Comparison of Validity of two Systems of Candidates' Admission for Pharmaceutical Studies: a 15-year Retrospective Study

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ABSTRACT

Background: Comparing predictive validity of admission criteria for the MsPharm (Master of Sciences of Pharmacy) studies in the period prior and following the reform of the university admission system in Poland illustrated on the example of data obtained from the Faculty of Pharmacy at the Medical University of Warsaw (MUW). **Methods**: Admission data was correlated with the learning outcomes of students who undertook the MA studies at the pharmaceutical department between the years 2000/01-2009/10 (N = 1702, mean age 19.3 ± 1.22). The method of predictive validity of the old admission system (specific entrance exam) and the new system (the national Polish maturity exam) was performed using correlation and method of multiple linear regression. **Results**: Chemistry, biology and the total score of ranking points showed a significant correlation with bioGPA, chemGPA, and cumulative GPA but its power was greater for the old system of admission. The analysis of regression showed that by and large, women achieve better learning outcomes. Age on entry was an important success predictor only in the old system of recruitment. Both recruitment criteria were a positive prognostic in the old admission system. The new system of recruitment showed significantly weaker predictive ability of student's performance during pharmaceutical study. **Conclusion:** Admission system based on the national Polish entry test exam is characterised by a much greater predictive validity of future student's performance than the admission system based on the results of the national maturity exam. It is necessary to monitor and improve the accuracy of currently used recruitment regulations further through testing evaluation of candidates' non-cognitive attributes.

Key words: Predictive validity, Student performance, Educational measurement, School admission criteria, Pharmacy education.

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BACKGROUND

Every year universities engage their personnel and funds into thorough recruitment process to select the best candidates for a given direction of studies. As a selective criterion, majority of Western countries apply various forms of entry examinations. Through the past several years, there have been numerous works published, connected with the evaluation of recruitment systems for pharmaceutical studies, mainly concerning the USA.[1-27]

The Faculty of Pharmacy at the Medical University of Warsaw (MUW) is one of ten academic units at Polish universities which educates pharmacists at uniform Master's studies.[28] Annually, there are about 130 graduates of MUW who receive the title of Master of Sciences of Pharmacy (MsPharm), which is about 10% of all students graduating from this direction throughout Poland (data from the Polish Pharmaceutical Society).[29] Up to the academic year of 2004/05 there has been a uniform mechanisms applied, based on the results of the national aptitude test, the structure of which was similar to other exams of such kind, such as American Pharmacy College Admission Test (PCAT).[17] A candidate could apply for a position only at one academic centre chosen by them. The test exam was prepared by the Central Committee for Medical Examination and allowed to evaluate a candidate's knowledge and skills

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gained during the learning process of a high school in two subjects: biology and chemistry. The test was carried out at the same time throughout the country and comprised of 120 multiple-choice questions (MCQs) (60 in each subject) in the format of best answer from a list of possible answers. The test type of the entry exam and calculations done outside the universities and following the same set of principles provided it with the quality of objectivity.

Complying with the reform of education in Poland in the academic year of 2005/06, new and current rules of admission for universities were introduced, based on the results of the national maturity exam (equivalent A-levels in UK, Baccalauréat in France, Maturità in Italy or Abitur in Germany). The result obtained by a candidate becomes the grounds on which they may apply for the possibility of studying at any Polish university, including one of the ten pharmacy education centres. Additionally, candidates may apply for any number of directions selected by them at universities of a different profile of education. Every university has the right to prepare their own criteria that will be evaluated during the recruitment process, thus deciding which subjects and at what level of advancement (basic or extended) they will become the grounds for selection. Most of the medical universities educating future pharmacists requires of a candidate to present their results of maturity exam in biology and chemistry on the extended level. The maturity exam prepared under the supervision of the Central Examination Board (CEB) comprises of 30-40 open questions that evaluate the knowledge and skills as well as the ability to reason, conclude and draw conclusions, use information from various sources, interpret the results, description and analysis of phenomena and processes in biology and chemistry. External examiners evaluate the works in individual subjects and the score (100 points to be gained in total in each subject) are then presented to universities through the National Registry of Maturity Exams. The threshold of admission is not set in advance but is a derivative of a number of candidates and the level of difficulty of the maturity exam in subjects that are the admission criterion for a given direction. CEB statistics from previous years show that every year the results in chemistry and biology are similar. However, due to the demographic decline, the overall number of candidates for universities decreases, although in case of pharmaceutical studies, this decline is not significant.[30]

One of the significant aspects of studies into the quality of admission policy is evaluation of predictive ability of the selected forms of entry exams. This analysis includes evaluating to what extent pre-pharmacy characteristics allow to assess accurately the learning outcomes of a student, measured by, e.g. the year average throughout the course of studies (cumulative GPA). Another important area of study is establishing which selection criteria are best in determining the future of graduates. As is emphasised by Ferguson *et al*.,[31] it is necessary to carry out well-planned, reliable and long-term studies that would establish the actual predictive value of the selected cognitive and non-cognitive criteria in relation to predicting students'/graduates' future. The National Association for College Admission Counselling recommended that each educational institution perform research on the validity of the admissions tests and share its results with other universities.[32] Analysis of attrition and predictors of academic success might yield multiple long-term benefits. Studies of attrition and identification of students who may struggle both academically and personally are important to enable evidence-based selection and support services at medical university.[33]

The strategy of selection that is commonly accepted in Poland is only based on the criteria of cognitive skills evaluation in relation to the results of educational studies that are accessible in the world literature, which may come into criticism.[34]

Some studies indicate that the absence of non-cognitive evaluation of candidates may contribute to a weaker prediction in the area of accurate evaluation of future successes during the course of studies as well as future professional carrier of graduates of a given direction of studies.[15,35] Nevertheless, solutions similar to the Polish one, are in use in other countries, which is an indirect solution between the strategy of selecting candidates that present certain specific predispositions in the area of cognitive and non-cognitive skills, and admission policy in which the proper selection of students for a given direction of studies is performed only after the first year of studies.[36]

Methodology of predictive studies allows to verify hypotheses concerning to what extent the measurement of competences on entry during the recruitment process allows to accurately predict some student's performance quantity criteria in the future (e.g. cumulative GPA). Selecting appropriate outcome variables is connected with the necessity to point to certain objective measurement of "success of a student". Due to that fact, the criterion variable is frequently a combination of different measurements, as it is the case of grade average, which reflects some average of achievements of a student in a given period of studies. Most frequent outcome

variables in correlation and regression analyses are the following ones: result achieved by a student after the first year of studies,[7,9,37-38] GPA value including biomedical (bioGPA) or chemical (chemGPA) subjects, grades in subjects connected with pharmaceutical sciences (profGPA), results of exams in pharmacology and pharmacotherapy, GPA value in practical classes and internship, and the result of the exam that provides access to the profession, such as, e.g. North American Pharmacist Licensure Examination Test (NAPLEX).[7,9,11,23-24,37-39]

Aim of study

Results of retrospective studies presented in this work are connected with comparing the predictive validity of admission criteria for pharmaceutical MA studies in the time before and after the national reform of maturity exams, illustrated by data obtained from the Faculty of Pharmacy at the Medical University of Warsaw.

MATERIALS AND METHODS

Data collection

Admission data as well as the learning outcomes of students who undertook MA studies at the pharmacy department in the years 2000/01-2009/10 (N=1702, age average 19.3 ± 1.22) was analysed. The observation covered the whole period of education for each year of students from October 1st 2000 to March 31st 2015. The vast majority of the studied group was women (74.0%) and graduates who completed their high school outside Warsaw (70.8%). A detailed characteristic of the studied group, divided into two periods of two different admission systems, is presented in Table 1.

Data concerning variables such as gender, age on entry, place of completing high school, were obtained from information presented in application forms completed by the candidates to universities. The results of preliminary exam tests from the years 2000/01-2004/05 were obtained from the data base of the Medical University of Warsaw Admission Board. However, data covering the years 2005/06-2009/10 were collected from the National Registry of Maturity Exams. As for learning outcomes, the collected data concerned GPA achieved by students in consecutive years throughout the whole period of studies (cumulative GPA) and three thematic blocks: bioGPA (biomedical subjects), chemGPA (chemical subjects) and proGPA (professional subjects). The above data were collected in the Main Students' Database that supports the administrative services for students.

The study did not require approval by the Bioethics Committee.

Description of the Master in Pharmacy program curriculum

Educating pharmacists in Poland is performed within uniform MA studies that last for five and a half years[40] and comprise of 11 semesters, the last one of which is an obligatory internship at a chemist's, which allows to obtain the right to become a professional pharmacist (no pharmacist licensure examination). Moreover, within the framework of studies, students realise two one-month internships at a chemist's and hospital or clinical pharmacy. Overall number of classes is no fewer than 5300, and during the course of studies, a student receives at least 330 ECTS points (European Credit Transfer System).

As part of their curriculum during the first two years of studies, students of the Faculty of Pharmacy at MUW are educated in the field of basic biological–chemical sciences. The first year includes 12 subjects (plus a Physical Education), four of which end in an exam: Anatomy, Biology with genetics, Pharmaceutical Botany and General/Inorganic Chemistry. First three subjects become the basis for further education in the area of biomedical sciences, such as physiology, patophysiology and microbiology. This thematic block is necessary for proper understanding of the mechanisms of drug activities and the practical application of drug substances in pharmacotherapy, which is the subject matter of classes in Pharmacodynamics/Pharmacology, Toxicology, and Biopharmacy during the further years of studies. Pharmaceutical studies also include a wide range of chemical sciences. Such subjects as General/Inorganic Chemistry, Organic Chemistry, Analytical Chemistry, and Physical Chemistry are the basis on which students build their professional competences in the field of Medicinal Chemistry, Pharmacognosy/Phytochemistry, Synthesis and technology of drugs, Drug formulation technology.

A graduate of a pharmaceutical department present a general knowledge in the area of chemical, biological, medical and social sciences, and also detailed knowledge in the area of pharmaceutical sciences. Students receive skills in preparation, production and evaluation of quality and origin of drugs. Moreover, graduates of this direction have competences allowing them to provide reliable and objective information on how drugs work and how to apply medical products in pharmacotherapy. Additionally, during their course of studies, students are prepared for carrying out scientific studies in the field of pharmaceutical and other related sciences.[28]

Statistical analysis

Evaluation of predictive validity of the old and new system of admission to pharmaceutical studies was performed using correlation and linear method of multiple regression. Linear correlation between the recruitment criteria–the result obtained in biology and chemistry, and the learning outcomes calculated as cumulative GPA throughout the whole course of studies, was assessed using r-Pearson linear correlation coefficient, multiple correlation and 3D scatterplots. The model of regression was adjusted to empirical data using the Ordinary Least Squares (OLS) method of estimation. While testing the assumptions for the multiple linear regression, a degree of predictors' correlation in the collinearity test was assessed (Variance Inflation Factor (VIF), assuming the impassable value on the level of 10.[41] Moreover, the analysis of residuals was performed, testing the following: homoscedicity (scatterplot and homogeneity Levene test),[42] normal distribution (W Shapiro-Wilk test)[43] and the degree of correlation of the residue (Durbin-Watson test).[44] In addition, as part of model diagnostics, outliers appearance was evaluated by establishing Mahalanobis and Cook's distance.[45-46] To interpret the distance, rules suggested by Larose[47] and Field[41] were applied.

In each of the suggested models of regression, five explanatory variables (predictors) were used: 1. gender, 2. age on entry, 3. place of completing the high school, 4. the score in biology and 5. chemistry. Depending on the tested model, one of the four dependent variables (outcome variables) were used: (1) the first year GPA, (2) bioGPA, (3) chemGPA, and (4) cumulative GPA. The direction and power of the relevant dependencies were interpreted through establishing β regression coefficients. In order to evaluate the degree of variance explanation for both models of regression, the value of corrected statistics R^2 was established.

Calculations were performed in a statistical set of STATISTICA 12.5 (StatSoft©, Inc.) according to the MUW licence. For all analyses, the relevance level assumed *a priori* was $\alpha=0.05$.

RESULTS

Correlation analysis

The analysis of quantitative relation between score achieved by the candidates for individual selective criteria and the results of students during the course of study shows that the power of this correlation was the highest in the first two years and then a declining tendency was observed until the final year of studies. The direction of these changes was particularly visible in case of a new recruitment system. Moreover, a significant correlation between the recruitment criteria and cumulative GPA was noted, which was more powerful than any of the correlations for GPA calculated for individual years of studies. It was observed that the correlations are much more powerful in case of the recruitment process based on the old rules as opposed to those introduced in the academic year 2005/06. Additionally, in case of the old selection system, correlations between the recruitment score in chemistry and biology and chemGPA and bioGPA are greatly visible. Detailed results of the correlation analysis divided into two periods of different admission systems being in force are presented in Table 2.

Testing the assumptions of linear regression

While testing preliminary assumptions for the linear analysis of regression with the estimation using the OLS method, also distribution of variables was evaluated. The results of Shapiro-Wilk test showed significant discrepancies from the normal distribution. However, for individual quantitative variables, no presence of data outliers in the Grubbs test was observed. Furthermore, the diagnosis of any potential influence of data outliers on the dispersion of the variables using Mahalanobis and Cook's distance does not point to any significant breach of the conditions concerning the presence of such results in the data set. The linear dependence between the recruitment criteria (scoring biology and chemistry) and cumulative GPA was evaluated using 3D scatterplots and multiple correlation (Figure 1). For the preliminary assumptions of the tested models of regression, also the degree of correlation of the predictors was assessed (Table 3). For none of the variables introduced into the tested model, any relevant collinearity was discovered (value VIF<10).

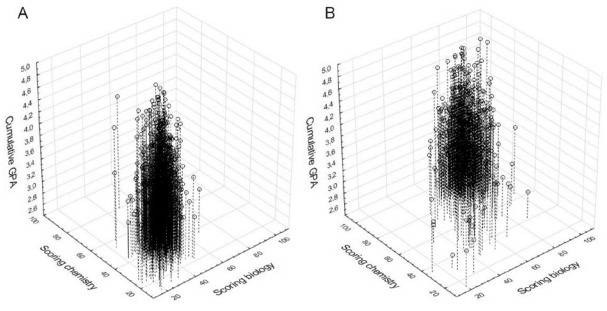

Figure 1. Assessment of dependency between admission criteria (total score of biology and chemistry) and cumulative GPA: (A) old admission system based on the national entry test exam (multiple R(z/xy)=0.352, P<0.00001); (B) new admission system based on the results of the national maturity exam (multiple R(z/xy)=0.256, P<0.00001)

Table 1: Characteristics of a studied group of students who undertook studies in the years 2000/01-2009/10 at the Pharmacy department at the Medical University of Warsaw. The old admission system based on the national entry test exam versus the new admission system based on the results of the national maturity exam

	Old admission system 2000/01–2004/05	New admission system 2005/06–2009/10	TOTAL
N of qualified candidates	3078	4850	7928
Percentage of qualified women	83.2%	80.0%	81.2%
Percentage of qualified candidates from outside Warsaw	69.7%	77.4%	74.4%
Mean age of candidates ± SD	19.5 ± 1.51	19.4 ± 1.48	19.4 ± 1.49
N of students entering the first year of study	851	851	1702
Percentage of women entering the first year of study	73.4%	74.5%	74.0%
Percentage of students from outside of Warsaw, who started the first year of study	70.3%	71.3%	70.8%
Mean age of students entering the first year of study ± SD	19.2 ± 1.08	19.3 ± 1.35	19.3 ± 1.22
Percentage of attrition students	13.0%	20.8%	16.9%

Table 2: r-Pearson linear correlation coefficients for the dependence between the results achieved by a candidate during the recruitment process for university and students performance at the Faculty of Pharmacy at the Medical University of Warsaw. Old admission system based on the national entry test exam versus the new admission system based on the results of the national maturity exam

	Old admission system 2000/01–2004/05			New admission system 2005/06–2009/10		
	Biology	Chemistry	Total score	Biology	Chemistry	Total score
1st year GPA	0,24	0,30	0,31	0,17	0,24	0,23
2nd year GPA	0,26	0,34	0,35	0,20	0,24	0,24
3rd year GPA	0,17	0,19	0,21	0,16	0,19	0,19
4th year GPA	0,22	0,18	0,23	0,11	0,16	0,15
5th year GPA	0,27	0,13	0,23	0,09	0,07#	0,09
bioGPA*	0,31	0,27	0,33	0,18	0,22	0,23
chemGPA**	0,26	0,33	0,35	0,20	0,28	0,27
proGPA***	0,23	0,19	0,24	0,14	0,17	0,17
Cumulative GPA	0,30	0,31	0,35	0,20	0,25	0,25

All correlations are statistically relevant (P-value> 0.05) excluding those marked (#).

*bioGPA–grade average calculated for the following subjects: Anatomy, Biology with genetics, Pharmaceutical Botany, Physiology, Pathophysiology, Microbiology

**chemGPA–grade average calculated for the following subjects: General and Inorganic Chemistry, Organic Chemistry, Analytical Chemistry, Physical Chemistry, Biochemistry, Medicinal Chemistry

***proGPA–grade average calculated for the following subjects: Pharmacodynamics and Pharmacology, Pharmacognosy, Toxicology, Synthesis and technology of drugs, Drug formulation technology.

Table 3: Evaluation of the level of correlation of predictors in multi-collinearity test

Variable	Variance inflation factor	
	Old admission system 2000/01–2004/05	New admission system 2005/06–2009/10
Gender	1.020	1.013
Age on entry	1.029	1.010
Secondary school	1.004	1.013
Score in Biology	1.283	1.659
Score in Chemistry	1.290	1.656

Table 4: Regression coefficients for models evaluating predictive ability of recruitment criteria of the old admission system and based on different outcome variables

Variables	b	β	95% CI lower	95% CI upper	P-value	adjusted R^2	SEE
Outcome variable: 1st year GPA							
Intercept	2,970	----	----	----	< 0,0001	0,126	0,4682
Gender: 0 = Female 1 = Male	-0,186	-0,149	-0,184	-0,114	< 0,0001		
Age on entry	-0,019	-0,040	-0,075	-0,005	0,2529		
Secondary school: 0 = Other 1 = Warsaw	-0,066	-0,062	-0,096	-0,027	0,0746		
Score of Biology	0,009	0,135	0,095	0,175	< 0,0001		
Score of Chemistry	0,015	0,240	0,200	0,280	< 0,0001		
Outcome variable: bioGPA							
Intercept	3,369	----	----	----	< 0,0001	0,154	0,4109
Gender: 0 = Female 1 = Male	-0,223	-0,196	-0,231	-0,161	< 0,0001		
Age on entry	-0,030	-0,066	-0,101	-0,031	0,0620		
Secondary school: 0 = Other 1 = Warsaw	-0,026	-0,028	-0,062	0,007	0,4284		
Score in Biology	0,014	0,230	0,191	0,270	< 0,0001		
Score in Chemistry	0,009	0,170	0,130	0,209	< 0,0001		
Outcome variable: chemGPA							
Intercept	3,606	----	----	----	< 0,0001	0,150	0,5541
Gender: 0 = Female 1 = Male	-0,169	-0,110	-0,145	-0,075	0,001		
Age on entry	-0,068	-0,110	-0,145	-0,074	0,002		
Secondary school: 0 = Other 1 = Warsaw	-0,080	-0,063	-0,098	-0,028	0,0729		
Score in Biology	0,010	0,129	0,090	0,169	0,001		
Score in Chemistry	0,020	0,269	0,230	0,309	< 0,0001		
Outcome variable: cumulative GPA							
Intercept	3,829	----	----	----	< 0,0001	0,173	0,4202
Gender: 0 = Female 1 = Male	-0,216	-0,183	-0,218	-0,148	< 0,0001		
Age on entry	-0,057	-0,119	-0,154	-0,084	0,001		
Secondary school: 0 = Other 1 = Warsaw	-0,052	-0,053	-0,088	-0,019	0,1225		
Score in Biology	0,011	0,181	0,142	0,220	< 0,0001		
Score in Chemistry	0,013	0,228	0,189	0,267	< 0,0001		

95% CI–95% confidence interval; SEE–standard error of estimation; b–regression coefficients; β–standardized coefficient.

Table 5: Regression coefficients for models evaluating predictive ability of recruitment criteria of the new admission system and based on different outcome variables

Variables	b	β	95% CI lower	95% CI upper	P-value	adjusted R^2	SEE
Outcome variable: 1st year GPA							
Intercept	2,170	----	----	----	< 0,0001	0,058	0,4595
Gender: 0 = Female 1 = Male	-0,099	-0,122	-0,161	-0,084	0,02		
Age on entry	0,017	0,048	0,010	0,086	0,1676		
Secondary school: 0 = Other 1 = Warsaw	-0,022	-0,003	-0,041	0,035	0,5691		
Score in Biology	0,001	0,073	0,025	0,122	0,6243		
Score in Chemistry	0,008	0,213	0,164	0,261	< 0,0001		
Outcome variable: bioGPA							
Intercept	2,339	----	----	----	< 0,0001	0,059	0,4268
Gender: 0 = Female 1 = Male	-0,122	-0,111	-0,150	-0,073	0,004		
Age on entry	0,015	0,051	0,012	0,089	0,1885		
Secondary school: 0 = Other 1 = Warsaw	-0,014	-0,014	-0,053	0,024	0,7120		
Score in Biology	0,003	0,076	0,026	0,125	0,1252		
Score in Chemistry	0,006	0,182	0,133	0,231	< 0,0001		
Outcome variable: chemGPA							
Intercept	2,058	----	----	----	< 0,0001	0,077	0,5656
Gender: 0 = Female 1 = Male	-0,107	-0,073	-0,111	-0,035	0,0554		
Age on entry	0,017	0,041	0,003	0,079	0,2851		
Secondary school: 0 = Other 1 = Warsaw	0,027	0,021	-0,017	0,059	0,5852		
Score in Biology	0,002	0,042	-0,006	0,091	0,3849		
Score in Chemistry	0,011	0,253	0,205	0,302	< 0,0001		
Outcome variable: cumulative GPA							
Intercept	2,408	----	----	----	< 0,0001	0,075	0,4311
Gender: 0 = Female 1 = Male	-0,136	-0,122	-0,161	-0,084	0,001		
Age on entry	0,015	0,048	0,010	0,086	0,2052		
Secondary school: 0 = Other 1 = Warsaw	-0,003	-0,003	-0,041	0,035	0,9369		
Score in Biology	0,003	0,073	0,025	0,122	0,1330		
Score in Chemistry	0,007	0,213	0,164	0,261	< 0,0001		

95% CI–95% confidence interval; SEE–standard error of estimation; b–*regression coefficients*; β–*standardized* coefficient.

Following estimation but prior to the interpretation of the results of the regression, evaluation of accuracy of the tested models in the analysis of the residue was performed. Evaluating the degree of the results dispersion along the line of regression for the low and high values was performed by dividing twenty sub-sets in ascending order against a set of data of the dependent variable. That was followed by the analysis of homogeneity of variance of residue for these sub-sets using Levene test. On the basis of the test results and a visual evaluation of the scatterplots for the standardized predictive values and standardized residue, no breaching of the homoscedicity for the tested models was discovered.

Another criterion of the analysis of residue was evaluation of the normality of residue distribution. The results of Shapiro-Wilk test showed that the residue of the model had their distribution similar to normal. Moreover, using the Durbin-Watson statistics, no autocorrelation of residue was confirmed. On the basis of the results of the analysis of residue it was discovered that the suggested models of linear multiple regression met the conditions for the OLS method of estimation and that data were correctly matched to the assumed formula of regression.

Interpretation of regression analysis results

Within the evaluation of the predictive validity of the old admission system which was based on the results of the national entry examination, the analysis of four models of regression was suggested, which differed in their outcome variables (Table 4). In the group of predictors from the demographic variables group it was discovered that in case of women significantly better results during the course of studies are noted, both with reference to the 1st year GPA, bioGPA, chemGPA, and cumulative GPA. As for the recruitment criteria, it was found that the score of biology is a better predictor of success measured by the value of bioGPA ($\beta_{stand.}$=0.230) than the score of chemistry ($\beta_{stand.}$=0.170). Contrary relations were observed in case of a variable chemGPA (β_{stand} 0.129 and 0.269 for biology and chemistry, respectively). Moreover, the score of chemistry presented a much higher predictive ability with reference to both outcome variable of the 1st year GPA, and cumulative GPA (β_{stand} 0.240 and 0.228, respectively).

Another analysed group of models of regression were those which referred to the predictive validity of new admission system, which is based on the results of the national maturity exam. The same outcome variables were used which were described for the old admission system (Table 5). Similarly as for the results of the analysis of regression described above, also in case of the new rules of selecting candidates, the variable "gender" was a significant predictor of success, not for the outcome variable chemGPA, however. In contrast to the results for the old admission system, no significant predictive relevance was noted for the score of biology criterion in case of new rules of selection. Moreover, the variable score of chemistry by definition presented lower β_{stand} values than those noted in case of the old rules of recruitment. In addition, while comparing the values of adjusted R^2 for both admission systems, it was observed that the models of regression for the old system explained the observed change in the GPA value better than it was the case in the new system.

DISCUSSION

Accessible literature devotes much attention to the evaluation of various factors that may have impact on the effectiveness of studying at the pharmaceutical department, which–to a large extent–concern the rules of admission in the USA. Great experience with a test entry examination for pharmaceutical studies (Pharmacy College Admission Test, PCAT) performed in the USA since 1974 and its (68% of the American Universities makes use of this recruitment tool), made the analysis of a number of predictive factors enabling forecasting the future of students during their learning at the university possible.[1-24] Such studies are based on the assessment of correlation between students pre-admission characteristics and academic success during pharmacy school.[1-24] The average in grades at high school as one of the good predictors (GPA, Grade Point Average): math or science GPA and cumulative GPA.[7,9,12,14,16] Although there have also been publications that do not confirm such a dependency.[8,11,15,19] Another important predictor is score achieved by candidates in various standardised tests: California Critical Thinking Skills Test (CCTST), Health Sciences Reasoning Test (HSRT) i PCAT.[11-13,17,19,48] There are contradictory findings concerning PCAT and its predictive validity,[6-9,15] although, as can be seen from the results of meta-analysis published by Kuncel *et al.*,[17] the results of PCAT are a good predictor of success during the course of studies. Specific pre-pharmacy courses, including biology and organic chemistry are yet another group of potential predictors.[16,20]

In the presented work, the authors attempted to answer the question whether the accepted criteria of selection of candidates for pharmaceutical studies, using two different systems of admission, are of predictive value in forecasting the future of students. The results of correlation analysis are by and large compliant with

the findings of other authors and confirm that a candidate's score is positively correlated with the GPA value achieved by a student in individual years of studies at the pharmaceutical department. This main observation is compliant with the results of studies performed at diifrent universities in the USA.[7,17,19,49] Kuncel *et al*.,[17] in their meta-analysis published in 2005, concluded that the score achieved by the candidates after their PCAT exam is positively correlated with the GPA value after their first year of studies (r-Pearson coefficient calculated from the sum of 22 studies was 0.45; confidence interval between 0.32 and 0.68). Similar results of the analysis were obtained also in case of correlations that were individual parts of PCAT exam: biology (r=0.39), chemistry (r=0.45) and mathematics (r=0.47). Moreover, some of the later studies carried out by Meagher *et al.* showed similar results of correlation coefficients for both overall PCAT exam result and its individual parts, which is also confirmed by the results of our own studies.[19,37,49] It needs to be emphasised that in case of GPAs calculated after the second, third and fourth year of studies, comparable results of a correlation analysis were obtained, however, the values of r-Pearson coefficients for the consecutive years had a declining tendency, which is also compliant with our own observations.[17,19]

While comparing the results of the correlation analysis for two different systematics of admission for pharmaceutical studies, it was observed that for the old principles of admission, the dependence between the results of the entry exam and achievements throughout the course of studies was stronger and more stable throughout the course of studies than it was the case with the new system of admission. Moreover, the results of subtests in biology and chemistry show a much stronger correlation with the value of bioGPA and chemGPA for the old recruitment rules as opposed to the new ones (r reached 0.31 and 0.33, respectively, *versus* 0.18 and 0.28). These results suggest that the accepted recruitment rules based on the competition of the national maturity exam are characterised by low accuracy in the evaluation of competences on entry. It seems that the new method of evaluating the candidates is not adjusted to measure those skills that are important for a student to achieve "success" at the Pharmacy department. An accurate recruitment system should ensure the selection of such candidates who will be able to face the hardships of such difficult direction as pharmacy.

Since assuming, in predictive studies, an r-Pearson or ranks-Spearman correlation coefficient is a very simplified model, the results obtained may be much more credible when applying the analysis of regression. Such approach assumes that the success achieved by a student throughout the pharmacy program is conditioned by more than one predictive factor. Several of the performed analyses of multiple regression include such socio-demographic variables into their models as gender, age on entry, type of the completed high school or parents' education.[6-7,9,16,37,50-51] The tested predictive models did not show any significance as far as the place of completing high school is concerned. Candidates considered „locals" (Warsaw) and „non-locals" (outside Warsaw) did not differ in terms of their achievements throughout the course of studies, regardless of the system they were recruited in for pharmaceutical studies. What is ambiguous, however, are the observations concerning age on entry and their impact on the learning outcomes. This demographic variable was a significant negative predictive factor towards cumulative GPA and chemGPA only in case of old rules of recruitment ($\beta_{stand.}$ -0.119 and -0.110, respectively). The available findings in this area show a significant importance of age on one hand,[6,50] and on the other, are not confirmed by other studies.[8,52] For instance, the results published by Charupatanapong & McCormick[6] showed a weak negative correlation between students' age and the GPA value (r=-0.13), yet the achievements of older students, as opposed to the younger ones, as is emphasised by the authors, were more dependent on such factors as community activity, study hours, pre-pharmacy GPA, working hours, and college activity. Charupatanapong & McCormick[6] also noted that older students worked longer hours and were more involved in community activities, which might lead to poorer performance compared with younger students. A similar influence of age of the studying on their learning outcomes at the pharmacy department was observed also by Unni *et al*.[50] They showed, on the basis of the analysis of logistic regression, that with age, the student's risk of lower achievements increases, both after the first and the second year of studies (OR 0.971 and 0.972, respectively).[50] On the other hand, data published by Chisholm *et al*.[8] concerning the impact of age of the students on their achievements after the first year of pharmaceutical studies do not confirm the existence of such a dependence. Bearing the above observations in mind, the ambiguous findings of our own can only confirm that the influence of the variable age is not quite clear and requires further and more detailed analysis in this field so as to establish its influence on student's performance and retention.

The analysed modes of regression point to the significant role of a student's gender as a predictor of success. The results point to the fact that women were more frequent to achieve significantly better learning results in each of the tested models ($\beta_{stand.}$ remained between

-0.196 and -0.110), yet this dependence was more clear in the old recruitment system. This observation is consistent with the findings of other authors who point to the fact that women are better at handling studies than men.[6,16,51,53-54] Houglum *et al*.,[16] on the basis of the results of the analysis of logistic regression discovered that women, as opposed to men, are characterised by a relatively lower risk of attrition during pharmaceutical studies (OR=0.26). According to Carroll & Garavalia,[54] males most frequently reported use of recall ability, followed by general organization and planning and then environmental restructuring; whereas females reported greater reliance on general organizing and planning followed by recall ability and environmental restructuring. It needs to be stressed, following Zwick & Green,[55] study that while performing predictive analyses, the possibility of bias of educational measurement directed at favouring males may be taken into account. The researchers noted the differences concerning the style of work in women when working on test tasks such as MCQs, which are frequently used in measuring the learning outcomes at medical universities.[56] Kessel & Linn[57] mention in their work that by and large, women need more time for thinking about a test question as they present a greater apprehension towards simplifying questions and guessing answers. The in-depth analysis concerning inter-gender differences in the achieved results of learning, which may suggest that they might be conditioned by a greater diligence, greater care in preparing exercises, more industry in attending classes in women than it is the case with men. According to the above thesis, women make greater progress throughout their course of studies than men with a similar academic background.[55] Future achievements of female students may be underestimated against male students if they are forecasted on the basis of the test entry examination. Such an assumption may explain why, in case of the old recruitment system that was based on the test exams of MCQ type, the inter-gender differences in learning outcomes are much more clear than in case of recruitment based on open question exams.

Apart from socio-demographic variables in the analyses of regression, it is of key importance to evaluate these predictors that are the element of entry examination for pharmaceutical studies. The results of American studies showed that individual elements of PCAT exam are good predictors of success.[4,14,24,49] All five PCAT multiple-choice subtests (biology, chemistry, quantitative ability, reading comprehension, and verbal ability) were predictive of first year pharmacy GPA, with different subtests having more or less predictive value for different levels of first-year GPA achievement.[49] Individual subtests that are parts of PCAT are characterised by a predictive value, however smaller that the total score, which is confirmed by the results of analysis for biology,[4,24,49] chemistry[14,24,49] and mathematics.[24,49] The results of our own studies using the simplified model of regression for two criterion variables (biology and chemistry) allowed to establish that in both recruitment systems, they are good predictive factors, but of greater influence on cumulative GPA value have the selection criteria applied in the old recruitment system than in the new one (multiple R(z/xy) 0.352 and 0.256, respectively). Thus these results confirm the observations made in the analysis of correlation. Also complex models of linear multiple regression point to similar tendencies concerning the predictive ability of the recruitment criteria applied in the new and old system. As it can be seen for recruitment based on the national testy entry exam (the old system), the criterion biology and chemistry maintain their predictive ability with reference to each result variable: 1st year GPA, bioGAP, chemGPA, and cumulative GPA. Whereas in case of new recruitment rules, the criterion biology lost its predictive ability towards each of the tested result variable. Interestingly, the result in the new system showed that bioGPA score achieved by a candidate in biology is not a positive predictor of students' achievements in the subjects that are related to biology. The estimated lack of influence of the criterion variable of biology on the results of students' education at the pharmaceutical department means that it insufficiently assesses the candidates' important competences on entry in this subject.

The above findings confirm that the new system of recruitment, based on the results of the national maturity exam, is characterised by a lower predictive accuracy as compared to the selection system based on the national entry test examination. The reasons of such conjuncture may be found in the different specificity of both systems of recruitment. The pool of maturity exam questions is prepared at CEB by teachers of high schools and is not verified bearing in mind the specific needs of competence measurement of the university candidates. Maturity exams are directed primarily at measuring the achievements of students in a given subject at high school level. Such an exam is of verifying character as it measures the level of knowledge and skills related to the requirements of the curriculum that aim at teaching a certain subject. Whereas an entry examination to university plays a totally different role, its main aim is to select the best candidates considering their predispositions and an appropriate level of competences on entry. Meanwhile, the same results of maturity exam in biology and chemistry are applied in parallel during the

recruitment process for medical analysis, dentistry and medical studies, as well as at biology and chemistry at universities. The national entry test examination that has been used throughout Poland since 2005 and was elaborated by a group of experts comprising specialists originating directly from academic environment of medical universities. In order to select candidates, there was a specifically prepared test exam, matching a particular direction of studies, which individually assessed a candidate's predispositions, depending on whether the recruitment was designed for medical or pharmaceutical studies. Thus, the old system showed many similarities to the American PCAT exam. Such a manner of performing a recruitment process ensures a good selection, which is confirmed by the results of correlation and regression analysis presented in this work.

Applying inadequate tools of educational measurement when evaluating the features which are relevant when undertaking studies, contributes to a greater ration of attrition. This dependency is particularly visible when comparing attrition rate of both systems of recruitment for pharmaceutical studies. Better accuracy of admission criteria in the old system conditions showed a lower ration of attrition during studies (attrition rate for the old and new system was 0.13 *versus* 0.21, respectively. It needs to be remembered that the purpose of an entry examination is not to verify the achieved learning outcomes from high school, but to evaluate whether a candidate has the necessary competences on entry in order to undertake pharmaceutical studies. Specificity of a given evaluating tool is its ability to select candidates who should not be accepted (negative selection). From the point of view of selecting the best candidates, these criteria are most beneficial which are characterised by a greater specificity, so as to avoid a situation in which among candidates there would be such people whose level of competences on entry is insufficient. A recruitment system does not plays its role well if a certain group of students is unable to meet the requirements due to the lack of appropriate features and predispositions, which were not properly evaluated (educational diagnosis) and verified during admission to academic institutions.

The issue of insufficient accuracy of selection criteria that are used in the new system, has already been described in the studies published previously by Panczyk *et al.*[24] These preliminary results of the predictive analysis concern the period of time in which there was an additional recruitment criterion in the basic level of mathematics, apart from biology and chemistry. As can be seen from the recently published results of these studies, selection of candidates based on the modified system of admission, increased its predictive accuracy against the learning outcomes of students measured in the 1st year GPA.[24] Further observations are necessary, however, which would allow to evaluate the outcome of the introduced changes in the recruitment system in a more distant timeline. However, the issue of the mechanism of evaluating candidates' competences itself remains unchanged as it is inscribed in the current rules of recruitment, based on the results of the national maturity exam. Perhaps one of the solutions that could be introduced as the next step to improve the quality of recruitment, could be applying not only assessment of cognitive skills, but also non-cognitive attributes. As can be seen in the accessible results of studies, no such evaluation of candidates may contribute to a worsened prediction in the area of accurate forecasting the future successes of candidates that are achieved during their course of studies and later on, in the future professional career of the graduates of a given faculty.[11,15,35,58]

LIMITATIONS

The current study is limited since the data were only obtained from a single university. As a consequence, it is difficult to predict if the determined criteria would be as valid in similar degree programs at other institutions. Ideally each institution would identify its own predictors of academic success based on their specific student population and the available measures. However, due to the lack of available studies of this kind which would refer to educating experts in the field of pharmacy, it seems relevant to introduce the members of the European academic environment to the issue of appropriate evaluation of tools which are used when selecting candidates for this direction of studies. Harmonization in the field of key competences and unification of education within the advancing implementation of the Bologna Declaration, allow to conclude that even the experiences of individual academic centres may become a valuable source of information for other participants of the European Higher Education Area.

RECOMMENDATIONS AND CONCLUSIONS

On the basis of the obtained results, it can be claimed with a high degree of certainty, that the recruitment system based on the national entry test examination is characterised by a much greater predictive validity than the admission system based on the results of the national maturity exam. It is necessary to further monitor and improve the currently used rules of recruitment, with particular attention paid to the evaluation of individual criteria of recruitment. In order to improve the

accuracy of selection it is also recommended to implement the evaluation of non-cognitive attributes that would allow to obtain the necessary evidence in the area of potential benefits of their application during future recruitment processes for pharmaceutical studies.

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CONFLICT OF INTEREST

The author have no conflict of interest.

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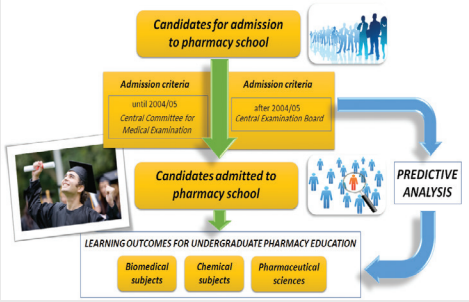
PICTORIAL ABSTRACT



SUMMARY

- The recruitment system based on the national entry test examination is characterised by a much greater predictive validity than the admission system based on the results of the national maturity exam.
- In order to improve the accuracy of selection it is recommended to implement the evaluation of non-cognitive attributes that would allow to obtain the necessary evidence in the area of potential benefits of their application during future recruitment processes for pharmaceutical studies.

ABBREVIATIONS USED

95%CI: 95% confidence interval for odds ratio; **bioGPA:** Grade point average of biomedicalsubjects; **CEB:** The Central Examination Board; **chemGPA:** Grade point average of chemical subjects; **GPA:** Grade point average; **MA:** Master of Arts; **MCQs:** Multiple-choice questions; **MsPharm:** Master of Sciences of Pharmacy; **MUW:** Medical University of Warsaw; **OLS:** Ordinary Least Squares; **OR:** Odds ratio; **PACT:** American Pharmacy College Admission Test; **profGPA:** Grade point average of pharmacology and pharmacotherapy; **R2:** coefficient of determination; **SEE:** Standard error of estimation; **VIF:** Variance Inflation Factor; β**stand.:** Standardizedregression coefficient.

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