A Predictive Validity Study of the *Pharmacy College Admission Test*

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ABSTRACT

Objectives. The purpose of this study was to examine the validity of the *Pharmacy College Admission Test* (PCAT) for predicting the grade point averages (GPAs) of students in years 1–4 of pharmacy programs.

Methods. Data were collected from the 11 pharmacy schools participating in the study on entering cumulative GPAs, entering math/science GPAs, and PCAT scaled scores (by subtest and Composite) for students entering in the fall of 2000, as well as GPAs for years 1–4 in the pharmacy programs and student status after four years (at the end of the 2003–04 academic year). These data were analyzed to determine the validity of the PCAT for predicting subsequent GPAs using correlation analysis, regression analysis, discriminant analysis, and diagnostic accuracy analysis.

Results. Both PCAT scaled scores and entering GPAs were found to be positively correlated with the GPAs of students in years 1–4 at the pharmacy schools participating in this study. Regression analyses also showed the predictive value of the PCAT scaled scores, especially in combination with entering GPAs. A discriminant analysis supported the positive correlation between PCAT scaled scores and the GPAs of students in years 1–4 at the participating pharmacy schools. A diagnostic accuracy analysis showed results consistent with the discriminant analysis and provided practical suggestions regarding the selection of optimal PCAT scaled scores to identify students most likely to succeed during the four years of professional pharmacy study. All analyses suggested the predictive value of the PCAT scaled scores.

Conclusion. Both PCAT scaled scores and entering cumulative GPAs showed moderate to strong predictive validity. Both of these predictor variables should be considered by pharmacy schools as useful indicators of candidates likely to succeed in pharmacy school.

INTRODUCTION

Since the introduction of the PCAT in 1974 by The Psychological Corporation (now Harcourt Assessment, Inc.), a number of studies have investigated the predictive validity of the PCAT and have found the test to have value as a predictor of subsequent performance in pharmacy programs. These studies generally have found the PCAT to be a moderate to strong predictor of both pharmacy-program grades and licensing exam scores.[1, 2] Studies of the predictive validity of the PCAT typically have used correlation and/or multiple regression analyses to examine the value of using PCAT scores to make predictions about subsequent GPAs earned by students in pharmacy school and to make predictions about other such indicators of success.

Several early studies conducted at various universities during the 1970s emphasized how well PCAT scores related to the academic performance of students entering schools of pharmacy. Research comparing the performance of first-year professional pharmacy students to their PCAT scores found that PCAT scores correlated positively with subsequent performance in specific coursework and throughout the course of a program.[3,4] Some studies also found that PCAT scores were predictive not only of students' performance in pharmacy school but also of their scores on the *National Association of Boards of Pharmacy Licensing Exam* (NABPLEX).[4,5] One study by Lowenthal found the PCAT to be a better predictor of academic performance in pharmacy school than the SAT–Verbal, SAT–Math, and *Otis Quick-Scoring Mental Ability Test* scores.[5]

In a 1985 study by The Psychological Corporation, in cooperation with the American Association of Colleges of Pharmacy (AACP), data collected from several pharmacy programs showed multiple correlations between PCAT scores and first-year pharmacy GPAs ranging from 0.35 to 0.77. When PCAT scores were combined with pre-pharmacy GPAs, the correlations with first-year pharmacy GPAs ranged from 0.56 to 0.82.[6]

Other studies conducted in the 1980s and 1990s generally showed that the PCAT provided useful assistance to pharmacy schools with their admission decisions.[7] One study conducted from 1984 to 1989 by Kawahara and Ethington found a declining trend in PCAT scores and found the Biology and Chemistry scores to be particularly sensitive to previous coursework.[8] These conclusions, however, supported a common misperception at the time that the academic quality of entering pharmacy students had been declining. Another study examining first-year pharmacy school performance focused especially on the development of desirable non-academic qualities and found the PCAT Verbal Ability and Reading Comprehension scores to be useful, not only in predicting first-year academic success, but also as the best predictors of characteristics such as responsibility, thinking ability, and professionalism.[9]

One study conducted in the 1980s by Bandalos and Sedlacek found that in addition to pre-pharmacy GPAs, only the PCAT Reading Comprehension scores were factors in predicting the performance for both African-American and Asian students and that PCAT

Biology and Reading Comprehension scores were the strongest predictors of first-year pharmacy school GPAs for the total group.[10] A study by Chisholm, Cobb, and Kotzen on factors useful in predicting first-year academic performance found the PCAT Verbal Ability and Composite scores to be stronger predictors of academic success for females than for males.[11] A study conducted by Wu-Pong and Windridge found that the best predictors of pharmacy GPAs to be the PCAT Chemistry scores, followed by entering GPAs and the PCAT Composite scores for applicants whose primary language was not English.[12] Another study also found statistically significant differences in mean PCAT scores among gender, racial, and native-language subgroups, but the researchers concluded that PCAT scores combined with GPAs were still useful in selecting applicants for admission to pharmacy school.[13]

More recent research on the ability of the PCAT to predict academic performance supports earlier findings regarding the general usefulness of the test. In one study, Allen and Bond evaluated the relationship between academic performance, PCAT scores, the *California Critical Thinking Skills Test* (CCTST) scores, interview scores, and GPAs.[14] The researchers found PCAT and CCTST scores to be the strongest predictors of subsequent success in courses and concluded that the PCAT may predict critical thinking skills in addition to academic success. In a different study of changes in critical thinking over a four-year doctor of pharmacy (PharmD) program, Miller found PCAT and CCTST scores to be highly correlated and concluded the PCAT to be a strong indicator of critical thinking.[15] Out of concern that the level of math skills influences medication errors in pharmacy practice, another recent study by Grillo, Latif, and Stolte examined the relationship between several preadmission indicators of basic math skills in first-year pharmacy students and found the Quantitative Ability section of the PCAT to be a significant predictor.[16]

Thomas and Draugalis found the PCAT to be a significant predictor of performance in the first year of pharmacy school, with the PCAT Chemistry score correlating highly with first-year GPA (0.58) followed by entering math/science GPA (0.48) and the PCAT Composite score (0.50).[17] Regression analyses also showed that in combination with previous GPA and college degree earned, PCAT scores account for over 40% of the variance in first-year GPAs, when multiple correlations were adjusted to account for chance error and sample size. In another recent study, Kidd and Latif investigated the relationship between seven predictors and examined how these predictors contribute to cumulative pharmacy GPAs, GPAs for years 1–3 in pharmacy school, and GPAs of clerkships in the fourth year of pharmacy school.[18] The researchers concluded that the PCAT is a significant predictor of success in pharmacy classroom courses and in pharmacy school overall. In a study of 1982–2002 student performance at one pharmacy school, Grandberry and Steigler found that PCAT scores rose over the study period, but that correlations between PCAT scores and professional pharmacy school GPAs dropped.[19] However, the researcher speculated that the greater increase in pharmacy grades than in PCAT scores may have been due more to grade inflation than to improved student performance.

A recent meta-analysis of the research related to the PCAT conducted by Kuncel and colleagues found that both pre-pharmacy GPAs and PCAT scores are valid predictors of performance in pharmacy school and on licensing exams.[1] According to these researchers, evidence from many research studies conducted over the years suggests that the PCAT continues to be a valid predictor of student success during the first three years of pharmacy school, especially for first-year GPA, and is a strong predictor of performance on the NABPLEX (presently known as the NAPLEX, the North American Pharmacy Licensure Exam). They concluded that any skepticism regarding the predictive validity of the PCAT is unnecessary and that together with pre-pharmacy GPAs, PCAT scores can be used in admissions decisions to substantially increase the likelihood of identifying students who will perform successfully in pharmacy programs.

In recent years, nearly all pharmacy schools have changed from offering only a bachelor of science (BS) degree in pharmacy, or the traditional post-graduate PharmD, to an entry-level PharmD degree, most requiring two or more years of pre-pharmacy coursework and four years of pharmacy coursework.[20] The PCAT continues to play an important role in selecting students for admission for the majority of these entry-level PharmD programs.

The purpose of this study was to examine data collected from 11 pharmacy schools and to determine the value of PCAT scaled scores and entering GPAs in predicting subsequent GPAs during four-year pharmacy programs. The methods of analyses employed in this study included both correlation and regression analyses, the two methods most commonly used in previous studies, as well as discriminant analysis and diagnostic accuracy analysis, two methods not used in previous studies of the PCAT. The results of these analyses support earlier findings on the predictive validity of the PCAT.

METHODS

To determine the predictive validity of the PCAT in terms of GPA over a four-year professional pharmacy program, the following data were collected from 11 pharmacy schools for students entering in the fall of 2000: entering cumulative GPAs, entering math/science GPAs, PCAT scaled scores, GPAs for years 1–4 in the pharmacy programs (for each year separately, not cumulative), and student status after four years (at the end the 2003–04 academic year). These data were analyzed to determine the validity of the PCAT in predicting subsequent GPAs using correlation analyses, regression analyses, discriminant analyses, and diagnostic accuracy analyses.

While nearly all similar previous studies of the PCAT used correlation coefficients as indicators of predictive validity and many used regression analyses, none employed discriminant analysis or diagnostic accuracy analysis. These two analyses support and extend indications of predictive validity for the PCAT in both theoretical and practical ways that will be discussed in this report.

Participants

In early 2004, the AACP provided the researchers with a list of 47 pharmacy schools in the United States that used the PCAT for admission decisions at that time. All of these schools were invited to participate in the study, and eleven agreed to participate. Of the eleven schools that participated, eight are public universities and three are private universities. Using the U.S. Census Bureau state regions and divisions to categorize the participating schools, seven are located in the South (three in the South Atlantic Division, two in the East South Central Division, and two in the West South Central Division), two schools are located in the Midwest (one in East North Central Division and one in West North Central Division), and two schools are located in the West (both in the Mountain Division).

Data Collection

A spreadsheet was sent to each participating school with the request for data on all candidates admitted for fall 2000, including PCAT scaled scores, entering cumulative GPAs, entering math/science GPAs, other standardized test scores, pre-pharmacy coursework completed, GPAs at the end of each of the four years of pharmacy study, and status at the end of the fourth year (graduated/still enrolled/discontinued enrollment). After the end of the 2003–04 academic year, each school provided what information they had on the spreadsheet, along with a brief description of their admissions criteria, and returned it to the researchers for analysis. In addition to the program descriptions provided by each school, information from the AACP website and the pharmacy schools' websites was analyzed to determine prerequisite course requirements and pharmacy school curricula. The researchers categorized the prerequisite courses and the courses required in the professional pharmacy programs for comparative purposes.

Data Analysis

All data analyses were done using Statistical Analysis System (SAS) version 9.1. The Pearson product-moment correlation coefficient was used to determine the degree to which PCAT scaled scores and entering GPAs were related to subsequent GPAs in the pharmacy programs. In this study, PCAT scaled scores and entering GPAs were used as independent predictor variables, and student performance in years 1–4 of the professional pharmacy programs was used as dependent outcome variables. The outcome variables include the GPA in each of the four years of professional pharmacy study for students who graduated with a PharmD after four years, students who graduated with a BS within four years, students who were still enrolled after four years, and students who had discontinued enrollment prior to the fourth year.

As an index of relationship degree for a pair of variables, a correlation coefficient (r) ranges from –1 to +1, with zero indicating no relation between two variables, and the 1 (± 1) indicating a perfect relationship between two variables. In this study, correlations were determined between PCAT scaled scores (for each subtest and Composite) and GPAs in years 1–4 of the professional pharmacy programs, and between entering GPAs

(cumulative and math/science) and GPAs in years 1–4 of the professional pharmacy programs.

Multiple regression analysis is similar to correlation analysis, but is used to indicate relationships between more than one independent predictor variable and one or more dependent outcome variables. A regression equation can be used to predict outcome variables from predictor variables. The results of multiple regression are expressed as a squared correlation coefficient, the coefficient of determination (R^2), which indicates the proportion of an outcome that can be predicted from the combined variables. In this study, two regression models were used. In one model, PCAT subtest scaled scores were combined with entering cumulative GPAs as predictor variables to predict subsequent GPAs in years 1–4. In a second model, PCAT subtest scaled scores were used alone to predict subsequent GPAs in years 1–4. In both models, parameter statistics indicate the degree of contribution made by each predictor variable in predicting the outcome variable.

In addition to correlation and multiple regression analyses, discriminant analysis was done to indicate predictions of group member performance and status using the optimal linear combination of independent variables. The value of discriminant analysis, in comparison to multiple regression, is that it weights each variable according to its relative predictive contribution and displays optimal values for predicting specified outcome criteria. In this study, two discriminant analyses were done, one with PCAT subtest scaled scores combined with cumulative entering GPAs as the predictor variables, and one with PCAT subtest scaled scores alone as the predictor variables. In both analyses, the predictor variables represent optimal values in predicting percents of students likely to be included among those earning the lowest 5% and the highest 95% of GPAs in the professional pharmacy programs. With discriminant analysis, the proportion of the poorest performers indicated when a specific criterion is selected is called *sensitivity*, and the proportion of the highest performers indicated for the same criterion is called *specificity*. Both sensitivity and specificity represent percentages of individuals from the groups defined as low and high performers who are able to be identified from specific predictor variables. In this study, 5% was selected as the low performing group for sensitivity (the probability of correctly predicting low performance) because around 5% of the students who enrolled in 2000 left the program prior to the fourth year and earned the lowest GPAs compared to students who graduated or were still enrolled after four years. Likewise, for purposes of this study, 95% represents the high performing group for specificity (the probability of correctly predicting high performance) because around 95% of the entering students either completed a degree or were still enrolled after four years of pharmacy school.

Similar to discriminant analysis, diagnostic accuracy (or signal detection) analysis is used to determine sensitivity and specificity outcomes from predictor variables. While discriminant analysis suggests the general predictive validity of optimal variables, the special value of diagnostic accuracy analysis is that all predictor variables are listed for consideration, along with the corresponding sensitivity and specificity proportions for each variable. In this analysis, the same two categories of student performance were used

to determine diagnostic accuracy as with discriminant analysis (percentages of the lowest 5% and the highest 95% of performance for specific predictor variables). However, for the diagnostic accuracy analysis, PCAT Composite scaled scores (an unweighted average of the five multiple-choice subtest scaled scores) were used as the predictor variables. What makes diagnostic accuracy analysis practical is that it can be used to determine the best range of PCAT Composite scaled scores from a specific sample that can be used to identify both students that are unlikely to complete the program successfully (sensitivity) and those who are likely to be successful (specificity). For this analysis, index values were calculated that were added to the mean PCAT Composite scaled score for the study sample to determine probabilities of success for specific PCAT Composite scaled scores.

For the correlation, regression, discriminant, and diagnostic accuracy analyses, the GPA data collected from the participating pharmacy schools were equated on a common scale to accommodate for differences in grading scales (i.e., 4.0 or 100), and all PCAT scaled scores were linked to adjust for the differences in sample means. Multiple imputation (MI) was used to fill in any missing PCAT scaled scores and GPAs with plausible values. MI was used only in cases where a student's PCAT subtest score or GPA was missing from the data submitted by a pharmacy school or seemed implausible, possibly due to a key entry error.

RESULTS

The results of this study are presented in five sections and six tables. The first section describes some characteristics of the participating pharmacy programs (Table 1) and the entering PCAT and GPA data and subsequent in-program GPA data for the students who began professional study at these schools in the fall of 2000 (Table 2). The next four sections present the results of analyses related to the predictive validity of the PCAT, including correlation analysis (Table 3), multiple regression analysis (Table 4), discriminant analysis (Table 5), and diagnostic accuracy analysis (Table 6).

General Characteristics of Participating Pharmacy Programs

Table 1 summarizes the prerequisite course credit requirements and professional pharmacy curricula for the 11 pharmacy programs that participated in this study. The information in Table 1 shows that the pre-pharmacy requirements at the participating schools emphasized credits in the biological sciences, chemistry, and the social sciences and humanities, with fewer required in English and speech, math, and physics. The information in Table 1 also shows that the curricula in the pharmacy programs varied in the types of credits required each year, with increasing concentrations on credits in professional pharmacy courses, internships, and other profession-related courses.

Table 2 shows the characteristics of the students in the study sample in terms of mean PCAT scaled scores, mean entering GPAs, and mean GPAs in the professional pharmacy programs for the 11 schools. The scaled scores for students in this study were based on the 1992 norms in effect in 2000 (used from 1992-2003), which ranged from 100–300 with a mean of 200. The pharmacy GPAs listed in Table 2 only include data for the 10

schools that reported GPAs on a 4-point scale. Sample sizes are also listed for all students entering a pharmacy program in the fall of 2000 and for each of the four years in the pharmacy programs.

From the data listed in Table 2, it is apparent that the end of four years, the vast majority of students had either graduated with a PharmD (84.4%) or a BS (5.2%) or were still successfully enrolled in a program (5.8%), and that only 4.5% (41) of the students had discontinued enrollment prior to the fourth year. Table 2 also shows that students who received a PharmD degree averaged the highest GPA for all four years (3.23, 3.21, 3.25, and 3.50, respectively). The mean GPAs earned by those who received a BS degree (2.88, 2.87, and 3.09, respectively) and those who still were enrolled after four years (2.62, 2.58, 2.76, and 2.88, respectively) were considerably lower than for students who received a PharmD in four years. Students who discontinued enrollment prior to the fourth year showed the lowest mean GPAs (2.57, 2.27, and 2.47, respectively).

Correlation Analysis

A correlation coefficient (*r*) represents the linear relationship between two variables, or the extent to which values of two variables are proportional to each other. Table 3 shows that for the overall study sample (n = 899), correlations between PCAT scaled scores and subsequent GPAs ranged from 0.19 to 0.43 (five subtests and Composite), depending on the program year, and correlations for entering GPAs (cumulative or math/science entering GPAs) ranged from 0.35 to 0.49, depending on the program year.

These data show that correlations are a little higher for entering GPAs than for PCAT scaled scores. For all independent variables, the correlation coefficients (*r*) generally decrease for each subsequent program year. The square of the correlation coefficient (r^2) indicates the strength or magnitude of the relationship, or the proportion of variance in common between an independent and dependant variable, and if multiplied by 100 provides the percent of variance in common between two variables. For example, the PCAT Composite scaled score correlation coefficient is 0.43 for the first year, which means that 18.5% (0.185) of the variance in the first-year GPAs can be accounted for by a PCAT Composite scaled score. While the correlation coefficients are somewhat larger for entering GPAs than for PCAT scaled scores, the proportion of variance in subsequent GPAs is not much more than for the PCAT Composite scaled scores.

Regression Analysis

While correlation coefficients suggest the relationships between variables, regression analysis shows the value of variables in predicting outcomes. With multiple regression, the relationship between several predictor variables and a dependent, or criterion, variable can be seen. Expressed as squared correlation coefficients, or the coefficient of determination (R^2), the multiple regression analysis indicates the proportion of the outcome that can be predicted from the combined variables. Table 4 represents the results of multiple regression analyses for the overall study sample and shows the degree to which combined independent variables predict specified outcome variables.

In Model 1, when PCAT scaled scores and cumulative entering GPAs are considered together, they account for 37%, 34%, 30%, and 21% of the variance in first, second, third, and fourth-year GPAs, respectively. In Model 2, when PCAT subtest scaled scores are considered alone, they account for 24%, 21%, 19% and 12% of the variance in first, second, third, and fourth year GPAs, respectively. The parameter statistics indicate the degree of contribution made by the independent variable in each model.

Discriminant Analysis

Discriminant analysis is used to determine which variables discriminate between two or more specified groups. The basic idea underlying discriminant analysis is to determine whether groups differ with regard to the mean of a variable, and to use that variable to predict group membership. In this study, PCAT subtest scaled scores plus cumulative entering GPAs were used as predictor variables for one analysis (Model 1), with each variable weighted according to its predictive contribution. In a second analysis (Model 2), only PCAT subtest scaled scores were used, again weighted according to the predictive contribution of each. Each analysis selects the best combination of sensitivity and specificity. For this study, sensitivity and specificity were defined as percentages of students in the sample likely to earn the lowest 5% (sensitivity) and highest 95% (specificity) of GPAs in a pharmacy program. Table 5 shows the results of these analyses.

The data for Model 1 show that when combined with cumulative entering GPAs, PCAT subtest scaled scores have predictive value in being able to identify between 83% and 65% of the lowest performing students and 75% to 62% of the highest performing students in years 1–4 of the professional pharmacy programs. The data for Model 2 show that when considered alone, PCAT subtest scaled scores have predictive value in being able to identify between 71% and 73% of the lowest performing students and 69% to 60% of the highest performing students in years 1–4. While in Model 1, the sensitivity predictions are higher for years 1–3 than in Model 2, and the specificity predictions are higher for all four years, Model 2 shows less variation from year to year when PCAT subtest scaled scores are considered alone. In Model 2, the sensitivity predictions are relatively consistent for each of the four years, and the specificity predictions decrease slightly for each year, but still remain relatively high.

Diagnostic Accuracy Analysis

As with discriminant analysis, the diagnostic accuracy analysis conducted for this study indicates the same sensitivity and specificity outcomes (defined as identified percentages of the lowest 5% and highest 95% of performers, respectively). The difference is that for the diagnostic accuracy analysis, the predictor variable was the PCAT Composite scaled score, an unweighted average of the five multiple-choice subtest scaled scores. As shown in Table 6, the diagnostic accuracy analysis also lists a range of PCAT Composite scaled scores and the corresponding percentages of sample examinees who represented the lowest and highest GPAs during each of the four years of the professional pharmacy programs that participated in the study. Table 6 lists both Composite scaled scores based

on the 1992 norms (the 2 columns on the far left) and the approximate equivalents based on the 2003 norms in effect since March 2004 (the 2 columns on the far right), which range from 200–600 with a mean of 400.[21]

The data in Table 6 have practical value in suggesting the PCAT Composite scaled scores that can best identify students who are most likely to succeed in the professional pharmacy program, assuming that the research sample was representative of the population of students admitted to pharmacy programs in general. For example, if a PCAT Composite scaled score of 198 (the 45th percentile) was used as a predictor variable, this score would identify only 53% of the entering students who would be among those earning the lowest 5% of GPAs during the first year in the program, but would identify 81% of those who would earn the highest 95% of GPAs during the same year. Conversely, this also suggests that 47% (100 – 53 = 47) of the lowest performing students and 19% (100 – 81 = 19) of the highest performers would not be correctly identified. The opposite extreme is observed for a Composite scaled score of 227 (the 90th percentile), which would predict that 100% of the entering students would be among those earning the lowest 5% of GPAs during the first year in the program, but only 18% would be in the highest 95% GPA group during the same year. The purpose of these diagnostic accuracy data is to determine the optimal balance between sensitivity and specificity predictions based on a PCAT Composite score, where both outcome measures are similar in value and both relatively high.

DISCUSSION

The overall results of this study support previous research studies that have shown moderate predictive validity of the PCAT in terms of correlation analyses and multiple regression analyses. This study expands previous examinations of the predictive value of the PCAT by including discriminant and diagnostic accuracy analyses. The analysis with the most practical value is the diagnostic accuracy analysis, because it suggests how well specific PCAT scaled scores can identify percentages of students who are likely to succeed in a professional pharmacy program.

From the data listed in Table 2, it is clear that the group of students earning the highest GPAs were those who went on to earn a PharmD degree in four years, followed by those who earned a BS, and those who still were enrolled after four years. If success is defined as students who either received a degree or were still enrolled after four years and expected to eventually complete the degree, then 95% of the students who entered a professional pharmacy program in fall 2000 met this description.

However, if GPA in the pharmacy program is considered, it is clear that there are different degrees of success. Students who received a PharmD degree averaged the highest GPAs for all four years. The GPAs earned by those who received a BS degree and those who were still enrolled after four years were considerably lower than the PharmD students. Not surprisingly, students who discontinued enrollment prior to the fourth year had the lowest mean GPA. For this last group, it is notable that the largest proportion of students discontinued enrollment before the second year (nearly 60%).

Apparently, the first year of pharmacy school is especially efficient at selecting those students who eventually will succeed from those who will not. This interpretation is significant when explaining each of the four predictive validity analyses conducted for this study.

Table 3 shows correlations between GPAs in years 1–4 of the pharmacy programs that ranged from 0.19 to 0.41 for PCAT subtest scaled scores, from 0.30 to 0.43 for PCAT Composite scaled scores, from 0.38 to 0.49 for entering cumulative GPAs, and from 0.35 to 0.47 for entering math/science entering GPAs. The results of this correlation analysis are consistent with findings by other researchers, particularly as summarized in the meta-analysis by Kuncel and colleagues.[1]

From these data, it seems clear that correlations are slightly higher for entering GPAs (both cumulative and math/science) than for PCAT scaled scores, and that for all independent variables, the correlation coefficients generally decrease for each subsequent program year. Correlations may be higher for both entering GPAs than for PCAT scaled scores because the contents of a typical pre-pharmacy curriculum are more similar to a pharmacy curriculum than the contents of the PCAT subtests. Pre-pharmacy GPA is also earned over an extended period of time, while PCAT scaled scores are earned in a single testing session that is undoubtedly quite stressful for many individuals. In any case, the PCAT subtests are similar enough in content to pre-pharmacy curriculum that the correlations are not much less than those for both entering GPAs, especially as indicated by the PCAT Composite scaled scores.

The decreasing correlations for each subsequent year of the pharmacy program may be influenced by some restriction of GPA range operative after the first year. Most students who discontinued enrollment did so before the second year (nearly 60%), resulting in narrower GPA ranges for students in years 2–4 than in the first year. The lower correlations in years 2–4 may reflect less variation in students' GPAs for those years. Nevertheless, the total number of students who discontinued enrollment is relatively small compared to the number who graduated. Moreover, the fourth year does not include any students who graduated with a BS degree, again a relatively small number (see Table 2). A more likely reason for the decreasing correlations between PCAT scaled scores and GPAs in each subsequent year may be due to the increasingly clinical nature of the program. In each subsequent year, the pharmacy programs required fewer credits in content areas assessed by the PCAT (See Table 1). Additionally, advanced pharmacy courses rely more heavily on knowledge acquired in prerequisite courses found earlier in the pharmacy curriculum than in courses taken prior to admission to a pharmacy program.

From the multiple regression analyses shown in Table 4, it is apparent that in Model 1, cumulative entering GPAs contribute more to subsequent GPAs than the PCAT Chemistry, Biology, and Reading Comprehension scaled scores, and that neither PCAT Verbal Ability nor Quantitative Ability contribute any significant predictive value. In Model 2, the same PCAT scaled scores make similar predictive contributions as in Model 1. However, the somewhat lower coefficients of determination (R^2) in Model 2 suggest the value of considering

cumulative entering GPAs in combination with PCAT scaled scores as seen in Model 1. The results of these analyses are consistent with findings by other researchers.[4, 5, 11, 13]

An explanation for why the PCAT Verbal Ability and Quantitative Ability subtests do not contribute significantly to the predictive validity in these two models may include the same causes as for the decreasing correlation coefficients over the four years in pharmacy programs. As seen in Table 1, relatively few credits are required in the professional pharmacy curricula (or pre-pharmacy prerequisites) that seem to draw specifically upon the verbal and quantitative skills included in these two PCAT subtests. Furthermore, both multiple regression models suggest that PCAT scaled scores and cumulative entering GPAs, while valuable in helping predict subsequent performance, must always be considered along with other information about candidates when making admission decisions.

The data in Table 5 show that when considered alone (Model 2), PCAT scaled scores have predictive value in being able to identify between 71% and 73% of the lowest performing students and 69% to 60% of the highest performing students in years 1–4 of the professional pharmacy programs. Even though the specificity prediction decreases slightly for each year in the pharmacy program, the percentages of students earning the highest 95% of GPAs remain relatively high. Sensitivity predictions above 70% and specificity predictions above 60% suggest that the PCAT scaled scores alone have predictive value. When PCAT scaled scores are combined with cumulative entering GPAs (Model 1), the predictive values are generally higher, consistent with the regression analyses. However, when considered alone, PCAT scaled scores show more consistent predictive values over years 1–4 than when combined with cumulative entering GPAs. These data support the correlation and multiple regression findings that PCAT scaled scores are generally valid predictors of subsequent performance.

While the discriminant analyses suggest predictive value in a theoretical sense, the diagnostic accuracy data shown in Table 6 have more practical value in suggesting specific PCAT Composite scaled scores that can identify the students most likely to succeed in a pharmacy program. The ideal use of these diagnostic accuracy data is to determine the optimal balance between sensitivity and specificity predictions based on a PCAT Composite scaled score, where both outcome measures are similar in value and relatively high. For example, the data in Table 6 suggest that during the first year of a professional pharmacy program with a mean entering PCAT Composite scaled score of 213 (75^{th} percentile) as seen in the study sample, PCAT Composite scaled scores in the 201–204 (52–58 PR) range predict that 69–73% of candidates would be among the lowest 5% of performers, and that 75–68% would be among the highest 95% of performers. The similarity of these scaled scores to the optimal scores determined by the discriminant analysis as shown in Model 2 of Table 5 suggests a strong predictive value for the PCAT Composite scaled scores.

The results of all four validity analyses suggest that the PCAT is a valid predictor of the performance of pharmacy students. While the results are most substantial for performance in the first year of study, the PCAT also is seen to have validity, though to a

lesser degree, in predicting GPAs in years 2–4. This study thus suggests that the PCAT continues to have value in predicting the success of students in professional pharmacy programs.

CONCLUSIONS

The authors of this study hope that pharmacy school faculty, administrators, and staff find the results reported here to be of practical value. Nevertheless, we must suggest that the results of this study be interpreted with consideration for several necessary limitations.

One limitation relates to the 11 pharmacy schools that chose to participate in this study. The majority of these schools (seven) are located in the South and are public institutions (eight). These factors may limit the generalizability of the findings, especially for private schools and schools in other regions. Another limitation relates to a study design that could not control for the differences among program admission and progression policies and curricula. For example, some programs allow students to repeat a course and allow the higher grade to count, while others require a student to repeat a course, but count only the lower grade or the average of the two grades together. In addition, the nature of the fourth-year GPA varies across schools. A typical fourth-year pharmacy school curriculum consists of experiential courses (rotations, clerkships, and internships), with grades that are often pass/fail or credit/no credit. Letter grades assigned for these courses tend to be high. For these reasons, fourth-year GPAs may appear inflated. A final limitation relates to restriction of range. Because the recent trend among pharmacy schools to tighten admission standards, there may be more variance in the sample used for this study (the fall 2000 entering class) than for a sample used in a study conducted at the present time. Furthermore, the cohort of students admitted in the fall of 2000 took versions of the PCAT that were constructed on a test blueprint that has since been revised with consideration for more stringent pre-pharmacy requirements.

To ensure greater generalizability, future studies should attempt to enlist more schools to participate, especially private schools and schools from the Northeast, Midwest, and West, and should attempt to control for the differences in program grading policies and curricula. Furthermore, future studies should utilize a cohort that was administered a version of the PCAT meeting the current test blueprint and admitted under more recent pharmacy school policies.

Regardless of the limitations of this study, the findings make a valuable contribution to the existing literature on the predictive validity of the PCAT. This study not only supports the findings of previous studies that examined the predictive validity of the PCAT through correlation and regression analyses, but also includes two analyses not previously done in such studies—discriminate analysis and diagnostic accuracy analysis.

The results of this study suggest that the PCAT continues to have moderate to strong value in predicting GPAs during four-year professional pharmacy programs, especially for the first year of study, and particularly when considered with a student's entering

GPA. This study also found that specific PCAT scaled scores can be used to identify candidates for admission who have a high likelihood of success. When used in combination with other pertinent information about the candidates, the PCAT can be a valuable tool in selecting students likely to perform successfully in a professional pharmacy program.

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Table 1. Prerequisite and Pharmacy Program Academic and Professional Course Requirements for the 11 Participating Pharmacy Programs

Pre-Pharmacy Requirements	Semester Credits Required	
	Range	**Mean**
Biological Sciences	4–16	11.2
Chemistry	15–18	16.3
Physics	0–8	4.7
Math	3–12	6.0
English & Speech	3–12	7.5
Social Sciences & Humanities	3–26	15.6

Pharmacy Program Requirements	Semester Credits Required							
	1st Year		2nd Year		3rd Year		4th Year	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Biological Sciences	4–15	11.0	0–14	7.3	0–14	3.7	0	0.0
Chemistry	0–9	6.4	0–12	4.9	0–4	1.0	0	0.0
Quantitative	0–7	3.4	0–6	2.5	0–12	2.8	0	0.0
Verbal/Communication	0–5	1.2	0–4	2.1	0–11	3.1	0–4	0.8
Professional Pharmacy	6–20	13.3	6–30	16.8	7–29	18.4	0–4	0.7
Internship/Clerkship/Rotation	0–4	2.5	0–4	1.9	0–14	3.4	30–50	37.7

Table 2. Characteristics of Students Entering in the Fall 2000 for 11 Participating Pharmacy Programs

Characteristics of Students Entering Fall 2000		Stat	All Students Entering Fall 2000	Grad. BS After 3 Years	Left Program Before 4th Year	Grad. PharmD After 4 Years	Still Enrolled After 4 Years
All Students Entering Fall 2000		*n*	899	47	41	759	52
PCAT Verbal	SS	*M*	210.5	193.4	201.3	212.3	208.1
PCAT Biology	SS	*M*	216.5	209.9	205.2	217.7	213.6
PCAT Reading	SS	*M*	208.2	190.6	200.0	209.9	204.7
PCAT Quantitative	SS	*M*	215.2	207.3	212.5	215.8	217.1
PCAT Chemistry	SS	*M*	215.0	209.4	212.2	215.6	213.4
PCAT Composite	SS	*M*	213.0	202.1	206.3	214.1	211.3
Entering GPA	Cumulative	*M*	3.25	3.14	3.16	3.28	2.99
	Math/Science	*M*	3.24	3.07	3.25	3.26	3.14
Pharmacy GPA—1st Year		*M*	3.15 (*n* = 796)	2.88 (*n* = 46)	2.57 (*n* = 29)	3.23 (*n* = 684)	2.62 (*n* = 37)
Pharmacy GPA—2nd Year		*M*	3.14 (*n* = 772)	2.87 (*n* = 46)	2.27 (*n* = 12)	3.21 (*n* = 681)	2.58 (*n* = 33)
Pharmacy GPA—3rd Year		*M*	3.21 (*n* = 759)	3.09 (*n* = 46)	2.47 (*n* = 5)	3.25 (*n* = 679)	2.76 (*n* = 29)
Pharmacy GPA—4th Year		*M*	3.48 (*n* = 709)	NA	NA	3.50 (*n* = 683)	2.88 (*n* = 26)

Legend: SS = scaled score; GPA = grade point average; Entering GPA = earned prior to admission to pharmacy program; Pharmacy GPA = earned during the four years of the professional pharmacy program.

Note: The scaled scores listed are based on 1992 norms (used from 1992–2003) and were on a scale of 100–300 with a mean of 200; the PCAT scaled score, GPA, and *n*-count data listed in this table only include cases where the information provided was complete or clear; PCAT scaled scores and GPAs have been adjusted for outliers and missing values; the number of students completing pre-pharmacy coursework is not included because not all the participating schools provided this information; entering GPA Cumulative and Entering GPA Math/Science were not reported for all entering students; mean Pharmacy GPAs and *n*-counts include data only for the 10 schools that reported GPAs on a 4-point scale.

The following standard deviations (SDs) are for all categories of students: PCAT subtest SS SDs range 21.5–38.0; PCAT Composite SS SDs range 19.3–24.0; PCAT PR SDs range from 25–35; entering cumulative GPA SDs range 0.36–0.42; entering math/science GPA SDs range 0.43–0.49; GPA in program SDs range 0.35–0.71.

Table 3. Correlations Between Predictors and GPAs in Years 1–4 of Professional Pharmacy Program

	1st Year GPAs		2nd Year GPAs		3rd Year GPAs		4th Year GPAs	
Variable	***r***	***r²***	***r***	***r²***	***r***	***r²***	***r***	***r²***
PCAT Verbal SS	0.27	0.073	0.23	0.053	0.22	0.048	0.19	0.036
PCAT Biology SS	0.35	0.123	0.31	0.096	0.27	0.073	0.19	0.036
PCAT Reading SS	0.31	0.096	0.29	0.084	0.30	0.090	0.26	0.068
PCAT Quantitative SS	0.29	0.084	0.28	0.078	0.27	0.073	0.21	0.044
PCAT Chemistry SS	0.41	0.168	0.39	0.152	0.38	0.144	0.29	0.084
PCAT Composite SS	0.43	0.185	0.40	0.160	0.38	0.144	0.30	0.090
Cumulative Entering GPA	0.49	0.240	0.47	0.221	0.43	0.185	0.38	0.144
Math/Science Entering GPA	0.47	0.221	0.45	0.203	0.42	0.176	0.35	0.123

Note: All correlations are statistically significant at 0.01; cumulative and math/science entering GPAs were not reported for all entering students.

Table 4: Multiple Regression Analyses for PCAT Subtest Scaled Scores and Entering Cumulative GPA

Model 1: PCAT Subtest SS + Cumulative Entering GPA	R^2	**Parameters**					
		Verbal SS	**Biology SS**	**Reading SS**	**Quant. SS**	**Chem. SS**	**Entering GPA**
1st Year GPA	0.37	*	0.39	0.27	*	0.44	0.54
2nd Year GPA	0.34	*	0.27	0.27	*	0.41	0.47
3rd Year GPA	0.30	*	0.12	0.30	*	0.33	0.32
4th Year GPA	0.21	*	*	0.18	*	0.15	0.20

Model 2: PCAT Subtest SS Only	R^2	**Parameters**				
		Verbal SS	**Biology SS**	**Reading SS**	**Quant. SS**	**Chem. SS**
1st Year GPA	0.24	*	0.37	0.37	*	0.60
2nd Year GPA	0.21	*	0.26	0.35	*	0.54
3rd Year GPA	0.19	*	*	0.35	*	0.42
4th Year GPA	0.12	*	*	0.21	*	0.21

Legend: * = no significant contribution by a predictor variable.

Note:; All coefficients of determination are statistically significant at 0.01; all indicated parameters are significant at level 0.01.

Table 5: Discriminant Analyses for Weighted PCAT Subtest Scales Scores and Cumulative Entering GPA

GPA in Pharmacy Program	Model 1: PCAT Subtest SS + Cumulative Entering GPA	
	Lowest 5%	Highest 95%
1st Year GPA	83	75
2nd Year GPA	83	73
3rd Year GPA	77	68
4th Year GPA	65	62

GPA in Pharmacy Program	Model 2: PCAT Subtest SS	
	Lowest 5%	Highest 95%
1st Year GPA	71	69
2nd Year GPA	71	67
3rd Year GPA	71	66
4th Year GPA	73	60

Legend: Lowest 5% = percent receiving the lowest 5% GPAs in program (sensitivity); Highest 95% = percent receiving the highest 95% GPAs in program (specificity).

Note: Analysis based on PCAT subtest scaled scores (SS) weighted according to the relative predictive contribution of each.

Table 6: Diagnostic Accuracy for Predicting GPAs in Professional Pharmacy Programs from Entering PCAT Composite Scaled Scores

Comp. SS Index	Entering PCAT Composite SS (sample *M* = 213)		Probabilities of Identifying Students Likely to Earn in the Lowest 5% and in the Highest 95% of Pharmacy Program GPAs Based on Entering PCAT Composite Scaled Scores and Percentile Ranks								Equivalent 2003 PCAT Composite SS (sample *M* = 407)	
			1st Year		2nd Year		3rd Year		4th Year			
			% of Lowest 5%	% of Highest 95%	% of Lowest 5%	% of Highest 95%	% of Lowest 5%	% of Highest 95%	% of Lowest 5%	% of Highest 95%		
	SS	PR									SS	PR
-15	198	45	53	81	51	81	49	81	40	81	392	35
-14	199	48	56	79	53	79	51	79	42	79	393	37
-13	200	50	64	77	60	76	56	76	47	76	394	39
-12	201	52	69	75	67	75	60	75	49	74	395	41
-11	202	54	69	73	67	73	62	72	56	72	396	43
-10	203	56	71	71	69	71	67	70	60	70	397	45
-9	204	58	73	68	71	68	67	68	62	68	398	47
-8	205	59	73	66	71	66	67	66	62	65	399	49
-7	206	61	76	63	73	63	69	63	64	62	400	51
-6	207	63	78	59	78	59	71	59	71	59	401	53
-5	208	65	78	57	78	57	71	56	71	56	402	55
-4	209	67	84	56	84	56	78	55	76	55	403	57
-3	210	69	84	53	84	53	78	53	76	53	404	59
-2	211	71	84	50	84	50	78	50	78	50	405	61
-1	212	73	87	47	84	47	82	46	80	46	406	63
0	213	75	87	44	84	44	87	44	82	44	407	64
1	214	77	89	43	89	43	89	43	84	42	408	66
2	215	78	91	41	91	41	89	41	87	41	409	68
3	216	79	91	38	91	38	89	38	87	38	410	70
4	217	80	91	36	91	36	91	36	87	36	411	72
5	218	81	96	34	96	34	96	34	87	34	412	73
6	219	82	98	33	98	33	96	32	87	32	413	75
7	220	83	98	30	98	30	96	30	87	30	414	76
8	221	84	100	28	98	28	98	28	87	28	415	78
9	222	85	100	26	98	26	98	26	87	25	416	79
10	223	86	100	25	100	25	98	24	87	24	417	80
11	224	87	100	23	100	23	98	23	87	23	418	82
12	225	88	100	22	100	22	98	22	89	21	419	83
13	226	89	100	20	100	20	98	20	89	20	420	84
14	227	90	100	18	100	18	100	18	89	18	421	85

Legend: Comp. SS Index = values added to the mean PCAT Composite scaled score for the study sample to determine the relationship between Composite scaled scores and probabilities; SS = scaled score; PR = percentile rank; % of Lowest 5% = percent of students receiving the lowest 5% GPAs in program (sensitivity); % Highest 95% = percent of students receiving the highest 95% GPAs in program (specificity).

Note: Analysis based on PCAT Composite scaled scores (unweighted average of the five multiple-choice subtest scaled scores); GPA data from participating pharmacy schools were equated on a common scale to accommodate for differences in grading scales (i.e., 4.0 or 100); scaled scores and percentile ranks include both those based on the 1992 norms in effect at the time the scores were earned (columns on left) and on the approximate equivalents based on the 2003 norms in effect since March 2004 (columns on far right).