Research Article

The Orthopaedic Match: Defining the Academic Profile of Successful Candidates

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ABSTRACT

Background: Research productivity forms a vital part of the resident selection process and can markedly affect the chance of a successful match. Current reports regarding the publication record among prospective orthopaedic surgery residents are likely inaccurate. Potential applicants have a poor understanding of the strength of their research credentials in comparison to other candidates.

Methods: We identified matched applicants from the 2013 to 2017 orthopaedic surgery residency application cycles. We performed a bibliometric analysis of these residents using Scopus, PubMed, and Google Scholar to identify published articles and calculate the *h*-index of each applicant at the time of application. Details were collected on medical school, advanced degrees, publication type, first authorship, and article relatedness to orthopaedic surgery.

Results: We included 3,199 matched orthopaedic surgery applicants. At the time of application, the median *h*-index was 0, the median number of publications was 1, and 40% of successful candidates did not hold any publications. The *h*-index (R 0.08, $P < 0.0001$) and median number of publications of matched orthopaedic surgery residency candidates significantly increased (R 0.09, $P < 0.0001$) across application cycles. Furthermore, the proportion of matched applicants without publications at the time of application significantly decreased (R −0.90, $P = 0.0350$). Conversely, the percentage of articles first-authored by applicants decreased (R −0.96, $P = 0.0093$), but article relatedness to orthopaedic surgery remained constant (R 0.82, $P = 0.0905$). Strikingly, notable changes were observed in the type of articles published by successful applicants: the proportion of preclinical studies decreased (R −0.07, $P = 0.0041$), whereas clinical research articles increased (R 0.07, $P = 0.0024$).

Conclusion: The publication count held by successful orthopaedic surgery applicants is substantially lower than the nationally reported

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average. Matched orthopaedic surgery candidates demonstrate increasingly impressive research achievements each application cycle. However, increased academic productivity comes at the cost of reduced project responsibility and a shift toward faster-to-publish articles.

Orthopaedic surgery continues to be one of the most competitive specialties in the residency match[1]; in 2018, almost one quarter of applicants to orthopaedic residency programs failed to match.[2] The high volume of applications has led many programs to use quantifiable characteristics to compare highly qualified candidates.[3,4] However, the United States Medical Licensing Examination (USMLE) Step 1 score which acts as a screening tool for many orthopaedic surgery programs[5,6] will change from a numeric value to a pass/fail system.[7] This may increase the importance of other objective metrics, such as publication record, as a means of evaluating candidates. Research productivity forms a vital part of the resident selection process and can markedly affect the chance of a successful match[1,8]; matched applicants consistently have greater research achievements than their unmatched counterparts.[9]

Unlike other objective application metrics, such as USMLE scores and Alpha Omega Alpha status, prospective applicants can continually augment their publication volume. This has resulted in escalating academic credentials. In 2019, matched orthopaedic surgery applicants had an average of 11.5 publications, presentations, and abstracts—a fourfold increase since 2007.[9-11] Given the impressive qualifications of matched orthopaedic surgery applicants, application for residency in this highly competitive field can present a daunting task to medical students.

However, potential applicants have a poor understanding of the strength of their research credentials in comparison to other candidates. Residency programs do not provide information regarding the qualifications of successfully matched applicants. Although the National Residency Match Program (NRMP) provides descriptive data on the research achievements of matched orthopaedic surgery residents,[11,12] its usefulness is limited by its self-reported nature; the lack of distinction between publications, abstracts, and conference presentations; a paucity of data on the relative contribution of the candidate (as indicated by position on the authorship list); and the use of parametric tests to report highly skewed data. Furthermore, standard deviations are not reported, so the variability of candidates' research portfolios is unknown. Given the impending change to USMLE scoring and the utility of research qualifications as an evaluative tool, reliable and comprehensive information on research achievements of matched orthopaedic surgery residency candidates is needed to properly inform prospective applicants and those who counsel them.

We hypothesize that the verified research portfolios of matched orthopaedic surgery candidates are less impressive than suggested by national reports. Using validated sources, we establish accurate data on the research credentials (publication volume and scholarly impact) of matched orthopaedic surgery residents at the time of application. Furthermore, we analyze trends in research achievements of matched orthopaedic surgery residents for the five consecutive application cycles and characterized factors associated with greater research contributions.

Methods

Study Population

This study was reviewed by the University of Maryland Institutional Review Board and deemed to be exempt. We identified orthopaedic surgery residency programs as listed by the Accreditation Council for Graduate Medical Education.[13] Current residents for each program were identified by visiting the official websites of each residency program. We collected data for the academic years 2014 to 2018, which correspond to the 2013 to 2017 application cycles. We then collected details on gender, postgraduate year, additional degrees, and medical school from individual program websites, Doximity (www.doximity.com), and/or LinkedIn (www.linkedin.com). Allopathic medical schools located in the United States were grouped into four tiers dependent on their National Institute of Health (NIH) research ranking[14]: top 40, ranked 41 to 80, ranked 81 to 120, and ranked below 120. We excluded all residents who applied for the residency match before 2013.

Academic Productivity

We used the Scopus (www.scopus.com), PubMed (www.ncbi.nlm.nih.gov/pubmed), and Google Scholar (https://scholar.google.com) databases to identify the peer-reviewed publications of each applicant. To account for publication lag, we included journal articles that were published on or before September of the first postgraduate year; that is, for an individual who was successful in the 2014 to 2015 application cycle and then started residency training in July 2015, we included

articles published in print on or before September 2015. This was done in an attempt to reflect the information that would have been available in the match applications and be inclusive of articles listed as "accepted" as part of the application.

We collected the following research details for matched candidates at the time of application: (1) *h*-index, (2) total number of research publications, (3) number of first-authored articles, (4) number of articles focused on orthopaedic surgery topics, (5) number of preclinical studies, (6) number of clinical research articles, (7) number of literature reviews, (8) number of systematic reviews and meta-analyses, (9) number of short reports, (10) number of book chapters, and (11) number of editorials. Erratums were excluded from publication counts.

The *h*-index measures the individual's scholarly impact by calculating a numeric value based on the number of publications and article citations. This provides a more effective measure of the quantity and quality of research.[15] We manually calculated the *h*-index at the time of application by reviewing the publication date of citing articles and only including those published before the application. The *h* value is equal to the numbers of articles, "*h*," that have been cited at least "*h*" times. For example, author A has three publications which have cited 1, 5, and 14 times, respectively. Author A has a *h*-index of two because only two articles have at least two citations. We also categorized the publications according to study type, for example, preclinical versus case reports. Publication type is often related to the level of evidence of an article so can act as additional proxy for research quality and a measure of the educational value and commitment of prospective residents.

Orthopaedic surgery-relatedness of the study was determined through review of the abstract and the specialty of the publishing journal. Preclinical studies included in vitro, in vivo, and biomechanical research. Clinical investigations and anatomic studies were categorized as clinical research articles. Short reports included case reports and technique articles. Editorials included letters to the editors, commentaries, and editorials.

Data Analysis

Composite data were stored and analyzed in a preformatted spreadsheet in Microsoft Excel (Microsoft 2016). The Kolmogorov-Smirnov test demonstrated that *h*-index and the number of publications did not follow a normal distribution. Therefore, these variables are summarized and analyzed using median values and interquartile ranges (IQRs). We also report the mean values for the purpose of comparison to NRMP data. The chi-squared test was used to test for differences between categorical data. Spearman rank correlation (coefficient r_s) and linear regression (Pearson correlation coefficient R) models were used to analyze temporal trends in nonparametric and normally distributed data, respectively. We performed a multivariate analysis to identify factors associated with an increase in *h*-index and publication count. Statistical significance was defined as a two-tailed value of $P \leq 0.05$.

Results

We included 3,199 matched orthopaedic surgery applicants. Most were men (84%) and graduated from an allopathic US medical school (98%). Over one-third (35%) of matched orthopaedic surgery applicants graduated from a medical school in the top 40 NIH ranking. Four percent of our cohort possessed an advanced degree in addition to their medical qualifications (Table 1).

At the time of application, candidates had an average of 2.6 ± 6.6 articles. However, these data were highly skewed, so we also report the median values. The median number of publications was 1 (IQR, 0 to 3) and the median h-index among matched candidates was 0 (IQR, 0 to 1).

Publication Details

Forty one percent (n = 1,308) of matched orthopaedic surgery residency applicants did not hold any publications at the time of application. Of the applicants with publications, the average candidate first authored over one quarter of their articles (28%) and most of their publications were dedicated to orthopaedic surgery-related topics (70%). Clinical research articles were the most common publication subtype (53%), whereas book chapters were the least prevalent (2%). Full details of the distribution of publication type are shown in Table 2.

Temporal Analysis

Matched orthopaedic surgery residency candidates demonstrated a significant increase in scholarly impact (Spearman r_s 0.06, P = 0.0009) and publication volume (Spearman r_s 0.11, $P < 0.0001$) across application cycles (Figures 1 and 2). During the same period, the proportion of matched candidates without any publications markedly decreased (R −0.90, P = 0.0350). Conversely, the percentage of articles first-authored by the applicant decreased over time (R −0.96, P = 0.0093). The percentage of publications related to

Table 1. Characteristics of Matched Orthopaedic Surgery Applicants

Characteristic	Matched Orthopaedic Surgery Applicants (*n* = 3,199)
Gender	
Male	2,701 (84.4%)
Female	498 (15.6%)
Application yr	
2013	627 (19.6%)
2014	630 (19.7%)
2015	634 (19.8%)
2016	650 (20.3%)
2017	659 (20.6%)
US allopathic medical school NIH ranking	
Rank 1-40	1,116 (34.9%)
Rank 41-80	1,118 (34.9%)
Rank 81-120	666 (20.8%)
Ranked below 120	229 (7.2%)
US osteopathic medical school	18 (0.6%)
International medical graduate	52 (1.6%)
Additional advanced degree[a]	143 (4.5%)

NIH = National Institute of Health
[a]Defined as possession of a graduate degree (masters or PhD) in addition to MD or DO degree

orthopaedic surgery increased, but this did not reach significance (R 0.82, $P = 0.0905$).

Strikingly, the distribution of certain publication types significantly changed across the five application cycles. The percentage of preclinical studies significantly decreased (R −0.07, $P = 0.0041$), whereas clinical research articles significantly increased (R 0.07, $P = 0.0024$). The other publication types did not show notable changes over time (Figure 3).

Multivariate Regression

We performed a multivariate analysis to identify applicant characteristics associated with an increase in *h*-index and publication count. Graduation from an international medical school and possession of an additional advanced degree were independently associated with increased *h*-index and publication count ($P < 0.0500$). International medical graduate status was associated with an increase of 1 in h-index and 16 additional publications, whereas attaining an advanced degree increased *h*-index by 0.85 and publication count by 2.4. NIH ranking of medical school did not influence research qualifications (Table 3).

Discussion

Research is an important factor used to discriminate between highly qualified orthopaedic surgery residency applicants. The impending change of the USMLE Step 1 scoring system to pass/fail[7] would preclude the use of a threshold score as a screening tool for orthopaedic surgery residency programs. This may increase the importance of publication volume as a tool to evaluate candidates. Therefore, an accurate assessment of the research credentials of successful applicants is needed to guide prospective medical students. We present accurate data on the research credentials among matched applicants at the time of application. There are four key findings: (1) the publication count held by successful applicants is substantially lower than the NRMP-reported average, (2) matched orthopaedic surgery candidates have more impressive research achievements each application cycle, (3) as publication volume increases, the role of the applicant decreases, and (4) matched applicants appear to be shifting research interests toward projects that are faster to publish.

Strikingly, the publication volume found using verified data sources (2.6) was substantially lower than the national average (11.5). This is consistent with previous studies that demonstrate inconsistencies between NRMP-reported data and the verified publication record of

Table 2. Publication Details of Matched Orthopaedic Surgery Applicants

	Publications (*n* = 8,467)
No. of articles first-authored by applicant	2,358 (28%)
No. of articles related to orthopaedic surgery	5,917 (70%)
Article type	
Basic science	1,650 (19%)
Clinical research	4,499 (53%)
Literature review	867 (10%)
Systematic review and meta-analysis	342 (4%)
Short report	695 (8%)
Book chapter	190 (2%)
Editorial	222 (3%)

Figure 1

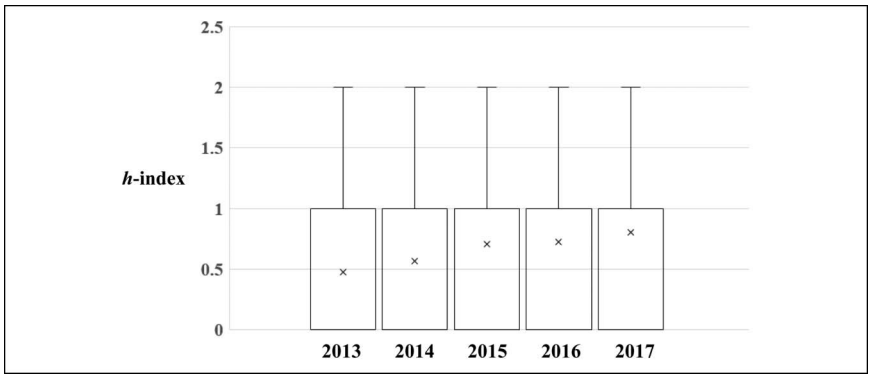

Chart showing the boxplot of *h*-index of matched orthopaedic surgery residency candidates at the time of application. This demonstrates a significant increase in *h*-index across five application cycles (Spearman r_s 0.06, $P = 0.0009$).

orthopaedic surgery residency candidates[16-18] and other surgical specialties.[19-21] This discrepancy may be due to a number of factors. First, the NRMP reports publications in the same total as abstracts and conference presentations; therefore, one's research profile can be artificially inflated by reporting multiple presentations and posters for a single project. This holds implications for unsuccessful candidates. Unmatched applicants share the same number of research experiences but produce half the number of research products (publications, abstracts, and presentations).[11] Given our finding that four of 10 matched orthopaedic applicants did not have any peer-reviewed publications at the time of application, it is possible that the number of research products bears more weight than the number of peer-reviewed publications. Second, NRMP data are self-reported and thus relies on the candor of the applicant. The phenomenon of phantom publications is common among orthopaedic surgery candidates.[17,18] Academic misrepresentation may not be deliberate and can simply be the inclusion of submitted manuscripts which, through circumstances outside of the applicant's control, may not be published.

The orthopaedic match process grows increasingly competitive with each passing year[9,10]; since the implementation of the 80-hour work week, residency applications to orthopaedic surgery increased by more than 20%.[22] Research and publications are an important factor in assessing residents' success,[5] and research productivity can strengthen a residency application.[8,23] Therefore, it is unsurprising that our results demonstrate increasing research qualifications as this likely mirrors the growing competition for a residency position. To our knowledge, we are the first study to report on the *h*-index of successful orthopaedic surgery residency applicants. Matched orthopaedic surgery candidates have a greater scholarly impact; this may reflect publication in higher impact journals or early involvement in research which allows citations to build over time.

Figure 2

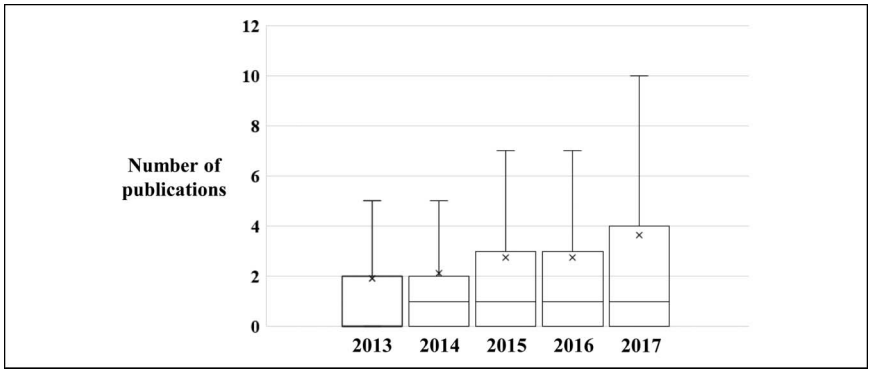

Chart showing the boxplot of the number of publications held by matched orthopaedic surgery residency candidates at the time of application. This demonstrates a significant increase in publication volume across five application cycles (Spearman r_s 0.11, $P < 0.0001$).

Figure 3

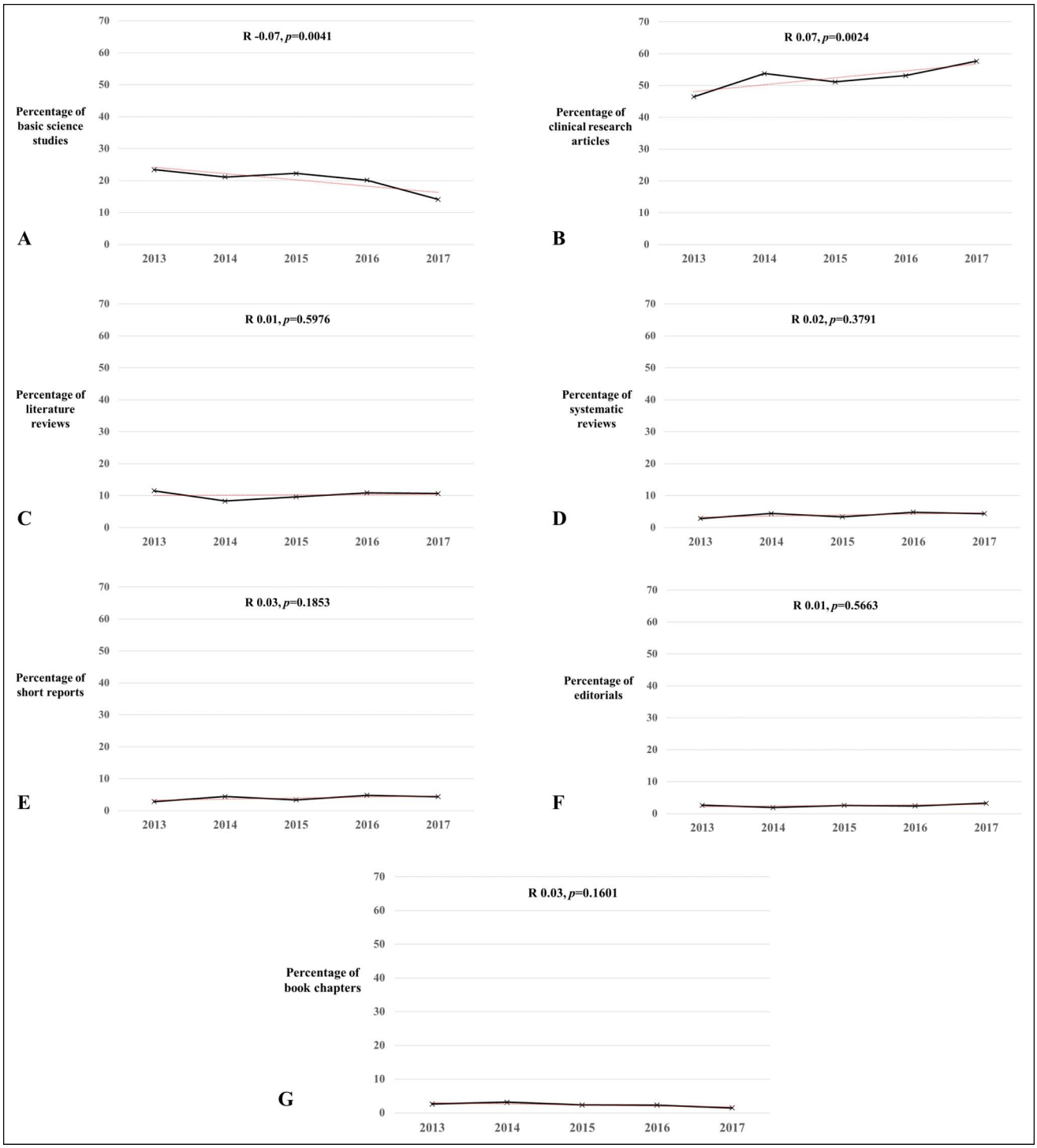

Illustration showing the trend in the percentage of article types of publications held by matched orthopaedic surgery candidates at the time of application. **(A)**, Basic science studies, (**B**) clinical research articles, (**C**) literature reviews, (**D**) systematic reviews, (**E**) short reports, (**F**) editorials, and (**G**) book chapters.

Predictably, possession of an advanced degree markedly increased publication count and academic impact. Those with additional graduate degrees are likely to have greater exposure and opportunity for research. Interestingly, NIH medical school ranking was not a predictor of increased research qualifications, consistent

Table 3. Multivariate Regression to Identify Associated Factors for Increased *h*-Index and Publication Count

Characteristic	*h*-index		Publication count	
	Correlation coefficient	*P* value	Correlation coefficient	*P* value
Medical school NIH ranking				
Rank 1-40	0.32	0.3151	0.68	0.6445
Rank 41-80	0.07	0.8161	−0.62	0.6726
Rank 81-120	−0.17	0.6015	−1.43	0.3312
Below rank 120	−0.11	0.7489	−1.25	0.4073
International medical graduate	1.00	**0.0063**	16.16	<**0.0001**
Additional advanced degree[a]	0.85	<**0.0001**	2.39	<**0.0001**

NIH = National Institute of Health
[a]Defined as possession of a graduate degree (Masters or PhD) in addition to MD or DO degree.
Bold text denotes statistical significance.

with the literature.[16] This suggests that medical school rank does not convey an advantage when seeking research opportunities. Conversely, graduation from a medical school outside of the US was markedly associated with a greater *h*-index and publication volume. This may be due to the increased barriers faced by international medical graduates who also have lower USMLE scores than their US counterparts.[11,12] Research can compensate for other deficiencies in an application; students who completed a research year have a higher match rate than the national average despite lower USMLE Step scores.[8] Indeed, successful international applicants report triple the number of research products than matched US candidates.[11,12]

Nonetheless, the increased academic productivity seems to come at the cost of diminished roles on each publication. We report a notable downtrend of the proportion of articles first-authored by successful orthopaedic surgery applicants. In addition, applicants may be shifting their attention away from longer projects in favor of less time-consuming studies. This is evidenced by the decreased percentage of preclinical studies which take longer to produce publishable data, highlighting a concern that applicants view publications as a means to an end. A peer-reviewed publication is not the sole product of research experiences; research enables medical students to build relationships with mentors which can lead to strong letters of recommendation. Furthermore, research participation teaches candidates critical thinking skills, teamwork, and problem-solving abilities. The value of research beyond enhancing publication count should be emphasized to prospective applicants.

There are limitations to this study. First, data on unmatched orthopaedic surgery candidates are not available, so we were unable to compare these two cohorts. Second, we used online resources to collect data on residents. Program websites may have been outdated or included an incomplete list of residents. However, we collected data on 82% of current orthopaedic surgery residents,[24] so our results are likely representative of the current cohort. Third, we did not collect details on published abstracts and conference presentations, both of which form part of the research profile of an orthopaedic surgery applicant. However, these data are not publicly available and this information cannot be reliably ascertained for every individual. Therefore, we chose to focus on publications to reduce the chance of random error within the data. Fourth, we did not consider journal characteristics, such as impact factor. Nevertheless recent studies demonstrate that the assessment of an individual orthopaedic study's quality should not be determined by the journal impact factor.[25] Although, there has been an increase in fee-based journals which has increased the opportunities to publish, evidence suggests that these lower impact journals publish articles of equivalent importance and quality to that of subscription-based journals.[26] Moreover, there has been a growth in poorly cited articles in peer-reviewed orthopaedic journals to a rate comparable with open access journals.[27] Fifth, the *h*-index can be artificially elevated through self-citation. Given the short academic career of medical students, this is unlikely to influence the *h*-index at the time of application. Finally, orthopaedic surgery residency programs are unique, and some may favor subjective attributes over academic prowess. Therefore, broad generalizations about the importance of research to a successful match cannot be made. However, our results provide important information and debunk myths about the research credentials of orthopaedic surgery applicants.

Furthermore, our data are strengthened by using multiple large databases to verify publications, in contrast to NRMP data which is self-reported.

Conclusion

The average matched orthopaedic surgery candidate has one peer-reviewed publication, and only one in four have first-authored an article. The publication volume of successful applicants is substantially lower than the nationally reported average. This has implications for prospective orthopaedic surgery trainees, program directors, and faculty advisers who may refer to the national data when gauging chances of successful match. In addition, matched orthopaedic surgery candidates demonstrate increasingly impressive research achievements each application cycle. However, increased academic productivity comes at the cost of reduced responsibility and an associated shift toward faster-to-publish articles. These results can inform and guide orthopaedic surgery applicants and those who counsel them regarding the trends in applicant research credentials.

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