The Relationship Among Pharmacy Students' Basic Math Scores, Traditional Preadmission Indicators, and Performance in a Pharmaceutical Calculations Course

David A. Latif

ABSTRACT. Basic mathematical skills are needed for both success in pharmacy school and success in pharmacy practice. Most pharmaceutical calculations require a requisite basic mathematics skill set. Examples include individualized patient dosing, extemporaneous compounding of new formulations, and an assurance that the precise supply of drug is dispensed in accordance with its directions for use.

The present investigation had three objectives. The first objective was to assess the relationship between the basic math skills (BMS) of two classes of first-year pharmacy students at a small Southeastern school of pharmacy and their performance in a pharmaceutical calculations course (PCC) taken during the students' first professional year. The second objective was to evaluate the convergent validity of the Basic Math Skills Test (BMST) with traditional measures of success in pharmacy school. The final objective was to assess the predictive ability of the BMST and traditional measures of academic performance on students' performance in the PCC. Results indicate the following: (1) that there is a significant relationship in the positive direction between basic math skills and performance in a pharmaceutical calculations class, (2) that scores on the BMST are significantly correlated with traditional measures of success

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in pharmacy school, and (3) that the predictive model including traditional measures of academic success significantly increased predictability of success in the PCC. The results are discussed within the framework of implications and possible solutions to identify and bolster those students who are deficient in basic math.

KEYWORDS. Basic Math Skills Test (BMST), pharmaceutical calculations, convergent validity, academic performance, traditional success measures

INTRODUCTION

Basic mathematics competency is an integral component of both the pharmacy curriculum and pharmacy practice. Most pharmaceutical calculations require a basic mathematics skill set. Examples include individualized patient dosing, extemporaneous compounding of new formulations, and an assurance that the precise supply of drug is dispensed in accordance with its directions for use (1). Results of pharmaceutical calculation errors can have potentially devastating results in pharmacy practice. A recent study by Pharmacists Mutual, a pharmacist liability company, reported that the second leading category of claims against pharmacists between 1989 and 1999 was the pharmacist filling the prescription with a different strength than that on the prescription (2). For example, a pharmacist prepared a bed-wetting medication for a five-year-old boy at five times the prescribed dosage. The doctor had prescribed 50mg of imipramine per teaspoon. The syrup prepared by the pharmacist contained 250 mg. The result could be death to the boy. Dosage errors accounted for 25.1% of all claims against pharmacists at Pharmacists Mutual during the 1989-1999 period. While one may argue that these errors were cognitive information processing ones, it is equally plausible that many of the errors were the result of deficient mathematics skills.

The present investigation had three objectives. The first objective was to assess the relationship between the basic math skills (as assessed by the BMST) of two classes of first-year pharmacy students at a small Southeastern school of pharmacy and their performance in a pharmaceutical calculations course (PCC) taken during the students' first pro-

fessional year. The second objective was to evaluate the convergent validity of the BMST with traditional measures of success in pharmacy school. The final objective was to assess the predictive ability of the BMST, in conjunction with traditional measures of success, on students' performance in the PCC. If statistical significance was found, educational interventions could be designed both to identify those students requiring basic mathematics remediation and to implement interventions that could bolster their basic mathematics skill set prior to experiencing academic difficulty.

This paper is organized as follows. First, the literature regarding basic math skills, the use of calculators in health professional curricula, and academic performance will be reviewed. Next, three hypotheses are advanced that examine the relationship between basic mathematics skills and the final grades in a first-year pharmacy calculations course, the convergent validity of the BMST with traditional measures of academic success, and the predictive ability of the BMST on PCC performance, in conjunction with traditional measures of academic performance. Then, the methods of the present study are described and the results are presented and discussed. Finally, the implications of this investigation are discussed from the perspective of potential educational interventions.

LITERATURE REVIEW

There has been a dearth of studies in pharmacy examining basic mathematics skills and academic performance in pharmacy calculations classes. Furthermore, reported findings have been contradictory. Boudinot and Martin examined several variables in an attempt to predict success in a pharmaceutical calculations class (3). The authors reported that significant predictors of success in the calculations class were prepharmacy GPA, prior degree, performance on the Quantitative Ability Section of the Pharmacy College Admissions Test (PCAT™-QP), and attendance at a junior college prior to pharmacy school. However, an earlier study by Lowenthal et al. reported that PCAT-QP scores were not significantly correlated to biopharmaceutics or pharmacy calculations course grades (4). Because of a lack of specific literature on predictors of success in PCCs, the literature review was broadened to include studies citing mathematics skills as predictors of general academic performance.

A recent study by Hardigan et al. examined the significance of several preadmission factors and pharmacy students' first-year grade point average (5). This study revealed that students' math grade point aver-

age, along with cumulative grade point average and comprehensive PCAT™, significantly correlated with pharmacy students' first-year grade point average. However, scores on PCAT-QP were not significantly correlated with students' first-year grade point average (5).

Grillo et al. examined the relationship between preadmission indicators and the basic math skills of 49 first-year pharmacy students at a 3-year-old school of pharmacy (6). The conditions required that students not use calculators during the administration of the BMST. It was reported that two preadmission indicators strongly influenced the basic math scores of this sample: percentile scores on the quantitative section of the PCAT and whether the student attended a private or public university prior to admission to pharmacy school (6). Specifically, it was reported that attendance at private universities prior to admission to pharmacy school was a negative predictor of performance on the BMST.

Previous empirical studies in college students in general suggest that significant mathematical deficiencies may exist among U.S. students (7). For example, the New Jersey Basic Skills Council revealed that only 30% of the 47,725 students entering the New Jersey college system in the fall of 1979 were proficient in basic mathematics (7). Recent data suggest that basic mathematical competency has not improved (8). The National Assessment of Education Progress reported in a 1996 investigation that 60% of 17-year-old students demonstrated mastery of such simple mathematical functions as simple fractions, decimals, percentages, and simple linear equations (8). When multistep problems were assessed, the percentage of students demonstrating mastery declined to 7%.

The nursing literature includes investigations that have examined basic mathematical deficiencies. Bindler and Bayne, in an assessment of the basic math skills of 700 junior-level baccalaureate nursing students, reported that no more than 38% of each student group was able to pass all of the components of the examination (9). McCann-Flynn and Moore assessed 64 female junior nursing students' performance on a medication calculations test, a math attitude questionnaire, and an anxiety inventory (10). The mean score and standard deviation on the medication calculations was 73% (± 19%), while mean scores on the math attitude and anxiety assessments were 125.7 ± 36.0 (range: 30-210) and 37.4 ± 12.1 (range: 20-80), respectively. The authors concluded that both medication calculations final grade and math attitudes were significant predictors of math performance.

Pozehl directly assessed the basic math skills of 56 nursing students and 56 students majoring in other fields (11). The author determined 70% and above as a cutoff for passing the basic math test. The mean score for the nursing students was 59.8% ± 16%, while the non-nursing students had a mean score of 72% ± 15% (11). The author speculated that math anxiety may affect females to a greater extent than males. Thus, nursing students, being predominately female, may perform more poorly on mathematics exams than other groups of students.

Does the use of calculators improve students' performance in math-intensive courses? Several empirical studies have assessed the relationship between the use of handheld calculators and performance in math-intensive courses. Roberts, Suydam, and Koop reported on studies that demonstrated minimal improvement in basic mathematical skills with the use of a calculator (12-14). However, none showed meaningful improvement in problem solving or conceptual skills.

In the health professions, Shockley et al. examined the use of calculators on the responses of undergraduate nursing students to items on a dosage calculations examination (15). The authors investigated the possible influence of calculators on both the arithmetic and conceptual skills associated with the solving of calculations problems. An experimental repeated measures design was used in which all students enrolled in a pharmacology course for nursing students completed two parallel forms of a calculations examination. One form used calculators while the other form solved the calculations without the use of calculators. It was revealed that use of a calculator was associated with improved arithmetic performance, but diminished conceptual skills performance.

Murphy and Graveley used a repeated measure, quasi-experimental design to examine the influence of using calculators in a nursing pharmacology course (16). It was reported that students having the option to use their calculators had significantly higher math scores and made significantly fewer calculation errors. However, overall course grades were not significantly higher for the group that was given the option to use their calculators. The authors concluded that calculator use does not assure success in solving basic math problems because students must also recognize the reasonableness of their answers.

HYPOTHESES

What are the consequences of making basic mathematical errors? The results can be life threatening. For example, Dexter and Applegate

cite a newly graduated registered nurse who administered an excessive amount of morphine to a patient due to a simple math mistake (17). This resulted in a life-threatening situation when the patient's respiration was depressed significantly.

As discussed previously, a 12-year study of causes of malpractice claims against pharmacists revealed that approximately one-fourth of all claims were due to the pharmacist administering the wrong strength of a prescribed drug (2). For example, a pharmacy receives a prescription for digoxin 0.150 mg and fills it with digoxin 0.50 mg (perhaps reasoning that these are similar numbers). Although reasons other than mathematical errors may be offered for these mistakes, it is reasonable to assume that a significant number of claims against pharmacists for administering the wrong strength of a drug to patients is the result of deficient basic math skills.

The public expects that health professionals are proficient in carrying out the requirements of their jobs. For pharmacists, one of those requirements means knowing basic mathematics. In addition, successful mastery of the pharmacy curriculum requires a basic math skill set. This investigation assesses the basic math skills of two classes of first-year doctor of pharmacy students and then examines the relationship between their math skills and subsequent performance in a pharmaceutical calculations course. Thus, based on prior empirical evidence, the first hypothesis tested is:

> H_1: There will be a significant relationship in the positive direction between first-year doctor of pharmacy students' scores on the BMST and their final grades in a first-year pharmacy calculations course (PCC).

The second hypothesis examined the convergent validity of the BMST with traditional variables purporting to measure student performance in pharmacy school. Convergent validity implies that one construct should be highly correlated with theoretically similar constructs (18).

> H_2: Scores on the BMST will be significantly correlated in the positive direction with composite PCAT, PCAT-QP, and math and science prepharmacy GPA.

The third hypothesis assessed the relationship between scores on the BMST, in conjunction with traditional markers of pharmacy school achievement, and performance in the PCC.

H_3: The BMST, in conjunction with the variables PCAT, PCAT-QP, and preadmission GPA, will explain a significant amount of the variance associated with performance in the PCC.

METHODS

This investigation used a convenience sample and was a blinded retrospective record review of two doctor of pharmacy classes entering the first professional year at a five-year-old, private Southeastern school of pharmacy (classes of 2003 and 2004). Institutional Review Board approval was obtained prior to beginning the investigation.

The sampled school of pharmacy is currently piloting a math mentor program to address the remedial math education needs of entering doctor of pharmacy candidates. All entering students are tested using a valid and reliable test of basic math skills at the eighth-grade level (19). Two classes of doctor of pharmacy students, the classes of 2003 and 2004, were assessed on their basic math skills during August of 1999 and 2000, respectively. All first professional year students attending orientation were required to take the BMST as part of the orientation process. Ninety-eight doctor of pharmacy students took the BMST during August of 1999 and August of 2000. The test is a 50-question, timed math test that covers 9 different competencies (addition, subtraction, multiplication, division, fractions, percentages, fraction to decimal conversions, interest rate calculation, and algebraically solving for one unknown). A sample question on the BMST is "Please convert 0.0025 to a percentage." The areas and level of difficulty were taken from a Grade 8 mathematics textbook (19). The test was designed to evaluate students for clerical and secretarial positions. Most of the questions reflect the type of mathematical problems encountered in these positions. This instrument has been shown to be both reliable and valid. The test-retest reliability has been shown to be 0.87, while criterion validity was demonstrated by using BMST scores of clerical workers and correlating those scores to supervisor ratings regarding basic math skills on the job (19). In addition, the BMST was internally validated for an eighth-grade level of difficulty by a local elementary school math teacher. During the BMST, students are permitted to use a pencil and paper for calculations, but calculators are not permitted. Students are allotted 20 minutes to complete the exam. The testing conditions, including the time limit, were consistent with those used to validate the instrument (19).

The PCC description describes it as "the study of the measurement units, and mathematical functions and applications that are essential to the safe, accurate practice of pharmacy." The PCC emphasizes pharmaceutical nomenclature, numerical expressions, measurement equivalents, calculation formulas, and problem solving and reasoning. The course objectives are as follows:

- To learn the units and translations of common pharmaceutical measurements
- To learn common abbreviations used in prescription writing
- To learn the interpretation and interconversion of common pharmaceutical concentration expressions
- To learn to calculate with common and natural logarithms and their inverses, and with exponential notation
- To learn to interpret, calculate, and interconvert concentrations, proportional parts, and ratio strengths
- To learn to calculate drug dosage rates according to different therapeutic standards.

In addition to the score on the BMST and the PCC grade, the student's PCAT score, PCAT-QP, and other demographic and scholastic information were obtained from the student's application file in a retrospective manner. All identifiers were removed before the data were submitted to the investigators.

Statistical analysis was performed using SPSS™ version 10.0 (SPSS Inc., Chicago, IL). A Pearson correlation was used to test this. In addition, the Student's *t* test using Levene's test for equality of variances was used to ascertain if the two classes were significantly different on variables of interest. Results indicated that they were not significantly different.

RESULTS

Demographics of Respondents and Descriptive Statistics for Variables

Table 1 reports on the ages, gender, PCAT scores, PCAT-QP scores, math-science scores (high school math and science grade point average), BMST scores, and the final PCC grades of the two classes of students. The equal variance assumption of the variables was assessed

using Levene's test. The analysis revealed that the classes were not significantly different based on the identified demographic and performance variables.

The first hypothesis of this investigation was to test the relationship between students' scores on the BMST and the final grade obtained in a first-year pharmaceutical calculations course. A Pearson's product-moment correlation was used to test this hypothesis. It was supported and is presented in Table 2.

Hypothesis 2 predicted that BMST scores would be correlated with theoretically similar measures. A Pearson's product-moment correlation demonstrated that the BMST was significantly correlated with the PCAT, PCAT-QP, and math/science preadmission GPA. Table 3 presents these results.

The third hypothesis predicted that BMST scores, in conjunction with the PCAT, PCAT-QP, and math/science GPA, would explain a significant amount of the variance associated with students' performance

TABLE 1. Age, Gender, and Descriptive Statistics for Variables of Two Classes.

Variable	*N*	Mean	SD
Age	98	24	4.45
Gender			
Male	26		
Female	72		
PCAT	98	45.46	29.16
PCAT-QP	98	42.80	26.05
MS-GPA	98	3.06	0.3648
PCALC	98	73.66	14.37
BMST	98	70.24	18.30

TABLE 2. Relationship Between BMST Scores and PCC Final Grades.

Variable	*N*	Mean	SD	1	2
PCALC Grade	98	73.66	14.37	1.00	0.321*
BMST Score	98	70.24	18.30		1.00

*Correlation is significant at the 0.01 alpha level (2-tailed).

TABLE 3. Relationship Among BMST and PCAT, PCAT-QP, and Math/Science Preadmission GPA.

Variable	*N*	Mean	SD	1	2	3	4
BMST	98	70.24	18.30	1.00	0.509*	0.673*	0.177*
PCAT	98	45.76	29.16		1.00		
PCAT-QP	98	42.78	26.05			1.00	
GPA	98	3.06	0.365				1.00

*Correlation is significant at the 0.05 alpha level (2-tailed).

in the PCC. Linear regression analysis revealed that the independent variables of PCAT, PCAT-QP, BMST, and math/science preadmission GPA accounted for a significant portion of the variance associated with PCC performance at the 0.01 alpha level ($r^2 = 0.283$). This model improved the variance explanation by 0.18 over and beyond examining the BMST as the only independent variable ($r^2 = 0.103$). Multicollinearity was not deemed to be a problem in the regression analysis.

DISCUSSION, IMPLICATIONS, AND LIMITATIONS

The obtained results support the three hypotheses, that is, those students who scored well on the BMST were significantly more likely to perform well in the PCC. The BMST was also highly correlated with more traditional measures of academic assessment tools. In addition, when used in conjunction with these traditional measures, the BMST made a significant contribution to PCC performance.

The present investigation has two main implications. First, if additional investigations assessing the relationship between basic math skills and performance in math-intensive pharmacy courses corroborate this one, educational interventions can be designed and implemented to identify those students deficient in basic math and then bolster their basic math skills. Two different options are advanced for remediating those students who are identified as being deficient in basic mathematics (e.g., those who achieve a percentage score of less than 70 on an eighth-grade math test). First, those students may voluntarily enroll in a mentor program. The mentor program could be designed to offer students an informal method of improving their skills. The proposed program could be self-paced. One version of this would allow students to

purchase a basic math workbook recommended by the school of pharmacy (20). Students could then work through the exercises on a predetermined schedule (in cooperation with each student's faculty mentor). When the enrolled students complete the math exercises, they will retake the BMST.

A second option for remediating students identified as deficient in basic math skills would require that those students purchase a basic math workbook recommended by the school of pharmacy (20). Then, an informal minicourse covering the nine basic math skills tested on the BMST could be developed by fourth-year doctor of pharmacy candidates doing an education rotation with their school of pharmacy. This would be under the supervision of the faculty preceptor. The fourth-year students could be required to develop a Web-based minicourse with objectives and handouts/slides. In addition, they could be required to administer the lectures and assign and grade homework/quizzes. A benefit of this option is that the fourth-year doctor of pharmacy candidates could receive any feedback on their teaching skills from students and the faculty preceptor. This could give the fourth-year students valuable experience in teaching. Upon completing the exercises, the remediating students could be required to retake the BMST to determine if the deficiencies were resolved.

A second implication of the present study is that, to the extent that basic math skills are prerequisites to success in pharmacy school, the present investigation illuminates a potential problem and identifies a solution for retaining more students in pharmacy school. This can have significant financial implications, especially for private schools of pharmacy. For example, tuition for four years at the sampled school of pharmacy costs approximately $68,000. If a student drops out after the first year due to poor grades resulting from inferior basic math skills, the opportunity cost to the university is $51,000 ($68,000 − $17,000).

A third implication is poor pharmacy practice in the future. If students with basic math deficiencies make it through the pharmacy curriculum and become pharmacists, they may have a greater propensity for committing medication errors due to poorer basic math skills. The financial and social implications of such a possibility are significant.

The present investigation is subject to at least two limitations. First, the study assessed students from only one school of pharmacy. Although two different classes were involved, it still may be difficult to generalize the obtained results to other schools of pharmacy in different regions of the United States; therefore, this investigation should be re-

peated at other schools of pharmacy in different regions of the United States.

A second limitation is related to the logistics of assessing basic math skills. If, as several studies indicate, PCAT-QP, prepharmacy grade point average, and having a prior degree are significantly correlated to PCC grades, why administer the BMST (3-6)? As discussed previously, different studies have revealed contradictory results regarding predictors of academic performance. In addition, if basic math skills are deemed important, it seems logical to measure those specific skills (as opposed to measuring other constructs).

CONCLUSION

This investigation sought to examine the relationship between the basic math skills of pharmacy students and their subsequent performance in a pharmaceutical calculations course. In addition, the convergent validity of the basic math test used and its contribution to performance in the PCC was assessed in conjunction with traditional measures of academic success. Results indicated that there was a significant relationship in the positive direction between basic math skills and performance in a pharmaceutical calculations class, that scores on the BMST were significantly correlated with traditional measures of success in pharmacy school, and that scores on the BMST, in conjunction with traditional measures of academic success, accounted for a significant amount of variance associated with performance in the PCC class. This result was discussed within the framework of possible solutions to bolster the basic math skills of pharmacy students.

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