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Abstract

Undergraduate selection, especially for medical degree programs, is a challenging and controversial matter for both national and international institutions. The importance of this paper lies in trying to identify the process of selecting prospective students for medical studies in Saudi Arabia. The currently applied admission criteria are the weighted average score (WAS) of the three pre-university attainments, the general secondary school (GSS), the general aptitude test (GAT), and the scientific achievement test (SAT). There is a different weightage assigned to WAS throughout the national medical institutions. It raises concern about the scientific rationale behind the differences. The present research correlates longitudinal school and university data of medical graduates using a robust methodology of multinomial logistic regression in an attempt to find statistically significant ratios of WAS. A quantitative critique of the admission process was conducted for relatively large 440 graduates of the six-year medicine program, enrolled in five academic years. Several scenarios of admission criteria have been investigated for their significant association and prediction of the academic and clinical performance of medical students. The findings suggest several choices of WAS according to the decision of educational policymakers. The future implications that may influence forthcoming decisions regarding selection criteria are humbly offered.

Keywords: Admission test, entrance exam, medical study, logistic regression, Qiyas tests, Saudi Arabia.

Introduction

The association of admission criteria with higher-education performance is essential for their use in admission selection (Bagabir, 2006; Herbaut, 2020; Rigol, 1999; Stern and Briggs, 2001). Therefore, to contribute to continuous educational improvement processes and support decision makers, educational institutions must monitor and evaluate the relationship between the approved admission policy and student performance on a scientific basis to identify and resolve any issues (Alqataee & Alharbi, 2012; Heaton-Shrestha et al., 2009). The literature indicated that the admission criteria to medical colleges around the world differ from one country to another, and from one educational institution to another. Moreover, it seems that there are two tracks in admitting students to medical degree programs, one of which tends to direct admission, and the other depends on the student entering the preparatory year before being competitively attached to a medical program, in addition to the fact that there are universities that emphasize the importance of high performance in standardized tests (Greatrix & Dowell, 2020).

International Affairs

Higher-education institutions around the world use admission criteria that are generally based on a combination of academic achievement, standardized testing, and personal interview (Greatrix & Dowell, 2020; Mercer et al., 2015; Patterson et al., 2016). Admission criteria based on cognitive and non-cognitive skills ensure graduates have attributes in academic (preclinical), clinical, and even professional aspects (Adam et al., 2015; Greatrix & Dowell, 2020; Meyer et al., 2019). For example, the admission process in the UK is that applicants must earn an A grade in science courses and then take the university clinical aptitude test (UCAT). The scores of the courses and UCAT are grouped equally, then the applicants with the highest scores will be selected (Greatrix & Dowell, 2020). However, since 2016, the contribution of UCAT has been reduced to 40%. Applicants will be rejected if they do not score a minimum grade in the "Status Judgment Test" part of the UCAT. As a final screening stage, some UK universities conduct personal interviews for applicants (Greatrix & Dowell, 2020). It is believed that verbal communication with patients or colleagues is a key performance indicator for medical practitioners and can be measured through a personal interview (Adam et al., 2015; Mercer et al., 2015). Furthermore, the admission interview can evaluate the student's motivation, commitment, and physical fitness (Mercer et al., 2015). However, academic achievements and admission tests are more effective selection methods and can be assessed more fairly than in-person interviews (Patterson et al., 2016). However, it appears that academic ability is necessary for a student's success in the study of medicine but not sufficient for a proficient medical doctor (MacKenzie et al., 2017; Patterson et al., 2016). It has been argued that the non-cognitive traits are essential to ensure a successful physician practice (MacKenzie et al., 2017; Mommert et al., 2020; Patterson et al., 2016). The standardized test has been introduced to supplement school outcomes in screening competitors in the institution of higher education (Bagabir, 2006; Lievens and Coetsier, 2002; Lievens et al., 2005; Rigol, 1999). As a prerequisite for admission to a higher education institution, an admission test that fits with its policy and educational system is usually used (Greatrix & Dowell, 2020; Rigol, 1999).

The objectives of admission tests are fair competition and standardized measurements and ensuring that all students have a similar background in important scientific topics related to the discipline of higher education (Rigol, 1999). Moreover, admission tests can eliminate corruption in secondary education which leads to grade inflation and does not reflect the true academic level of students (Rigol, 1999). The most popular admission tests designed for medical student selection were proved to be positively related to undergraduate performance, such as the UCAT (Adam et al., 2015; Mwandigha et al., 2018), MCAT (Julian, 2005), BMAT (Emery &

Bell, 2009), and GAMSAT (Mercer et al., 2015). However, the literature indicates contradictory results regarding the importance of the admission test compared to secondary-school education. One group believes that the admission test is an important indicator of success in higher education (Alqataee & Alharbi, 2012; Dimitrov & Alharbi, 2014; Liu, 2008;), while some studies suggest that a high school grade is a better predictor of college success than an admission test (e.g., Svensson et al., 2001). There are also published studies showing that the best indicator of study success is achieved by combining high school grades and admission tests (Bagabir, 2006; Beller, 2000). However, some researchers assert that there are no statistically significant differences between students accepted based on high school grades and those accepted based on admission tests (Henriksson & Wolming, 1998).

National Affairs

The present section is devoted to giving background on the Saudi admission process and studies conducted on the impact of pre-university education on the performance of students studying medicine. Enrollment in medical studies, particularly medicine, in Saudi Arabia is very competitive, with demand exceeding available places. Most students consider joining medical colleges as their first choice of study. This is due to the culture of the society in which almost every student wishes to become a medical doctor, due to the distinguished social status and a guaranteed job with a high income. Therefore, the applicants are high performers who have already achieved exceptional results in secondary education. But the question that arises for those interested in higher education is what the credibility of school education is. The selection process has been modified since 2002 after introducing two additional national admission tests prepared by Qiyas (Alqataee & Alharbi, 2012; Qiyas, 2022). The first test is the general aptitude test (GAT), which aims to test the general ability to learn by measuring students' analytical and inferential skills (Qiyas, 2022). The second test is the academic achievement test for scientific specializations (SAT) which measures the achievement of secondary-school knowledge and understanding in specific courses, Biology, Chemistry, Mathematics, and Physics (Qiyas, 2022). In general, the former is supposed to assess the lower cognitive level of Bloom's taxonomy (remember, understand, and apply), while the latter measures the upper cognitive levels (analyze and evaluate). Accordingly, the currently adopted competitive selection criteria are based on the weighted average score (WAS), which is a combination of the general secondary school (GSS) and the two national Qiyas tests, GAT and SAT. Admission criteria are based on the discretion of medical colleges, knowing that their consensus is about the disagreement over school education outcomes. Therefore, national medical institutions differ in the weightage of the admission criteria, WAS, as shown in Table 1. Recently, because of the Corona pandemic, some universities relaxed the WAS ratio in favor of GSS, due to the difficulties that accompanied Qiyas standardized tests.

Table 1

The weightage assigned to admission criteria (weighted average score, WAS) applied in Saudi universities.

University	GSS (%)	GAT (%)	SAT (%)
Islamic; King Abdelaziz; Umm al-Qura	50	30	20
Northern Borders; Taibah	50	25	25
Jazan; Najran; Taibah	40	30	30
Tabuk	40	20	40
Hail	35	35	30
King Saud; King Faisal; King Khalid; Princess Nourah; Qassim; Taif	30	30	40

Source: Data was collected from individual university websites.

Many previous studies in Saudi Arabia raise concerns about the ability of pre-university education to adequately prepare students for higher education (Alqataee & Alharbi, 2012). Table 2 summarizes the literature review to measure the strength of association between indictors (dependent variables) and predictors (independent variables). Most of the studies used simple correlation analysis, as shown in Table 2 (Alalwan, 2009; Alalwan *et al*., 2013; Albishri *et al*., 2012; Alenezi, 2019; Alhadlaq *et al*., 2015; Alrukban *et al*., 2010; Murshid, 2013). The correlation association is measured by the

Pearson correlation coefficient ($-1 \le r \le 1$). For a better correlation fit, the value of the coefficient is closer to one. If the correlation method is used, no causal effect is implied (Hosmer *et al*., 2013). However, some studies applied the linear regression method (Alalwan *et al*., 2013; Albishri *et al*., 2012; Alhadlaq *et al*., 2015; Alrukban *et al*., 2010; Dabaliz *et al*., 2017). In general, regression establishes functional relationships which can be used to find out the causal effect and predict future events (Hosmer *et al*., 2013). Linear regression effect is either measured by standardized coefficient ($-1 \le \beta \le 1$) or unstandardized coefficient ($-\infty > B < \infty$). The admission criteria were measured against preclinical theoretical medicine achievements, Table 2 (Alalwan, 2009; Alalwan *et al*., 2013; Alenezi, 2019; Alhadlaq *et al*., 2015; Alrukban *et al*., 2010; Dabaliz *et al*., 2017; Murshid, 2013) and clinical or graduation achievements (Albishri *et al*., 2012; Alenezi, 2019). Bagabir *et al*. (2021) utilized multinomial logistic regression which is characterized by the odds ratio (OR≥0). The OR has an intuitive interpretation, the value of one suggests no difference OR greater/less than one suggests a higher/lower chance that graduation will occur. The higher the OR, the higher the probability that graduation will occur. For more clarification, as shown in Table 2, a one-level increase in SAT score will increase the probability of graduating on time by 6%. In contrast, one-level increases in GSS and GAT reduce relative graduation probability by 17% and 7%, respectively (Table 2).

Table 2

Summary of the literature review conducted at medicine colleges in Saudi universities (arranged chronically).

Reference	University	Sample	Method (Factor)	Indicator	Predictor GSS	GAT	SAT
Alalwan (2009)	King Saud	91 (2nd year)	Correlation (r)	2nd year GPA	0.93	0.97	0.87
Alrukban *et al.* (2010)	King Saud	193 (1st -4th year)	Correlation (r)	GPA	0.14	0.11	0.22
			Linear regression (β)		0.10	0.00	0.20
Albishri *et al.* (2012)	Anonymous	727 (Graduates)	Correlation (r)	Graduation GPA	0.22	0.24	0.39
			Linear regression (β)		0.13	0.08	0.32
Alalwan *et al.* (2013)	King Saud	87 (3rd year)	Correlation (r)	3rd year GPA	0.65	0.65	0.66
			Linear regression (B)		0.07	0.02	0.02

Reference	University	Sample	Method (Factor)	Indicator	Predictor GSS	GAT	SAT
Murshid (2013)	Taibah	478 (1st -4th year)	Correlation (*r*)	GPA	0.43	0.04	0.21
Alhadlaq *et al.* (2015)	King Saud	766 (2008-2010)	Correlation (*r*)	2nd year GPA	0.10	–0.01	0.21
			Linear regression (*β*)		0.17	–0.08	0.19
Dabaliz *et al.* (2017)	Alfaisal	484 (1st -3th year)	Linear regression (*B*)	GPA	0.21	–0.05	0.08
		253 (4th-6th year)			–0.09	–0.06	0.06
Alenezi (2019)	Northern Border	182 (2009-2011)	Correlation (*r*)	Preclinical GPA	0.00	0.27	0.45
				Clinical GPA	0.06	0.16	0.36
Bagabir *et al.* (2021)	Anonymous	632 (2010-2014)	logistic regression (OR)	On-time graduation	0.83	0.93	1.06

The discrepancy in the findings shown in Table 2 could be due to several factors, the most important of which are the statistical method used, the number of samples, as well as the educational performance of the school varies from one region to another (Adam *et al*., 2015). Most of the previous studies agreed that the SAT has the greatest impact on higher-education achievements (Albishri *et al*., 2012; Alenezi, 2019; Alhadlaq *et al*., 2015; Alrukban *et al*., 2010; Bagabir *et al*., 2021). There is ambiguity about the impact of the other two criteria, GSS and GAT. Among the researchers are those who concluded the advantage of GSS over GAT (Alhadlaq *et al*., 2015; Alrukban *et al*., 2010; Murshid, 2013), and others came to the opposite (Albishri *et al*., 2012; Alenezi, 2019; Alalwan, 2009). However, the third party decided that there was no significant effect of both GSS and GAT on medical education attainment (Alalwan, 2013; Bagabir *et al*., 2021; Dabaliz *et al*., 2017). All studies shown in Table 2 refer to medicine, but the findings and recommendations can be generalized to other health sciences (Alhadlaq et al., 2015).

As shown before in Table 1 that Saudi medical institutions differ in weighting the admission criteria, WAS. Therefore, the question that comes to mind is what the scientific rationale behind each institution's selection of the percentages is that make up the admission criterion. The current research aims to fill the gap in national research in predicting the impact of pre-university achievements on higher education students' progress. The study offers rationale admission criteria based on a reliable statistic methodology of multinomial logistic regression. The implemented models examine different scenarios of criteria for medical studies against two key indicators, GPAs at the first year (foundation) and graduation. Therefore, the objectives of the study are to (i) Review and explore admission criteria based on the various criteria currently applied in Saudi universities, (ii) predict the most effective school achievement, and (iii) predict the weighted average admission criterion/criteria that most influences the medical study.

The following section is dedicated to a research methodology that describes the variables and provides a background on mathematical models. The third section presents the outcomes of the statistical models and their analysis. Next, a discussion and implication of the current findings are written in the fourth section limitations are also included. Finally, the conclusion is drawn.

Methodology

Multinomial logistic regression models were used to predict more than two dependent variables (indicators) of undergraduate students' academic and clinical achievements given different scenarios of admission criteria as independent variables (predictors).

Study sample

Students have been observed in a college of medicine in Saudi Arabia for ten years from 2010 to 2020. The minimum period for completing a bachelor's degree is six years. However, the student is allowed to finish the program degree in an additional period of 100% depending on the circumstances of the student. A relatively large sample of 440 graduates of five cohorts was investigated. The collected data contains pre-university achievements (GSS, GAT, and SAT) and the foundation and graduation cumulative grade point averages (GPAs). The mean and standard deviation of the single pre-university predictors and indicators are shown in Table 3. Ten criteria under investigation of single, double, and triple pre-university scores are presented in Table 4. Three of them are criteria based on a single achievement, GSS, GAT, or SAT. Criteria A and B are based on double scores, GSS and GAT, or GSS and SAT, respectively (Table 4). The remaining six criteria are made up of different weights of the pre-university achievements. According to the recommendation of Qiyas, 30% GAT weight is fixed for the criteria C-F, Table 4. However, criterion G of 20% GAT is introduced because some universities used weight less than 30% (see Table 1).

Table 3

Descriptive statistics of the single predictors and indicators.

Variable	Mean	SD
GSS	99.2%	1.34
GAT	80.5%	6.06
SAT	79.7%	6.07
Foundation GPA	4.2	0.53
Graduation GPA	3.5	0.53

Table 4

Admission criteria (predictors) under investigation.

#	Criterion	GSS (%)	GAT (%)	SAT (%)
1	GSS	100	0	0
2	GAT	0	100	0
3	SAT	0	0	100
4	A	50	50	0
5	B	50	0	50
6	C	50	30	20
7	D	40	30	30
8	E	30	30	40
9	F	20	30	50
10	G	50	20	30

Figure 1

Categories of the indicator GPAs at foundation and graduation.

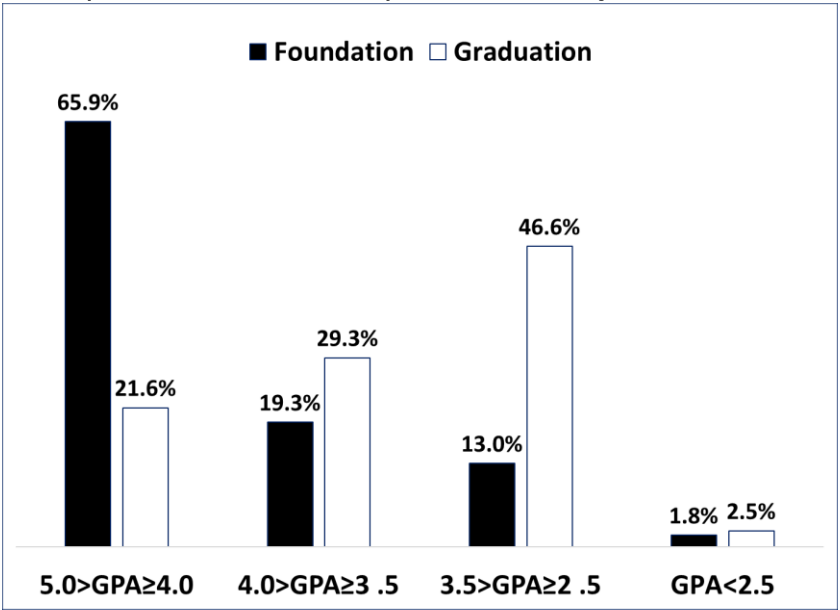


Figure 1 illustrates the two main indicators of the foundation and graduation GPAs and their four categories. The GPA is measured out of five by adding the grade of each course by the number of credit hours for that course and then dividing this total by the total number of credit hours. It seems that the GPA is much higher in the foundation than upon graduation (see Fig. 1). This can be attributed to the fact that the courses of the first medical year are a repetition of what was studied in secondary school. This emphasizes the importance of first-year achievement as a predictor (Bagabir *et al*., 2021) and as an indicator (Alqataee & Alharbi, 2012) of higher education performance. A student who accomplishes high achievement in the first year is more likely to complete a bachelor's degree while the opposite presents a significant risk of diminished retention (Bagabir *et al*., 2021; Briggs, 2012; Herbaut, 2020; Neethling, 2015).

Multinomial logistic regression

Logistic regression establishes a statistically significant relationship between variables (Harrell, 2015). It is used to find out the causal effect and to predict the probabilities of binary dummy indicators. An indicator is chosen as a reference then the other indicator is regressed against it. Logistic regression is preferred over linear regression for many aspects such as accuracy and ease of interpretation of its results (Harrell, 2015; Hosmer *et al*., 2013). The employed multinomial logistic regression is a modified version, which can independently model more than two indicators (Harrell, 2015). The admission criteria based on the pre-university scores (GSS, GAT, and SAT) are modeled as multivariable predictors, while the rest of the criteria (A-G) are simulated successively as a single predictor one by one. It is worth mentioning that the indicator GPA< 2.5 is considered a reference category. It should be noted that a 95% confidence interval (*CI*) is considered. The statistical significance predictor, when the *p*-value is less than 0.05, indicates that the regression results cannot be explained by chance and is evidence against the null hypothesis (Hosmer *et al*., 2013). The lower and upper *CIs* have two statistical indicators. The first is that the smaller the range, the higher the degree of certainty that can be attributed to the regression model. The second indication is that if the lower and upper limits of the *CI* do not overlap with 1.0, this is clear evidence that the predictor is statistically significant (Harrell, 2015; Hosmer *et al*., 2013). The odds ratio (OR>0) is used to compare the relative odds of an event of interest for exposure to a variable of interest. The OR can be expressed as shown in the following equation (Harrell, 2015):

$$ln(OR) = b_0 + b_1\text{GSS} + b_2\text{GAT} + b_3SAT \quad (1)$$

The coefficients of association, b_S, are the predictable increase in the Log odds of an indictor per unit increase in the value of a predictor, e.g., the term e^{b_1} is the OR associated with a unit increase in the predictor, GSS. If OR equals one, the two events are independent, i.e., the probability of one event being the same in the presence or absence of the other event (Harrell, 2015). If the value of OR is equal to half, the probability of failure is twice the probability of passing. If the OR value is two, then the probability of passing is twice the probability of failure. The higher the OR, the more likely the event will occur.

Regression Results

Table 5 presents the results of the multinomial logistic models for single and combined admission criteria as predictors of medical student achievements. The table shows the odds ratio, OR, and lower and upper *CIs*. Firstly, the results of the single selection criteria, GSS, GAT, and SAT, will be presented and interpreted. Regarding the foundation GPA indicators (columns 1-3 of Table 5), regression models reveal that the secondary school score, GSS, is the most effective predictor of medical education (ORs: 1.14-2.80). Specifically, the highest category of students who can get a GPA equal to or greater than four (OR: 2.80, CI: 1.57-3.92). The odds ratio compares the relative odds of having a GPA≥4 to a GPA< 2.5 for exposure to the GSS predictor. Since the OR is greater than one (2.80), it can be interpreted as a unit increase in GSS indicating a 2.8-fold increase in the first-year incidence of GPA≥4. The scientific achievement test, SAT, is ranked second as a predictor of student achievement (OR:1.07-1.26) after the GSS. In contrast, the general aptitude test, GAT, has a negative correlation with the progress of all foundation indicator categories. Since the OR is less than one (OR: 0.88-0.96), it expects less chance of events. Regarding graduation indicator (columns 4-6 of Table 5), a similar observation could be made for GSS with some decrease in OR values, however, GAT shifted from negative to slightly positive effect for all levels of students.

It is appreciated that most readers do not have a significant background in applied statistics. Therefore, a simplified practical demonstration will be presented. Suppose that four students, with school grades as shown in Table 6, apply to a college of medicine. The multinomial logistic regression models reveal the following relationship in terms of the predictors, GSS, GAT, and SAT.

$$ln(\mathrm{OR}) = -113.064 + 1.031(\mathrm{GSS}) - 0.040(\mathrm{GAT}) + 0.231(\mathrm{SAT}) \qquad (2)$$

Accordingly, the odds ratio (OR) of the indicator event, which is the foundation GPA≥4, can be calculated based on the individual OR contribution of the predictor, GSS, GAT, and SAT (2.80, 0.96, 1.26, respectively, as shown in Table 5). Student#1 has an almost 5% higher chance of getting the event. If student#2 applied with the same grades as student#1 except that the GSS score is a unit higher, there is a 295% higher chance of the event happening. The OR of student#2 is 180% (=$(2.95-1.05)/1.05=1.80$, which is ΔOR=OR–1=2.80–1=1.80) higher than student#1 (Table 6). The term (ΔOR=OR–1) can be defined as the percentage contribution of a predictor to the OR of an event for each unit increase of a predictor (Hosmer *et al.*, 2013). Similar manipulation can be applied to student#3 and student#4, which have a unit higher than student#1 in GAT, and SAT, respectively. As shown in Table 6, it reveals ΔOR%=–4% and =26% for student#3, and student#4, respectively.

Table 5
Odds ratios, OR (95% CI), for predicted effects of admission criteria on the progress of medicine students.

Indicator	Foundation GPA			Graduation GPA		
Criterion	≥ 4	≥ 3.5	≥ 2.5	≥ 4	≥ 3.5	≥ 2.5
GSS	2.80 (1.92-4.08)	1.39 (1.02-1.89)	1.14 (0.85-1.52)	2.48 (1.57-3.92)	1.74 (1.25-2.42)	1.26 (0.97-1.62)
GAT	0.96 (0.84-1.10)	0.89 (0.78-1.02)	0.88 (0.76-1.01)	1.07 (0.95-1.20)	1.02 (0.91-1.15)	1.01 (0.90-1.13)
SAT	1.26 (1.08-1.47)	1.12 (0.97-1.31)	1.07 (0.92-1.25)	1.21 (1.07-1.38)	1.16 (1.03-1.32)	1.12 (0.99-1.27)
A	1.15 (0.90-1.46)	0.89 (0.70-1.14)	0.83 (0.65-1.07)	1.42 (1.15-1.76)	1.24 (1.00-1.52)	1.15 (0.94-1.41)
B	1.74 (1.33-2.28)	1.26 (0.97-1.65)	1.11 (0.85-1.45)	1.71 (1.37-2.13)	1.48 (1.19-1.84)	1.32 (1.07-1.63)
C	1.50 (1.12-2.02)	1.02 (0.75-1.38)	0.89 (0.66-1.22)	1.77 (1.37-2.29)	1.47 (1.15-1.88)	1.30 (1.03-1.66)
D	1.42 (1.10-1.83)	1.02 (0.78-1.32)	0.91 (0.70-1.19)	1.63 (1.31-2.03)	1.39 (1.12-1.72)	1.26 (1.02-1.55)
E	1.34 (1.08-1.68)	1.01 (0.81-1.27)	0.93 (0.74-1.17)	1.52 (1.25-1.83)	1.32 (1.10-1.59)	1.22 (1.02-1.46)
F	1.29 (1.06-1.56)	1.01 (0.83-1.23)	0.94 (0.77-1.15)	1.43 (1.21-1.69)	1.27 (1.08-1.49)	1.18 (1.01-1.38)
G	1.71 (1.26-2.33)	1.13 (0.83-1.53)	0.97 (0.71-1.33)	1.86 (1.44-2.40)	1.54 (1.20-1.97)	1.35 (1.06-1.72)

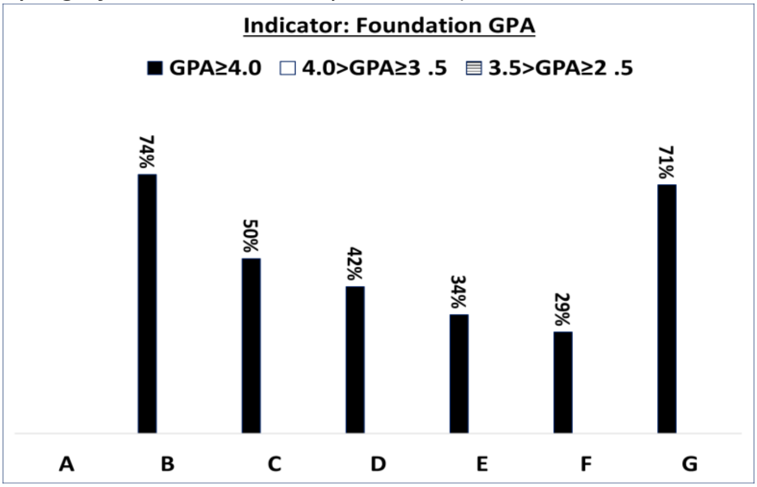
Table 6

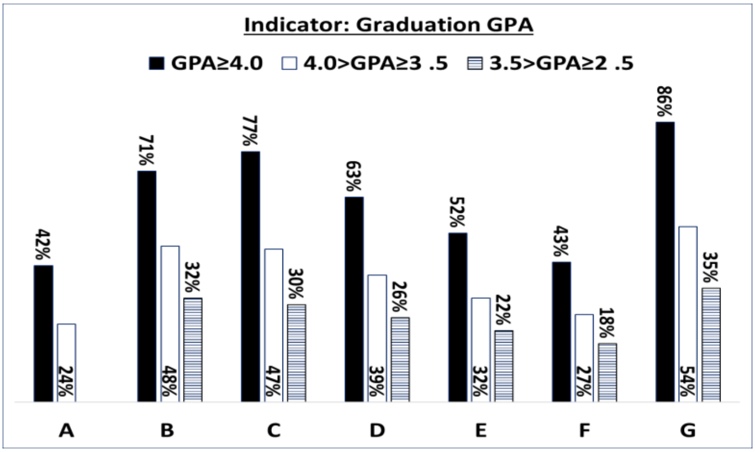
Demonstration of the effect of OR on different scenarios of pre-university achievements corresponding to foundation GPA≥ 4 (Table 4).

Description	Scenarios			
	Student #1 (Ref.)	Student #2	Student #3	Student #4
GSS	96	97	96	96
GAT	80	80	81	80
SAT	75	75	75	76
OR	1.05	2.95	1.01	1.33
ΔOR%		180%	-4%	26%

Figure 2

Effect on ORs (ΔOR%) for a unit increase in admission criteria (only statistically significant criteria are presented).





On the other hand, as shown in Table 5, for double combination criteria (A and B), the effect of criterion B on GSS and SAT (ORs:1.11-1.74) is more pronounced in the early preclinical and clinical years than the effect of criterion A of GSS and GAT (ORs:0.83-1.42). Criterion B (50%GSS and 50%SAT) shows convincing performance at all GPA levels. However, for the triple combination of the three pre-university achievements (criteria C-G), the weighted average score (WAS) has a greater impact on the graduation than on the foundation for all GPA categories (Table 5). It is observed that for C-F criteria as GSS contribution decreases and SAT weight increases, the effect of the criteria on student performance decreases (Table 5). The most effective criterion of them is C (50%GSS, 30%GAT, and 20%SAT) at both early (ORs:0.89-1.50) and late (ORs:1.30-1.77) study levels. However, by increasing the contribution of SAT and decreasing GAT weight by 10%, the G criterion (50%GSS, 20%GAT, and 30%SAT) proves to be the highest performance of the three-score criteria (i.e., C-G) at both foundation (OR: 0.97-1.71) and graduation (OR:1.35-1.86) levels.

Figure 2 illustrates the percentage contribution of admission criteria (ΔOR%) to the OR of the foundation and graduation GPAs for criteria of a combination of double and triple scores. It is worth mentioning that the statistically insignificant predictors are not included in the charts, which compare indicators for a unit increase in each criterion. For a student to get a GPA≥4 at early and late study levels, all admission criteria have a statistically significant positive impact on the performance of medical students (Fig. 2). The most effective weighted average combination criteria at the foundation level are B (74%), G (71%), and C (50%) and at the graduation are G (35%-86%), C (30%-77%), and B (32%-71%).

Discussion

Academic assessment

The difference in the results of previous studies conducted about the effect of the three school outcomes on the performance of students at the national medical programs described in Section 2 could be due to the statistical method used as most of the studies applied correlation and linear regression, which are less accurate than the multinomial logistic regression (Hosmer *et al*., 2013; Harrell, 2015). The effect of the method used was evident in the contrasting results of studies using both correlation and linear regression (e.g., Albishri *et al*., 2012; Alalwan *et al*., 2013). Furthermore, the cited studies, that showed the GAT outperformed or had the same performance as the SAT, used relatively small numbers of the study sample of less than a hundred (Alalwan, 2009; Alalwan *et al*., 2013). Nevertheless, most of the previous studies agree with the present results of multinomial logistic regression, which indicates that the GAT does not increase the cognitive abilities of medical students while the SAT does (e.g., Dabaliz *et al*., 2017). The different effects of the two national tests can be justified by the fact that the SAT measures the same secondary school courses relevant to medical studies, while the GAT assesses arithmetic and verbal skills in Arabic, which is not reflected in English-medium medical studies. However, the present models show that measures of aptitude ability (i.e., GAT) correlate negatively with students' academic performance in the foundation year and slightly affect the non-cognitive clinical performance at graduation. This can be attributed to the fact that aptitude tests assess cognitive skills that do not directly serve preclinical study, and conversely, the GAT also covers some non-cognitive abilities such as critical thinking that appear to contribute slightly to clinical success.

However, the present regression models reveal that student admission based on GSS significantly correlates with student performance throughout the undergraduate career and is the most predictive single criterion. The study demonstrated that increasing GSS contribution to admission criteria increases its ability to predict the achievements of medical students. The current findings regarding the role of GSS in determining university performance are consistent with the results of a previous national study by Dabaliz *et al*. (2017) and Murshid (2013). Although, GSS proves to be the most effective admission criterion, however, it can have been excluded as a single criterion because its average score is 99.2%, which makes it a difficult mechanism to rely on in student screening. Moreover, the university accepts diverse students from almost all Saudi regions, and it is reported that the outcomes of school education affect admission policies and the undergraduate performance of students (Adam *et al*., 2015; Patterson *et al*., 2016). It should be noted that the assessment of secondary schools is based on self-evaluation for each school separately, and there is no national assessment except Qiyas standardized tests after completing the school stage. Therefore, each university is expected to have a unique admission criterion based on a weighted average score (WAS) due to the different outcomes of school in each of the thirteen regions of Saudi Arabia.

Qiyas admission test often provides an additional selection tool to help challenge the distinction among many academically superior applicants. It also measures the attributes needed for applicants to make them good doctors other than academic acknowledge. Therefore, there is a tendency that the selection criteria should have a part to assess non-cognitive skills to predict the potential academic performance of medical students (Alhadlaq *et al*., 2015; Alrukban *et al*., 2010; Murshid, 2013). After adding each of the two admission tests with the GSS in a pairwise mixture, the regression models show that the best predictor of academic achievement in the foundation year is the dual combination of GSS and SAT (criterion B). However, the national education policy is based on admission criteria based on the three school outcomes (i.e., GSS, GAT, and SAT), which are known as weighted average scores (WAS). Therefore, the models suggest the criterion G (50%GSS, 20%GAT, and 30%SAT) or the criterion C (50%GSS, 30%GAT, and 20%SAT), which is based on cognitive and non-cognitive abilities to predict attributes and qualities in the academic and clinical stages of medical education. However, according to Qiyas explicit policy made to institutions, the weight assigned to the GAT in admission criteria should be between 30% and 40%, with the remainder distributed between GSS and SAT (Qiyas, 2022). Criterion C complies with the Qiyas assigned weight to the GAT.

Implications

The importance of the research lies in drawing the attention of educational policymakers to the interest in evaluating selection criteria periodically to make the necessary adjustments that correspond to the inputs and outputs. It is worth mentioning that in addition to medical studies, the GAT is also used in the admission criteria for science and engineering colleges. For this reason, there is no question section directed at measuring specific traits related to medical fields like what is found in UCAT. The current form of the GAT is not effective in predicting the performance of students in medical education programs. The arithmetic question items of GAT need prior knowledge to answer the questions and it is more relevant to engineering programs. It was found that the GAT had a negative effect on graduation rates in both medical and engineering studies, in contrast, it reduced the dropout rates in engineering programs (Bagabir *et al*., 2021). Like the UCAT, the aptitude test should include question items targeting non-cognitive traits of the student such as decision-making, teamwork, interpersonal skills, and professional ethics (Greatrix & Dowell, 2020). This is because medical practitioners need these skills to work effectively and ethically with patients and colleagues and need skills to create alternative options/procedures to choose the best one (Mercer *et al*., 2015; Mommert et al., 2020). Furthermore, it is preferable to expand the existing two subtests (verbal and arithmetic reasoning) of the general aptitude test (GAT) into five subtests like the British test (UCAT), and each subtest is scored separately in the final result. This helps in using the part belonging to each discipline (medical, engineering, or scientific) in the required student selection criteria. Then, 50% of the contribution of the GSS in the weighted criterion C will be from selected courses and 30% of the GAT will be from its subtests relevant to the medicine discipline. Finally, admission criteria may include an English language proficiency test as it positively affects academic performance (Dabaliz *et al*., 2017).

Limitations

This section is devoted to the acknowledgements of the research limitations of the present study. The first limitation to be mentioned is that the study sample consisted of 440 graduates from five cohorts, who took the exams between 2010-2014. Since then, the structures and items of the Qiyas GAT and SAT tests have been modified frequently. Therefore, a similar study could be conducted using an updated dataset to investigate the impact of the modified tests on the performance of the foundation students because there will not be graduates yet. On the other hand, it is assumed that the implications of the current research findings generalize to national medical institutions that use similar admission criteria. However, another limitation is that the study was conducted on a sample of students from one medical college in Saudi Arabia. Therefore, more similar studies in other medical institutions would have a more comprehensive implication on national admissions policy. A third limitation is that the present study only focused on the effect of cognitive admission criteria. More studies are needed to establish the effect of non-cognitive issues on predicting medical student performance.

Conclusion

Saudi higher-education institutions rely on a combination of academic accomplishment and Qiyas academic and aptitude tests for the selection process of prospective students. The present research is based on quantitative criticism to determine the rationale behind differently weighted admission criteria applied to the selection of medical students. The main strength of this study is the use of a sophisticated statistical method to predict the performance of a relatively large number of medical education graduates representing five cohorts. The paper will be useful for academics, researchers, and decision makers to explore broader options in the selection of medical students. The study cannot impose a specific criterion for admission to medical studies because it depends upon the implication and policy of higher-education decision makers.

In general, the current results indicate that the impact of pre-university performance is higher in the foundation year than it is at graduation. This may be because teaching, learning, and assessment in school focus more on the lower cognitive levels of educational learning objectives than the higher cognitive levels and soft skills on which the clinical and professional aspect of the medical practitioner depends. Colleges must bridge the gap with teaching and learning based on active learning and critical thinking pedagogies. However, the present predictive logistic regression models suggest several selection criteria, B, G, and C arranged by the prediction of preclinical achievement in the introductory year, and criteria G, C, and B, ranked based on clinical achievement and prediction. Despite the present study referring to medicine, the findings can be generalized to other health science colleges such as dentistry, nursing, pharmacy, and applied medical sciences. Finally, it is highly recommended that a similar study be conducted in national institutions and that initiatives be taken to revise trends over time and adjust admission policy.

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