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RESEARCH

Equity, Diversity and Inclusion

# Exploring institutional stratification: Minority-serving institutional pathways to medical school acceptance in the United States

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## Abstract

**Introduction:** Recruiting and training a diverse pool of physicians from historically excluded groups is vital to solving complex scientific problems and increasing access to patient care. Disparate educational and health outcomes of COVID-19 amplified this need. In stratified higher education systems, underfunded institutions that serve greater numbers of underrepresented in medicine (URM) students face unique barriers to entering physician training. However, pathways from historically underfunded minority-serving institutions (MSIs) in the United States to medical school (MD) are not well understood.

**Method:** A hierarchical logistic regression analysis of 328 488 de-identified applicants to US MD-granting medical schools for academic years 2017–2018 through 2022–2023 was used to determine predictors of acceptance based on MSI attendance compared to predominantly White institutions (PWI) and other literature-informed predictors. An interrupted time series analysis determined the significance in changes in observed differences in application acceptance before and after the COVID-19 pandemic.

**Results:** In model 1, MSI attendance was associated with significantly lower odds of acceptance, with a 42% to 52% chance of acceptance compared to PWI applicants. Adding MCAT and GPA significantly increased odds of acceptance for most MSI applicants in model 2. MSI attendance, MCAT, GPA and socio-economic status indicators were useful predictors, improving the acceptance model by 39% better than the null model. Although some predictors showed a change in odds over time, none changed significantly when comparing before and after COVID-19.

**Discussion:** MSI attending students were less likely to be admitted to MD programmes, highlighting systemic stratification until other academic factors were introduced to the model that alleviated lower odds, and the COVID-19 pandemic did not substantially change these trends. Improved pathways and strengthened institutional relationships between institutions that have greater proportions of underrepresented

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students and medical schools may help improve MSI applicant odds furthering diversity within the physician-trained workforce.

## 1 | INTRODUCTION

Postsecondary education in the United States, unlike most systems internationally, is not coordinated by a central agency.[1] Instead, it is highly decentralised and can be best described as a 'system of systems' with considerable influence coming from a myriad of stakeholders, including states and national accreditation agencies.[1,2] The influence of the national government is perhaps most significant in its role as an institutional funding stream. American postsecondary education is highly stratified due to factors including funding sources, mission and selectivity, which systematically harms underrepresented students.[2,3] While the makeup of the collegiate student body is extremely diverse, and underrepresented groups are making gains, underrepresented students are attending less selective institutions, which limits their access to graduate school.[4,5]

Medical training pathways vary by country, and in the United States, an undergraduate degree is required before seeking admission to medical school.[6] Attending a highly selective undergraduate institution is positively correlated with enrolling in a post-baccalaureate medical programme, but lower-income and underrepresented students are less likely to attend such institutions.[7,8] Globally, matriculants to medical schools face a multifaceted and competitive admission process considering various academic criteria.[6] In the United States, the undergraduate grade point average (GPA) and a standardised medical school entrance examination (MCAT) are key factors.[9,10] It is known within the literature that GPA and MCAT scores demonstrate collinearity and may offer predictive value in assessing potential success in medical school.[10–12] However, underrepresented students tend to perform lower in the MCAT and GPA metrics due to various factors, including the lack of access to MCAT preparatory courses or decreased study time due to employment obligations.[13] American medical school admissions committees also consider non-academic criteria such as an applicant interview and extracurricular activities.[8,9] For this reason, many 'prospective physicians seek advantages to differentiate themselves from the masses'.[9]

## 2 | STRATIFICATION THEORY

Stratification theory refers to the concept that educational opportunities and outcomes are unequally distributed across social groups, which reinforces social hierarchy.[14] Higher education contributes to stratification by emphasizing cultural capital through prestige and legitimizing social inequality in funding.[15] Globally higher education promotes a stratified structure of opportunity, ranging from highly selective universities and high-profile professional degrees to the spaces occupied by mass education with uncertain outcomes.[16] High public spending and no tuition led to relatively flat stratification in Nordic societies.[17] In contrast, South Korean society merges high social mobility with a stratified system prioritizing elite universities and high private costs in other institutions.[17] Stratification and tuition are higher in Canada compared to Europe but more modest than in the United States where financial impediments are aggravated by larger social inequalities.[17,18] Postsecondary stratification virtually guarantees that students from wealthier families have an increased likelihood of graduating from the most prestigious educational programmes and securing better career prospects.[16]

## 3 | MINORITY-SERVING INSTITUTION SUB-SETS

There are four historically underfunded minority-serving institution (MSI) sub-sets explored in this study that represent nearly half of all undergraduate institutions in the United States.[19] First is the Strengthening Institutions Program (SIP), which qualify to compete for federal funding based on the number of low socio-economic students attending the school.[20] SIP receives the largest proportion MSI-designated federal awards with $127 million dollars allocated to 301 institutions.[20] Second, Hispanic-serving institutions (HSIs) must enrol at least 25% full-time equivalent students self-identifying as Hispanic to compete for MSI-designated federal funds.[21] In 2022, there were 571 HSIs across 28 states, with an additional 401 emerging HSIs nearing designation.[22,23] Third, Asian American and Native American Pacific Islander-serving institutions (AANIPISIs) must enrol at least 10% full-time equivalent students identifying as Asian American, Native American or Pacific Islander.[24] This institution type totalled 192 institutions in 2022 and served an AAPI student population, which represents more than 48 ethnicities.[24] Finally, fourth, predominantly Black institutions (PBIs) and historically Black colleges and universities (HBCUs) combined provide critical pathways to higher education for African American students.[25,26] PBIs are based on percentage of low socio-economic students who are at least 40% African American.[25] In 2021, there were 97 federally funded and accredited HBCUs with a student demographic that identified as 83% Black,[27] accounting for 16% enrolment and 24% baccalaureate graduations earned by African Americans nationwide.[28]

## 4 | STRATIFIED MSI FUNDING

Because of the highly stratified system and the need to sustainably offer competitive advantage to its students, many institutions seek grants, contracts, endowments and revenue from auxiliary sources.[29,30] However, routinely underfunded US postsecondary institutions such as MSIs only receive 5% of total revenue from private gifts, grants and contracts compared to 22% predominantly White institutions (PWIs).[31] State appropriations to HBCUs have been

substantially lower for decades than their PWI counterparts.[30,32] As a result, MSIs spend significantly less per student on instruction and other student support services that facilitate educational achievement compared to non-MSIs.[31] When considered in totality 'funding disparities create a caste system in higher education', as students enrolled in better-funded institutions can take advantage of a myriad of benefits and services.[30] This trend is not unique to the United States, as internationally, postsecondary systems in many countries, also maintain various forms of resource stratification that influence which graduates will be more competitive in the employment market.[17,33]

MSIs provide extraordinary access to postsecondary education and economic mobility to diverse populations. More than half of students enrolled at MSIs are first-generation college students.[34] The student bodies of MSIs are more diverse than PWIs in race, ethnicity and income, and MSIs play an essential role in training students of colour for STEM disciplines.[35] Year-to-year retention and graduation rates for exclusively full-time students at some MSIs are substantially higher than national averages.[36]

## 5 | STRATIFIED COVID-19 EXPERIENCES

COVID-19 not only disproportionally impacted racial and ethnic minority groups,[37] but it also impacted students. Some MSI students struggled balancing academic responsibilities with family demands and succeeding in the remote COVID-19 learning environment while navigating the application process.[38] Internationally, institutional decisions to suspend on-campus instruction and evacuate students due to COVID-19 safety protocols resulted in detrimental psychological effects. The disruption of extracurricular activities, the loss of on-campus employment, the ambiguity surrounding the completion of internships, research projects and graduation, as well as the burden of potentially being an asymptomatic carrier, heightened anxiety among an already vulnerable population.[39,40]

Furthermore, the COVID-19 pandemic compelled more college students than usual to confront challenges associated with essential needs insecurity, but the situation was even more dire for students of colour.[39,41] In spring 2020, more than 70% of Black and 65% of Hispanic students reported food or housing insecurity, compared to roughly 50% of White students.[41] Basic needs concerns coupled with technological problems, inadequate study spaces, family obligations and a sense of disconnect from the online environment caused many Black, Hispanic/Latinx and economically disadvantaged student groups to experience a more challenging shift to remote learning compared to their non-underrepresented in medicine (URM) counterparts.[42,43]

## 6 | DIVERSIFYING TRAINED MDS

Educating a more diverse medical workforce has been identified as one strategy to improve patient experiences, patient satisfaction and access to care.[44,45] However, MD programmes struggle to recruit diverse student populations. Black or African American applicants constituted 8.9% and Hispanic or Latino applicants made 5.9% of the applicant pool for the 2022–2023 academic year.[46] Matriculants in the same year were 8.1% Black or African American and 6.4% Hispanic or Latino.[47]

Prior research indicates MCAT and GPA are positive predictors of acceptance, and first-generation, low SES and URM are associated with negative predictors of acceptance.[13,48,49] Despite deliberate efforts to enhance minority representation in the healthcare sector, the number of Black male physicians has remained stagnant over the past three decades.[28,50] Approximately 6% practising physicians identified as Hispanic and 5% identified as Black or African American, and there are too few URM students in the graduate training pipeline to sustain or grow these proportions.[51,52] Selecting applicants to study medicine is complex, and reliance on admissions tests, interviews and other criteria may be best used holistically.[53,54]

A serious challenge facing the global academic medicine community is training enough URM students in health disciplines to both meet workforce demands and increase representation among health providers.[55,56] Therefore, there is a need to fully explore the MSI and MD pathway given the crucial role MSIs play in facilitating access for URM students within the stratified higher education system, and the need to diversify the physician workforce. Further, the opaque MSI to MD pathway may have been changed due to the impacts of COVID-19, which bears importance on long-term workforce shortages.

The purpose of this study is to investigate the MSI pathway as it relates to medical school admission in the United States. This study is guided by two research questions:

**RQ1.** What is the impact of MSI attendance on medical school acceptance?

**H1.** MSI applicants will be less likely to be accepted to medical school compared to PWI applicants.

**RQ2.** What differences in acceptance exist before and after COVID-19 for MSI attending applicants?

**H2.** A significant negative impact on likelihood of acceptance will be observed after COVID-19 at a 1-year lag.

## 7 | METHOD

Eastern Virginia Medical School IRB approved our cross-sectional hierarchical logistic regression (HLR) analysis of 3 284 88 de-identified applicants to US MD-granting medical schools for academic years 2017–2018 through 2022–2023, which represents the entire population of applicants in this timeframe. The applicant pool was 96.4% permanent residents of the United State and slightly representative of the US population (50.5% female, 75.3% White, 13.7% Black,

6.4% Asian, 19.5% Hispanic, 3.1% multiple race/ethnicity, 17.9% rural and 27.9% low SES).[57]

A custom dataset including key study variables was procured from the Association of American Medical Colleges (AAMC), a non-profit coalition of US medical schools and teaching hospitals. The data were extracted from application data from the American Medical College Application Service (AMCAS), the common application used by 90% of US-based medical schools, and non-AMCAS schools (Table 1). The AAMC respects and treats with care the data it collects about individuals in medical education, follows published data responsibility policies and requires a signed data licensing agreement by researchers using the data.

## 8 | DATA ANALYSIS

Data were imported then tidied in IBM Statistical Package for Social Sciences (version 29). Ex post facto observational studies are sensitive to outlying data points[58]; therefore, data were diagnosed for appropriateness before each analysis to identify possible outliers and test assumptions. G*Power was used to conclude a two-tail power analysis, $\alpha = 0.05$, sample 328 488 and odds ratio 0.4, resulting in power $(1 - \beta) = 0.95$.

HLR, which includes two or more orders of logit models,[59] was used to address RQ1. HLR is useful for predicting a dichotomous dependent variable using log odds of outcomes using maximum likelihood estimation while better understanding the first-order model, which makes HLR the most appropriate analysis. The first step in HLR

**TABLE 1** Dataset description by continuous and categorical variables.

| | Attended MSI | | Attended PWI | | Full dataset | |
|---|---|---|---|---|---|---|
| **Characteristic** | ***M*** | ***SD*** | ***M*** | ***SD*** | ***M*** | ***SD*** |
| GPA | 3.56 | 0.38 | 3.59 | 0.45 | 3.58 | 0.43 |
| MCAT | 501.81 | 10.16 | 507.61 | 9.02 | 505.98 | 9.71 |
| | *n* | % | *n* | % | *n* | % |
| Sex | | | | | | |
| Female | 49 011 | 52.9 | 126 290 | 53.6 | 175 301 | 53.4 |
| Male | 43 688 | 47.1 | 109 230 | 46.4 | 152 918 | 46.6 |
| Race | | | | | | |
| White | 32 395 | 38.1 | 115 027 | 54.6 | 147 422 | 49.9 |
| Black | 12 503 | 14.7 | 16 444 | 7.8 | 28 947 | 9.8 |
| Hispanic | 10 843 | 12.8 | 10 346 | 4.9 | 21 189 | 7.2 |
| Asian | 19 479 | 22.9 | 51 251 | 24.3 | 70 730 | 23.9 |
| Multiple race/ethnicities | 9730 | 11.5 | 17 709 | 8.4 | 27 439 | 9.3 |
| Geography | | | | | | |
| Rural | 4661 | 5.7 | 13 190 | 6.0 | 17 851 | 5.9 |
| Not rural | 77 819 | 94.3 | 208 229 | 94.0 | 286 048 | 94.1 |
| SES | | | | | | |
| Low indicated | 28 756 | 39.8 | 52 414 | 25.4 | 81 170 | 29.2 |
| High indicated | 43 547 | 60.2 | 153 639 | 74.6 | 197 186 | 70.8 |
| Institution | | | | | | |
| MSI indicated | 92 701 | 28.2 | 235 728 | 71.8 | 328 429 | 100% |
| MSI by type | | | | | | |
| AANIPISI | 12 145 | 13.1 | | | | |
| HSI | 49 949 | 53.9 | | | | |
| HBCU/PBI | 6069 | 6.5 | | | | |
| SIP | 24 538 | 26.5 | | | | |

*Note*: Female, male or no response/missing/decline to answer were the only response options for sex/gender. Race rolled up by AAMC identity array. Rurality established from applicant legal residency and defined as outside a SMSA with fewer than 50 000 residents. Low SES includes service and unskilled bachelor's or less than bachelor's holding households (AAMC E01 and E02), and high SES includes executive professional bachelor's or graduate holding households (AAMC EO3–5). MSI Indicated as yes if record included any MSI type. The table excludes missing values (no missing categorical data, <25% missing data for continuous variables), and categories representing less than 1% of the data were excluded from analysis.

is to conduct a series of univariate analysis to describe and summarise patterns in a single variable. The second step is to create a forced-entry model in hierarchical layers to examine the differences between each analysis. In some cases, interaction terms are entered into the model to address the multiplicative effect had by two or more predictor variables. Logistic regression assumes binomial distribution, and when observations are independent of one another, the HLR model is known to be a robust statistic.[60] A logistic model is evaluated by goodness of fit against the null model using significant Wald chi-square tests and odds ratio.

Interrupted time series (ITS) analysis, which establishes an underlying trend interrupted by a point in time,[61] was used to evaluate RQ2. The emergence of COVID-19 was considered the interrupting event using the clear delineator as before and after. ITS studies are generally unaffected by confounding variables; however, assumptions of independence of observations and model sensitivity are examined. The autoregressive integrated moving average (ARIMA) ITS model uses correlations between errors at different time points and generates plots and statistics to use in evaluating the validity of the model demonstrating shifts in the outcome either immediately or a lag period before an effect is expected. Autocorrelation function (ACF) and partial autocorrelation function (PACF) plots are used to identify potential misfitted data less than two standard errors on either side of zero correlation.[62]

## 9 | PREDICTOR MEASURES

The primary predictor variable was MSI attendance, and therefore, it was the only predictor used to generate model 1. Using public data provided by the US Department of Education, a list of eligible MSIs was collated. There were 2516 institutions eligible in one or more categories. Duplicates that were eligible under more than one designation were identified. When institutions were eligible for multiple designations, mission-based and longevity of MSI type were used to assign institutions to one category. HBCUs and PBIs were combined, and any institution that included HBCU/PBI were categorized as such. Institutions without HBCU/PBI but with HSI and any other designation were included in the HSI group, and AANIPISI plus SIP were included in the AANIPISI group. Institutions in the SIP category were not inclusive of any other MSI type. A total of 1959 institutions were represented in the final dataset. Per the data agreement and to protect the anonymity of institutions, some MSI types that yielded fewer applicants, such as Native American-erving, Alaska Native and Native Hawaiian-Serving and Tribally Controlled Colleges and Universities, were excluded from analysis. This exclusion represents only 5% of the MSI population. Finally, MCAT and GPA were added into model 2, and model 3 added race and SES indicator.

## 10 | OUTCOME MEASURES

To address RQ1, the outcome variable was accepted to a medical school. To address RQ2, the same outcome variable was used, but the file was filtered by application year to plot likelihood of acceptance by MSI type before COVID-19 (application years 2017, 2018 and 2019) and after COVID-19 (application years 2020, 2021 and 2022).

## 11 | RESULTS

In this study, GPA and MCAT were found to have moderate collinearity ($r = 0.465$, tolerance $= 0.78$) as anticipated,[10–12] nominal predictor variables were found to have minimal chi-squared change, and no outliers were found; therefore, assumptions were intact, and the logistic regression proceeded.[60] To address the lopsided distribution of acceptance, the classification cut-off was changed to 0.4.

First, univariate analysis was conducted to determine the relationship of single predictors to the outcome (Table 2). MSI attendance was associated with a 9.8% gain in model accuracy, MCAT was associated with 29.2% gain in model accuracy, GPA was associated with a 19.7% gain in model accuracy, race/ethnicity was associated with a 2.5% model gain, and SES garnered 7.8% increase in model accuracy. Sex and being from a rural area did not contribute to a predictive model for acceptance.

Second, using the established relationships from the univariate analysis, an HLR determined whether MSI attendance predicted acceptance after controlling differences due to student performance and characteristics, providing nuance to the interpretation of RQ1. Model 1 replicated the univariate finding predicting acceptance using only MSI attendance by type gained 9.8% in model accuracy over the null model. Model 2 adding MCAT and GPA to MSI attendance gained an additional 21.9% (see Table 3), and model 3, the final model, adding race and SES to the other variables added 2.4% in model accuracy (see Table 4). Classification results for each model are shown in Table 5.

In model 3, the predictor variable Race changed direction for some categories. This is explained by Simpson's paradox, a statistical phenomenon in which associate disappears or reverses when the population is subdivided.[63] Results of model 3 show that the race became a significant effect for all categories, a change from model 1 for Hispanic and Asian students. Furthermore, the effect for Black and Hispanic applicants was changed from negative odds, when comparing race individually to the outcome of acceptance, to positive odds when examining the outcomes for each race within the subset of MSI-type attendance, on the outcome of acceptance. To confirm the supression effect of Simpson's paradox, the HLR for model 3 was run again, adding interaction variables between dummy coded categorical variables and mean centred continuous variables. This resulted in Hispanic*GPA becoming non-significant and the race returning to the original negative direction for Black and Hispanic but reversed the odds direction for the Asian and multiple groups, which may have implications for how applicant race and institution type are used within the same model (see Table 6).

In summary, the null hypothesis for RQ1 is rejected, finding initial support for H1 that MSI applicants were less likely to be accepted. However, further examination of the variables demonstrates adding academic and demographic factors most often improves the odds of acceptance for MSI applicants.

**TABLE 2** Univariate logistic regression predictive of acceptance to a medical programme.

| | B | SE B | Wald χ2 | p | OR | 95% CI OR |
|---|---|---|---|---|---|---|
| MSI by type | | | 4653.48 | <0.001 | | |
| AANIPISI | −0.55 | 0.02 | 763.52 | <0.001 | 0.58 | 0.56–0.60 |
| HSI | −0.55 | 0.01 | 2751.80 | <0.001 | 0.58 | 0.57–0.59 |
| HBCU/PBI | −0.73 | 0.03 | 644.51 | <0.001 | 0.48 | 0.46–0.51 |
| SIP | −0.53 | 0.01 | 1402.93 | <0.001 | 0.59 | 0.57–0.61 |
| MCAT | 0.16 | 0.00 | 50117.30 | <0.001 | 1.18 | 1.17–1.18 |
| GPA | 2.16 | 0.02 | 20413.57 | <0.001 | 8.65 | 8.40–8.91 |
| Low SES | −0.45 | 0.01 | 2724.98 | <0.001 | 0.64 | 0.63–0.65 |
| Race | | | 421.45 | <0.001 | | |
| Black | −0.27 | 0.01 | 375.52 | <0.001 | 0.77 | 0.75–0.79 |
| Hispanic | −0.01 | 0.02 | 0.37 | 0.543 (ns) | 1.00 | 0.96–1.00 |
| Asian | −0.02 | 0.01 | 3.40 | 0.065 (ns) | 0.98 | 0.97–1.00 |
| Multiple race/ethnicities | 0.05 | 0.01 | 11.59 | <0.001 | 1.05 | 1.02–1.07 |
| Female[a] | −0.01 | 0.01 | 0.12 | 0.730 (ns) | 1.00 | 0.98–1.1 |
| Rural[a] | −0.06 | 0.02 | 12.67 | <0.001 | 0.95 | 0.92–0.98 |

*Notes*: MSI type, PWI was reference; Low SES, high SES was reference; race, White was reference; Sex, male was reference; rural, not rural was reference. Unknown data or data in categories representing less than 0.01% (Pacific Islander, Native American, but not multiple) of the dataset were treated as missing.
[a]Did not contribute to model.

**TABLE 3** Model 2 logistic regression predictive of acceptance to a medical programme.

| | B | SE B | Wald χ2 | p | OR | 95% CI OR |
|---|---|---|---|---|---|---|
| MSI by type | | | 972.18 | <0.001 | | |
| AANIPISI | −0.37 | 0.03 | 182.52 | <0.001 | 0.69 | 0.66–0.73 |
| HSI | 0.07 | 0.02 | 20.35 | <0.001 | 1.07 | 1.04–1.10 |
| HBCU/PBI | 1.18 | 0.04 | 748.14 | <0.001 | 3.24 | 2.98–3.53 |
| SIP | 0.08 | 0.02 | 17.07 | <0.001 | 1.09 | 1.04–1.13 |
| MCAT | 0.145 | 0.00 | 34822.17 | <0.001 | 1.16 | 1.16–1.16 |
| GPA | 1.84 | 0.2 | 8548.88 | <0.001 | 6.28 | 6.04–6.53 |

**TABLE 4** Model 3 logistic regression predictive of acceptance to a medical programme.

| | B | SE B | Wald χ2 | p | OR | 95% CI OR |
|---|---|---|---|---|---|---|
| MSI by type | | | 401.85 | <0.001 | | |
| AANIPISI | −0.49 | 0.03 | 229.04 | <0.001 | 0.61 | 0.58–0.65 |
| HSI | −0.24 | 0.02 | 168.93 | <0.001 | 0.79 | 0.76–0.82 |
| HBCU/PBI | 0.16 | 0.05 | 8.71 | 0.003 | 1.17 | 1.05–1.29 |
| SIP | 0.05 | 0.02 | 5.61 | 0.018 | 1.06 | 1.01–1.10 |
| MCAT | 0.18 | 0.00 | 32256.44 | <0.001 | 1.20 | 1.20–1.20 |
| GPA | 2.45 | 0.02 | 10142.37 | <0.001 | 11.53 | 10.99–12.09 |
| Low SES | 0.11 | 0.01 | 68.70 | <0.001 | 1.18 | 1.09–1.15 |
| Race | | | 9588.10 | <0.001 | | |
| Black | 1.98 | 0.03 | 5950.53 | <0.001 | 7.22 | 6.87–7.60 |
| Hispanic | 1.65 | 0.03 | 3908.67 | <0.001 | 5.22 | 4.95–5.49 |
| Asian | −0.20 | 0.02 | 180.12 | <0.001 | 0.82 | 0.80–0.85 |
| Multiple race/ethnicities | 0.74 | 0.02 | 1150.42 | <0.001 | 1.12 | 1.09–1.15 |

To examine RQ2, the impact of COVID-19 on acceptance to an MD program, univariate logistic regression by year was conducted. Predictors were MSI by type, MCAT, GPA and SES indicator, selected based on their significance in RQ1, and the outcome was acceptance. Because the MSI types HSI and SIP were consistently non-significant in logistic regression analysis by year, they were inappropriate to include in the full model.

Shown in Figure 1 are the year-to-year unadjusted differences and forecasted trendline in outcomes by predictor type. Visual examination of the trendlines shows little to moderate year-to-year difference in unadjusted differences before or after COVID-19. SES appears to have an upward trend demonstrating chances of acceptance improved over time for low-SES applicants. HSI, SIP and GPA appear to have downward trends, suggesting odds are deteriorating for each group. Visual examination supports the interpretation of the subsequent inferential model because change and trend direction can be observed.

A time series analysis using an ARIMA model was conducted. None of the ACF or PACF exceeded the 95% confidence interval lines; therefore, no autocorrelation was observed, and the data were appropriate to use in the ARIMA model. The observed and model fit pattern lines were similar but shifted forward one time period, as hypothesized. As shown in Table 7, t-values were close to 0, and no model components were significant at $p = 0.05$, indicating that acceptance trends before and after COVID-19 were not significantly changed. In summary, we fail to reject the null hypothesis for RQ2, finding no evidence of significant change in acceptance before and after COVID-19 for MSI applicants.

**TABLE 5** Final model post hoc classification.

| | | Predicted | | |
|---|---|---|---|---|
| Observed | | Accepted | | Percentage correct |
| | | N | Y | |
| Model 1 | N | 32 538 | 72 989 | 30.8 |
| | Y | 18 333 | 73 574 | 80.1 |
| Overall percentage | | | | 53.7 |
| Model 2 | N | 70 769 | 34 758 | 67.1 |
| | Y | 14 934 | 76 973 | 83.8 |
| Overall percentage | | | | 74.8 |
| Model 3 | N | 74 294 | 31 233 | 70.4 |
| | Y | 13 872 | 78 035 | 84.9 |
| Overall percentage | | | | 77.2 |

*Note*: Cut value 0.400.

## 12 | DISCUSSION

This is the first study investigating multiple MSI pathways to US MD-granting schools. The findings reveal that a substantial proportion of applicants (28%) from 2017–2022 utilized MSI pathways to medical school. However, most applicants (71%) followed a PWI pathway. This underscores the stratified nature of US higher education where attending a better-resourced institution can bolster an applicant's competitiveness when seeking a professional degree.[2,5,7,8,17] Logistic regression analysis consistently identified MSI type as a significant predictor, enhancing model accuracy by nearly 10% over chance. Unfortunately, this study reveals that, when used alone, an MSI attendance negatively impacts the likelihood of MD acceptances. Considering the need to recruit and train a diverse pool of physicians and that MSIs serve more diverse student populations, the lower odds of MSI applicant acceptance serve as a sobering reminder of the gains to be made towards diversifying the physician pool.

Importantly, when adding MCAT and GPA to the model, the accuracy improved an additional 21.9%, and the MSI acceptance gap was reduced for all MSI types. Statistically significant odds reversal was observed in HBCU/PBIs, HSIs and SIPs, suggesting that historical academic performance and admission tests neutralize other factors

**TABLE 6** Model 3 with interaction variables diagnosing Simpson's paradox.

| | B | SE B | Wald χ2 | p | OR | 95% CI OR |
|---|---|---|---|---|---|---|
| MSI by type | | | 407.47 | <0.001 | | |
| AANIPISI | −0.49 | 0.03 | 228.95 | <0.001 | 0.61 | 0.58–0.65 |
| HSI | −0.24 | 0.02 | 166.56 | <0.001 | 0.79 | 0.76–0.82 |
| HBCU/PBI | 0.20 | 0.05 | 15.11 | 0.003 | 1.22 | 1.10–1.36 |
| SIP | 0.05 | 0.02 | 5.34 | 0.018 | 1.05 | 1.01–1.10 |
| MCAT | 0.18 | 0.00 | 32106.65 | <0.001 | 1.20 | 1.19–1.20 |
| GPA | 2.53 | 0.04 | 5306.94 | <0.001 | 12.58 | 11.75–13.46 |
| Low SES | 0.11 | 0.01 | 69.60 | <0.001 | 1.12 | 1.09–1.15 |
| Race | | | 9140.00 | <0.001 | | |
| Black | 1.91 | 0.03 | 5031.94 | <0.001 | 6.75 | 6.40–7.12 |
| Hispanic | 1.66 | 0.03 | 3833.75 | <0.001 | 5.27 | 5.00–5.55 |
| Asian | −0.23 | 0.02 | 197.26 | <0.001 | 0.79 | 0.77–0.82 |
| Multiple race/ethnicities | 0.77 | 0.02 | 1234.59 | <0.001 | 2.15 | 2.06–2.25 |
| Black*GPA | −0.58 | 0.08 | 59.49 | <0.001 | 0.56 | 0.48–0.65 |
| Hispanic*GPA | −0.08 | 0.09 | 0.71 | 0.401 | 0.93 | 0.78–1.11 |
| Asian*GPA | 0.33 | 0.07 | 24.96 | <0.001 | 1.39 | 1.22–1.58 |
| Multiple*GPA | −0.70 | 0.08 | 76.64 | <0.001 | 0.50 | 0.42–0.58 |

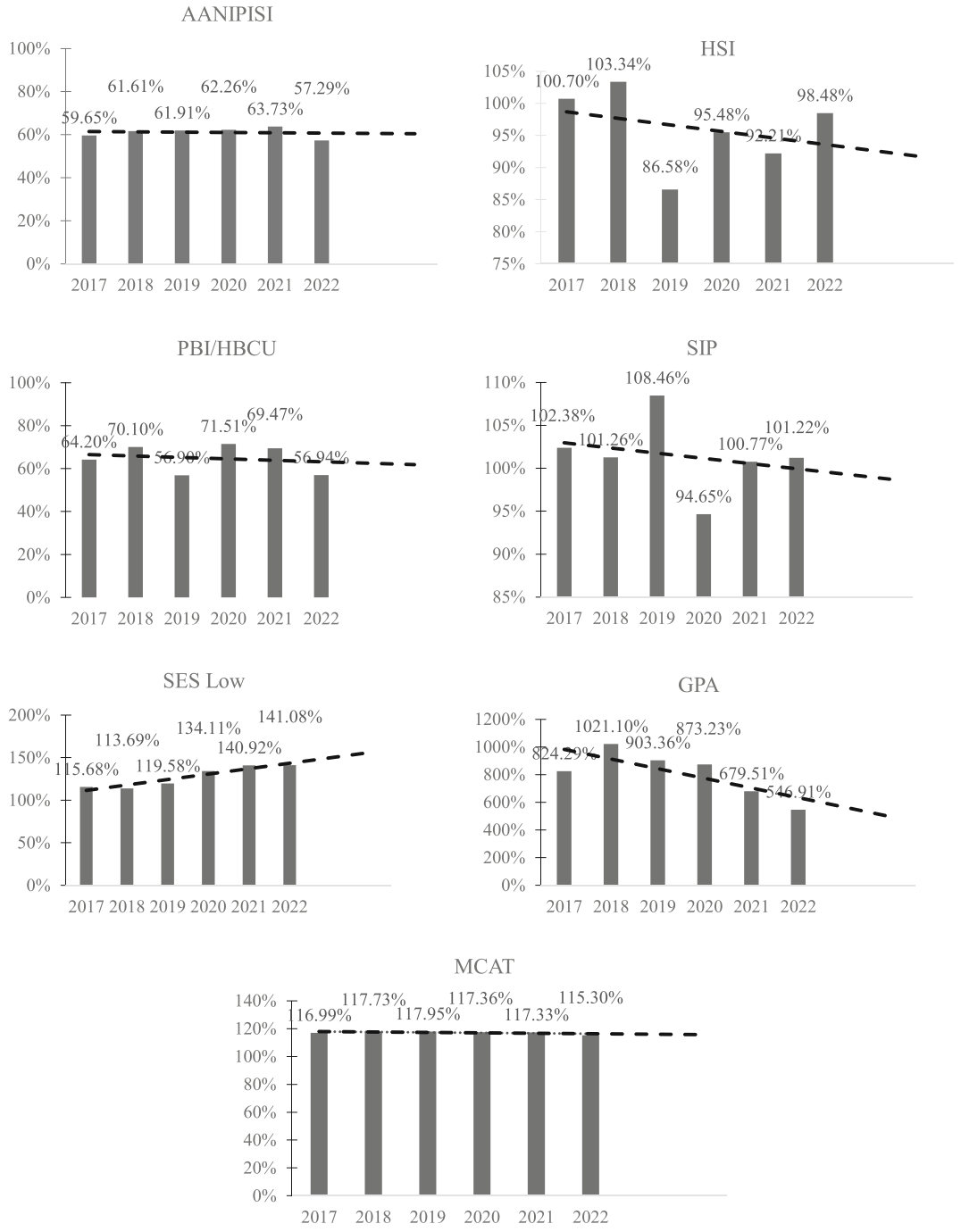


**FIGURE 1** Trends in predictors of acceptance. Shown in this figure are the year-to-year unadjusted differences and forecasted trendline in MD acceptance for by predictor.

**TABLE 7** Time series analysis of MD acceptance predictors before and after COVID-19.

| Model component | ARIMA model | Stationary $R^2$ | Estimate ($PP_c$) | t | p |
|---|---|---|---|---|---|
| AANIPISI | (0,1,0) | 0.01 | 0.01 | 0.16 | 0.885 |
| PBI/HBCU | (0,1,0) | 0.54 | 1.38 | 1.89 | 0.155 |
| MCAT | (0,1,0) | 0.09 | −0.01 | −0.53 | 0.631 |
| GPA | (0,1,0) | 0.01 | 0.32 | 0.16 | 0.882 |
| SES | (0,1,0) | 0.63 | 0.11 | 2.27 | 0.108 |

that contributed to lower odds. Overemphasizing MCAT scores has been linked to inhibiting DEI efforts, and racial group differences tied to structural racism.[64,65] In this study, however, MCAT scores alleviated acceptance gaps faced by the racially and economically diverse pool of MSI applicants. Given the long-standing stability of using scores in admissions[54] and the need to diversify medical trainees as a public good,[65] the nuances of the relationship between MSI applicants, GPA and MCAT requires further exploration. Based on the results of model 2, MSI institution types may need to emphasize GPA and MCAT in favour of other methods of differentiation.[9]

Identifying the MSI acceptance gap offers institutions an opportunity to make meaningful strides. Strategic initiatives to collaborate across stratification divides with MSIs could provide a seamless pathway to medical education for URMs, mitigating the lower odds and gradually diversifying the physician workforce. Many medical school offers a pipeline or pathway program, and the majority of these programmes are on the college or university level.[66] Yet, much remains to be understood regarding best practices for delivering instruction,[67] the impact of the programme on intended outcomes[68] and the retention of URM students through the training pipeline.[69] Concentrated efforts to increase representation in STEM fields have had positive impacts,[70,71] but the same effects have not been observed in the physician pipeline and workforce.[48] Because MSI attendance was negatively associated with the likelihood of medical school acceptance unless other model factors are controlled, it appears necessary for administrators and scholars to revisit pathway partnerships between medical schools and MSIs to increase applicant odds.

Surprisingly, when race was included in model 3 where MSI type, MCAT, GPA and SES, was included in the model, Black and Hispanic applicant odds changed directions from negative in the univariate analysis to positive in the hierarchical analysis, and all race groups became significant predictors. Simpson's paradox explains suppression effects within subgroups, and this is a logical extension of what is known about race and MSI attendance. In essence, overall MSI type trends negatively on acceptance, but within each MSI type, URM racial categories were no longer indicative of lower odds. This further suggests that despite the lesser odds in the initial model of MSI applicant acceptance, there may be advantages to some students who attend MSIs, particularly URM applicants with GPA and MCAT scores at or above the mean. The inclusion of race in a model with MSI types is further complicated by the change in significance for some predictors and the reversal of direction when interaction variables were included. An intersectional analysis is needed to parse out the complicated relationship between race, institutional type, GPA and medical school acceptance with careful attention paid to the potential multiplicative effects of including both in the model.

To rebalance systemic inequalities which impact educational outcomes, affirmative-action policies have been used to ensure all applicants are given fair consideration in college admissions. However, in June 2023, the US Supreme Court invalidated these policies,[72] leaving admissions officers cognizant of the impact of stratification to find legally viable avenues for increasing educational access.[73] The findings of this study may demonstrate the usefulness of MSI attendance as a suitable alternative admissions factor to consider. Moreover, admission practices that uniquely impact MSI applicants warrant further consideration.

Finally, the time series analysis of the impact of COVID-19 on acceptance outcomes for MSI-attending applicants was non-significant. Although much attention has been given to the unique challenges faced by URM populations during remote instruction and distancing pandemic phases, in aggregate, MSI applicant outcomes did not substantially change. This finding raises significant questions about the longitudinal outcomes for diversifying the physician workforce, suggesting that even amidst a global crisis, the existing disparities in medical school acceptance remained largely unchanged. Despite COVID-19's documented disproportionate impact on marginalized populations and URM students, there were no discernible trends in the differences of predictor variables before and after the pandemic. Additional research is necessary to explore the intersection of the variables, and potentially include an additional 2 years of data to establish longer trends. This underscores the complexity of medical school admission, which has remained competitive and multifaceted for decades.[53,74]

There are several limitations to this work. First, this study is cross-sectional and therefore cannot be used to make causal claims. Second, there are several admissions factors that could not be included in the analysis. To mitigate this, important research-supported factors were initially evaluated in univariate models and carried forward to hierarchical analysis when valuable. Nonetheless, factors such as preparation, extracurricular experiences, interview performance and applicant attributes may be relevant but were outside the scope of this study. Third, this study uses an institutional-level variable related to individual student outcomes, which may be criticized for being too distant to be relevant. However, undergraduate college selection is based on individual circumstances such as distance, cost and perceptions of institutional reputation,[75] and the inclusion of individual-level predictors such as MCAT, GPA and SES mitigates the potential mismatch. Nonetheless, the large-scale nature of the dataset necessitates an overarching inclusion of these categories, and nuances of the intersection among these variables may be lost with this approach. Finally, the dataset is delimited to US medical school applicants. Although stratified systems of education and training exist worldwide, the results of this analysis should be tested within additional bounded systems using unique examples of stratification within each system.

## 13 | CONCLUSION

This comprehensive study sheds light on the significant impact of MSIs on the pathway to medical school acceptance in the United States, unveiling a potential stratification barrier for MSI applicants that affects the likelihood of acceptance, unless controlled by other factors. Notably, acceptance odds were improved, and in some cases, reversed, when GPA and MCAT were introduced as controls in the model. This MSI odds loss, and subsequent GPA and MCAT-

related odds gains, may guide collaborative efforts between medical schools and MSIs to address systemic barriers and enhance pathways for URM students. Moreover, the study highlights the resilience of MSI applicants during the COVID-19 pandemic, as their acceptance outcomes remained relatively stable, albeit lower than PWI applicants, despite the challenges posed by remote learning and disrupted educational environments. Notwithstanding study limitations, the findings provide direction for future research exploring MSIs as a viable pathway to an MD, particularly when emphasizing at or above mean GPA and MCAT scores among these applicants. Moving forward, it is imperative for stakeholders to prioritize strategies that promote equity, diversity and inclusion in medical education and strive to reduce the impacts of a stratified system on educational outcomes in order to cultivate a more representative healthcare workforce.

## AUTHOR CONTRIBUTIONS

The authors have met the ICMJE criteria for authorship. Amanda K. Burbage contributed substantially to the conceptualisation, literature review, data procurement, data analysis, results reporting and discussion. Eushekia Y. Hewitt contributed substantially to the literature review and discussion. Both authors edited the manuscript prior to final approval and submission, and the authors are equally responsible for all aspects of the work.

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## DATA AVAILABILITY STATEMENT

The data are proprietary and were used under a fully executed data-use agreement. Contact the Association of American Medical Colleges regarding acquisition of research data.

## ETHICS STATEMENT

Ethical approval was waived for this project which does not involve human subjects by Eastern Virginia Medical School IRB Committee (IRB# 23-01-NH-0020) on 9 January 2023.

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