Relationship between Quantity of Undergraduate Science Preparation and Preclinical Performance in Medical School

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ABSTRACT

Purpose. The primary purpose of this study was to determine whether a relationship existed between the quantities of undergraduate science education completed by medical students and their subsequent preclinical performances in medical school. The secondary purpose of the study was to determine the nature of any relationship present and to re-verify standard predictors of preclinical performance in medical school.

Method. This study was undertaken at Albany Medical College in conjunction with Sage Graduate School, Albany, New York. The analysis encompassed 120 systematically and 80 randomly selected medical student academic records (200 total cases) from the entering classes of 1977 through 1992. Twelve distinct variables were collected. Data transformations were completed as required, and the data subsequently standardized. Standard descriptive statistics, correlation between variables, *t*-tests between systematically and randomly selected groups, and factor analysis were performed on the data collected.

Results. It was determined that there was no significant relationship between total hours of undergraduate science completed and average preclinical performance in medical school. In addition, correlation between subdivisions of total hours of undergraduate science (total hours of chemistry, total hours of biology, total hours of math, and total hours of physics) and subdivisions of average preclinical performance (year-one preclinical performance and year-two preclinical performance) also proved to be nonsignificant. However, significant relationships between average preclinical performance and its subdivisions and other standard predictors of preclinical performance (Medical College Admission Test score and science grade-point average) were found to be in line with values in recent literature. In addition, significant relationships were found with the National Board of Medical Examiners Part I examination. Factor analysis of all variables yielded three underlying factors: medical school preclinical performance factor, undergraduate performance factor, and quantity of non–life-sciences factor.

Conclusion. Quantity of science-based undergraduate premedical education, either in its entirety or in subdivisions, did not materially affect the performances of the selected medical school students in their preclinical years of medical school.

Acad. Med. 70(1995):230–235.

It has generally been agreed that a solid undergraduate background in the basic sciences is required for a medical student to perform adequately in medical school.[1,2] Although medical school admission criteria are not truly standardized and may vary slightly from medical college to medical college, they are likely to include the following basic core, with laboratories: two semesters of introductory chemistry, two semesters of organic chemistry, two semesters of introductory biology, two semesters of physics, and two semesters of calculus or other math. The Medical College Admission Test (MCAT) reflects these basic undergraduate science requirements in its testing, and the National Board of Medical Examiners Part I examination (NBME I) tests preclinical knowledge built from these undergraduate science requirements.

Consequently, the science preparation paradigm has long been assumed to be the most appropriate way to prepare students for the rigors of medical school, i.e., premedical students have traditionally majored in the sciences. Many students and premedical advisers may still believe that science majors have the "competitive edge" with admission committees at medical schools, even though it has been

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demonstrated that students who concentrate their academic efforts on a specific area (such as the sciences) often forego education in other areas, such as the liberal arts.[1,2]

The science major paradigm, however, has been challenged by numerous leaders in medical education. The Association of American Medical Colleges' (AAMC's) *Medical School Admission Requirements* expresses a rather distinct preference concerning the desired goal of premedical education:

> [The nation's medical schools] recognize the importance of a broad education. . . . a solid background in the social sciences and humanities. . . . Additional science courses are not required. . . . The practice of taking additional science courses that cover material taught within the medical school curriculum in the belief that they will be useful in gaining admission to and succeeding in medical school should not be recommended. . . . Studies in the humanities and in the social and behavioral sciences . . . are strongly suggested. . . . Students who select a major area of study solely or primarily because of the perception that it will enhance the chance of acceptance to a school of medicine are not making a decision in their best interest.[2, pp. 23–24]

However, even in light of this statement, the perception may still persist among many premedical advisers and medical school applicants that being a non-science major reduces the chances of being accepted into medical school.

Predictors of Medical School Performance

Since medical school admission committees must make a very difficult determination of who will make a future competent physician, reliable criteria are highly desirable. Admission decisions have come to rest primarily upon a number of well-defined secondary, quantitative objectives related to academic performance in medical school.

In terms of today's predictors of preclinical performance, the 1977–1990 MCAT employed in this study was found to have an improved predictive power over the previous MCAT as demonstrated by Cullen et al., Leonardson et al., and others.[3,4] Additionally, Leonardson et al., among others, found undergraduate cumulative and science grade-point average (GPA) measures to be good predictors of medical school performance.[4] Friedman et al. found science GPA to be "the most important predictor variable when total examination (NBME Part I) is the outcome measure."[5] With premedical curricula and MCAT refinement ordered in a symbiotic relationship, it is not surprising that one finds good predictive ability using a test such as the MCAT to assess knowledge supposedly developed from closely related course work.

Method

In an effort to shed light on the undergraduate science linkage to premedical performance, research was undertaken using student transcripts at Albany Medical College from the entering classes of 1977 through 1992. Science GPA, cumulative GPA, and MCAT score were examined as predictors because of the strong research base and practical application that supports them. Nine additional variables were used to explore the relationship between the quantity of undergraduate science completed and preclinical performance: hours of chemistry (HrsChem), hours of biology (HrsBio), hours of math (HrsMath), hours of physics (HrsPhy), total hours of science (HrsTl), NBME I score, year one preclinical performance (Yr1Perf), year two preclinical performance (Yr2Perf), and average preclinical performance (AvgPerf).

Descriptions of Variables

Dependent variables. The mean performances of the medical student were computed for the first (Yr1Perf) and second (Yr2Perf) years of medical school. Alphabetic grades were first converted to ordinal numeric values by assigning the lowest possible alphabetic grade a numeric of 0 and subsequently higher grades the next whole positive number (e.g., F = 0, D = 1, C = 2, B = 3, A = 4) following the work of DeVaul et al.[6] The converted numeric grade of each course was then multiplied by the number of contact hours assigned to the course to yield a weighted performance score; from the weighted performance scores for all courses, averages were computed for the first and second preclinical years. The numeric mean of Yr1Perf and Yr2Perf after conversion from the alphabetic grade was calculated in the following manner: AvgPerf = (Yr1Perf + Yr2Perf)/2. The NBME I variable was included in order that it might be used as a correlative measure of performance with the dependent variables Yr1Perf, Yr2Perf, and AvgPerf, since it is also a measure of preclinical performance.

Independent variables. The hours of undergraduate chemistry, biology, math, and physics completed by the students were summed and form the four science categories. It should also be noted that the subdivision of HrsChem included biochemistry, while HrsBio did not, making HrsBio a life-science variable and HrsChem, HrsMath, and HrsPhy non–life-science variables. Following the AAMC's *Medical School Admission Requirements*, semester courses with laboratories were considered to encompass four credit hours of study.[2] The total hours of undergraduate science (chemistry, biology, math, and physics) completed by the student were calculated by summing the science subdivisions in the following manner: HrsTl = HrsChem + HrsBio + HrsMath + HrsPhy.

Intervening variables. The average of the MCAT subtest scores was taken for this study, with the highest average score from a single test employed when the MCAT was taken more than once. As mentioned previously, the MCAT is a proven predictor of preclinical performance.[5] As a predictor, cumulative GPA appears to be relatively reliable and was included on the basis of the work of Leonardson et al.[4] and Friedman and Bakewell.[5] Science GPA is a subset of the cumulative GPA, reflective of the science courses collected in the HrsTl variable, and has been selectively employed in studies of medical school performance.[4,5]

Exclusion Criteria

Cases for which the undergraduate institution varied from the normal two-semester system (i.e., trimesters, quarters) were excluded. Cases with any graduate training or advanced degrees beyond the bachelor's level were excluded. Also omitted were cases with non-standard grading schemes. Only those cases using the standard 4.0 scale (A, B, C, D, F) or modified 4.0 scale (A+, A, A−, B+, B, B−, C+, C, C−, D+, D, D−, F) were included in the study.[7] Transfer cases from other medical schools were omitted rather than standardizing grading schemes from one medical college to another. In addition, cases for which the MCAT was not taken between the years of 1977 and 1990 were excluded since the 1991 MCAT did not, at the time of data collection, provide a large enough sample.

Assumptions in Data Collection

In collecting data from undergraduate transcripts, it was found that a wide variation in grading schemes existed even within the standard and modified 4.0 GPA scale. Therefore it became necessary to make assumptions like those of Dressel[7] and Hill[8] regarding certain ambiguous or non-standard elements encountered in the data collection. Undergraduate grades of satisfactory or pass were mapped to a standard recalculated grade of C during the data collection. In the cases of combined or dual grades of the A/B, B/C, C/D type, the highest of the two grades was taken.[7,8]

It was decided that separate laboratory grades would be excluded from the science GPA and cumulative GPA calculations. Advanced placement (AP) credit from post-secondary institutions was included in the study. AP grades were treated as pass/fail and assigned a grade of C. If undergraduate courses were retaken, the highest of the two grades was used in the calculation of both the science GPA and cumulative GPA variables. Courses dropped were excluded from the calculation of both the science GPA and cumulative GPA variables. Courses audited were excluded from the calculation of both the science GPA and cumulative GPA variables.

Data Calculations and Conversions

Case selection was twofold: Group 1 consisted of 120 cases selected systematically by taking every third case from the pool in reverse chronological order (i.e., 1992, 1991, 1990, etc.); Group 2 consisted of 80 cases selected randomly by sequentially numbering the cases in the pool and using a random number table to select cases. Duplicated cases were avoided by recording the last four digits of the social security number of each case and running a systematic duplicate check. It was necessary to re-calculate the science GPA and cumulative GPA variables from student transcripts on a case-by-case basis within the standard or modified 4.0 GPA scale framework.[7]

Results

Description

Six semesters of chemistry, seven semesters of biology, two semesters of physics, and two semesters of math were completed on average. The average numbers of semesters of chemistry and biology exceeded the AAMC's recommendations, but the average numbers of semesters of math and physics were closely in line. Further analysis showed that some cases made virtually entire degrees of one subject, while other cases escaped completing physics and math requirements completely. (Having no hours of math or physics on the student transcript occurs when a medical school tentatively accepts students who have not completed all of the requirements for admission under the premise that they will complete the missing requirements prior to starting medical school.) One case with 116 hours of chemistry was a chemistry major but completed a second major in another subject and therefore had over 150 credit hours in two majors.

Averages

The means for science GPA and cumulative GPA were 3.30 and 3.35, respectively. The HrsTl mean of 71.13 is a clear indication of the seriousness of science preparation among undergraduates headed for medical school. Assuming a normal undergraduate degree would encompass 120 hours, the mean total hours of science at 71.13 hours account for approximately 59% of the degree. As expected, most of the science hours were in biology and chemistry (means of HrsBio of 29.27 and HrsChem of 23.32 versus HrsMath of 9.78 and HrsPhy of 8.76). (The modes for HrsBio and HrsChem were both 16.00). The mean MCAT score was 9.55.

In examining medical school performance numbers, the means show an interesting contrast. For Yr1Perf the mean was 3.60; for Yr2Perf the mean was 2.97, creating a reduction between year one and year two of 0.63. The combined performance average of year one and year two (AvgPerf) was 3.28. The mean NBME I score was 501.23.

Relationships

It was believed that correlation analysis using z-score conversions of well-accepted indicators of preclinical performance in medical school and undergraduate premedical curricula would shed light on the linkages presumed to exist among them. The use of z-scores was undertaken to smooth any possible differences arising from case selection procedures. Used in regression analysis, z-scores (sometimes called standard scores), with an mean of 0 and a standard deviation of +1 or −1, allow for more reliable relationship analysis.

A complete listing of the correlation coefficients is presented in Table 1. Among the findings are the low but significant correlation coefficients between total hours of science completed and each of the GPA measures: .2590 for HrsTl and science GPA and .1441 for HrsTl and cumulative GPA, significant at the .01 and .05 levels, respectively. The significance is likely due to the fact that 74% of the summary HrsTl variable may be attributed to component variables (HrsChem at 23.32 and HrsBio at 29.27) and, as mentioned previously, approximately 59% of a complete undergraduate degree may be also accounted for by the HrsTl variable. Low but significant correlation findings also hold true for science hours completed within the individual science subdivisions and either of the two GPA subdivisions as well. For example, HrsChem and HrsBio correlate with science GPA at .1595 and .1735 respectively, both significant at the .05 level. The figures result from the heavy hours loading of both of these variables in relation to the science GPA variable. The coefficient between science GPA and NBME I is .2226 and is significant at the .01 level, indicating that while not large, performance in the undergraduate sciences is linked to an examination designed to measure preclinical performance in medical school (NBME I) rather than the examination designed to measure overall medical school apti-

Table 1

Correlation Coefficient Matrix of Normalized Predictors of Preclinical Performance in Medical School*

	HrsChem†	HrsBio‡	HrsMath‖	HrsPhy¶	HrsTl§	Science GPA††	Cumulative GPA††	MCAT	NBME I‖‖	Yr1Perf¶¶	Yr2Perf***	AvgPerf†††
HrsChem†												
HrsBio‡	−.2541§											
HrsMath‖	.2625§	−.0898										
HrsPhy¶	.0236	−.0049	−.0032									
HrsTl§	.5460§	.5888§	.4091§	.2335§								
Science GPA††	.1595‡‡	.1735‡‡	.0468	.0144	.2590§							
Cumulative GPA††	.0815	.1345	.0359	−.0189	.1441‡‡	.8590§						
MCAT§§	.1008	−.0039	.0170	.0247	.0637	.0561	−.0985					
NBME I‖‖	.0389	.0765	.0027	.0769	.1020	.2226§	.1040	.4252§				
Yr1Perf¶¶	−.0481	.0241	.0520	.0429	.0127	.1704‡‡	.0950	.3506§	.6118§			
Yr2Perf***	−.0355	.0495	.0427	.0566	.0150	.1386	.1124	.1492‡‡	.5641§	.5927§		
AvgPerf†††	−.0472	.0405	.0080	.0553	.0155	.1740‡‡	.1157	.2857§	.6600§	.9038§	.8803§	

*The analysis was based on 200 student transcripts from the entering classes of 1977 through 1992 at Albany Medical College. All variables were normalized prior to correlation.

†HrsChem: hours of undergraduate chemistry courses; ‡HrsBio: hours of undergraduate biology courses; §p = .01 (two-tailed t-test); ‖HrsMath: hours of undergraduate math courses; ¶HrsPhy: hours of undergraduate physics courses; §HrsTl: total hours of undergraduate science courses; ††GPA: grade-point average (undergraduate); ‡‡p = .05; §§MCAT: Medical College Admission Test average score; ‖‖NBME I: National Board of Medical Examiners Part I examination score; ¶¶Yr1Perf: year-one performance in medical school; ***Yr2Perf: year-two performance in medical school; †††AvgPerf: average preclinical performance in medical school (years one and two).

Table 2

Factors of Preclinical Performance in Medical School*

Factor 1: Medical School Preclinical Performance		Factor 2: Undergraduate Performance		Factor 3: Quantity of Non-life Sciences		Factor 4	
AvgPerf†	.95760	Cumulative GPA**	.96472	HrsChem††	.86382	HrsBio‖‖	−.90530
Yr1Perf‡	.88459	Science GPA**	.93540	HrsMath‡‡	.67577	HrsTI§§	.79239
Yr2Perf§	.82186			HrsTI§§	.56531		
NBME I‖	.80188						
MCAT¶	.48454						

*The factor analysis was based on 200 student transcripts from the entering classes of 1977 through 1992 at Albany Medical College. Varimax rotation was performed with Kaiser normalization using standardized data. Variables with factor loadings of .3 or less were not considered as contributing to the factors.

†AvgPerf: average preclinical performance (years one and two); ‡Yr1Perf: year-one performance; §Yr2Perf: year-two performance; ‖NBME I: National Board of Medical Examiners Part I examination score; ¶MCAT: Medical College Admission Test; **GPA: grade-point average; ††HrsChem: hours of undergraduate chemistry courses, including biochemistry;‡‡HrsMath: hours of undergraduate math courses; §§HrsTI: total hours of undergraduate science courses; ‖‖HrsBio: hours of undergraduate biology courses.

tude (MCAT). The NBME I and AvgPerf are related at a level of .6600 in these data, significant at the .01 level. This result is as anticipated, since the NBME I was designed to measure preclinical performance and should be a solid predictor.

However, for the majority of the remaining variables, correlation coefficients are low and nonsignificant. The generally low correlations and lack of significance among the science variables are striking considering the abundance of the science hours taken on average and the premedical preparation these students had undertaken.

Factor Analysis

For a thorough exploration of the data, a factor analysis was undertaken in an attempt to transform any presumed relationships into a smaller number of underlying factors, if possible. A factor analysis is an analytic technique designed to reduce a large number of variables into a smaller set of underlying shared unities (clusters) called factors. The factor loadings (strengths of associations among correlation coefficients) are calculated for each of the variables, and the variables are grouped into unnamed factor categories based on commonality among variables. In this manner, one may attempt to explain complex interrelations among many variables in more simple and concise terms. These factor categories may be subsequently named based upon the variables grouped under them and their presumed underlying unities. For the variables in this study, varimax rotation specifying a maximum of four possible factors was performed to make any factors stand out as clearly as possible. A varimax rotation is a factor-analytic term meaning the relationships were sorted to create a maximum difference among possible factors, thus allowing the variables most alike to be grouped together. No distinction was made between independent or dependent variables.

Table 2 presents four factors. Clearly emerging as a distinct pattern of intercorrelated variables is Factor 1, probably best labeled the Medical School Preclinical Performance Factor. NBME I, Yr1Perf, Yr2Perf and AvgPerf all cluster together, with strong associations to the factor of no less than .80188. The MCAT, while lower in its contribution to the factor grouping at .48454, may still be considered a part of this factor. Logically, one would expect to see these measures forming a natural and significant dimension of medical school performance. Factor 2 seems logical as well and might best be labeled the Undergraduate Performance Factor. One might reasonably expect a premed major's cumulative GPA and science GPA to work together, since a premed major's course work would form a significant element of his or her GPA. Yet, no other standard medical school performance predictor or actual performance indicator can be seen as contributing in any substantive way to this factor. Factor 3 presents itself most logically as the Quantity of Non-Life Sciences Factor. HrsChem and HrsMath dominate this factor rather than the life science of biology (i.e., HrsBio). Biology would logically be expected to appear as a contributor to this factor in a medical school preparation context, but it does not. If this were a purely mathematical factor, one might also reasonably expect to see math and physics clustered with chemistry, but HrsPhy is conspicuously absent. The fourth factor remains unnamed, as there appears to be only the strong negative HrsBio loading of −.90530 and a positive loading of .79239 for HrsTI, suggesting that biology actually pulls away from the other science measures in the data.

The factor analysis demonstrated that among these data there appear to be no distinct patterns of medical school preparation success within the presumed factors to achieve such success. Course work either substantiatively or in length does not show any patterns that are associated with performance in medical school. In the grouping of variables forming what can clearly be seen as performance in medical school (medical school preclinical performance factor), not a single undergraduate science discipline shows any association with the performance elements of the factor. Moreover, no patterns appear among the undergraduate science disciplines. The disciplines one would expect to find clustering together because they would seem the most germane to medical school performance are not found clustered together.

Conclusion

The conclusions that can be drawn here are directly applicable to the one medical school (Albany Medical College) and the 200 cases selected; yet the results are clear. For these cases, the quantity of undergraduate premedical science preparation, either as a whole or in its subdivisions, did not appear to correlate in any significant manner with performance in the first or second preclinical years of medical school. Equally clear are the findings that the well-regarded MCAT correlates significantly with average preclinical performance and its subdivisions. In addition, science GPA correlates significantly with average preclinical performance and year one preclinical performance. It is evident that MCAT and science GPA still point the way to medical school performance. Since the standard variable indicators chosen for use here are ones developed and used by researchers in the field, the results produced are not likely to be because of poor indicators. Furthermore, these are well accepted measures used by medical school admission committees. Moreover, the factor analysis performed on these data confirm the very close relationship among standard predictors of preclinical performance found in the literature. A sample drawn from multiple schools and transcripts would provide the confirmation or denial of the findings from the 200 cases employed in this study.

The authors gratefully acknowledge the cooperation of Albany Medical College in this study. They specifically thank Anthony Tartaglia, MD, Dean of Albany Medical College, for his consistent cooperation. Finally, one author (Stocks), would like to express his most sincere appreciation for the diligent expertise of Ms. Kristen Spensieri, formerly of Albany Medical College, currently of Yale School of Epidemiology and Public Health. Without Ms. Spensieri's enthusiasm, foresight, expertise, and genuine concern for the study, its completion would not have been possible.

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