The mathematics behind medicine

Medicine is advancing daily, as increasingly specialised treatments and techniques are continuously developed. Biostatisticians, such as **Professor Sumithra Mandrekar** and **Professor Jay Mandrekar** at **Mayo Clinic** in the US, are behind every medical advance, as they use their statistical skills and knowledge to bring real-world benefits to every field of healthcare.

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PROFILE

Field of research
Biostatistics

Research project
Using biostatistics to design and analyse clinical trials, leading to improvements in healthcare and medical treatments

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TALK LIKE A ...

BIOSTATISTICIAN

Biomarker — a biological molecule in the body, the presence of which indicates a specific condition

Biostatistics — the branch of statistics that studies data related to living organisms

Clinical trial — a research study that investigates the effects of new medical interventions on humans

Demographic data — statistical information that describes the characteristics of certain groups, such as age, race and sex

Intervention — any medical treatment

Mutation — a change in the DNA sequence of an organism

Neurology — the branch of medicine that involves the study and treatment of disorders of the nervous system

Oncology — the branch of medicine that involves the study and treatment of tumours, typically cancerous tumours

When was the last time you took medication? Perhaps you swallowed a painkiller, had a vaccine or used an inhaler. How could you trust that the drug you took was safe and effective? Or, if you have ever been to hospital for a medical procedure, how did the doctor know the best method for treating your condition? The answer to both these questions relies on data and biostatistics.

Before any new drug or medical treatment can be used, it must undergo a rigorous testing process to ensure it is not only effective, but also safe. Biostatisticians, such as Professor Sumithra Mandrekar and Professor Jay Mandrekar at Mayo Clinic, play a key role in this procedure, as they analyse the data collected at each stage of the process to statistically evaluate the effectiveness and safety of the intervention.

"Biostatistics combines data and biology," explains Jay. "Biostatistics helps in all stages of medicine, starting with the development of new drugs in the lab, through the initial testing of experimental drugs or treatments on animals, to finally testing them on humans in clinical trials."

What are clinical trials?

This last step – testing treatments on human patients – forms the focus of Sumithra and Jay's work. "Clinical trials are research studies performed on humans, to help understand and evaluate medical interventions," says Sumithra. "They are the primary way that researchers discover if a new treatment is safe and effective." Every new medical intervention – including drugs, diets, surgical procedures, psychiatric techniques and medical devices (e.g., pacemakers and blood sugar monitors) – must be assessed in a clinical trial before it is used on patients.

Clinical trials rely on patients with the medical condition of interest, who volunteer to take part. Some participants in the trial will receive the usual intervention given to patients with that condition, while others will receive the new intervention being investigated. By examining the data

collected on the health outcomes of each group of participants, biostatisticians can statistically determine which intervention is best.

Clinical trials are all about the data. Researchers collect a wealth of information about each participant, including demographic data, medical history, lifestyle factors that may affect their medical outcome (e.g., smoking, diet, exercise), how they respond to the intervention (e.g., Did their condition get better or not? Was their quality of life improved by the intervention?) and any side effects they experience. With so many variables to consider, and as most clinical trials contain hundreds of participants and continue for several years, they produce very large, incredibly detailed and highly complex datasets.

Why do clinical trials need biostatisticians?

"As biostatisticians, we help design the trial so it can answer the questions posed by the researchers," says Jay. "For example, researchers may want to know if the intervention can prolong participants' lives and, if so, for how long?" This information determines how many participants need to be enrolled in the trial, and for how long researchers will need to collect data from them.

"When the trial is completed, all the collected data are reviewed to ensure there are no questionable data points or missing information," says Sumithra. The data are then analysed using a variety of statistical techniques to draw conclusions about whether the new intervention benefitted participants and should, therefore, be made available to other patients.

In this way, biostatisticians contribute to medical advances, by providing the evidence to prove which treatments should be given to which patients, and paving the way for new drugs, surgical procedures and medical devices that enhance patients' quality of life.

Real-world applications of biostatistics

Organ donations can save lives by supplying patients with a healthy organ to replace a deficient one of their own. While living people can donate some organs, such as a kidney, most donor organs come from people who have died. However, to be usable, the organs must be taken very soon after death. "In many instances, patients with catastrophic neurological diseases, who have no possibility of survival, are the best candidates for organ donation," says Jay. "Once life support is withdrawn, death is inevitable, but predicting the time of death is challenging." By statistically analysing data collected from such patients, Jay's team identified simple neurological and respiratory measurements that can predict the time of death to within an hour's accuracy, allowing doctors to maximise the chances of successful organ donation. "By providing up to eight organs and a variety of tissues, a single patient can save or enhance the lives of over 50 people," says Jay.

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In his work as a biostatistician, Jay has not only evaluated healthcare data and clinical trial results, but he has also helped improve the clinical trial process. Most clinical trials collect data using surveys answered by patients or their caregiver. For example, to determine the severity of neurological symptoms, patients had to answer 169 questions about their condition. "Long questionnaires can be time-consuming, burdensome for sicker patients and overly complex," says Jay. "This increases the risk of missing important information and reaching biased conclusions." Jay's team statistically evaluated which data were most important for assessing neurological symptoms and designed a much simpler questionnaire, containing only 31 questions, that still provides statistically robust data. "This survey is being used in clinical trials and has improved the quality of data being collected, leading to more reliable conclusions," he says.

While Jay applies biostatistics to neurology, Sumithra applies it to oncology. Chemotherapy is a common treatment for cancer, but it attacks the rest of the body as well as the cancerous cells, leading to unpleasant side effects such as nausea, hair loss and an increased risk of infections. "However, cancer is becoming increasingly understood on a cellular and molecular level," Sumithra explains. "These days, many cancers can be described using biomarkers or tumour genetic mutations." New therapies are being developed to target the tumour mutations specifically, many of which have successfully completed clinical trials and been approved for use. "More recently, therapies that unleash the patient's own immune response to fight cancer cells are being tested in clinical trials," says Sumithra, who has been designing and analysing clinical trials in oncology.

Medicine is becoming increasingly personalised, so instead of being tailored to a certain disease, it is tailored to a specific individual. "Certain molecular or genetic traits can capture information on the nature of a disease along with relevant patient-specific information," says Sumithra. "This allows doctors to define the optimal course of treatment for each patient." For instance, there is a clinical trial in progress to screen patients with a particular form of lung cancer, to see if their tumours contain specific biomarkers that can be targeted by specialised treatment. Such personalised treatments, supported by statistics, have the potential to revolutionise the whole field of medicine, bringing benefits to everyone receiving healthcare.

ABOUT *BIOSTATISTICS*

Biostatistics involves the application of statistical mathematics to any area of biology, be it medicine, genetics or epidemiology. Within medicine, where Sumithra and Jay work, it provides the analytical tools necessary to ensure that research into medical interventions is robust and accurate.

What skills do biostatisticians need?

A mathematical mind can bring big benefits to the world of medicine. "The ideal biostatistician is excited by data," says Sumithra. "They are adept at analytical and logical reasoning, have good communication and teamwork skills, can think outside the box, and can learn and understand the biology behind experiments and clinical trials."

Why is biostatistics exciting?

Sumithra and Jay were both drawn to biostatistics as it takes mathematics, which can seem like a theory-based subject, and applies it to find exciting and impactful solutions for real-world problems. "Biostatistics is a fundamental discipline at the core of modern health data science," says Sumithra. "It underpins most key public health research efforts, whose solutions have far-reaching positive impacts for society."

Collaboration is a necessary and highly rewarding part of a biostatistics career. "Biostatistics is an exciting field, where individuals often work with other health scientists and professionals in an interdisciplinary environment," says Jay. "Such people collaborate to identify, measure and solve problems that pose threats to public health. As a result, biostatistics touches the lives of people in a meaningful and measurable way."

Pathway from school to *biostatistics*

- Mathematics and biology are key subjects to study at school and post-16.
- Some universities offer degrees in biostatistics. A degree in mathematics, statistics, data science or public health could also lead to a career in biostatistics.
- Sumithra and Jay recommend taking classes in data analyses, public health policy, health services research, clinical trials and experimental design.

Explore careers in *biostatistics*

- Biostatistical skills are valuable in a wide range of careers, providing a variety of career opportunities. "Biostatisticians can work across many different sectors, using their skills in analysis, problem solving, communication and critical thinking," says Jay. "This can involve working in the healthcare industry, government, public health policy organisations or biomedical firms."
- Mayo Clinic where Sumithra and Jay work, offers summer internships and training opportunities for high school and college students: jobs.mayoclinic.org/trainingprogramsandinternships
- Sumithra and Jay recommend This is Statistics (www.thisisstatistics.org) as an excellent resource to explore the many avenues for pursuing a career in statistics, going beyond medicine and public health.

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Meet Sumithra

Growing up, I always had an interest in the field of medicine. Originally, I wanted to be a cardiologist, focusing on the heart. I wanted to find a career that combined my interest in biology and medicine with teamwork, leadership and human connections.

Working as a team is highly rewarding. I love the ability to interact and work closely with world-class doctors and scientists to find new treatments for cancer.

I fill my free time with creative pursuits. I enjoy reading, music, travelling and spending time with my family.

It is important to have a passion for what you do. And don't feel shy to reach out and ask for information, advice or training opportunities from experts in the field you are interested in.

Biostatistics helps in all aspects of medicine
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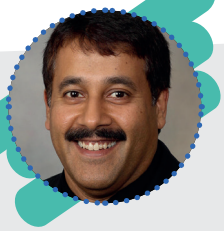

Meet Jay

I have always been interested in numbers and analytics. When I was younger, I was interested in becoming an applied mathematician, but not necessarily in the medical field. It was my personal health issues that made me curious to learn about biology and medicine. This then prompted me to explore opportunities to apply mathematical and statistical skills to the medical field.

I love working with a wide range of individuals from a variety of disciplines. In my work, I collaborate with nurses, doctors, statisticians and engineers, among others. Additionally, it's incredibly rewarding to see my work go on to transform patients' lives.

> ***STATISTICS CAN SEEM DAUNTING, BUT DON'T BE PUT OFF BY STATISTICAL COURSEWORK!***

I have a variety of hobbies outside of work. I enjoy travelling, listening to music, watching movies, powerlifting and spending time with my family.

Statistics can seem daunting, but don't be put off by statistical coursework! These days, most real-world statistical work is conducted by sophisticated software, and solving real-life clinical problems using these statistical tools is fun.