Wake Up and Smell the New Biomechanical Brew!

Simon Bartold advises us to embrace the paradigm shifts in running shoe technology or become irrelevant.

BY BEN PEARL, DPM

After 23 years of clinical practice as a DPM, a new opportunity arose for Simon Bartold, in part because of his outspoken remarks on the state of some Asics shoes. Fast forward and his career took off as a technical consultant with Asics, and he now heads up his own independent consulting firm. He is heavily published in the foot biomechanics literature, received the Richard O Schuster Award for biomechanics in 2009, and has attended several Olympic Games as medical support.

He now sees podiatry at a crossroads.

In the height of the barefoot running movement, after Chris McDougall's *Born to Run* book came out, he and Craig Payne, who opposed this fad, received death threats. Never one to hold back on his opinions, he has a message for his podiatry colleagues: Embrace the world of 3D print design and evolving technology for footwear and orthotics or be replaced by alternatives. Here is an abridged transcription of our discussion just after the Olympics on the podcast *Fit Foot U*:

Simon Bartold

Ben Pearl: *What is the message you have for podiatrists regarding embracing 3D print design and evolving technology?*

Simon Bartold: We are entering a brave new world here. The traditional model of referring a client to a running shoe store for a shoe recommendation will be a dead duck. It will be possible for a clinician to obtain biometric measurements and upload that file to a lab in Belgium or Taiwan. The lab will 3D print a last and add any modification and deliver it to your office. The shoe will be much more functional with an embedded custom midsole that is sport-specific. You will be able to change the individual viscosity in the midsole for a point guard versus a forward in basketball, depending on the requirements of the player.

Pearl: *You mentioned the ability to make 3-D print shoes. One industry leader I spoke to, Paul Linton, believes we are still a few years away. How long do you think it will be before it is more available to patients and consumers at a reasonable price point?*

Bartold: I want to make the distinction between 3D printing shoe lasts versus 3D printing whole shoes. Simply collect the data from the patient and scan the foot and 3D print the last, which then is used to build the shoe. It is then possible to 3D print a lattice mesh, which is like a honeycomb, and that means the shoe will essentially function as an orthotic device. It can be backfilled with different viscosity materials like EVA or PU (polyurethane). That technology is available now and will probably have a surcharge of around 20 US dollars. Right now, a company like Adidas can 3D print last shoes at a rate of about 5,000 a year.

A company like Asics produces about 1.5 million Kayano models per year, but the economies of scale are not quite there yet from a profit standpoint. In the future, companies will be able to have a library of different lasts available to them to be used on the shoes. The clinician then simply picks the last from the library that best suits that individual

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patient. I don't want people to think I believe this will replace an orthotic device, but it will become a much more functional shoe that can be sport-specific.

Pearl: *I heard a recent discussion you did with Benno Nigg where he opined that while viscosity in the rearfoot sole can influence comfort and performance, he did not see a role for it in the forefoot. Everything is context but what is your thought on that statement?*

Bartold: Benno often talks in theory and those theories often become fact, but I'm not sure that I agree that viscosity has no role in the forefoot. It is far more obvious in the rearfoot, but I think there is a role for influence in the forefoot as well. It is far more obvious in the rearfoot for things like the ability to influence peak braking moment (the horizontal force that opposes ground reactive force). I don't see why that would not apply in the acceleration phase of gait in the forefoot. I think what Benno is saying is that viscosity is more important in the rearfoot in the AP direction (not pronation/supination) than in the forefoot. The other interesting effect of viscosity is it can have a profound effect on the magnitude and frequency in the vibrations in the foot. When you hit the ground, a shock wave is created like dropping a pebble in a pond.

Pearl: *How is viscosity important for running?*

Bartold: If you can attenuate the vibrations in the foot, you can reduce fatigue and injuries. Viscosity is an important element in modulating those vibrations. Benno and I worked together on this concept when I was working with Salomon.

Pearl: *I agree with that. I remember Benno Nigg had done research for a track surface company and had concluded at that time that you could not game the surface of the track to increase performance or decrease injuries. I think that he also felt the same way about the stiffness or softness of running shoes. I did a triathlon once and after the swim and bike ride, my legs were fatigued. I have an ACL deficient left knee and it was more comfortable during the final run to run on the grass on the road border than the asphalt surface of the road. Is he interviewing Simon or having a discussion with him?*

I think the ankle is more important than the subtalar joint. A limitation in the ankle is a big problem, especially dorsiflexion.

Bartold: The brain monitors input load every 50 milliseconds. If you step from a soft surface to a hard surface, the body acts like a spring and will increase knee flexion to make the leg more springy. Conversely, when we go from a hard surface to a soft surface, we stiffen our legs. Benno Nigg used this concept when he was working with the Cirque du Soleil. Their acrobats had been doing their routines on a springy stage and sustaining a lot of injuries. He decided to increase the stiffness in the stage and the injuries decreased. People gravitate towards soft cushioning, but there's no evidence to suggest that this decreases injuries. Your example, Ben, highlights the point of treating athletes as individuals. What worked for you may not work for your friend. We need to let go of the concept that a rigid foot needs a cushioned shoe.

Pearl: *You've referenced the paradigm shift away from aligning the foot to neutral and using pronation as a yardstick, which Benno proposed, culminating in a paper in 2015. Can you expand on this and the role of the ankle?*

Bartold: I think the ankle is more important than the subtalar joint. A limitation in the ankle is a big problem, especially dorsiflexion. Measuring subtalar joint motion is more nebulous. No one really knows how much pronation is too much. There may be too much pronation but there could also be too much adduction or abduction. There might be a breakdown in the midsole of the shoe. There could be a delay in transitioning to the forefoot. In 2015, Benno wrote a paper regarding the "preferred motion path." If someone is injured, this may not necessarily apply because you have to take into account the tissue and offloading.

Pearl: *The Kirby skive allows correction while retaining a low profile on the device for shoe fit. How do you think the Kirby skive fits into the current theories?*

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Bartold: I think the Kirby skive works because it exerts a supination moment to the sustentaculum tali rather than trying to grab the heel and bring it to vertical. You can't really do that, because the fatty tissue of the plantar fat pads will just distort. It provides this steep angle and counter force fairly distal on the orthotic device. Kevin is a friend but we do have some difference of opinion on stability shoes. I think that the shoe may look vertical but the foot can be happily pronating within the shoe. I believe things like dual density midsoles and little bits of

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plastic embedded in the shoe simply add weight to the shoe. You can accomplish far more by changing the geometry of the shoe with rounded contours. There is really no study of significant power or numbers to support stability shoes. There is a researcher out of Luxembourg, Malisoux, who showed that motion control does change kinematics, but he is doing it with a very large forefoot varus wedge. So the research is kind of null and void. There is no commercially available shoe with a very large forefoot varus wedge. Pronation is difficult to measure. We really don't know how much is too much. So Kevin and I have this ongoing competition and so far (he laughs) I'm winning...

Pearl: *In an interview you did with Benno Nigg he opined that we do not know what is causing the improvement in the Nike 4% shoe. He mentioned that a carbon fiber plate delays the transfer of energy but he did not see any basis for energy return. What do you think is happening?*

Bartold: To be classified as a super shoe, it has to have a rocker. It has to have a carbon plate and it has to have a foam. Let's look at Galen Rupp's best performance in the marathon compared to Kipchoge's somewhat contrived sub 2 marathon. Galen Rupp looked like he was about to die at 2:03 while Kipchoge looked like he was ready to run another marathon. Nike owned almost all the world records with the exception of Adidas in the half marathon. So is it the carbon fiber plate, is it the rocker, or is it the foam? Wouter Hoogkamer, the Nike scientist now at University of Amherst and Roger Kram, also involved in the Nike 4% studies, have both speculated that the carbon plate has a small effect, maybe 1%; the foam has a large effect and the rocker is the great unknown.

I think the geometry of the shoe is super important. Nike uses a material called Pebax®. The thing about Pebax is you can change the recipe to make it more viscous or more flexible. It is 20% lighter and has 25% more energy return. Nike published data that showed a curved plate has better efficiency than a flat plate. How close the plate is to the foot is also a factor. There is an Adidas shoe that has five rods embedded longitudinally that may give the Nike Vapor Fly series a challenge.

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Pearl: *He did mention the ellipse shape of the shoe may have some effect on the performance as the plate is bent in the shoe. He backed that up with an article in 2020 titled "Teeter totter Effect a New Paradigm to Understand Shoe Related Improvements in Long-Distance Running" (BJSM). Thoughts?*

Bartold: The plate probably has a smaller effect than the radius and geometry of the shoe. The rocker shape sole of the new super shoes also increases foot turnover and decreases fatigue.

Pearl: *One article that particularly impressed you was the "Effect of Material Characteristics on Shoe Soles on Muscle Activation and Energy Aspects During Running." (Human Performance Laboratory, Calgary 2002)*

Bartold: You bring up an interesting point that is worth discussing. Most runners get up in the morning and turn left and run the same route on the same side of the road. If we vary the route, we are less likely to sustain injury.

Benno is on a mission to solve the problem of tuning vibrations. He is 82 years old but has a mind like a steel trap. Tissues each have their own frequency. When I was at Salomon, we mapped out 24 different ones from the calcaneus to the cervical spine. We know that the Achilles has a tuning frequency of between 10 and 30 Hz. If we have a ground reactive force that has that same frequency range, we end up with resonance which is uncomfortable. This is why when you hit a baseball with the sweet spot off the bat, there is a large vibration. So the idea is to get the shoe modification, i.e. the viscosity, above or below the tuning range of the tissue. We had a shoe we were working on at Salomon that decreased the vibrations by 4 decibels. When we presented the data to Benno, he nearly fell off his chair. What we have not cracked is tuning the shoes to different tissue frequencies. We are getting closer, though, because we talked about changing the viscosity to the tissues we are trying to manipulate and off load. That's Benno's legacy. To give you an idea of how important vibrations are, there are about nine parameters that can affect the foot, such as ground reactive force, acceleration, pressure, etc. Vibrations account for more than 20% of the forces altering the foot and lower extremity. Vibrations have been in this black hole vibrating away. Nobody has been looking at it. Everyone was focused on vertical ground reaction force and using cushioning to affect that which does nothing. Benno put the spotlight on it saying it's important for injuries, comfort, and performance.

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Pearl: *Are we accurately measuring the internal forces in joints?*

Bartold: You can accurately measure the joint moments with a force plate. You can also accurately measure the joints with computer models. This has been particularly beneficial in this time of COVID because we could not bring people into the lab.

Pearl: *I saw you recently mention you posted a comparison between hard and soft soled shoes. What are your conclusions?*

Bartold: Benno Nigg wrote a paper in 2015 called the preferred motion pathway which proposed you will minimize injury and habituate to running more efficiently. Who? How? A second article hypothesized that comfort will determine the preferred motion pathway. This was accepted as gospel by many running retailers and podiatrists. I think the comfort filter paradigm was only about step in comfort—how does the shoe feel when you put it on? When you have a soft shoe in 10 out of 10 runners, you will have an increase in ground reactive force because the brain will recognize the soft surface and stiffen up the leg.

Pearl: *I came across an article you referenced from Biomechanics in 2008 titled, "Wedge Brings New Angle to Treating Hallux Limitus". It discusses the Cluffy wedge, invented by Jim Clough, DPM of Montana. This area is especially interesting to me because I designed a hallux limitus/turf toe splint with OS1st that uses a Morton's extension on a forefoot compression sleeve. Why don't we see more things like the Cluffy wedge introduced into shoes and orthotics?*

Bartold: I think we don't look at this stuff enough so I think what you are doing with the turf toe splint is admirable. We need to think more about what we want to modify to accomplish it. What the Cluffy wedge does is it adds a little bit of material under the base of the proximal phalanx so that it can allow more clearance for the first metatarsal head. I have not seen any published studies on it, but I have used it and it seems to work. I do think that this makes sense mechanically. I do think we need to put more of these thought processes in to terms of what we are trying to achieve. The people that are getting good results are thinking outside the box and they think about what they are trying to change.

Pearl: *Doug Richie referenced the Kogler study in his book which described a valgus forefoot wedging to reduce strain through the fascia. What are your thoughts?*

Bartold: Geza Kogler is a very old friend of mine and his initial study was groundbreaking. We followed up his study with one of our own with cadavers. We measured the strain in the plantar fascia with a series of surgically implanted strain gauges. We then measured the strain in the fascia in about four places with approximately 10 degrees of valgus in a strapping. We thought the taping might reduce the strain by about 5%. We actually ended up with about a 48% reduction in strain through the fascia by plantarflexing the first ray and everting the foot with a strapping. Forefoot valgus wedging reduces strain in the plantar fascia and is highly effective in the management of plantar heel pain.

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Pearl: *And the shoe you developed with the first ray in mind?*

Bartold: We wanted to help increase the supination in late midstance in runners that we felt had too much pronation. With Asics, the original Gel Creed morphed into the 3000 series. It did not have a Cluffy wedge but it did have a Morton's extension built into the EVA of the sole. We were trying to increase the propulsive supination moment. Another shoe that I designed followed the geometry of the foot articulations in the outsole of the shoe.

Pearl: *A lot of people have experience with the watershed area of the Achilles. There is a lot of confounding evidence in this area. Some studies are with running and others are with walking. You were involved with a study on the effects of heel lifts on the Achilles while walking on a treadmill. How do you reconcile some of the differences in studies with a heel lift in shoes and load on the Achilles tendon?*

Bartold: We did a study where we measured the acoustic velocity of a shockwave through the Achilles tendon at different heel heights in running shoes. We measured this with subjects walking on a treadmill. Strain in a tendon is directly linked to the speed at which a sound beam travels up a tendon, so in this way we were able to measure the load on the tendon with different perturbations. We published five papers on this. We applied a transmitter to the Achilles and then receivers at four different sites along the length of the tendon and measured the time a shockwave traveled up the Achilles at heel strike.

The results showed that the barefoot subjects had less force going through the Achilles than the ones with a 12mm lift. When a 22mm lift was used, strain was reduced and returned to nearly barefoot levels. I think the result with the standard running shoe (12mm lift) was a bit of an anomaly but it was not a running study.

Pearl: *Is there any help with Osgood Schlatter's Disease (OSD) and*

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any footwear solutions or a role for shockwave in the growing athlete?

Bartold: First, it is not generally known that OSD has an age range from 9 to about 45 as described in the scientific literature. It can and does present in adulthood and as such we should stop calling it a self-limiting disease. There is not much that footwear can do. In relation to ESWT, the knee is a weight-bearing joint unlike something like tennis elbow but shockwave might be worth a try. I don't see much of a downside. I am aware of some of my colleagues who have used it for calcaneal apophysitis. It is recommended to have a certain level of exercise. We have a course we developed that has information on the most common lower extremity osteochondritites. (https://www.bartoldclinical.com/product/osteochondroses-of-the-foot-and-leg-course/)

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Pearl: *Recently, Podiatry Management (June 2021) had an article by Jarrod Shapiro, DPM titled, "Why are the Podiatry School Graduates not Grasping Biomechanics?" What do you think the problem is and what is the solution?*

Bartold: I can't speak to the U.S. because I am not as familiar with it, but there are some differences in how Australian podiatry education is from the U.S. It all starts in podiatry school. If your training is biased towards surgery, you are not learning as much biomechanics. Biomechanics is an interesting term because we get taught podiatric biomechanics in school. In Australia, our focus is not on surgery so we are more focused on biomechanics. There are also not that many podiatrists who really know conditions like rheumatology. I can only think of about three in the world.

Pearl: *We are in challenging times with small boutique-run retail facing challenges from Amazon and the pandemic. Some podiatry practices are having challenges. Other entities like physical therapy are also vying for runners and weekend warrior patients. It seems there used to be more collaboration between the different entities. You spoke to me before about an "unhappy marriage" between run retail and podiatry at times. You mentioned that there are podiatrists like Kevin Kirby who still go to their local Fleet Feet on a regular basis because he is a shoe geek and loves the interaction around the running shoe store, but this is not typical these days.*

Bartold: Kevin is a rarity. He is just so interested and invested. However, I hate to offend any of my colleagues but most podiatrists know less about athletic footwear than most technical retail. This comment is not designed to shock or offend, it is simply a fact, just as retail does not know about injury and medicine and should not be advising on this. Understand where the expertise lies! I can show you technical retail people that have PhDs in biomechanics and physiology, and as a resource for podiatrists, they are second to none. The trick is to source these experts. Shoes are evolving at a rapid rate. I'm not sure that Nike even knows what's going on with their Nike 4%. So let's learn from retail. Let's park our egos. Let's educate retail in terms of what we know and what we can do. The two should be symbiotic. When we get competitive, everyone loses. I think at the moment, it's a bit of an unhappy marriage, but it doesn't have to be that way if we say let's take ego out of it and learn from each other. I think that's a sensible approach. **PM**

Dr. Pearl is a fellow of the American Academy of Podiatric Sports Medicine. He is the team podiatrist for the District Track Club, an elite Olympic development track team in Washington DC. He serves as medical director for the SUNY New Paltz High School cross country camp. He hosts the podcast Fit Foot U.