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Title:

Predicting academic performance of medical students: the first three years.

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Objectives: The purpose of this exploratory study was to identify a cluster of variables that would most economically explain variation in the grade point average of medical students during the first three years of study. Method: Data were derived from a study of 92 students admitted to the 3rd Faculty of Medicine in 1992/93 academic year on the basis of entrance examination and were still in the medical school at the end of the sixth semester. Stepwise regression analysis was used to build models for predicting log-transformed grade point average change after six semesters of study, at the end of the first, second, and the third year. Predictor variables were chosen from the four domains: a) high school grade point average in physics, mathematics, and Czech language over four years of study, b) admission tests in biology, chemistry, and physics, c) admission committee assessment of applicants ability to reproduce a text, motivation to study medicine, and social maturity, d) Tridimensional Personality Questionnaire Sentimentality and Dependence scale scores. Results: Regression model, which included high school physics, admission test in physics, applicants motivation, and Sentimentality scale, accounted for 32% of the grade point average change over six semesters of study. The regression models using the first, second and third year grade point average as the dependent variables showed slightly decreasing amount of explained variance toward the end of the third year of study and within domains changing structure of predictor variables. Conclusions: The results suggest that variables chosen from high school, written entrance examination, admission interview and personality traits assessment domains may be significant predictors of academic success during the first three years of study.

The first author used to meet Melvin Sabshin from time to time on the occasion of common meetings of the WPA Executive Committee and Standing Committee on Long Range Planning. In 1995, Melvin Sabshin came to Prague to attend a regional WPA meeting. We learned from him that questions and challenges in medical education represent important objectives of our effort both in psychiatry and in medicine as a whole. Mel was active not only as a chairperson of Continuing Medical Education Committee of WPA (1983), but also as an author of papers focused on students' behavior (17) and education (11, 14, 15). His enthusiasm contributed to our fascination with the process of medical education and with people who have chosen medical careers. Soon after the breakdown of communism in our country we recognized the necessity of a deep transformation of our health-care and educational systems. As our entrance examinations to the university appeared ambiguous, we launched a longitudinal study on predictors of academic performance of medical students (8, 9, 10).

The decision to accept a student into medical program presents a major problem for all members of a medical school community. The admission decision affects both the students and the institution, given that the quality of students influences the school´s reputation and vice versa. The selection of admission criteria is a problem which has not been successfully solved until now. The qualifications of an applicant include qualitative and quantitative variables. A different structure of a students´ attributes is probably required to succeed at different stages of the study.

In the search of predictors of academic performance during the past 20 years considerable effort has been devoted to finding indicators of the applicant´s potential using cognitive abilities, high school grades, personality traits, letters of reference and socio-economic data. The academic success has been operationalized in most cases as a grade point average. Correlation matrices were, with few exceptions (13), analyzed using linear regression and criterion variance explained by regressors never, to our knowledge, exceeded 19% (1, 5, 6, 15). Failure to account for the greater part of the difference in academic success among students indicates that focusing on the improvement of tuition

methods might be more effective approach to the problem solution then trying in vain to construct prognostic instruments (19).

However, the admission policies, procedures and capacity of medical schools have not changed as rapidly as the number of applicants and they show much wider diversity both in their preparation and hierarchy of values. Besides, medical schools reflecting the changing demands of society activate new programs and curricula requiring cognitive flexibility and ability to process information creatively rather than mechanical memory which is frequently the main admission criterion (11).

The present day medical schools are preparing physicians for the next millennium under the strong pressure of a marked increase in the number of applicants, the government curbing it rising costs, and the society demands. It is obvious that the modification of admission criteria based on a careful analysis of available data is advisable, and is still not entirely rational to abandon nomothetic approach because so far only few stable correlation patterns appeared.

Our study was undertaken 1) to identify variables chosen from the premedical education grades, admission procedure, and personality structure domains with predictive validity for academic success over three years of study, 2) to determine whether there were differences in structure and predictive validity of those variables for each of the subsequent years during the first three years of study.

METHODS

Subjects

The subjects were 92 students (40 females, mean age 18.2, SD = 0.7; 52 males, mean age 18.5, SD = 1.3) admitted to the 3rd Faculty of Medicine in 1992/93 academic year on the basis of entrance examination and were still in the medical school at the end of the sixth semester.

Measures

On the basis of previous studies (8, 9, 10) suggesting the possible predictive utility of the university academic achievement the independent measures were

chosen from four domains: a) high school: the arithmetic average of the courses taken in math, physics, and Czech language (five-point scale; 1 excellent - 5 insufficient) over the course of four years, b) written entrance examination: 30 four-choice question tests on physics, biology, and chemistry, c) admission interview: committee assessment of applicants´ performance during an interview which consisted of the evaluation of text reproduction from the point of view of information density, the estimation of her/his motivation to study medicine and his/her social maturity (5-point scale; 5 excellent - 1 insufficient), d) personality traits assessment: Tridimensional Personality Questionnaire (2, 3) Reward Dependence scale RD1 Sentimentality - Tough Mindedness (high scores: sympathetic, understanding individuals who tend to be deeply moved by sentimental appeals and experience vicarious emotion intensely; low scorers: practical, tough minded, coolly detached, insensitive to the feelings of other people, unable to establish social rapport), and RD3 scale Attachment - Detachment (high scores: prefer intimacy over privacy, tend to form lasting social attachments and are sensitive to rejection and slights; low scorers: manifest pronounced detachment and disinterest in social relationships, they impress others as self contained, alienated, detached and indifferent to rejection and slights). The psychometric integrity of the TPQ Czech version is reported elsewhere (7). The entrance examination in 1992 was experimental and applicants were informed that only their performance on the tests of physics, biology and chemistry but not psychological tests, would be considered as the admittance criterion.

The dependent variables were the first year grade point average (GPA1) based on the courses in biophysics, medical chemistry, biology, anatomy, first aid, Latin; the second year grade point average (GPA2) based on courses in histology, biochemistry, physiology; the third year grade point average (GPA3) based on courses in microbiology, immunology, molecular biology, pathology, pathological physiology, psychology, introduction to clinical praxis, and the total grade point average (GPA) based on the three years´ study examination results. All values were adjusted for the number of examination failures. An examination has been traditionally oral, evaluated on 4-point scale (1 excellent - 4 insufficient), and students are entitled to three attempts). Since the subjects

were not expected to fail all examinations and thus the distributions of the dependent variables were inherently highly positively skewed (range 1.18 - 1.31) the data were subjected to natural logarithmic transformation (range of skewness after transformation for dependent variables 0.35 - 0.29). The distribution of the transformed criteria were tested using Lilliefors modification of Kolmogorov-Smirnov test of normality; GPA1 (K-S=0.11, df=92, p = 0,008), GPA2 (K-S=0.12, df=92, p = 0,002, GPA3 (K-S=0.101, df=92, p = 0,2), GPA (K-S=0.076, df=92, p = 0,2). Apart from GPA the distributions of the dependent variables were still statistically different from normal distribution after transformation. However, in normal probability plots the points clustered reasonably well around a straight line and so we presume that the data are sufficiently normally distributed.

Statistical analysis

We examined relationships among all variables included into the analysis using correlation coefficients. Linear regression by groups was used to test equality of regression models for females and males. We used multiple and one factor analyses of variance to compare gender differences on dependent and independent variables. Stepwise multiple linear regression analyses (criterion: probability F-to-enter $\geq$ 0,05, F-to-remove $\leq$ 0,051) were used to assess the predictive value of the independent variables. As stepwise method tends to capitalize on sampling error that is unique to the given sample and the method may yield conclusions that will not replicate (18), we reanalyzed the data using all possible subsets regression approach and observed no differences between the stepwise and the estimated "best" subsets of predictor variables regression equations. Collinearity and influence diagnostics were performed on all regression equations, and multicollinearity and extreme outlier effects were ruled out. Data were analyzed with the Statistical Package for the Social Sciences (12) and BMDP Statistical Software (4).

RESULTS

The test of equality of regression equations over gender groups yielded statistically insignificant F ratio for all measures of academic success (GPA: F=0.89, df = 12, 68, p= 0.56; GPA1: F = 1.03, df = 12, 68, p= 0.43; GPA2: F=0.93, df = 12, 68, p= 0.52; GPA3: F=0.75, df = 12, 68, p= 0.70) thus we assumed that the regression coefficients for males and females were identical. In addition, we observed the effect of gender neither on the GPA1, GPA2, GPA3 (MANOVA, Wilks´ λ =0,98, df = 3, 87, p = 0,76), and on the GPA (ANOVA, F=0.53, df = 1, 91, p=0,46) nor on eleven independent variables (MANOVA, Wilks´ λ =0,83, df = 11, 80, p=0,18) and did not used gender as a classification variable.

The correlation matrix (Tab. 1) indicates statistically significant relations among GPA1, GPA2, and GPA3 suggesting that the academic success measures had on the average 47% of the variance in common. Apart from the results of the entrance examination in chemistry and biology we found a statistically significant correlation between all predictors and the GPA and, with two exceptions, the GPA1, and GPA3 measures. The interview variables correlated insignificantly with the GPA2. The predictors within the high school and admission interview domains were closely associated. Across domains we observed a statistically significant correlation pattern between the high school and written entrance examination variables.

The entrance examination results in biology and chemistry, the admission committee assessment of applicants´ social maturity, and the high school grade point average in Czech language variables did not enter into any regression equation.

The multiple linear regression full mode accounted for 32% of the variance in GPA (Tab. 2). The semipartial correlation coefficients indicated comparable incremental validity for all predictors included into model by the stepwise method. Nonetheless, the most important was the contribution from the first two predictors. Together, these two variables had only 7% of variance in common and accounted for 21% of the total explanatory power of the equation.

The regression models using GPA1, GPA2, GPA3 as the dependent variables showed a different structure of predictor variables and slightly decreasing amount of explained variance toward the end of the third year of study (Tab. 3, 4, 5). Only high school grade point average in physics had the statistically significant regression coefficients in all models and a similar incremental validity. In predicting GPA2 changes high school grade point average in physics was substituted by high school grade point average in mathematics. Admission committee assessment of applicants´ motivation was included only in the model explicating the GPA3 variation. In the model explaining GPA1 variation the text reproduction variable became the substitute of applicants´ motivation estimation, and RD3 Attachments scale variable was replaced by RD1 Sentimentality scores. Apart from the regression model estimating GPA2 variation where we did not observe variables from the interview domain the changes in regressor structures of all models were within particular domains indicating probably the influence of masking effect.

DISCUSSION

The changes in the predictor structures during the course of three years, which were always within the particular domain might be probably explained as a random error variation considering that examinations were oral and the students achievement in a particular subject was estimated frequently by different examiners. Besides, as the correlation coefficients in Tab. 1 suggested, admission committees probably found it difficult to differentiate among the text evaluation, motivation to study medicine, and social maturity assessments. In addition, the content of written entrance examination in physics, intended to compensate for differences in high schools educational level, more or less corresponded to the high school curriculum. The semipartial correlation coefficients indicated that the incremental validity of predictors from cognitive domains tended to decrease toward the end of the third year in comparison to the predictors from the personality trait and self-presentation interview domain. This finding suggest that personality dispositions might compensate for mental ability deficiencies in achieving academical success.

The inclusion of the text reproduction variable into the regression equation estimating GPA1 changes probably reflected the exclusively theoretical content of the first year courses where success depended substantially on information retention and reproduction. The GPA2 was based only on the results from three examinations in subjects where logical information processing skill rather than mechanical memory was decisive for success. No variable from the interview domain was entered into the model where cognitive ability variables accounted for 20% of the model´s 26% explanatory power. Most of the third year seven examinations are considered very demanding and each requires different mental skills including the potential to absorb emotional load stemming from personal contact with patients, which was reflected in the reduced differences between cognitive and personality characteristic incremental validity.

CONCLUSION

The results suggest that variables chosen from high school, written entrance examination, admission interview, and personality traits assessment domains may be significant predictors of academic success during the first three years of study. It appeared that cognitive potential represented in this study by the ability to solve problems based on a skill to apply physical and mathematical axioms, plausibly manifested strong motivation to become a member of medical community, and independence from sentimental considerations which leads to practical and objective views might be associated with academic performance at the first half of study when contact with patients, especially during the first two years, is still limited and theoretical knowledge processing constitutes the main criterion for students performance evaluation.

Although the variance explained by the models is considerable in comparison to the previous studies and the predictors structure relatively stable over the six semesters, it is apparent that the regression analysis results which are necessarily limited to the particular kind of study group, do not contribute substantially to the estimation of student risk of academic failure. Admission committees are interested in predicting probability of success or failure rather then estimation of grade point average which has the prevailingly theoretical,

illustrative significance only. In the future research using categorical approach may produce more applicable information.

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Tab. 1 Correlation coefficients of variables analyzed in the study.

variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
3.	-	.66*												
4.	-	.69*	.70*											
5.	-.17	-.18	-.15	-.14										
6.	-.15	-.14	-.11	-.15	.05									
7.	-.37*	-.42*	-.34*	-.30*	-.14	.30*								
8.	-.27*	-.32*	-.16	-.22*	.05	.07	.22*							
9.	-.29*	-.25*	-.14	-.30*	.07	.03	.17	.79*						
10.	-.26*	-.27*	-.16	-.26*	.05	.05	.20*	.86*	.89*					
11.	.22*	.10	.16	.25*	.05	-.01	.02	-.07	-.14	-.13				
12.	.23*	.20*	.22*	.20*	.03	-.23*	.05	-.08	.01	-.01	.19*			
13.	.34*	.40*	.39*	.24*	-.23*	-.31*	-.31*	-11	-04	-.09	.05	-.03		
14.	.36*	.47*	.31*	.25*	-.15	-.37*	-.27*	-.08	-.01	-.05	-.02	.06	.69*	
15.	.24*	.25*	.32*	.17	-.23*	-.22*	-.20*	-.03	-.09	-.07	.01	-.04	.45*	.45*

* $p \leq 0.05$, two tailed

Criteria:

1. log transformed grade point average weighted by the number of the examination failures: the first three years of study
2. log transformed grade point average weighted by the number of the examination failures: the first year of study
3. log transformed grade point average weighted by the number of the examination failures: the second year of study
4. log transformed grade point average weighted by the number of the examination failures: the third year of study

Predictors:

5. entrance examination test in biology (inverse to all GPA measures)
6. entrance examination test in chemistry (inverse to all GPA measures)
7. entrance examination test in physics (inverse to all GPA measures)
8. admission committee assessment of student´s performance on text reproduction (inverse to all GPA measures)
9. admission committee assessment of student´s motivation to study medicine (inverse to all GPA measures)
10. admission committee assessment of student´s social maturity (inverse to all GPA measures)
11. Cloninger´s Tridimensional Personality Questionnaire TPQ: RD1 Sentimentality scale
12. Cloninger´s Tridimensional Personality Questionnaire TPQ: RD3 Attachment scale
13. high school grade point average in mathematics over the course of four years
14. high school grade point average in physics over the course of four years
15. high school grade point average in Czech language over the course of four years

Tab. 2 Stepwise multiple linear regression for predicting GPA for medical students after three years of study.

		R^2						correlations	
step	R^2	F change	df	p	β	F	p	partial	part
1[a]	.14	14.48	1,90	.000	-.27	8.28	.005	-.30	-.26
2[b]	.21	8.06	1,89	.005	.27	8.56	.004	.30	.26
3[c]	.27	6.66	1,88	.012	-.24	7.11	.009	-.28	-.24
4[d]	.32	6.66	1,87	.012	.23	6.60	.012	.27	.23

Dependent variable: natural log transformed grade point average weighted by the number of the examination failures (GPA).

Variables entered:

a. entrance examination test in physics (inverse to GPA)

b. high school grade point average in physics

c. admission committee assessment of student´s motivation to study medicine (inverse to GPA)

d. Cloninger´s Tridimensional Personality Questionnaire TPQ: RD3 Attachment scale

Beta designates the regression coefficient for the full model. Criterion probability F-to-enter = 0.05, F-to-remove = 0.051. The full model F = 10.12, df = 4, 87, $p \leq 0.001$.

Tab. 3 Stepwise multiple linear regression for predicting GPA1 for medical students: the first year of study.

	R^2							correlations	
step	R^2	F change	df	p	β	F	p	partial	part
1[a]	.22	25.25	1,90	.000	.36	17.30	.000	.41	.35
2[b]	.31	11.53	1,89	.001	-.28	9.75	.002	-.32	-.26
3[c]	.36	6.88	1,88	.010	-.21	6.14	.015	-.26	-.21
4[d]	.39	4.61	1,87	.035	.18	4.61	.035	.22	.18

Dependent variable: natural log transformed grade point average weighted by the number of the examination failures (GPA1).

Variables entered:

a. high school grade point average in physics

b. entrance examination test in physics (inverse to GPA1)

c. admission committee assessment of student´s performance on text reproduction (inverse to GPA1)

d. Cloninger´s Tridimensional Personality Questionnaire TPQ: RD3 Attachment scale

Beta designates the regression coefficient for the full model. Criterion probability F-to-enter = 0.05, F-to-remove = 0.051. The full model F = 13.97, df = 4, 87, $p \leq 0.001$.

Tab. 4 Stepwise multiple linear regression for predicting GPA2 for medical students: the second year of study.

	R^2							correlations	
step	R^2	F change	df	p	β	F	p	partial	part
1[a]	.15	15.66	1,90	.000	.31	10.35	.002	.32	.30
2[b]	.20	5.80	1,89	.018	-.25	6.79	.011	-.27	-.24
3[c]	.26	6.75	1,88	.011	.24	6.75	.011	.27	.24

Dependent variable: natural log transformed grade point average weighted by the number of the examination failures (GPA2).

Variables entered:

a. high school grade point average in mathematics

b. entrance examination test in physics (inverse to GPA2)

c. Cloninger´s Tridimensional Personality Questionnaire TPQ: RD3 Attachment scale

Beta designates the regression coefficient for the full model. Criterion probability F-to-enter = 0.05, F-to-remove = 0.051. The full model F = 13.97, df = 4, 87, $p \leq 0.001$.

Tab. 5 Stepwise multiple linear regression for predicting GPA3 for medical students: the third year of study.

	R^2							correlations	
step	R^2	F change	df	p	β	F	p	partial	part
1[a]	.10	9.08	1,90	.003	-.22	4.77	.032	-.23	-.20
2[b]	.16	7.14	1,89	.009	.23	5.84	.018	.25	.23
3[c]	.21	5.24	1,88	.024	-.23	5.80	.018	-.25	-.23
4[d]	.24	4.00	1,87	.049	.19	4.00	.049	.21	.19

Dependent variable: natural log transformed grade point average weighted by the number
of the examination failures (GPA3).
Variables entered:
a. entrance examination test in physics (inverse to GPA3)
b. Cloninger´s Tridimensional Personality Questionnaire TPQ: RD1 Sentimentality scale
c. admission committee assessment of student´s motivation to study medicine (inverse to GPA3)
d. high school grade point average in physics
Beta designates the regression coefficient for the full model. Criterion probability F-to-enter = 0.05, F-to-remove = 0.051. The full model F = 6.92, df = 4, 87, $p \leq 0.001$.