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ORIGINAL RESEARCH

Attitudes Towards Conflicts of Interest in Medical Research: A Survey of US Medical Students

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Abstract

Industry funds nearly two-thirds of US healthcare research, and industry-sponsorship may produce more favorable research results and conclusions. Medical students report feeling inadequately prepared to avoid negative industry influence. Research of educational interventions that educate students on the potential effects of industry influence is lacking, and no interventions have demonstrated long-term benefit. Surveying and assessing student opinions of the relationship between industry and research may help improve future educational interventions. We surveyed preclinical and clinical students at seven US medical schools regarding their attitudes towards industry conflicts of interest (COIs) in medical research. A total of 466 medical students including 232 preclinical and 234 clinical students completed the survey. Of those who had research experience, clinical students were more likely than preclinical students to look for COIs (62.0% v 45.9%, $p = .014$) and to consider whether author COIs are pertinent to the article (68.1% v 54.1%, $p = .023$). Many disagreed that they felt adequately educated on the issue of COIs (42.7%), but most agreed that medical school should take a role in guiding student interactions with industry (65.0%). Students responded that all listed financial relationships between industry and investigator, except for providing food and/or beverage, would likely bias the investigator's research. Many students feel inadequately educated on industry issues in biomedical research, and most believe medical schools should help guide interactions with industry. Our findings support further development of educational interventions that prepare students to navigate the relationship between industry and medical research during and after medical school.

Keywords Industry · Medical school · Conflict of interest

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Introduction

The immense and expanding role of industry in US healthcare has allowed for tremendous financial support yet controversial relationships that have made conflicts of interest (COIs) ubiquitous in medical research. A recent report found that industry accounted for nearly two-thirds of all US medical and health R&D investment at $161.8 billion in 2020, compared to $61.5 billion from federal funding [1], yet top pharmaceutical firms have also been shown to spend up to three times more on marketing rather than R&D expenses [2]. Furthermore, newly registered clinical trials are increasingly turning towards industry as their primary source of funding rather than federal sources [3].

The primary concern with such pervasive industry involvement is its potential to influence evidence-based patient care. In addition to directly influencing physician

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behavior [4–9], industry interactions and COIs have been repeatedly shown to influence research outcomes [3, 10–13]. A Cochrane review of 75 drug and device studies found that industry sponsorship from the manufacturing company leads to more favorable results and conclusions than non-industry sponsorship [13]. Efforts to mitigate potential negative influence are challenged with doing so while preserving industry's crucial support, which has led to research of interventions that improve medical education and to development of programs that increase transparency of the industry-healthcare relationship, such as the Open Payments Program established by the Physician Payments Sunshine Act (PPSA) [14–18].

Industry influence starts at the beginning of medical education, with most preclinical and clinical students reporting regular, even weekly interactions with industry [19]. Most students report not feeling adequately prepared to undergo these interactions while avoiding negative influence [20, 21], but perhaps more worrisome is that many students feel immune to such influence, despite evidence to the contrary [19]. Few studies have evaluated educational interventions to improve medical school education regarding interactions with industry, but early evidence suggests they can increase student awareness of and skepticism towards industry promotional practice in the short term but not yet the long term [14–17, 22]. Surveying medical students can potentially increase the likelihood that these interventions yield long-term effects as well, for example, by identifying areas in which students feel inexperienced such as the prevalence and extent of industry research funding. While studies have assessed student opinions of industry interaction with physicians [19–21, 23, 24], none have assessed student opinions of industry influence on medical research or their medical research exposure and experience.

We created a survey to examine medical student opinions and attitudes towards industry COIs in medical research. The survey was designed with three objectives: to assess medical student exposure to medical research and industry, to determine the level of bias students associate with commonly reported financial relationships between investigators and industry, and to determine student opinions on the relationship between industry, education, and research.

Methods

This cross-sectional survey study was conducted at seven US medical schools accredited by either the Liaison Committee on Medical Education or the American Osteopathic Association Commission on Osteopathic College Accreditation: Florida Atlantic University Charles E. Schmidt College of Medicine, Kansas City University College of Osteopathic Medicine, McGovern Medical School, New York Institute of Technology College of Osteopathic Medicine, Northeast Ohio Medical University, Quinnipiac University Frank H. Netter M.D. School of Medicine, and University of Connecticut School of Medicine. Institutional Review Board (IRB) approval was obtained from the Hartford HealthCare IRB (E-HHC-2021-0302), which served as the lead IRB, and from the IRB of each participating medical school. Surveys were distributed on January 1, 2022, and were accepted until June 6, 2022. All participants were between 18 and 65 years of age at the time of their response. The electronic survey was made and distributed via email using Research Electronic Data Capture (REDcap) or Qualtrics. A medical student representative and administrator from each school was contacted prior to study enrollment to facilitate distribution. Students were incentivized to respond with a $50 gift card given randomly to one respondent from each school. Surveys were distributed by each school administrator, and all respondents were subsequently enrolled. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

The final survey was drafted with input from a representative of each included medical school and through reference to several prior studies [19–21, 23, 24]. The survey consisted of three parts: the first included questions regarding demographic background, biomedical research experience, and industry exposure; the second asked respondents to rate specific financial relationships, which were inspired by those reported to the Open Payments database, on a 5-point Likert scale with responses ranging from "very unlikely to bias" to "very likely to bias"; the third asked respondents to rate their level of agreement or disagreement with statements regarding the relationship between medical education, biomedical research, and the biomedical industry, with responses ranging from "strongly disagree" to "strongly agree." Each Likert scale included a neutral midpoint.

The analyses, conducted at Hartford HealthCare, were primarily descriptive statistics of each survey part, with frequencies and proportions given for each question. Comparisons in responses were made between preclinical (first and second year) and clinical (third and fourth year) medical students, between allopathic (MD) and osteopathic (DO) medical school students, and between students who reported having and not having had research ethics training. For dichotomous and other categorical questions, these two groups were compared using chi-square tests of proportion. Questions from parts two and three of the survey were considered ordinal scales, and responses were analyzed using Wilcoxon ranked sum test. A significance level of 0.05 was established for all analyses.

Results

A total of 5634 students were emailed and eligible to complete the survey, and 466 (8.3%) responses were received, including 232 preclinical and 234 clinical students. As shown in Table 1, preclinical and clinical students did not differ in gender distribution, but clinical students were older. No differences in age ($p = 0.275$) or gender ($p = 0.484$) were found between MD and DO school students, but MD students were more likely to report having had experience in research ethics training ($p = 0.012$) as well as having any research experience, including conducting translational and clinical research as well as writing literature reviews (92.7% v 80.2%, $p < 0.001$). No statistically significant differences in responses were found in comparisons between students with and students without prior research ethics training. Most medical students reported that they had experience reading biomedical research (67.4%) as well as had training or education from their school regarding industry involvement in biomedical research (67.0%). Of those who had experience reading biomedical research, clinical students were significantly more likely than preclinical students to look for COIs (62.0% v 45.9%, $p = 0.014$) and to consider whether author COIs are pertinent to the article (67.5% v 54.1%, $p = 0.023$). Preclinical students were more likely to have had no interactions with the biomedical industry (81.0% v 65.8%, $p < 0.001$). Slightly more than half of students had contributed to writing a manuscript or presented at a conference. Clinical versus preclinical students (15.4% v 6.5%, $p = 0.002$) and MD versus DO students (14.9% v 6.3%, $p = 0.002$) were more likely to be aware of the Open Payments database, with 51 (10.9%) students aware overall. Less than 10% of students received gifts (3.0%) or free drug samples (3.6%) from industry or attended a company-sponsored event (7.3%). Clinical students were more likely than preclinical students (29.9% v 15.9%, $p < 0.001$) to have received free food or beverage from the biomedical industry, which was the most common interaction overall (23.0%).

Students varied widely in their responses to whether they thought specific financial relationships between researchers and industry could bias the researcher's work (Fig. 1 and

Table 1 Exposure to research and industry

Characteristic	Total ($n = 466$)	Preclinical ($n = 232$)	Clinical ($n = 234$)	p value
Gender, female, *n* (%)	296 (63.5)	147 (63.4)	149 (63.7)	0.993
Age, *n* (%)				< 0.001
18–23	84 (18.0)	78 (33.6)	6 (2.6)	
24–29	346 (74.2)	145 (62.5)	201 (85.9)	
30 and older	36 (7.7)	9 (3.9)	27 (11.5)	
Received training/education from medical school about industry involvement in biomedical research	312 (67.0)	155 (66.8)	157 (67.1)	0.948
Research experience				
Contributed to a manuscript	238 (51.1)	103 (44.4)	135 (57.5)	0.004
Contributed to a protocol	159 (34.1)	78 (33.6)	81 (34.6)	0.821
Contributed to a literature review	174 (37.3)	84 (36.2)	90 (38.5)	0.615
Presented poster	250 (53.6)	116 (50.0)	134 (57.3)	0.116
Others	28 (6.0)	15 (6.5)	13 (5.6)	0.680
None	85 (18.2)	49 (21.1)	36 (15.4)	0.109
Experience reading biomedical research articles/books/etc	314 (67.4)	148 (63.8)	166 (70.9)	0.100
Of those who said yes to above:	**($n = 314$)**	**($n = 148$)**	**($n = 166$)**	
Looks to see whether authors have conflicts of interest	171 (54.5)	68 (45.9)	103 (62.0)	0.014
Considers whether author financial relationships and activities are pertinent to the article	193 (67.5)	80 (54.1)	113 (68.1)	0.023
Aware of Open Payments database	51 (10.9)	15 (6.5)	36 (15.4)	0.002
Industry interaction				
Received gift	14 (3.0)	10 (4.3)	4 (1.7)	0.100
Received drug sample	17 (3.6)	10 (4.3)	7 (3.0)	0.448
Received food/beverage/meal	107 (23.0)	37 (15.9)	70 (29.9)	< 0.001
Industry social event	28 (6.0)	15 (6.5)	13 (5.6)	0.680
Industry educational event	34 (7.3)	19 (8.2)	15 (6.4)	0.461
None	342 (73.4)	188 (81.0)	154 (65.8)	< 0.001

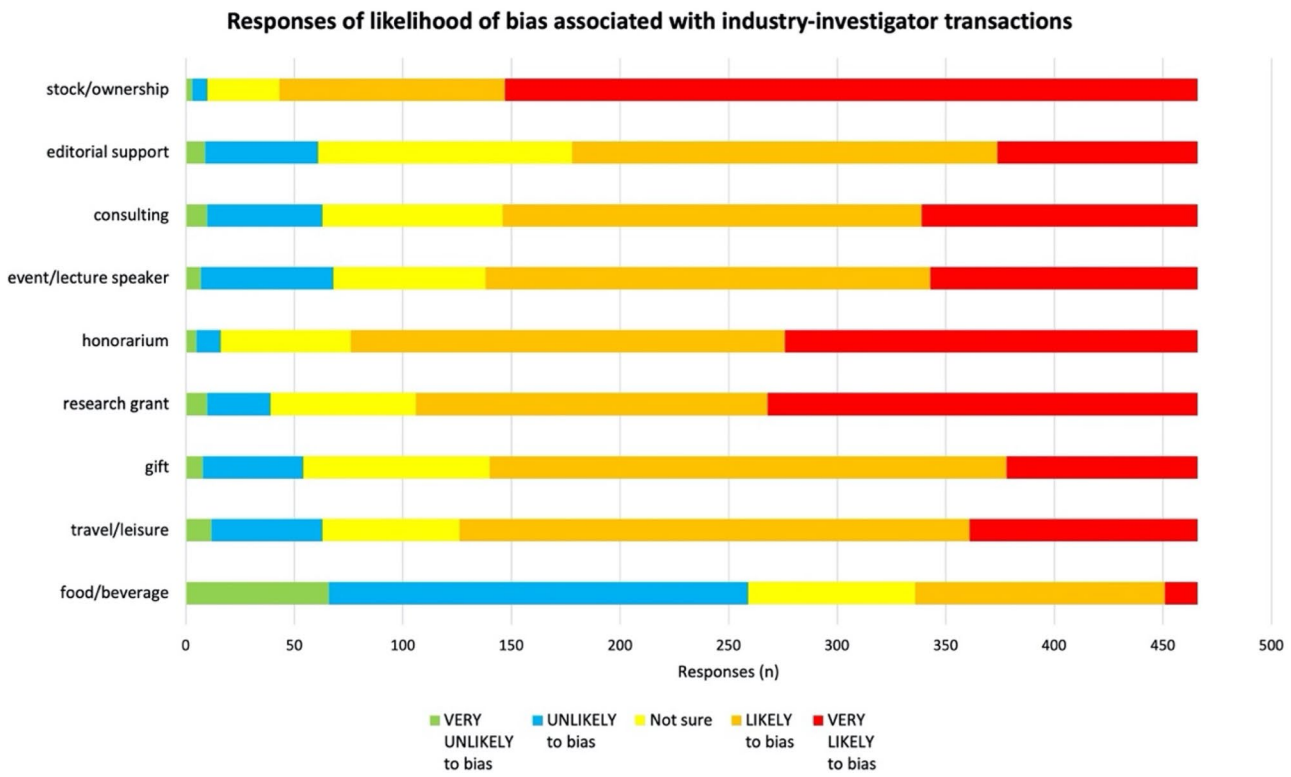

Fig. 1 Medical student responses of likelihood of bias associated with each industry-investigator transaction

Table 2). Relationships that the majority of students thought were likely or very likely to lead to bias included receiving compensation in the form of travel, speaking, consulting, gifts, grant, honorarium payment, or editorial support, or owning stock in the company. The only relationship for which the majority of students answered as unlikely or very unlikely to lead to bias was receiving food or beverage from industry. Clinical students were significantly more likely to report that compensation for travel would be likely to lead to bias ($p=0.011$), and there was a trend for clinical students to also report that receiving a gift ($p=0.055$) or holding company ownership ($p=0.063$) would be more likely to lead to bias. MD compared to DO students were more likely to state that honorarium payment ($p=0.010$), lecture compensation ($p=0.009$), consulting compensation ($p<0.001$), editorial support ($p=0.002$), and owning stock ($p=0.002$) are likely to lead to bias.

Medical students had mixed opinions on several statements regarding the relationship between industry, research, and medical education, with few statements garnering much agreement (Table 3). The two following statements received significantly different distributions of responses when comparing preclinical and clinical students, with more clinical students generally agreeing with both statements: "Investigator-initiated trials have greater integrity than industry-sponsored trials" ($p=0.010$) and "I believe there is adequate separation between my school's hospitals/faculty and the biomedical industry" ($p=0.014$). Most students agreed with the American Medical Association (AMA) statement that "Physicians who engage in research should refrain from knowingly participating in a financial relationship with a commercial entity with whom they have a research relationship until the research relationship ends and the research results have been published or otherwise disseminated to the public" (71.4%). MD compared to DO students were more likely to agree that medical schools should guide student interactions with industry ($p=0.033$), and they were less likely to agree with responding that accepting gifts is appropriate ($p=0.001$) or that medical schools should have events sponsored by industry ($p=0.061$); though, this was not significant.

Discussion

Industry influence begins as early as medical school, and, therefore, medical students can provide valuable insight towards developing educational and policy efforts aimed to curb potential negative effects. Our study is the first to survey US medical students about their attitudes and opinions towards the relationship between industry and medical research. We found that students are aware of the effects of industry on medical research, and furthermore, they feel

Table 2 Ratings of likelihood of bias for given financial relationships

Financial relationship, *n* (%)	Medical school year	Very unlikely to bias	Unlikely to bias	Not sure	Likely to bias	Very likely to bias	*p* value[a]
The investigator received food and/or beverage from the company	**Total**	**66 (14.2)**	**193 (41.4)**	**77 (16.5)**	**115 (24.7)**	**15 (3.2)**	
	Preclinical	34 (14.7)	104 (44.8)	34 (14.7)	53 (22.8)	7 (3.0)	0.195
	Clinical	32 (13.7)	89 (38.0)	43 (18.4)	62 (26.5)	8 (3.4)	
The investigator was compensated for travel and/or leisure from the company	**Total**	**12 (2.6)**	**51 (10.9)**	**63 (13.5)**	**235 (50.4)**	**105 (22.5)**	
	Preclinical	7 (3.0)	32 (13.8)	36 (15.5)	111 (47.8)	46 (19.8)	0.011
	Clinical	5 (2.1)	19 (8.1)	27 (11.5)	124 (53.0)	59 (25.2)	
The investigator received a gift from the company	**Total**	**8 (1.7)**	**46 (9.9)**	**86 (18.5)**	**238 (51.1)**	**88 (18.9)**	
	Preclinical	5 (2.2)	27 (11.6)	43 (18.5)	121 (52.2)	36 (15.5)	0.055
	Clinical	3 (1.3)	19 (8.1)	43 (18.4)	117 (50.0)	52 (22.2)	
The investigator received a research grant from the company	**Total**	**10 (2.1)**	**29 (6.2)**	**67 (14.4)**	**162 (34.8)**	**198 (42.5)**	
	Preclinical	7 (3.0)	15 (6.5)	35 (15.1)	77 (33.2)	98 (42.2)	0.384
	Clinical	3 (1.3)	14 (6.0)	32 (13.7)	85 (36.3)	100 (42.7)	
The investigator received an honorarium payment from the company	**Total**	**5 (1.1)**	**11 (2.4)**	**60 (12.9)**	**200 (42.9)**	**190 (40.8)**	
	Preclinical	4 (1.7)	6 (2.6)	35 (15.1)	93 (40.1)	94 (40.5)	0.207
	Clinical	1 (0.4)	5 (2.1)	25 (10.7)	107 (45.7)	96 (41.0)	
The investigator received compensation from the company for speaking at an event/lecture on its behalf	**Total**	**7 (1.5)**	**61 (13.1)**	**70 (15.0)**	**205 (44.0)**	**123 (26.4)**	
	Preclinical	5 (2.2)	35 (15.1)	34 (14.7)	99 (42.7)	59 (25.4)	0.167
	Clinical	2 (0.9)	26 (11.1)	36 (15.4)	106 (45.3)	64 (27.4)	
The investigator received compensation from the company for consulting	**Total**	**10 (2.1)**	**53 (11.4)**	**83 (17.8)**	**193 (41.4)**	**127 (27.3)**	
	Preclinical	5 (2.2)	34 (14.7)	42 (18.1)	86 (37.1)	65 (28.0)	0.202
	Clinical	5 (2.1)	19 (8.1)	41 (17.5)	107 (45.7)	62 (26.5)	
The investigator received editorial support from the company	**Total**	**9 (1.9)**	**52 (11.2)**	**117 (25.1)**	**196 (42.1)**	**92 (19.7)**	
	Preclinical	5 (2.2)	27 (11.6)	55 (23.7)	97 (41.8)	48 (20.7)	0.875
	Clinical	4 (1.7)	25 (10.7)	62 (26.5)	99 (42.3)	44 (18.8)	
The investigator holds stock/ownership in the company	**Total**	**3 (0.6)**	**7 (1.5)**	**33 (7.1)**	**104 (22.3)**	**319 (68.5)**	
	Preclinical	2 (0.9)	4 (1.7)	20 (8.6)	56 (24.1)	150 (64.7)	0.063
	Clinical	1 (0.4)	3 (1.3)	13 (5.6)	48 (20.5)	169 (72.2)	

[a]*p* value based on Wilcoxon rank sum test, treating the scale as ordinal

current education and policy are insufficient for adequately mitigating undue influence and that efforts should be made to prevent financial relationships during ongoing research.

As a result of the PPSA and subsequent Open Payments Program [18], disclosure of all financial relationships exceeding ten dollars between physicians and industry is required, yet it is unknown whether the program has had any tangible effects on industry's influence [25]. While there is widespread belief among researchers that simple disclosure is sufficient [26], students in our study did not believe that disclosure of COIs is an adequate method to mitigate bias, and further they did not believe that readers can adequately assess potential influence due to COIs. Students generally agreed that any financial relationship between research investigators and industry are likely to introduce bias into research, with the exception of gifting food or beverage, which is notable considering that this was the most reported interaction for students in our study. Whether this finding was due to the students being normalized to this relationship or rather the benign nature of the relationship will have to be explored. In contrast to our study, a similar survey of UCLA medical students found that students generally did not believe any gifts would influence prescribing behavior [24]. This might be explained

Table 3 Opinions on statements regarding the relationship between industry, research, and medical education

Statement, *n* (%)	Medical school year	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	*p* value[a]
Investigator-initiated trials (i.e., trials promoted or sponsored by academia, research centers, not-for-profit organizations, charities, etc.) are less likely to be biased than industry-sponsored trials	**Total**	**4 (0.9)**	**55 (11.8)**	**86 (18.5)**	**224 (48.1)**	**97 (20.8)**	
	Preclinical	3 (1.3)	33 (14.2)	44 (19.0)	106 (45.7)	46 (19.8)	0.081
	Clinical	1 (0.4)	22 (9.4)	42 (17.9)	118 (50.4)	51 (21.8)	
Investigator-initiated trials have greater integrity than industry-sponsored trials	**Total**	**5 (1.1)**	**51 (10.9)**	**165 (35.4)**	**184 (39.5)**	**61 (13.1)**	
	Preclinical	3 (1.3)	34 (14.7)	86 (37.1)	81 (34.9)	28 (12.1)	0.010
	Clinical	2 (0.9)	17 (7.3)	79 (33.8)	103 (44.0)	33 (14.1)	
Disclosing a conflict of interest adequately mitigates its potential to cause bias	**Total**	**32 (6.9)**	**181 (38.8)**	**107 (23.0)**	**127 (27.3)**	**19 (4.1)**	
	Preclinical	17 (7.3)	79 (34.1)	60 (25.9)	65 (28.0)	11 (4.7)	0.216
	Clinical	15 (6.4)	102 (43.6)	47 (20.1)	62 (26.5)	8 (3.4)	
Readers can adequately judge to what extent conflicts of interest influence biomedical research	**Total**	**52 (11.2)**	**223 (47.9)**	**102 (21.9)**	**83 (17.8)**	**6 (1.3)**	
	Preclinical	21 (9.1)	116 (50.0)	52 (22.4)	39 (16.8)	4 (1.7)	0.662
	Clinical	31 (13.2)	107 (45.7)	50 (21.4)	44 (18.8)	2 (0.9)	
I feel adequately educated on the issue of conflicts of interest in biomedical research	**Total**	**32 (6.9)**	**167 (35.8)**	**104 (22.3)**	**133 (28.5)**	**30 (6.4)**	
	Preclinical	17 (7.3)	94 (40.5)	45 (19.4)	60 (25.9)	16 (6.9)	0.144
	Clinical	15 (6.4)	73 (31.2)	59 (25.2)	73 (31.2)	14 (6.0)	
I believe there is adequate separation between my school's hospitals/faculty and the biomedical industry	**Total**	**10 (2.1)**	**30 (6.4)**	**192 (41.2)**	**191 (41.0)**	**43 (9.2)**	
	Preclinical	6 (2.6)	17 (7.3)	110 (47.4)	78 (33.6)	21 (9.1)	0.014
	Clinical	4 (1.7)	13 (5.6)	82 (35.0)	113 (48.3)	22 (9.4)	
It is appropriate for medical students to accept gifts (e.g., meals, textbooks, pens, etc.) from biomedical companies	**Total**	**41 (8.8)**	**96 (20.6)**	**148 (31.8)**	**158 (33.9)**	**23 (4.9)**	
	Preclinical	16 (6.9)	47 (20.3)	88 (37.9)	68 (29.3)	13 (5.6)	0.855
	Clinical	25 (10.7)	49 (20.9)	60 (25.6)	90 (38.5)	10 (4.3)	
The medical school curricula should include events sponsored by biomedical industry	**Total**	**67 (14.4)**	**145 (31.1)**	**148 (31.8)**	**89 (19.1)**	**17 (3.6)**	
	Preclinical	30 (12.9)	67 (28.9)	83 (35.8)	44 (19.0)	8 (3.4)	0.349
	Clinical	37 (15.8)	78 (33.3)	65 (27.8)	45 (19.2)	9 (3.8)	
Medical schools should take a role in guiding students' interactions with the biomedical industry	**Total**	**6 (1.3)**	**35 (7.5)**	**122 (26.2)**	**225 (48.3)**	**78 (16.7)**	
	Preclinical	3 (1.3)	18 (7.8)	56 (24.1)	113 (48.7)	42 (18.1)	0.477
	Clinical	3 (1.3)	17 (7.3)	66 (28.2)	112 (47.9)	36 (15.4)	
Physicians who engage in research should refrain from knowingly participating in a financial relationship with a commercial entity with whom they have a research relationship until the research relationship ends and the research results have been published or otherwise disseminated to the public	**Total**	**5 (1.1)**	**38 (8.2)**	**90 (19.3)**	**220 (47.2)**	**113 (24.2)**	
	Preclinical	2 (0.9)	22 (9.5)	48 (20.7)	97 (41.8)	63 (27.2)	0.908
	Clinical	3 (1.3)	16 (6.8)	42 (17.9)	123 (52.6)	50 (21.4)	

[a]*p* value based on Wilcoxon rank sum test, treating the scale as ordinal

by the difference in how students perceive research behavior versus prescribing behavior and how vulnerable each behavior is to internal biases. Perhaps students see research operations as being more susceptible to investigator biases compared to the more objective and regulated operations of physician prescribing.

A manuscript from the *Journal of Law and Policy* concluded that disclosure does not provide an adequate solution to COIs in science as the mere presence of funding affects scientific outcomes [26, 27]. In addition, trials with industry COI disclosures have repeatedly been associated with publication bias [3, 13]. The AMA emphasizes in their Code of Medical Ethics (Opinion 7.1.4) that physicians conducting research with a company should refrain from having financial relationships with the same company prior to dissemination of their research results, a statement that was widely agreed upon by our readers, which stresses that steps beyond disclosure must be taken to eliminate unethical influence. While disclosure is an important step towards increasing transparency and a necessary requirement to keep readers

informed, it alone may be an inadequate measure for eliminating the potential for conflicts to introduce bias.

A recent article summarized methods for mitigating industry influence in industry-sponsored research [25], and it referenced several tools developed to help readers and reviewers assess the risk of bias associated with randomized clinical trials and reviews, such as the ROB-2 tool and GRADE system [28, 29]. However, even with these systematic methods for quantifying bias, journals vary widely in their approach towards reviewing and publishing articles with bias, and until more stringent policies are made, the presence of bias may have little effect on an article's likelihood of being published in more lenient journals [25]. In addition, providing readers with a quantitative value for bias does not necessarily mean they can translate this into meaningful information on which they can base their clinical decisions. Even armed with a number value for the bias associated with a research article, readers without proper education on the implications of such bias may still accept the article's findings without objection.

Education is known to influence physician behaviors, and educational interventions have become a primary method explored to mitigate the potential detrimental effects associated with industry influence [22, 30]. We found that students believe medical school should have a role in guiding their interactions with industry. While most students in our study reported that they had received education or training about industry involvement, they generally did not feel adequately educated on the issue, which is consistent with similar surveys conducted at medical schools including Harvard Medical School, Creighton University, and Georgetown [19–21]. However, our results suggest that education may increase awareness of COI disclosure and the Open Payments database in addition to increased skepticism towards industry-sponsored studies in favor of investigator-initiated trials. Randomized trials of educational interventions imparted during medical school have yielded improvements, for example, by increasing skepticism of industry-sponsored research [15, 16, 22]. One study surveyed students at four medical schools before and after a series of interventions that aimed to educate students on physician-industry interactions [15]. The authors found that the interventions increased skepticism about these interactions and awareness of their potential to impart bias. However, whether these educational interventions have the durability to last throughout residency and independent practice is still unknown [17, 22], and one study even found that short-term improvements yielded by its intervention later dissipated during residency [17]. Thus, educational interventions that prepare students with a foundation to last throughout their careers are needed, which may require that education continue throughout residency and independent practice.

Effective educational interventions must also compete with industry-sponsored educational materials and workshops. A prophetic article published in *Academic Medicine* in 2001 wrote, "How doctors obtain the information about new and changing pharmaceuticals…has the potential to have a profound impact on health care costs and pharmaceutical companies' profits" [16]. Industry has, indeed, become intertwined with medical education, and most students report some sort of interaction with industry perhaps as often as once per week, including receiving and using industry-sponsored educational resources, materials, and information [19]. Without proper education, students may accept research with industry COIs at face value and without considering the increased likelihood for biased reporting [13, 16, 31]. As it seems most students are involved in some sort of research, it is imperative that medical schools help educate students on how to navigate medical research and assess for validity and bias.

The strengths of our study include its broad population, which represents medical students of all school years and from several allopathic and osteopathic schools across the US. In addition, it is the first study to survey students about the issue of industry influence specifically in medical research. Finally, our study and survey were designed with significant input from current premedical students, medical students, residents, and physicians to produce findings that would be most informative for future medical education and policy.

The limitations of our study include its low sample size relative to what has been reported in similar studies [19]. A possible explanation for this is that students may have been more likely to respond to emails at the time when previous studies were conducted, which was primarily between 2005 and 2015 when email volume was perhaps lower. Another limitation is the possibility of sampling bias, and the study population may not be an accurate representation of the overall US medical student population. For example, students with strong opinions of industry influence, medical research, or educational reform may have been more likely to respond. Furthermore, the external validity of our study is limited based on the likelihood that students represented in our study have varying levels of exposure to both research and COI education compared to students external to our study due to differences in curricula between medical schools. Additionally, though this was not a stated objective, our survey did not inquire about all industry interactions, and students may have had more interactions with industry than is represented. Lastly, our study did not attempt to control for confounding variables, such as through logistic regression, and it did not compare students based on their history of having a COI with industry; we did, however, compare students according to whether they had prior training in research COIs, and this yielded no statistical differences.

Our findings support that medical schools should educate students about the influence of industry on US healthcare, including on clinical practice, medical education, and medical research. While educational interventions have successfully led to short-term improvements in fluency regarding the issue of industry influence, no study has offered an intervention capable of yielding long-term improvements that last beyond residency. Thus, research should aim to develop interventions to prepare medical students to navigate the relationship between industry, medical education, and medical research throughout their careers. Furthermore, since students receive minimal education on the implications and effects of conflicts of interest in research, medical schools should incorporate required trainings, such as those through the Collaborate Institutional Training Initiative (CITI) Program, that prepare students to be able to critically assess the quality of published evidence as future physicians and investigators.

Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics Approval This is a survey study. Institutional Review Board (IRB) approval was received from the Hartford HealthCare IRB (E-HHC-2021-0302), which served as the lead IRB, and from the IRB of each participating medical school.

Consent to Participate Informed consent was obtained from each survey participant in this study.

Conflict of Interest The authors declare no competing interests.

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