

# Disparities Among Industry's Highly Compensated Orthopaedic Surgeons

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**Background:** The prosperous financial relationship between physicians and industry remains a highly scrutinized topic. Recently, a publicly available website was developed in conjunction with the U.S. Affordable Care Act to shed light on payments from industry to physicians with the goal of increasing transparency. The purpose of this study was to assess possible relationships between industry payments and orthopaedic surgeon gender, subspecialty training, and practice settings.

**Methods:** A retrospective analysis was performed using publicly available information from the Centers for Medicare & Medicaid Services (CMS) to identify the 25 orthopaedic surgeons with the highest compensation from each of the 10 largest orthopaedic companies from 2013 to 2017. Statistical analyses were conducted to investigate the factors that contributed to payment differences.

**Results:** Among the 347 highest-compensated orthopaedic surgeons, only 1 woman (0.29%) was identified. Orthopaedic surgeons in the subspecialties of spine (32.9%), adult reconstruction (27.9%), and sports medicine (14.5%) made up a majority of the 25 highest earners. A larger proportion of the physicians in this study worked in private practice (57.6%) compared with an academic setting (42.4%). Orthopaedic surgeons who subspecialize in sports medicine had significantly higher total mean payment amounts when compared with all other specialties. The primary method of compensation was found to be through licensing or royalty payments.

**Conclusions:** The large majority of orthopaedic surgeons who are highly compensated from industry are men. Among these, the greatest number specialize in the spine, while sports medicine surgeons receive significantly higher total mean payment amounts. Additional studies are warranted to evaluate the disparities between men and women and encourage policies to promote gender equality.

Physician-industry relationships exist throughout all specialties of medicine, and previous studies have demonstrated the beneficial impact that these relationships have with respect to medical innovation and improving patient outcomes<sup>1,2</sup>. However, concern exists regarding conflict of interest for physicians who have financial relationships with industry<sup>3</sup>. Legislation mandating increased transparency of these financial relationships aims to prevent inappropriate patient care, medical misinformation, and unnecessary medical costs<sup>4</sup>. As with many procedural specialties, orthopaedic surgeons and industry have an integral relationship, enabling the development of new surgical technology to enhance patient care. Specifically, the development of new implants, fixation devices, and associated systems has been attributed to orthopaedic surgeons' close relationship with medical industries<sup>1,5</sup>.

Because of the potential for impropriety, there has been increased legislation and monitoring of industry payments to physicians<sup>6</sup>. The introduction of the U.S. Affordable Care Act in 2010, further enhanced by the Sunshine Act, made physician compensation from industry publicly available. Specifically, industry manufacturers are required to report physician payment data on the publicly available website of the Centers for Medicare & Medicaid Services (CMS)<sup>7,8</sup>.

Recent studies have highlighted the potential conflict of interest that is associated with industry compensation to physicians, necessitating further discussion<sup>1,4,9</sup>. The initial reports of industry payments have demonstrated that orthopaedic surgeons are the highest compensated of all physician specialties<sup>10</sup>. Within this subset, there has been a lack of representation by certain groups, notably women<sup>11</sup>. Orthopaedic surgery has the

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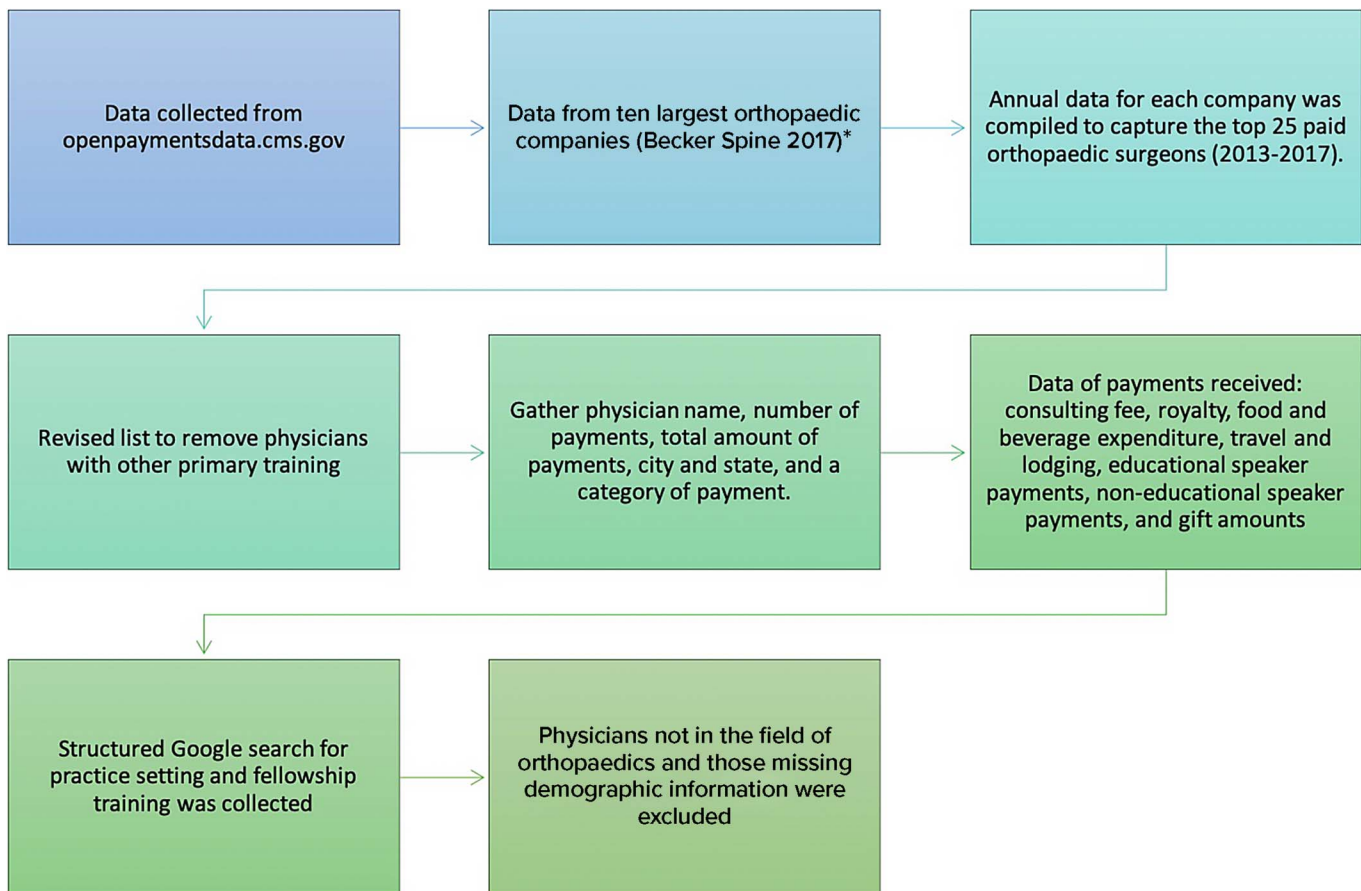


Fig. 1  
Flowchart outlining the process of delineating the appropriate data. \*Reference 15.

lowest female representation among all medical specialties (14%)<sup>12</sup>. This gender inequality is further exaggerated with respect to leadership and innovation in the field<sup>12</sup>. Previous studies have identified disparities in industry compensation to orthopaedic surgeons, including but not limited to differences between men and women, but, to our knowledge, none have explored and analyzed disparities among the top earners<sup>7,13,14</sup>.

Given the disparities in other subsets of orthopaedic surgery as mentioned above, we hypothesized that disparities among the highly compensated group of orthopaedic surgeons may be present as a function of academic affiliation, subspecialty training, company-related factors, and gender.

## Materials and Methods

### Data Gathering

After obtaining institutional review board approval, a retrospective analysis of publicly available information from the CMS database was performed. The data were collected from the CMS website ([openpaymentsdata.cms.gov](http://openpaymentsdata.cms.gov)) between January and May 2019. Queries were built to gather data from each of the 10 largest orthopaedic companies as determined by Becker's Spine Review<sup>15</sup>, including Medtronic, DePuy Synthes, Arthrex, Zimmer Biomet, Smith & Nephew, NuVasive, Stryker,

Wright Medical, Globus Medical, and Orthofix. The company names were recorded as documented in the data that were available in 2017. However, some of these companies have since merged, notably Stryker and Wright Medical. Annual data for each company were compiled to capture the 25 highest-compensated orthopaedic surgeons during a 5-year period (2013 to 2017). The list of physicians was filtered to include only those who were identified as orthopaedic surgeons. For each physician, the following data were obtained: physician name, number of payments, total amount of payments, city and state, and category of payments. The CMS database lists the following categories for which payments are received: consulting fee, royalty and licensing, food and beverage expenditure, travel and lodging, educational speaker payments, noneducational speaker payments, education, grant, entertainment, and gifts. The method employed was comparable with those that have been used in previous CMS studies<sup>16,17</sup>.

Structured Google search queries using physician names and locations were performed to identify physician profiles that were listed on hospital or academic but nonhospital-affiliated practice websites. Information regarding practice setting and fellowship training was collected from these websites. Academic practices were defined as employment associated with a university health system, a medical school, or a residency

**TABLE I Payment Information Based on Practice Type**

	Academic Practice	Private Practice	P Value
No. of surgeons*	396	521	0.76
Total compensation	\$410,817,999	\$436,850,164	
Mean compensation	\$1,037,419	\$838,484	0.830
Total no. of payments	15,626	23,268	
Mean no. of payments	39.5	44.7	<0.001†

\*Physicians represented in multiple years were counted for every appearance to show total compensation in academic and private practice. †Significant.

program. For those who had participated in multiple fellowships, data regarding the fellowship that was related to the description of their current practice were collected. Self-identified gender was also collected by using pronouns that were listed on individual profiles (Fig. 1).

### Statistics

Statistical analysis was performed by individuals with Master's level coursework in statistics using SPSS version 26 (IBM). Descriptive statistics were used to analyze the prevalence of different factors such as gender, subspecialty fellowship training, and practice setting. Care was taken to ensure that each unique orthopaedic surgeon was only counted once in all of the demographic descriptions, regardless of whether he or she was reported as a top earner from multiple companies or for multiple years. During the analysis, compensation in each year was counted as a separate entry to ensure that there was an accurate representation of payments. Mean compensation and mean number of payments were analyzed as a function of gender, subspecialty, and practice setting using analysis of variance (ANOVA). Post hoc

testing was completed using the Tukey honestly significant difference (HSD) for significant results. P values that were <0.05 were considered significant.

### Source of Funding

This research did not receive funding from public, private, or nonprofit sources.

### Results

Of the 1,250 possible physicians who were identified on the CMS website, 1,025 met our identified inclusion criteria as described above, and represented 347 unique orthopaedic surgeons. Among these top-compensated orthopaedic surgeons, only 1 female orthopaedic surgeon was identified (0.3%). Four of the 347 physicians received >20% of the total earnings in this study population. The majority of physicians in this study worked in private practice rather than an academic setting (58% versus 42%;  $p = 0.76$ ). While the mean compensation was not different between academic and private practice physicians, private practice physicians received more individual payments (Table I).

All orthopaedic subspecialties were represented in the data that were collected. The distribution of subspecialties included spine (32.9%), adult reconstruction (27.9%), sports medicine (14.5%), general (9.3%), foot and ankle (9.0%), shoulder and elbow (5.6%), pediatrics (2.3%), trauma (2.3%), hand (2.0%), and oncology (0.3%). A significant difference based on specialty training was seen with the mean payment amount ( $p = 0.05$ ) and the mean number of payments ( $p < 0.001$ ). Post hoc analysis revealed that sports medicine fellowship-trained physicians received significantly higher mean payment amounts compared with foot and ankle (\$1,611,517 versus \$478,228;  $p < 0.01$ ) and spine (\$1,611,517 versus \$749,623;  $p = 0.02$ ) fellowship-trained physicians (Table II). Foot and ankle physicians received significantly more frequent payments compared with all other specialties (all  $p < 0.02$ ) (Table II).

**TABLE II Payment Data Based on Subspecialty Training**

Subspecialty	No. of Surgeons*	Total Compensation (\$)	Mean Compensation (\$)	Total No. of Payments	Mean No. of Payments per Surgeon
Sports medicine	118	190,159,006	1,611,517	5,711	48
Adult reconstruction	260	269,614,540	1,036,979	14,040	54
General	76	71,862,484	945,559	1,870	25
Shoulder and elbow	40	31,921,000	798,025	1,900	48
Spine	308	230,883,884	749,623	8,378	27
Multiple fellowships	21	12,944,505	616,405	998	48
Foot and ankle	66	31,563,048	478,228	5,524	84
Hand	14	3,469,032	247,788	195	14
Pediatric	11	2,515,315	228,665	153	14

\*Physicians represented in multiple years were counted for every appearance to show total compensation for each subspecialty.

TABLE III Payment Data Based on 10 Largest Orthopaedic Companies

Company	No. of Surgeons*	Total Compensation (\$)	Mean Compensation (\$)	Total No. of Payments	Mean No. of Payments
Medtronic	35	85,560,813	2,444,595	1,447	41.3
DePuy Synthes	117	191,875,886	1,639,965	1,547	13.2
Arthrex	114	167,887,140	1,472,694	6,387	56.0
Zimmer Biomet	106	106,621,932	1,005,867	4,309	40.7
Smith & Nephew	88	75,353,229	856,287	4,224	48.0
NuVasive	91	73,618,260	808,992	3,772	41.5
Stryker	125	100,488,525	803,908	8,528	68.2
Wright Medical	77	24,337,216	316,068	5,730	74.4
Globus Medical	96	15,622,696	162,736	2,065	21.5
Orthofix	68	6,302,568	92,685	809	11.9

\*Physicians represented in multiple years were counted for every appearance to show total interaction with industry.

Additionally, payments from individual companies were evaluated to discern any differences among companies. There was a significant relationship between company and both mean payment amount ( $p < 0.01$ ) and frequency of payments ( $p < 0.01$ ). Medtronic had higher mean payments compared with all of the other companies. Wright Medical had significantly more frequent payments compared with all of the other companies except Stryker. NuVasive was the only company to have a female payee among their top 25 highly compensated physicians. Table III provides additional details regarding the individual companies. Analysis of the types of payments showed that royalty and licensing payments were the main mechanism of payment among payees (Fig. 2; Table IV).

## Discussion

Physician relationships with industry remain a controversial topic in the media and the medical literature<sup>3,18</sup>. The CMS database was created to make industry-related compensation to physicians publicly available, with the goal of minimizing conflicts of interest and increasing transparency. Analysis of the orthopaedic surgeons most highly compensated by the largest orthopaedic manufacturers highlights the differences in compensation based on gender and subspecialty training.

Over the past decade, there has been a large increase in industry compensation overall, with orthopaedic surgeons benefiting more than other medical specialties<sup>2</sup>. Specifically, this increase seems to be related to a few high-earning orthopaedic surgeons rather than to all physicians within the specialty<sup>19</sup>. Consistent with the intent of the Sunshine Act to increase transparency and reduce conflicts of interest, the CMS Open Payments database provides granularity to understand disparities among earners and drivers in the field of orthopaedic surgery.

Our analysis found substantial relationships regarding total earnings within the subset of the top earners who were included in the study. More than 20% of the total sum of

earnings was earned by just 4 physicians (each in different subspecialties), encompassing  $> \$180,000,000$  over 5 years, for an average of  $> \$9,000,000$  per physician per year. Focusing specifically on the gross sum of reimbursement, it is evident that earnings, even in the highest echelon of earners, are skewed by a select few.

Additionally, of the 25 orthopaedic surgeons most highly compensated by the 10 largest orthopaedic companies over a 5-year period, only 1 female surgeon (0.3%) was identified out of 347 surgeons included. The 1 female orthopaedic surgeon had spine fellowship training and worked in an academic practice. She was a high earner in 3 of the years that were studied and had an average of 21 individual payments per year and a total payment of \$681,783 per year. In comparison to the mean amounts from the male top earners in this study, she received 21 fewer payments and \$243,406 less in total payment. This further supports the relationship between gender and

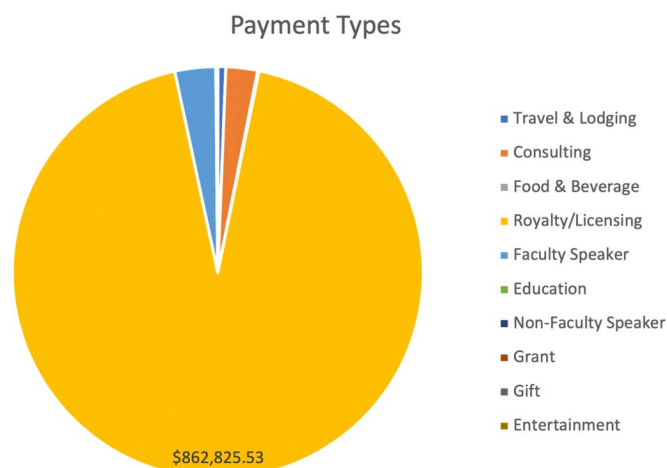


Fig. 2

Graph showing the distribution of types of payments received by the physicians who were included in this study.

TABLE IV Distribution of Types of Payments Earned by Payees

Type of Payment	Mean (\$)	Maximum (\$)
Royalty and licensing	862,826	30,167,003
Educational speaker	29,635	5,077,656
Consulting	23,005	348,000
Travel and lodging	5,797	57,560
Noneducational speaker	1,029	77,000
Food and beverage	990	43,607
Education	322	64,063
Grant	58	20,000
Gift	0	30
Entertainment	0	24

compensation as seen in a previous study that explored all orthopaedic earners listed on the CMS Open Payments database<sup>11</sup>.

According to the Association of American Medical Colleges (AAMC), in 2019, women outnumbered men in medical school. Yet, this shift in demographics has not translated to the surgical subspecialties<sup>12</sup>. Specifically, orthopaedic surgery remains heavily dominated by men, with women representing 14% of the total number of orthopaedic surgery residents and only 6.5% of members of the American Academy of Orthopaedic Surgeons (AAOS)<sup>20</sup>. This disparity is further carried into industry compensation, with women representing <0.5% of the top earners. This has been noted in other areas of medicine with studies that have provided evidence that not only are women compensated less, but they have received substantially fewer consultant, royalty and licensing, ownership, and speaker payments (although they received more in research payments than men)<sup>21</sup>. Previous studies have suggested that industry should take a greater role in addressing these differences by increasing the engagement of women in “consultancies, speaking engagements, and research.”<sup>21,22</sup> It should be noted that in recent years, there has been an increase (27.3% from 2005 to 2016) in female trainees in orthopaedics<sup>20</sup>. However, these women are early in their careers, and most of the top physician industry earners tend to be older and more established. It remains to be seen if the increase in female representation in the field of orthopaedics will translate to greater involvement with industry.

No significant difference in total payment amount was identified based on practice setting. It was noted, however, that academic surgeons had similar total compensation despite having fewer surgeons than the private practice setting. This potential disparity may be related to research productivity in academic versus private practice settings. We hypothesize that physicians in an academic practice may have more exposure to implant design, leading to increased payments related to licensing and royalties. In addition, academic surgeons are typically involved with educational pursuits that may predispose them to participating in industry-sponsored innovation

and educational activities. Furthermore, academic surgeons are often compensated less than their private practice counterparts, which may lead some to seek additional avenues of income.

Additionally, differences in total cumulative payment were noted based on subspecialty, especially among those who specialize in sports medicine. This is likely due to the high level of innovation in implant design and techniques as a result of the ambulatory nature of this subspecialty when compared with other subspecialties<sup>23</sup>. These opportunities lead to increased avenues for industry-physician relationships and subsequent payments. Additional research is needed to better understand increased compensation within subspecialties.

Lastly, differences in payments were identified when comparing individual companies (Table III). Specifically, Medtronic had higher mean payments compared with all of the other companies, while Wright Medical had significantly more frequent payments compared with all of the other companies except Stryker. Interestingly, Stryker, the company with the most physician earners, did not lead in total compensation, mean compensation, or mean number of payments. However, it did lead in the total number of payments, suggesting a diluting effect of payments among its numerous payees. Additional studies are needed to evaluate the difference between the value of numerous smaller payments to more people compared with larger payments to a limited number of individuals.

This study is not without limitations. First, only the 10 largest companies were included. Additionally, with few self-identified women in this study population, it is hard to make conclusions regarding disparities in earnings in this gender subset. The findings of this study suggest that there is an ongoing disparity in reimbursement and payments to female physicians compared with male physicians. Similar issues were encountered when it came to subspecialties, particularly with pediatrics and hand-trained physicians, who were a minority in this study population. Top earners also may have skewed the data since 4 high-earning physicians received >20% of the total earnings. Additionally, we were unable to obtain the ages of the physicians in this study and acknowledge that the age distribution may have helped to explain the gender disparity within this study's population. This study also relied on the accuracy of information that was gathered from the CMS website, which could be a potential limitation. Finally, there is a growing trend for mixed academic and private practice office types in the field of orthopaedics. We counted these hybrid groups as academic practices in this study, but they do blur the lines between true academic and private practice settings, which presents a limitation to the granularity of this comparison for the few physicians who are in this category.

### Conclusions

There exists a large disparity in gender among the top orthopaedic physician industry earners, with <1% being female. Among the subspecialties, sports medicine had the highest mean compensation from injury, while spine had the highest

mean compensation per physician. Additional studies are warranted to evaluate the disparities between men and women and encourage policies to promote gender equality. ■

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## References

- Malchau H, Bragdon CR, Muratoglu OK. The stepwise introduction of innovation into orthopedic surgery: the next level of dilemmas. *J Arthroplasty*. 2011 Sep;26(6):825-31.
- Chatterji AK, Fabrizio KR, Mitchell W, Schulman KA. Physician-industry cooperation in the medical device industry. *Health Aff (Millwood)*. 2008 Nov-Dec;27(6):1532-43.
- Fickweiler F, Fickweiler W, Urbach E. Interactions between physicians and the pharmaceutical industry generally and sales representatives specifically and their association with physicians' attitudes and prescribing habits: a systematic review. *BMJ Open*. 2017 Sep 27;7(9):e016408.
- Jacobs JJ, Galante JO, Mirza SK, Zdeblick T. Relationships with industry: critical for new technology or an unnecessary evil? *J Bone Joint Surg Am*. 2006 Jul;88(7):1650-63.
- Hughes JD, Shin JJ, Albers M, Musahl V, Fu FH. A Closer Look at the Relationship Between Industry and Orthopaedic Sports Medicine Surgeons. *Orthop J Sports Med*. 2019 Jan 22;7(1):2325967118823175.
- United States Department of Justice. Five Companies in Hip and Knee Replacement Industry Avoid Prosecution by Agreeing to Compliance Rules and Monitoring. Accessed 2020 August 11. <https://www.justice.gov/sites/default/files/usao-nj/legacy/2013/11/29/hips0927.rel.pdf>
- Cvetanovich GL, Chalmers PN, Bach BR Jr. Industry financial relationships in orthopaedic surgery: analysis of the Sunshine Act Open Payments database and comparison with other surgical subspecialties. *J Bone Joint Surg Am*. 2015 Aug 5;97(15):1288-95.
- Litman RS. The Physician Payments Sunshine Act: Implications and Predictions. *Pediatrics*. 2018 Feb;141(2):e20171551.
- Ross PR, Wood SM, Chung KC. Industry Funding and Self-Declared Conflict of Interest in Hand Surgery Publications. *J Hand Surg Am*. 2020 Jun;45(6):479-87.
- Samuel AM, Webb ML, Lukasiewicz AM, Bohl DD, Basques BA, Russo GS, Rathil VK, Grauer JN. Orthopaedic Surgeons Receive the Most Industry Payments to Physicians but Large Disparities are Seen in Sunshine Act Data. *Clin Orthop Relat Res*. 2015 Oct;473(10):3297-306.
- Lajam CM. CORR Insights®: Men Receive Three Times More Industry Payments than Women Academic Orthopaedic Surgeons, Even After Controlling for Confounding Variables. *Clin Orthop Relat Res*. 2020 Jul;478(7):1600-2.
- Association of American Medical Colleges. AAMC Data Book 2019 FACTS: Applicants and Matriculants Data. Accessed 2020 August 12. <https://www.aamc.org/data-reports/students-residents/interactive-data/2019-facts-applicants-and-matriculants-data>
- Ray GS, Lechtig A, Rozental TD, Bernstein DN, Merchan N, Johnson AH. Gender Disparities in Financial Relationships Between Industry and Orthopaedic Surgeons. *J Bone Joint Surg Am*. 2020 Feb 19;102(4):e12.
- Forrester LA, Seo LJ, Gonzalez LJ, Zhao C, Friedlander S, Chu A. Men Receive Three Times More Industry Payments than Women Academic Orthopaedic Surgeons, Even After Controlling for Confounding Variables. *Clin Orthop Relat Res*. 2020 Jul;478(7):1593-9.
- Dyrda L. Top 10 Orthopedic Companies by Market Share - And Where They'll Be in 2024. 2019 Jan 18. Accessed 2020 June 3. [www.beckersspine.com/orthopedic-a-spine-device-a-implant-news/item/44330-top-10-orthopedic-companies-by-market-share-and-where-they-ll-be-in-2024.html](http://www.beckersspine.com/orthopedic-a-spine-device-a-implant-news/item/44330-top-10-orthopedic-companies-by-market-share-and-where-they-ll-be-in-2024.html)
- Almaguer AM, Wills BW, Robin JX, Chodaba Y, Arguello AM, McMichael BJ, McGwin G Jr, Ponce BA. Open Payments Reporting of Industry Compensation for Orthopedic Residents. *J Surg Educ*. 2020 Nov - Dec;77(6):1632-7.
- Wills BW, Almaguer AM, Robin JX, Archie A, McMichael BJ, McGwin G Jr, Ames SE, Ponce BA. Association of State Legislation and Industry Compensation to Orthopaedic Residents: A 3-Year Review of the Centers for Medicare and Medicaid Services Open Payments Database. *J Am Acad Orthop Surg*. 2020 Nov 15;28(22):e1020-8.
- Keller F, Marczewski K, Pavlović D. The relationship between the physician and pharmaceutical industry: background ethics and regulation proposals. *Croat Med J*. 2016 Aug 31;57(4):398-401.
- Weiner JA, Cook RW, Hashmi S, Schallmo MS, Chun DS, Barth KA, Singh SK, Patel AA, Hsu WK. Factors Associated With Financial Relationships Between Spine Surgeons and Industry: An Analysis of the Open Payments Database. *Spine (Phila Pa 1976)*. 2017 Sep 15;42(18):1412-8.
- Chambers CC, Ilnow SB, Monroe EJ, Suleiman LI. Women in Orthopaedic Surgery: Population Trends in Trainees and Practicing Surgeons. *J Bone Joint Surg Am*. 2018 Sep 5;100(17):e116.
- Weiss A, Parina R, Tapia VJ, Sood D, Lee KC, Horgan S, Freischlag JA, Blair SL, Ramamoorthy SL. Assessing the domino effect: Female physician industry payments fall short, parallel gender inequalities in medicine. *Am J Surg*. 2018 Oct;216(4):723-9.
- Raber I, McCarthy CP, Al Rifai M, Vaduganathan M, Michos ED, Wood MJ, Smyth YM, Ibrahim NE, DeFaria Yeh D, Asnani A, Mehran R, McEvoy JW. Gender differences in industry payments among cardiologists. *Am Heart J*. 2020 May;223:123-31.
- Hansen E, Bozic KJ. The impact of disruptive innovations in orthopaedics. *Clin Orthop Relat Res*. 2009 Oct;467(10):2512-20.