual and collective reading grade level for articles by treatment type.

	AVBT vs Distraction			AVBT vs PSF			Distraction vs PSF		
Readability Test	AVBT (Mean [range])	Distraction	*P*	AVBT	PSF	*P*	Distraction	PSF	*P*
Bormuth Grade Placement	10.6 (9.8–11.8)	10.4 (9–11.7)	0.217	10.6 (9.8–11.8)	10.2 (7.9–11.6)	0.032	10.4 (9–11.7)	10.2 (7.9–11.6)	0.295
Coleman-Liau	13.1 (10.2–17.5)	12.4 (8.5–17.2)	0.225	13.1 (10.2–17.5)	12 (5.1–16.8)	0.069	12.4 (8.5–17.2)	12 (5.1–16.8)	0.484
Fry	14.7 (10–17)	12.7 (7–17)	0.011	14.7 (10–17)	12.9 (6–17)	0.029	12.7 (7–17)	12.9 (6–17)	0.867
Gunning Fog	13.9 (10.1–18.4)	12.9 (7.8–18)	0.106	13.9 (10.1–18.4)	13.2 (7.5–18.4)	0.290	12.9 (7.8–18)	13.2 (7.5–18.4)	0.632
Harris-Jacobson Wide Range Formula	11.1 (9.6–11.3)	10.7 (6.4–11.3)	0.158	11.1 (9.6–11.3)	10.3 (4.6–11.3)	0.018	10.7 (6.4–11.3)	10.3 (4.6–11.3)	0.239
Läsbarhetsindex	10.9 (8–13)	10.5 (6–13)	0.343	10.9 (8–13)	10 (5–13)	0.049	10.5 (6–13)	10 (5–13)	0.283
New Dale-Chall	12.8 (9.5–16)	12.3 (7.5–16)	0.389	12.8 (9.5–16)	11.8 (4–16)	0.148	12.3 (7.5–16)	11.8 (4–16)	0.483
Rate Index	11 (8–13)	10.5 (6–13)	0.329	11 (8–13)	10 (5–13)	0.038	10.5 (6–13)	10 (5–13)	0.263
Raygor Estimate	14.3 (10–17)	12.9 (7–17)	0.078	14.3 (10–17)	12.2 (6–17)	0.010	12.9 (7–17)	12.2 (6–17)	0.371
SMOG	14.6 (11.9–17.9)	13.6 (8.8–17.5)	0.035	14.6 (11.9–17.9)	13.3 (8.5–17.4)	0.008	13.6 (8.8–17.5)	13.3 (8.5–17.4)	0.674
Collective	12.7 (10.1–15.2)	11.9 (7.5–15)	0.082	12.7 (10.1–15.2)	11.6 (6.4–15.2)	0.032	11.9 (7.5–15)	11.6 (6.4–15.2)	0.566

Abbreviations: AVBT, anterior vertebral body tethering; PSF, posterior spinal fusion; SMOG, Simple Measure of Gobbledygook.

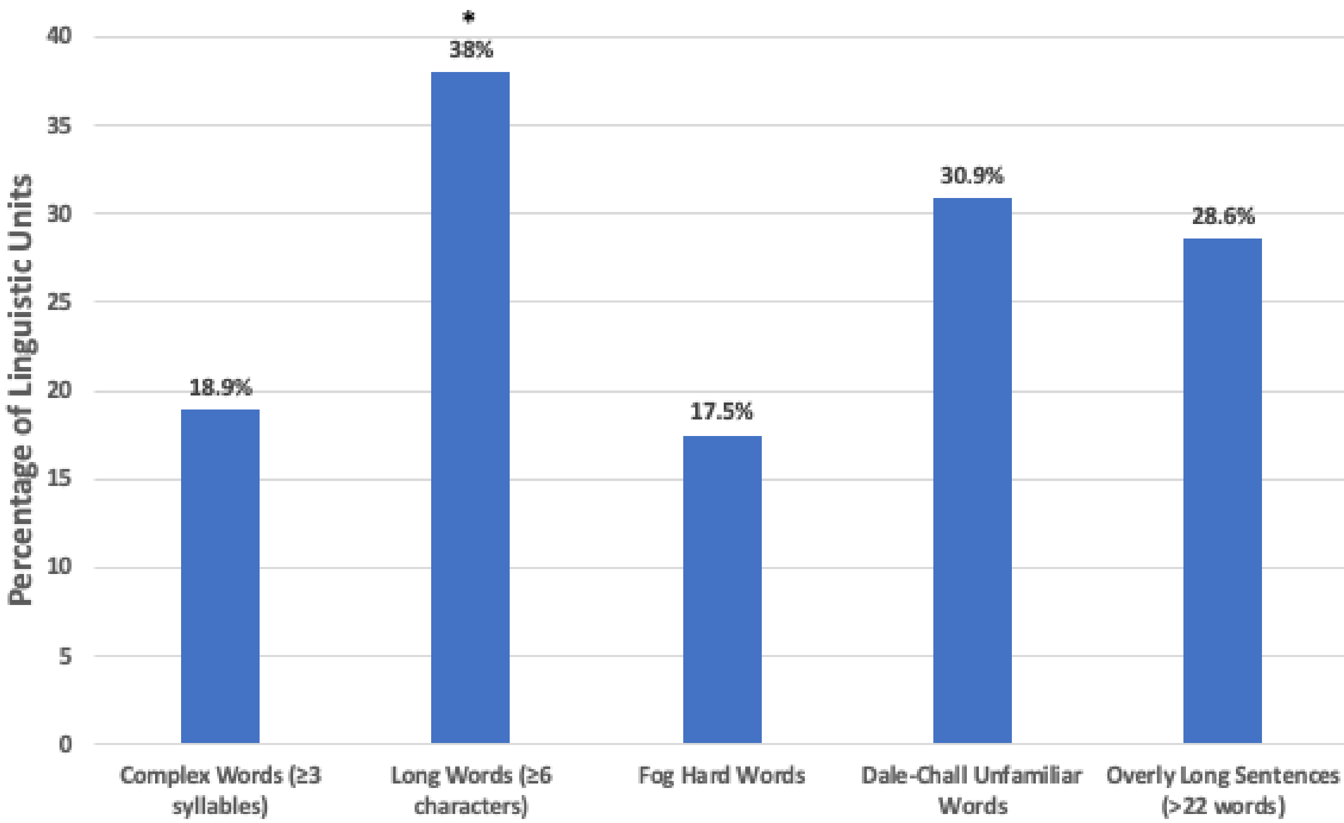

Figure 3. Mean percentage of various linguistic units; * represents a percentage different than all others at a $P < 0.05$.

higher reading level when compared with distraction-based methods and PSF. Upon further subgroup analysis stratifying between website type, AVBT was found to be written at a higher reading level compared with the other 2 treatment methods across GMWs; however, this statistical significance was lost among AHIWs. The readability of PEMs pertaining to AVBT, distraction-based methods, and PSF exceeding the target audience reading level ties into the broader concept of health literacy and its impact on overall child health outcomes.

Health literacy, defined as the "degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions," has been shown to be the single greatest indicator of an individual's health status.[15,29] Lower health literacy has been associated with a worse understanding of the surgical procedure involved, lack of compliance with perioperative instructions, and higher rate of hospitalization, postoperative complications, and mortality.[30–33] Parental health literacy is particularly important in pediatric surgical settings, where parents are often tasked to make decisions for their children on treatment methods with relatively large risks involved. Low health literacy on behalf of a parent is associated with increased levels of parental anxiety, which can influence a child's perioperative course.[34,35] Finally, poor health literacy has an economic impact, with an annual cost of more than US $50 billion to the US health care system.[15]

The Institute of Medicine Health Literacy Report found that 90 million American adults lack the literacy skills to use the US health care system effectively.[29] They recommended developing ways to reduce the negative effects of limited health literacy. Designing online PEMs to provide accurate information that is easily comprehended by patients with limited health literacy is one such strategy. The access to and use of online PEMs has, to a large extent, transformed the physician-patient relationship; however, the wide availability of high-quality information does not translate to reader comprehension. The American Medical Association,[15] the Agency for Health care Research and Quality,[16] and the National Work Group in Cancer and Health[17] recommend that PEMs be written at a sixth-grade reading level or lower, and the National Institutes of Health (NIH) recommend that PEMs not exceed the seventh- to eighth-grade levels.[36] Nevertheless, studies have shown that the reading level of PEMs is too advanced across numerous pediatric subspecialties and in pediatric orthopedics specifically.[18–21]

Badarudeen and Sabharwal[37] examined the patient education libraries of the American Academy of

Orthopedic Surgeons (AAOS) and the Pediatric Orthopedic Society of North America and found that the majority of PEMs pertaining to pediatric orthopedics were too complex for the general US population. Ten years later, Doinn et al[38] evaluated the readability of PEMs in pediatric orthopedics provided by the AAOS, Pediatric Orthopedic Society of North America, and American Academy of Pediatrics websites to determine whether any progress had been made. Once again, they concluded that the readability scores exceeded recommendations. When it comes to the complexity of spinal disorders and treatment for complex spinal deformity in children, the necessity of comprehensible online PEMs is even more pronounced. Time constraints during a physician-patient encounter, lack of medical knowledge on behalf of the patient and family, and the complexity of the procedures involved may further hinder comprehension. Vives et al[24] conducted an internet search of PEMs on the North American Spine Society, American Association of Neurological Surgeons, and AAOS and found that most of the spine-related PEMs had readability scores that were too high.

The results of this present study corroborate the results of the aforementioned studies and highlight that PEMs are still being written at a level well above the national recommendations. This was found to be true across the board for PEMs written for AVBT, distraction-based therapies, and PSF, whether they are provided by websites affiliated with an academic medical center (AHIWs) or general medical organization (GMWs). Furthermore, AVBT was found to be written at a higher reading level than the other 2 treatment methods among GMWs. While the reasons for this requires additional study, we suspect that higher RGLs of AVBT PEMs may be influenced by the technique's relative novelty. Similarly, AVBT entails technical growth concepts that may be challenging to describe to the public. Nonetheless, it is crucial that this technique be described in a manner that is easily understandable. Physicians are used to writing in a style that is suited for comprehension by other physicians, such as in scientific journals. It is perhaps due to this that physicians lack the awareness of the drastic difference in reading comprehension among their peers and the general population. Interestingly, when selecting for AHIWs alone, AVBT was not found to be written at a significantly higher reading level than distraction-based methods or PSF. This result supports the conclusion that at the very least, patients could be navigated toward websites that are affiliated with a university or academic medical center, as these seem to be more consistent. Nevertheless, PEMs for those 3 treatment modalities were still well above the national recommended reading level, and there is still much work to be done to correct this discrepancy.

Our findings support the need for greater awareness among providers and authors of PEMs to provide information that is more easily comprehensible and accessible to the general public. There are in fact examples where efforts to improve the readability of PEMs have been effective. Sheppard et al[39] improved readability levels of PEMs in foot and ankle surgery by shortening sentences to no more than 15 words according to the NIH guidelines. They showed that this intervention improved the readability of 8 articles by an average of 1.41-grade levels. Although we showed that PEMs for AVBT, PSF, and distraction-based methods exceeded the recommended level by 5.1 grades, this small effort can be influential in closing this large gap in comprehension. Other suggestions for improving the readability of PEMs have been previously reported. Limiting sentences to 8 to 10 words, avoiding complex medical terms, good formatting, and simple nuances such as color, font type, size, and inclusion of illustrations can enhance comprehension.[17,40,41]

The results of this study should be interpreted in light of several limitations. First, the study only compares written materials. Videos, figures, and diagrams, which may impact health literacy, were not included in the analysis. Other tools, such as the Suitability Assessment of Materials and the PEMs Assessment Tool, can be used to include nontextual elements in the analysis. However, we decided not to use these tools because they do not produce a quantifiable target such as an RGL that can be used to compare to national recommendations. In addition, only English language resources were included. Readability of resources in other languages may differ, thus impacting the understanding of patients for whom English is not the preferred language. Finally, it was assumed that the reading and comprehension skills of patients and families seeking treatment for scoliosis were reflective of the reported reading and comprehensive skills of the general public. We did not perform an analysis to directly assess the reading and comprehension skills of our patient population specifically.

Nonetheless, the results suggest that patients would likely benefit from published material that is written at an appropriate reading level, or at the very least be directed toward AHIWs. The majority of patients expect their physician to recommend specific online resources. As such, physicians should be aware of these findings so that they can better guide their patients and families or implement other teaching modalities to improve understanding of proposed procedures.

CONCLUSION

The readability of online PEMs pertaining to pediatric orthopedic spinal deformities is of particular importance given the age of the patients and the impact of health literacy on patient health outcomes. Nevertheless, online information regarding AVBT, PSF, and distraction-based therapies is written at a reading level well above the national recommendations. As patients and their families increasingly turn to the internet for online health information, it is incumbent upon physicians and authors of PEMs to improve the readability of these resources. Incorporating practices laid out by national recommendations can enhance the readability of such resources and help enhance child health outcomes following these procedures. Physicians and health educators may also consider additional teaching modalities such as pamphlets, videos, and podcasts to improve health literacy and guide patient's decision-making.

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