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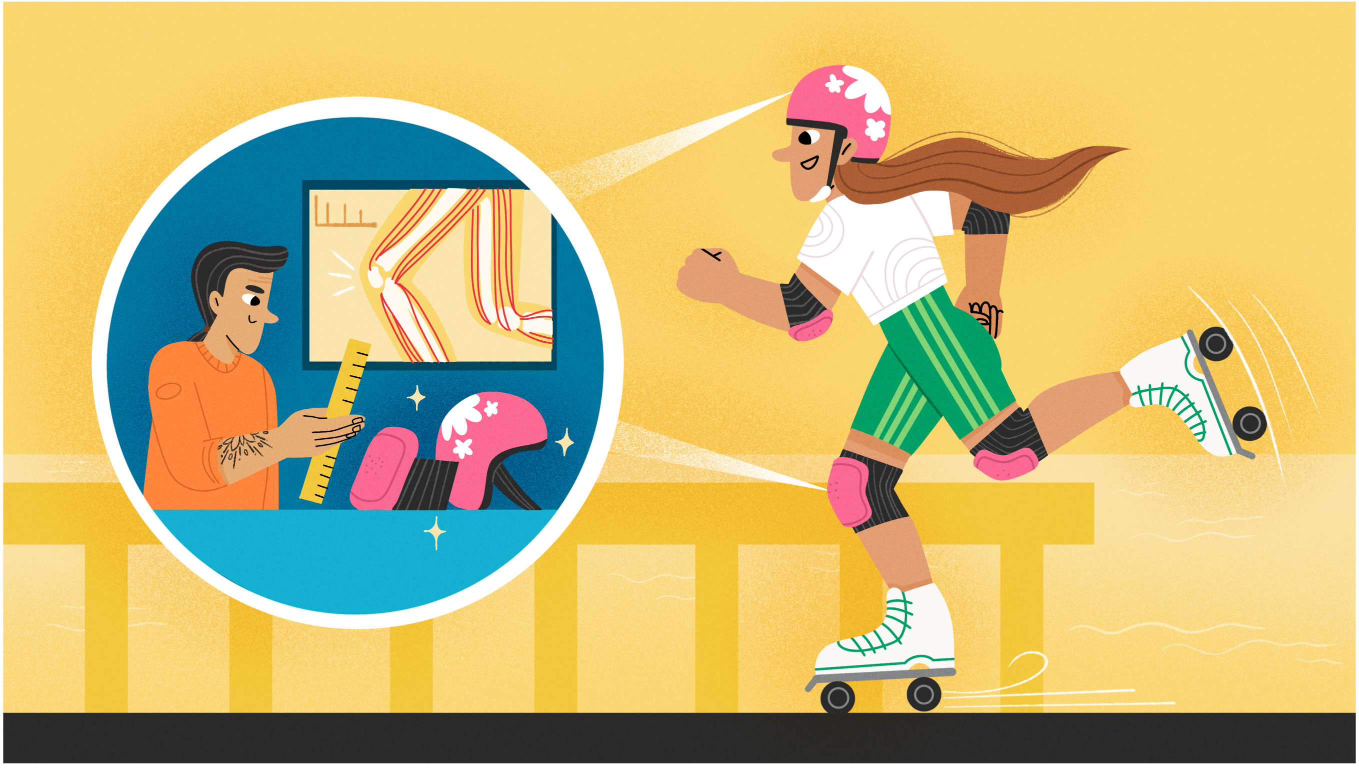

THE SECRET BEHIND YOUR PHYSICAL SAFETY: HOW COMPUTERS HELP

Numaira Obaid [1,2*]***, Dexter L. Zamora*** [1,2]***, Fatemeh Khorami*** [1,2]***, Fernando Gomez*** [1,2]***, Teresa Lau*** [1,2]***, Cesar Jimenez-Gonzalez*** [1,2] ***and Carolyn J. Sparrey*** [1,2*]

[1] *School of Mechatronic Systems Engineering, Simon Fraser University, Surrey, BC, Canada*
[2] *International Collaboration on Repair Discoveries, Vancouver, BC, Canada*

YOUNG REVIEWERS:

ARIA
AGE: 13

LANDON
AGE: 10

Have you ever wondered how scientists know what happens inside the body during an injury? Injuries happen when a push or pull (force) on the body becomes too high, like from a sudden impact. But scientists cannot see these forces, so we use computer models to help solve this mystery. We feed computer models clues like the person's size, age, and activity before the injury, as well as injury details. If we can figure out how much force caused the injury, this can help engineers design equipment to protect the body. We use different types of computer models to understand different injuries. Rigid body models help us study whole-body movements like falls or car crashes. Musculoskeletal models simulate activities like walking or lifting. Finite-element models look at a single body part like a knee ligament in a slide tackle. We need to know a lot about how each body

part behaves and turn those behaviors into math for the computer to solve.

For a summary of this article, see Video 1.

VIDEO 1

An overview of how scientists use computer models to study our body.

HOW DO BODIES MOVE AND HOW DO THEY GET INJURED?

Your muscles and bones work together to help you move. Muscles pull on bones to move your arms and legs around, like a puppet. How hard the muscles pull on the body is called a **force**. People also feel pushing forces on their bodies every day. For example, when you stand, the ground is pushing on the bottom of your feet. Forces (push or pull) can be good and help people move the way they want to. But too much force can cause the body to break. Forces can act *inside* the body, like between bones in your knee as you walk. Forces also act *outside* the body, like the ground pushing on your hand when you fall. When someone gets injured, there is usually a force acting on the outside of the body that causes a chain reaction of forces inside the body. For example, if you lift a very heavy box, your hands and arms might be able to carry the load without getting hurt. But the forces pass all the way through your body and may be too much for your back. Each body part can take a different amount of force before it breaks. These breaking forces are also different for different people.

FORCE

A push/pull on an object. Forces can come from inside the body (like muscles pulling on bones) or outside the body (like gravity which keeps you on the ground).

WHY DO WE NEED COMPUTER MODELS TO STUDY INJURY?

If scientists and engineers know how much force causes an injury, they can design safety equipment to make sure that the body does not experience forces close to this point. By making sure the forces that the body experiences are low, we can try to prevent injuries from happening. But injury is a hard thing to study. It is impossible to see or measure the forces inside a living person. People are not usually covered in sensors when they get hurt, and we cannot hurt people on purpose for science.

Computer models can help us calculate the forces that cause an injury by simulating what happened. For example, say a person fell on their elbow and fractured a bone. We might know what this bone looked like before it was injured, and we can use X-rays to see what it looks like after the injury. We might also know what the person was doing when they fell. If we are missing information, like what type of ground the person fell on or how fast they were moving, we guess. The great thing about computer models is that we can try many guesses. We can see how our guesses affect the forces in the elbow. If the elbow fracture was caused by a boy falling at a playground, a safety engineer might use models to decide whether rubber or woodchips are better

COMPUTER MODEL

A digital version of a real-life object, built on a computer so scientists can test ideas and situations to see what might happen without using real people.

for a new playground. If the elbow fracture was caused by a teenage girl falling off a skateboard, an equipment company might design new elbow pads and use the models to decide how thick they should be and what material to use for the padding. Computer models can tell us lots of things about an injury that we cannot figure out from images or experiments alone!

How do Computer Models Work?

Computer models use **software** to solve math equations, so everything in the model must be turned into math first. Scientists collect information like the shape of the body, outside forces, how muscles and bones move, and properties like how different body parts stretch or break. These are converted into numbers and equations the computer can understand and use as inputs. How the model runs depends on what we want to know. It can be as simple as using a smartphone app that records how the body moves and automatically turns it into a computer model, or it can be very complex and require **supercomputers** with software that can take days or even weeks to finish one model.

SOFTWARE

A set of computer programs that tells a computer what to do. Special software can run on computers to solve complicated math problems.

SUPERCOMPUTER

A very powerful computer that can solve very large problems faster than a regular computer.

WHAT ARE THE TYPES OF COMPUTER MODELS USED TO STUDY THE HUMAN BODY?

There are different types of computer models that help us understand the forces and movements of the human body. Each one is designed to answer specific questions (Figure 1).

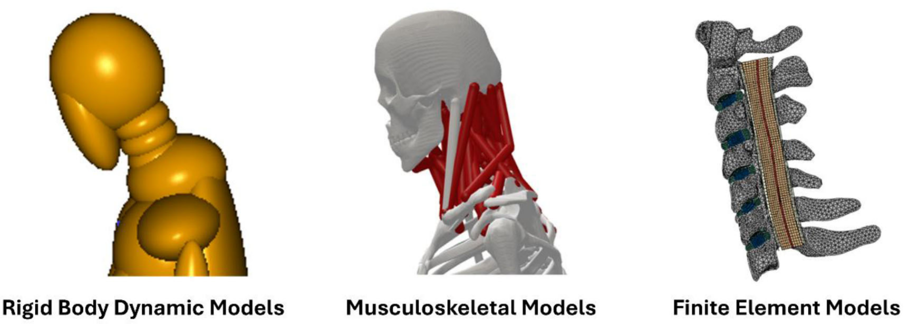

Figure 1

Figure 1

We can use different computer models to look at the neck, based on the research question we are trying to answer. For example, Rigid body models estimate how internal forces change in response to external loads, such as in car crashes or falls, musculoskeletal models add muscles to examine how they influence motion and injury, and Finite element models divide tissues into small elements to map stresses and strains within individual structures.

Rigid Body Models

Rigid body models take a "big picture" approach to see how the whole body moves together. We imagine the human body as a series of parts, like Lego blocks, connected by joints. These models calculate how *outside* forces acting on the body (like in a car crash or fall) create forces *inside* the body, in bones, joints, or tissues. For example, we can use this type of model to estimate the forces at the hip joint during a fall or the forces in the neck during a rear-end collision. We can run lots of

RIGID BODY MODELS

Computer models that simplify the body into connected parts, like Lego blocks, to study how the body moves and how outside forces affect it.

simulations quickly by simplifying the body into Lego blocks for each part. This makes it great for testing new safety equipment [1].

Musculoskeletal Models

In some injuries, it is not enough to consider the body as blocks. Sometimes we need to know what these blocks are made of—bones, muscles, tendons, or ligaments. Each of these parts can change the forces inside the body. To understand these parts, scientists use **musculoskeletal (MSK) models**. MSK models still use rigid bodies to capture the bones of the skeleton but also include individual muscles. These muscles can apply different forces to help us understand how the tissues are affected by impacts or movements, like forces in a slide tackle that cause an ankle sprain. MSK models can also be used to change the properties of muscles, like their shape or stiffness, to model specific muscle conditions. For example, in children with **cerebral palsy**, scientists can model movement and see how it changes with different treatments [2].

MUSCULOSKELETAL MODELS

Computer models that include both bones and muscles to study how these tissues work together to create movement or cause injury.

CEREBRAL PALSY

A condition that affects movement, balance, and posture in affected people.

Finite Element Models

Sometimes we need even more detail to understand injuries. For example, what if we want to know where specifically in the bone the injury might happen? Will a force cause a full fracture across the bone or just a small hairline fracture? For shapes and materials as complex as human body parts, there are no math equations to calculate what is happening in each tissue. Instead, we use **finite element models** that divide the complex body part into very small blocks, called elements. We use computers to calculate what happens in each block in situations where people experience forces. The blocks with the highest forces can tell us which body area is most likely to become damaged [3].

FINITE ELEMENT MODELS

Computer models that break a body part into many tiny pieces (elements) so scientists can see exactly how forces are spread within tissues and where damage might occur.

What are Some Applications of Computer Models?

We have already talked about a few areas where computer models can help us, but there are lots of other areas where they might be useful. For example, if we want to design a new car, we cannot test its safety with real people inside. So, engineers can use rigid body models to figure out what happens to a person during a car crash. In sports, we might use musculoskeletal models to figure out what happens if you twist your ankle while trying to jump rope. We can also figure out the forces on an athlete’s joints when they run. This information can help coaches train athletes to use better techniques or suggest exercises to strengthen specific muscles.

Engineers are always looking for ways to make the environment safer to prevent injuries. So, any time you see safety equipment—seatbelts in cars, helmets in sports, fall protection in a construction zone—these all need to be designed and tested. How do you know if a seatbelt will protect you? Or which car seats keep babies safest? Computer models are a very important part of making sure the safety equipment we make is keeping people safe. By testing different designs in computer models, we can estimate the outside forces experienced by the body. We can keep making design changes to make sure these forces stay below the levels that could cause an injury [4].

Can we Solve Everything Using Computer Models of the Human Body?

While computer models can help us answer key questions about the how the human body works, it is not as easy as it seems to make a model. We cannot use computer models for everything. First, everyone is different. We have different heights and weights, and even on the inside, the shapes of our bones and muscles are unique. This means that computer models need to capture different people [2]. Second, what we get out of these models depends on what we put in. For example, we may not have all the inputs we need to run a model. So, scientists try different guesses until the model's results match what they expect to see. While models can tell us a lot about safety and the human body, they are not the only way to figure these things out. Sometimes, experimental tests are used, and sometimes experimental tests are combined with models to give us a better picture. It takes years of research to build just one model, and many scientists build on each other's work to improve models. There is still lots of work left to do before we can completely understand the human body, but each model helps us get a little bit closer.

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AI TOOL STATEMENT

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ARIA, AGE: 13
Aria loves playing with her two guinea pigs and feeding birds and squirrels in her backyard. She gave each squirrel a unique name and lots of peanuts. Aria is always curious about science and she has a lot of questions about nature, animals, and universe. She also likes singing and drawing in her spare time.

LANDON, AGE: 10

Landon, 10 years, is an award-winning member of Davinci Dragon's North Carolina Science Olympiad Team and two-time participant in Kyran Anderson Science Academy. He holds citizenship in two countries and loves to play music, read, swim, and rock climb.

AUTHORS

NUMAIRA OBAID

Numaira Obaid is a postdoctoral scholar researching how spinal morphology influences neuro-biomechanics during spinal trauma. She specializes in understand ing spinal cord injury biomechanics in degenerated spines with particular emphasis on incorporating inter-individual anatomical differences to identify risk factors that increase injury risk in certain populations. Dr. Obaid earned her Ph.D. in chemical engineering from the University of Toronto, where she specialized in the mechanics of complex materials, and her B.A.Sc. in chemical engineering from the University of Waterloo. She is also passionate about teaching and communicating science, with a commitment to inspiring the next generation of scientists and engineers. *nobaid@sfu.ca

DEXTER L. ZAMORA

Dexter Lagasca Zamora is a Mechatronic Systems Engineering Master's student in the NeuroSpine Lab at Simon Fraser University with expertise in robotic applications and computational modeling of preclinical spinal cord injury. One aspect of his work is using models to better understand the underlying injury biomechanics under various loading mechanisms. Driven by a passion for user-centered design in health applications, he aims to develop innovative solutions with tangible real-world impact. He has also contributed to a workshop series that connects the public to experts in existing and emerging health technologies and aspires to advance research in soft medical robotics.

FATEMEH KHORAMI

Fatemeh Khorami received her M.Sc. in Biomedical Engineering with a specialization in Biomechanics from Amirkabir University of Technology. Her passion for understanding human injury mechanisms grew during her Ph.D. studies at Simon Fraser University, where she explored fall dynamics, sex differences, and soft tissue biomechanics. Fatemeh defended her thesis in November 2024 and is now a postdoctoral fellow at the University of British Columbia. Her current research focuses on the intersection of data science and women's health to improve outcomes for diverse populations.

FERNANDO GOMEZ

Fernando Gomez is a Mechatronic Systems Engineering Master's student in the NeuroSpine lab at Simon Fraser University. His current research focuses on the development and efficacy of an ankle orthotic design meant to streamline and improve the overall recovery of patients that have suffered major ankle injuries. Fernando's research interests focus on the overlap between healthcare and engineering design. He believes that collaboration between clinicians, and end-user

alike are necessary to seamlessly pair technology with treatment plans to deliver the best care possible.

TERESA LAU

Teresa Lau is a Mechatronic Systems Engineering Master's student in the NeuroSpine Lab at Simon Fraser University. Her research focuses on redesigning hospital laundry hampers to improve healthcare worker safety and reduce injury risks. Teresa is passionate about bridging the gap between engineering designs and the needs of clients, clinicians, and end-users through effective communication and collaboration. Committed to combining technology and human-centered design, she is dedicated to enabling users and creating meaningful, practical solutions that address real-world challenges.

CESAR JIMENEZ-GONZALEZ

Cesar Jimenez-Gonzalez received his B.S. in Mechatronics Engineering from Tecnológico de Monterrey, Querétaro, Mexico. He developed an interest in studying human injuries during a summer internship at Simon Fraser University's NeuroSpine Lab in BC, Canada. He later returned to Canada to pursue his M.A.Sc. at the same lab, focusing on computational models of spinal cord injury and applying machine learning to analyze the results. Cesar defended his thesis in April 2024 and now works as the lab's research engineering assistant, helping to instrument a crash test dummy and set up a data-acquisition system for future biomechanical research projects.

CAROLYN J. SPARREY

Dr. Sparrey is the Director of the NeuroSpine Lab at Simon Fraser University and internationally recognized for her work in spinal cord injury biomechanics. She applies engineering principles to explore biomechanics, understand and prevent human injury, and develop biomedical wearables to support injured patients. Dr. Sparrey enjoys engaging all stakeholders in the research process. Her work includes testing fall protection with Iron Worker instructors and apprentices, designing assistive rowing technology for people with spinal cord injuries, developing a calibrated air cannon to test spear head technologies with archaeologists, and studying traffic patterns around elementary schools with grade 1–3 student collaborators. *csparrey@sfu.ca