



1 The seminar attracted an international audience and was fully booked.

Practical implementation of biomechanics in the field of orthopedic footwear

BY KATHRIN ERNSTING

During the 4th ORTHOPÄDIE SCHUH TECHNIK – International Trade Fair and Congress in Cologne in 2017, Thomas Stief, responsible for the biomechanics department at the University of Gießen, Germany, offered a workshop where biomechanics met practical implementation. He focused on a special and very common shoe modification: rocker soles.

Thomas Stief works in human motion science and psychology of sports at Justus Liebig University in Gießen, Germany. In the first part of his fully booked workshop with an international audience he explained the basics on both biomechanics and orthotic footwear. Especially because work is different in the participating countries and the approach is not uniform, it was very useful for the audience to come to a common base for the second part.

Before he immersed in the topic, Thomas Stief raised the question why biomechanics are so interesting for the field of footwear technology. He quoted Benno Nigg et al, who wrote in 1994: “Biomechanics is the science that examines

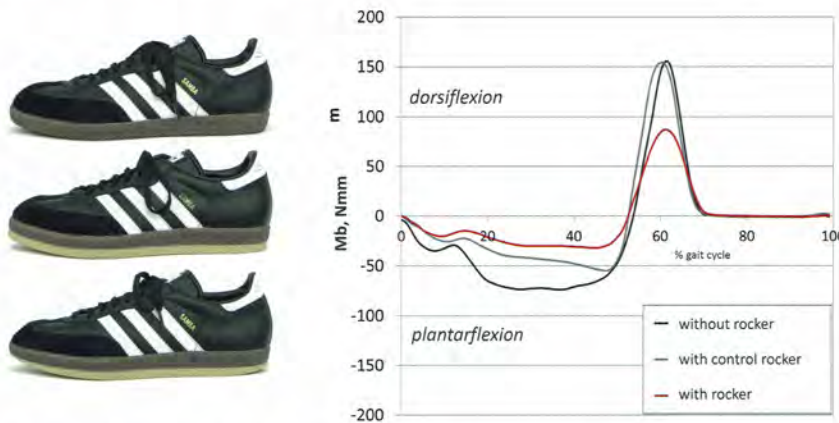
forces acting upon and within a biological structure and the effects produced by such forces.” As pedorthists and shoe specialists try to optimize standing and walking for their patients, they want to influence biomechanics by orthopedic footwear, Stief explained. “All different types of products are the same in one respect: you and me want to achieve treatment objectives”. For him these objectives are pain relief, stress relief, management of deformities, changing the course of motion, management of abnormal neuromuscular function and stimulation of the motor-sensory feedback. “If you want to achieve these objectives with any kind of orthopedic products, you have to know biomechanics”, he concluded.

Explanation of biomechanic terms

In the theoretical introduction he differentiated the most important concepts such as mechanics, kinematics, dynamics, statics and kinetics as effects produced by forces.

Mechanics can be divided in kinematics, described as the study of observed motions without regard of circumstances causing them, and dynamic, described as the study of motion and its relation to forces and moments. Stief described statics as the study of equilibrium and its relation to forces and moments, whereas kinetics is the study of motion and its relation to forces and moments.

Bending load during gait cycle



2 Changing of only one condition per measurement is essential to compare two conditions. In this case the scientists around Stief measured the bending load during gait cycle without rocker, with rocker and with a control rocker to exclude stiffness of the used material as responsible parameter. It becomes clear that it is the rocker which reduces plantarflexion and dorsiflexion.



3 The Adidas Samba shoe model was modified with a rocker. Material properties of the modifications are EVA with SH 40A – SH 60A.

When talking about treatment objectives, terms like load, stress and load-bearing capacity come into play. Load, Stief explained, is the totality of all determinable influences, which have an external effect on structures or persons; Stress is the individual reaction of a structure or person, e.g. the load that is measurable by changing various physiological parameters. He introduced the participants to two typical types of stress: force and torque. “Nobody can see force, but it can be measured and you can tag the effects of forces as deformities or acceleration.” Load-bearing capacity is the highest load intensity up to which a structure or person can be loaded without incurring limitations, discomforts as well as reversible or irreversible damage.

“Pressure is the result of forces and bending is the result of moment and torque”, Stief declared. The further presentation focused on bending stress and compression stress, because these kinds of stress can be detected with different types of measurement systems.

“If you have a problem – pathologies or pain – you want to change the loadings, bending or torsion”, Thomas Stief explained the concept of designing orthotic footwear. To have a closer look at the possibilities of a shoe modification he showed torque at the ankle joint du-

ring the gait cycle in prefabricated footwear. For a better understanding it was important for him to represent the different types of (bio-) mechanical stress like compression, bending, torsion, shear or tension. With many diagrams and curves he illustrated his explanations and the differences over the phases of the gait cycle.

Implementation of rocker soles

After the theory, the talk went on to the practical implementation of the treatment objectives of orthotics and orthopedic footwear. Thomas Stief deepened individualized rocker soles as an example.

“We want to relief mechanical stress which means we want to relief plantar pressure or reduce bending stress with rocker soles”, Stief said. Rocker soles are one of the most common footwear modifications prescribed. The basic function is to rock the foot during stance phase without bending foot and shoe. The type of the rocker sole varies with the clinical treatment objectives, related to the patient’s individual foot problem. There is a wide range of rocker soles you can use and with each one you want to achieve different treatment objectives. These types of rocker sole modifications are forefoot (toe only) rocker sole, forefoot

(toe only) rocker sole with cushioning in the metatarsal region, forefoot (toe only) rocker sole with impression for the distal phalanx 1, mid foot rocker sole, heel to toe rocker sole (rocker bottom sole) and tip rocker sole.

The general biomechanical effects are the compensation of lost motion in the foot or ankle joints related to pain, deformity, or stiffness, resulting in an overall improvement of gait and relieving bending of the joints and relieving pressure in some area of the plantar tissues. “We want to manage the deformities, maybe we want to reduce the stiffness, or we want to improve the gait – that’s what you should control with the different kinds of measurement systems.”

To illustrate this with the example of the rocker sole, Stief first explained a typical construction of individualized rocker soles. For each of the above mentioned different rocker soles you first use different positions and angles and secondly different kinds of rocker shapes. The third difference is the distance between the tip of the shoe and the ground. “All of these three different construction details have to be individualized to the special problem of the individual requirements”, Thomas Stief claims. For this individualization the pa-



4 The participants of the workshop were interested in the application of the measuring system Thomas Stief used for detecting bending and torsion with and without a rocker sole.

tient's footprint is used as a guideline. For all variations it is important that the mid stance length of the shoe ensures balanced standing and walking.

"You cannot change the ground reaction force because the person will not lose mass. What you can change is the distance between the ground reaction force and the center of pressure", Thomas Stief summarized the objective of all variants.

To make it more visible, he talked about his own experience. In a study he and colleagues measured shoes and modified shoes with rocker, without rocker and with control rocker (same material, different shape). This third model came in use because the stiffness of the material might be the reducing factor. The researchers wanted to exclude that. The output of the research was that you can clearly see that the rocker shape reduced bending stress during the late stance phase of gait – not the material property. That means stiffer material itself does not reduce dorsal extension stress at MTP I.

At the end of his remarks on this subject Thomas Stief gave the audience an important hint: "All of you know that if you want to rock the foot you have to also adapt or compensate the height of the heel on the other, contralateral side!" It might be necessary to compensate the contralateral side by a rocker sole, too, to achieve a symmetrical gait.

Evidence and research

There is evidence for the effect of individualized rocker soles. Several authors mention that the classical rocker construction is a good treatment for several kinds of problems at the forefoot and the ankle joint. Hutchins et al. said 2009 that "...for reducing in-shoe pressure the rocker outsole is one of the most effective footwear design". In 2000 Van Schie et al. concluded that "...the apex position may need to be individually adjusted to maximize offloading" and Chapman et al. found in 2013 to "...reduce plantar stress, like plantar pressure in patients with Diabetic Foot Syndrome". In the same year Vogelbusch et al. saw that "...bending stress could be significantly reduced at MTP I and MTP V by using a customized rocker sole construction compared to a neutral shoe and a control condition."

Thomas Stief also does research on this topic. With his colleagues he did a study with the measurement system "vebito" he presented in Cologne: "We checked the bending stress at MTP I by using the insole system where you can detect bending and torsion with the three different kinds of shoes." For practical insights, the comparison, which was done in the study, was recreated live. The participants could control the effect of the rocker sole Stief had brought along, compared to a not modified shoe.

Tackle it practically

Again, there were tips from the speaker: "If you want to check the effect of the footwear modification, you have to define which kind of these different mechanical stresses should be influenced or

treated", he emphasized and pointed out that there is no relation between pressure and bending. "If you want to change bending, you have to control it with a system where you can detect the effects of changing bending and if you are interested in changing pressure, you have to use pressure measurement systems".

Another important note from Thomas Stief was to not measure the first step during gait because you have acceleration during start. It is better to start measurement after the second step. "Also you have to record enough gait cycles", he said. The simple rule: The more gait cycles you have, the more significant the result you get is. In 2011 Arte et al. found that you have to record and analyze at least twelve gait cycles.

If you want to compare two conditions, you have to measure under the same conditions, e.g. with the same gait velocity, the same numbers of recorded and analyzed gait cycles and so on. Changing of only one condition per measurement is also essential. If you want to compare the shoe without modification with the same shoe with rocker sole you must not change the insole or something else at the same time.

"Concluding you can say that orthotic footwear modifications have to be designed and manufactured to meet the clinical needs of the individual user", Thomas Stief finished. "If you want to get the optimal treatment with adaptations to orthotic footwear, the only possibility is to track the treatment objectives in a clear way." Biomechanical competences as well as technical and orthopedic skills play an important role in their formulation and implementation in daily practice. ■