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Social Media Attention and Citation Metrics as Predictors of U.S. Neurosurgery Residency Reputation

Patrick Pema

patrick.pema@hmhn.org

Hackensack Meridian School of Medicine

Akil Anthony

Jersey Shore University Medical Center

Youssef Atef AbdelAlim

Hackensack Meridian School of Medicine

Jack Kilgallon

Hackensack Meridian School of Medicine

Kush Desai

Hackensack Meridian School of Medicine

Paxton Sweeney

Hackensack Meridian School of Medicine

Daniel Monahan

Hackensack Meridian School of Medicine

Michael Chaga

Jersey Shore University Medical Center

Ira Goldstein

Jersey Shore University Medical Center

Shabbar Danish

Jersey Shore University Medical Center

Nitesh Patel

Jersey Shore University Medical Center

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Abstract

Introduction

Social media presence exerts a growing influence on visibility both at the individual and program level. In this study, we aim to assess the degree of influence that citation impact and social attention metrics assert by determining the degree to which these measures predict program reputation.

Methods

A paper level dataset for U.S. Neurosurgery residency program faculty was compiled from the Top 25 programs by reputation as listed by doximity.com, including each physician's three most cited publications, and aggregated to the program level. The Altmetric tool was used to gather social media occurrences. We modeled program rank as an ordered outcome using ordinal logistic regression with three specifications: (A) aggregate attention + citations, (B) disaggregated attention (tweets, blogs, news) + citations, and (C) social-only. Model fit and generalization were compared via AIC, likelihood-ratio tests, and leave-one-out cross-validation. Predictive performance was summarized with Spearman correlation and mean absolute error (MAE).

Results

Models emphasizing social attention consistently outperformed citation-based approaches across all analytic metrics. The disaggregated social-attention model demonstrated the best overall performance, achieving an AIC of 198.5 versus 211.9 for aggregate attention + citations, and a significantly improved likelihood-ratio test ($p < 0.001$). Predictive accuracy was highest for social models (Spearman $\rho \approx 0.60–0.62$; MAE ≈ 4.4).

Conclusions

Neurosurgery program reputation correlates more strongly with multi-platform social engagement than with reference volume. Integrating research dissemination with strategic digital communication may enhance both visibility and perceived academic prestige.

Introduction

Program rank is an important consideration for residency applicants each year and influences decision making throughout medical school. Selection of away rotations, involvement with research organizations, and submission of the residency application itself are actions that are all in part affected by the level of prestige of each target program in which a student may be interested. While such rankings

change year to year and are multifactorial in nature, gaining insight into how medical culture shapes such program reputation can inform medical students, residents, and faculty alike.

Recent studies demonstrate that research productivity, as measured by bibliometric indices (such as h-index, publication count, and citation metrics), is strongly correlated with neurosurgery program rankings and reputation[3, 6, 10, 12]. Institutional bibliometric profiles, including 3 and 5-year publication and citation counts, are significantly associated with Doximity rankings and social media presence, reflecting the importance of research output in program evaluation[10, 13, 18]. The ih(5)-index and related metrics have been validated as robust tools for comparing academic productivity across programs and are less susceptible to distortion by outlier faculty, further supporting their use in ranking systems. Resident research productivity, as measured by h-index and publication count, also correlates strongly with faculty productivity and program ranking, highlighting the importance of a research-oriented environment in top programs[4, 12].

Analyses also showed that programs with higher research output are more likely to be highly ranked, with greater emphasis placed onto clinical trials, dedicated research time for residents and faculty, and incoming applicant research acumen. These programs also tend to attract more competitive applicants; as such, research productivity is a key differentiator in the residency selection process. Thus, program reputation is both underscored and influenced heavily by academic output as judged by metrics such as unique citations, h-indices of faculty, and prestige of journals of publication.

While objective measures such as h-index and citation count have existed for decades, social media platforms have only been active since the turn of the century. Use of sites like Facebook, Twitter, Instagram, Wikipedia, and more, can increase exposure for physicians, hospital systems, and residency programs alike[6]. Data shows that neurosurgery programs with strong social media presence have better patient reviews and are more likely to be ranked higher on sites such as Doximity[3]. As Doximity does not include a social media component, capturing this dimension of neurosurgery residency program exposure is critical to understand how reputation is shaped in the digital age.

Altmetric is a research analytics tool that measures the online attention surrounding scholarly work in real time and is increasingly used in medical research, including neurosurgery, to complement traditional citation-based metrics. It systematically tracks mentions of academic works across multiple online platforms such as news outlets, policy documents, blogs, Wikipedia, and social media platforms like Twitter and Facebook, as well as academic bookmarking tools like Mendeley. Each source type contributes a weighted value to the Altmetric Attention Score (AS), with higher weights assigned to sources considered more influential, such as major news coverage or policy citations. The resulting score provides an indicator of the reach, dissemination, and societal engagement of a publication. In neurosurgery, Altmetric has been used to evaluate how clinical trials, surgical innovation papers, and systematic reviews gain visibility beyond traditional academic circles, often highlighting which topics attract broader public or policy interest. This makes Altmetric particularly valuable for identifying high-

impact areas of translational research and assessing how new findings influence clinical discourse, patient advocacy, and public health awareness.

Using this tool, we set out to assess the respective influence of research prowess and social media-related attention on program rank. Our purpose is to determine the degree of correlation that social media attention has on neurosurgery residency program reputation and determine if online presence is an independent predictor of program rank in the 21st century.

Methods

Data Acquisition

This study used publicly available bibliometric and altmetric data and did not involve human participants, patient data, or animals. We gathered data from the top 25 neurosurgery residency programs as listed on Doximity.com. Doximity's ranking is generated each year from three metrics: 1. Resident satisfaction data based on anonymized surveys of current residents and recent alumni, 2. Reputation data based on a national survey of board-certified neurosurgeons where each can nominate up to five programs they believe offer the best clinical training, and 3. Objective program data including a research-output score that combines alumni h-index, publication and clinical-trial participation rates, and research grants, as well as other metrics such as program size and subspecialty rate[18].

Members of the faculty of each program were identified via the program's own website. Included faculty members had MD or DO degrees; physicians with PhD, MS, MPH, and other degrees were included only if an MD or DO degree was concurrently present.

For each physician, bibliometric data was obtained from Scopus.com and included the number of unique publications and citation count for each paper. Given this direct impact of citational research output score on Doximity ranking, Altmetric data for the top 3 publications by citation count were gathered. Using the Altmetric tool[19], data for each publication was collected and included tweets, blogs, news occurences, Facebook posts, Wikipedia references, and patents. The data gathering stage yielded 2047 publications across 695 faculty from 25 programs.

The relationship between online impact, Scopus references, and program reputation was quantified using a hierarchical aggregation pipeline, characterized as such: 1. Paper level → 2. Faculty level → 3. Program level. Regression modeling was conducted utilizing ordinal logistic regression, treating program rank as the ordered outcome.

Paper level

To represent each physician's most visible work, the top 3 most cited papers from Scopus.com were retained. We mitigated author name ambiguity in Scopus by verifying each faculty member's profile using institutional affiliation and specialty, and resolved discrepancies by cross-checking publication titles. For each distinct publication, year of publication and Scopus references were collected along with

metrics measured by Altmetric: attention score, news, tweets, blogs, Facebook, Wikipedia, patents. A derived amplification ratio was computed for each paper as attention_score/(Scopus_citations +1) to describe attention per citation. If no Altmetric record was returned, it was treated as missing and omitted within aggregations.

Faculty level

For each faculty member, paper level metrics were averaged. Mean citations, mean attention score, mean Tweets, blogs, news, Facebook, Wikipedia, patents, and mean attention per citation were calculated. Faculty data regarding number of unique publications and h-index were also collected.

Program level

Faculty metrics were averaged across all faculty members in a program to ascertain program-level predictors. Mean citations, mean attention, and mean tweets, news, blogs, Facebook, Wikipedia, patents were calculated along with mean h-index. The outcome was the program's Doximity reputation rank, with rank 1 = best.

Modeling Strategy

A proportional-odds ordinal logistic regression modeling system was used with program rank as the ordered response. Three model families were outlined to compare different representations of online attention:

1. **Aggregate model (A):** rank ~ mean_attention + mean_citations
2. **Components model (B):** rank ~ mean_tweets + mean_blogs + mean_news + mean_citations
3. **Social-only model (C):** rank ~ mean_tweets + mean_blogs + mean_news

For Models B and C, predictors were program-level means (averaged across faculty, then across each faculty member's top three cited publications); thus, a 1-unit increase represents one additional mention per paper in that program-level mean for the specified source (such as blogs, news, or tweets).

Model coefficients are reported on the log-odds scale, with Wald z-statistics from the model summary used for inference

Model comparison and fit

The Akaike Information Criterion (AIC) was used for primary model selection to guide whether social metrics demonstrate explanatory value beyond aggregate attention and citations.

Effect Size Comparison

Interpretability was enhanced by converting log-odds coefficients to odds ratio (OR) via exponentiation and calculated 95% Wald confidence intervals as $\exp(\beta \pm 1.96 \times SE)$.

Cross-validation and Robustness

Robustness was assessed using leave-one-out cross validation (LOO-CV). For each left out program, a model was re-fit on the remaining programs and AIC recorded. The mean and SD of LOO AIC across folds were used to compare the out-of-sample parsimony of model.

Predictive Performance Checks

To complement AIC-based comparisons, each fitted model produced category probabilities for ranks; these were collapsed to an expected rank (probability-weighted average of rank categories). We summarized in-sample predictive performance with Spearman correlation between expected and observed rank and mean absolute error (MAE). These metrics provide practical, unit-interpretable checks of alignment between model predictions and observed program ranks.

Visualization and reporting

Descriptive distributions (e.g., histograms of attention), bivariate scatterplots (attention vs citations) at paper/faculty/program levels, forest plots of ORs with 95% CIs (log scale), AIC bar charts (raw vs LOO means), and predicted-vs-observed rank scatterplots were used for presentation and model diagnostics in figures. Tabular results (OR tables) were rendered with gt[9].

Software

All analyses were performed in R, using Modern Applied Statistics with S (MASS)[14] for ordinal models, dplyr[16]/tidyr[17] for data wrangling, ggplot2[15] for figures, and gt for tables.

Results

Study Sample Characteristics

The cleaned dataset yielded 2047 publications across 695 physicians of the top 25 programs.

Paper-level analysis

Faculty level analysis

Most faculty have relatively low mean attention scores, with an average attention score of 66.08 across 695 individuals. This dynamic resulted in a heavy right skew. A small minority of faculty had very high mean attention scores. These findings, depicted in Figure 2, demonstrate that attention is not evenly distributed among faculty members and that some physicians achieve a high level of online notoriety. Analysis yielded a mildly positive correlation between mean citations and attention score for each physician, suggesting that attention and citations are related but distinct measures of influence, and emphasizing that those metrics may be independent predictors of program rank.

Program level analysis

At the program level, mean citations and mean attention per faculty showed a moderate positive association (Figure 3). Programs with higher citation averages also tended to have higher attention averages. The spread indicates that attention is not a perfect proxy for citations. Some programs achieve higher attention relative to their citation output, suggesting they could be more effective at disseminating their work broadly, while others are more citation-heavy but draw less public/social attention.

Ordinal Logistic Regression and Odds Ratios

Ordinal logistic regression was used to test the relationship between academic and social media metrics and Doximity program reputation. Three models were compared. The aggregate model (A), which combined mean attention and citation counts, did not identify either variable as a significant predictor of program rank (AIC = 211.9). The component model (B) separated attention into tweets, blogs, and news mentions while controlling for citations. This model fit the data more accurately (AIC = 198.5). Blog mentions were a strong positive predictor of higher rank (OR 29.6, 95% CI 3.9–226.4, $p < 0.01$). News mentions showed a weak negative trend (OR 0.57, 95% CI 0.33-1.00). Tweets and citations were not significant.

The social-only model (C), which excluded citations, showed the best overall fit (AIC = 196.6). Blog mentions again remained significant (OR 26.9, 95% CI 3.8-192.4). News mentions remained weakly negative, and tweets were not associated with rank. Cross-validation confirmed consistent results (mean LOO-CV AIC 187-189). Model performance was strongest for the component and social-only models (Spearman ρ = 0.60–0.62). Aggregate attention and citation-based measures alone did not explain variation in program reputation.

Cross-validation and Robustness

Leave-one-out cross validation (LOO-CV) confirmed the accuracy of Model C (social-only) when compared to Model A and B. Model results were: Aggregate (A): mean LOO-CV AIC = 201.45 (SD 0.35), Components (B): mean LOO-CV AIC = 188.66 (SD 2.60), Social-only (C): mean LOO-CV AIC = 186.87 (SD 2.57). These findings indicate that the social-only and components models fit the data better and generalize more effectively to programs with lesser attention.

Predictive Performance

In predictive accuracy analyses, the aggregate model (A) showed limited ability to reproduce observed Doximity reputation rankings. The correlation between predicted and observed ranks was low (Spearman ρ = 0.20), and the mean absolute error (MAE) was 5.85 ranks.

Model B achieved a Spearman correlation of .62 and MAE of 4.42. Model C demonstrated Spearman correlation of .60 and MAE of 4.43. Thus, incorporating social media variables increased rank-order

agreement roughly threefold and reduced prediction error by ~1.4 rank positions compared with the aggregate citation-based model.

Discussion

Neurosurgery as a specialty has placed high importance historically on the research output of its faculty, fellows, residents, and even prospective applicants[3, 10]. Academic acumen, as gauged by factors such as h-index, citations, and unique publication counts, is a key feature of any neurosurgery residency application. Likewise, program ranking itself has been highly influenced by and correlated to objective measures of research output, with more prestigious programs often placing higher importance on the aforementioned factors[4, 10, 11]. In recent years, online visibility has played an increasingly significant role[3]. Neurosurgeons across the country have been able to promote both their individual practice and program through online visibility. Our goal through this analysis is to provide insight into the degree of impact this online attention has on program reputation.

At the paper level, exposure to any given publication may occur through means such as PubMed, Google, Scopus, or other search as well as promotion through social media. Impactful literature is often posted, tweeted, and blogged through many different sites, apps, and profiles. Our paper-level analysis, showing skew towards a few publications, supported the idea that some papers and their content gain massive amounts of traction online. Papers that employ eye-catching titles and easy-to-understand terminology can appeal to readers who may not have an advanced level of medical knowledge, increasing like, share, and repost counts. Such exposure increases visibility not only for the authors but also for their associated institution. For example, *Human hippocampal neurogenesis drops sharply in children to undetectable levels in adults* by Sorrells et al. had one of the highest attention scores in our analysis (2291), with an associated 1183 tweets and 167 news articles. Its understandable and appealing title likely contributed to its extremely high tweet count, allowing their findings to spread fast and generating more visibility for the authors and the neurosurgery department at University of California, San Francisco.

The faculty-level analysis demonstrated a similar dynamic. Certain authors possessed extremely high levels of online attention, while the mean attention store across all was low, leading to another right skew. This finding once again supports the notion that some physicians are able to gather a large amount of social attention while the average neurosurgeon's online attention remained lower. Additionally, the correlation between mean attention and citations was moderate, indicating that the impact of those two variables is related yet distinct. Regression analysis also showed that mean citations per faculty and mean attention per faculty were moderately correlated, indicating that programs with more citations also garnered more attention. Moderate correlation indicates that attention is related to, but not fully correlated to academic output. A possible explanation for this trend is that programs that output more research also strive to increase their attention online. Departments that promote their own literature through their respective social media channels can increase read and citation count via that channel, which could explain the moderate correlation between those factors. Relying on journal

publication alone as means to report findings may result in both lower social exposure and total online attention.

Regression modeling revealed interesting trends among the top 25 programs. In model A, aggregating social attention and citations failed to demonstrate significance, reinforcing the idea that those two variables influence rank separately. Model B, including all components of social attention, had a substantially lower AIC, revealing that evaluating total attention separately by social component and citations improves predictability. In the same manner, the social-only model had the best AIC; in particular, blog coverage was an extremely strong predictor. On the whole, social media engagement was a far stronger and more robust predictor of reputation rank, a conclusion which is reinforced by the results of the LOO cross-validation. Splitting attention into its two distinct components increased predictive value, reinforcing the idea that social attention is an entirely separate influencer of rank.

Publications are at the heart of this analysis due to their historical impact on reputation, and the ways in which they exert that influence seem to be changing. While journal content via website and print edition lend traditional exposure to paper content, increasing usage of platforms like Facebook, Twitter, and more allows authors to promote their content through such sites as well. Advantages offered by presenting publication material in that manner include shorter reading time, lack of journal paywall, easy sharing/reposting options, and greater engagement with readers. Physician and program-specific pages automatically present posted content to followers, generating clicks and increasing engagement with said pages and the entities they represent. Programs that lean into this dynamic can generate greater amounts of exposure and increase their reputation by demonstrating their important literature in a concise and easy to read manner.

With this dynamic in mind, dissemination of study results through social media before peer review has taken place can lead to misconceptions and premature conclusions. An example of such rapid spread was observed when the NASCIS II clinical trial, which reported that high-dose methylprednisolone administration within 8 hours of spinal cord injury improved neurologic recovery[2]. These results were widely promoted and implemented by institutions around the country. However, later review revealed that this conclusion was based on post-hoc analysis, and the actual benefit was controversial[5, 8]. Today, modern guidelines do not recommend high dose steroids for acute spinal cord injury[1]. This instance reflects the direct effect that social attention has on clinical practice and should inspire caution when disseminating early preliminary study results.

In similar fashion, blog coverage may also reflect deeper engagement within the neurosurgical community. Many posts highlight ongoing projects, clinical achievements, or new publications The University of Miami Department of Neurosurgery engages in this sort of activity with its blog *Neurosurgery Blog: More Than Just Brain Surgery*[20]. Their site encourages posts from their own faculty as well as physicians from other programs across the country, publishing several in-depth articles monthly. This type of communication can shape perceptions of productivity and leadership in ways that citation counts do not, allowing direct communication between physicians from different programs.The

results suggest that program visibility, especially through consistent online engagement, may now play a measurable role in how reputation is formed.

Limitations and Future Directions

Several limitations should be acknowledged in this study. The analysis was restricted to the top 25 neurosurgery residency programs, which may limit generalizability to mid- or lower-ranked institutions. Only the top three publications per faculty member were included, potentially underrepresenting overall scholarly output and online impact. Social media metrics such as tweets, blogs, and news mentions are also inherently ambiguous and may reflect institutional promotion or general public interest rather than true program-driven engagement. Although robust modeling approaches were used, the relatively small sample size reduces the ability to detect more subtle associations. Expanding publication capture beyond each faculty member's top three works would allow a more comprehensive assessment of scholarly activity and visibility. Additionally, evaluating emerging platforms such as podcasts, TikTok, LinkedIn, and YouTube may provide a fuller understanding of how modern digital presence influences residency program reputation.

This study is an exploratory analysis of elite programs; such institutions have garnered a level of fame and interest through long-term academic reputation that may not generalize well towards newer and less academically focused programs. The observational design prevents causal inference, as higher program reputation may itself drive greater online visibility just as increased visibility may influence perceived reputation. Future projects may expand on these conclusions by quantifying a larger or even all-encompassing dataset of neurosurgery residency academic metrics.

Lastly, Doximity rankings, while multifactorial in nature, include certain subjective characteristics which may introduce bias. Some authors argue that Doximity rankings may include a circular methodology to characterize programs, where reputation influences rank which in turn influences reputation later on. As such, Doximity rankings should be viewed as a metric of reputation perception rather than an objective assessment of program training quality. Despite such limitations, the Doximity system is one of the most prominent and widely viewed[7], hence its utilization in this study.

Conclusion

In the current era of digital communication, social media has become a central part of academic medicine, shaping how research is shared, reputations are formed, and professional networks expand. In neurosurgery, it has emerged as an important means for academic visibility and engagement. Platforms like Twitter, Instagram, LinkedIn, and YouTube allow surgeons to share new techniques, highlight clinical cases, discuss evidence-based updates, and disseminate research more rapidly than traditional journals alone.

The results of this study suggest that social media activity contributes directly to program reputation. Among leading neurosurgery residency programs, online engagement, especially through blog mentions,

was more strongly associated with higher Doximity rankings than traditional citation metrics. This reflects a shift in how academic influence is recognized: visibility and accessibility of research discussions online now play a meaningful role alongside established bibliometric indicators.

This trend underscores the growing importance of digital presence in shaping academic identity. Programs that use social media strategically to communicate research, showcase achievements, and engage with the broader medical community may enhance both their visibility and perceived leadership. As social platforms continue to evolve, their integration into academic culture will likely remain essential for effective communication, collaboration, and public engagement in neurosurgery.

Declarations

Conflicts of Interest

The authors have no conflicts of interests or disclosures to report.

Competing Interests

The authors declare no competing interests.

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Author Contribution

Patrick Pema conceived and led the study. Patrick Pema directed study design, coordinated project execution, interpreted the findings, and wrote the first draft of the manuscript. Patrick Pema designed the figures and outlined tables. Akil Anthony and Michael Chaga performed the statistical analyses and contributed to interpretation of the data. Youssef Atef AbdelAlim, Jack Kilgallon, Kush Desai, Paxton Sweeney, and Daniel Monahan contributed to data collection and manuscript editing. Ira Goldstein, Shabbar Danish, and Nitesh Patel contributed to manuscript appraisal, critical revision, and editorial guidance. All authors reviewed previous versions of the manuscript, read and approved the final manuscript.

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project.

Data Availability

The data used in this study were derived from publicly available sources, including neurosurgery program rankings from Doximity.com, Scopus.com for author h indices and citation metrics, and Altmetric.com for social media occurrences using the Altmetric bookmarklet, a free tool available to the public. Current faculty were gathered from each program's own website. The processed dataset generated during the current study is available from the corresponding author on request.

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Figures

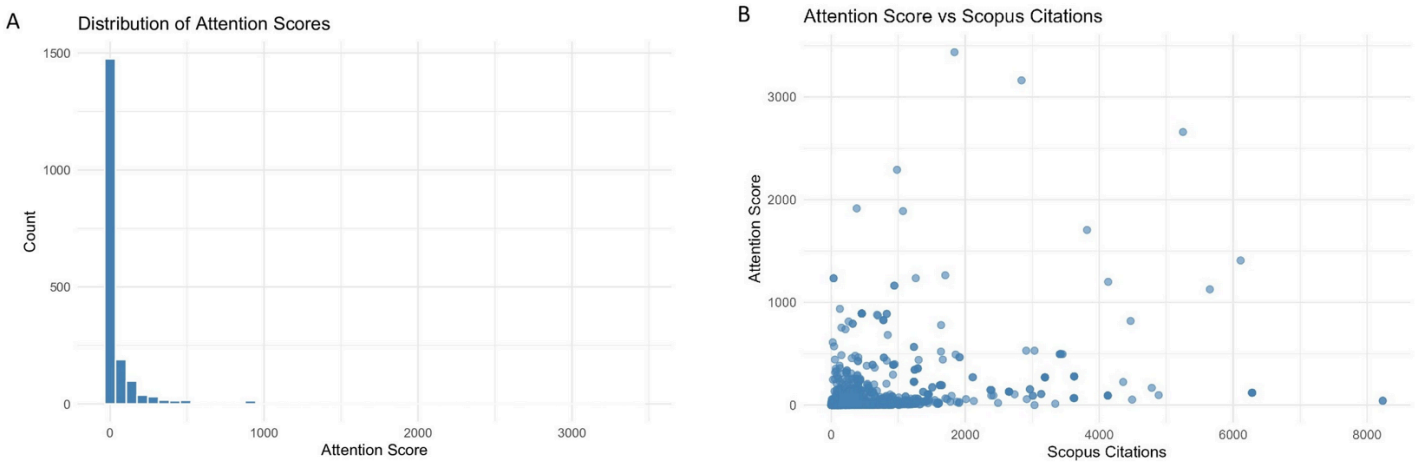


Figure 1

A: Distribution of attention scores of individual papers. The vast majority of papers had an Altmetric attention score of less than 10 (1071 out of 2047), indicating low exposure on social media. Certain papers have an extremely large amount of social media attention, leading to a right skewed distribution.
B: Attention Score vs. Scopus Citations. The scatterplot indicates that, while a moderate correlation is observed between Scopus citations and attention score, these variables are not redundant. Many papers have low citations but high attention scores, and many others have high citations but minimal attention online. This finding supports the central hypothesis that attention score captures a different dimension of reader activity and that online impact matters independently of traditional metrics like citations.

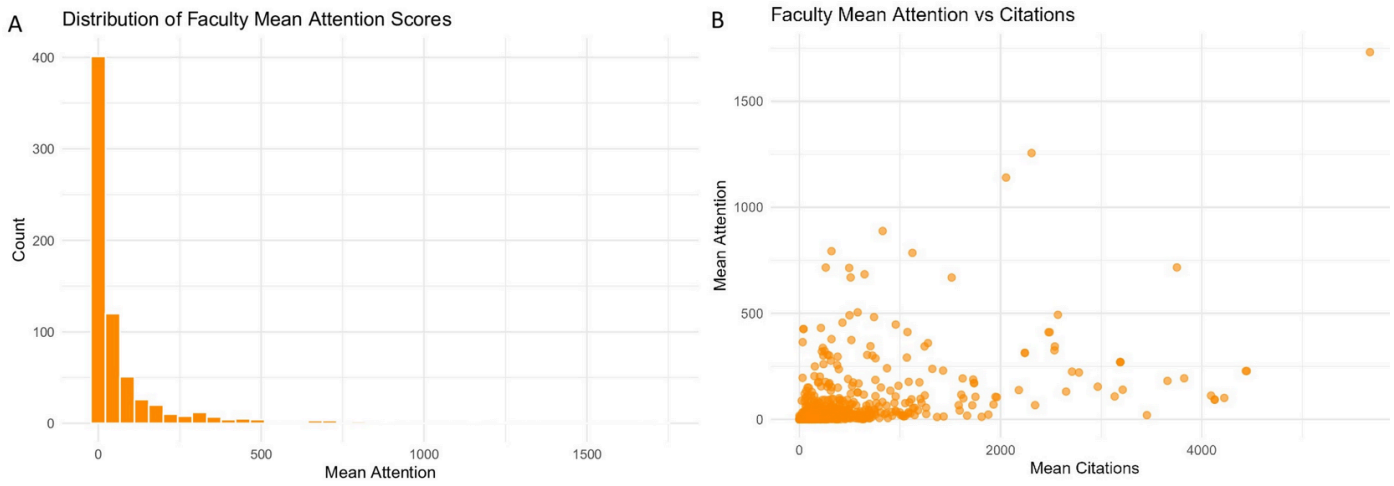


Figure 2

A: Distribution of faculty mean attention scores. B: Scatterplot of mean citations vs attention score for each physician. The plot depicts a mildly positive correlation between citations and Scopus references (R^2 = .2109).

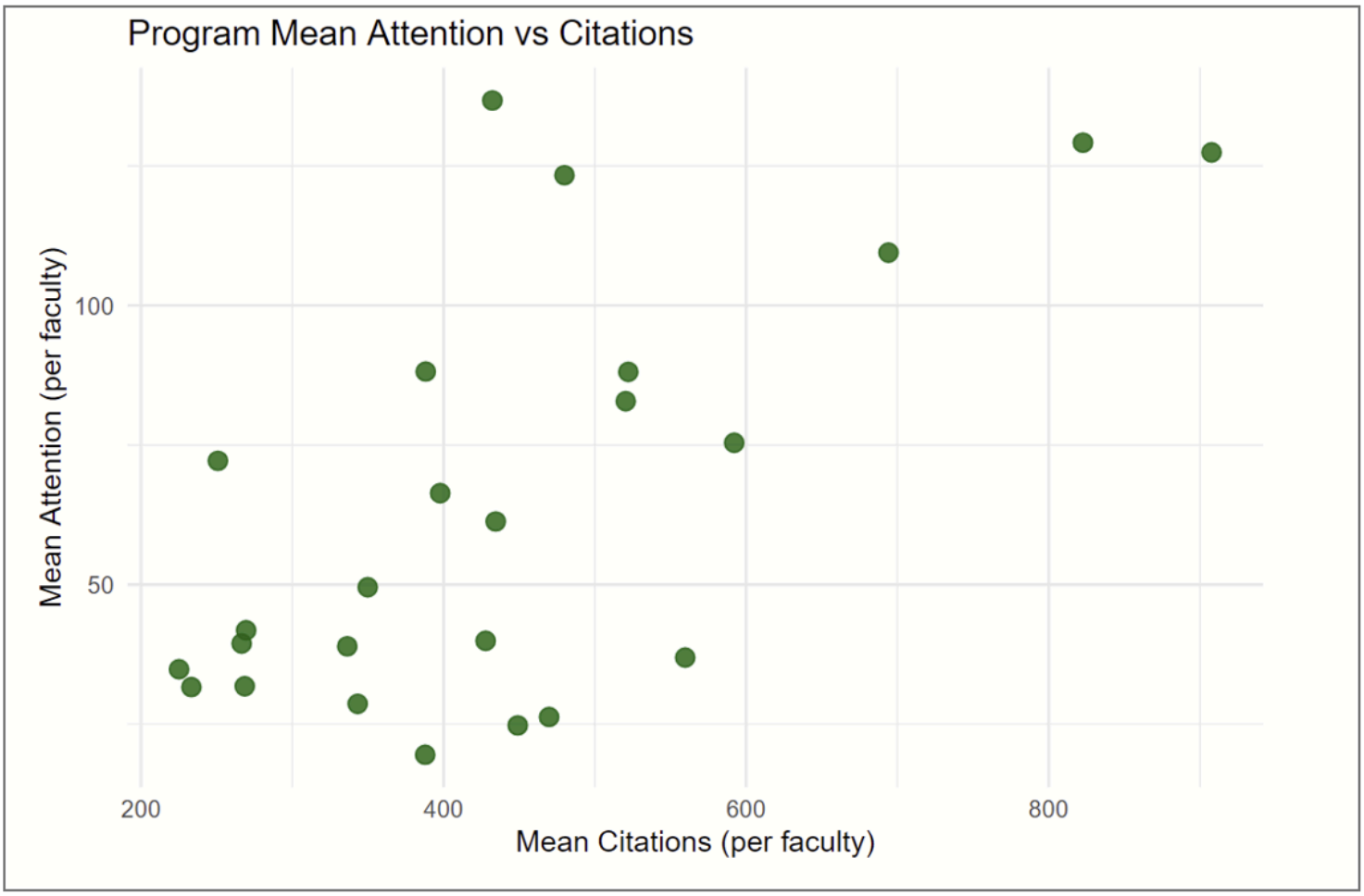


Figure 3

Mean citations vs. Mean attention score per faculty of each program. The plot shows a moderate positive relationship (R2= .4209).

Odds Ratios with 95% CI (Ordinal Regression)

term	OR	CI_low	CI_high	t_value	model
mean_attention	0.99	0.97	1.01	-0.9968274	Aggregate (A)
mean_citations	1.00	1.00	1.01	0.8689179	Aggregate (A)
mean_blogs	29.59	3.87	226.44	3.2621329	Components (B)
mean_news	0.57	0.33	1.00	-1.9726992	Components (B)
mean_tweets	0.98	0.92	1.06	-0.4641064	Components (B)
mean_citations	1.00	0.99	1.01	-0.3766135	Components (B)
mean_blogs	26.92	3.77	192.44	3.2813512	Social-only (C)
mean_news	0.60	0.36	0.99	-1.9816462	Social-only (C)
mean_tweets	0.97	0.93	1.02	-1.2150593	Social-only (C)

Figure 4

Odds Ratios with 95% CI for Models A, B, C. Blog attention was the strongest predictor of program rank.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalTable1.docx