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Academic Influence as Reflected by h Index Is Not Associated With Total Industry Payments but Rather With NIH Funding Among Academic Orthopaedic Sports Medicine Surgeons

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Purpose: (1) To compare the total number and dollar amount of industry funding and National Institutes of Health (NIH) funding to academic orthopaedic sports medicine surgeons and (2) to examine the impact of academic influence on industry funding and NIH funding to academic orthopaedic sports medicine surgeons. **Methods:** Academic orthopaedic sports medicine surgeons were identified using faculty web pages. Academic influence was approximated by a physician's Hirsch index (h index) and number of publications and obtained from the Scopus database. Total industry payments were acquired through the Open Payments Database, and NIH funding was determined from the NIH website. Statistical analysis was performed using Mann-Whitney U test and Spearman correlations with significance set at $P < .05$. **Results:** Physicians who received industry research payments and NIH funding had a significantly higher mean h index and more mean total publications than physicians who did not receive industry research payments and NIH funding. There were no significant differences in h index ($P = .374$) or number of publications ($P = .126$) between surgeons receiving industry nonresearch funding and those who did not. h Index and number of publications were both weakly correlated with the amount of industry research and nonresearch funding. **Conclusion:** Although academic influence is associated with industry research funding and NIH funding, there is no association between measures of academic influence and total industry and industry nonresearch payments. Combined with the weak associations between academic influence and the amount of industry payments, academic influence does not appear to be a major determinant of industry funding to academic orthopaedic sports medicine surgeons. **Clinical Relevance:** Surgeons should be cognizant of potential conflicts with industry, but the relationship between academic sports medicine surgeons and industry may be less subject to bias than previously believed.

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In recent years, the relationship between orthopaedic surgeons and the medical device industry has gained increased attention.[1,2] Orthopaedic surgeons require products from industry, including implantable devices, surgical instruments, and navigation technologies, to appropriately advance surgical care and enhance the clinical outcomes of patients.[1-3] Further, industry relies heavily on the input of the end users of their products—orthopaedic surgeons—to continue to successfully develop innovative ideas and technologies.[2] In all, studies have quantified this relationship, determining that orthopaedic surgeons receive among the most industry payments of any medical specialty, and that the median amount of industry payments has been increasing annually.[1-3]

As with any pertinent financial relationship, the interaction between orthopaedic surgery and the

medical device industry may be subject to potential conflicts of interest and bias.[4] To increase transparency between both parties, the Physician Payments Sunshine Act was enacted in 2010.[1-3,5] This landmark legislation requires payments of >10 dollars made by the medical device industry to physicians to be disclosed to the Center of Medicare and Medicaid Services (CMS) and to be publicly made available in the online Open Payments Database.[1,2] Since then, numerous studies in orthopaedic surgery have analyzed these data to gain additional insights into the types, amounts, and trends in industry payments.[3,6-9]

An area of recent interest has been the role of academic influence and scholarly productivity, as measured by Hirsch index (h index) and number of publications, on the amount and type of industry payments to surgeons.[7,8,10,11] Orthopaedic surgeons do not receive substantial contributions in terms of National Institutes of Health (NIH) funding compared with industry funding.[12] Notably, the total amount of NIH grants awarded to orthopaedic surgeons in 2014 was $12,237,334, whereas the total amount of industry funding to orthopaedic surgeons was $137,089,647 in 2014.[7] Thus, because of the limited NIH funding, it has become a necessity for orthopaedic surgeons to use the greater contributions from industry to fund their research and enhance their academic careers.[12] Notably, greater research output and scholarly productivity have been shown to be associated with academic promotion and greater faculty rank.[4,13]

However, there exists limited information regarding the role of academic influence on the amount and type of industry payments and NIH funding to academic orthopaedic sports medicine surgeons. Previous studies have shown that payments to orthopaedic sports medicine surgeons are substantial and significantly differ from those to other orthopaedic subspecialties.[3,6] Thus, the aims of the current study were (1) to compare the total number and dollar amount of industry funding and NIH funding to academic orthopaedic sports medicine surgeons and (2) to examine the impact of academic influence on industry funding and NIH funding to academic orthopaedic sports medicine surgeons. It is hypothesized that academic orthopaedic sports medicine surgeons will receive significantly greater amounts of industry funding compared with NIH funding and that academic influence will be positively associated with the total number and dollar amount of industry and NIH funding to academic orthopaedic sports medicine surgeons.

Methods

Study Population

Accredited academic orthopaedic surgery residency programs were identified through the American Medical Association's FREIDA residency and fellowship database during the 2020 to 2021 academic year.[14] In total, 200 orthopaedic surgery residency programs were identified, faculty listings were obtained for 175 programs (87.5%), and 6,333 total orthopaedic surgery faculty members were identified. Departmental web sites for individual orthopaedic surgery residency programs were used to obtain the names of academic orthopaedic sports medicine surgeons, defined as orthopaedic surgeons with a subspeciality practice of sports medicine and affiliated with an institution with an orthopaedic surgery residency program. Specifically, inclusion criteria consisted of surgeons with a primary departmental listing of sports medicine or with fellowship training in orthopaedic sports medicine. Exclusion criteria consisted of faculty with nonphysician degrees (PhD, PT, etc.), faculty with a non-operative sports medicine practice (family medicine, emergency medicine, etc.), affiliated faculty, and residency programs with missing web pages. Inclusion and exclusion criteria were based on previous studies.[3,7,8] After application of inclusion and exclusion criteria, 911 academic orthopaedic sports medicine surgeons were included for analysis.

Academic Influence, Rank, and Leadership

Academic influence was approximated through the h index and total number of publications using the publicly available 2021 Scopus database.[15] Briefly, the h index quantifies an author's research productivity and citation impact into a single numerical value.[16] The value of the h index is equal to the number of the author's publications (n) that each has n or more citations (where n is the highest value for that author). For example, an author with 15 total publications that each had 4 citations (and <5 publications with ≥5 citations) would have an h index of 4. Notably, the h index provides a rough approximation of a researcher's scholarly productivity and does not consider other important factors related to an individual's multifaceted research portfolio. Other factors that should be considered in evaluating a portfolio include the specific research field, the size (number of scientists) in a research field, and the average number of publications produced by a typical individual in the research field. All these factors cause differences in h index between research fields.[17] In orthopaedic surgery, the h index has been shown to effectively classify scholarly impact, defined as academic productivity and scientific relevance.[18] Additionally, academic faculty rank, including title as instructor, assistant professor, associate professor, or full professor, was recorded. Lastly, academic leadership, including title as residency director, fellowship director, or chair, was collected for each faculty member. Data on faculty rank and leadership were obtained through individual program websites or

publicly available personal web pages, such as Doximity or Linkedin.

Industry Payments and NIH Funding

The CMS Open Payments Database was queried to collect industry payments to orthopaedic sports medicine surgeons during the 2019 fiscal year, the most recent year for which payment data is publicly available.[19] Industry payments are reported in the Open Payments Database as general payments, research payments, and associated research payments. In the present study, general payments, which consist of payments such as royalties, consulting, ownership and investment interests, travel and lodging, education, and food and beverage, were classified as "industry nonresearch payments." Further, research payments and associated research payments, which encompass payments made in connection with a research agreement and payments made in which the physician was named principal investigator, respectively, were combined and classified as "industry research payments." Lastly, the NIH Research Portfolio Online Reporting Tool (RePORT) was queried to identify NIH funding for orthopaedic sports medicine surgeons in fiscal year 2020.[20]

Statistical Analysis

Because of the non-normality of the data, the associations between academic influence (h index and number of publications) and any industry payment, industry nonresearch payments, industry research payments, and NIH funding were determined through the Mann-Whitney *U* test. Also because of the non-normality of the data, the correlations between academic influence (h index and number of publications) and industry nonresearch and research payments were determined using Spearman correlations. Next, the association between academic faculty rank (instructor, assistant professor, associate professor, full professor) and industry payments and NIH funding was calculated using the Kruskal-Wallis rank test owing to the nonparametric nature of the payments. Lastly, the association between academic leadership title (residency director, fellowship director, chair) and any industry payment, industry nonresearch payments, industry research payments, and NIH funding was calculated using the Mann-Whitney *U* test owing to the non-normality of the data analyzed. All statistical analysis was performed using Stata version 16.1 (StataCorp, College Station, TX). All tests were 2-sided, with significance set at a probability value of $P < .05$.

Results

Study Sample

In all, 911 academic orthopaedic sports medicine surgeons were identified across 175 orthopaedic surgery residency programs (Table 1). The mean h index and number of publications of the orthopaedic sports medicine surgeons were 12.5 (standard deviation [SD] 14.6) and 46.7 (78.6), respectively (Table 1). The ranges of h indices and numbers of publications of the orthopaedic sports medicine surgeons were 0 to 110 and 0 to 896, respectively. In terms of payments, 90.7% of orthopaedic sports medicine surgeons received industry nonresearch payments, 11.1% received industry research payments, and 1.0% received funding from the NIH. The greatest contributions to industry nonresearch funding included royalties (53%), consulting fees (13%), and compensation for services other than consulting, including speaking at an event (12%).

Industry and NIH Funding to Sports Medicine Surgeons

In terms of industry nonresearch payments, 826 orthopaedic sports medicine surgeons received payment, and 85 surgeons did not receive payments (Table 2). The mean industry nonresearch payment was $31,797 (SD $296,952). Notably, nonresearch payments ranged from $10 to $8,139,292. The total amount of industry nonresearch payments was $26,264,536.70. Figure 1 shows the breakdown of industry nonresearch payments in specific increments. Notably, 5% of surgeons (n = 41) received payments greater than $100,000, and 9% of surgeons (n = 85) received no industry nonresearch payments. Further, 203 surgeons (22.3%) received 95% of all industry nonresearch payments. These individuals had a mean h index of 21.52 and a mean number of publications of 93.40.

In terms of industry research payments, 101 orthopaedic sports medicine surgeons received payments, and 821 did not receive payments. The mean industry research payment was $48,856 (SD $106,308). Industry research payments ranged from $30 to $871,474. The total amount of industry research payments was $4,934,436. Figure 2 shows the breakdown of industry research payments in specific increments. Notably, 1% of surgeons (n = 12) received payments

Table 1. Demographics of academic orthopaedic sports medicine surgeons and industry payments

Item	n
Academic programs	200
Academic surgeons	911
Industry payments	826 (90.7)
Nonresearch payments	826 (90.7)
Research payments	101 (11.1)
None	85 (9.3)
NIH funding	9 (1.0)
h Index	12.5 ± 14.6
Publications	46.7 ± 78.6

Data are n, n (%), or mean ± standard deviation.
NIH, National Institutes of Health.

Table 2. Payments to academic orthopaedic sports medicine surgeons

Item	Total Industry Payments		National Institutes of Health Payments
	Nonresearch	Research	
Surgeons who received payment	826	101	9
Surgeons who did not receive payment	85	821	913
Payment amounts ($)			
Mean	31,797.26	48,855.80	451,963.60
Standard deviation	296,951.70	106,308.10	408,662.10
Minimum	10.55	30	78,250
Maximum	8,139,292	871,473.8	1,313,070
Sum	26,264,536.70	4,934,436	4,067,672

Data are n unless noted otherwise.

greater than $100,000, and 89% of surgeons (n = 810) received no industry research payments. Further, 58 total surgeons (6.4%) received 95% of industry research payments. These individuals had a mean h index of 24.06 and a mean number of publications of 110.59.

In terms of NIH funding, 9 orthopaedic sports medicine surgeons received funding, and 913 surgeons did not receive funding. The mean NIH award was $451,964 (SD $408,662), and the range of payments was $78,250 to $1,313,070. The total amount of NIH funding was $4,067,672 (Table 2).

The Association of Academic Influence, Rank, and Leadership on Industry and NIH Funding

There were no significant differences in the mean h index of surgeons receiving any industry payment (12.5) compared with surgeons who did not receive any industry payment (11.8; $P = .374$) (Table 3). Similarly, there were no significant differences in the mean number of publications of surgeons receiving any industry payment (47.4) compared with surgeons who did not receive any industry payment (40.4; $P = .126$) (Table 3). Further, there were no significant differences in the mean h index and number of publications in surgeons receiving industry nonresearch payments compared with surgeons who did not receive industry nonresearch payments ($P = .374$ and $P = .126$, respectively).

Surgeons receiving industry research payments had a significantly higher h index (21.4) than surgeons who did not receive industry research payments (11.2;$P < .001$) (Table 3). Similarly, surgeons receiving industry research payments had a significantly higher number of

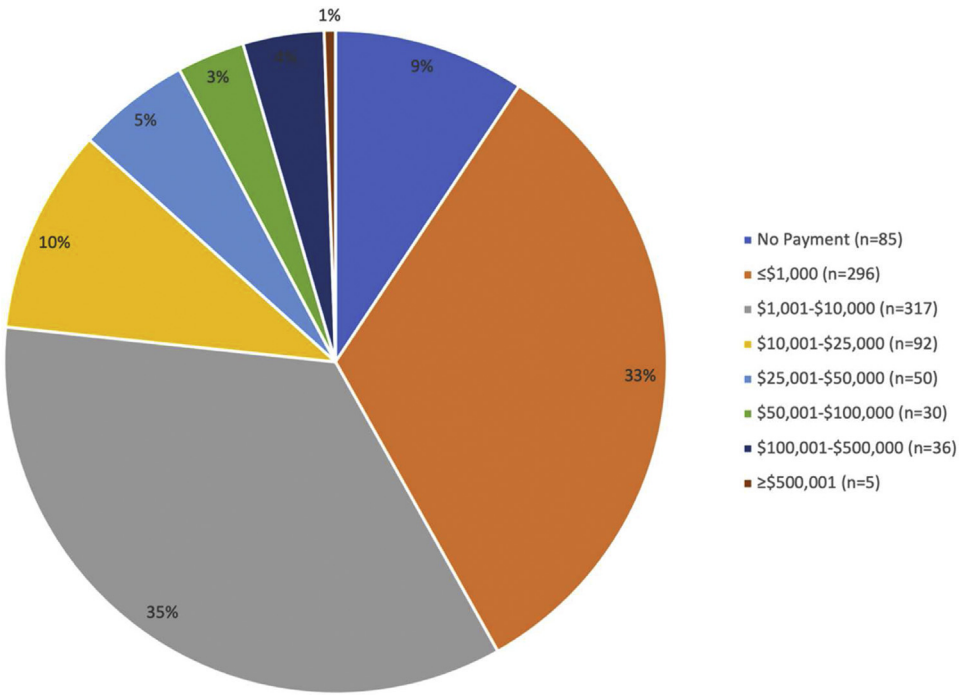

Fig 1. Distribution of Industry Non-Research Payments to Academic Orthopedic Sports Medicine Surgeons

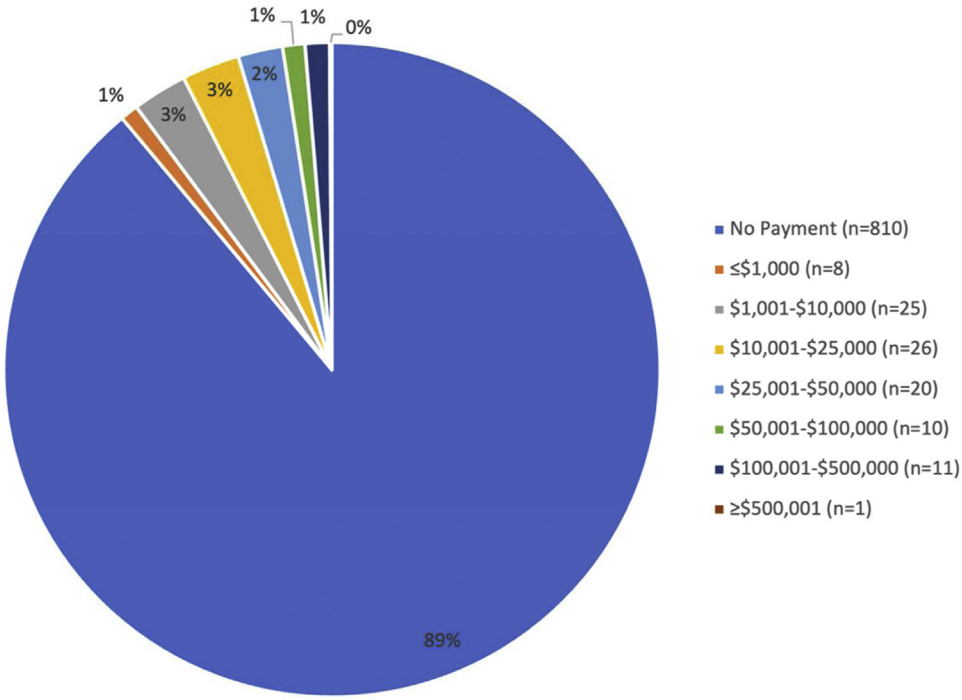

Fig 2. Distribution of Industry Research Payments to Academic Orthopedic Sports Medicine Surgeons

publications (95.9) than surgeons who did not receive industry research payments (40.0; $P < .001$). Surgeons receiving NIH funding had a significantly higher h index (40.1) than surgeons who did not receive NIH funding (12.1; $P < .001$). Surgeons receiving NIH funding had a significantly higher number of publications (206.8) than surgeons who did not receive NIH funding (44.6; $P < .001$).

There was a significant association between faculty rank and the amount of any industry payment and industry research payments ($P = .032$ and $P = .003$, respectively). Although there were no statistically significant differences, there was a trend toward an association between faculty rank and the amount of industry nonresearch payments and NIH funding ($P = .068$ and $P = .084$, respectively).

In terms of academic leadership, there were no significant differences overserved between title as residency program director and chair between industry payments and NIH funding ($P > .05$). However, surgeons who served as a fellowship program director had higher amounts of any payment, industry nonresearch payment, and industry research payment compared with surgeons who were not fellowship director ($P < .001$). There was no association between title as fellowship program director and amount of NIH funding ($P = .131$).

Correlation Between Academic Influence and Industry Payments

The correlations between the h index and the amount of industry nonresearch payments and industry research payments were 0.260 and 0.262, respectively (Fig. 3). The correlations between the number of publications and the amount of industry nonresearch payments and the amount of industry research payments were 0.292 and 0.281, respectively (Fig. 4). In all, the correlations between academic influence and

Table 3. Relationship of Average h Index and Number of Publications with Payment Type

	Average h Index			Average No. of Publications		
Payment	Did Not Receive Payment	Received Payment	*P* Value	Did Not Receive Payment	Received Payment	*P* Value
Any industry payment	11.8	12.5	.374	40.4	47.4	.126
Industry nonresearch payment	11.8	12.5	.374	40.4	47.4	.126
Industry research payment	11.2	21.4	<.001	40.0	95.9	<.001
NIH funding	12.1	40.1	<.001	44.6	206.8	<.001

NIH, National Institutes of Health.

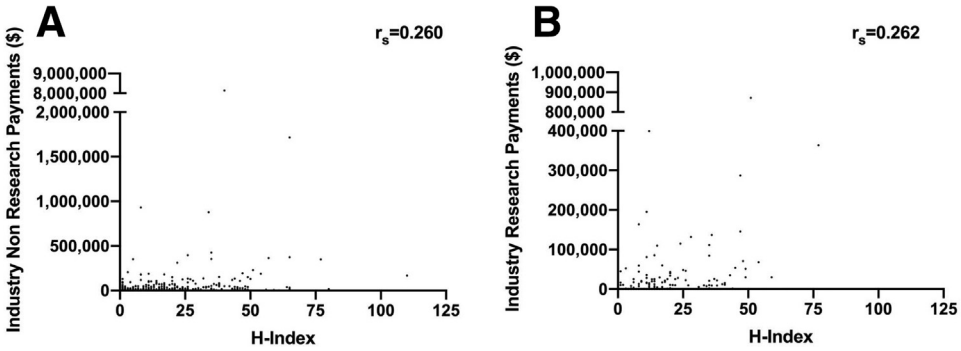

Fig 3. Association of H-Index and a) Industry Non-research Payments and b) Industry Research Payments

the amount of industry nonresearch and research payments were weak.

Discussion

The present study determined that academic influence, as measured by h index and number of publications, is not associated with total industry and industry nonresearch payments but is associated with NIH funding to academic orthopaedic sports medicine surgeons. Although numerous studies in orthopaedic surgery have analyzed the Open Payments Database to further characterize the amount and type of payments from industry to physicians, there remains limited evidence surrounding the distribution of industry payments and NIH funding, and the role of academic influence on industry payments and NIH funding to academic orthopaedic sports medicine surgeons.

First, the results showed that academic sports medicine surgeons had a much more prevalent relationship with industry than with the NIH. Notably, 90.7% of surgeons (n = 826) in this sample received an industry payment compared with just 1.0% of surgeons (n = 9) who received NIH funding. In addition, total industry nonresearch and research payments ($26,264,536.70 and $4,934,436, respectively) were greater than total NIH funding ($4,067,672). These results reiterate previous findings that have shown the overall lack of NIH funding to orthopaedic surgeons, who are thus forced to rely on industry support to fund their research efforts.[12,21] Despite published literature surrounding the topic, the number of sports medicine surgeons receiving NIH funding has barely increased, improving to 9 individuals in 2020 from 7 in 2014.[12]

Next, both industry nonresearch and research payments varied widely between physicians, as shown by the large SDs in industry payments. This makes the mean industry payments difficult to interpret, as a few influential individuals receiving large amounts of industry support skew the means to greater values. Notably, 5% (n = 41) and 1% (n = 12) of surgeons received industry nonresearch and research payments greater than $100,000, respectively. In contrast, 42% (n = 381) and 90% (n = 818) of surgeons received industry nonresearch and research payments less than $1,000, respectively. Thus, although the mean industry payments may not accurately reflect the average payment to academic orthopaedic sports medicine surgeons, Figures 1 and 2 most accurately depict the distribution of industry payments in this cohort.

The main results of the present study demonstrated that academic influence has no association with total industry and industry nonresearch payments. Further,

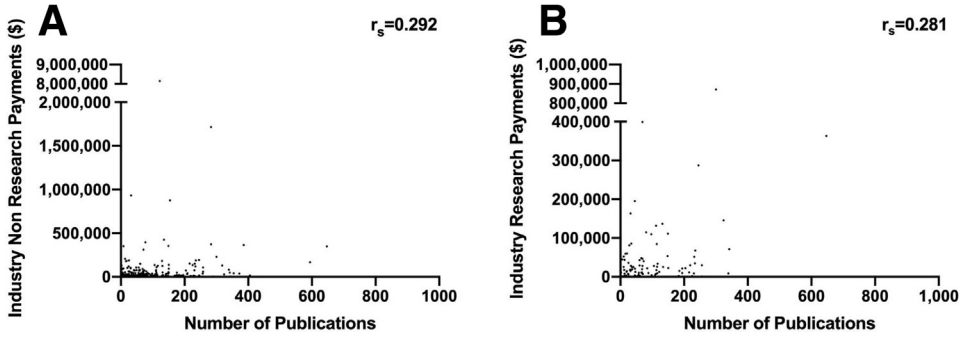

Fig 4. Association of Number of Publications a) Industry Non-research Payments and b) Industry Research Payments

the correlations between academic influence and the amount of industry nonresearch payments were weak. Although there was a large discrepancy in payment amounts, in which the minimum nonresearch payment was $10 and the maximum nonresearch payment was $8,139,292, these findings suggest that academic influence does not appear to explain this wide variation in industry nonresearch payments to academic sports medicine surgeons. In other terms, industry payments do not contribute to published research or academic advancement. Notably, the results of the present study are consistent with the previous studies in orthopaedic surgery examining academic influence and industry payments.[7,8] Buerba et al.[7] examined academic influence and industry payments among all orthopaedic surgeons in the 2013 to 2014 academic year using the 2014 Open Payments Database. As in present study,no association was found among academic influence and total industry and industry nonresearch payments. However, they analyzed a dated sample of orthopaedic surgeons and combined all orthopaedic specialties in their analysis. Recent evidence has demonstrated that orthopaedic subspecialities significantly differ in the type and amount of industry payments, with adult reconstruction and spine reporting the greatest amount of industry payments.[6] In addition, Partan et al.[3] recently noted that the median amount of industry compensation to orthopaedic sports medicine surgeons significantly increased from 2014 to 2019. Thus, the results of the present study represent a novel, contemporary analysis of academic influence and industry payments among a population of solely academic sports medicine surgeons.

Although there is no association between academic influence and total industry payments and industry nonresearch payments, academic influence is associated with a component of industry payments, or industry research payments, and is associated with NIH funding. Previous studies in orthopaedic surgery have demonstrated that both h index and academic influence are associated with NIH funding.[18,22] Further, the results of the present study determined a weak association between academic influence and the amount of industry research payments to orthopaedic sports medicine surgeons. This finding may be due to the low percentage of orthopaedic sports medicine surgeons receiving either industry research (11%) or NIH (1%) funding. However, when these results are combined with similar analyses in orthopaedic surgery, it may appear that academic influence does not play a major role in the amount of research payments to academic orthopaedic sports medicine surgeons.[7,8]

As academic influence has a poor association with industry payments, other characteristics of academic orthopaedic sports medicine surgeons should be explored as potential contributors to industry payments. The results of the present study highlighted several of these factors, most notably academic rank and fellowship director status, as having associations with the amount of industry payments. This finding was similarly seen among a sample of adult reconstruction surgeons.[8] In addition, other factors such as gender, academic practice type, and geographic location have all been shown to be associated with industry payments in orthopaedic surgery and other orthopaedic subspecialities.[3,6,10,23,24] Future studies are required to further characterize the role of these factors and to determine the role of other factors, such as age, race, and surgical volume, on industry payments to academic orthopaedic sports medicine surgeons.

Further, the use of the h index to help approximate academic influence has advantages and disadvantages, and its use in the present study certainly affects the results. Introduced by Hirsch[16] in 2005, the h index provides an objective measurement of both the quality and quantity of research in a single indicator. In orthopaedic surgery, Bastian et al.[18] determined that the h index can effectively classify scholarly impact, defined as academic productivity and scientific relevance. It has also been used in high-impact studies in orthopaedic surgery examining the relationship between academic influence and industry payments.[7,8] However, limitations of the h index include the inability to account for career length and for authors that publish less frequently but have high citation counts.[18] For example, an author with 6 publications with 200 citations each would have the same h index as an author with 6 publications with 6 citations each. Alternative measures of academic influence, including the m index and the g index, which consider active years of publication and provide more weight to highly cited articles, respectively, have been introduced to address the limitations of the h index.[16,18,25]

Lastly, the sample included in this analysis examines solely academic orthopaedic sports medicine surgeons, or surgeons that practice at an institution with an orthopaedic surgery residency program. This is opposed to examining all orthopaedic sports medicine surgeons, including private practice physicians. Notably, in academic medicine and academic orthopaedic surgery, greater publication productivity and h indices are associated with greater academic faculty rank, thus providing an incentive for academic surgeons to conduct and publish research.[13,26] Furthermore, individuals who publish high volumes of research have considerable influence and the potential to shape the field.[26,27] Thus, academic orthopaedic surgeons are uniquely positioned and influential in the field as a whole, and thus may naturally be a target for industry to promote a certain product. In fact, Buerba et al.[6]

demonstrated that mean industry payments are greater for academic orthopaedic surgeons compared with community orthopaedic surgeons. Further, the previous studies by Buerba et al.[7] and Chen et al.[8] examining academic influence in orthopaedic surgery also looked exclusively at a sample of academic orthopaedic surgeons. Therefore, the current analysis did not include private practice sports medicine surgeons and examined a cohort of exclusively academic sports medicine surgeons.

Limitations

The present study has notable limitations. Although h index and number of publications are widely used to approximate academic influence, the h index is subject to potential confounding through variables such as a longer career and older age, both of which naturally increase citation count.[16,18] Next, the data reported in the Open Payments Database is submitted by industry, putting it at risk for selection and reporting bias.[3] Further, the findings of the study are associative, and the exact rationale behind payments is unknown. Next, the faculty data collected by the present study relied on the use of individual web pages, which may be outdated and fail to consider factors such as institutional changes, retirement, and death among the faculty. Lastly, the data for 25 orthopaedic surgery residency programs were not included in this study, which leaves a risk of selection bias, as these programs may have fewer resources and faculty with fewer publications.

Conclusions

Academic influence is associated with industry research funding and NIH funding, but there is no association between measures of academic influence and total industry and industry nonresearch payments. Combined with the weak associations between academic influence and the amount of industry payments, academic influence does not appear to be a major determinant of industry funding to academic orthopaedic sports medicine surgeons.

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