



HAL
open science

Motivation and socialization during summer predict medical students' success: An artificial intelligence study

Joris Pensier, Florent Benoist, Lucas Deffontis, Nicolas Boulet, Bader Al Taweel, David Costa, Philippe Deruelle, Delphine Capdevielle, Audrey de Jong, Denis Morin, et al.

► To cite this version:

Joris Pensier, Florent Benoist, Lucas Deffontis, Nicolas Boulet, Bader Al Taweel, et al.. Motivation and socialization during summer predict medical students' success: An artificial intelligence study. *Medical Teacher*, 2024, pp.1-10. 10.1080/0142159X.2024.2429614 . hal-04804154

HAL Id: hal-04804154

<https://hal.science/hal-04804154v1>

Submitted on 26 Nov 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Motivation and socialization during summer predict medical students' success: An artificial intelligence study

Joris Pensier ¹, Florent Benoist ¹, Lucas Deffontis ², Nicolas Boulet ³, Bader Al Taweel ⁴, David Costa ^{5 6}, Philippe Deruelle ⁷, Delphine Capdevielle ⁸, Audrey De Jong ¹, Denis Morin ⁹, Gérald Chanques ¹

¹ Anesthesiology and Intensive Care, Anesthesia and Critical Care Department B, Saint Eloi Teaching Hospital, PhyMedExp, University of Montpellier, INSERM U1046, Montpellier, France.

² Department of Anesthesiology and Critical Care Medicine, Lapeyronie University Hospital, University of Montpellier, Montpellier, France.

³ Department of Anesthesiology, Critical Care, Intensive Care, Pain and Emergency Medicine, Nîmes University Hospital, University of Montpellier, IMAGINE, UR-UM 103, Nîmes, France.

⁴ Digestive Surgery and Transplantation, Montpellier University Hospital, University of Montpellier, Montpellier, France.

⁵ Department of General Practice, School of Medicine, University of Montpellier, France.

⁶ Debrest Institute of Epidemiology and Public Health (IDESP), University of Montpellier, INSERM, France.

⁷ Department of Obstetrics and Gynaecology, Arnaud-de-Villeneuve University Hospital, University of Montpellier, Montpellier, France.

⁸ University Department of Adult Psychiatry, CHU Montpellier, IGF, University of Montpellier, CNRS, INSERM, Montpellier, France.

⁹ Pediatric Nephrology, CHU Montpellier, SORARE reference center, Montpellier, France.

Keywords:

Medical studies; artificial intelligence; machine learning; sociology; teaching.

CONTACT

Joris Pensier pensier.joris@gmail.com Département d'Anesthésie Réanimation B (DAR B), 80 avenue Augustin Fliche, 34295 Montpellier Cedex 5, France

Abstract

Purpose:

The latest reform of French medical studies has moved the National Ranking Examination before residency to the beginning of the sixth-year for undergraduate medical students, thus placing unprecedented workload during the preceding summer. The main objective was to determine whether study conditions and psychosocial factors were associated with student success in this model of intense workload.

Materials and methods:

An online survey designed with six student-partners was sent at a French Medical School after the examination in 2023. The primary outcome was student success in achieving their main goal (Ranking, Knowledge, Well-being). A machine-learning model (eXtreme Gradient Boosting) was developed and explained using Artificial Intelligence. An AI-guided multivariate logistic regression was performed, Odd Ratios were calculated.

Results:

Out of 123 responses, 75 (61%) of the students achieved their main goal. Motivation and socialization during the summer were the two most important variables for predicting student success. In guided multivariate logistic regression, summer motivation (Odd Ratio = 4.12, 95%CI[1.75-10.30]), summer loneliness (Odd Ratio = 0.35, 95%CI[0.14-0.86]), and student's main goal (Ranking, Odd Ratio = 2.94, 95%CI[1.15-7.79]) were associated with student success.

Conclusions:

Motivation and socialization during the summer preceding high-stakes examinations are strongly predictive of undergraduate medical students' success. This study highlights the importance of well-being during summer for student success.[Box: see text].

Introduction

The evolution of teaching methods in medicine is a constant necessity to adapt to new academic and professional requirements [1]. The reform of medical studies in France introduced new pedagogical methods aimed at improving the learning of undergraduate students [2]. Undergraduate medical education in France lasts six years, comprising pre-clinical and clinical education. Sixth-year French medical students undergo National Ranking Examination granting access to residency. This process is the sole determinant of both the specialty and the city in which a student will complete their residency. Until 2023, the National Ranking Examination was a written examination planned in June, at the end of the sixth academic year. The reform of the medical studies split the National Ranking Examination in two parts (Figure 1). The addition of Objective Structured Clinical Examinations (OSCE) was the main evolution of the reform of the medical studies [3–5]. These OSCE take place in June, simultaneously in each French Medical School. Thus, the written test (National Digital Exams, EDN) was advanced to October, at the beginning of the sixth academic year. The EDN and the OCSE account respectively for 60% and 30% (with the remaining 10% accounting for individual cursus including research, associative, professional, or sportive activities), in the new process determining the choice of the specialty and the city for sixth-year medical students. Consequently, the EDN is the most decisive examination to determine a student’s specialty and the location of their residency, making it the most influential examinations in a medical student’s career.

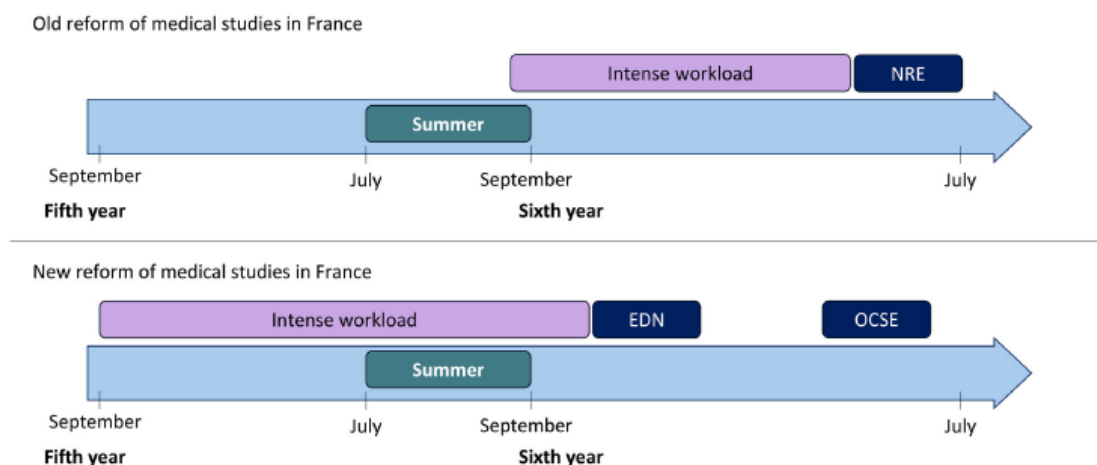


Figure 1. Revision calendar for the National Ranking Exam under the old and new reform of the French medical studies. NRE: National Ranking Examination, EDN: National Digital Exams, OCSE: Objective Structured Clinical Examination

This new schedule has driven medical students to adapt their working methods. The summer between the fifth and the sixth year has become a period of intense workload (Figure 1). The working methods that were passed down from one generation of students to the next since the birth of the National Ranking Examination in 2004 suddenly became obsolete [6,7]. This shift has placed unprecedented pressure on students, making the summer months a critical period

for both academic preparation and personal wellbeing (Context S1, Electronic Supplement). Moreover, Medical Schools and Universities are traditionally closed during the summer. This factor limits the available resources to support the students. Little is known about their study conditions during this time, including where they study when most universities are closed, their access to air conditioning during the hot Southern France summer, and the level of social support available at home.

In this context, motivation and socialization become important factors for students to maintain their focus and manage loneliness [8,9]. Motivation enables students to sustain their intense study schedules [10], while socialization provides support and mitigates the loneliness that can arise during this crucial period [11]. Together, these factors play a vital role in determining a student's ability to balance academic demands with personal well-being [10, 11]. As half of medical students face burnout syndrome during their studies, it is relevant to question the impact of this new schedule on their preparation for the EDN [12–14].

The main objective of this study was to determine the psycho-social factors and study conditions associated with student success at a high-stakes examination, defined according to their personal goal. Our main hypothesis was that psychosocial factors, namely the level of motivation and loneliness experienced by students during the summer preceding the EDN, were associated with student success. This study was constructed and conducted with six second cycle student partners from the Medical School of Montpellier-Nimes (Montpellier University, France), and one student partner (FB) participated in writing the manuscript [15,16].

Materials and methods

Study design

This study is a single-center cross-sectional study conducted by distributing an online survey to 256 sixth-year medical students at the Medical School of Montpellier- Nimes (University of Montpellier) during the 2023–2024 academic year. The survey was sent to students on November 30, 2023. To increase exposure, the survey was sent both by email (Medical School mailing list) and via social networks. Two reminders were set at 7 and 14 days. This survey was retrospectively sent to sixth-year medical students, five weeks after the EDN had taken place. The timing was carefully determined in collaboration with student partners: it was set after the publication of the ranking, which allowed students to self-assess their success or failure based on their personal objectives. It was also sent after the one-month holiday period, in order to maximize participation. Based on discussions with student partners, we anticipated that the response rate would drop significantly if students were asked to participate prospectively during their intensive study period. Students were aware of their results. The study was conducted in accordance with the TRIPOD[‡] AI statement for reporting clinical prediction models that use regression or machine learning methods [17], and the Artificial Intelligence Technology Enhanced Learning (AITELE) checklist (AITELE checklist, Electronic Supplement) [18].

According to Article 2 of Decree No. 2017-884 of May 9, 2017, amending certain regulatory provisions relating to research involving human subjects, 'Research [...] aimed at evaluating [...] teaching practices in the field of health are not considered research involving human subjects within the meaning of this title.' Therefore, approval from an Ethics Committee is

not required. Student consent to participate in this study was considered through voluntary participation. No personal data were collected. The survey was anonymous

Data collection

The survey responses were collected by two authors (JP and FB) in an Excel spreadsheet specifically designed for the study. Demographic data collected included the students' site of attachment (Nimes or Montpellier), student gender (male, female, other, prefer not to say), student residence during the academic year (living alone or with others), study location during the academic year (home, University), and participation in a student association during medical studies.

Regarding the second cycle reform, the impact of organizing the EDN in October on students was collected on a numerical scale from 0 (deterioration) to 10 (improvement), separating the overall impact, the impact on students' work organization, and the impact on students' well-being [19]. The evaluation of the actions led by the Medical School to support students in this reform was collected on a numerical scale from 0 (ineffective) to 10 (effective) [19].

Regarding study organization during the summer, the student's residence during the summer (living alone or with others), the study location during the summer (home, University), and access to air conditioning at the study location were collected. Southern France experiences very high temperatures during the summer, often exceeding 30 °C (86 °F) from June to September, even reaching in the specific region of Montpellier and Nimes the national highest temperature records the two past years. These conditions can make sustained studying particularly challenging, especially during the summer preceding the EDN. As a result, access to air conditioning becomes an essential factor to consider in this setting.

Regarding psychosocial factors, motivation at the beginning of the fifth year of medical studies and during the summer preceding the EDN was collected on a numerical scale from 0 (disinterested) to 10 (motivated) [19]. The loneliness felt at the beginning of the fifth year of medical studies and during the summer preceding the EDN was collected on a numerical scale from 0 (no loneliness) to 10 (loneliness) [19, 20].

The student's main goal during their revisions was collected using a closed-ended question with three categories: ranking in the EDN (Ranking), consolidating a knowledge base for medical practice (Knowledge), and maintaining personal balance and quality of life (Well-being) [7]. Each student chose one of these categories as their main goal. The achievement of these objectives was then assessed through self-assessment, where students reported whether they felt they had succeeded or not in achieving their stated goals. The student's achievement of this objective was dichotomized into success and failure. These goals were elected by the student partners who constructed the study.

Primary endpoint

The primary endpoint was the student's success in achieving their personal goal, dichotomized into success or failure. This primary endpoint was chosen with six sixth-year student partners in the Medical School (listed in the Acknowledgement section), who were consulted in the drafting of the survey, in the study design, and for data interpretation [15, 21].

As the student's goal could be either Ranking in the EDN, consolidating Knowledge, or maintaining Well-being, the student's success was thus evaluated according to a criterion chosen by the student and not according to a single academic ranking criterion [22].

Analyses

A descriptive analysis of the cohort was performed. Quantitative variables were expressed as mean (standard deviation [SD]) or median (interquartile range [IQR], 25–75%), and compared by a Student's t-test or Wilcoxon test according to the distribution of variables (Gaussian or non-Gaussian) [23]. Qualitative variables were expressed as numbers (proportions) and compared using a Chi-square test without correction or Fisher's exact test, depending on the number of events. The Kruskal–Wallis test was used for ordinal variables. No imputation technique for missing data was used [24]. To account for training data bias, we checked for imbalanced classes and for demographic skew [18].

To assess the construct validity of the survey, we conducted a post hoc Exploratory Factor Analysis [25]. The analysis included survey items measured on numerical scales ranging from 0 to 10. The Exploratory Factor Analysis was performed using principal axis factoring with promax rotation to allow for correlated factors. The analysis aimed to identify distinct factors related to the constructs being measured, including the impact of the reform, motivation, and loneliness. Items with high factor loadings on their respective factors were considered indicative of strong construct validity, and the absence of cross-loadings would support discriminant validity between the constructs [25]. To assess the reliability of the two-item scales for motivation and loneliness, we applied the Spearman-Brown Prophecy Formula [26]. This formula was used to estimate the internal consistency of the scales by calculating the correlation between two timepoints: motivation and loneliness measured during the summer and at the beginning of the academic year.

A univariate logistic regression was performed to identify variables associated with student success [27]. Odds Ratios (OR) were calculated with corresponding 95% confidence intervals (95%CI). Predictive variables proposed to the model were the study site, student gender, residence during the academic year, study location during the academic year, participation in an association, residence during the summer, study location during the summer, and access to air conditioning at the study location, motivation at the beginning of the fifth year and during the summer preceding the EDN, loneliness at the beginning of the fifth year and during the summer preceding the EDN, and the student's main goal.

A machine learning model was developed using a gradient boosting tree algorithm called eXtreme Gradient Boosting (XGBoost, version 1.7.8.1) to evaluate the variables associated with student success (Method S1, Electronic Supplement) [28]. XGBoost is a machine learning algorithm that uses a decision tree-based method, where each new tree aims to correct the classification errors of the previous trees in the sample [28]. The machine learning model allows overcoming collinearity issues between variables (motivation at different periods, loneliness and participation in associative life, study location, and access to air conditioning) that invalidate the results of conventionally developed logistic regression models [29]. The model built by XGBoost was represented by a variable importance graph [28]. The model's discrimination performance was measured by the area under the receiver operating characteristic curve (AUC ROC) [30].

An artificial intelligence tool, SHapley Additive exPlanations (SHAP, Method S2, Electronic Supplement), was used to explain the machine learning model [31]. SHAP identifies the most important variables in the model's prediction.

A multivariate logistic regression analysis guided by the machine learning and artificial intelligence model was performed to develop a simplified model [30]. Variables with a p-value < 0.10 in univariate analysis were selected for the multivariate analysis [27,30]. When variables were strongly correlated, only the most important variable in the XGBoost model explained by SHAP was entered into the model. Continuous variables were dichotomized based on the distribution of their SHAP values in the machine learning model [30]. A stepwise procedure was used to select the model based on the Akaike information criterion (AIC) [27]. The absence of collinearity between variables was verified by measuring variance inflation factors (VIF) [27, 32]. The model's discrimination performance was measured by the AUC [30]. Internal validation by bootstrap of each model was performed by resampling with replacement for 2000 iterations [27].

In exploratory analyses, two logistic regression models were developed by adding interaction terms. The second logistic regression model combined interaction terms between the study site and summer motivation, and between the study site and summer loneliness to the previous model. The third logistic regression model combined interaction terms between the student's main goal and summer motivation, and between the student's main goal and summer loneliness to the previous model. The significance of interaction terms was tested by an ANOVA test [24].

The three logistic regression models were used to create a conceptual framework [8]. Tests were two-sided, and a pvalue < 0.05 was considered significant. R software (version 4.3.1) was used for all statistical analyses. BioRender.com was used to design the conceptual framework.

Results

The survey was sent to 256 sixth-year medical students. A total of 123 responses were received (response rate of 48%). Overall, 75 students (61%) considered that they had achieved their main goal. The students' main goal was Ranking for 52% of them (64/123), consolidating knowledge for 31% (38/123), and well-being for 17% (21/123). Table 1 presents the summary of the survey responses. Figure S1 shows the motivation and loneliness of students during the summer according to their success.

Construct validity and reliability

The post hoc Exploratory Factor Analysis identified three distinct factors. Factor 1 (PA1) captured the impact of the reform on the students, Factor 2 (PA2) represented motivation, and Factor 3 (PA3) captured loneliness (Figure S2). The factor loadings for each construct were higher than 0.7, indicating that the items within each factor were highly correlated. No cross-loadings were observed, meaning that the items measuring motivation did not overlap with those measuring loneliness.

Table 1. Summary of survey responses.

Variable	Total (n = 123)	Failure (n = 48)	Success (n = 75)	p-value
Site: Montpellier (vs Nimes)	74 (60%)	19 (42%)	55 (71%)	<0.001
Gender: Female (vs Male)				0.40
Female	87 (71%)	32 (71%)	55 (71%)	
Male	35 (28%)	12 (27%)	23 (29%)	
Other	0 (0%)	0 (0%)	0 (0%)	
Prefer not to say	1 (1%)	1 (2%)	0 (0%)	
Involvement in a student association	79 (64%)	31 (69%)	48 (62%)	0.53
Perceived impact of the schedule (numerical scale of 0-10, 0 = degradation, 10 = improvement)				
Overall impact	3.4 (1.9)	3.0 (1.8)	3.7 (1.9)	0.07
Impact on work organization	3.6 (2.0)	2.9 (1.6)	4.1 (2.0)	<0.001
Impact on well-being	3.1 (2.0)	2.5 (1.8)	3.5 (2.0)	<0.001
Evaluation of the actions of the Medical School (numerical scale of 0-10, 0 = ineffective, 10 = effective)	6.8 (2.2)	6.6 (2.1)	6.8 (2.3)	0.61
Residence during the year: alone (vs shared)	66 (54%)	25 (56%)	41 (53%)	0.89
Residence during the summer: alone (vs shared)	47 (38%)	18 (37%)	29 (39%)	0.90
Change of residence for the summer	44 (36%)	15 (33%)	29 (37%)	0.82
Study location during the year: home (vs University)	57 (46%)	18 (40%)	39 (50%)	0.38
Study location during the summer: home (vs University)	67 (54%)	24 (53%)	43 (55%)	0.99
Change of study location for the summer	65 (53%)	22 (49%)	43 (55%)	0.63
Air conditioning during the summer	60 (49%)	32 (71%)	28 (36%)	<0.001
Motivation at the beginning of the year (numerical scale of 0-10), mean (SD)	7.2 (2.2)	6.8 (2.3)	7.4 (2.2)	0.21
Motivation during summer (numerical scale of 0-10), mean (SD)	6.5 (2.7)	6.2 (2.4)	7.1 (2.5)	<0.001
Loneliness at the beginning of the year (numerical scale of 0-10), mean (SD)	5.6 (2.4)	5.8 (2.4)	5.4 (2.4)	0.38
Loneliness during summer (numerical scale of 0-10), mean (SD)	6.6 (2.5)	7.2 (2.3)	6.2 (2.5)	0.02
Student's main goal				0.04
Ranking	64 (52%)	18 (40%)	46 (59%)	
Knowledge	38 (31%)	20 (44%)	18 (23%)	
Well-being	21 (17%)	7 (16%)	14 (18%)	

In post-hoc analysis using the Spearman-Brown Prophecy Formula, the reliability of the Motivation scale was 0.75, indicating acceptable internal consistency. For the Loneliness scale, the reliability was 0.61, indicating moderate internal consistency.

Univariate analysis

The results of the univariate analysis are presented in Table 2. Variables associated with student success were the Montpellier site (OR = 3.23; 95%CI [1.54–7.14], $p < 0.01$), air conditioning (OR = 0.23; 95%CI [0.10–0.49], $p < 0.01$), summer motivation (OR = 1.28; 95%CI [1.07–1.55], $p < 0.01$), summer loneliness (OR = 0.83; 95%CI [0.71–0.97], $p = 0.03$), and the student's main goal (Ranking vs Knowledge: OR = 2.84; 95%CI [1.24–2.66], $p = 0.02$). Association between air conditioning and other significant variables in univariate analysis is displayed in Table S1.

Table 2. Univariate analysis.

Variable	Odd Ratio	95% CI	p-value
Site: Montpellier (vs Nimes)	3.23	[1.54 – 7.14]	<0.01
Gender: Female (vs Male)	0.89	[0.38 – 2.00]	0.89
Involvement in a student association	0.72	[0.33 – 1.56]	0.41
Residence during the year: alone (vs shared)	0.88	[0.42 – 1.85]	0.75
Residence during the summer: alone (vs shared)	0.94	[0.36 – 2.14]	0.79
Change of residence for the summer	1.18	[0.55 – 2.59]	0.67
Study location during the year: home (vs University)	1.49	[0.71 – 3.23]	0.28
Study location during the summer: home (vs University)	1.07	[0.51 – 2.27]	0.84
Change of study location for the summer	1.28	[0.62 – 2.69]	0.51
Air conditioning during the summer	0.23	[0.10 – 0.49]	<0.01
Motivation at the beginning of the year (per point)	1.11	[0.94 – 1.32]	0.20
Motivation during summer (per point)	1.28	[1.07 – 1.55]	<0.01
Loneliness at the beginning of the year (per point)	0.93	[0.80 – 1.09]	0.38
Loneliness during summer (per point)	0.83	[0.71 – 0.97]	0.03
Student's main goal			
Ranking	2.84	[1.24 – 6.66]	0.02
Well-being	2.22	[0.75 – 7.03]	0.16
Knowledge	1	reference	reference

Machine learning model

Summer motivation and summer loneliness were the two most important variables associated with student success in the model developed by XGBoost (Figure 2(A)). These were followed by the study site, the academic year residence, and the change of study location for the summer. All students were correctly classified by the model. The confusion matrix is presented in Table S2. The AUC of the model was 1.00 (95%CI [0.97–1.00]). In internal validation by bootstrap, the model’s AUC was 1.00 (95%CI [0.96–1.00]).

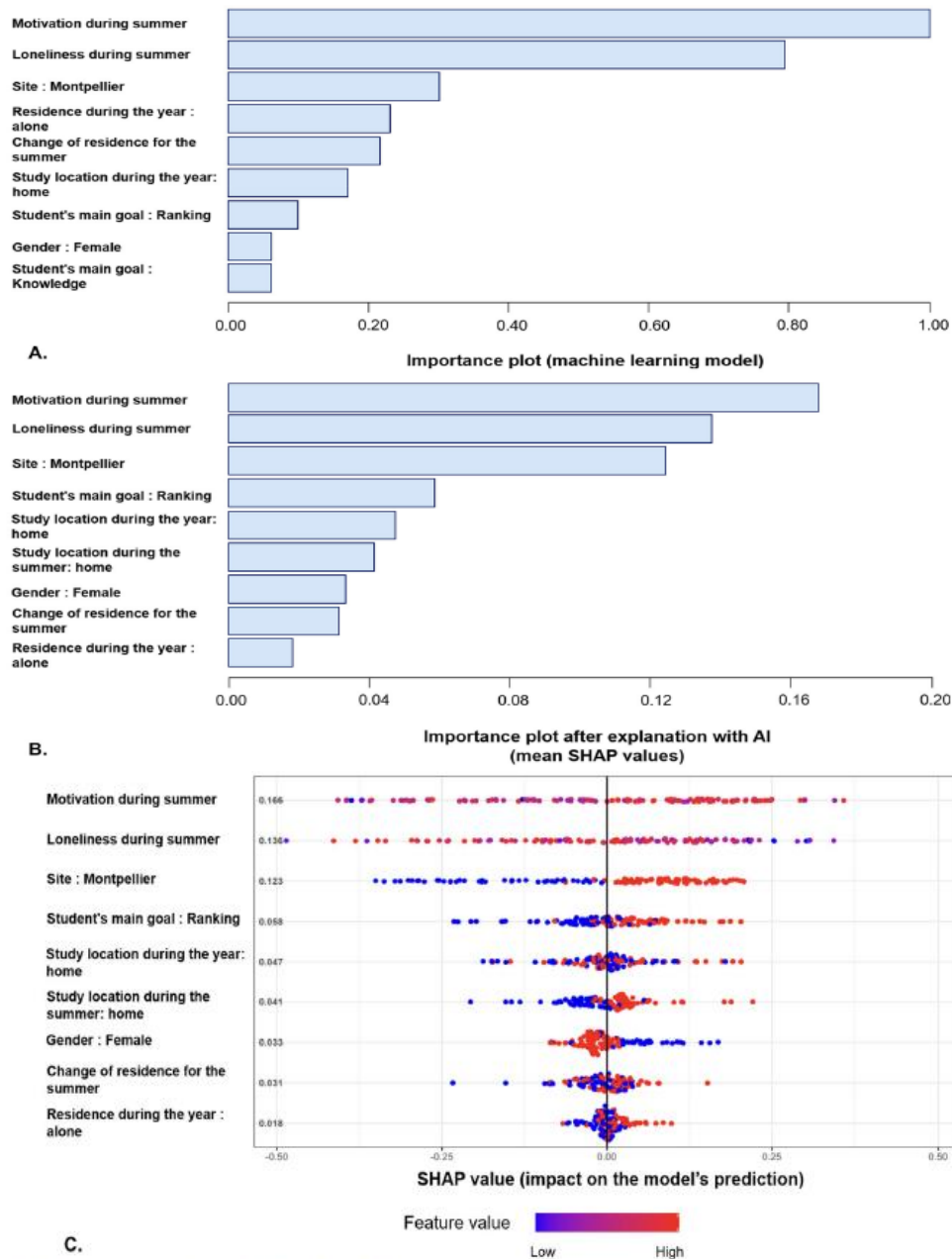


Figure 2. Machine learning model explained by artificial intelligence.

A. Predictive variables for student success in the machine learning model.

The variables are organized by relative importance from top to bottom. The most important variable is at the top of the chart, represented by a relative importance value of 1. The relative importance of each variable is represented for each variable.

B. Predictive variables for student success according to SHAP explanation.

The variables are organized by relative importance from top to bottom. The most important variable is at the top of the chart. The average SHAP value is represented for each variable.

C. SHAP summary plot of the importance of variables in predicting student success.

A summary plot using the SHAP artificial intelligence tool of the importance of variables in the model prediction. Each student is represented by a dot on each line. The color of the dot represents the value of the variable. The position of the dot on the horizontal axis represents its SHAP value, i.e., its impact on the model's prediction. The further to the right a dot is located on the chart, the more it increases the probability of student success in the machine learning model.

Explanation of the model with artificial intelligence

Summer motivation and summer loneliness were the two most important variables (respective SHAP values 0.17 and 0.14) associated with student success after explanation of the machine learning model by SHAP (Figure 2(B,C)). These were followed by the study site and Ranking as the student's main goal (respective SHAP values 0.12 and 0.06). Figure S3 presents the SHAP values according to summer motivation and summer loneliness. A summer motivation of 8/10 or higher increased the probability of student success, and a summer loneliness of 8/10 or higher decreased the probability of student success (Figure S3).

Logistic regression model

The study site, summer motivation (<8/10 vs ≥8/10), summer loneliness (<8/10 vs ≥8/10), and the student's goal were significantly associated with student success in the logistic regression model (Table 3, Figure S4). The model's AUC was 0.77 (95% CI [0.68–0.86]). In internal validation by bootstrap, the model's AUC was 0.75 (95% CI [0.66–0.84]).

Table 3. Multivariate logistic regression model.

Variable	Odd Ratio	95% CI	p-value
Site: Montpellier (vs Nimes)	3.44	[1.54 – 8.33]	<0.01
Motivation during summer (≥8/10)	4.12	[1.75 – 10.3]	<0.01
Loneliness during summer (≥8/10)	0.35	[0.14 – 0.86]	0.02
Student's main goal			
Ranking	2.94	[1.15 – 7.79]	0.03
Well-being	2.42	[0.67 – 9.43]	0.19
Knowledge	1	reference	reference

Exploratory logistic regression models with interaction terms

The interaction between the study site and summer motivation, and the interaction between the study site and summer loneliness were both significant in the second model by ANOVA test (respectively $p < 0.001$ and $p = 0.03$). Summer motivation and summer loneliness at the Nimes site were significantly associated with success (Table S3). For students at the Montpellier site, neither summer motivation nor summer loneliness was significantly associated with success. The effects of summer motivation and summer loneliness by site are shown in Figure S5 and Figure S6.

The third regression logistic model is shown in Table S4. The interaction between the student's main goal and summer motivation was not significant in the third model by ANOVA test ($p = 0.36$). The interaction between the student's main goal and summer loneliness was significant in the third model by ANOVA test ($p < 0.001$). The effects of summer motivation and summer loneliness by student's main goal are shown in Figures S7 and S8.

Conceptual framework

The results of the three logistic regression models were used to conceive a conceptual framework linking summer motivation and summer socialization to student's success, with the study site and the student's main goal as moderators (Figure 3.).

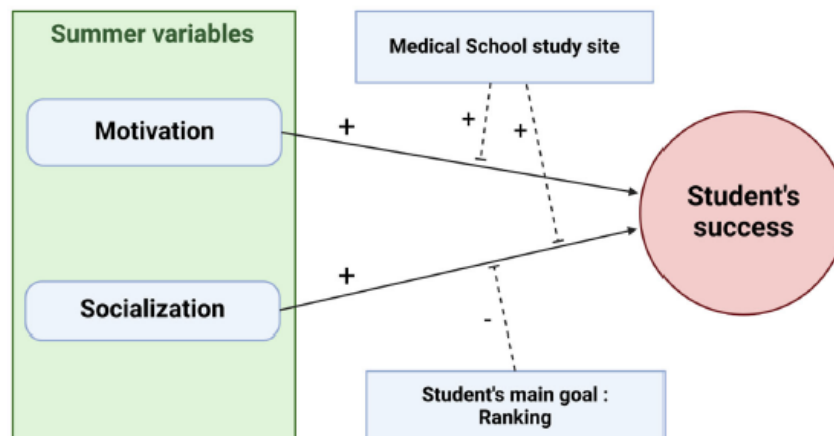


Figure 3. Conceptual framework of the association of summer motivation and socialization with the student's success.

Discussion

In this study, evaluating the responses of 123 sixth-year undergraduate medical students from a French Medical School to an online survey designed with student partners, summer motivation, and summer loneliness were the two variables most associated with personal success in a machine learning model. This model was able to predict a student's success with an AUC of 1.00 (95% CI [0.96–1.00]) after internal validation. The artificial intelligence used to explain the model showed that a summer motivation level of 8/10 or higher and a summer loneliness level below 8/ 10 were associated with a higher probability of success. The significant association of these two variables with student success persisted in logistic regression models. A conceptual framework was designed.

The first result of this study highlighted that, in the context of the high-stakes EDN examination, which determines the specialties and cities of residency for medical students, 52% of students prioritized ranking, 31% focused on consolidating knowledge, and 17% prioritized personal wellbeing. This illustrates that while the examination result remains the primary concern for most students, personal well-being is becoming an increasingly important consideration for undergraduate medical students.

Regarding the psychometrics properties of our survey, the factor loadings in Exploratory Factor Analysis (Figure S2.) for each construct were high, indicating that the items within each factor were highly correlated, thereby supporting the coherence of the constructs. Content validity was ensured through this collaborative design process, involving both the student partners and faculty professors. The survey was then piloted with four additional students to refine the questions for clarity and relevance. Importantly, no cross-loadings were observed, meaning that the items measuring motivation did not overlap with those measuring loneliness, providing strong evidence for discriminant validity. In terms of reliability, post hoc analysis showed an acceptable internal consistency for the Motivation scale and a moderate internal consistency for the Loneliness scale.

The association of motivation with academic success has been reported in the literature [10, 33]. Our study is the first to quantify its direct impact in the context of the EDN. The threshold level of 8/10 means that maintaining very high motivational levels is necessary during the summer before the sixth year of medical studies (Figure S3).

Loneliness has been associated with medical studies around the world [9, 11]. The current student promotions are particularly at risk of loneliness as they have been marked by constrained distance learning during the COVID-19 pandemic [34]. Preventing loneliness in undergraduate medical students should be a priority for universities, especially in periods of intense workload [9, 20]. Interventions promoting peer assistance and mentoring have been effective in fostering socialization among students [9]. During the 2024–2025 academic year, a methodological tutoring program will be organized at our Medical School by sixth-year student partners for fifth-year students to enhance inter-class connections. The implementation of a chatbot to prevent and diagnose loneliness, anxiety, and depression in undergraduate students during the summer will be studied in our Medical School [35, 36]. Recently, a chatbot demonstrated effectiveness in mitigating loneliness and suicidal ideation in international students [35]. Given the reduced availability of human resources in Medical Schools and Universities during the summer, this intervention may help to detect at-risk students and provide them with tailored, multifaceted support.

The study site (Nimes or Montpellier) was significantly associated with students' success (Table 3). The exploratory logistic regression model showed a significant interaction between the study site and summer motivation or summer loneliness (Table S3). The effects of loneliness and decreased motivation are particularly significant for students at the Nimes site. This result can be partially explained because top-ranked students after the first year of medical school preferentially choose Montpellier. After discussions with the six student partners, this result can be explained by the geographical location of the Nimes site, outside the city center and without nearby amenities (restaurants, shops). To address this difference, students proposed organizing close monitoring for all students with the option to request a mentor, with enhanced communication at Nimes starting in summer 2024. The Medical School increased the number of accessible study places during the summer and extended the opening hours, requiring the recruitment of additional security staff, thus making a financial effort to maintain student connections and reduce the impact of social inequalities during the summer [37, 38]. The study site also partially explained the surprising association between air conditioning and lower success in univariate analysis.

The association of socialization with the student's success was lower when the student's main goal was the ranking at the National Ranking Exam (Figure 3). It indicates that students aiming at the ranking are more prone to tolerate loneliness during the study period. The search of academic performance above all might be a barrier to mental health care in medical students [39]. It might also indicate that students with mental health issues are less able to reach academic performance in medical school, as described in a recent study [40].

The artificial intelligence's explanation of the model showed a small effect of gender on student success (Figure 2B). Female gender decreased the probability of success in the model's prediction. However, gender was not significantly associated with success in the multivariate logistic regression model. While the proportion of female students in medical studies is increasing worldwide [41], some studies have shown that women are more exposed to psychosocial risks during their health studies, including anxiety and depression [42,43].

The involvement of six student partners in this study is its main strength. Their expectations and interpretations were considered in the study design and data analysis [21, 44]. The choice of the primary endpoint was decided with them, to not only consider academic results as in previous studies [6, 45]. The originality of this study lies in a change of mindset that allows students to choose their own objective: either ranking, consolidating knowledge or maintaining well-being. They can consider themselves successful regardless of their ranking. The student partners' contribution allowed designing student-led interventions [46]. The organization of methodological mentoring and personal support during the summer will be effective next summer and coordinated by senior students themselves. The Medical School supported student requests by increasing the number of study places open during the summer to reduce loneliness and support student motivation [47]. The survey will be sent again next year to evaluate the impact of these changes [46]. Another strength of the study is the use of statistical techniques based on machine learning and artificial intelligence to overcome collinearity issues between variables and provide explainable and actionable results. Logistic regression models performed without a first step of machine learning and artificial intelligence showed high collinearity. This study is the first to highlight the importance of the summer preceding the National Ranking Examination on student success. The strong associations between summer motivation and loneliness and student success increase the internal validity of the study.

The main limitation of the study is the limited number of participants (n=123), as the study was conducted at a single center. The survey was filled out by students retrospectively one month after the EDN, so a recall bias is possible. Unknown and uncontrolled confounding factors may exist. Then, the response rate was only of 48%. Since the survey was anonymous, we could not study the demographics and results of students who responded to the survey compared to those who did not respond. The survey was sent retrospectively, as we anticipated that the response rate would drop if students were asked to participate during their intensive study period. Moreover, since this study allowed students to choose their own objective, it was challenging to maintain the comparability between the objectives of ranking, knowledge, and well-being, as well as to avoid participants' subjective views. To address this, we approached each goal from the perspective of individual student priorities, reflecting the diversity of their experiences and motivations during their studies. To ensure a structured analysis despite the inherent diversity of goals, we dichotomized the primary endpoint into success or failure.

Finally, the measurement of psychometric properties of the survey was not prospectively planned. Thus, we did not assess test-retest reliability or compare multiple motivation and loneliness scales.

Conclusion

Motivation and socialization during the summer preceding National Ranking Exam are strongly predictive of undergraduate medical students' success, in a machine learning model explained by artificial intelligence. This study, performed with undergraduate student partners, highlights the importance of the summer preceding high-stakes examination for medical students.

Acknowledgements

The authors thank Assiah Imzourh, Yasmine El Marrouni, Nisrine Hdid, Alexandre Carrat, and Alexandre Pommier, student partners of the study. The authors also thank Brigitte Lundin, director of the Support Center for Pedagogical Innovations of the University of Montpellier, for her review of the manuscript.

Authors' contributions

JP, FB, LD, NB, BAT, DM and GC designed the study. JP and FB acquired the data. JP and ADJ performed the data analysis. JP, FB, DCo, PD, DCa, DM and GC were involved in data interpretation. JP, FB, LD, NB, BAT, DM and GC drafted the manuscript and all authors reviewed it. All authors approved the final version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Disclosure statement

ADJ reports receiving speaker fees from Medtronic, Sanofi, Fisher and Paykel, Sedana, Viatrix, Mindray. Other authors declare no conflicts of interest.

Notes on contributors

Joris Pensier Anesthesiology and Intensive Care; Anesthesia and Critical Care Department B, Saint Eloi Teaching Hospital, PhyMedExp, University of Montpellier, INSERM U1046, 1; 80 avenue Augustin Fliche, Montpellier Cedex 5, France.

Florent Benoist Anesthesiology and Intensive Care; Anesthesia and Critical Care Department B, Saint Eloi Teaching Hospital, PhyMedExp, University of Montpellier, INSERM U1046, 1; 80 avenue Augustin Fliche, Montpellier Cedex 5, France.

Lucas Deffontis Department of Anesthesiology and Critical Care Medicine, Lapeyronie University Hospital, University of Montpellier, Montpellier Cedex 5, France.

Nicolas Boulet Department of Anesthesiology, Critical Care, Intensive Care, Pain and Emergency Medicine, Nîmes University Hospital, University of Montpellier, IMAGINE, UR-UM 103, Place du Professeur Debré, Nîmes, France.

Bader Al Taweel Digestive Surgery and Transplantation, Montpellier University Hospital, University of Montpellier, Montpellier Cedex 5, France.

David Costa Department of general practice, School of Medicine, University of Montpellier, France; Debrest Institute of Epidemiology and Public Health (IDESP), University of Montpellier, INSERM, France.

Philippe Deruelle Department of Obstetrics and Gynaecology, Arnaud de Villeneuve University Hospital, University of Montpellier, Montpellier Cedex 5, France.

Delphine Capdevielle University Department of Adult Psychiatry, CHU Montpellier, IGF, University of Montpellier, CNRS, INSERM, Montpellier, France.

Audrey De Jong Anesthesiology and Intensive Care; Anesthesia and Critical Care Department B, Saint Eloi Teaching Hospital, PhyMedExp, University of Montpellier, INSERM U1046, 1; 80 avenue Augustin Fliche, Montpellier Cedex 5, France.

Denis Morin Pediatric Nephrology, CHU Montpellier, SORARE reference center, Montpellier, France.

Gérald Chanques Anesthesiology and Intensive Care; Anesthesia and Critical Care Department B, Saint Eloi Teaching Hospital, PhyMedExp, University of Montpellier, INSERM U1046, 1; 80 avenue Augustin Fliche, Montpellier Cedex 5, France.

Data availability statement

The data that support the findings of this study are available from the corresponding author (JP), upon reasonable request.

References

1. Frenk J, Chen L, Bhutta ZA, et al. Health professionals for a new century: Transforming education to strengthen health systems in an interdependent world. *Lancet*. 2010;376(9756):1923–1958. doi: 10.1016/S0140-6736(10)61854-5
2. Ollier E, Pelissier C, Boissier C, et al. Analyse systématique des évaluations de circuits multiples d'examen clinique objectif structuré (ECOS): variables explicatives et corrélations inter-évaluateurs. *La Revue De Médecine Interne*. 2024;45(6):327–334. doi: 10.1016/j.revmed.2024.03.013
3. Sharma A, Hassan-Smith Z, Stocker CJ. Peer-led formative OSCEs: Enhancing learning medicine together. *Med Educ*. 2023; 57(11):1120–1121. doi: 10.1111/medu.15225
4. Khan R, Payne MWC, Chahine S. Peer assessment in the objective structured clinical examination: A scoping review. *Med Teach*. 2017;39(7):745–756. doi: 10.1080/0142159X.2017.1309375
5. Teichgraber U, Ingwersen M, Sturm M-J, et al. Objective structured clinical examination to teach competency in planetary health care and management – a prospective observational study. *BMC Med Educ*. 2024;24(1):308. doi: 10.1186/s12909-024-05274-9
6. Lhuire M, Dramé M, Hivelin M, et al. Predictive factors of success at the French National Ranking Examination (NRE): a retrospective study of the student performance from a French medical school. *BMC Med Educ*. 2019;19(1):469. Dec doi: 10.1186/s12909-019-1903-5
7. Hill MR, Goicochea S, Merlo LJ. In their own words: stressors facing medical students in the millennial generation. *Med Educ Online*. 2018;23(1):1530558. doi: 10.1080/10872981.2018.1530558

8. Norouzi A, Parmelee D, Norouzi S, et al. Metamotivation in medical education: the 4F conceptual framework. *Med Teach.* 2024; 46(10):1304–1314. doi: 10.1080/0142159X.2024.2308068
9. Cheng SM, Taylor DL, Fitzgerald AA, et al. Build & belong: a peer-based intervention to reduce medical student social isolation. *Teach Learn Med.* 2022;34(5):504–513. doi: 10.1080/10401334.2021.1984921
10. Wu H, Li S, Zheng J, et al. Medical students' motivation and academic performance: The mediating roles of self-efficacy and learning engagement. *Med Educ Online.* 2020;25(1):1742964. doi: 10.1080/10872981.2020.1742964
11. Walton GM, Cohen GL. A brief social-belonging intervention improves academic and health outcomes of minority students. *Science.* 2011;331(6023):1447–1451. doi: 10.1126/science.1198364
12. IsHak W, Nikraves R, Lederer S, et al. Burnout in medical students: a systematic review. *Clin Teach.* 2013;10(4):242–245. doi: 10.1111/tct.12014
13. Meeks LM, Pereira-Lima K, Plegue M, et al. Disability, program access, empathy and burnout in US medical students: a national study. *Med Educ.* 2023;57(6):523–534. doi: 10.1111/medu.14995
14. Rolland F, Hadouiri N, Haas-Jordache A, et al. Mental health and working conditions among French medical students: a nationwide study. *J Affect Disord.* 2022;306:124–130. doi: 10.1016/j.jad.2022.03.001
15. Mabvuure NT. Twelve tips for introducing students to research and publishing: a medical student's perspective. *Med Teach.* 2012;34(9):705–709. doi: 10.3109/0142159X.2012.684915
16. Li SL, Ivatorov A, Donroe J, et al. Incorporating undergraduate students into graduate medical education. *Med Educ.* 2023;57(5):464–465. doi: 10.1111/medu.15047
17. Collins GS, Moons KGM, Dhiman P, et al. TRIPOD β AI statement: updated guidance for reporting clinical prediction models that use regression or machine learning methods. *BMJ.* 2024;385: E078378. doi: 10.1136/bmj-2023-078378
18. Masters K, Salcedo D. A checklist for reporting, reading and evaluating Artificial Intelligence Technology Enhanced Learning (AITELE) research in medical education. *Med Teach.* 2024; 46(9):1175–1179. doi: 10.1080/0142159X.2023.2298756
19. Tourangeau R, Conrad FG, Couper MP. *The Science of Web Surveys* [Internet Oxford University Press; 2013]. ; [cited 2024 Apr 27]. Available from: <https://academic.oup.com/book/12050>.
20. Bull S, Terry R, Rice N, et al. Social connections and social identity as a basis for learning and support: Experiences of medical students with minoritised and non-minoritised ethnic identities. *Med Educ.* 2024;58(9):1126–1135. doi: 10.1111/medu.15367

21. Zhang G, Wu H, Xie A, et al. The association between medical student research engagement with learning outcomes. *Med Educ Online*. 2022;27(1):2100039. doi: 10.1080/10872981.2022.2100039
22. Fikrat-Wevers S, Stegers-Jager K, Groenier M, et al. Applicant perceptions of selection methods for health professions education: rationales and subgroup differences. *Med Educ*. 2023;57(2): 170–185. doi: 10.1111/medu.14949
23. Pensier J, De Jong A, Monet C, et al. Outcomes and time trends of acute respiratory distress syndrome patients with and without liver cirrhosis: An observational cohort. *Ann Intensive Care*. 2023;13(1):96. doi: 10.1186/s13613-023-01190-1
24. Aarab Y, Debourdeau T, Garnier F, et al. Management and outcomes of COVID-19 patients admitted in a newly created ICU and an expert ICU, a retrospective observational study. *Anaesth Crit Care Pain Med*. 2024;43(1):101321. doi: 10.1016/j.accpm.2023.101321
25. Robertson KA, Gunderman DJ, Byram JN. Formative peer evaluation instrument for a team-based learning course: content and construct validity. *Med Teach*. 2024;8:1–7. doi: 10.1080/0142159X.2024.2374511
26. Zaidi NB, Swoboda C, Wang LL, et al. Variance in attributes assessed by the multiple mini-interview. *Med Teach*. 2014;36(9): 794–798. doi: 10.3109/0142159X.2014.909587
27. Pensier J, De Jong A, Chanques G, et al. A multivariate model for successful publication of intensive care medicine randomized controlled trials in the highest impact factor journals: the SCOTI score. *Ann Intensive Care*. 2021;11(1):165. doi: 10.1186/s13613-021-00954-x
28. Sinha P, Churpek MM, Calfee CS. Machine learning classifier models can identify acute respiratory distress syndrome phenotypes using readily available clinical data. *Am J Respir Crit Care Med*. 2020;202(7):996–1004. doi: 10.1164/rccm.202002-0347OC
29. Bayman EO, Dexter F. Multicollinearity in logistic regression models. *Anesth Analg*. 2021;133(2):362–365. doi: 10.1213/ANE.0000000000005593
30. Sunaga Y, Watanabe A, Katsumata N, et al. A simple scoring model based on machine learning predicts intravenous immunoglobulin resistance in Kawasaki disease. *Clin Rheumatol*. 2023;42(5):1351–1361. doi: 10.1007/s10067-023-06502-1
31. Dupont T, Kentish-Barnes N, Pochard F, et al. Prediction of posttraumatic stress disorder in family members of ICU patients: a machine learning approach. *Intensive Care Med*. 2024;50(1):114–124. doi: 10.1007/s00134-023-07288-1
32. Reyes LF, Murthy S, Garcia-Gallo E, et al. Respiratory support in patients with severe COVID-19 in the International Severe Acute Respiratory and Emerging Infection (ISARIC) COVID-19 study: a prospective, multinational, observational study. *Crit Care*. 2022;26(1):276. doi: 10.1186/s13054-022-04155-1
33. Wouters A, Croiset G, Galindo-Garre F, et al. Motivation of medical students: Selection by motivation or motivation by selection. *BMC Med Educ*. 2016;16(1):37. doi: 10.1186/s12909-016-0560-1

34. Tabari P, Amini M. Educational and psychological support for medical students during the COVID-19 outbreak. *Med Educ.* 2021;55(1):125–127. doi: 10.1111/medu.14376
35. Maples B, Cerit M, Vishwanath A, et al. Loneliness and suicide mitigation for students using GPT3-enabled chatbots. *Npj Ment Health Res.* 2024;3(1):4. doi: 10.1038/s44184-023-00047-6
36. Klos MC, Escoredo M, Joerin A, et al. Artificial intelligence–based chatbot for anxiety and depression in university students: pilot randomized controlled trial. *JMIR Form Res.* 2021;5(8):e20678. doi: 10.2196/20678
37. An M, Ma X, Wu H. Medical students’ academic satisfaction: social cognitive factors matter. *Med Educ.* 2023;57(12):1239–1247. doi: 10.1111/medu.15070
38. Scheepers RA, Hilverda F, Vollmann M. Study demands and resources affect academic well-being and life satisfaction of undergraduate medical students in the Netherlands. *Med Educ.* 2024;58(9):1097–1106. doi: 10.1111/medu.15456
39. Thesen T, Marrero WJ, Konopasky AJ, et al. Towards precision well-being in medical education. *Med Teach.* 2024:1–5. doi: 10.1080/0142159X.2024.2357279
40. Humes EC, Iosifescu DV, Siqueira JO, et al. Association of performance in medical residency selection with a psychiatric diagnosis, and depressive and anxiety symptoms. *Med Teach.* 2024: 1–9. doi: 10.1080/0142159X.2024.2337248
41. Watari T, Mizuno K, Sakaguchi K, et al. Gender inequality improvement in medical school admissions in Japan. *J Womens Health (Larchmt).* 2024;33(3):339–344. doi: 10.1089/jwh.2023.0291
42. Rodr_iguez-Roca B, Subir_on-Valera AB, Gasch-Gall_en _A, et al. Gender self-perception and psychological distress in healthcare students during the COVID-19 pandemic. *Int J Environ Res Public Health.* 2021;18(20):10918. doi: 10.3390/ijerph182010918
43. Luong V, Ajjawi R, Burm S, et al. Unravelling epistemic injustice in medical education: The case of the underperforming learner. *Med Educ.* 2024;58(11):1286–1295. doi: 10.1111/medu.15410
44. Kassab SEE, Sayed W, Hamdy H. -Student engagement in undergraduate medical education: A scoping review. *Med Educ.* 2022; 56(7):703–715. doi: 10.1111/medu.14799
45. Azoyan L, Lombardi Y, Renaud MC, et al. Association entre les performances cliniques des étudiants et leur réussite aux Épreuves classantes nationales informatisées: Une étude de cohorte rétrospective monocentrique. *La Revue De Médecine Interne.* 2023;44(1):5–11. doi: 10.1016/j.revmed.2022.07.004
46. Kirubakaran S, Kumar K, Worley P, et al. Establishing new medical schools in diverse contexts: a novel conceptual framework for success. *Med Educ.* 2024; May 27;medu.15421. doi: 10.1111/medu.15421

47. Chanques G. 1220-2020: Le 800e anniversaire de l'enseignement médical universitaire dans le contexte d'une nouvelle pandémie – leçon inaugurale du congrès biennal de la SFVTT à Montpellier. *Transfus Clin Biol.* 2022;29(4):279–286. doi: 10.1016/j.tracli.2022.08.149

