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Autoreferát disertační práce



Study success in view of modern data analyzing method
Úspěšnost studia z pohledu moderních metod analýzy dat

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Abstrakt

Cílem práce je pomocí statistické analýzy údajů dostupných o uchazečích v době přijímacího řízení přispět k co nejlepší predikci budoucí studijní úspěšnosti studentů na 1. LF UK v Praze a umožnit tak kvalitnější výběr uchazečů.

Pro výběr uchazečů o studium bývají využívány informace o studijním výkonu na střední škole, přijímací testy, pohovory a další metody. V práci analyzujeme kritéria pro přijímání studentů na 1. lékařskou fakultu. Kromě tradiční formy přijímacích testů z profilových předmětů (B, CH, F) byla v roce 2002 otevřena možnost přijetí části studentů na základě jejich výsledků na střední škole.

Analyzujeme nejprve data 383 studentů přijatých ke studiu všeobecného lékařství v roce 1999, kdy byly naposledy pro všechny uchazeče známy i středoškolské studijní výkony a přitom všichni absolvovali přijímací test. Všichni studenti z této kohorty již dostudovali: 163 studium zanechalo a 220 studium úspěšně dokončilo. Použitím Pearsonových korelací mezi prediktory, shlukové analýzy a logistické regrese ukazujeme, že průměrný prospěch na střední škole umožňuje předpovídat celkový úspěch studia medicíny s podobnou přesností jako samotné přijímací testy, ale každý z těchto faktorů popisuje jinou dimenzi schopností uchazeče. Prokazujeme, že přijímání části studentů na základě jejich výtečného středoškolského prospěchu je racionální a opodstatněné. Ukazujeme, že současné využití obou zdrojů informací o uchazeči by mohlo zvýšit kvalitu výběru studentů.

V letech 2008-2010 byl ke standardním testům z profilových předmětů (B, CH, F) přidán test všeobecné studijní připravenosti (VSP). Zabýváme se proto porovnáním predikční validity jednotlivých testů pro předpověď studijních výsledků v prvních letech studia. Na datech z let 2002-2009 studujeme predikční validitu odborných testů, porovnáváme ji s predikční validitou testu VSP, abychom zjistili, jaký je přínos testu VSP k tradičním odborným testům. Ukazuje se, že testy z profilových předmětů prokazatelně přispívají ke správnému výběru studentů, zatím co příspěvek testu VSP je sporný.

Klíčová slova:

přijímací řízení, studijní úspěch, přijímací testy, prediktivní validita

Abstract

The aim of the project is to find, by statistical analysis of the data available at the time of entrance examination, parameters that predict the student's ability to finish his/her studies successfully.

We analysed admission criteria based on admission test (AT) and on undergraduate grade-point average (uGPA) supplemented by some other criteria.

The study analyses admission procedure at the largest school of medicine in the Czech Republic. It is based on 1999 data of 383 students admitted that year. By use of Pearson's correlations between predictors, cluster analysis and logistic regression we show that preadmission grades predict the overall success in medical study with the same accuracy as admission tests but each of them describe different dimension of students' abilities. Simultaneous use of GPA and AT in admission process of all students should bring higher quality of selection process and also practical advantages for future analyses. At the same time we can confirm, the idea to accept part of students only on base an excellent GPA, could be considered a quite reasonable one.

General aptitude test (GAT) was temporarily added to admission process at the First Faculty of Medicine of Charles University in Prague, to prove predictive validity of GAT and to compare it with validity of current scientific knowledge test (ST). The added value of GAT was also examined. Prediction validity was estimated by Pearson correlation within cohorts (years 2002 – 2009) and by the correlation after each variable has been group-mean centred for all cohorts together. Incremental validity was assessed by testing submodels in linear and logistic regression models.

Although the predictive validity of GAT is significantly nonzero; it is markedly lower than predictive validity of ST. Also, scientific knowledge tests contribute significantly to the proper selection of students, whereas the contribution of GAT can be inferred only in part.

Keywords: admissions, academic achievement, entrance tests, predictive validity

The prediction and probability for successful completion in medical study based on tests and pre-admission grades

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ABSTRACT

The study analyses admission procedure at the largest school of medicine in the Czech Republic. Based on 1999 data of 383 students admitted that year, it should be noted that 163 of them failed and 220 have succeeded to finish the study. By use of Pearson's correlations between predictors, cluster analysis and logistic regression we show that preadmission grades predict the overall success in medical study with the same accuracy as admission tests but each of them describe different dimension of students' abilities. Simultaneous use of GPA and AT in admission process of all students should bring higher quality of selection process and also practical advantages for future analyses. Nevertheless, the idea of having a group of the students admitted based only on an excellent GPA, could be considered a quite reasonable one

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Key words: education, admission criteria, pre-admission grades, admission test, medical study

INTRODUCTION

The proper selection of students to the higher education is crucial point both for the applicants and the institution: the quality of students influences the school's reputation and vice versa. The number of applicants often exceeds available spaces and admission committees face a very difficult and challenging task. Developing a clear definition of suitability for medical training is the first priority, whether locally or nationally (Parry et al, 2009).

There have been many studies written on predictors of medical academic performance. Salvatori (2001) made a review of 83 articles from field of medical education and examined various selection tools. She concluded that the pre-admission overall grade-point average (GPA) is clearly the best predictor of academic performance.

Medical College Admission Test (MCAT) - standardized test given in USA, Canada and 15 other countries, was found to be a good predictor and Salvatori cited studies, where MCAT scores together with GPA accounted for 21% of the variability in academic in-course grades.

Although GPA is single best predictor of academic achievement, much of variability of academic performance still remains unexplained. However, the evidence to support the continued use of personal interviews, essays or letters of reference remains controversial; further research is needed to find more reliable and valid ways of accessing the non-cognitive characteristics of applicants.

The relationship of GPA to clinical performance is even less clear (Salvatori, 2001). Other, perhaps non-cognitive variables are contributing to clinical performance. Firstly, students have already learned how to study at university. Secondly, in clinical subjects the requirements for memorizing are not so high, while the accent is put on logical thinking and interconnecting knowledge from different subjects. Students also newly come into personal contact with patients and their motivation and level of responsibility changes.

Emery and Bell (2009) studied the predictive validity of the BioMedical Admissions Test (BMAT) used in the United Kingdom. As a reaction, McMannus et al. argued that without evidence of incremental validity it is difficult to assess the value of any selection tests for medicine (McMannus et al. 2011a). Mentioned publications describe attitudes in countries with different cultural background and different education system, thus their results cannot be transferred without further verifications nevertheless the requirements on incremental validity of tests can be generalized.

Entry to Czech medical schools is very competitive task. For example, at First Faculty of Medicine of the Charles University in Prague (1st LF UK) in the period of 2006 – 2011 the number of applications to study of general medicine exceed in average 2.5 times number of admitted students (derived from Línová, 2011). We should consider the fact that students often apply for more schools and if they are admitted they have the possibility to choose. Nevertheless, schools do count with this “inflation” (at 1st LF UK, in the given period, only $53\% \pm 0,06\%$ of admitted students started the study) and they admit more students than the spaces they have. In the result, more than one half of the applicant for the study of general medicine at 1st LF UK remains unsatisfied.

In the Czech Republic, conditions for acceptance for higher medical education differ greatly between universities, but also between university faculties and sometimes even between study branches inside the same faculty. Traditionally, faculties organize in-house admissions consisting mainly of knowledge tests, general aptitude tests and/or interviews. Some faculties take into account students’ pre-admission performance (mostly measured by GPA). While in the United States, the Great Britain and other countries, examination of relationship between admission test performance and subsequent study performance is part of the test evaluation, in the Czech Republic, this issue has rather been neglected; the changes in admission process often take place without previous analysis of quality of existing tests (Rubešová, 2007).

Admission process to medical schools in the Czech Republic is often discussed at domestic conferences (Štuka and Smutek, 2003), but there were and are only few works finally published in journals (national or even international). Admissions to Czech medical schools were systematically studied by composite authors Höschl, Kožený and Tišanská who analysed admission process to the Third Faculty of Medicine of the Charles University in Prague. Study at 3rd LF UK is compatible with other medical faculties, but unlike other faculties it is in done by PBL (problem based learning). Therefore the conclusions made on study performance predictors at 3rd LF UK should be applied at other schools of medicine only with caution.

In this article, we analyse admission process to 1st LF UK and similarly to the work of Höschl and Kožený (1997) and work Štuka and Šimeček (2006), we try to identify variables predicting overall academic success and to find the optimal admission criteria for medical study. Compared to mentioned work and work of Kožený and Tišanská (2001) we do not look for the high-school subject, which grades best predict success in medical study, but rather investigate whether subject GPAs give more information than overall GPA. Beside of searching for relationships between different predictors and estimation of their predictive power, we centralize on verification of the current two-step admission and on relevance of the criteria for offering place at 1st LF UK without admission tests. The aim of the study was:

1. To assess the contribution predictors for successful study bring, based on total secondary/high school grades; contribution of predictors based on individual parts of medical college admission test, and to compare the validity of their predictability in both instances.
2. With the help of such predictors to find an optimal model predicting success in medical studies.
3. To assess and evaluate criteria used during students' admission based on previous academic performance and high school grades.

METHODS

Subjects

The study is based on data of students who were admitted in 1999 to 6-year Master course of General Medicine held in Czech language at 1st LF UK. Year 1999 was the last year when all the students must have passed admission tests to get admitted to 1st LF UK. In total, 467 students started the freshmen year (386 Czech, 75 Slovak students and 6 other foreigners with average age of 19.88 (\pm 2.18)). Those students were excluded from analysis who were admitted to 1st LF UK repeatedly (24 students), whose data about year of high-school graduation (10) and overall GPAs (17) were not complete and who did not possess grades from high school (56 students). In total, 383 students were analysed. Out of them were 316 Czech and 67 Slovak, 253 women and 130 men, 348 studied Gymnasium and 35 different type of high school.

Admission conditions

At 1st LF UK, the admission process changed during past decade. While earlier, it has been based on total score of admission test (AT) consisting of test in biology (ATb), chemistry (ATc) and physics (ATp), since 2002, good pre-admission study performance may give a student an advantage of being accepted without AT. Approximately 45% of available space is offered to students with best pre-admission GPA without requirement on passing AT. Beside excellent average high-school GPA (better than 95 on scale 100=excellent to 0=insufficient), three additional criteria must be fulfilled by students, who want to apply for acceptance without AT:

A1 Successful graduation from high-school in the year of application (elimination of repeated attempts)

A2 Completion of two semesters of course in profile subjects (biology, chemistry, physics) within the last two years of high-school study with final grade not less than 75 (students and type of high school on science)

A3 Passing the Czech language graduation exam (program is held in the Czech language)

Maximal number of students admitted without AT is determined and made public in advance (for year 2011 it was 210 out of approx. 470 admissions). Applicants with best overall GPA satisfying conditions A1 - A3 are given an offer for 1st LF UK. Other applicants are invited to admission test.

Since 2009, General Aptitude Test has been added into admission process for three years, but it is not subject of this work and a separate publication is planned on this topic.

Measures in the data

High school performance

For all applicants, **type of high school** and **year of graduation** (corresponding to condition **A1**) were recorded. Final grades in math, physics, biology, chemistry and the national language courses were recorded for all four years of high-school study. Out of them, mean scores over the 4 years were enumerated and assigned as **GPA_m**, **GPA_p**, **GPA_b**, **GPA_c**, **GPA_{cz}**. Also, accomplishment of condition **A2** was checked. Overall **GPA** based on all courses taken by student within the 4 years of study was recorded.

Written entrance examination (admission test, AT)

The admission test consisting of chemistry, physics and biology subtest, each included 100 multiple-choice items. One point was assigned for each item in case of choosing all (and only) correct answers; giving maximum of 100 points for each sub-test (assigned **AT_c**, **AT_p**, **AT_b**) and 300 points for the whole test (**AT**). Items for each sub-test were chosen randomly from set of approximately 1000 items, most of which were published either in exact wording or its variation. All of the students taking the test in the same day took the same test, but the order of items in the test and of given answers were different.

Other information about student

For all applicants, beside other information, their **sex** and **nationality** were recorded. Czech nationality was used as an indicator of fulfilment of condition A3 (Czech language graduation exam is mandatory for all Czech high school students).

Success in the medical study

The predicted variable was student's overall success in the medical study. Usual length of medical study at 1st LF UK is 6 years (suggested as predicted variable in Höschl, Kožený (1997) and used in Kožený, Tišanská (2001)), but recently many students take advantage of exchange programs and extend their study, we had therefore waited until the study result (finished successfully/failed to finish) was known for all students .

Statistical analysis

The strength of relationship between predictors was estimated by *Pearson correlations*. The dissimilarities between predictors were analysed by *cluster analysis*; Euclidean distance was used as metrics. *Stepwise logistic regression* based on Akaike's information criterion (*AIC*) was used to find the best logistic model for prediction of success in medical study. *Likelihood-ratio test* was used for testing equivalence between chosen models of logistic regression. *Contingency tables* of true success in medical study and success predicted by different combination of variables were computed and compared by means of *odds ratio (OR)*. All statistical analyses were performed with the help of the statistical environment R (R 2010) and its libraries *rms* (Harrel, 2012), *MASS* (Venables & Ripley, 2002) and *Epi* (Carstensen et al., 2011).

RESULTS

Out of 383 analysed students admitted in year 1999 to 1st LF UK, 220 succeeded to graduate and 163 failed. Detailed description of students by their academic success is included in Table 1 and Table 2.

Table 1: Characteristics of students by their academic success at 1st LF UK

	Succeeded (N=185)		Failed (N=198)	
Sex	145 Female	75 Male	108 Female	55 Male
Type of high school	212 Gymnasium	8 Other	136 Gymnasium	27 Other
Year of HS graduation (A1)	174 True	46 False	78 True	85 False
profile B+C+P (A2)	159 True	54 False	57 True	106 False
Czech graduation exam (A3)	172 True	48 False	144 True	19 False

Table 2: Descriptive statistics of GPA and AT predictors by academic success at 1st LF UK

	Succeeded (N=220)					Failed (N=163)				
	mean	SD	Min	max	N	mean	SD	min	Max	N
GPAm	73.75	19.32	25.00	100.00	219	65.19	19.41	25.00	100.00	161
GPAp	80.95	16.83	25.00	100.00	217	69.67	18.69	25.00	100.00	161
GPAc	83.58	14.76	37.50	100.00	217	73.62	17.89	33.33	100.00	160
GPAb	91.25	10.93	58.33	100.00	218	82.51	15.06	43.75	100.00	154
GPAcz	82.22	14.17	43.75	100.00	220	74.22	17.51	31.25	100.00	163
GPA	87.14	9.43	62.50	100.00	220	79.26	12.71	47.50	100.00	163
ATc	72.54	15.33	34.00	99.00	220	64.28	14.37	27.00	97.00	163
ATb	82.08	11.56	51.00	99.00	220	76.12	11.04	51.00	99.00	163
ATp	78.33	13.74	42.00	100.00	220	69.77	13.82	35.00	100.00	163
AT	232.94	37.00	166.00	298.00	220	210.18	32.87	166.00	295.00	163

min minimum value, **max** maximum value, **SD** standard deviation, **GPA** high-school grade-point average, **m** mathematics, **p** physics, **c** chemistry, **b** biology, **cz** Czech/Slovak language, **AT** admission test

Relationship between different GPA and AT predictors

Pearson correlations between different GPA and ATs are displayed in Table 4. We can see that ATs give quite different information about student than GPAs (low values of correlation coefficient in upper right part). On the other hand, information given by different ATs is quite similar to each other (high values in lower right part), and information given by single GPAs is similar to each other, too (high values in upper left part).

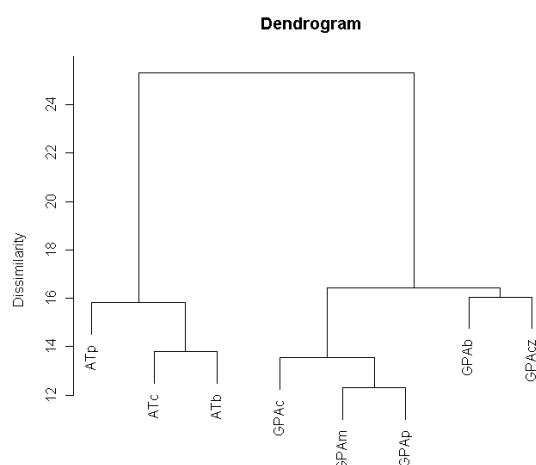
Table 3: Pearson correlations between predictors

	GPAm	GPAp	GPAc	GPAb	GPAcz	GPA	ATc	ATb	ATp	AT
GPAm	1.00	0.79	0.75	0.64	0.70	0.84	0.24	0.19	0.19	0.23
GPAp		1.00	0.77	0.71	0.63	0.83	0.24	0.20	0.20	0.24
GPAc			1.00	0.71	0.68	0.82	0.24	0.22	0.17	0.24
GPAb				1.00	0.65	0.79	0.20	0.20	0.13	0.20
GPAcz					1.00	0.83	0.20	0.20	0.14	0.20
GPA						1.00	0.26	0.24	0.22	0.27
ATc							1.00	0.74	0.67	0.91
ATb								1.00	0.66	0.88
ATp									1.00	0.88
AT										1.00

GPA grade-point average, **m** mathematics, **p** physics, **c** chemistry, **b** biology, **cz** Czech/Slovak language, **AT** admission test

Dissimilarities between predictors are displayed in dendrogram of cluster analysis (Figure 1). Measure of dissimilarity is the height at which they join a single group. Again, we can see that ATs give different information about students' quality than information given by GPAs. Looking more closely at dendrogram, beside big difference between ATs and GPAs (two parts of dendrogram), inside ATs we can see a dissimilarity between physics and other two AT subtests (biology and chemistry) which are not concentrated so much on logical thinking but rather on memorizing. Similarly, GPAs in physics and mathematics describing student's logical thinking are the two most similar, connecting further with chemistry and standing apart from biology and Czech/Slovak language.

Figure 1: Cluster analysis dendrogram.



Optimal model for predicting study success

Having only scores from three admission tests ATc, ATp and ATb, we might look for their optimal weights for prediction of academic success at 1st LF UK. Such model accounts for 13% of the variability in academic success (Nagelkerke $R^2=0.128$). Nevertheless, we cannot reject the submodel of prediction of academic success by their sum AT ($p=0.498$). Such submodel accounts for only slightly less variability (Nagelkerke $R^2=0.124$). Thus, equal weighting of subtests is reasonable.

Another question might arise - whether all three subtests are needed. Analysis show, that important information is carried only by physics subtest which by itself explains 12% of variability (Nagelkerke $R^2=0.115$). Both other subtests – chemistry and biology may be omitted without significant information loose ($p=0.126$).

Similar predictability (and even higher than AT) possesses also high-school performance: total GPA accounts for 15% of the variability in success at 1st LF UK. The same percentage of variability is explained by optimal combination of performance in single subjects GPAc, GPAm, GPAP, GPAb and GPAcz.

As was shown earlier, AT and GPA describe different parts of student abilities and thus their combination should have better prediction ability than AT and GPA themselves. Logistic regression for prediction of study success by combination of AT and GPA gives model

$$\text{Logit}(P(\text{success})) = -7.745 + 0.015 \text{ AT} + 0.056 \text{ GPA} \quad (\text{model 1})$$

According to this model, optimal weight of AT (with max. 300 points) to GPA (max 100 points) is 45% to 55%. This model accounts for 22% of the variability of success at 1st LF UK.

Let us now try to find optimal predictor of student's success in medical study based on all accessible variables. All five categorical predictors mentioned in Table 1 and all ten continuous predictors displayed in Table 2 were taken into the null model of logistic regression for predicting probability of success in medical study. Automated stepwise model

selection was processed: in each step, one predictor was removed with aim to maximize Akaike's information criterion (AIC), criterion of optimal prediction which penalizes number of predictors. Resulting model contains these variables: type of high school, criterion A1 (year of graduation), criterion A2 (profile classes), admission test score (AT), performance at high school represented by GPA and GPA_m. After removing insignificant predictors – criterion on profile classes (highly dependent on type of the high school and on GPA) and GPA_m (strongly correlated with total GPA) we get optimal model for prediction of study success at 1st LF UK:

$$\text{Logit}(P(\text{success})) = a_0 + a_1 \cdot (\text{year} = 1999) + a_2 \cdot (\text{type of HS} = G) + a_3 \cdot AT + a_4 \cdot GPA \quad (\text{model 2})$$

with estimates given in Table 4.

Table 4 Coefficients of optimal model of prediction of success at 1st LF UK

Coefficient	Estimate of a_i	SE(a_i)	Z	p value
a_0	-8.973	1.255	-7.147	<0.001
a_1 (year = 1999)	1.082	0.279	3.880	<0.001
a_2 (HS type = G)	1.164	0.465	2.502	0.012
a_3 (AT)	0.018	0.004	5.082	<0.001
a_4 (GPA)	0.042	0.012	3.638	<0.001

SE standard error, Z test statistics, G Gymnasium

Model accounts for 31% of the variability in success. According to this model, optimal weight of AT (with max. 300 points) to GPA (max. 100 points), criteria on year of graduation (max. 1 point for year 1999) and type of high school (max. 1 point) is 46% to 35% to 10% to 9%. Compared to model 1, the impact of conditions on year of graduation and type of high school is at the expense of lowered impact of GPA.

Current admission criteria

Current admission criteria to 1st LF UK were set up in 2001 more or less on the basis of estimation and experiences of admission committee. Nevertheless, they greatly correspond with results given in previous part of our analyses, where GPA, AT and conditions A1 and A2 (dependent on GPA and type of high school) were selected as the important ones for prediction of success.

Nevertheless acceptance to 1st LF UK is not decided by weighted sum of GPA, AT, A1 and A2. Instead, the best students according to GPA and satisfying conditions A1, A2 and A3 are given an offer to 1st LF UK without passing AT. And the AT score decides only on admission of the rest of students. This saves costs for admission process and encourages the students with best GPA to choose 1st LF UK.

New admission criteria led to quite different population of students from population admitted in 1999 and earlier: students who might have been admitted today without passing AT, may have not been admitted in 1999 - because of not passing AT, or even not trying to pass AT.

In recent years, approximately 210 out of 450 available spaces are offered to students with best GPA without requirement on passing AT. In year 1999, only 77 out of 383 analyzed students (20%) had $GPA \geq 95$, and only 32 students (8%) satisfied also the three additional criteria and would be given an offer for 1st LF UK without AT today. As a consequence, average GPA of students admitted in 1999 was probably somewhat worse than the current one. Bearing this limitation in mind, in following we try to show, how the current criteria for admission without AT improve the study success at 1st LF UK.

In Fig. 2 we compare the current criterion for admission without AT (A1+A2+A3, black line) with criteria not containing A1, A2, or A3. The higher the odds ratio OR is, the more suitable is the criterion. For less strict GPA requirements, eliminating A3 (red line) seems to be profitable, nevertheless for more strict GPA requirements (1st LF UK requires $GPA \geq 97$) eliminating of condition A3 causes lowering of the odds ratio and thus the current requirements A1+A2+A3 may be proved as reasonable.

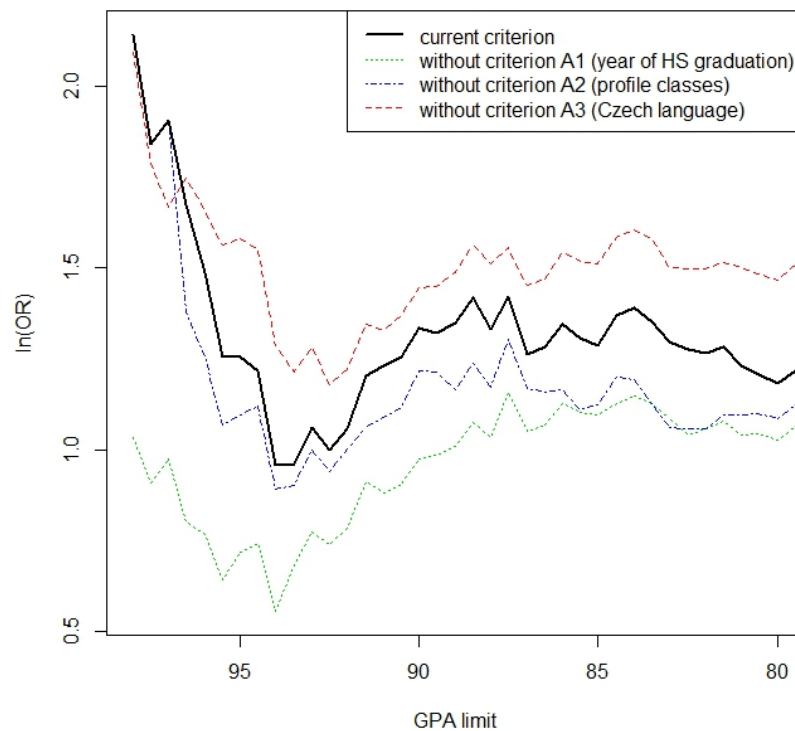


Figure 2: Comparison of criteria combinations involving different GPA limits on the basis of logarithm of odds ratio.

DISCUSSION

In this study, preadmission grades (GPA) were shown to predict overall success in medical study almost with the same accuracy (and even a bit higher) as admission tests. This is true despite of existing differences between high schools and their quality/difficulty.

Admission tests and pre-admission grades were shown to describe different dimensions of students' abilities. While preadmission GPA describes long-term study success and ability to succeed in wide scale of high-school subjects, as the opposite, the admission tests cover only knowledge in profile subjects and are cross-sectional (measured at the moment) and thus might be affected by many biases (caused by student's actual health condition, examination fever, nervousness etc.). On the other hand, they describe student's ability to learn large amount of information in limited time, which might be crucial for future medical studies. And unlike GPA, which might be affected by school's quality/difficulty, the admission tests are equal for all students, or their equal difficulty can be easily ensured in the case of more versions of the test.

Beside predictive validity of admission tests for 1st LF UK, also their incremental validity was proved by this study, as required by McManus et al. (2011a) for psychometric data reports. We have proved that admission tests give new information about students' predispositions to succeed in medical study **over** information given by preadmission GPA. Question remains, whether the incremental validity of current admission tests will be proved also in future with respect to central leaving examinations, newly introduced in the Czech Republic. There are doubts however, whether our current GCSE equivalent exam in its present form will remain usable, with respect to aggregate subjects tested for during medical college admission tests.

Also, it was shown that overall GPA describes ability to succeed in medical study with the same accuracy as subject GPAs. Advantage of overall GPA is that it describes the breadth of student's knowledge and that it should be less affected by the teacher effect. Profile subjects nevertheless are of some importance: condition A2 was found to be important.

Optimal model contained AT, GPA, conditions A1 and A2 and accounted for 30% of variability of predicted value. In this sense we have also proved suitability of current admission process. Instead of weighted sum of optimal predictors, the school offers places to given number of applicants with best GPA and satisfying conditions A1, A2 and A3, while the rest of the students selected solely on the basis of AT. As an advantage of this two-step process, 1st LF UK saves money and also encourages talented students to study at 1st LF UK, particularly those who would not have even attempted to pass the difficult and memorizing admission test. As a disadvantage, the two-step process is less accurate, since either only GPA or only AT is used for selection of students but never both together. As a consequence, possibilities of future analyses are limited due to data incompleteness. Incorporating GPA as weighted score for the group of students who also took AT should bring improvement of the selection process and more complete data.

In most of the studies concerning admission process, the study success comes from practical reasons defined only by average GPA in the first years of medical study. Höschl and Kožený (1997) looked for optimal predictor of academic performance in the first three years of medical study and found associations in higher class of medical study to be weaker. They explained this feature by the fact that in the first two years, the contact with patients is still limited and the processing of theoretical knowledge constitutes the main criterion for evaluating students' performance. They concluded that admission committees are interested in predicting probability of success or failure rather than estimating grade point averages, which are primary of theoretical and illustrative significance only. In our study, we fulfil recommendations given in mentioned work by analysing the overall success in medical study. A great disadvantage of this approach is the fact that we had to wait more than seven years;

meanwhile the population of admitted students might have changed as well as curriculum or admission criteria.

Optimal model for the prediction of study success in Höschl and Kožený (1997) contained high-school GPA in physics and the admission subtest in physics. Kožený and Tišanská (2001) found mathematics to be the best high-school subject to predict success in medical study. Both physics and mathematics involve logical thinking more than memorizing. In our study, the difference of these two subjects from other subjects is proved by cluster analysis. The admission test in physics was moreover the only one whose removal from the admission test would cause significant loss of information. We assume, that subtest in physics would have differed even more from other two subtests if the most of the questions (or their analogous versions) were not published in advance. Published items cause the current admission test to 1st LF UK to be the test of willingness and ability to memorize large amount of information.

Mentioned qualities are in view of further medical study necessary due to huge volume of curriculum, and our analyses prove that they are of use at 1st LF UK. Nevertheless, evolution of society and progress of information technologies in the last twenty years raise doubts, whether the paradigm is still true. Strategy of large amount of published items resulted from requirements on transparency of the admission process and equal chances for all applicants. By oversatisfying these requirements we lose the possibility to test logical thinking and ability to creatively apply the gained knowledge, which should be crucial in further clinical praxis of medical graduates.

CONCLUSION

In spite of differences in the level, degree and standards secondary schools of particular type may have, preadmission grades (GPA) were shown to predict overall success in medical study almost with the same accuracy (and even a bit higher) as admission tests (AT). While GPA accounted for about 15% of variability of predicted value, single AT accounted for only 13%. Overall GPA was shown to have similar predictive power as optimal combination of subject GPAs. Further it shows up that equal weighting of the three admission subtests is optimal; nevertheless, chemistry and biology subtests may be removed without significant loss of information.

AT and GPA were shown to describe different aspects of students' abilities to successfully graduate from medical school.

Incremental validity of admission tests over preadmission grades was proved; optimal combination of AT and GPA explained 22% of variability of success. Adding information on year of graduation and type of high school (which together with GPA strongly influences fulfilment of conditions on profile classes) raised percentage of explained variability to 31%.

Current admission criteria to 1st LF UK are in agreement with findings of this study. Offering places without AT to students with best pre-admission GPA is reasonable as well as additional criteria on profile subjects and year of graduation. Better results might be reached by incorporating GPA into admission process of all students.

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Predictive Validity of Scientific Knowledge Test and Intellectual Aptitude Test Used in Admission for Medical School Performance during the First Year

Introduction

The selection of students for medical studies is an important task and it receives a constant attention. Information on academic performance at secondary schools, entrance exams, interviews and other methods are used in admission process.

The purpose of the admission procedure is to select students who will be able to successfully complete their entire studies. Faulty selection leads to the ineffective use of the teaching capacity of a school on the one hand, and to the loss of time of students spent by studying in an unsuitable field on the other hand. In terms of schools, the losses resulting from an incorrect choice are directly related to an economic loss. From the perspective of students, a properly set admission procedure could help applicants determine whether they have the necessary aptitude and ability for the demanding studies (Kuncel, Ones et al. 2001).

Admission procedures at Czech faculties of medicine

All seven Czech faculties of medicine use some kind of scientific knowledge tests (ST) containing items in physics (P), chemistry (C) and biology (B) in the admission procedure. Some schools supplement the tests with an interview, interpretation of a text or a general aptitude test (GAT), which is a test of intellectual aptitude similar to an abbreviated IQ test.

In 2002, First Faculty of Medicine of Charles University in Prague (FFM), and in subsequent years several other Czech medical schools, implemented the possibility of admissions without having to take entrance exams but only based on outstanding undergraduate grade point averages (uGPAs). Information about admission procedures for the year 2010 at faculties of medicine in the Czech Republic is summarized in Table 1.

Table 1: Admission procedures at faculties of medicine in the Czech Republic in 2010

School	Test in Biol., Chem., Phys.	Known Sample items	General Aptitude Test (GAT)	Interview	Interpretation of a text	Admission based on uGPA	Number of admitted*	Number of applicants*
First Faculty of Medicine of Charles University in Prague	1	1	1	0	0	1	450	3,374
Second Faculty of Medicine of Charles University in Prague	1	1	1	1	0	0	150	1,813
Third Faculty of Medicine of Charles University in Prague	1	0	0	1	1	1	155	1,413
Faculty of Medicine of Charles University in Hradec Králové	1	1	0	0	0	1	165	1,415
Faculty of Medicine of Charles University in Pilsen	1	1	0	0	0	1	230	1,850
Faculty of Medicine of Palacký University in Olomouc	1	1	0	0	0	1	220	1,838
Faculty of medicine of Masaryk University in Brno	1	1	0	0	0	0	400	2,894

*The number of admitted students and applicants applies to study of general medicine in the national language.

Admission procedure at the First Faculty of Medicine of Charles University in Prague

FFM is the largest of seven Czech faculties of medicine. Each year approximately 450 students, out of usually 3,500 applicants, are admitted to study general medicine in the national language at this faculty.

Multiple choice tests from three scientific subjects have been used in admission process at FFM since 1990. Before this, the admission procedure included interviews, which since 1990 have been omitted from exams in order to eliminate all personal influences. Items used in knowledge tests are created in scientific institutes of FFM. Sample items are made public in advance in order to ensure equal access to study materials.

In 2008, General Aptitude Test (GAT), with questions similar to those used in IQ tests, was experimentally added to ST. The GAT was developed at the Faculty of Arts of Charles University in Prague. Unlike the ST measuring the knowledge of chemistry, biology and physics, the new test focused on intellectual aptitude, particularly on logical and analytical skills and spatial reasoning.

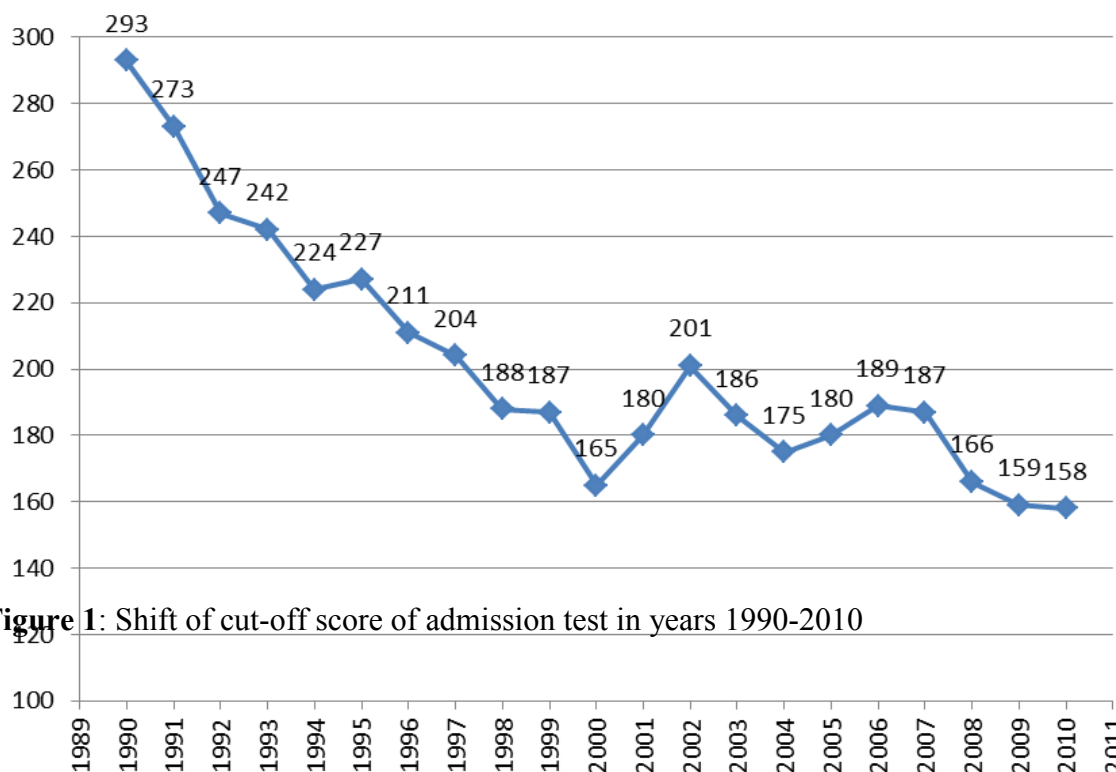


Figure 1: Shift of cut-off score of admission test in years 1990-2010

The appropriateness of intellectual aptitude test was repeatedly questioned:

Both McManus and Emery (Emery and Bell 2009) (McManus, Ferguson et al. 2011) point out the different contributions of knowledge and aptitude tests in Biomedical Admissions Tests (BMATs) as predictors of academic performance. In their works authors show that in BMAT, used in the UK, its Section 2, focusing on Scientific Knowledge and Applications, correlates clearly better to grade point averages in the first and second year of studies than Section 1 focusing on Aptitude and Skills. In their other work (Emery, Bell et al. 2011) authors further

show that in order to predict the grade point average in the first year of studies at a university, Section 2 significantly contributes to the prediction while Section 1 does not.

The appropriateness of the use of intelligence tests for the selection of candidates for studying medicine in UK was discussed by McManus et al. (McManus, Powis et al. 2005). They summarise previous findings (McManus, Smithers et al. 2003) and the conclusions of other studies stating that “Since the 1970s, university achievement has been shown to be predicted by A levels but not by intelligence tests” and that “Schools are introducing tests of intellectual aptitude without evidence of appropriateness, accuracy, or added value, making them open to legal challenge”.

Aims

The primary objective of this work is to compare the predictive validity of scientific knowledge test (ST) and aptitude test (GAT) as parts of admission procedure for medical study at FFM, and to decide, whether the two parts significantly contribute to the prediction of the success of students’ study.

With reference to relevant works in UK we try to generalize our findings and to discuss the appropriateness of both types of admission tests, which measure the different skills and abilities of applicants.

Methods

Admission tests

Since 1992 the admission procedure at FFM consists of written scientific knowledge tests (ST). In order to ensure the equal chances of applicants, it was decided to make public approximately 1,300 sample items for each scientific subtest (P, C, B) in advance. The admission test then comprises these questions themselves or with a slight variation (e.g. changes in the numerical values of examples or a change in the order of answers).

Admission test (AT) always has a total of 300 items. Until 2007 it was 100 randomly selected multiple-choice items for each subtest of ST (Physics, Biology and Chemistry). Since 2008, after the addition of GAT, the number of questions on knowledge tests was reduced to 240 (80 for each subtest) and the GAT had 60 questions.

The test items allow to choose one or more correct answers from four possible answers. A correct item is considered to be the one in which all of the correct answers are marked.

The points acquired from individual subtests are added together and based on this the final ranking of candidates is determined. Then, according to this ranking, the determined number of the best applicants is admitted so as to fully utilize the capacity of a school, i.e. in our case around 450 students. This number and admission test method applies to students studying in the national language. Students studying concurrently in English are counted separately and their admission procedure is different.

In 2002, FFM implemented the possibility of admitting some students based on their undergraduate grade point averages (uGPAs). The percentage of students admitted in this manner gradually increased from 25% to the current approximately 33% of all admitted students. We discuss this in detail with the comparison of the academic performance of

students admitted in both ways in a separate article (Martinkova, Stuka et al.). The predictive abilities of admission tests (AT) and uGPAs have shown to be essentially comparable. However, it seems that each method captures a different part of an applicant's abilities. A combination of both (AT and uGPA) would show significantly greater predictive validity than either method alone.

However, the comparison of grades at secondary schools is only possible at comparable schools. Although most students come from Gymnasiums, whose difficulty and curriculums are comparable, some applicants come from technical secondary schools, which have different curriculums and levels of difficulty. Although there is an option of implementing correction factors for the correction of uGPAs from technical secondary schools, the values of correction factors could be the subject of disputes that are difficult to resolve. Instead, supplementary criteria on students who want to be admitted without AT based on their uGPAs were implemented (the completion of specific subjects to a given extent, etc.) that de facto define the type of school. Admission tests serve to assess students' abilities regardless of the type of secondary school they attended.

In 2008, General aptitude test (GAT) was included in the set of admission tests at FFM - an intellectual aptitude test, whose questions are similar to those used in IQ tests. It comprises of 60 questions focusing on conceptual, spatial and numerical reasoning and comes from the Department of Psychology, the Faculty of Arts of Charles University in Prague. In the first year (2008), the GAT was added as a trial - it was not used for the ranking of applicants. In 2009, the GAT was used for the selection of candidates for the first time.

Academic performance

Studying medicine at faculties of medicine in the Czech Republic lasts six years. However, during their studies many students use the opportunity to study abroad for one or two semesters. Because in the assessment of tests it would be impractical to wait for the completion of studies, an alternate criterion is used against which is examined the predictive ability of admission tests - mostly the grade point average in the first year of studies. In our case this premise is justified because the first years of studies are very difficult: Figure 1 depicts the percentage of students who dropped out of the FFM in each year of the study for students admitted in 2002 and 2003. Graduates are depicted in the upper part and unsuccessful students in the lower part of the graph. In both years the percentage of unsuccessful students (shown by the horizontal dividing line) is around 40%.

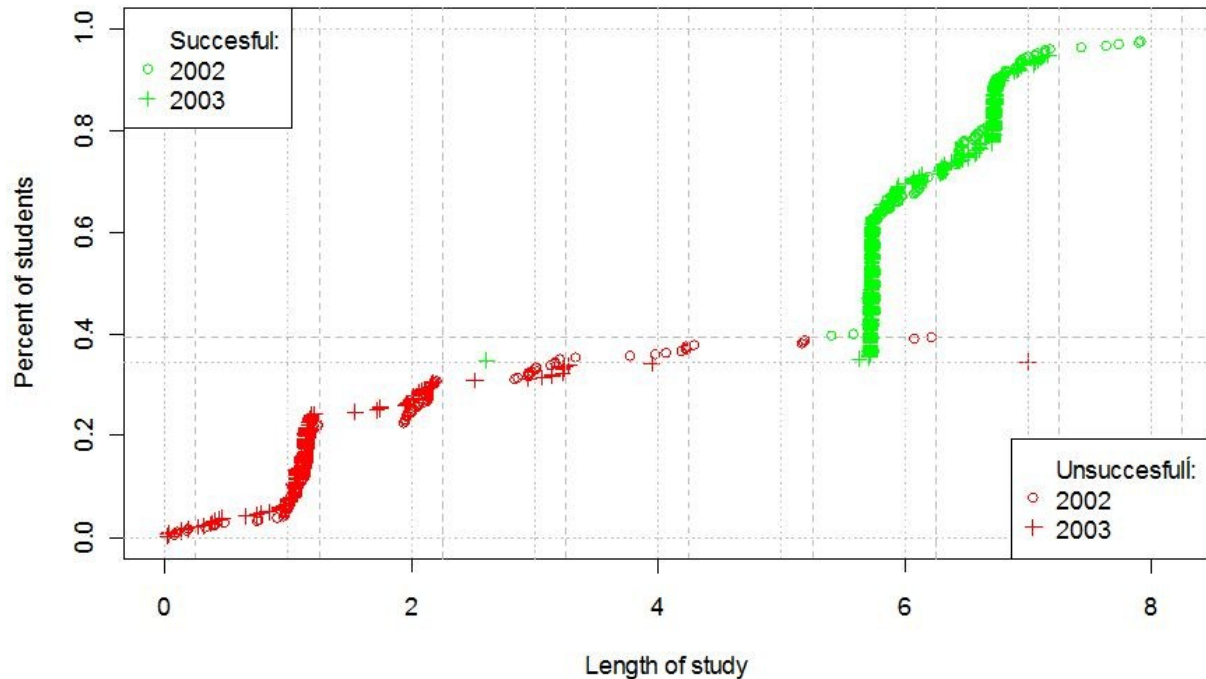


Figure 2: Length of studies of successful and unsuccessful students admitted in 2002 and 2003

The course of the leaving study shows the difficulty of the first year. Most students who drop out after failing do so within three months after the first year. Due to its high difficulty level, the first year at this school can be perceived as part of the admission procedure (Sulek and Hilser 2008). If the curriculum would change in order to avoid the said phenomenon, it would be necessary to increase the capacity of the faculty in higher (clinical) years so that it would be able to handle the non-reduced number of students.

Success in the first year is defined using information as to whether a student did not drop out within 3 months of the official end of the first academic year, i.e. by December, 31st. Formally, the decisive date for measuring success should be October, 30th, because the official end of the exam period ends on September, 30th, and a month is the statutory period for handling an appeal, but in practice many appeals take place and if we wait until the end of a relevant calendar year, we acquire much more accurate information as to whether a student passed the year or not (see Figure 2).

For a finer assessment of the success, we also use the **overall grade point average in the first year** (GPA1). The required subjects are the same for all students during the first year of study and over the years they changed very little. Required subjects included Biophysics, Latin, Medical Informatics, Histology and Embryology, Anatomy, and a Foreign Language. A student on an exam is graded with the grades of 1 (excellent) to 4 (failed). A student has the option of taking one regular examination and two re-sittings of an examination of a given subject. The average was calculated from all attempts, and if a student did not come to an examination, he received a 3 times failed grade for the purposes of this analysis.

Data set

In this paper, we focus on applicants admitted to FFM in the years 2002 to 2009. We included only applicants applying to the field of general medicine in Czech language, who applied for admission to this faculty for the first time. In Table 2, we can see the number of students who started the FFM in years 2002 – 2009 and were admitted based on admission tests and based on uGPAs. For analysis in this work, only those who passed admission tests were used.

Table 2: Number of students who were admitted to the field of general medicine taught in Czech language at FFM and started the study

Year	2002	2003	2004	2005	2006	2007	2008	2009
Admitted via a test	276	277	280	286	323	214	261	311
Admitted via uGPAs	94	96	142	100	99	99	115	155

The differences in the number of students in cohorts are due to changes in the admission policies of FFM, for example, the varying number of students admitted solely on the basis of their uGPA, as well as changes in other faculties (the expanding of admission based on uGPA led to the multiple applications of the best students and an increase in the number of students that finally did not start studies at a given faculty)

The data set contains, among other, the following data about students concerning their success in studies:

Current study status; date when study status came into being,

Academic year of admission

The grade point average of a given year (all general medicine students in a given cohort have the same prescribed tests in their first years of studies),

Number of re-sitting examinations of subjects from which the grade point average is calculated (each examination has one regular examination and two re-sittings of an examination, therefore a total of 3 attempts)

Data on *the number of points* earned in each of four tests of the admission procedure (*ST* and its subtests in *Biology, Chemistry and Physics*, and for cohorts 2008 and 2009 also *GAT*).

Statistical analysis of data

Predictive validity of admission tests generally shows to what extent a given variable is able to predict future success of a student in the university study. We assess the validity of admission tests as the degree of dependence between individual admission subtests and the grade point average during the first year of study (*GPA1*). We use *Pearson's correlation coefficient* for measuring dependence in individual cohorts. For the overall assessment of

multiple cohorts, we calculate the correlation between admission tests and the grade point average after each variable has been group-mean centred (Robinson 1950).

We assess incremental validity using testing submodels in regression models. We use a linear regression model for modelling the dependence of GPA1, and we use logistic regression for modelling the dependence of success in the first year (dichotomous variable dropped out / continued on).

Statistical analysis was performed and figures were plotted in free statistical environment *R* (R_Development_Core_Team 2009), including its libraries *multilevel* (Bliese 2008) and *meta* (Schwarzer 2010).

Results

The values of the correlation coefficients between GPA1 and admission tests (GAT, ST and its subtests C, P and B) are shown in Figure 2. We can conclude that the validity of the tests varies within individual years. All correlations are significantly nonzero. Also, there is a significant correlation for the GAT, but it is clearly the smallest.

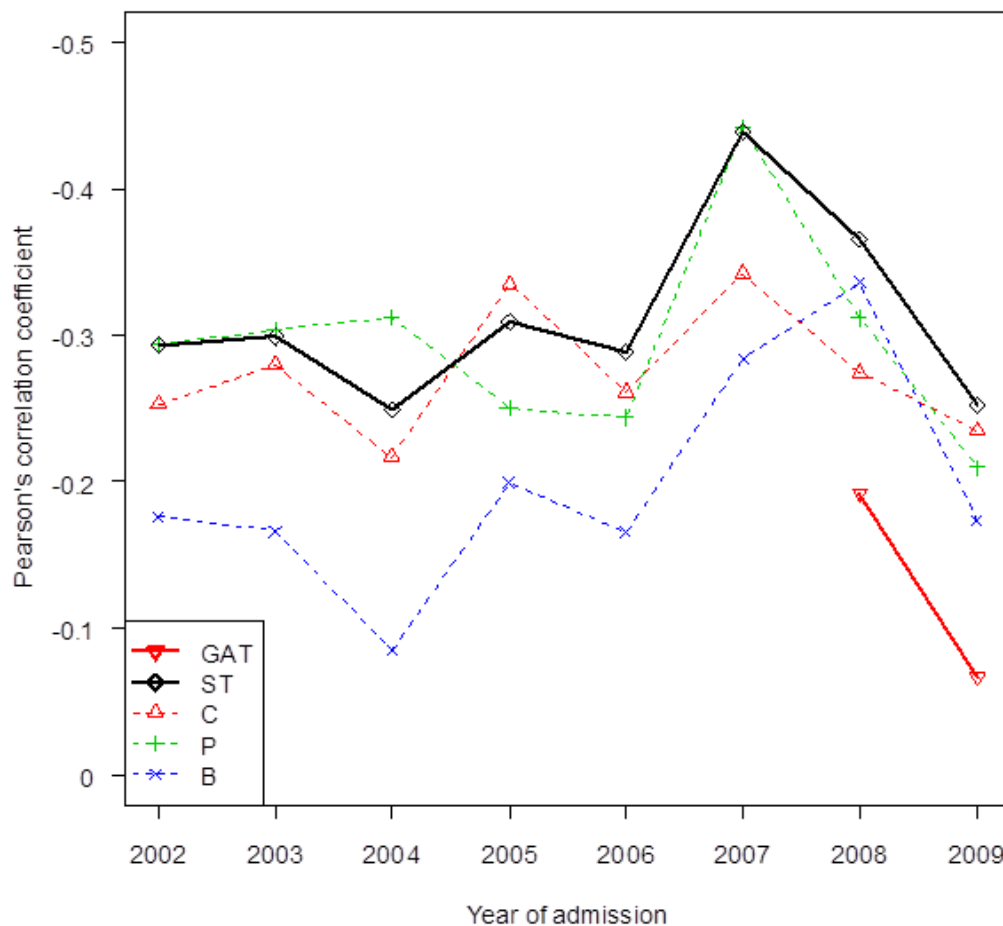


Figure 3: Validity of individual parts of the admission test for individual cohorts (years of admission) ST - Scientific knowledge test, C – Chemistry test, P – Physics test, B – Biology test, GAT - General aptitude test (IQ)

In Table 3, the information from Figure 2 is summarized by computing the correlation of AT and GPA1 after each variable has been group-mean centred. The first column shows correlations calculated from data of those admitted in the years 2002-2009). The second column show correlation calculated solely from the years 2008-2009, for which we also have available data from GAT. We got almost identical values using a meta-analysis (Schwarzer 2010).

Table 3: Correlations of admission tests and GPA1 after each variable has been group-mean centred.

Admission test	Years 2002-2009	Years 2008-2009
ST	-0.30	-0.30
Subsets:		
C	-0.27	-0.25
P	-0.29	-0.26
B	-0.19*	-0.25
GAT		-0.13

ST - Scientific knowledge test, C – Chemistry test, P – Physics test, B – Biology test, GAT - General aptitude test (IQ)

**test from Biology, as is evident from Figure 2, shows poor results especially in earlier years*

Besides predictive validity, also incremental validity of tests was studied. For assessing the incremental validity of the newly added GAT, we used only the cohorts admitted in the years 2008 and 2009, for which we have GAT data available. When predicting **GPA1** by ST and by the newly implemented GAT, both of them significantly ($p < 0.001$) contribute to the prediction. When predicting **success in the first year of study** (dichotomous variable dropped out / continued on) only ST contribute significantly ($p < 0.001$) and effect of GAT was no longer significant ($p = 0.286$).

Discussion

We noted that the substitution of the criteria of success of the entire length of studies with the criteria of GPA1 of studies is acceptable especially because we know (Figure 1) that success in the first year, in most cases, is decisive for the entire length of studies.

We proved that all parts of scientific knowledge test (Biology, Chemistry and Physics) are beneficial for the proper selection of students. In comparison, the predictive validity of the new GAT is lower and its contribution can be inferred only partially (it significantly adds new information if we predict GPA1, however, if we predict actual success in the first year of studies, its contribution is not significant).

It turns out that the predictive validity of individual tests varies between years. This is due to the established methodology of the (random) selection of test items from the battery of items, without taking into account their quality, ascertained via an item analysis. In 2007, we conducted an item analysis of the first round of admission tests that took place in 1999. The time interval of eight years, during which the admitted students had enough time to complete their studies, enabled us to assess the actual validity of items (not only the validity relative to the first year of studies). This item analysis showed that the quality of questions varies widely from explicitly useful questions to questions that correlated negatively with the entire results of studies, i.e. students who were unsuccessful in overall studies were more likely to choose the right answer to the question (Stuka, Martínkova et al.).

If we compare the predictive validity of individual subtests, we see that the quality of knowledge tests is comparable, although it greatly varies from year to year. The contribution of the general aptitude test for the years 2008-2009 is considerably smaller.

Similar relations between tests were also found in schools in the UK (McManus, Powis et al. 2005). Therefore, it seems that when assessing the appropriateness of tests, we find similar relations regardless if they were observed in the Czech Republic or the United Kingdom.

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