

Pre-Medical Preparation in Microbiology among Applicants and Matriculants in Osteopathic Medical School in the United States

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It is recognized that medical school curricula contain significant microbiology-related content as part of the training of future physicians who will be responsible stewards of antimicrobials. Surprisingly, osteopathic and allopathic medical schools do not require pre-medical microbiology coursework, and the extent to which medical students have completed microbiology coursework remains poorly understood. In this report, we show that fewer than 3% of applicants and matriculants to osteopathic medical school (OMS) have completed an undergraduate major or minor in microbiology, and fewer than 17% of applicants and matriculants to OMS have completed one or more microbiology-related courses. These data demonstrate limited pre-medical microbiology-related knowledge among osteopathic medical students, which may be associated with an increase in perceived stress when learning this content or during clinical rotations as well as a potential lack of interest in pursuing a career in infectious diseases.

INTRODUCTION

Microbiology is an important component of the curriculum of all United States (US) medical schools (1, 2). Didactic elements of microbiology during pre-medical years often include basic concepts such as the biology and diversity of microorganisms (e.g., bacteria, viruses, fungi, and protozoa), routes and mechanisms of infection, and the effects of antimicrobial agents, while advanced microbiology courses emphasized particularly during the clinical years of health-related professions often include the epidemiology and pathology of infections, diagnostic testing, infection control and use of aseptic techniques, and antimicrobial resistance stewardship. Due to the importance of microbiology in medical education, educators have debated whether pre-medical coursework in microbiology should be a prerequisite for medical school and other allied health programs (3). Many advocates of such a requirement argue that pre-medical microbiology courses provide the basis for important medical competencies including infection control and prevention (3). In addition, microbiology-related content is a significant component of medical education,

and there are growing pressures to add more microbiology content to the medical curriculum as the scientific body of microbiology knowledge grows and as the emergence and prevalence of infectious diseases grows worldwide, resulting in considerable human morbidity and mortality. Thus, lack of exposure to pre-medical microbiology coursework may lead to added perceived stress and anxiety for medical students when they learn this important subject to fulfill their degree requirements. Moreover, medical students understand that microbiology-related questions are an important component of testing for competency on national medical boards such as the US Medical Licensing Examination (USMLE) and the Comprehensive Osteopathic Medical Licensing Examination (COMLEX).

There are limited quantitative studies examining pre-admission coursework in microbiology or other disciplines among US medical students (4). Using data from applicants and enrolled students in osteopathic medical schools (OMSs), we demonstrate that despite the importance of microbiology in medical school, a limited number of students have taken courses in microbiology or completed a major/minor in microbiology as undergraduates compared with other life science majors. This report provides a better understanding of medical students' pre-admission coursework in microbiology that may help institutional administrators address the needs of their students in the context of admission requirements, curricular changes, student mentoring, and training of clinical competencies. Furthermore, the methodology used in the current study provides a novel approach to understanding medical students' pre-admission credentials that may have a positive

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impact on their future success. Notably, this initiative can also be extended and applied to research on pre-admission credentials of students interested in pursuing a career in allied health care professions.

METHODS

The American Association of Colleges of Osteopathic Medicine (AACOM) oversees a centralized application portal for students applying to all OMSs in the US with the exception of University of North Texas-Texas College of Osteopathic Medicine (UNTHSC-TCOM) and the émigré-physician program of the New York Institute of Technology College of Osteopathic Medicine (NYITCOM). This database contains information on applicants' academic portfolios, including the type of courses taken, institutions attended, grades received, degrees received, etc. As part of the application process, students report their undergraduate major from over 100 possible majors categories (including No Major) listed on the application form, which includes majors in the life sciences (including "microbiology"), math, physical sciences, technology, social sciences, and humanities. Prior to 2016, a total of 120 majors were listed on the application; beginning in 2016, a total of 182 majors were listed on the application form. Also in 2016, students reported whether an undergraduate minor was completed. Applicant data in the AACOM database is verified per information listed on official academic transcripts. All data described in this report contained no personally-identifiable information.

We performed a search of the database of reported undergraduate majors and minors from applicants who completed the AACOM application between 2012 and 2016. The number of applicants and matriculants for all major and minor categories listed on the application were calculated, as well as percentages. We also performed a database search for applicants/matriculants who had taken at least one microbiology-related course. Our search strategy involved looking for the term "microbio" in the course title/name. The percentage of applicants and matriculants who had taken at least one microbiology-related course was determined as well as the total number of microbiology-related courses taken by each applicant and matriculant. Data were analyzed using Excel (Microsoft, Seattle, WA) or Prism (Graphpad, La Jolla, CA) software.

RESULTS

One simple way to determine the extent to which medical student applicants and matriculants have completed previous coursework in microbiology is to search from the AACOM database of majors and minors. From 2012 to 2016, AACOM received 103,356 total applications and 36,426 students enrolled in OMS. First, we determined the numbers of applicants and matriculants to OMS majoring in microbiology and compared them with graduates of other life science majors. In 2016, microbiology as a major ranked

12th among students in the pool of OMS applicants (348 out of 19,486; 1.79% of all applicants) and matriculants (120 out of 6,545; 1.83% of all matriculants) (Table 1); however, these students represented a very small number and percentage. In addition, the number and percentage of microbiology majors from the total pool of student applicants and matriculants has been less than 2.5% from 2012 to 2016 (Fig. 1). The largest percentage of applicants (2.15%) and matriculants (2.34%) who completed a microbiology major was observed in 2015 and 2012, respectively. Chi-squared analyses showed a flat trend and no differences in the number of applicants or matriculants majoring in microbiology for the last five years. These findings suggest that the number of microbiology majors who apply or matriculate to OMSs has been similar during the same period. Thus, the number of applicants and matriculants with extensive coursework in microbiology has been low over the past five years compared with other undergraduate majors.

We also analyzed data of applicants and matriculants who completed moderate coursework in microbiology by obtaining an undergraduate microbiology minor. Data for undergraduate minors were only available for the 2016 application cycle. A rank-order of undergraduate minors revealed that microbiology was 41st out of 182 minors completed by applicants or matriculants (Table 2). Many more undergraduate minors were completed in diverse social sciences (e.g., anthropology, psychology) or other life sciences (e.g., biochemistry, neurosciences) than in microbiology. Specifically, only 23 students (<0.01%) completed an undergraduate minor in microbiology compared with the 11,324 total students who completed a minor in any other discipline and applied to an OMS. Only 8 students (<0.01%) completed an undergraduate minor in microbiology compared with the 3,910 total students who completed a minor in any other discipline and matriculated in OMS.

In addition to microbiology majors and minors, numerous additional applicants and matriculants may have completed any undergraduate coursework in microbiology. In order to evaluate this possibility, we searched through a portion of our database containing the names/titles of courses completed by applicants and matriculants using the search term "microbio." Preliminary searches using this approach identified a diverse listing of microbiology-related courses which applicants had taken at two- or four-year colleges. With this in mind, we performed a more detailed search of coursework from among a sample of 30,109 applicants (including 11,890 matriculants) who had completed any coursework in either a two- or a four-year college and applied to an OMS between 2009 and 2015. This approach yielded 6,930 total courses completed by 5,090 applicants with course titles including "Microbiology," "General Microbiology," "Introduction to Microbiology," "Fundamentals of Microbiology," and "Microbiology Lab." Therefore, only 16.91% (5,090 out of 30,109) of applicants had taken at least one microbiology-related course. From among this cohort, only 1,931 matriculants had taken at least one

TABLE 1.

Distribution of undergraduate majors of applicants and matriculants to osteopathic medical schools in 2016.

2016 Majors	No. of Applicants	%	2016 Majors	No. of Matriculants	%
All Majors Total	19,486	100.00	All Majors Total	6,545	100.00
Biology	5,986	30.72	Biology	1,981	30.27
Psychology	1,345	6.90	Psychology	432	6.60
Biological Sciences	1,282	6.58	Biological Sciences	431	6.59
Biochemistry	1,222	6.27	Biochemistry	426	6.51
Chemistry	758	3.89	Neuroscience	273	4.17
Other/Not Listed	747	3.83	Chemistry	259	3.96
Neuroscience	746	3.83	Other/Not Listed	231	3.53
Biomedical Science	590	3.03	Biomedical Science	219	3.35
Molecular Biology	461	2.37	Molecular Biology	164	2.51
Exercise Science	365	1.87	Exercise Science	150	2.29
Health Science	349	1.79	Health Science	122	1.86
Microbiology	348	1.79	Microbiology	120	1.83

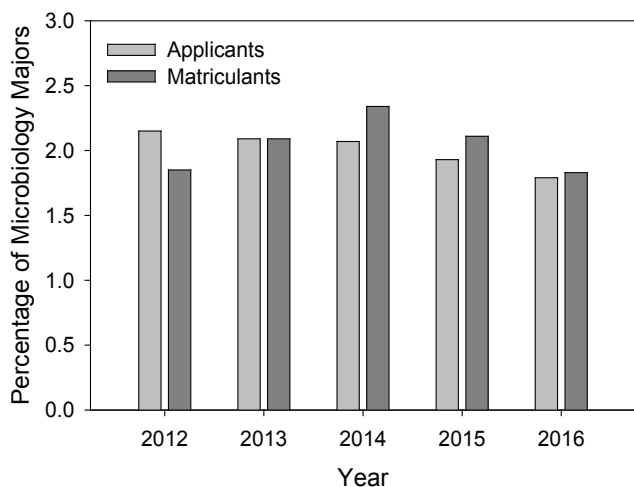


FIGURE 1. Percentage of all applicants (light bars) and matriculants (dark bars) to osteopathic medical schools who have completed an undergraduate microbiology major.

microbiology-related course, which represents 16.24% (1,931 out of 11,890) of the total number of matriculants.

Finally, we calculated the total number of microbiology courses completed per student from among the 1,931 matriculants to OMSs who had completed any microbiology coursework. The majority (1,401 out of 1,931 matriculants; 72.55%) of this small cohort of OMS matriculants had completed a single microbiology-related course. Only 413 (21.39%) and 69 (3.57%) matriculants from among this cohort had completed two or three microbiology-related courses, respectively. Less than 3% of these matriculants had taken four or more courses. It is likely that this group of students represents a fraction of the student pool that majored in microbiology. Taken together, these data indicate that fewer than 17% of OMS matriculants have taken any

microbiology-related coursework, and, among those who had completed previous microbiology coursework, only one course was completed.

DISCUSSION

The breadth, depth, rigor, and volume of content in medical school curricula are recognized as major sources of perceived stress for medical students, which can cause anxiety, depression, burnout, reduced quality of life, and even suicidal ideations (5, 6). In particular, medical students feel overwhelmed by their academic workload, a sensation that relates not only to the curricular demands but also to the students' pre-medical preparation and completed undergraduate coursework. Microbiology-related content within medical school curricula is found throughout didactic instruction of all organ systems, yet remarkably, pre-medical coursework in this important area is not a pre-admission requirement of any medical school. Therefore, lack of microbiology exposure during undergraduate coursework likely poses a challenge to medical students unfamiliar with this content and possibly contributes to the stressful academic workload. In contrast, familiarity with microbiology-related content due to previously completed coursework, even at the introductory level, may be perceived as lightening the academic workload. There are no quantitative data testing these assertions, and this represents an important area for future research.

This report presents novel data on the pre-admission coursework completed by applicants and matriculants of OMSs using data obtained from AACOM. By examining the completed majors or minors of matriculants, we documented that fewer than 3% of students enrolled in OMSs have taken a general microbiology course. This small cohort of OMS students probably represents individuals who completed various courses in microbiology. They may be less

TABLE 2.
Undergraduate minors of applicants and matriculants to osteopathic medical schools in 2016.

2016 Minors	No. of Applicants	%	2016 Minors	No. of Matriculants	%
All Categories	11,324	100.00	All Categories	3,910	100.00
Chemistry	2,279	20.13	Chemistry	771	19.72
Psychology	725	6.40	Psychology	238	6.09
Biology	594	5.25	Other/Not Listed	226	5.78
Other/Not Listed	580	5.12	Biology	203	5.19
Spanish	458	4.04	Spanish	155	3.96
Biochemistry	150	1.32	Mathematics	52	1.33
Mathematics	148	1.31	Public Health	49	1.25
Public Health	143	1.26	Anthropology	44	1.13
Music	118	1.04	Neuroscience	43	1.10
Anthropology	113	1.00	Biochemistry	39	1.00
Foreign Language	108	0.95	History	37	0.95
Neuroscience	105	0.93	Business/Management	36	0.92
Business/Management	104	0.92	Foreign Language	35	0.90
Philosophy	95	0.84	Music	34	0.87
Business Administration	95	0.84	Religion	34	0.87
Sociology	88	0.78	Sociology	33	0.84
English	87	0.77	Biological Sciences	33	0.84
Religion	87	0.77	Business Administration	31	0.79
Pre-medical	84	0.74	French	30	0.77
Biological Sciences	83	0.73	Economics	28	0.72
History	83	0.73	English	27	0.69
French	77	0.68	Pre-medical	25	0.64
Nutrition	65	0.57	Philosophy	24	0.61
Economics	59	0.52	Nutrition	19	0.49
Health Science	50	0.44	Art	19	0.49
Art	47	0.42	Biomedical Science	19	0.49
Political Science	46	0.41	Health Science	17	0.43
Other Social Sciences Major	43	0.38	Political Science	14	0.36
Classics	36	0.32	Other Social Sciences Major	14	0.36
Biomedical Science	33	0.29	Women's Studies	13	0.33
Women's Studies	32	0.28	Art History	12	0.31
Health	31	0.27	Molecular Biology	12	0.31
Art History	30	0.26	Health	11	0.28
Molecular Biology	29	0.26	Communications	11	0.28
Physics	28	0.25	Classics	10	0.26
Environmental Studies	26	0.23	Ethics	10	0.26
Education	26	0.23	Theology	10	0.26
Ethics	26	0.23	Physics	9	0.23
African Studies	24	0.21	Education	9	0.23
Microbiology	23	0.20	Environmental Studies	8	0.20
			Microbiology	8	0.20

challenged by the microbiology-related material contained in the medical school curriculum than those students with less or no previous coursework in microbiology. One hypothesis yet to be tested is whether OMS students with previous exposure to several undergraduate microbiology courses perform better on medical school microbiology-related course assessments or experience less perceived stress

when studying this material than those students without similar experience (4).

We also searched through the academic coursework of a large sample of OMS applicants and matriculants to determine the number and percentage of students who had completed any pre-medical microbiology-related coursework. We found that fewer than 17% of students

enrolled in OMS had completed any pre-medical courses in microbiology. Moreover, the majority of this small cohort of OMS students had completed only one microbiology course. Therefore, using student coursework data as an indicator of microbiology content exposure, our data demonstrate that OMS students are largely unfamiliar with microbiology-related content that they encounter in their medical school curriculum. It would be important to investigate in the future whether the cohort of OMS students lacking any pre-medical courses in microbiology experience greater perceived stress in learning material on infectious diseases and laboratory diagnostic techniques (4).

Despite the novel and quantitative nature of our study, it has several limitations. First, our analyses do not include any medical school applicants/matriculants to allopathic medical schools or to UNTHSC-TCOM and the émigré-physician program of NYITCOM. While it has been previously documented that an overwhelming majority of students who apply to OMS also apply to allopathic medical schools (7), there may exist pre-medical differences in the coursework completed between applicants who enroll in osteopathic versus allopathic medical schools. It would be very interesting to compare the pre-medical preparation in microbiology of allopathic and osteopathic medical students. Second, we had only a sample of the many tens of thousands of applicants to OMS. Third, we cannot determine from the data at hand the extent to which applicants or matriculants of OMSs have covered microbiology-related material in other pre-medical courses. Moreover, we performed course searches based on the search term “microbio,” which may have missed microbiology-related courses that have course titles lacking the search-term. Regardless of the above limitations, our analyses include more quantitative data than previously reported specifically for pre-medical preparation in microbiology of OMS applicants and matriculants.

Our findings are important because the information included was obtained from students’ applications that consist of verified data from academic transcripts. This gives our approach an advantage over data acquired through surveys, which are limited by the number of responders and the accuracy of their responses. These results are of interest to faculty and administrators of OMSs seeking to understand the breadth and depth of pre-medical knowledge of microbiology among admitted medical students, which may have important implications related to pre-clinical academic performance, perceived stress and anxiety management, clinical competencies, and personal satisfaction. In this regard, we recently demonstrated the need for practical experiences in microbiological techniques among OMS students during pre-clinical training to facilitate learning and basic understanding and competency in diagnostic testing (8). More broadly, our findings point to the need for communication between microbiology educators at the collegiate and medical school levels to understand the depth and breadth of pre-medical preparation in microbiology for medical students. These groups of educators would then

also be in the best position of consensus to recommend or not changes in microbiology pre-admission requirements for medical school. Alternatively, we propose that early diagnostic testing in microbiology of admitted and enrolled medical students may help educators identify deficiencies in this subject. The dearth of medical students’ exposure to microbiology can then be supplemented with individualized tutoring or small group lessons emphasizing perceived stress reduction. Furthermore, identifying students’ perceived stress, specifically related to microbiology inefficiencies, might be possible by frequent administration of surveys after exams covering microbiology content, with a view to evaluating the students’ emotional health and views on this subject and its relationship to the workload.

In conclusion, this study serves as the basis for subsequent studies demonstrating limited pre-medical microbiology knowledge among applicants and matriculants to OMS. Likewise, lack of microbiology coursework may be associated with students’ perceived stress and a heavy pre-clinical course load. We hope that by making the problem of insufficient microbiology preparation among applicants and enrolled medical students more visible and supported by meaningful data, we can stimulate an evidence-based conversation about the importance of competent microbiology preparation in areas such as infectious diseases and antimicrobial resistance, thus promoting future changes in the medical school admission requirements and curriculum involving collaborations between medical and undergraduate educators. Finally, we envision that a similar approach can be used to examine the pre-medical knowledge in other important content areas in the medical school curriculum among OMS applicants and matriculants, as well as in students of other health-related professions (e.g., physician assistant, pharmacy, dental schools) where a centralized application portal is used.

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