H-Index Predicts Academic Rank Among Full-time Academic Orthopaedic Trauma Surgeons Affiliated with Fellowship Programs

Joshua E Simson, MD[1], Clare K Green[2], John P Scanaliato, MD[3], Adam H Adler, MD[1], Justin D Orr, MD[3], Michael M Polmear, MD[3]

1) Texas Tech University El Paso TX. 2) George Washington University School of Medicine DC. 3) William Beaumont Army Medical Center TX.

Objectives: The purpose of this study was to investigate the association between Hirsch index (H-index) and academic rank among orthopaedic trauma surgeons affiliated with Orthopaedic Trauma Association (OTA) and Accreditation Council for Graduate Medical Education (ACGME) fellowship programs with academic appointments. Additional variables investigated included total number of publications and training program affiliation.

Design: Database review.

Participants: Orthopaedic trauma surgery faculty members at OTA and ACGME orthopaedic trauma surgery fellowship.

Main outcome measurement: H-index, total number of publications, academic rank, and fellowship training pedigree.

Results: The H-indices of 273 orthopaedic traumatologists from 57 fellowship programs were organized and calculated. There are strong correlations among total number of publications, citations, and H-index. Overall, there is a strong association with number of publications, number of citations, and H-index with higher academic rank. Overall, H-index was a stronger predictor of academic rank than total number of publications and citations. Appointment to the same program as an individual's fellowship training program and orthopaedic subspeciality fellowship outside of traumatology were not associated with academic rank.

Level of Evidence: IV, cross sectional analysis
Key words: trauma, fellowship, academic rank, H-index
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INTRODUCTION

Research productivity has traditionally been a key determinant for professional advancement within academic medicine, relying on number of publications and citations.[1] However, number of citations may be skewed by outliers from one or a few publications and provides limited insight regarding the overall quality of a researcher's scholarly activity.[2-5]

In recent years, there has been a push to move past these simple measures of productivity.[1-4] J. E. Hirsch first proposed the H-index in 2005 as a bibliographic metric to objectively assess the quality of a researcher's publications.[6] While originally developed for use in the natural sciences, its association with academic rank has since been validated by studies within a variety of both medical and surgical specialties.[7-16] Within the field of orthopaedics, the H-index has been used to evaluate research productivity among spine, sports medicine, hand, and total joint replacement surgeons.[17-21]

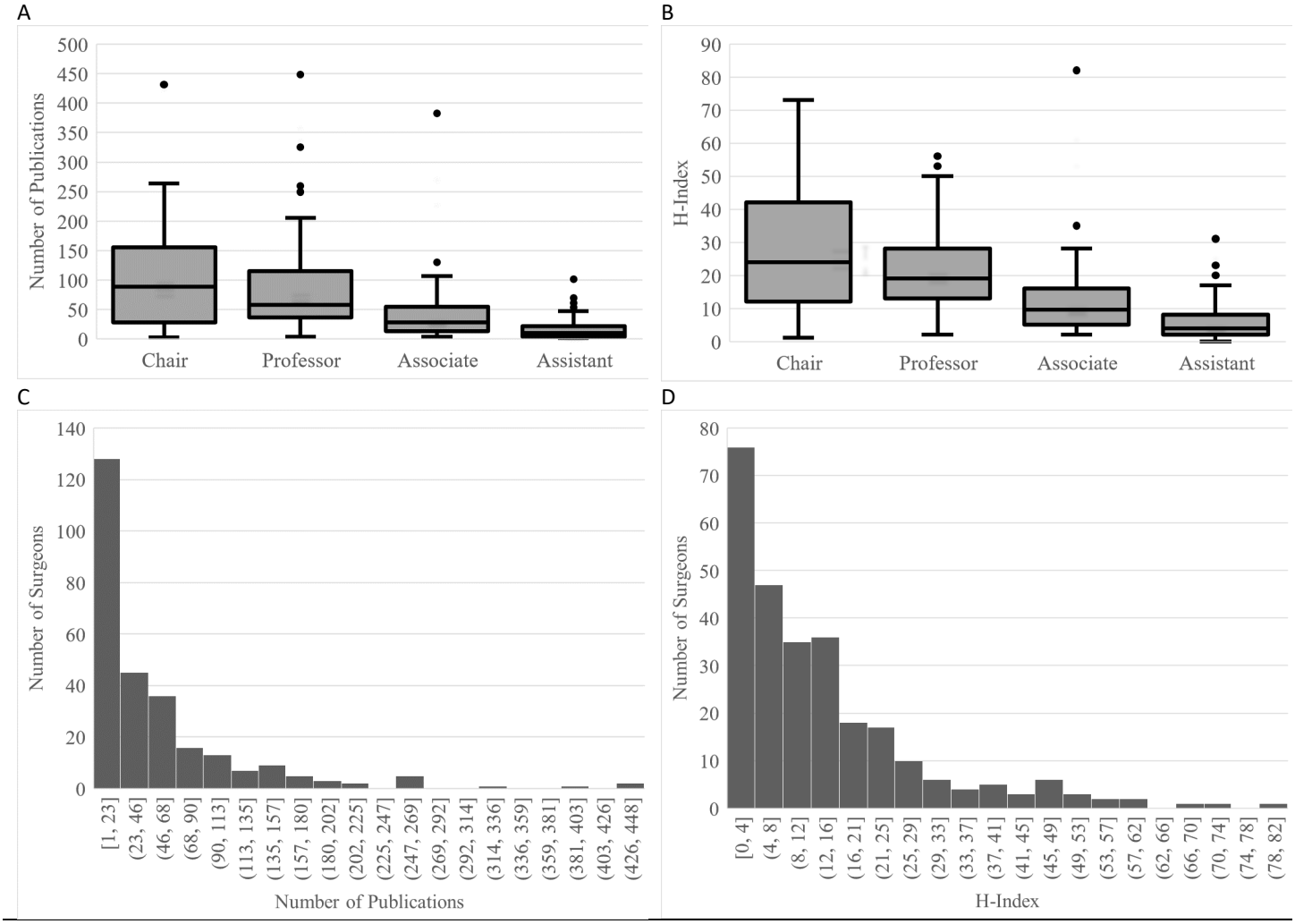
The purpose of this study was to assess the association between H-index and academic rank among orthopaedic trauma surgeons on faculty at fellowship training programs and with academic appointments. We hypothesized that H-index will have a much stronger correlation with academic rank than number of publications alone, number of citations alone, and training affiliation to current appointment. Secondarily, we hypothesize that location of fellowship training in relation to current appointment and subspeciality of fellowship will not be associated with current academic rank. Further, we hypothesize that there will be no differences in research productivity among geographic locations within the United States.

Table 1. Research productivity and affiliated training pedigree by academic rank

Rank	Surgeons	Affiliated Training (%)*	Publications**			Citations†			H-Index‡		
			Median	IQR	Min	Median	IQR	Min	Median	IQR	Min
Chair	39	15%	88	123	2	2263	4559	14	24	29	14
Professor	68	29%	58	69	3	1333	2133	9	19	15	9
Assoc Professor	58	24%	28	41	3	468	648	5	10	10	5
Asst Professor	108	23%	10	17	1	94	237	0	4	6	0
Total	***273***	*65 (24%)*	*25*	*56*	*0*	*415*	*1331*	*0*	*9*	*15*	*0*

Assoc: associate; Asst: assistant; IQR: interquartile range; Min: minimum
*Overall Kruskal-Wallis is not significant (p = 0.92) for differences in frequency of affiliated training among academic ranks.
Overall Kruskal-Wallis for academic rank and training affiliation by geographic region was not significant (p = 0.71).
**Overall Kruskal-Wallis was significant for total individual publications by academic rank (p < 0.001). Table s2a post-hoc analysis.
†Overall Kruskal-Wallis was significant for total individual citations by academic rank (p < 0.001). Table s2b post-hoc analysis.
‡ Overall Kruskal-Wallis was significant for individual H-Index by academic rank (p < 0.001). Table s2c post-hoc analysis. Bonferroni correction p = 0.005.

Figure 1. Number of publications by academic rank in box-and-whisker (A) and histogram (C) plots. H-index by academic rank in box-and-whisker (B) and histogram (D) plots.



METHODS

This is a cross-sectional study of full-time orthopaedic surgeons affiliated with orthopaedic trauma association (OTA) and Accreditation Council for Graduate Medical Education (ACGME) fellowship programs in the United States with academic appointments. The study population was constructed by querying the OTA website (accessed July 19, 2020) to obtain a complete record of all orthopaedic traumatology fellowship training programs. A total of 62 programs were identified, 51 of which were accredited by the OTA and 11 of which were accredited by the ACGME. For each program, the department website was used to generate a list of faculty members with academic appointments at affiliated institutions. Orthopaedic trauma fellowship programs constitute a heterogenous population of programs with academic, hybrid programs where some surgeons pursue academic appointments, and private practice where academic appointments are rare. Surgeons without academic appointments were excluded to decrease heterogeneity and narrow study population to full-time surgeons with academic appointments.

The primary predictor variables collected and utilized were number of publications, number of citations, H-index, fellowship sub-specialty, and location of fellowship training. H-index and number of publications were obtained from the Scopus database (accessed August 22, 2021, Elsevier B.V., Waltham, MA). For surgeons with multiple profiles, these variables were manually calculated to include all published works. The primary study outcome was academic rank, which was assigned one of four variables: chair, professor, associate professor, or assistant professor. Department chairs were classified in addition to their academic rank to demarcate leadership position.

Geographic region was assigned based on United States Census regions. Northeast region includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, and Pennsylvania. South region includes Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, and Texas. Midwest region includes Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa,

Table 2. Demographic and regional characteristics of affiliated training and research productivity by academic rank.

Region	Academic Rank	Surgeons	Affiliated Training (%)*	No. Publications			No. Citations			H-Index		
				Median	IQR	Min	Median	IQR	Min	Median	IQR	Min
Northeast (9 programs, 16%)	Chair	6	0	39	121	2	1306	3227	14	13	24	1
	Prof	11	27	59	35	25	1607	1341	248	20	10	8
	Assoc	9	22	34	21	10	348	413	24	10	5	2
	Asst	7	14	20	24	2	413	384	40	9	10	1
	Subtotal	*33 (12%)*	*18*	*41*	*40*	*2*	*586*	*1640*	*14*	*13*	*11*	*1*
South (21 programs, 37%)	Chair	9	11	94	111	5	1452	5254	75	22	35	3
	Prof	16	25	103	94	8	2390	2093	17	24	13	2
	Assoc	18	22	25	39	4	375	678	5	8	9	2
	Asst	45	24	7	16	1	64	152	0	4	5	0
	Subtotal	*97 (36%)*	*24*	*18*	*60*	*1*	*211*	*1217*	*0*	*7*	*16*	*0*
Midwest (12 programs, 21%)	Chair	8	50	48	73	11	856	953	28	16	9	3
	Prof	14	14	54	28	3	848	1048	9	16	10	2
	Assoc	5	0	18	32	4	288	591	26	7	9	3
	Asst	20	10	8	14	1	110	193	0	4	5	1
	Subtotal	*50 (18%)*	*20*	*25*	*47*	*1*	*437*	*1006*	*0*	*10*	*12*	*1*
West (15 programs, 26%)	Chair	16	6	127	92	25	3502	4517	357	32	24	10
	Prof	27	41	51	66	4	706	2845	24	16	17	2
	Assoc	26	31	28	46	3	479	913	36	10	10	2
	Asst	36	31	10	22	1	106	270	0	5	7	0
	Subtotal	*93 (34%)*	*28*	31	*75*	*1*	*478*	*1684*	*0*	*10*	*16*	*0*
Total (57 programs)		***273***	***65 (24%)***	***25 Total 14113***	***56***	***1 Max 448***	***415 Total 385292***	***1331***	***0 Max 21621***	***9 Total 3844***	***15***	***0 Max 82***

Chair: chairperson; Assoc: associate professor; Asst: assistant professor; IQR: interquartile range; Min: minimum; Prof: professor

Overall regression is significant ($p < 0.001$). Affiliation of training pedigree to current fellowship program appointment ($p = 0.81$) and sub-specialty of fellowship training (trauma vs. non-trauma, $p = 0.92$) were not significant predictors of academic rank.

Table 2a. Multivariate regression analysis for academic rank with H-index, number of citations, and number of publications.

	Coeff	Std Error	*P*	95% CI
No. Pubs	-0.0079	0.00084	<0.001	-0.01, -0.006
No. Citations	-0.00020	0.000021	<0.001	-0.0002, -0.0001
H-Index	-0.044	0.0038	<0.0001	-0.05, -0.04

Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. West region includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, Alaska, California, Hawaii, Oregon, and Washington. Productivity by region was calculated as number of publications divided by number of surgeons in each region.

Statistical analysis was performed using Prism GraphPad (San Diego, CA). Data normality was assessed using the Shapiro-Wilk test. Variance was assessed using Kruskall-Wallis test for non-parametric data that were not normally distributed due to skew and outliers. Post-hoc analysis on non-normally distributed data was performed using Mann-Whitney test with Bonferroni correction. Median differences for non-normal data were determined by Hodges-Lehman estimation. Median and interquartile ranges (Q3-Q1, IQR) were reported.

RESULTS

The OTA currently recognizes 62 orthopaedic trauma fellowships. Five programs (8%) did not have any faculty with academic appointments, and these programs were excluded from further analysis, leaving 57 (92%) programs for further characterization. Overall, 322 full-time fellowship-program associated orthopaedic trauma surgeons were identified. There were 49 (15%) surgeons without academic appointments, and they were excluded from further analysis. A total of 273 (85%) orthopaedic trauma surgeons on faculty at fellowship training programs were identified with concurrent academic appointments at affiliated teaching institutions (Table 2). Overall, these 273 surgeons have published 14,113 publications.

Table 3. Research productivity by training pedigree affiliation with current fellowship appointment for all academic ranks

Training Affiliation	Surgeons (%)	Publications			Citations			H-Index		
		Median	IQR	Min	Median	IQR	Min	Median	IQR	Min
Affiliated	65 (24)	31	52	0	536	1157	0	13	16	0
Not Affiliated	208 (76)	25	56	0	353	1393	0	9	16	1
Total	*273*	*28*	*54*	*1*	*444*	*1275*	*0*	*11*	*16*	*0*

No statistical difference in research productivity for those with affiliated training pedigree to current appointment by number of publications ($p = 0.57$), number of citations ($p = 0.75$), and H-Index ($p = 0.78$).

Table 4. Research productivity by region for all academic ranks

Region	Programs	Surgeons (%)	Total Pubs	Productivity* (pubs/surgeon)	Publications			H-Index		
					Median†	IQR	Min	Median‡	IQR	Min
Northeast	9	33 (12)	2540 (18)	77	41	40	2	12	15	1
South	21	97 (36)	4462 (32)	46	18	60	1	6	12	0
Midwest	12	50 (18)	1855 (13)	37	25	47	1	7	11	0
West	15	93 (34)	5256 (37)	57	31	75	1	10	17	0
Total	*57*	*322*	*14113*	*51*	*25*	*56*	*1*	*9*	*15*	*0*

*Productivity is an aggregate and does not distinguish from multiple authors on the same publication.
Overall Kruskal-Wallis was not significant for productivity by region (p = 0.42).
†Overall Kruskal-Wallis was not significant for median individual publications by region (p = 0.24)
‡Overall Kruskal-Wallis was not significant for median H-Index by region (p = 0.090).

The total H-index for this group of surgeons was 3844. Number of publications was a stronger predictor of H-index than number of citations (p < 0.0001, Figure 2). Number of publications, number of citations and H-Index tend to increase with academic rank (p < 0.001, Table 1, Figure 1).

There were 65 surgeons (24%) on faculty at their fellowship alma mater. There exists no significant trend with respect to affiliated training amongst the various academic ranks. Affiliation of training pedigree to current fellowship program appointment was not a significant predictor of academic rank (p = 0.81). Orthopaedic trauma versus other orthopaedic sub-specialty fellowship training was not a predictor of academic rank (p = 0.92). There exist no geographical differences with regards to academic rank and training affiliation (p = 0.71).

Productivity by region was defined as the total number of publications divided by number of surgeons in the region was not significantly different and was not significantly different among regions (p = 0.42, Table 4). Median individual number of publications was not significantly different among regions (p = 0.42). Median individual H-index was not significantly different among regions (p = 0.090)

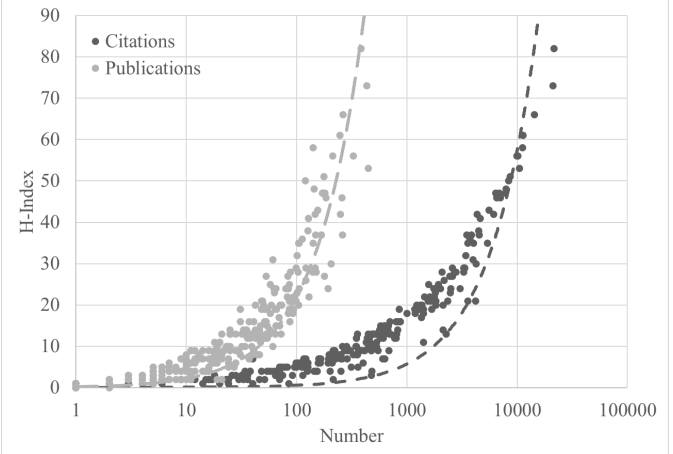
There is no statistical difference in research productivity for those with affiliated training pedigree versus those not affiliated with respect to number of publications (p = 0.57), number of citations (p = 0.75) and H-Index (p 0.78, Table 3).

DISCUSSION

The purpose of this study was to examine the relationship between H-index, research productivity, and academic rank in the field of orthopaedic trauma surgery. The H-index is an unbiased bibliographic metric that may be used to evaluate the cumulative impact of an author's publications.[6] Studies from a wide-range of medical and surgical specialties have validated the H-index as a measure of academic productivity among physicians.[7-21] Our multivariate regression analysis showed a direct association between H-index and position along the tenure track, with a higher H-index corresponding to a higher academic rank. The median H-index for each academic rank may provide supplemental information on academic promotion trajectory. This relationship has been described in other orthopaedic subspecialties,[17-21] and our findings indicate that it is valid for fellowship-affiliated orthopaedic trauma surgeons, as well.

We identified several additional variables associated with academic rank. Number of publications and citations both increased with academic rank. It is logical that these variables would correspond positively with higher academic rank, and this pattern has been previously reported among orthopaedic surgeons.[17,18] The Chair category was composed uniformly of surgeons from the professorship rank, suggesting that this group represents a highly productive subset of professors.

Figure 2: H-Index versus number of citations and publications plotted on logarithmic scale. Regression analysis of number of citations and publications as predictors of H-Index. Overall regression is significant (p-value < 0.0001). CI: confidence interval. Trendlines are non linear.



	Coeff	Std Error	P-value	95% CI
No. Citation	0.0016	0.0002	< 0.0001	0.001, 0.0022
No. Pubs	0.17	0.01	< 0.0001	0.15, 0.19

Among H-index, number of citations, and number of publications, we found H-index to be a stronger predictor of academic rank.

Neither sub-specialty of fellowship training nor affiliation of training pedigree to current fellowship program appointment were found to be significant predictors of academic rank. Additionally, there was no difference in H-index, total publications, or total citations between surgeons with and without training affiliation. The relationship between training affiliation and academic rank did not vary significantly by geographic region, suggesting there is no obvious partiality by region. We found no difference in productivity or number of publications between surgeons. This finding contrasts with those reported by Ence et al., who noted a trend of lower H-indices among Southern surgeons in their analysis of over 4600 orthopaedic surgeons.[22]

Limitations

While the H-index has been repeatedly validated as a reliable metric of scholarly impact, it is not without limitations. The H-index is a time-independent measurement and does not account for fluctuation in research productivity over time.[18,20] Additionally, the H-index does not account for authorship position, which is noteworthy as the first and last authors on a publication often contribute more than those listed in between.[18] There is also the potential that deliberate self-citation by an author may lead to artificial inflation of their own H-index. However, this concern has been evaluated by several studies, none of which have found any significant differences in H-index after controlling for self-citation.[23-26] Lastly, it is worth noting that while research productivity is an important component, it is not the sole determinant of professional advancement within academic medicine. Some surgeons may prioritize teaching or administrative responsibilities and the H-index is unable to account for these additional factors that are likely to influence promotion along the academic tenure track.

Regarding study-specific limitations, we relied on the accuracy and current updates of the Orthopaedic Trauma Association and program-specific websites. We limited our sample population to full-time orthopaedic trauma surgeons affiliated with fellowship training programs with concurrent academic appointments. As a result, our findings may not be applicable to fellowship program faculty without academic appointments, surgeons who work part time, or who are not affiliated with a training program. We excluded 49 surgeons from the study who are on faculty at fellowship programs included in this analysis but who do not hold an academic rank. The median H-index of this group was 2 (IQR 3) and included nine surgeons with H-indices greater than the median of the study population of 9, with a respective median H-index of 15 (IQR 15, range 11-48). Further, some orthopaedic trauma fellowship programs are not affiliated with large academic teaching centers, which may decrease access to institutional resources and emphasis on publishing. Regarding H-indices, it is possible that the Scopus database may not include all an author's publications.

CONCLUSION

H-index had a much higher correlation with academic rank than number of publications alone or number of citations alone among full-time orthopaedic trauma surgeons affiliated with fellowship training programs. There was no measurable impact of staying at the fellowship institution in any predictor of academic rank. There was no difference in values of any measured variable based on geographic regions. Hybrid "privademic" and private practice fellowship program represent a minority of programs and elucidating objective measures for promotions within these programs is an area of further research.[27]

While research productivity is not the only benchmark for achievement in academic medicine, it has historically been considered a key determinant for professional advancement. Our findings suggest that the H-index may be a useful metric for evaluating academic impact within the field of orthopaedic trauma surgery.

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Supplementary