# Selection of Medical Students to Meet Physician Manpower Needs

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THE MALDISTRIBUTION OF PHYSICIANS in the United States, both geographically and by specialty, has been the subject of many articles in recent years. A number of different approaches have been tried to achieve a better distribution, or at least to provide increased numbers of physicians to shortage areas. (In this paper the term "shortage area" means any geographic or specialty area in which physicians are judged to be in short supply.) For example, to influence geographic distribution, some States have offered financial incentives to induce medical graduates to practice in rural areas, even if only temporarily. Also, many States have increased their output of medical graduates in the hope that with more graduates a greater number would remain to take up practice within the State.

One specialty area in which physicians continue to be in short supply is primary care, which was recognized as a specialty in 1969. A variety of efforts have been made to increase the number of medical students choosing this specialty. Both the Federal and State Governments have encouraged the training of residents in primary care. Also, some medical schools, in selecting students, are placing less emphasis on the applicant's research interests and purely academic qualities and more on the person's preferred type and geographic area of practice. However, among those approaches that have been in effect long enough for their efficacy to be judged, only a few can be considered successful.

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Several authors, including Athelstan and Edwards (*1,2*), have suggested that physician maldistribution could be alleviated by changing both the priorities and the techniques used in the selection of students for medical school. Our search of the literature, however, has not revealed any practical design for effecting such changes. The selection of students for U.S. medical schools has traditionally been based largely on the applicant's academic ability and estimated general suitability for a career in medicine. The low dropout rate in U.S. medical schools for academic reasons and the general consensus as to the high quality of U.S. medicine both attest to the effectiveness of the traditional emphasis of these two factors. It seems to follow that a big dent could be made in physician maldistribution if in the medical school selection process, something approaching the degree of emphasis put on the two traditional criteria were to be put on the maldistribution problem.

But how might a medical school actually take physician maldistribution into account in its selection process? Generally speaking, the school's admissions committee would first have to determine medical manpower needs by specialty, geographic area, or both. For example, it might be decided that more family physicians were needed—in toto, in rural or inner city areas, or in the State as a whole. Then with the currently available knowledge of the factors influencing career choices within medicine, the committee would select those applicants whose careers could be predicted to meet the particular manpower needs. Given an abundance of qualified applicants, an incoming medical school class presumably could be chosen that would meet any defined medical manpower needs and yet would have general qualifications as high as a class chosen without consideration of manpower needs. The main prerequisite for selection of an applicant would be that the person's relevant career behavior, such as choice of location or type of practice, could be predicted at the time of the application to medical school.

There are two principal obstacles to this approach. One is that powerful predictors of career choice in medicine are scarce (*3*). The other is that there has been no statistical model incorporating those means that are available for predicting the relevant aspects of career choice. The second obstacle is especially serious, because a simplistic application of selection procedures favoring one type of applicant over others could produce major, unpredictable distortions in the qualities of a medical school class. For example, if students who tended to choose a career in a certain shortage area of practice also tended to have relatively low academic aptitude, their selection, even though the purpose was to alleviate the shortage, could inadvertently yield a class of academically incompetent students.

### Statistical Model for Selecting Students

We propose a statistical model for selecting an entering medical class that would be of a specific composition in terms of the members' predicted choice of specialty or location of practice and that would also meet the traditional admissions criteria. With our statistical model, an incoming class can be identified in which the number of applicants eventually choosing to practice in some shortage area will be close to a given predetermined number. In this paper, family practice is taken as the shortage area of interest.

In the selection process that we propose, the admissions committee would need to compute two numbers for each applicant. One number, which will be called the general index (GI), would represent the overall suitability of each applicant for a career in medicine. Of any two applicants, the one with the higher GI would be considered better qualified for admission. This number could be determined by any of several means, including a vote of the committee after review of an applicant's credentials, an objective rating, or a score representing a combination of measures. The GI could be used by itself to select an entering class comprised of the highest ranking applicants. This selection scheme would presumably yield the most qualified class, but it would not take into account the need to train physicians who will enter family practice.

The other number that has to be computed is the estimated probability of the applicant's entering family practice. This number can be calculated by assuming that the true probability is given by the multiple logistic function (*4*):

$$P = \frac{1}{1 + \exp\left(-\sum_{i=0}^{v} \beta_i z_i\right)}$$

Here $P$ is the true probability just referred to, and the $z_i$s represent a set of independent variables, which in general are based on the applicants' biographical and academic histories and on their scores on the Medical College Admissions Test (MCAT) and other standardized tests. The specific independent variables used in this study are described in the box.

The $\beta_i$s are parameters that would have to be estimated from a sample of physicians who had already entered a specialty, either as residents in training or practitioners. Once the $\beta_i$s are estimated, these estimates would be used together with the $z_i$s to estimate the $P$ for each applicant. These probabilities are called "conditional" because they depend on the $z_i$s of the individual applicants. (Note: In all cases, $z_0 = 1$ to allow for a constant term in the summation.) The symbol $\tilde{P}$ will be used to represent the estimated conditional probability that an applicant will enter family practice.

The expected number of family physicians that any potential entering class would yield is the mean $P$ for the group multiplied by its size, or equivalently, the sum of the $P$s for the group. In general, the $P$s are not known and have to be estimated as described in the preceding paragraph. The sum of these estimated probabilities for a group of applicants will be called $\tilde{\mu}$ and will be taken as a prediction of the number of future family physicians in the group.

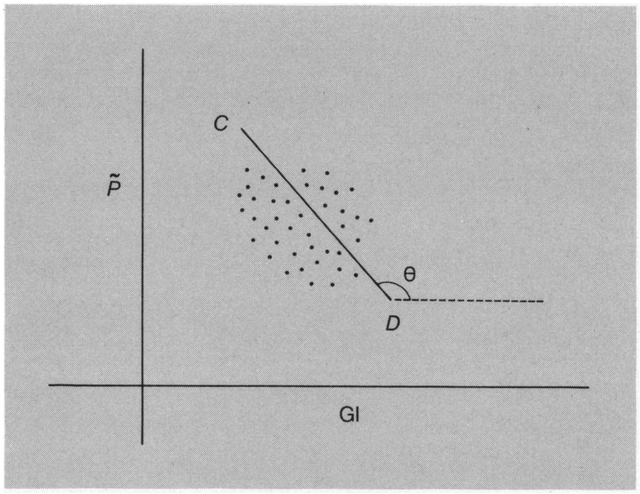
Thus, an incoming class can be selected so as to yield a specified number of family physicians if a group of applicants with a $\tilde{\mu}$ close to the desired number is chosen. There are two sources of error in this prediction. First, the number of family physicians is a random quantity that varies around its expected value; second, the usefulness of this model will depend in large part on the accuracy with which the variables in the equation predict the applicants' choice of family practice.

In this model, one criterion for choosing an entering class is that its $\tilde{\mu}$ should be within some narrow range about the intended number of family physicians. A second criterion which seems reasonable is that the entering class should be one of the best qualified of all the potential entering classes with an acceptable $\tilde{\mu}$. Of any two groups of applicants of the same size, the group having the higher total general index would be considered to be the more qualified.

The graph illustrates a procedure by which these two criteria can be met. This graph is a representation of the scatter diagram that would be obtained by plotting $\tilde{P}$ versus GI for an entire pool of applicants.

In the graph, $CD$ is a straight line with a negative slope and is meant to be used as a decision boundary; that is, it does not represent a fitted regression line. One can show by elementry algebra (*5*) that the set of points lying above $CD$ has a total GI that is larger than the total GI for any other set of the same number of points having a $\tilde{\mu}$ at least as great. In particular, no set can have the same number of points, the same $\tilde{\mu}$, and a total GI as great as, or greater than, the set of points lying above $CD$. For this reason, sets of points

Schematic representation of a plot of $\tilde{P}$ versus GI (general index)




that are located above a straight line of negative slope (such as $CD$) will henceforth be referred to as "optimal groups."

The capacity of a line such as $CD$ to mark off optimal groups suggests a way in which the two criteria for an entering class, mentioned previously, can be met. Once the $\tilde{P}$s and GIs have been computed for all the applicants, an optimal group equal to the size of the entering class can be found for each of a series of values of $\theta$ (see graph); each series is obtained by increasing $\theta$ from 90° to 180° through equal angular increments. The $\tilde{\mu}$s for these optimal groups increase monotonically with $\theta$; therefore, the appropriate angular interval can be subdivided to get an optimal group with a $\tilde{\mu}$ even closer to the intended number of family physicians. Thus it should be possible to find a group with an acceptable $\tilde{\mu}$, and since this group would be an optimal one, it would be one of the best qualified of all of the groups having an acceptable $\tilde{\mu}$.

## Retrospective Test of Model

This model was tested retrospectively on a sample of 1,076 University of Minnesota Medical School graduates from the classes of 1958 through 1966 (*5*). The 13 independent variables listed in the box were fashioned from information that these subjects had provided the admissions committee upon their application to medical school. All family physicians in the sample were identified by using current survey data of the American Medical Association. By Mallows' $C_p$ selection procedure (*6*), a "best" subset was picked from the 13 independent variables for use in the multiple logistic function. Mallows' procedure is based on a multiple regression model, but the criterion for deciding which variables to select depends neither on significance levels nor on explained variance ($R^2$),

**Description of the $z_i$s, the independent variables used to compute the *P*s**

1. Home town location
   $z_1 = 1$ if applicant's home town is in Minnesota.
   $z_1 = 0$ if applicant's home town is outside of Minnesota.

The home town was defined as the community in which the applicant had spent the greater part of his or her high school days.

2. Home town population
   $z_2 = 1$ if applicant's home town had a population of 25,000 or less.
   $z_2 = 0$ if applicant's home town had a population above 25,000 or was a near suburb of a metropolitan area.

(Population sizes were taken from the 1960 census.)

3. Age at application
   $z_3 =$ applicant's age in years at the time of application to medical school.
4. Marital status
   $z_4 = 1$ if applicant is single at time of application.
   $z_4 = 2$ if applicant is married, divorced, separated, and so forth at time of application.
5. Undergraduate school
   $z_5 = 1$ if applicant's undergraduate school was a well-known college with a good academic reputation and extensive graduate offerings.
   $z_5 = 2$ if applicant's undergraduate school was not a well-known college, had a relatively poor academic reputation, and little or no graduate offerings.

The undergraduate school was defined as the school at which the BA or its equivalent was received, or the last undergraduate school that person attended before entering medical school.

6. Extracurricular activities
   $z_6 =$ the number of extracurricular activities that the applicant participated in as an undergraduate, according to the application blank. An upper limit of 9 was set for $z_6$; if more than 9 activities were reported, $z_6$ was nevertheless set equal to 9.
7. Previous medical work
   $z_7 = 1$ if applicant had worked in a medical setting before applying (for example, as an orderly, nurse, or drug clerk).
   $z_7 = 0$ if applicant had not worked in a medical setting before applying.
8. Student self-support
   $z_8 = 0$ if student will not have to work to support himself during the school year
   $z_8 = 1$ if student will have to work part time or full time to support himself.
9. General grade point average
   $z_9 =$ the applicant's overall grade point average as an undergraduate.

10–13. Medical college admission test scores
   $z_{10} =$ the applicant's verbal ability raw score.
   $z_{11} =$ the applicant's quantitative ability raw score.
   $z_{12} =$ the applicant's modern society raw score.
   $z_{13} =$ the applicant's science raw score.

but on the "total squared error." The total squared error is the expected value of the sum of the squared differences between the predicted and the expected values of the dependent variable, in this case, specialty status. With Mallows' $C_p$ procedure, the subset that gives the smallest estimated total squared error is to be chosen. (For further details, see the article by C. L. Mallows (*6*) or the thesis on which this paper is based (*5*).)

After choosing a subset of variables, the parameters of the multiple logistic function had to be estimated. This estimation was done by the maximum likelihood method, in the manner suggested by Hartz (*7*). In this method, the joint density function of the observations, called the likelihood function, is treated as a function of parameters. Those values of the parameters that give the likelihood function its greatest value are taken as the parameter estimates. Thus, as in Mallows' $C_p$ procedure, significance levels and explained variance ($R^2$) play no part in the estimation procedure. (Details of this procedure are contained in the previously cited article by Hartz (*7*) and are also reproduced in the thesis on which this paper is based (*5*).) Using the maximum likelihood parameter estimates and the subset of variables produced by the $C_p$ method, one then computes $\tilde{P}$ for each graduate.

In our test of the model, no broad measure of an applicant's overall suitability for a career in medicine, such as the general index, was available. Instead, a measure called the academic index (AI) was used, which is the weighted sum of the applicant's undergraduate grade point average and totaled MCAT scores. The AI is used at the University of Minnesota to predict academic performance in the first 2 years of medical school. Even though the shortcomings of the AI as an indicator of an applicant's qualifications for a medical career are obvious, for the purpose of this test it provided an appropriate substitute for the GI.

A computer algorithm was devised to locate line *CD* (see graph), so that for a given value of $\theta$, there would be 240 subjects above the line (240 being the approximate size of recent entering classes of the University of Minnesota Medical School). This algorithm was applied for several values of $\theta$, and some of the results are presented in the table. It should be kept in mind that the groups listed in this table are all optimal groups in the sense described earlier.

The $\mu$ increases and the mean AI decreases, both monotonically, as $\theta$ increases. The mean AI does not decrease when $\theta$ goes from 90° to 96°, since the group size for $\theta = 90°$ is 245 because of applicants having the same AI. The number of family physicians ($n$) is overpredicted by $\mu$ in all cases, but the difference $\mu - n$ is never more than 11, and this difference becomes rather small for the larger values of $\theta$. This prediction could be sharpened considerably if preadmission variables were more closely related to career choice than the ones used in this study.

The group having $\theta = 90°$ is the one most qualified for medical school, since it is the group of 240 applicants (barring ties in AI scores) having the highest AIs. However, the group for which $\theta = 180°$ is the group having the highest $\mu$ or estimated number of family physicians. A sacrifice in the mean AI (or GI) is implicit in this model, since a new criterion for choosing an entering class is added to the traditional yardstick of general suitability for a medical career. In changing from $\theta = 90°$ to $\theta = 180°$, the estimated drop in the mean AI was approximately 1.7 standard deviation units. However, since this model permits the selection of optimal groups, the sacrifice in the mean AI shown in the table is kept to a minimum.

**Mean academic index (AI) as related to the number of predicted family physicians in optimal groups of 240 entering medical students**

| $\theta$ *(degrees)* | *Number of family physicians* | $\mu$ | *Mean AI* |
|---|---|---|---|
| [1]90 | 33 | 40.150 | 5708 |
| 96 | 31 | 41.396 | 5709 |
| 102 | 36 | 43.626 | 5708 |
| 108 | 40 | 46.853 | 5704 |
| 114 | 43 | 50.942 | 5697 |
| 120 | 44 | 53.451 | 5692 |
| 126 | 46 | 56.445 | 5684 |
| 132 | 51 | 60.549 | 5670 |
| 138 | 54 | 63.998 | 5656 |
| 144 | 61 | 69.773 | 5626 |
| 150 | 65 | 73.262 | 5603 |
| 156 | 72 | 76.689 | 5575 |
| 162 | 77 | 79.555 | 5544 |
| 168 | 78 | 81.306 | 5517 |
| 174 | 77 | 82.041 | 5497 |
| 180 | 81 | 82.333 | 5470 |

[1] 245 subjects.

If an admissions committee wished to choose an optimal group having 64 family physicians, it would select the group corresponding to $\theta = 138°$, since in this case $\mu$ is close to 64. This group actually has 54 family physicians, so that it falls short of the intended number. However, it would still provide over 20 family physicians more than the group having the highest mean AI ($\theta = 90°$), a result that seems to indicate that the model has merit even given the poor prediction afforded by $\mu$ in some cases. (Choosing the group having $\theta = 90°$ is used here as an analog to the traditional method of selecting an incoming class.)

If by the variable selection procedure described earlier, one or more of the five academic variables (overall grade point average and MCAT scores) for calculating $P$ are picked, then $P$ and the academic index will have at least one independent variable in common and can be expected to show a correlation. This correlation was not calculated for our example of family practice. However, a slight negative correlation was found between the AI and family practice, a finding indicating that subjects who chose family practice tended to have a lower AI. This tendency points to a slight negative correlation between $P$ and AI.

Whether this correlation is responsible for the overprediction of the number of family physicians by $\mu$ noted earlier is not clear. Anyway, the correlation may have little practical significance. It should be kept in mind that the AI is used here as a stand-in for the general index, which is a broader measure of an applicant's qualifications. The GI will depend partly on such things as interviews and letters of recommendation, which have no bearing on the $P$ and the AI. If the GI is determined by a largely subjective measure such as a vote of the admissions committee, it might have no correlation with $P$ worth considering.

## Extensions of the Model

It is natural to ask whether this model can be extended to cases in which the intended composition of the entering class is to include more than one variety of medical practice. The committee, for example, might want to select an incoming class of 240 students that would eventually produce 60 family physicians, 50 surgeons, 50 internists, and 80 physicians of other types. In this case, the desired entering class would consist of four distinct groups. The letter $k$ will be used to designate the number of parts into which this entering class would be subdivided if our model was applied.

For each subject, $k - 1$ of the $P$s would be computed; the $k^{th}$ $P$ could be determined by the criterion that the $\tilde{P}$s add up to 1 for each subject. Also, the general index of every subject would have to be determined. Then all subjects could be considered to be plotted in a $k$-dimensional rectangular coordinate system to provide a scatter diagram analogous to the graph. One axis of this system would represent the GI, while the other $k - 1$ axes would represent the $\tilde{P}$s.

In the elementary case $k = 2$, we stated that a straight line of negative slope could be used to define an optimal group. For the general $k$, the analog to a straight line of negative slope is a hyperplane having a positive intercept with each coordinate axis (*8*). As in the case of $k = 2$, it can be shown (*5*) that such hyperplanes define optimal groups. Thus, the method described here can be generalized to the case in which several specialty categories are to be considered in selecting an incoming class to medical school.

## Areas for Future Research

In our model, the parameters of the multiple logistics function must be estimated by using a sample of physicians whose career choices are known; these estimates are then used in computing the $\tilde{P}$s for a pool of applicants to medical school. The disparity between these two groups can lead to what Rydberg (*9*) calls "selective bias," which occurs when an equation derived from a selected, relatively homogeneous group is applied to a more diverse, heterogeneous sample. Rydberg gives the corrections for this effect when the multiple regression model is used. A possible avenue for future research is to investigate the effect of selective bias on the multiple logistic function. However, to satisfy the practical requirements of accurate prediction in an actual selection process, a single cross-validation of the equation would probably suffice.

Also, in conducting further research in this area, variables should be sought that will better predict the conditional probability of a person's entering a given category of medical practice. The Strong Vocational Interest Bank is a psychological test that has shown some promise of being able to provide such predictions (*10*). The bank, or its current version, the Strong-Campbell Interest Inventory, should be investigated for this purpose. Also, the model described here should be further tested, both retrospectively and prospectively.

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## SYNOPSIS


MORADIELLOS, DARWIN, P. (Travenol Laboratories, Inc.), and ATHELSTAN, GARY T.: *Selection of medical students to meet physician manpower needs. Public Health Reports, Vol. 94, January–February 1979, pp. 16–21.*

One way to help overcome the maldistribution of physicians would be to select an entering medical school class of a specific composition in terms of its members' predicted choice of specialty or location of practice, or both. To aid in selecting such a class, a statistical model was devised, which was tested retrospectively on 1,076 graduates of the University of Minnesota Medical School with encouraging results.

In applying the model, two numbers were calculated for each medical school applicant. The first was the estimated probability of the applicant's eventually becoming a family physician if admitted to medical school. A statistical formula was used to compute this number from biographical, academic, and standardized test data. The other number was an index of the applicant's general qualifications for a career in medicine as judged by the admissions committee.

Because it was assumed that an admissions committee would desire to choose a group of applicants that would eventually yield not only a specified number of family physicians but also a highly qualified group, the technique devised took both these aims into account.