# PHYSICS SCORES AS PREDICTORS OF THE MEDICAL COLLEGE ADMISSIONS TEST

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*ABSTRACT*

Assessment tools used in a physics course were evaluated in terms of their predictive ability of student performance on the medical colleges admissions test (MCAT) physical sciences subtest. In particular, using regression and correlational analyses, relationships between the exams, final exam, overall semester scores, quiz scores, lab scores, paper score, and the MCAT scores on the physical sciences subtest were analyzed. The strongest correlations with the subtest scores existed with those tools that assessed analytical abilities. Specifically, the score on a comprehensive, multiple-choice final exam provided a single tool that can serve as an effective predictor of the subtest score. This study was undertaken to serve as an assessment tool to establish a baseline database from which future curriculum revisions could be planned and evaluated.

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Medical schools use a variety of predictors to select those applicants who best match the programs and who will offer the most to the profession. One of the principal tools in the decision to admit a student is the medical college admissions test (MCAT). Students' performance on the MCAT ranks high among the preadmission variables and is given significant weight by medical school admission committees in deciding which candidate is given the highest consideration for admission (Henry and Bardo 1990). Several researchers have demonstrated the power of the MCAT in predicting success in medical school (e.g., Golman and Berry 1981, Jones 1983). But how well do undergraduate institutions prepare the students for this important test? How predictive is a student's overall performance in a natural science course and their MCAT scores? The motivation for the current study was the interest in using MCAT scores as an external assessment of a physics program's effectiveness.

The present paper investigated how students, who have completed an introductory physics course, performed on the MCAT physical sciences subtest. In particular, this research: (1) examined the correlations between variables testing the students' performance in physics and their MCAT physical sciences subtest performance, (2) identified the variables which are good predictors of MCAT subtest scores, (3) investigated the combinations of variables as predictors of MCAT physical sciences subtest scores, and (4) gender differences.

Standardized tests have been shown to predict performance on academic tasks (Sternberg and Williams 1997). In the case of the medical school research, the MCAT has been shown to predict later performance of an academic type but not the essential clinical performance of medical school students, which involves solving different types of problems from those found on standardized tests and course exams (Gough and Hall 1975). There are three components to the MCAT test: a) Scientific Reasoning, b) Verbal Reasoning, and c) Essays (Flowers and Silver 1996). The MCAT's scientific reasoning component is divided into two sections: the Physical Sciences and Biological Sciences. The Physical Sciences subtest consists of questions concerned with physics and inorganic chemistry, whereas the Biological Sciences subtest consists of questions from biology and organic chemistry. The preparation for medical school almost always involves the completion of an undergraduate introductory course in physics. This course is often designed to teach problem-solving and analytical-thinking skills as well as physics. It is therefore important to consider whether an undergraduate general physics course adequately prepares the students for this important test and what portions of such a course would best prepare them for it. In the present study, the structure of one particular General Physics course (the course required one semester of calculus as a prerequisite) whose enrollment is dominated by pre-medical students is considered.

Throughout the academic year, students are asked to solve particular physics problems (multiple choice and workout) during exams. Weekly quizzes which involve multiple choice testing, solving one problem, or finding a group solution to a more difficult problem are required to promote continuous, collaborative study between the students in the class. Introductory physics courses typically include time spent in a laboratory where the students are asked to experience the physics principles they have learned from lectures and discussion classes.

The course investigated in this study chose to use a lab manual that emphasized conceptual understanding rather than extensive statistical evaluation (numerical treatment) of data. To encourage active participation, weekly laboratory write-ups were required. Furthermore, each semester, the students wrote a paper on a subject relating to a real world application or historical context requiring the students to generalize their knowledge in a way that involved their verbal and composition skills. Finally, at the end of each semester a final comprehensive, multiple choice exam was meant to reflect the students' overall understanding of physics and their ability to solve problems. The overall physics grade was based on the average performance in each of these areas of the course (45% exams, 15% quizzes, 10% laboratory write-ups, 10% paper, and 20% final exam). Based on these various assessments, it was reasonable to assume that a student's performance in physics would reflect their performance on the MCAT physical sciences subtest.

It has long been observed that women earn higher college grades than expected on the basis of their scores on achievement tests (Stricker et al. 1993). Many females have a clear advantage on quantitative tasks in the early years of school, but this reverses before puberty; many males then maintain their superior performance into old age (Neisser 1996). For example, the mathematics portion of the Scholastic Aptitude Test (SAT) shows a substantial advantage for males ($d$ = 0.33 to 0.50), with many more males scoring in the highest ranges (Halpern 2000). Males also score consistently higher on tests of proportional and mechanical reasoning (Halpern 2000). Although the average amount of over- or underprediction on achievement tests is small, it can still be important if women are systematically disadvantaged. Some of the explanations that have been advanced to account for this phenomenon have been: differences in childhood training and experience, attitudes, parental and teacher expectations and behaviors, course taking, and biological characteristics (Feingold 1988). Furthermore, psychometric explanations (i.e., unreliability of the predictors) and problems with selection (e.g., self-selection) have also been proposed (Stricker et al. 1993). This study explores whether gender is a major factor in predicting a student's MCAT physical sciences subtest performance.

### Hypotheses

The present study examined the correlations among components of the students' grades for two consecutive semesters of an introductory physics course and their subsequent performance on the MCAT physical science subtest. It was hypothesized that because MCAT scores are predicting the broad-based retention of academic and analytical skills rather than practical skills, one would expect stronger correlations between (a) the exams, (b) final exam, and (c) overall semester scores, which assess analytical abilities than (d) the quiz scores, which assess analytical abilities related to only the most recent material, and (e) the laboratory scores, which reflect the students' practical skills, or (f) the paper, which reflects a student's composition skills. Based on the research findings on sex differences in achievement testing and male superiority in mathematics testing, it was predicted that there would be a small sex difference between men's and women's physics performance scores and their MCAT subtest scores, with men scoring slightly higher than women. Furthermore, congruent with the requirement of the physics course, the comprehensive multiple choice final exam, an exam similar in form, was expected to be the best predictor of future performance on the MCAT physical sciences subtest.

## METHOD

### Participants

A total of 46 undergraduate junior and senior students (24 men and 22 women) from a Midwestern private university participated in this study. The majority of the students came from a middle-class, white background. They were enrolled for two consecutive semesters in an introductory physics course. Thirty of the students in the study attended the classes in the fall semester 1995 and the spring semester 1996, whereas sixteen participants attended the classes in the fall of 1996 and spring of 1997. All the participants voluntarily agreed (prior to taking the MCAT) to release a record of their MCAT physical science subtest scores for program assessment purposes. The MCAT physical science subtest scores represent one of several assessment tools to determine if the physics course goals are being met.

### Procedure

The data were derived from the student physics records. For each semester, the student's percentage scores for the following independent variables were considered: a) average quiz score, b) average exam score, c) laboratory score, d) research paper, e) final exam score, and the gender of the participant as well as the overall semester score. The MCAT for the physical subtest scores constituted the dependent variable or criterion. The MCAT physical sciences section is composed of 77 multiple-choice questions that test reasoning in general chemistry and physics. Questions are equally divided between the two subjects. Sixty-two of the questions are based on passages that describe a situation or a problem (Association of American Medical Colleges 1995). The test contains 10 or 11 of these problem sets, each containing 4 to 8 questions. An additional 15 questions are independent of any passage and of each other. Every MCAT candidate receives four separate scores: one for verbal reasoning, one for physical sciences, one for biological sciences, and one for the two writing samples combined.

In order to test the hypotheses and to examine which variables were more predictive of MCAT subtest scores, instructors from the physics department ($n$ = 10) at the same Midwestern university assigned a rating (strong, medium, weak) to each predictor variable. The faculty proposed that (a) the final exam, followed by (b) the exam and semester scores should be most predictive of the MCAT physical science subtest performance.

**Analyses**

Using SPSS (Vax version 4.0) descriptive statistics, frequency analyses, and correlations among all variables for the combined genders were computed. Separate descriptive statistics and correlation analyses were performed for each gender and for each of the two class years. Because there were no statistically significant differences between the raw scores of the two class years and two semesters, the variables were combined for the remaining analyses. In order to determine which of the variables were the best predictors, a stepwise multiple regression analysis with (a) MCAT physical sciences subtest scores as the criterion, (b) exams, (c) finals, and (d) semester scores as the predictors was computed. In order to assess the contribution of the other predictors (excluding the single best predictor) to the prediction of MCAT subtest scores a hierarchical multiple regression analysis with (a) MCAT physical sciences subtest scores as the criterion, (b) exam and quiz, (c) lab and paper, and (d) gender as the predictors was performed. Finally, to examine the overall proportion of variance in the MCAT subtest scores accounted for by all 6 variables and to determine the increment in R square accounted for by the independent variables above and beyond that of the single best predictor, another hierarchical regression analysis was performed. Again, (a) the MCAT subtest scores constituted the dependent variable, whereas (b) the final exam, (c) exam and quiz scores, (d) lab and paper scores, and (e) gender were the independent variables entered at each step.

## RESULTS

Table 1 shows the means, standard deviations, and ranges for the dependent (MCAT) and each of the independent variables for the combined genders. Overall, the average scores for both semesters were similar. That is, overall, the participants performed equally well in both the first and the second semester in physics. T-tests for each set of variables revealed that only the laboratory scores differed significantly from one semester to the next ($t(45) = -4.16$, $p < 0.05$). Furthermore, the two highest means were the laboratory scores for both semesters ($M_{lab1} = 92.68$, $SD = 4.88$; $M_{lab2} = 96.33$, $SD = 4.34$). These differences may be due to increased familiarity with the grading system; with time, the students improve in their ability to write lab reports.

Descriptive statistics performed on each class year separately showed that there were no significant differences between the two separate samples of students ($n_1 = 30$; $n_2 = 16$). The subsequent analyses included the full data set ($n = 46$). On average, the participants in the combined sample achieved a score of 8.1 on the MCAT physical sciences subtest (maximum = 15) ($M_{MCAT} = 8.09$, $SD = 1.95$). The national average on the physical science MCAT subtest in 1997 was also 8.1 (personal communication, November 1997). The range of MCAT subtest scores for this combined sample was rather large (*range* = 4–13).

Because the individual semester means did not differ significantly from each other (except for the laboratory scores whose evolution can be accounted for) the two semester variables for each predictor were collapsed for the subsequent analyses. That is, only the total score for each predictor was considered (i.e., lab, paper, quiz, exam, final, semester). Correlations for the combined sample are listed in Table 2. All correlations between MCAT subtest scores and the predictor variables were statistically significant. As expected, the strongest positive relationships were found between the MCAT subtest scores and those scores that test analytical abilities: exams, final exams, and semester scores respectively ($r_{MCATexam} = .6464$, $p < .05$; $r_{MCATfinal} = .7275$, $p < .05$; $r_{MCATsemester} = .7270$, $p < .05$). Presumably, a student performing well on exams throughout the year, and doing well on the comprehensive final exam, and overall in the course will have understood the basic concepts in physics. Furthermore, a similar test format is used in both the final exam and the MCAT subtest. The ability to solve physics prob-

Table 1. Means, standard deviations, minima, and maxima for the dependent and independent variables for the overall sample (gender combined) ($n$ = 46)

| Variable | *M* | *SD* | *Min.* | *Max.* |
|---|---|---|---|---|
| MCAT | 8.01 | 1.95 | 4 | 13 |
| Quiz 1 (first semester) | 88.77 | 8.08 | 67 | 100 |
| Quiz 2 (second semester) | 88.75 | 7.79 | 68 | 100 |
| Exam 1 | 85.35 | 10.67 | 44 | 97 |
| Exam 2 | 85.75 | 9.21 | 59 | 99 |
| Laboratory 1 | 92.68 | 4.88 | 80 | 99 |
| Laboratory 2 | 96.33 | 4.34 | 70 | 100 |
| Paper 1 | 89.85 | 5.85 | 68 | 100 |
| Paper 2 | 91.46 | 7.44 | 69 | 100 |
| Final exam 1 | 80.44 | 13.75 | 40 | 100 |
| Final exam 2 | 83.30 | 10.39 | 58 | 100 |
| Semester grade 1 | 86.30 | 7.93 | 62 | 97 |
| Semester grade 2 | 87.21 | 7.38 | 66 | 97 |

Note: "1" after the variable names = 1st semester; "2" after the variable names = 2nd semester

lems subsequently gives the students an advantage in solving similar problems on the MCAT physical sciences subtest.

The correlations between MCAT subtest scores and quiz scores, paper scores, and laboratory scores were also positive and statistically significant, but not as strong as the correlations between the final and exam variables ($r_{MCATquiz}$ = .5695, $p$ < .05; $r_{MCATpaper}$ = .4508, $p$ < .05; $r_{MCATlab}$ = .4289, $p$ < .05). Although the quizzes were strongly correlated with the MCAT subtest, they seemed to be slightly less effective in assessing the skills needed for the MCAT subtest. The paper was also strongly correlated with the MCAT subtest score. Presumably, the composition skills required to write a coherent paper also benefit the students who take the MCAT subtest. Finally, as predicted, the weekly laboratory write-ups were the least effective in assessing skills necessary for the MCAT physical subtest. Although there was a moderately strong correlation between the lab scores and the MCAT subtest scores, it was not as strong as those variables assessing analytical skills. The lab grade is primarily intended to be indicative of the student's participation in the experiential component of the course along with their willingness and ability to summarize their experience in a clear and coherent manner.

In order to assess sex differences between the MCAT subtest performance and the predictors, descriptive statistics and $t$-tests as well as correlations for each gender were performed separately. $T$-tests revealed that none of the means were statistically different from one another (see Table 3). However, in absolute numbers, most of the correlations between MCAT and the predictors were different. As can be seen in Table 3, overall, the correlations for women were not as strong as those for men. All correlations for men were significant at an alpha level of 0.05 whereas only three of the correlations for women were statistically significant ($r_{MCATfinal}$ = 0.6827, $p$ < .05, $r_{MCATsem}$ = 0.6273, $p$ < .05, and $r_{MCATexam}$ = 0.5171, $p$ < .05). Fisher z-transformations did not reveal any statistically significant gender differences between the sets of correlations. However, this pattern might be significant with a larger sample size.

In order to determine which one of the variables would be the best predictor, taking into account the physics faculty's recommendations and based on the previous correlational analyses, a stepwise multiple regression analysis with MCAT scores as the criterion and (a) final scores, (b) exam scores, and (c) semester scores as the predictors was computed. Not surprisingly, the only statistically significant predictive variable from that group of variables was the final exam. The total regression and R square were statistically significant ($R^2$ = 0.5293, $F(1,44)$ = 49.48, $p$ < 0.05). Almost 53% of the variance in the MCAT physical subtest scores was accounted for by the comprehensive final exam score. The regression weight was also sta-

Table 2. Correlations between predictors and criterion for the overall sample (gender combined) ($n = 46$)

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| (1) Quiz | 1.000 | .7663* | .3287* | .2155 | .7710* | .8261* | .5695* |
| (2) Exam | | 1.000 | .4811* | .5353* | .7874* | .9564* | .6464* |
| (3) Laboratory | | | 1.000 | .4116* | .4427* | .5420* | .4289* |
| (4) Paper | | | | 1.000 | .4469* | .5460* | .4508* |
| (5) Final | | | | | 1.000 | .9055* | .7275* |
| (6) Semester | | | | | | 1.000 | .7270* |
| (7) MCAT | | | | | | | 1.000 |

* $p < .05$

tistically significant ($b = 0.1314$, $t(44) = 7.034$, $p < 0.05$). Because the semester score assessed the weighted average of all the predictors used in this sample and because it was strongly correlated with the final ($r_{semfinal} = 0.9055$, $p < 0.05$), the exam ($r_{semexam} = 0.9564$, $p < 0.05$), and quiz scores ($r_{semquiz} = 0.8261$, $p < 0.05$) it was removed from the subsequent analysis. Moreover, because the final exam was the best single predictor, it was not used in the subsequent hierarchical regression which was designed to investigate the incremental validity.

In order to examine whether combinations of other variables could produce similar predictive results, a hierarchical regression with MCAT scores as the criterion, (a) analytical ability variables (exams and quiz), (b) verbal ability variables (lab and paper), and (c) gender were computed. Both the total regression and R square were statistically significant ($R^2 = 0.4312$, $F(2,43) = 16.30$, $p < .05$). Together, the quiz and exams variables accounted for approximately 43% of the variance in MCAT scores. The proportion of variance in the criterion accounted for by these variables is similar to the one predicted by the final exam score alone. Their distributions were highly correlated. All three variables (i.e., final, exams, quiz) assessed some degree of the students' analytical ability to solve physics problems. As expected, this first block selection revealed that the exams score was more predictive of MCAT subtest scores than the quiz score ($b_{exam} = 0.5088$, $t(43) = 2.84$, $p < 0.05$ vs. $b_{quiz} = 0.1796$, $t(43) = 1.0$, *ns*). In other words, the exams score contributed more unique information to the prediction of MCAT scores than did the quiz score. The second block selection investigated the predictive ability of two variables that reflect a blend of practical and verbal skills (lab and paper). As hypothesized, both variables did not add any significant information to the prediction of MCAT scores ($R^2_{change} = 0.0436$, $F_{change} = 1.70$, *ns*). The increment in R square was not statistically significant. The exams score, which had previously contributed unique information to the prediction of MCAT scores was not statistically significant any longer. Overall, all 4 variables (quiz, exams, lab, paper) accounted for approximately 47 % of the variance in MCAT scores ($R^2 = 0.4748$, $F(4,41) = 9.27$, $p < .05$). Gender did not add any statistically significant information to the prediction of MCAT scores. The R square change was not statistically significant and close to zero ($R^2_{change} = 0.0123$, $F_{change} = 0.96$, *ns*).

In summary, the combination of these 5 variables (excluding the final exam score) accounted for about half of the variance in MCAT scores ($R^2 = 0.4871$, $F(5,40) = 7.60$, $p < 0.05$) However, the final score alone accounts for nearly 53% of the variance in MCAT scores.

A hierarchical regression analysis with the MCAT subtest as the criterion and (a) the final exam score, (b) exam and quiz, (c) lab and paper, and (d) gender as predictors was performed to investigate contributions to R square beyond that of the final exam alone. The results showed an $R^2_{change}$ of only 0.0157 ($F_{change} = 0.724$, *ns*) when the exam and quiz scores were added to the regression equation. The increment in R square was not statistically significant. Both variables added about 2% to the variance in the MCAT subtest scores above and beyond the proportion of variance accounted for by the final exam alone. These findings suggest that these measures of analytical ability account for essentially the same portion of the variance. The addition of the lab and paper to the regression equation resulted in an increment in R square of 0.0154 ($F_{change} = 0.7007$, *ns*) whereas gender added about 1% to the variance in the MCAT subtest scores above and beyond the variance explained by the other variables ($R^2_{change} = 0.0110$, $F_{change} = 1.005$, *ns*). Furthermore, due to large correlations, the inclusion of all 6 variables (final,

Table 3. Correlations between criterion (MCAT) and predictors, means and standard deviations for men ($n$ = 24) and women ($n$ = 22)

| Predictors | Men | *M* | *SD* | Women | *M* | *SD* |
|---|---|---|---|---|---|---|
| Quiz | .6908* | 88.96 | 7.52 | .4046 | 88.53 | 6.93 |
| Exam | .7492* | 86.58 | 9.37 | .5171* | 84.43 | 9.85 |
| Laboratory | .5974* | 93.97 | 4.02 | .2195 | 95.09 | 2.88 |
| Paper | .4838* | 90.89 | 5.11 | .4118 | 90.39 | 5.40 |
| Final | .7606* | 82.42 | 11.40 | .6827* | 81.27 | 10.37 |
| Semester | .7939* | 87.15 | 8.14 | .6273* | 86.32 | 6.98 |
| MCAT | | 8.33 | 2.10 | | 7.82 | 1.79 |

* $p < .05$

exam, quiz, lab, paper, and gender) allowed one to account for 57% ($R^2 = 0.5715$) of the variance in MCAT subtest scores, an increase of only 4% over the final exam score alone.

In order to assess the consistency of the scores, eight test-retest scores were computed. Consistent with national MCAT retest physical sciences change scores, the test-retest reliability was 0.92.

## DISCUSSION

The present study was designed to test the effectiveness of a physics program using MCAT physical subtest scores as assessment. It attempted to demonstrate an association between performance in physics courses and performance on the MCAT subtest. As predicted, correlational analyses demonstrated that assessments that test the analytical ability of a student (e.g., final, exams, semester scores) were more strongly intercorrelated than assessments that test a student's practical (lab scores) or verbal skills (paper scores). Students' abilities in solving physics problems seem to be predictive of how well students perform on the MCAT physical sciences subtest. A stepwise multiple regression analysis on three highly correlated variables (final, exams, and semester scores) indicated that the final exam, which assessed the student's overall understanding of introductory college physics, was the best predictor.

The results of hierarchical regression analyses showed that, as hypothesized, the ability to solve physics problems was predictive of a student's performance on the MCAT physical sciences subtest, whereas verbal skills and practical, real-world tasks did not predict performance on the subtest. Furthermore, gender did not contribute any new information to the prediction of the MCAT subtest scores either. Although the men in this sample performed slightly better than the women in all variables, overall, gender is not a good predictor of the MCAT physical sciences subtest results.

The results of the study further suggest that the structure of the test itself may be important and a likely predictor of MCAT scores. The results revealed that the larger the fraction of multiple choice items in a test, the stronger their correlation with the MCAT scores (i.e., quizzes had 40% multiple-choice items, exams 70%, and the final 100%). This result may be due to the fact that longer tests (and multiple choice tests) are frequently the most reliable types of assessments and thus scores with more precision would be better predictors. The results also showed that the more the course content was related to comprehensive knowledge, the stronger the correlation with the MCAT scores. Because exams test for comprehensive knowledge which involve long-term retention of material and making associations between one part of the course and another, they may be better suited to assess the students' abilities to integrate and understand physical concepts which are important aspects of the MCAT physical subtest. However, from the data, it is difficult to unfold the relative importance of these two conclusions.

The results of the present study should be interpreted with caution. The relatively small sample size placed a restriction on the power of the significance tests used in this study to detect actual differences or relationships and placed a similar restriction on the generalizability of these results. The small sample size relative to the number of variables investigated further restricts the generalizability of the results. The range restriction may have attenuated some correlations, although the standard deviations and ranges were rather large. Furthermore, substantial correlations were obtained between MCAT scores and the final and semester scores. The impact of range restriction is probably minimal. Furthermore, as with all correlational analyses, it is conceivable that a third variable may account for the associations. For example, it is possible that mathematics courses that were likely taken concurrently with physics courses or overall scholastic aptitude may explain the correlations.

Although the sample was limited, it appears to be reasonably representative of the student population taking the MCAT. The participants voluntarily chose to disclose their MCAT scores. They did so prior to taking the test, but not all students who later took the MCAT accepted. Consequently, the volunteer nature of the sample may have decreased the reliability of the measures. The sample considered showed an MCAT subtest mean and standard deviation consistent with both the complete college sample and the national sample. As a demonstration of reliability, the scores of a subset of the present sample (students retaking the MCAT) were examined. Test-retest results were also similar to the national retesting score changes of the Physical Science subtest.

In conclusion, assuming that the MCAT physical subtest assesses problem-solving skills, the present results suggest that a comprehensive exam in a general physics course may reflect these same problem-solving skills. Administrator and admissions officers should expect a high correlation between students' performance in a physics course and scores on the MCAT physical subtest.

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