by Rosemarie Connelly

Sports shoe technology

Setting a Fast Pace

"The most important piece of equipment a runner has is his shoes," wrote Bob Anderson, the editor of *Runner's World* in 1975. The statement holds true today. Since the running boom of the 1970s, the running shoe has undergone a tremendous revolution. Many of the sneakers on the market today resemble futuristic moonboots, with various features such as spring-like heel mechanisms (the new Nike Shox), instep support devices™ (Saucony), and elastic forefoots (Adidas Equipment Ride). With the vast selection of sneakers and all of their fancy features, shopping for running shoes can be a daunting experience. How does one distinguish between the hype and the really helpful features that will protect feet from the stresses of running?

Before buying a shoe, it helps to understand the biomechanics of running, and specifically of one's own feet. A "normal" foot is categorized by an arch of medium height. "Flat-footed" people are most likely to overpronate, or cave in at the arch. High arched runners may have weak rearfoot stability. In addition to the geometry of the foot, other factors such as the runner's weight and frame, speed, mileage per week, and running surface should be considered.

Brian Moore, a Saucony representative, explains overpronation by comparing the heel to a baseball. "When [a baseball] hits the ground at a certain angle, it's going to roll and continue on that same path. When you step down on your heel, you're hitting it from the outside in because your heel bone is round, and you're going to tend to keep rolling the way that you land. Depending on how flexible the tendons and ligaments in the foot are, that will determine how far the heel rolls. If you have a flat, flexible foot, it's going to roll a lot, and you're going to need some pronation control."

According to the American Academy of Family Physicians, 70% of all runners experience injury. The most frequent injuries are knee injuries (25%), followed by Achilles tendinitis (18%) and shin splints (15%). In addition to overpronation, another important factor causing injuries is the high impact of the heel-strike. Sneaker companies are constantly creating new designs to reduce the stresses of running and therefore prevent injury.

When asked if the latest shoe technologies contribute to faster times or decreased injuries, Bob Wischnia, shoe expert at Runner's World magazine, responded, "Times have undoubtedly gotten faster, but I wouldn't attribute that solely to shoe technologies. Better nutrition, better emphasis on full time training, and improvement of tracks have all contributed. But shoe technologies have definitely decreased injuries. I mean, 20 years ago knee injuries and shin splints were so prevalent. Shoes today have much greater stability."

"The running shoes today are lighter, more breathable, more durable, and more stable than the shoes of the past," says Wischnia. According to www.nikebiz.com, running shoes before the 1970s had midsoles fabricated from sponge rubber wedges. These sponge wedges were dense, heavy, and became compacted quite quickly. With the inventions of ethylene vinyl acetate (EVA) and polyurethane (PU), midsoles were able to become more durable.

Moore says, "Before the 1970s, running shoes were made out of more of an open-cell foam. What that means is that they broke down a lot quicker. When you ran in them, they flattened out in a matter of weeks. EVA and polyurethane are two foams that they found that could actually take a beating because they were closed."

Almost all running shoes use these two materials for their soles, but different shoe companies have designed various features based on their independent research. In 1978 Frank Rudy, an aerospace engineer at North American Rockwell, envisioned a running shoe with encapsulated air for cushioning. Nike patented that idea, calling it "Nike-Air." Essentially, this technology features a gas of a large molecular structure pressurized into a tough yet flexible urethane bag. These "Nike-Air units" are long-lasting because the molecules of gas are larger than the openings in the urethane membrane.

Nike improved upon this idea with the "Zoom-Air." Two fabric layers are connected by thousands of vertical fibers, which are surrounded by the pressurized gas inside a "Nike-Air" unit. The pressurized gas exerts an outward force as the fibers exert an inward force, preventing the air bag from ballooning out. Zoom-Air is only 8 mm thick, so that the foot is cushioned, yet it remains close to the ground for "optimum feel and quick response."

Saucony uses a different method. Their shoes feature a "Grid" device to divert the impact. "When you step down and put all of your weight onto the ground, the shock will shoot right up into your legs," says Moore. "So if you can take the heel and not have it land directly on the hard ground, and create a void beneath it, then it won't have direct contact with the ground and there won't be as much shock. Think of it like a tennis raquet over an open space. The pressure is absorbed in the Grid cassette. It's an elastic but very strong plastic material that will cradle the heel in that void. Because it has a lot of memory it will spring back into its original shape as you take the pressure off of it."

How does a shoe company come up with a new design? Moore explains, "Initially we come up with a concept. How do we address a particular foot type for a particular runner? Basically the midsole is made out of either EVA or polyurethane. Once you identify what type of foot you're addressing, then the first thing to do is to identify which material to use as your base material."

"Although both are still used, over the last 20 years the material used for the midsole has shifted from polyurethane to EVA," says Wischnia. Polyurethane is denser and more durable, but also heavier than EVA, which is a lightweight, cushy foam. Some shoes use both materials, with EVA in the forefoot and polyurethane at the rearfoot for extra stability.

Once the midsole material and shape are decided upon, the next step is to modify the shoe according to the runner's needs. For example, an overpronator would need more support on the medial side of the heel. A firmer density EVA may be used on this side (known as "medial post" or "dual density").

Computer technologies also play a role in shoe design. Mario LaFortune at the Nike Sport Research Lab explains in an on-line interview (www.nikebiz.com) that many different pieces of equipment are involved in foot analysis for new sneaker design. One motion analysis system "allows us to measure and quantify by following bony landmarks on the foot," says LaFortune. Using five different cameras, this machine takes up to 200 pictures per second, giving a three-dimentional analysis. Another machine, a goniometer, measures ankle angles when somebody is running with different footwear. Other tools measure the static shape of the foot at rest to address the question of fit.

Special insoles can measure the forces — or loading — on the foot. Wischnia said that the research and development departments of major shoe companies use a machine called the Cad-Scan, which has "revolutionized shoe design."

Once the research is complete, designers analyze the data and come up with different possible solutions for problem areas.

Shoe companies use a last (pictured left), which is a plastic model of a foot, to begin a sneaker design. The last is essentially an "average" of millions of feet that have been scanned using the Cad Scan or a similar machine. Using a last allows the shoe company to manufacture in mass quantity instead of catering to individual needs. A company may have several lasts, representing different cross-sections of the population. These lasts differ depending on the activity for which the show is designed and unique foot characteristics.

New Balance uses 13 different lasts for their line of shoes. In general, lasts are occasionally modified according to changes in the population, but for the most part the same lasts are used from year to year.

Machines similar to the Cad Scan are more often used to make orthotic inserts. Footmaxx is one company which uses a computerized device to measure foot shape. First, a subject walks across a proprietary force plate. The pattern of foot function and weight distribution is scanned 30 times per second by 960 electronic measurement points. The data is displayed on a monitor as a two or three-dimensional image.

The data is then sent to the diagnostic laboratory. Footmax's software, Metascan™, calculates arch height , length and the rise of the orthotic in order to correct the individual biomechanical abnormalities of the subject.

While shoe companies design sneakers for different foot types, the type of activity also plays a role in the sneaker design. There really is a difference between basketball shoes, running shoes, and cross trainers.

Brian Moore explains, "A running shoe is meant to go from back to front only. There's nothing built in a running shoe to keep you from rolling off of it. That's why running shoes are horrible to play basketball in or tennis or aerobics. Basketball and cross training shoes have to build up the sides because there's more lateral motion."

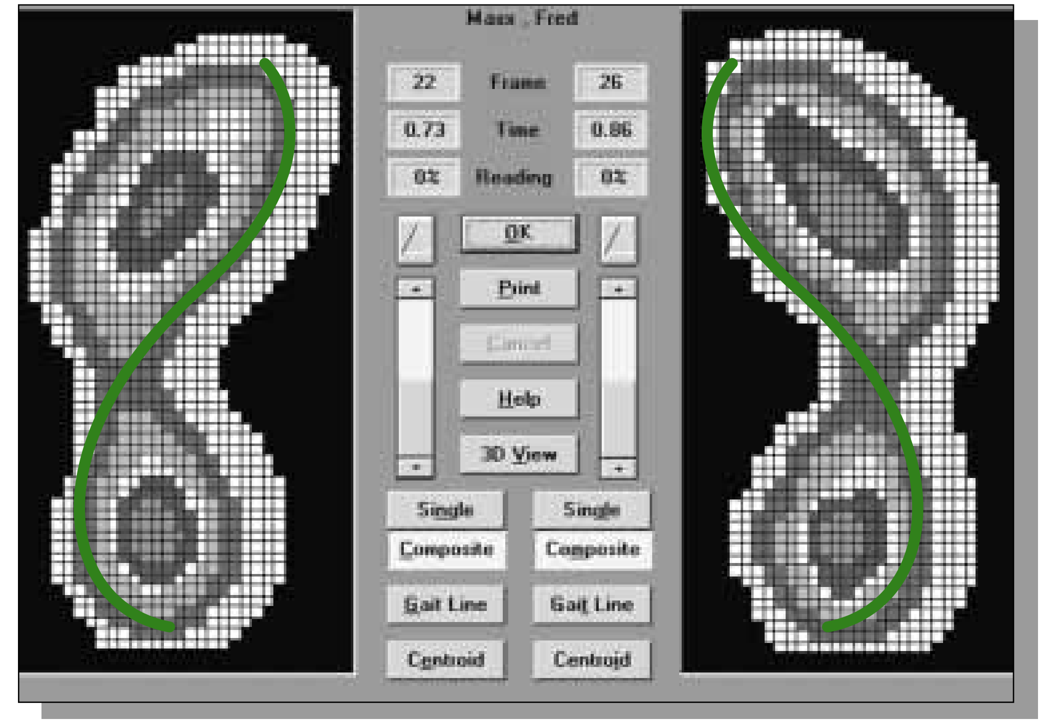
Researchers at labs such as the Nike Sports Research Lab devote much of their time to identifying the individual needs of different athletes. Mario LaFortune speaks specifically about basketball. The frequency of certain movements (i.e. cutting, shuffling, braking, moving forward, moving backwards, moving sideways, breaking to the hoop) made during the game is noted. The athletes themselves are also a data source; they inform the researchers during which moves they feel their footwear plays a critical role.

Research shows that the biomechanical needs of athletes are not just sport-specific, but even position-specific. For example, a power center on a professional men's basketball team is typically close to 7' tall, around 250-275 lbs. His position requires that he run up and down the court at a leisurely pace; when he jumps, it's straight up and down. Alternately, a guard on the team will be about 6'3-6'7, around 180-200 lbs. His position requires him to move from side to side at various speeds. Obviously these two players have very

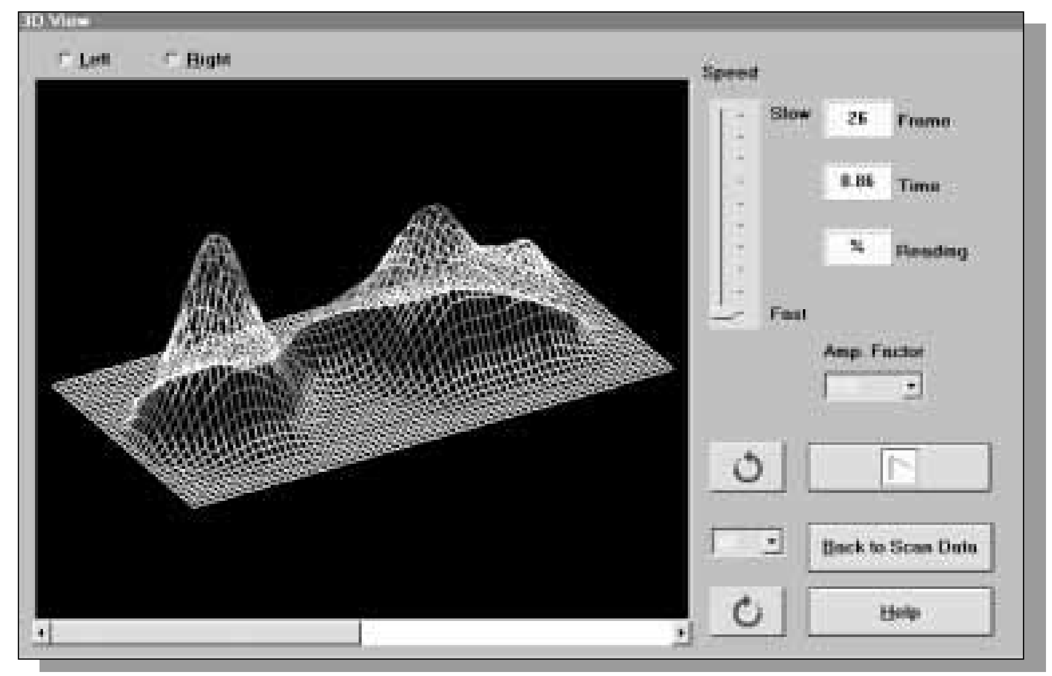
different needs, and the features of their shoes would reflect those needs.

The biomechanical needs of an athlete is gender-specific as well. According to LaFortune, Nike data shows that for basketball, "Men play a more stop-and-go game while the women's game has a more cool, continuous pace." In terms of running, women's feet differ from men's, and these differences are reflected in the shoes. According to Bob Wischnia, women's feet have a wider forefoot and a narrower heel, and they overpronate faster. In addition, women's hips are wider, giving them a different gait.

All of these factors in shoe design can make shopping confusing for the average consumer. Visiting a specialty shoe store with a knowledgeable staff is probably the best option. Some stores even have their own gait-analysis machines to help you make your decision. Another option is to use the internet. Most major shoe company websites can help you find the "perfect model" when you enter some personal data such as height and weight. The Runner's World site is less brand-biased (www.runnersworld.com/shoefinder). Just remember to look past the marketing and the hype of the shoe and recognize the features that will really help.



The green line overlaid on the scan of each foot shows a normal "gait curve." Imagine that the curve is a string attached to the bottom of the foot. The more a person "overpronates"–rolls their foot too much medically–the more they pull the curve out of the string.



The three-dimensional image shows the pressures under a person's foot as he or she moves through a "gait cycle" (or skip).

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DESIGN BRIEF

by Pat Hutchinson

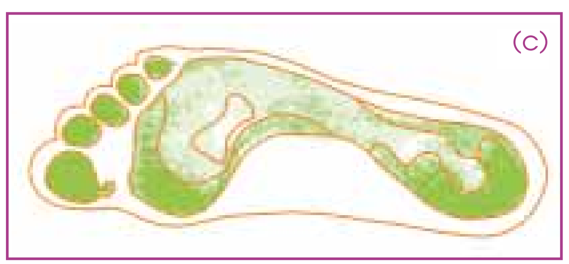
The engineering that goes into sneakers is nearly mind-boggling, but then, athletic shoes are serious business. Even to the less athletically inclined, the prospect of continued mobility throughout a long life makes the science and technology of footcare important.

In the Mar/Apr '00 issue of *TIES* I described an activity we use to explore both structural principles and aesthetic preferences through the design first of paper sandals, then of sneakers. That activity scratches the surface of these issues. This article suggests some ways to delve more deeply into the real issues of sneaker design.

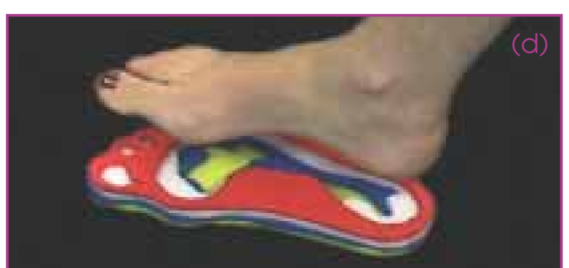
One of the most critical aspects of sneaker design has to do with gathering information about the foot. As Rosemarie Connelly has pointed out, that is a sophisticated science. Comfortable and efficient movement in sports means that measurements of many kinds must be taken, not just of feet at rest, but of feet in action, and from all angles. Our challenge is to try to simulate some of that measuring in the classroom.

At first I thought that advanced Electronics or Control Technology classes might be able to simulate the pressure pads used by orthotics manufacturers to acquire data about individual feet, but the sheer number of tiny sensors needed seems to be out of reach of the average technology class. Gathering information about pressure exerted by a foot at rest is only the beginning of the kind of diagnostics that lead to good support, as indicated by the information from the Footmaxx company, a maker of advanced orthotics.

So how can a technology class gather information about the pressure a foot exerts? Here's a path of experimentation I decided to follow.



(c)



(d)

Dust for footprints

I wondered whether a white on black or a black on white print might supply more information. So I put a layer of talc in the bottom of one shoe box, a layer of black powdered poster paint in another.

I tried both, consecutively, with my right foot and then examined the prints. The black print (a) was clearer. I repeated the process to compare the prints, this time remembering to also draw around my foot (b). My aim was to use this information to make a supportive insole, and I needed to know the size and shape of the bottom layer.

I envisioned using the information about my foot to build up an insole from layers—stereolithography-style. Contrary to my expectations, I could tell that the darkest areas of my print were not the areas of greatest pressure. In fact, the areas that got the most pressure were medium gray, because the pressure bonded the powder to my skin and pulled the dry poster paint away with my foot. Areas of contact but little pressure were the darkest. I tested this theory on another print I'd made in which I rocked forward, putting more pressure on my toes. The toes on this print were lighter.

Turning the print into a topographic map was the next step. After considerable thought, I scanned the images, then tried several Photoshop effects, finally using the "cut-out" effect to try to isolate the continuous tones into four levels: black, white and two grays. With a red grease pencil I smoothed the edges of the shapes (c), then used these layers as templates to cut out 1/4" layers of Plastizote™ to build up a contoured insole, and glued the layers together to create the negative of the shape of my foot's imprint (d).

The resulting insole can be attached to a more rigid support. Designing bands of leather or fabric to attach the sole to the foot sets the stage for wear-testing the insoles for comfort and further refining.

Students Compete at 2001 National Technology Student Association (TSA) Conference in Richmond, Virginia.

By Hillary Lee

Top technology education students from thirty states, Puerto Rico, and Germany recently attended the Technology Student Association's 23rd Annual National conference in Richmond, Virginia. The conference, which was held from June 21st through June 25th, 2001 at the Richmond Convention Center, attracted more than 3300 young people, their advisors, and other attendees who participated in national level technology competitions, special interest sessions, general sessions, and TSA national officer candidate campaigns and elections. An awards ceremony at the close of the conference recognized the top ten finalists in each category of competitive events.

TSA is a membership association comprised of approximately 115,000 elementary school, middle school, and high school students who have a strong interest in technology and who are, or who have been, enrolled in technology education courses. Currently, there are 1500 TSA chapters in forty-five states across the nation. TSA's goal is to promote technological leadership and personal growth through student participation in challenging technological competitions that cover problem-solving, decision-making, and critical thinking skills as they relate to communications, power, energy, transportation, engineering, manufacturing, and construction. Students attending the national conference in Richmond competed for awards in more than fifty events; the events ranged from structural engineering and computer-aided drafting to extemporaneous presentation and graphic design.

In addition to the competitions, other highlights of the conference included a keynote address by the nationally recognized speaker, Rolfe Carawan, founder and president of LifeMatters International, as well as a one-day Education Fair that was held on Saturday, June 23rd. The fair featured the sponsors of the 2001 conference and exhibitors who displayed the latest innovations in technology education. Among the growing list of companies that support TSA activities and who came to the conference were DuPont, Pitsco, Inc., DEPCO, Inc., Autodesk, Nortel Networks, and the International Communications Industries Association.

For more information about the Technology Student Association and a complete list of finalists from the conference, visit TSA's homepage at http://www.tsaweb.org/. Or, contact National TSA by mail at 1914 Association Drive, Reston, VA, 20191, by phone at 703/860-9000, or by fax at 703/758-4852.

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