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ABSTRACT

A procedure for developing a nomogram that depicts expectancy of success on a criterion from performance on two predictors is presented. Data from 574 medical students attending Michigan State University College of Human Medicine's classes of 1979 through 1984 were used to develop a model for predicting the expectancy of success on Part I of the National Board of Medical Examiners examination (NBME-I). The average score on the Medical College Admission Test (MCAT) and undergraduate science grade point averages (GPAs) were used as predictors. The three steps required to produce the nomogram were: (1) develop a predictor model for NBME-I performance based on MCAT scores and GPAs; (2) develop an expectancy table for success on the NBME-I based on this model; and (3) create a nomogram from the prediction model and the expectancy tables. Actual computations and graphing of the nomogram were done with a spreadsheet-graphics package called "Quattro." Such nomograms are effective tools for presenting the expectancy of success based on two predictors in an easily used form. One graph represents the nomogram, and two tables present study information. (SLD)

A Graphic Approach for Presenting Expectancy of Success Based on Two Predictors

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ABSTRACT

Expectancy tables are useful for presenting the likelihood of success on a criterion variable given an individual's score on a predictor. In many cases, multiple measures in combination are more predictive than each of the measures individually. Unfortunately it is difficult to present predictive information from multiple measures in a form that is easily interpreted. This paper presents an procedure for developing a nomogram that depicts expectancy of success on a criterion from performance on two predictors.

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Standardized test scores and prior academic performance are the two most common objective criteria used by admissions officers in educational institutions to make selection decisions. There is a large body of evidence suggesting these measures are predictive of future academic performance, (Hills, 1971). They also tend to be more predictive of future performance in combination than they are individually, (Weitzman, 1982).

One of the major hurdles medical students face is passing board examinations. Michigan State University's College of Human Medicine (CHM) like many other institutions requires its students to successfully complete Part I of the National Board of Medical Examiners examination (NBME-I) before entering the clinical portion of the College's curriculum. Determining the likelihood of a candidate passing this test is an important consideration in the College's selection decisions.

While developing a model for locating students at risk of failing the NBME-I is an important goal, for it to be most useful, it is also necessary to present the information in such a way that can be easily interpreted by candidates and admission committee members. Single entry expectancy tables are an effective method of presenting the relationship between a single predictor and a criterion (Anastasi,1968). In many situations multiple measures in combination provide better predictions than any single measure individually. Unfortunately it is more difficult to present predictive information from multiple measures in a form that is easily interpreted. This paper presents a method of creating nomograms that provide the expectancy of success on a criterion from two predictors. While predicting success on NBME-I from a composite Medical College Admissions Test (MCAT) score and undergraduate science GPA is discussed, the approach can be applied in any similar situation.

Method

Data from 574 medical students attending Michigan State University College of Human Medicine's matriculation classes of 1979 through 1984 were used to develop a model for predicting the expectancy of passing the NBME-I. An average MCAT score was formed by combining the biology, chemistry, physics, reading and quantitative sub-test scores. Each of the sub-tests was found to correlate moderately with NBME-I. The correlations ranged from .37 (reading) to .53 (biology). A confirmatory factor analysis using an

approach developed by Hunter and Gerbing (1979) suggested the sub-tests formed a unidimensional scale. The combined MCAT scores were found to correlate .58 with NBME-I scores. Undergraduate science GPA was found to correlate .33 with NBME-I performance.

Producing the Nomogram

Three steps were required to produce a nomogram depicting expectancy of passing the NBME-I based on the two predictors.

1. Developing a prediction model for NBME-I performance based on the combined MCAT scores and undergraduate GPA.

2. Developing an expectancy table for success on NBME-I from predicted NBME-I performance based on the model developed in step one.

3. Creating a nomogram from the information in the expectancy table and the prediction model.

The first step in the procedure was to determine the linear combination of science GPA and MCAT scores that best predicts performance on the NBME-I examinations. Multiple regression was used for this purpose. The multiple R was approximately .61. The analysis also confirmed that the combination of the predictors was superior to using either individually. The details of this analysis are given in Table 1.

Table 1

Results of Regressing NBME Part I Scores on Undergrad. Sci. GPA and Total MCAT Score for 574 Michigan State University College of Human Medicine Students

Predictor	Regression Weight	Standard Error	Pearson Correlation	t	Sig.
MCAT Composite	31.92	2.07	.58	15.39	.000
Science GPA	37.83	8.12	.33	4.66	.000
Constant Term	42.08	27.51			
Multiple R	.61				

The next step in the process was to form an expectancy table for passing the NBME-I examination based on the predicted NBME-I scores produced by the regression analysis. The expectancy table displayed the percentage of individuals with scores in a given

predictor score range passing NBME-I.

To form the expectancy table, the students' predicted NBME-I scores were first grouped into decile ranges. The proportion passing NBME-I[1] in each decile was used to form a tentative expectancy table. There is no definitive rule for grouping the data in an expectancy table. Deciles were chosen in this example because they provided a relatively large number of categories while including approximately 58 students within each group. It was felt that 58 observations were enough to provide moderately stable estimates of the percentage passing with a given MCAT/anatomy score range. Based on the percentage of students passing in each decile range, some of the score ranges were collapsed to form larger ranges with similar pass rates. A 95% confidence interval was computed for the percentage passing in each range. The results are presented in Table 2.

Table 2

Expectancy of Passing NBME Part I Board Examination Based on Predicted NBME Part I Score Ranges

Group	NBME Part I Score Range	Number	Percent Passing	95% Confidence Interval
1	< 365	57	51%	±13%
2	366 - 412	54	82%	±10%
3	413 - 428	56	91%	± 7%
4	429 - 476	233	97%	± 2%
5	477 >	174	99%	± 1%

A graph where undergraduate GPA was the x axis and combined MCAT was the y axis was used as the basis for creating the nomogram. To form the nomogram it was necessary to graphically represent the boundaries of the score ranges contained in the expectancy table. Given that these boundaries were predicted NBME-I scores, the regression equation forming the prediction model was used to obtain combinations of MCAT and anatomy scores that resulted in the predicted NBME-I scores forming the boundaries.

The regression equation is given below:

(1) Predicted NBME-I = 42.08 + (Sci. GPA * 37.83) + (MCAT * 31.92)

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[1]"Passing" NBME-I is based on CHM's requirement for entering the clinical portion of the program. This is different than NBME's requirement for certification.

Using simple algebraic manipulation, a formula for computing composite MCAT scores from predicted NBME-I and undergraduate science GPA was developed.

(2) MCAT = [Predicted NBME-I - 42.08 - (Sci. GPA * 37.83)] / 31.92

By entering arbitrary undergraduate science GPA values and each NBME-I score forming a boundary in the expectancy table into this formula, it was possible to obtain combinations of undergraduate science GPA and MCAT scores for each predicted NBME-I score forming a boundary in the expectancy table. Given the regression equation was linear, only two pairs of MCAT/undergraduate GPA scores were needed to graph each boundary. The area between each set of boundary lines in the graph contains the MCAT/undergraduate GPA score combinations for a given level of expectancy of success on NBME-I.

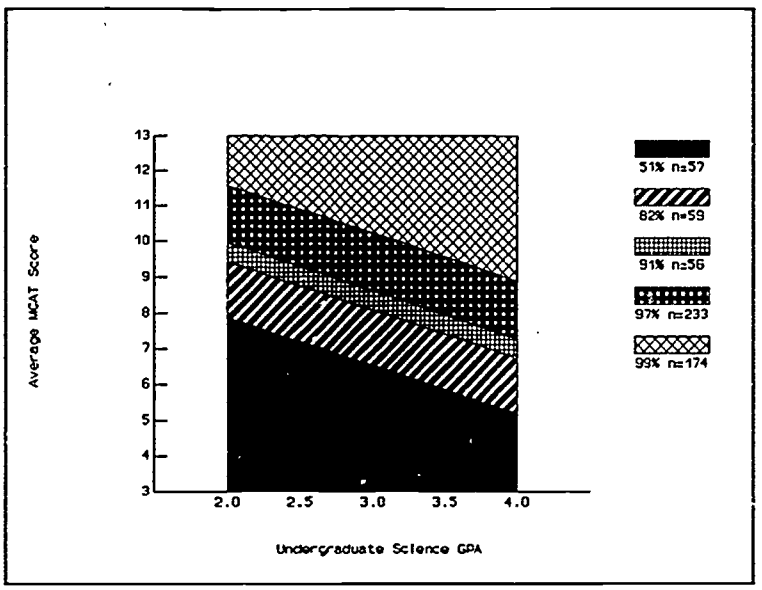

Figure 1 Nomogram Depicting Expectancy of Success on NBME-I from MCAT and Science GPA

The nomogram that was developed is presented in Figure 1. The actual computations and graphing of the nomogram was done using a spreadsheet-graphics package called Quattro[2].

To use the nomogram, one extends a vertical line up from the point on the horizontal axis indicating a student's undergraduate science GPA and a horizontal line to the right from the point on the vertical axis indicating the student's composite MCAT score. The band of the nomogram in which the lines cross indicates the expectancy of passing NBME-I for that student. For example, if a student had a composite MCAT score of 10 and an undergraduate science GPA of 3.0, the nomogram indicates that 97% of the students in previous classes with similar scores passed NBME-I.

Discussion

Nomograms such as the one presented in this paper can provide an effective tool for presenting expectancy of success based on two predictors. They certainly are not the only way to present this type of information. Double entry expectancy tables which contain the

[2]Quattro is a registered trademark of Borland International.

expectancy of success for different combinations of scores on two predictors are another approach. However they generally require a very large sample to assure an adequate numbers of observations in each predictor score combination. Even with large samples complex smoothing techniques may be required to remove anomalies (Kolen & Whitney, 1978).

While useful nomograms such as the one presented should be interpreted with caution. The combination of predictors via multiple regression is based on a compensatory model (Magnusson, 1966). This approach allows low scores on MCAT to be compensated for by high science GPA and visa-versa. This may not always be appropriate particularly in extreme cases. The nomogram of course suffers the same problems that any other prediction method would based on the same data. Factors such as selection bias and the comparability of GPAs obtained from different institutions must be considered.

Despite problems, prediction models clearly provide useful information. It is also felt that nomograms such as the one presented in this paper can provide an effective method of presenting information from a multiple predictor model in a form that is easily interpreted and used by both laymen and professionals.

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