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When treating foot problems and foot deformities physicians often have to face the question if a surgical intervention or a conservative treatment with orthopedic appliances is preferable. Many aspects can play a role when deciding in favor or against a therapy. Ideally the participating physicians and the patient are familiar with all therapy options and the treatment is chosen that serves the patient best.

Unfortunately this ideal case only rarely occurs. Also in countries where professions related to pedorthics and prosthetics and orthotics have been established for a long time the treating physicians often lack the knowledge about the orthopedic appliances available today that can avoid for example surgeries which often involve a risk for the patient.

In many countries not only the physicians lack the knowledge, but also there are not enough trained specialists that are able to produce these orthopedic appliances. This can be seen in our case study from South Africa. The three-years old Jaron is completely healthy except for his midfoot and forefoot that have not been completely formed osseously. This is why he is limited in his movements and his condition would have led more than likely to an overloading of the knee and hip joints if not treated. As a treatment the physicians recommended an amputation of the lower leg.

Luckily his mother met Micha Oelsner, a German-trained pedorthist who has lived and worked in South Africa for many years. In an interdisciplinary way and over many thousands of kilometers, she developed with her partners a solution for Jaron enabling him untroubled mobility considering also the family's limited financial options and his future growth (see page 22). This example shows that the development of pedorthics still has many problems in numerous countries. There is not enough knowledge about conservative treatments, often there is no health insurance for people less well-off and there are not enough trained specialists. That is why many people have to deal with limited mobility when they could have been helped with simple means.

A possibility to improve this situation is certainly the survey of the World Health Organization. In order to enable world-wide access to conservative therapies and the corresponding orthopedic appliances, the GATE-program of the WHO is currently working on a Priority Assistive Products List. All treating people, patients and their families should participate in this global survey so that the orthopedic appliances, so important for mobility and health, are anchored in this list. You can participate in this survey until 3 March 2016. On page 15 you can find further information.

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**Lack of Knowledge Impairs Mobility of Many People**

When treating foot problems and foot deformities physicians often have to face the question if a surgical intervention or a conservative treatment with orthopedic appliances is preferable. Many aspects can play a role when deciding in favor or against a therapy. Ideally the participating physicians and the patient are familiar with all therapy options and the treatment is chosen that serves the patient best.

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Foot Pressure Measurements

The aim of this article is to present the main characteristics of measuring technologies used for analysing the foot-ground-contact, to differentiate the main parameters measured by the mentioned technologies, to discuss the settings of optimal values for the defined parameters, and finally to show two examples of typical applications in the fields of orthopedics and sports.

Etiology of Hallux Valgus

An understanding of how hallux valgus develops is important for treating the deformity. The functional analysis from clinical practice shows how they affect the biomechanics of the foot as well as gait execution.

Diabetes-related Amputations

Researchers said double-digit decreases in two of three types of common diabetes-related amputation emphasize improvements in care made in the last two decades.

Foot Pressure Measurements

In this study the bending and torsional stress acting on the foot in the Darco Relief Dual offloading shoe were compared to occurring stress in a competitor which was already licensed.
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The technical terms of any profession have rarely been fully standardized. Different terms become established, depending on the country or even the occupational background. Even if there are binding definitions on terminology, for example based on agreements with the statutory health insurance companies, the common jargon is not rarely a colorful mixture of concepts describing the features and technical application of the products being used. The parties involved mostly know what is meant. However, when it comes to writing a textbook on a specialized subject, it is obviously important to mention the vernacular, but provide definitions that are standardized and appropriate. This is particularly relevant when a textbook is being translated. The translation should not only be correct according to the dictionary. Rather, it also aims to use the terms and descriptions common in the professional vernacular of the book’s target readership.

In the case of a book, that task proves especially challenging. The textbook entitled “Pedorthics” looks back on a centuries-old tradition of a craft in Central Europe called “orthopedic shoe technology”. Over the years, the manufacturing techniques and therapeutic concepts have been brought up to the state of the art. Nowadays, custom-made orthotic footwear, foot orthoses, compression stockings, special shoes and sport orthoses for the foot, belong to the range of services offered and products crafted by master pedorthists. They acquire their knowledge and skills in a three-year dual professional, workshop- and classroom-based training program which can be supplemented by an additional qualification to become a master craftsman in pedorthics. The master orthopedic shoemaker is a practitioner in charge of the design, manufacture, fit, and modification of foot appliances as prescribed for relief of painful or disabling conditions of the foot.

Now, the book has been translated into English and targets readers in many countries governed by thoroughly different traditions. Whereas some countries already have state-certified educational programs, in many others, the orthotic care of foot disorders is still in its baby shoes. The qualifications and areas of application are variously characterized. Indeed, there is no standardized terminology applicable to all countries. In commissioning the translation of this book, we obtained the advice of numerous experts, while our translators undertook extensive research to identify the terms commonly used in other countries to describe the products, tools and procedures in order to establish the most appropriate translation of that term. Among others, we have applied international standards that set down the terminology on specific orthopedic appliances and pedorthic devices.

Nevertheless, the authors couldn’t resist adding a chapter on terminology to explain to the reader the etymology of the main terms used and the variety of possible synonyms and internationally common translations. Even when a term may seem to have an equivalent in the other language, each country tends to have its specific legislation and training program governing the field. Thereby, the term and the profession it denotes have entirely different meanings in the respective countries.

One prime example is the term “podology”. In most English-speaking countries, the term is the equivalent of “podiatry” or “chiroprody”, a specialized field of medicine dealing with the study and care of the foot. However, the German term “Podologie” cannot be translated “literally”. This term is not to be confused with the practice of podiatry or chiroprody. In Germany, the profession “Podologiest” is protected by law. The statutes differentiate between practitioners in the field of professional foot care with state-certified qualifications and persons with minimal vocational training or none at all who give pedicures.

Foot orthoses
In the vernacular, numerous terms are used to describe the orthopedic appliances designed to support, align, prevent or correct deformities or to improve the function of the foot, sometimes referred to as orthotic insoles, inlays, insoles, custom-made insoles, orthotics or orthoses. In the textbook, we decided to use the term “foot orthosis” because it best reflects the function of the appliance. A foot orthosis is prescribed to correct the foot and support its physiological kinematics and kinetics by means of specially incorporated features. This definition is in compliance with ISO 13404:2007(E). In the case of foot orthoses, it is important to distinguish between custom-made and prefabricated foot orthoses.

Individual foot orthoses are not only fabricated for the patients’ feet, but for their individual functional needs as prescribed by the physician. Impressions of the foot are taken, usually with plaster casts, and the dimensions of the foot are measured by hand or digital on a scanner.

Prefabricated foot orthoses are supplied in a variety of designs, each aimed at fulfilling certain functional requirements. They are either modified for insertion into the shoe or adapted to fit the specific patient.

The term foot orthosis should not be used to refer to any type of insertable
Pedorthics:

Foot disorders – foot orthoses – footwear

Prof. René Baumgartner, M.D.,
Michael Möller,
Dr. Hartmut Stinus

360 pages, 52 Chapters,
more than 1 000 pictures and illustrations
119 Euro
ISBN 978-3-87517-050-4

The textbook “Pedorthics” covers all of the aspects essential to providing pedorthic care of the foot using the most modern techniques and technologies – from the medical basics and the relevant diseases up to and including the individual production of tools. The objective of this book is to provide a comprehensive presentation of pedorthics as it exists today. Three experts have teamed up for this: the Master pedorthist Michael Möller from Münster and two orthopedic surgeons who have more than just an academic interest in the field. One learned the trade before turning to orthopedics, the other is proud to be an honorary Master of the craft. Both aim to bring conservative and operative orthopedics together under one roof. The help of recognized specialists was enlisted for individual chapters. All in an effort to not only inspire pedorthists, but other orthopedic specialists as well.

The first German edition of the book was so popular with the inclined readership that only two years after publication, the second revised edition was published. During the revision process, authors and collaborators have done their best to critically check and review the state of their knowledge and pass it on in comprehensible form. The translation into English is based on this second edition.

This work’s clear structure, more than 1 000 color illustrations and comprehensive presentation make it an ideal companion for training and daily practice.

The book takes a multidisciplinary approach: a compact and competent presentation of diseases of the foot is aligned with treatment strategies and the planning and implementation of tools such as foot orthoses, orthotic footwear and orthotic devices. Chapters on posture and movement analysis, the basics of biomechanics, physiotherapy, orthopedic and surgical operations as well as compression treatment round off the spectrum of topics. An entire chapter is dedicated to comprehensive treatment of the diabetic foot.

It is not merely practitioners and apprentices who will find answers and assistance in providing patients with pedorthic treatment in this book. Anyone involved in the prescription of orthopedic aids or who deals with the problems associated with pedorthic foot care will appreciate the book as an ideal reference. It provides all the essential information on diseases, medical treatment strategies and pedorthic treatment in concentrated form.
sole (insole, insert, inlay, socket liner etc.) unless it is designed to support the foot in its function.

The term "foot orthotic" is also used to describe a foot orthosis. Currently, debates are ongoing about how best to delineate these two terms from one another. One proposal is to coin the term "Foot Orthotics" not as a singular footwear product or item worn on the lower limb, but as a descriptive term encompassing the entire working area involved in treating foot disorders by means of foot orthoses, for example their classification, their function, their fabrication and their use.

**Orthotic footwear**

Shoes are our companion on most of our journeys. Most shoes are industrially manufactured. The aim is to make them to fit the largest general group of people. However, they do not claim to offer any solution to our personal foot problems. Meanwhile, a broad range of prefabricated shoes is flooding the market tailored to meet the demands of patients with certain pathologies, or ones that feature options to individually adapt the shoes to the needs of a patient. If the modifications to a prefabricated shoe are not sufficient, single shoes can also be custom made to meet the functional needs of the patient. The English language has many different terms to describe a foot orthosis. Currently, the term "prefabricated orthotic footwear" is used to describe shoes developed to meet the needs of a specific target group and featuring options for custom modification, whether by making changes to the shoe or by inserting a customized foot orthosis. This term describes our attitude towards the function of these shoes, which by virtue of their construction, by modifications made to the shoe or through the custom-made foot orthosis assume the function of an orthosis.

In the book, the term "prefabricated orthotic footwear" is used to describe shoes developed to meet the needs of a specific target group and featuring options for custom modification, whether by making changes to the shoe or by inserting a customized foot orthosis. This term describes our attitude towards the function of these shoes, which by virtue of their construction, by modifications made to the shoe or through the custom-made foot orthosis assume the function of an orthosis.

As stated above, custom-fabricated shoes are indicated when the foot is so severely deformed that it does not fit into a regular prefabricated shoe or the foot's function is so severely impaired that a regular shoe will not long achieve the therapeutic objective set by the doctor. As a rule, such shoes are prescribed by a specialist in orthopedics. A customized last is manufactured according to the patient's foot dimensions and needs and the shoe is fabricated around the customized last.

Functional insertable orthotic devices like reinforcements, stiffening, supporting devices, cushioning and footbeds fabricated according to the individual requirements prescribed by the doctor turn a normal custom made shoe into an orthotic custom-made shoe. There are a multitude of terms used to refer to these shoes: custom-made orthopedic shoes, orthopedic made-to-measure shoes, measurement-shoes, custom orthotic footwear, bespoke shoes. In the book, the term "custom orthotic footwear" is used for this type of footwear. We are aware that this term has not yet become established as common vernacular. Nevertheless, it is our opinion that the word "orthotic footwear" best describes the functionality of this pedorthic appliance. It describes the fact that we are dealing with a shoe that not only conforms to the dimensions of the patient's foot measurements, but also serves as a functional orthosis, which gives the foot stability and positively influences the gait characteristics and the loading of the foot by means of the insertable orthotic device inside the shoe.

Prof. René Baumgartner, Michael Möller, Hartmut Stinus

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**Swiss Association with New Structure**

After a two-year long project period, the Swiss association "Fuss & Schuh" ("Foot & Shoe") as well as the two associations of pedorthists and shoemakers have been organized into one single association since 1 January. The members of the associations agreed upon the consolidation without any negative votes on the occasion of the extraordinary general assemblies in fall 2015. With this action the forces of the three associations that had been legally independent will now be carried out by the respective groups within the association "Fuss & Schuh" ("Foot & Shoe"). For the presentation in the public the pedorthists will additionally use their previous logo, which shall now serve as the label of the owner's professional qualification.

The idea is that the association will gain more efficiency through the simpler organizational structures. There is less overlapping in the panels and in the administration and thus decisions can be made faster and more directly.
Diabetes-related amputations fall significantly since 1990s

Researchers said double-digit decreases in two of three types of common diabetes-related amputation emphasize improvements in care made in the last two decades.

Improvement of diabetes treatment has led to a significant decrease in amputations related to the disease, according to a study of medical records in Denmark.

Nerve and blood vessel damage are among the long-term effects of the disease, and often lead to poor circulation in the lower limbs and feet. The circulation can be so bad that hospitalization and amputation are necessary. Better care of diabetes patients – specifically improved drugs, and inspection and self-care of foot ulcers related to the disease – has led to the decrease in poorer conditions that lead to amputation.

"The introduction of vascular surgery and improved surgical techniques cannot explain our findings, since these procedures are applied equally in individuals with and without diabetes," researchers wrote in the study, published in Diabetologia. "The findings in individuals with diabetes can therefore only be explained by improved diabetes care, namely improved metabolic control through drugs or lifestyle, or changes in how care is delivered, including better screening – we believe it to be both."

Researchers at Odense University Hospital in Denmark analyzed health records collected between 1996 and 2011 in the County of Funen, home to about half a million people, from the hospital administration system, Danish National Diabetes Register and Statistics Denmark. During the 15-year period, the researchers found a total of 2,832 amputations performed – 1,285 on patients with diabetes and 1,547 among those without diabetes.

Diabetes patients had eleven times the risk of below-ankle amputations, seven times the risk for from-ankle-to-knee amputations, and four times the risk of needing above-knee amputations, but the rate of each type of amputation fell by 10 percent, 15 percent, and 3 percent during the study period, researchers reported.

"The reduction of amputations among diabetics is encouraging. The results presented here indicate that multidisciplinary diabetic clinics optimized for screening and treating complications linked to diabetes are beneficial," the researchers wrote. "It is encouraging that the overall amputation rate is declining in most parts of the world. However, amputation rates in patients with diabetes remain high compared to individuals without diabetes posing a great challenge to improve care."

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Etiology of Hallux Valgus

An understanding of how hallux valgus develops is important for treating the deformity. From a biomechanical point of view, one key causal factor might be decisively related to shortened calf muscles. The following functional analysis from clinical practice shows how they affect the biomechanics of the foot as well as gait execution.

It is striking that not only scientific journals but also textbooks dealing with the subject of hallux valgus usually begin by explaining the pathoanatomy of hallux valgus deformities. These descriptions cover the enlarged intermetatarsal angle, the metatarsophalangeal angle, the size of the false exostosis, the altered articular surface angle, subluxation of the sesamoid bones, rotational malpositioning of the hallux along with the alternating directions in which the tendons inserting into the hallux pull. Attention is also focused on the extent of degeneration. No detail should be overlooked when taking the patient’s status, which should be taken into account during the later correction.

However, there is hardly ever mention of why hallux valgus occurs. This is not a question of an unusually peculiar entity. Indeed, knowing the etiology allows the therapeutic approach to be converted into a sustainable treatment outcome. This article is not concerned with the rare congenital hallux valgus; therefore, the congenital etiology will be disregarded here.

Is improper footwear the root cause of the problem?
There have been times when it was presumed that, because of the gender-specific frequency of the occurrence of bunions in the females of our species, fashion trends in shoes were responsible for the development of hallux valgus. High-heeled shoes with insufficient heel support and a narrow, V-shaped toe box were considered to be the significant causative factor in hallux valgus development. In addition, women often purchase this type of shoe.

1–2 Many deformities are associated with shortened calf muscles, which can cause supination malpositioning of the forefoot towards the hindfoot (right). The abduction of the forefoot can lead to incorrect loading of the big toe, manifested by a distinct pattern of callus formation (left).
Lateral view of the bare foot (top) and foot in the pump (bottom). A body weight of 60 kg corresponds to a weight force of 600 N when standing on one foot. As the force parallelogram on the right shows, these 600 N are distributed along the bare foot such that 488 N are taken up by the heel and 112 N by the metatarsal heads. When wearing her pumps fashioned with a heel lift of 4.5 centimeters, however, her heel must bear 280 N and her metatarsal heads 320 N.
When the young woman stands barefooted, the weight force distribution changes such that 280 N must be borne by the heel and 320 N by the metatarsal heads. In addition, during each deceleration of the foot in the stance phase of the gait cycle, the foot has the tendency to slip forward on the inclined plane of the high-heeled shoe, forcing the toes into the V-shaped toe box. This might explain the etiology of hallux valgus. Yet in practice, despite the fact that high heels are now worn less often, at least in Germany, the incidence of hallux valgus deformities has remained consistent. So what is the crux of the matter?

**Shortened calf muscles**

Pediatric orthopedists have long known how significantly a pes equinus component can affect forefoot position. Shortened calf muscles lead to a three-dimensional deformation of the foot. Firstly, severe plantar flexion of the hindfoot causes the medial longitudinal arch to flatten. The talar head forces itself between the sustentaculum tali of the calcaneus and the navicular bone – the plantar calcaneonavicular ligament widens. Secondly, the Silfverskjöld test allows conclusions to be drawn on whether shortened calf muscles are the underlying cause of the deformity. The flexibility of the gastrosoleus muscle is tested with the knee flexed and the ankle in dorsal extension (left). Next, the knee is slowly brought into the extended state (right), causing the gastrocnemius muscle to be stretched as well. If the dorsal extension of the ankle decreases during this movement, it is an indication of a shortened gastrocnemius muscle.

Shoe in a size too small for their feet, which has a biomechanically damaging effect on their big toe.

Thoughts such as these are logical and closer inspection reveals observable changes in weight distribution and in the forces acting on the foot and toes.

Figure 3 shows a dorsoplantar view of the foot and the associated high heel from above. Hard to imagine, but the foot does let itself be wedged into a much narrower shoe. The distribution of the acting (weight) forces exerted on the fore- and hindfoot during standing can be divided across a force parallelogram. Figures 4 - 9 show the clinical macroscopic, radiographic and diagrammatic views with and without the heeled pointed-toe shoe.

When this young woman weighing 60-kg stands on one foot, her body weight translates into a weight force of approximately 600 Newton (N). This converts into a distribution of 488 N onto the heel and 112 N onto the metatarsal heads when she stands barefooted. When wearing her pumps with a heel lift of 4.5 centimeters, however, the weight force distribution changes such that 280 N must be borne by the heel and 320 N by the metatarsal heads.

In addition, during each deceleration of the foot in the stance phase of the gait cycle, the foot has the tendency to slip forward on the inclined plane of the high-heeled shoe, forcing the toes into the V-shaped toe box. This might explain the etiology of hallux valgus. Yet in practice, despite the fact that high heels are now worn less often, at least in Germany, the incidence of hallux valgus deformities has remained consistent. So what is the crux of the matter?
there is simultaneous abduction of the forefoot in relation to the hindfoot and, thirdly, an eversion movement of the entire foot which is more pronounced in the forefoot than in the hindfoot. For the hindfoot, this means that the heel is forced into a valgus position – called the valgus foot or pes valgus.

Because the eversion movement of the forefoot is greater than that of the hindfoot, this causes malalignment of the forefoot towards the hindfoot on supination over the long term. Georg Hohmann illustrated this very impressively in his book “Fuß und Bein” [Foot and Leg]. Therefore, if the hindfoot is brought into its orthograde position during manual examination, the forefoot will be in malalignment on supination (Fig. 2).

The abduction of the forefoot causes incorrect loading of the hallux, which in turn no longer experiences loading in the direction of plantar flexion / dorsal extension, but rather pressure from plantar medial surface; this is usually identifiable by the pattern of callus formation (Fig. 1).

Identifying muscular imbalances

It appears that the change in pre-tensioning of the calf muscles also alters the biomechanics of the foot. As did Prof. Buchmann, Travell and Simons noted that a failure of our joints is always accompanied by a shift in the balance of the surrounding muscles. Muscles cannot tell whether this dysfunction is caused by a blunt impact trauma, subluxation of the joint, inflammation, immobilization in a cast, a tumor or something else.

The response is always the same, producing greater tone in the muscles affected by the functional unit. However, because the more tonic and more phasic muscles in the musculoskeletal system react differently, specific muscular imbalance patterns develop. While more phasic muscles tend to become weaker in the case of dysfunction, more tonic muscles tend to shorten. Of course, the division of skeletal muscle into tonic versus phasic muscles is an oversimplification; the long evolution of us Homo sapiens has resulted in our muscles no longer being purely phasic or purely tonic, but always a mixture of both. Nevertheless, this simplified view makes sense because it can help us deduce and recognize imbalance patterns.

This fact can easily be verified for the calf muscles with the help of the Silfverskjöld test (Fig. 10-13). During examination of the left leg, the examiner’s left hand encircles the patient’s foot such that the ball of the thumb reduces the medial longitudinal arch while finger and thumb place the heel in orthograde orientation and the forefoot rests on the examiner’s distal forearm. The examiner’s right hand guides the patient’s knee. At 90-degree flexion of the knee joint, the ankle joint’s ability of for dorsal extension is tested without the foot flattening in the medial longitudinal arch or the forefoot assuming an abduction position. At a 90-degree flexion position of the knee, the gastrocnemius muscle is initially relaxed because of its close vicinity to the origin (muscles attaching to the tibial and fibular condyles) and insertion (calcaneal tuberosity). First, the flexibility of the gastrocnemius muscle is tested. Next, the knee is slowly brought into full extension, causing pre-tensioning of the gastrocnemius muscle due to the distance from origin and insertion. Frequently, dorsal extension of the ankle is reduced.

Clinical observations made in a separate study by the author showed that a coincidence of a shortened gastrocnemius muscle was present in 97% of hallux valgus deformities.

Impact on the biomechanics of gait execution

Shortening of gastrocnemius muscle changes the biomechanics of gait execution. In all cases, there is increased loading on the forefoot, because the heel no longer has full mobility in the plantar direction, thereby preventing the forefoot from deviating to the dorsal during the propulsion phase of the gait cycle.

What happens after that depends on the individuality of the foot’s skeletal structure. If the “weak point” is in the subtalar and/or Chopart joint, the foot deviates into abduction and the pressure from the plantar medial surface causes the development of hallux valgus.

If the foot is very stable within the subtalar and Chopart joint, yet has a “weak point” in the Lisfranc joint line, pes transversoplanus may develop with hallux valgus developing as one of the secondary sequelae.
If the foot is quite stable in this area as well, the pressure is transferred onto the metatarsal heads producing the extensor substitution phenomenon. During this reaction, the extensors are activated to "assist" the tibialis anterior muscle and facilitate better dorsal extension. In relation to the foot, the toes are also pulled into maximum dorsal extension as part of the movement and the forces acting in the retrograde direction induce a plantar pulling force to act on the metatarsal heads.

Another known etiology of hallux valgus is the instability of the first metatarsocuneiform joint. Whether this is more primary or secondary, however, is unclear. In likelihood, both etiological mechanisms are possible. Nevertheless, under all circumstances, they must be considered in the diagnosis of hallux valgus as well as in its treatment. The same applies to any insufficiency of the tibialis posterior muscle due to injury or degeneration, as well as to all other imbalances arising from any number of reasons. As clinical observation has shown, the biomechanical "dysfunction" of the foot stereotypically causes a shortening of the calf muscles.

Given the biomechanical causes of hallux valgus described above, the treatment approach of the early nineties has been adapted to include the gastrocnemius muscle and (less often) the gastrosoleus muscle in therapeutic strategies. A follow-up study conducted as part of a doctoral thesis on more than 700 patients with relevant foot diseases showed that hallux valgus coincides with shortened calf muscles in more than 97% of cases, but that surgical intervention was only necessary in 20%.

With the modern trend toward evidence-based medicine straight-jacketing the way medical findings are interpreted, it is likely to be randomized controlled trials conducted elsewhere that will prove whether medical practice based on observation and experience will establish whether medium-term or even long-term benefits for patients with hallux valgus will evolve in general and specifically by giving consideration of shortened calf muscles. At any rate, podiatrists in the US are increasingly addressing this aspect in their work.

The treatment of hallux valgus offers a broad enough scope to allow additional approaches to be applied. Whole publications are devoted to descriptions of individual methods for treating specific types of hallux valgus deformities. These treatments must always be based on the individual's pathology and can no longer be carried out according to "standard operating procedures".

In terms of shortened calf muscles, any successful therapy must take them into account. The indication for a hallux valgus correction is never rendered in an emergency situation. That means that there is generally always time to apply a conservative approach. Physiotherapeutic interventions in the form of detonification of the calf muscles, stretching exercises, trigger point treatment, antagonist training and coordination exercises complemented by physical therapy, such as the application of heat to "tense" muscles, all belong to the conservative standard treatment regimen. Needless to say, physical therapy is essentially a guide to self-treatment and therefore only marginally burdens the limited budgets of private-practice physicians.

If appropriate, a technically well-crafted foot orthosis and/or shoe modification made by a podorthist may help improve the biomechanics of the foot to the extent that a less extensive surgical procedure is required in the end. The possibility for influencing the outcome should be revisited prior to each impending surgery.

References

References with the author

Dr. Ludwig Schwering has been the medical head of the technical orthopaedics at the Mathias Spital in Rheine from 1 September 2014. He is an orthopedist and an orthopedic surgeon with the additional denominations sports medicine, chiropractic therapy, children’s orthopaedics and special orthopedic surgery. He was the leading senior physician and deputy chief physician of the department for children's and severely disabled persons' orthopaedics/foot surgery of the department for orthopaedics and traumatology at the university hospital Freiburg. From 2012 until 2014 he developed the department of children's orthopaedics at the American Hospital Dubai.
Global Survey: WHO Priority Assistive Products List (APL)

The World Health Organisation (WHO) is conducting a survey about assistive products. Aim of the survey is to establish a list of the 50 top assistive products. To reach many people, the survey is conducted in many languages. The survey is short and will be closed on the 3rd of March 2016.

More than a billion assistive products are needed now – two billion by 2050. However, today only one in ten persons in need has access to assistive products (AP). To change this scenario, based on the success and learning of Essential Medicines List (EML), WHO is developing a WHO Priority Assistive Products List (APL) to assist Member States to plan policies and programmes related to the provision of AP. Like the EML, the main goal of this initiative is to improve access to high-quality affordable assistive products.

The World Health Organisation (WHO) is conducting a survey about assistive products. The survey is open to all stakeholders and in particular to those that use assistive products, potential users and their families. It is likewise open to professionals that treat, supply or fit and manufacture those assistive products.

Aim of the survey is to establish a list of the 50 top assistive products. Such a list will help WHO member countries, including your government, in their legislation and health care planning to make those products available to those that will need it.

To reach many people, the survey is conducted in many languages. "The survey is short and will be closed on the 3rd of March 2016, so please do it now", explains Karl-Heinz Schott who is working on the part of GATE which refers to gate, shoes and feet. "I hope that many will contribute to this fact finding mission. Therefore please pass this information or this email on to your members and colleagues!"

He emphasizes: "Enable your patients, clients and staff to participate as well and do it yourself. It is in everyone’s interest, but in particular in the interest of the people who need the assistive products. Distribute the information about the survey to others."

All stakeholders, especially the users/potential users or their family members/organizations are encouraged to take part in this survey. Please complete this survey online or download the survey form and send the completed survey after selecting the 50 most Priority Assistive Products to assistivetechology@who.int.

"Should you agree, please fill up your personal details in order to enable us to keep in touch and inform you about progress related to this endeavour. All survey result will be analysed anonymously and no personal identifiers will be linked to the individual responses. All information will remain confidential", says Chapal Khasnabis, who is responsible for GATE.

How to get pedorthic products listed in APL

To get products like foot orthoses, footwear for diabetes/neuropathic foot and orthopaedic shoes or footwear in general in WHO’s Priority Assistive Products List (APL), it is necessary that many give there vote for those products. For that you just have to tick the products in the survey which you consider important – the ones on "Mobility" are listed in the first section.

About GATE

The World Health Organization WHO works on the so-called "GATE"-Program. GATE stands for Global Cooperation on Assistive Technology. Part of this program is the development and introduction of an index of types of aids and appliances, in order to provide world-wide access to them – thus this program will have a big impact on the world-wide treatment with aids and appliances in the future and this way also on the work of pedorthic.

In his report on the GATE-Meeting in Cologne in October 2015, Karl-Heinz Schott explained: "Furthermore WHO and ISPO work on the development of standards in the area of prosthetics and orthotics. Since the services of orthopedic shoe technology also belong to this area, the IVO tries to support the users of aids and appliances within orthopedic shoe technology in this framework. If you are an ISPO-member yourself, I would like to ask you to contribute at the ISPO that the benefit of pedorthic for people will not be overlooked. We need pedorthists who are committed to make the topic orthopedic shoe technology more known and to call attention to the possible benefit of treatments for people! International cooperation and presence are more important than ever, otherwise there is the danger that our profession’s performance for people with foot problems is easily ignored and replaced by less developed and less progressive low-grade foot treatments."

For further information: https://extranet.who.int/dataform/355553/

Kathrin Ernsting is editor for the German journal “Orthopädieschuhtechnik” and the English “foot & shoe”.

@more

Please find online the PDF-File of the survey for your download.
Basics of Foot Pressure Measurements

The aim of this article is to present the main characteristics of measuring technologies used for analysing the foot-ground-contact, to differentiate the main parameters measured by the mentioned technologies, to discuss the settings of optimal values for the defined parameters, and finally to show two examples of typical applications in the fields of orthopaedics and sports.

In many situations in human life contact between the human and his surrounding is realized by the feet. That is, one foot or both feet have contact to the ground during activities like standing, walking, running or jumping. This may be a direct contact in barefoot situation, or the person may ware shoes as an interface between the feet and the ground.

However, from a biomechanical point of view this contact may be seen as an interaction of forces. In case of easy standing there is, on the one hand, a force acting from the body to the ground which is caused by the human body weight. On the other hand there is the ground reaction force which is acting from the ground to the body. Under static conditions these two forces have equal amount and opposite direction. Under dynamic situation the ground reaction forces are in general different to the body weight force. This may range from zero (e.g. in flight phase during running or jumping) up to a multiple of the body weight (e.g. during rapid deceleration in landing after jumping).

To analyse the effects of the ground reaction forces on the human body force sensor systems are placed under the feet. In this way it is the aim to investigate whether these forces have positive or negative influence on the load of the body or on the performance of the movement, respectively. In addition to the pure force, other biomechanical parameters may influence the effects of the ground contact to the human body, as follows:
- the distribution of the force across a given area which means pressure;
- the duration of the acting force which means force-time-integral, or casually called impulse.

In whatever way the analysis of the feet contact to the ground might be applied, these questions need to be answered:
1) Which of the above mentioned parameters should be analysed for the required task?
2) What is an optimum value for this parameter?
3) Under which conditions (utilities like shoes, or practice procedures) can the optimum values be realized?

All of this can be applied to orthopaedics problems, like the load reduction for avoiding pain or even injuries, as well as to sports practice, like the improvement of movements for getting stronger, running faster or jumping higher.

With regard to this, it is the aim of the present article
- to present the main characteristics of measuring technologies used for analysing the foot-ground-contact;
- to differentiate the main parameters measured by the mentioned technologies;
- to discuss the settings of optimal values for the defined parameters, and finally
- to show two examples of typical applications in the fields of orthopaedics and sports.

Measuring technology

The history of measuring the interaction between the human foot and the ground goes back to the end of the nineteenth century. Marey (1895) developed a pneumatic device for detecting the pressure under the forefoot during walking (fig. 1). He placed an air-pocket under each foot which was connected to a hand-hold display-unit via flexible tubes. Thus it was possible to detect directly the forefoot pressure during walking. Nowadays, forces are measured electronically. That means, a force-sensitive element is integrated into an electrical circuit. If a force is acting on the sensor the electronic resistance in the circuit will change. This can be measured by an increase or a decrease of the amperage.

A calibration is necessary to assign the registered amperage to the acting force. During the calibration procedure known forces will act on the sensor by known weights or by a controllable hydraulic press, where different steps of forces may be applied. The measured amperage assigned to the particular force will be stored in the system, resulting in a characteristic curve for each calibrated sensor. Later, in the real measurement, these characteristic curves are used to calculate the correct force value on the base of the measured amperage.

The calibration procedure is the same for the measurement of pressure apart from the fact that there is a greater number of sensors disposed over the defined area. Usually, the high number of sensors results in a
difficulties. They developed the so-called multiplex procedure, which is used in every pressure measuring system until today. The sensors are connected in a matrix, in which cables run from one sensor to the next in rows and columns, respectively. The electronic control system builds up a circuit for each sensor by using the connection in rows for input and the connection in columns for output. In that way one sensor after the other can be sampled. This is done on a very high frequency which generally is in the region of some kHz. Thus, a sufficient high sum sampling rate can be realized.

Moreover, there are different types of sensors on the market. These have different characteristics and thus different advantages and disadvantages. Namely, there are strain gauges, capacitive sensors, piezo-resistive sensors and force-resistive sensors. The four listed sensor principles vary in their more or less differences concerning accuracy, reliability, temperature dependency, sensor thickness as well as in their prize.

A user of a measuring system should be aware of the possible errors of the system and know how these errors might be avoided as best as possible. The influence of the temperature, for instance, can be neglected if...
The force platform
A force platform is able to measure the ground reaction forces in three dimensions. Usually, it is integrated into the floor and can be used for all kinds of movement, stationary. The biggest advantages of the system are the high amount of accuracy and the possibility to analyse the forces in horizontal directions.

The main disadvantage is the relatively small measuring area in case of using one unit, especially for fast movements like running or jumping. Furthermore, a force platform is not cheap, which might be a problem, particularly for using more than one unit to overcome the small area problem. Finally, with a force platform the distribution of force under the foot cannot be measured.

The pressure platform
In contrast to the force platform a pressure platform (fig. 2) can measure the force distribution under the foot, but only in vertical direction. Horizontal components cannot be detected. Depending on the used sensor type the accuracy may differ. The problem of the stationary use only is the same as mentioned above for the force plate. In contrast to the high sampling rate of a force plate (in general 1000 Hz) the pressure platform has a much smaller measuring frequency which is in the region of 200 Hz. This may be a problem for high frequency aspects of movement like rapid stopping or landing. The spatial sensor resolution on the plate is however quiet high with approximately two to four sensors per cm². That means, it is highly suitable for analysing the load on small bony structures like the metatarsal heads.

The in-shoe pressure mat
Using the two systems described above, it is not possible to get information about the forces or pressure distribution in the shoe. Therefore, there will be no evidence about the influence of special shoes or insoles. To overcome this lack sensor mats are placed in the shoe under the foot (fig. 3). For that, mats in different sizes as well as special shapes like insoles for stump feet or charcot feet are necessary.

In contrast to plate measurements, one bene-
fit is the high amount of flexibility. The two contact areas, for example the sole of the foot and the foot-bed of the shoe or rather the insole, are not flat. Furthermore, it may change during the ground contact in walking or running. Therefore, the flexibility of a sensor mat is very important. Unfortunately, this demand is in contrast to the requirement on a high spatial resolution with a great number of sensors placed closely together. Generally, the spatial resolution of the in-shoe pressure mat is much lower than that of pressure platforms.

On the other side, the great advantage of the in-shoe system is the low rate of interference by the measuring system itself. Almost any situation may be measured without problems which might be crucial for sports applications. The development of the electronic technologies increased this advantage in the past. While data was transferred via direct cable connection to the computer 20 years ago, the way of transferring data has changed from buffering it on a memory card, to using radio transfer via bluetooth or wlan, thus decreasing the sizes of the electronic devices to very small boxes with a weight of less than 100 gram.

Analysis of data
Independent of the used system – force platform, pressure platform or in-shoe pressure mat – different parameters may be analysed. On the one hand the pressure cannot be evaluated by using a force platform, on the other hand the pressure measuring systems are not able to determine the horizontal components of the forces. Apart from that, all other analysis are equal and will be presented commonly.

Pressure
When using a pressure measurement system, the first step of analysis is the display of the distribution under the feet (fig. 4). This is done via a coloured scale for the left and right foot. It is universally accepted that the scale indicates low pressure by cold colours (grey-blue-green) and high pressure by warm colours (yellow-orange-red). Furthermore, a mask is laid on top of the foot display in order to divide the foot in different small areas. This may vary among different manufacturers, but nevertheless, the user may change the suggested partition as he likes. In the example in fig. 4 six single areas can be distinguished, namely the heel, the mid-foot, the lateral forefoot, the central forefoot, the medial forefoot and the toes. For each area the maximum pressure with its exact location and its value is indicated.

In a barefoot measured situation this display can be used to get information about the special characteristics of the particular foot, for example low pressure in the mid-foot region indicates a hollow foot, whereas high pressure indicates a flat foot. The absolute pressure peaks show the location of the foot where problems may occur. Thus high pressure values at one of the metatarsal heads (frequency it is number two) may indicate a risk for pain or even injuries, like micro fracture of the bone. In conclusion, the efficiency of an individual treatment by customized shoe or insole settings can be controlled by in-shoe measurements. This task can be realized well by comparing the measurements before and after the treatment.

Force
As described above, force can be measured directly by a force platform. Using a pressure measuring system the force can be calculated. Pressure p is defined by force F divided by area A: \( p = \frac{F}{A} \), and therefore force is defined as: \( F = p \cdot A \). Due to the fact that not only the measured pressure, but also the area is known each pressure system releases a force-time-plot. In fig. 5 the force-time-plot from the ground contact of one foot during walking is displayed as an example.

The running time is displayed on the horizontal axis and the vertical axis shows the acting force. After reaching a small peak in the beginning of the curve the force decreases. This is called the impact peak and can be explained as follows: During the first contact of the heel to the ground sensory elements in different anatomical structures (mainly in the skin) record the impact. Afterwards, a nerve impulse will start to run to the spinal cord via afferent nerves, and from there back to the muscles via efferent nerves. This process will take some msec. resulting in a short delay of the reaction of the muscles for an active cushioning of the impact. The time between heel contact and muscular reaction is called latency time. In the force-time-plot it is the time from the starting point up to the impact peak. Generally, it ranges from 30 to 40 msec.

In the following curve progression there are two further peaks. The first one is caused by the passive deceleration of the body during landing, the second one results from the active forefoot lift-off. In between the two peaks there is a more or less load reduction caused by a knee bending in the middle stance phase. Usually, the two great peaks should be almost equal at a level of approximately 120 per cent of the subjects body weight.

If the force curve has an atypical shape, this may result from a relieving posture caused by pain or a special defective position. Thus a reduced first peak may be induced by problems or pain in the heel region due to a calcaneal spur.

Force-time-integral, impulse
Looking at the pressure only no information can be retrieved about the duration of the load at a special point under the foot. A peak pressure point may act both for a short time only or for a longer time period which has great influence on the risk of developing problems. The force-time-integral is the essential parameter for the analysis of the duration. It will be determined as follows: Firstly, the total force-time-plot is divided into the six above explained areas of the foot. Therefore, six single force-time-plots can be distinguished. In fig. 6 this is displayed for left and right foot for normal walking, whereas there is the sum force-plot (grey) on the top followed by the single areas from toes (yellow) to heel (pink).

Mathematically, the force-time-integral is defined by the surface area under the force-time-curve. Therefore, the integrals are correlated to the surfaces of the coloured areas in the figure. In the example of fig. 6 the greatest integral occurs on the right heel, which can be identified visually as well as by reading the value for \( I = 188.21 \text{Ns} \).

What does the force-time-integral mean? The best way to answer this question is a physiological approach. Pressure under the foot could be critical, if it is higher than the pressure in the blood vessels, because the vessels...
will be closed and the oxygen support is broken. This may result in a tissue dieback. This however, is much more critical, if the vessel is closed for a longer period of time. A short stop of blood flow caused by a single pressure peak is less critical. Since the duration of the acting load is part of the force-time-integral, this is a salient parameter.

Applications
Treatment of the diabetic foot
One of the most common applications for pressure measurement systems in orthopaedics is the treatment of the diabetic foot. In case of neuropathy disease the patient is not able to register pressure under his feet. Consequently, there is no defence mechanism to avoid permanent load at a single location.

During walking or even running there would be a high rate of repeated impacts so that blood flow may be influenced and the oxygen supply may not be guaranteed. Therefore, the risk for getting ulcers is very high for diabetic patients. To avoid this, orthopaedic shoemakers have to realize appropriate treatment by customized shoes and/or insoles. The in-shoe pressure mat system is the instrument used to control the treatment in order to reduce the risk of ulceration.

From the biomechanical point of view, it would be desirable to define critical values for the peak pressure and for the force-time-integral. In other words: Are there absolute values for both parameters which should not be exceeded after the treatment?

In the past, health insurances in Germany demanded a reduction of the peak pressure measured in barefoot situation by 30 per cent. Publications from the last years, however, showed that it is possible to define such absolute values as critical threshold. Already Cavanagh (1991) claimed that the absolute value of peak pressure is responsible for a high risk of ulceration. More recent studies investigated the conditions under which relapsed ulceration occurs for diabetic patients (Owings et al., 2009; Bus et al., 2013). The observation of a very high number of patients yields to quite conclusive results. They found out that there is no relapsed ulceration if peak pressure is less than 20 N/cm². Therefore, the proposal is to take this value as a general critical threshold for the peak pressure in the shoe after the treatment of a diabetic patient.

As mentioned above peak pressure is covering only one but not all aspects of an appropriate treatment. The second one is the force-time-integral in where the duration of the acting load is considered additionally. Is it possible to define a critical value for this parameter as well? To answer this question, the influencing factors of the force-time-integral should be considered.

Firstly, the body weight of a person influences the force-time-plot in that way that the curve is higher for a heavy person in comparison to a lightweight one. That means, the force-time-integral would increase, too. Secondly, the total duration of the ground contact influences the force-time-integral which is affected by the walking speed. Unfortunately, both factors have negative impact for diabetic patients, since they are rather heavy and they are walking rather slowly. However, this shows that it is not possible to define an absolute critical value for the parameter force-time-integral. Nevertheless, the parameter should always be distributed equally between rear-foot and forefoot. That means, a measured discrepancy should be adjusted by the shoe treatment.

In conclusion, using an in-shoe pressure mat for controlling the treatment of a diabetic patient orthopaedic shoemakers should pay attention to reduce the maximum pressure under 20 N/cm² and to distribute the force-time-integral equal between rearfoot and forefoot. The pressure, however, is mainly influenced by the shape and the material of the insole while the force-time-integral is mainly influenced by the setting of the shoe. Hence, in case of a high impulse value at the forefoot, a ball roll can be used to accelerate the final stance phase during walking.

Performance diagnostics in ski jumping
There are various applications of force or pressure measurements in sports. Many studies dealt with running (Cole et al., 1995; Nigg, 1997; Walther, 2005) focusing mainly on the analysis of load. In the field of performance diagnostic and control there are also several studies present. As examples the works of Vetter et al. (2004) in beach-volleyball and Schnittger et al. (2015) in soccer should be referred. As an actual example by our research group the measurement of the in-shoe pressure in ski jumping will be presented (fig. 7).

One of the most important information for ski jumping coaches is the force-time-plot during take-off. In
fig. 8 the complete force-time-plot from inrun, take-off, flight and landing is displayed. Thereby, the red curve represents the right foot, the green one shows the left foot and the sum of both is displayed in blue. At the moment of the take-off (approx. from 6 to 7 sec. after the start) it is important to look exactly at the time of peak force. It should neither be to early nor to late, otherwise an optimal take-off is not possible. Furthermore, the relation between left and right foot as well as between rearfoot and forefoot are investigated as this has a direct impact on the body position in the early flight phase. One possible problem for athletes may be a strong push-off over the forefoot with less contact on the heel. Consequently, it is more difficult to reach quickly the lent forward V-position in early flight. Natrup (2015) investigated the effects of insoles with lateral rearfoot and heel increase on the pressure distribution and the force during take-off. As a result, the insoles constructed in that way have a positive effect on the power of the take-off. Finally, this results in longer jump distances.

In conclusion, the described application in ski jumping is only one example, but it shows very impressive, how the pressure measuring system can be used to analyse sports performances. In that way, it may be very helpful for coaches and their high-level athletes to become more successful.

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Dr. Jörg Natrup has a PhD in sports science and was an assistant professor at the „Institut für Bewegungswissenschaften“ (Institute for Motion Science) in Munster, Germany. Today he works as a scientist for GeBioM in Munster, Germany. His key activities are biomechanics, load analysis of the locomotor system when walking, running, sitting and lying down as well as the electronic measuring technology.
Jaron’s mother was nine weeks pregnant, when she found out that she was expecting a child. At that time she was taking several drugs, amongst them also antibiotics, to treat an illness. When the antibiotics did not help to treat her influenza, the doctors examined her blood and only then discovered her unplanned pregnancy. Because of her exposure to so many drugs, the mother had her doubts about carrying out the child – but the test results showed “Down syndrome negative”.

However, a routine anomaly ultrasound scan at 21 weeks revealed an underdevelopment of the left foot of the fetus.

Situation so far
Jaron is completely healthy, except for his left foot. According to the treating doctors only his heel and ankle are osseously developed. At this stage, however, his mid-foot and fore-foot have not been osseously developed. Despite his limitations, Jaron is able to stand on his toes with both feet.

In South Africa adequate pedorthic treatment is generally not available. Without the required treatment, the progressive uneven growth of both his feet are expected to impair his gait. In the medium to long term chronic problems of his knees and hip joints will be inevitable.

The treating doctors in South Africa have only recommended amputation of the entire left lower leg – a huge shock for the mom! Having to raise her two sons as a single mother, Jaron’s mom cannot afford a trip to Europe to have Jaron treated there. Jaron’s family does not have any health insurance, a common situation for the majority of South Africans.

The treatment up to now
German trained pedorthist, Micha Oelsner, (see “Talking with...” edition 2/2011, page 30), who has her workshop in Durban, KZN, South Africa, has been in cooperation with Upper Manufacturers Seidich in Germany for quite some time. She supplies and takes care of Jaron. Unfortunately, in South Africa, most of the materials and machines needed for adequate and comprehensive pedorthic treatment are not available locally. Also, considering the very high cost for specialised custom-made therapeutic devices, Jaron’s family simply cannot afford the necessary treatment. Following many conversations and in-depth correspondence between Micha Oelsner Hartmut Seidich, Mr Seidich agreed to take on Jaron’s treatment free of charge. Both parties involved firmly believe an amputation of the entire lower leg should really be the very last resort.

Obviously, with the patient living thousands of kilometers away, with no opportunity for team Seidich to personally examine the little patient, the
The doctors have not found out yet what exactly prevents Jaron’s left leg from growing.

Micha Oelsner took the necessary measurements in Durban, South Africa and made a plaster cast and a foam imprint and sent it to Seidich in Germany.

According to the specifications of Micha Oelsner the last, an exact replica of Jaron’s left foot, was manufactured there. This worked out that well only because of Micha Oelsner’s excellent preparatory work.

conditions for optimal treatment are far from ideal. In this case, however, the experienced pedorthist, based now in Durban, 600 kilometres away from Jaron’s home, is there to help.

The team began its search for an optimal solution 10 000 kilometers away from Jaron’s home in the German area “Ruhrgebiet”, after having received a detailed medical report, blue prints, foam impressions, measurements, images, several videos showing Jaron’s gait, and an exact plaster mold of the left foot. In order for team Seidich to manufacture the last, (an exact replica of Jaron’s left foot), the accurate and perfect preparatory work supplied by Micha Oelsner, was absolutely

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Dich has been hand-crafting orthopaedic uppers and high-quality custom-made shoes for three generations. For many years the company has passionately been supporting humanitarian projects for children – mainly in war zones and areas of conflict.

Comparable to a forefoot amputation
Choosing a holistic approach by consulting several medical-professional experts, the decision was made to treat the under-developed left foot like a forefoot amputation. For that reason, instead of manufacturing orthopaedic custom-made boots, an internal shoe (inner shoe) with a forefoot replacement device (Inlay), was the choice of treatment. Such a device will allow Jaron to wear regular shoes, possibly also sandals in the summer, which is a huge advantage in a hot climate like South Africa.

Considering further growth
The uneven growth of both feet present another problem. Whereas the right foot is growing age-appropriate (at this age that means fast), the left foot is developing very slowly. Uneven growth aside, Jaron still has to wear the same size shoes on both sides. Most off-the-shelf shoes differ not only in length, but also in sole thickness and heel height, according to different styles and size categories. Jaron’s shoes will always have to be one hundred per cent identical, to ensure the child’s pelvis is even. A false leg-length discrepancy can result in pelvic obliquity and cause damage to the hip. In this case, the total thick-

In order to consider the growth of both feet, the internal shoe has been constructed in a way that the exchangeable carbon sole and the lacing make the adjustment of the shoes possible.

Please find online the videos and a photo gallery of Jaron, his treatment and the production of the shoe that grows with him.
ness of 12 millimeters, that makes up the internal shoe device’s sole, inserted in the left shoe, has to be considered. To achieve an even gait, the off-the-shelf insert of the left shoe needs to be removed, consequently reducing the heel-difference slightly. On the opposite (right) side, a cork wedge with the correct thickness (about eight millimeters) is then glued underneath the off-the-shelf insert to compensate for the heel-difference.

If however, Jaron is to wear the same shoe size on both – differently sized – feet, the internal shoe has to be adjustable and adaptable to future shoe sizes, as Jaron grows older. As the healthy right foot grows in length, the left foot also needs “to grow” at a certain stage. Usually in a case like this, it is common practice to manufacture a completely new device. In Jaron’s case, this is not an option due to logistical and financial constraints. The crucial technical solution to this challenge is a carbon spring, implemented into the internal shoe. By inserting the carbon spring inside a solid pouch (glued and stitched) at the bottom of the internal shoe, firm positioning is achieved, eliminating any side-movement. The carbon spring can easily be removed and exchanged for a longer carbon sole by simply removing two rivets. The carbon spring has been molded in a specific way, allowing for natural toe off of the underdeveloped foot.

The entire foot is firmly held in place by a specially designed internal shoe upper, equipped with a high and slightly enforced heel/ankle cap, in order to support the foot all around and to prevent overloading of the tendons. Jaron’s tendons might not be fully developed and need extra support. The total weight of the forefoot device and the internal shoe is only 165 grams.

An eight millimeter latex cushion has been placed in the toe area of the forefoot device. In case of a growth spurt it can easily be removed. Any potential increase in leg circumference can be accommodated with the adjustable lacing. In addition, a flexible elastic band has been attached to the rear closure of the internal shoe upper, allowing for further expansion. Consequently, depending on the growth of the left foot, this internal shoe device is expected to last for about two years.

If future growth of the left foot does not accommodate further use of this internal shoe, a new one has to be made according to the new measurements. In order to monitor the growth and development of Jaron’s feet and the correct fit of the internal shoe, Jaron will have to see Micha Oelsner for a follow-up consultation every six months.

Material
Special care was taken while choosing the material, to assure that every material in contact with the skin is pollutant-free. As leather-lining (lining of upper and forefoot replacement), high-quality, purely herbal Valonea-calf leather from Ecopell (Germany), a producer from the German region “Allgäu”, was used. This leather is particularly skin-friendly and very sweat absorbant.

The enforced leather heel/ankle cap is made of cavern-tanned calf leather from the traditional tannery Rudolph in Thüringen (Germany). This cap has been attached to the upper with potato-starch-based glue that remains breathable once dry.

The leather used for the upper is made from the finest Nappa leather from an Italian tannery and complies with the regulations of the German Medicinal Devices Act. It was a joy to correlate with another supporter of Jaron’s treatment, Superfit, the Swiss producer of children’s shoes. They were extremely helpful and very pleasant to work with. The idea was to supply shoes from the Superfit range that are as durable and high-quality as possible. In a non-bureaucratic way Superfit provided several pairs of shoes in different sizes from the same range.

The forefoot replacement was fitted into the smallest size shoe that currently fits the right foot. The larger size shoes will in future accommodate the growth of Jaron’s feet.

Hartmut Seidich, owner of the company Seidich Schäfte in Herne, Germany, specializes in severe orthopaedic cases and in exceptional uppers for custom-made footwear. He is a lecturer for production of shoe uppers at the Academy of Craft in Düsseldorf. His new and detailed textbook of “Manufacturing Uppers” will be published by C. Maurer Fachmedien, Geislingen, Germany, soon. Hand-made shoes with Seidich’s uppers are both worn by victims of land mines or congenital deformities and by princes or Hollywood stars. (www.seidich.com).
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On our own behalf

Due to translation errors of the editorial staff the article Effect of proprioceptive insoles on patients with cervical spine syndrome Original Research Report by Simone Werner et al foot&shoe 2/2015, page 38 ff. has been completely revised and is now available on-line in the updated version. Please excuse our problems!

Thanks to its thermoplastic properties, "Astro form 15" optimally moulds itself to the second ply during deep drawing without having to be heated separately. The permanently resilient properties of this material are retained to the maximum extent.

Further information
www.nora-shoe.com
ANNOUNCEMENTS OF THE INDUSTRY

C. Maurer Fachmedien

From May 3 to 6, 2016, the global O&P sector meets up at OTWorld, International Trade Show and World Congress in Leipzig, Germany. The trade show and the congress will also have a section for pedorthics. "foot&shoe" will also be at the trade show. If you come to Leipzig, you will find us at the booth of C. Maurer Fachmedien (1-H17). We will present the latest issues of foot&shoe as well as the new textbook "Pedorthics". We are looking forward to meet you to discuss and share ideas for the further development of our journal.

The area of OTWorld that focuses on the wholesale and retail trades offers visitors an opportunity to look beyond the confines of their own horizons. Major suppliers will be represented at the trade fair. The forum on future concerns will include lectures on sales and marketing, as well as on staffing and finances, and a special show devoted to tips and tricks relating to shop fitting and product display. Pedorthists will get an overview of the market at OTWorld. In both trade fair and congress a comprehensive insight into the neighbouring fields of expertise that impact on orthopaedic footwear technology will be offered.

Think Schuhwerk GmbH

Premiere in the shoe industry. Think! is the first shoe producer that has been awarded the "Austrian ecolabel" in October. The model "Chilli" has been certified, a black lace-up from the ladies' shoes collection.

The "Austrian ecolabel" is considered as one of the strictest sustainability certificates in Europe. In order to meet all of the criteria, the product is not only checked during the final production. Also the production of the used materials has to be carried out in a verifiably eco-friendly way. Additionally the distinguished products have to meet ambitious social criteria.

The certification of the lace-up "Chilli" is another step for Think! towards a production chain that is traditionally sustainable and eco-friendly.

"We have gained valuable insight through the very demanding and time-consuming certification, that we will use for the development of our new collections", Walter Breuer, the managing director of Think! promises.

Register now - its free!

THE INTERNATIONAL JOURNAL FOR FOOT ORTHOTICS

www.foot-and-shoe.com/newsletter
Upcomming events

March 25 – 27, 2016: Rehacare & Orthopedic China, Guangzhou

R&OC 2016, the 6th edition of the annual event is the only one platform showcasing the rehabilitation equipments, assistive technology and prosthetics & orthotics products in China, serves to feature the latest state of development of the Chinese industry and introduces the worlds latest technologies to the Chinese market. The combination of International Rehabilitation Canton Forum (IRCF) makes the R&OC an optimal trading and dialogue platform for professionals, market leaders, suppliers, dealers and innovative newcomers from China and across the world.

The last fair attracted the presence of 186 well-known companies from 21 countries and regions that covers 481 booths, gathering about 13 393 industry professional visitors from 59 countries and regions. It is expected to have about 600 booths consisting of 250 exhibitors in R&OC 2016. The concurrent event International Rehabilitation Canton Forum (IRCF) was held by International Society of Physical and Rehabilitation Medicine (ISPRM). IRCF 2015 forum triumphantly invited 127 renowned domestic and overseas experts to make academic speeches and share their latest researches to 1 362 professional audience, while an expectation of 300 illustrious experts and 3 000 attendances in 2016.

A great success for all parties concerned, featuring 250 exhibitors of 600 stands, 20 000 square meters including exhibition area and the forum. Besides, there are more than 25 000 domestic and overseas visitors expected in R&OC 2016.

Further information http://en.cantonrehacare.com

May 8 – 10, 2016: OTWorld, Leipzig

Every two years, the global O&P sector meets up at OTWorld, International Trade Show and World Congress. More than 20 000 visitors come to discuss the latest research and development work and practical experiences with speakers and exhibitors from all over the world. Interdisciplinarity is focussed at OTWorld: all disciplines involved in the use of artificial aids in the treatment of patients meet here. These include, for example, orthopaedic technicians, orthopaedic shoemakers, engineers, doctors, physiotherapists and occupational therapists. The Congress involves many distinguished delegates and its attendance list reads like a Who’s Who of the sector. International professional associations in the sector meet up in the Global Networking Area, a platform for information and communication, to discuss current issues in the sector at an international level and to share their work and activities.

“We are delighted that we are again able to host the worlds largest gathering of professional associations in our sector. The Global Networking Area offers an ideal platform for making many new personal contacts and establishing new networks, which can and will impact positively on our shared future long-term,” insists Klaus-Jürgen Lotz, President of the German Association of Orthopaedic Technology.

“I am, moreover, very pleased that we shall be seeing greater international participation among what is also the biggest gathering of young orthotics and prosthetics. Alongside German students and trainees in technical orthopaedics and medical students, young members of the sector from France and the Netherlands are now also invited to the Youth Academy,” explains Professor Frank Braatz of the Private University of Göttingen / University Medical Center Göttingen (UMG) and Congress President at OTWorld 2016.

Further information http://ot-world.com/

May 26 – 28, 2016: FIP-IFP Congress, Montreal

The FIP/IFP is an international not-for-profit association focused on global leadership and the development of pediatric medicine around the world. Working together collaboratively with leaders of the podiatry profession, the Federation enhances the pediatric profession through the sharing of knowledge, practice and research among member countries. The FIP World Congress of Podiatry is held every three years and attracts participants from around the world, including podiatrists in private practice, the public sector, the educational stream and students. As well, you can expect to meet vascular surgeons, nurses, diabetologists and other members of the medical team. The exhibit hall is an integral part of the World Congress that enables delegates to see a wide array of foot related products and services from around the world. With an expected 1200 active participants, this will be the largest gathering of international foot and ankle practitioners/specialists. This meeting is the forum for professionals, industry and academia practicing in this field to interact.

Further information http://registration.cgi-pco.com/WCP2016

Kathrin Ernsting is editor for the German journal “Orthopädie und Orthopädieschuhtechnik” and the English “foot & shoe”.
Iris Burtscheidt and some examples of her work.

Talking with...

Name: Iris Burtscheidt
Marital status: married
Date of birth: 05/04/1976
Profession: Orthopaedic Shoe Technician / Pedorthist
Place of residence: Eupen, Belgium
Company and position: Managing Director Burtscheidt-Orthopädie PGmbH
Place of work: Eupen, Belgium

I came to the shoe trade... through my parents. My grandpa opened the company in 1945, my father took it over in 1980. I used to be a lot in the workshop when I was little, sometimes I helped. In 1994 I began my education in my parents' company. Since 1995 my husband has also worked here.

What I like about my job... is the diversity. We work with patients in order get the best-possible solution for their foot problems. Also manual skills and creativity are needed, so that the limitation is not "visible". And I also enjoy the office work.

It is very important for me... that the patient is satisfied with our work and that he can walk better. I also pay a lot of attention to custom-made work, since every patient should be treated individually. Unfortunately this is not understood anymore in our industry.

My next aim is... to deal with modern media like Facebook, Twitter, etc.

Shoes are for me... passion! A high-quality and beautiful shoe can thrill me. Unfortunately the quality of ready-made shoes is getting worse, since the end consumer wants to have many and low-priced shoes.

I would like that the shoe industry... pays more attention to quality. Many foot problems are caused by low-quality shoes, for example the lack of steel joints, bad stiffeners...

Interview by Kathrin Ernsting
Analysis of Bending and Torsional Stress on the Foot in Different Offloading Shoes

Original Research Report

Nora Dawin, M.Sc.1,2; Nicole Dirksen, M.Sc.1; Philipp Buss, M.Sc.1; Klaus Peikenkamp, Prof. Dr. habil.2

Abstract

This study compares the bending and torsional stress acting on the foot in the Darco Relief Dual offloading shoe to that of an already licensed competitor. Levels of functional limitation and forefoot offloading were analysed in 22 healthy subjects (9f, 13m; 35 ± 8y) using the vebitoSCIENCE measuring system. 30 gait cycles were monitored and the mean values calculated for selected parameters. The Darco Relief Dual significantly reduced (p<0.05) maximum dorsal extension moments at MTP I and V. There was also a significant reduction in the range of motion at MTP V and a significant decrease in the total load on MTP I and V over the entire gait cycle. In the competitor shoe, a significantly reduced maximum plantar flexion moment and alternating load were measured at MTP I and DIP I.

Keywords: Bending moment, torsional moment, stress, offloading shoes

S

cialized orthopedic devices for stabilizing and offloading the foot are often used to support the rehabilitation process after foot surgery [2]. There are different types of shoes prescribed after surgery, such as those specialized for wound management or with offloading functions. In Germany, these therapeutic shoes must meet essential requirements to receive an official number in the German register of medical technical aids and it is therefore necessary to test their quality and functions. Wound management requires bacterial material and postoperative shoes have to be firmly affixed to the foot to reduce loading in the forefoot area. Postoperative shoes must also be comfortable, even if the foot is bandaged. Forefoot offloading shoes are used when load has to be taken off the injured area but the patient needs to stay mobile, for example, after hallux valgus surgery.

How much the injured area is off-loaded can generally be justified by measuring plantar pressure. In addition to plantar pressure, however, multidimensional stresses like bending and torsional moments also act on the foot.

Bending moments, which are calculated by multiplying the acting force by the respective lever arm, cause bending deformations in the shoe; or rather, on the foot in the shoe. If, for instance, the forefoot is extended dorsally with respect to the hindfoot, there is an acting dorsal extension moment. In the case of a cyclical movement like walking, alternating loading occurs in the form of both dorsal extension and plantar flexion moment. Alternating load cannot be detected by conventional pressure measurement systems [5].

The first findings on bending loads acting on the foot were published by Arndt et al. (2002) [1]. The authors conducted an in-vivo study in which strain gauges were surgically implanted into the second dorsal metatarsal bone. These measured strain on the 2nd metatarsal head during walking and were capable of detecting both tensile stress and compression stress. In the past, invasive procedures such as this were the only way to measure bending and torsional stresses acting on the foot in shoes. However, a new, non-invasive insole measurement system, developed at the Biomechanics Research Laboratory at Münster University of Applied Sciences (Germany), is now available.

Stief and Peikenkamp presented the first results obtained with the new insole measuring system in 2015, demonstrating that it could detect plantarflexion stress followed by dorsiflexion stress during each gait cycle [4, 5].

After aggregating their calibration results, they concluded that the insole measuring system is able to easily and reliably measure bending and torsional moments at the forefoot [5].

This study analysed the effects of two different offloading shoes on bending and torsional moments at the forefoot: the Relief Dual offloading shoe (Darco Europe GmbH, Raisting, Germany) and a competitor post-op shoe. Both are postoperative offloading shoes, but their designs are very different. The competitor shoe is indexed in the German register of medical technical aids, which is a precondition for the reimbursement through the health insurance. The aim of the study was to investigate whether the mechanical conditions present in the two shoes have comparable or significantly different influences on stress at the forefoot.

The insole measuring system vebitoSCIENCE (veбитosolution GmbH, Steinfurt, Germany) was used to monitor bending and torsional stress. This system uses 5 parameters to measure a shoe’s functional limitation and forefoot offloading effect.

22 healthy subjects (mean age: 35 years; 9 female, 13 male) participated in the present study. Loading curves for 30 consecutive gait cycles were acquired from each test person, after which the mean values were calculated. The curve of bending and torsional moments were measured at five different sensor positions and parameters like maxima, range and alterna-
Methods
Participants
The loads occurring under different shoe conditions were recorded in trials with 22 test persons (mean age: 35 ± 8 years, between 25 and 52). Nine of the 22 subjects were female. Age and normal, physiological gait pattern were the selection factors for choosing test persons.

Relevant data on the test persons and their medical history were collected using a questionnaire before any measurement took place. An examination to identify abnormal gait patterns and malpositioning of the feet, hip and knee joints was conducted for each subject. In addition, the range of motion of the upper and lower ankle joint was determined according to the neutral-zero method. Subjects with notable limitations of movement or pathological abnormalities were excluded from measurement. Subjects gave their written consent before participating in this study.

Shoe Conditions
In this study, two different shoe conditions were analysed for the right foot. On their left foot, participants wore a neutral shoe with height compensation (Adidas Samba; Adidas AG, Germany). Height compensation was modified in each case to match shoe height for each individual shoe condition and shoe size.

In this study, the offloading shoes Relief Dual (DARCO International Inc., Huntington, USA) (see Figure 1) and a postoperative shoe from a competitor were compared.

For more information about the competitor shoe please contact the author.

Both shoes were offloading shoes. The competitor shoe is indexed in the German register of medical technical aids, which is a precondition for the reimbursement through the health insurance (medical technical aids classification number group: 31.03.03.). The Darco Relief Dual did not have an medical technical aids classification number at the beginning of this study. The offloading shoes are very different in design. The competitor is a closed model with cushioned interior, featuring a rigid, full outsole with a double-rocker. The Relief Dual is an open shoe, which protects the toes, with an extended outsole. The outsole is made of two different materials with a continuous, rigid stiffening sole. Both shoes are fastened to the foot with Velcro.

In total, seven shoe sizes of the Relief Dual (34 female – 48 male) and five sizes of the competitor (37 – 46) were compared. Heel heights of the competitor shoes ranged from 30 – 32 mm and the Relief Dual from 31 – 39 mm.

Bending and torsional insole measurements

The vebitoSCIENCE insole measurement system described above was used to measure bending and torsional stress (5 sensor positions, 125 Hz, 16 bit).

The vebitoSCIENCE measurement system was developed by the Biomechanics Research Laboratory, Münster University of Applied Sciences, Germany. Strain gauges are fixed to a specially shaped flexible layer in the insoles. The purpose of the special shaping is to detect bending and torsional loads independent of the medi and lateral forefoot. Mirror-inverted and interconnected strain gauges can be found on both the upper and bottom surface. The interconnection of the strain gauges into half bridge circuits for bending and full bridge circuits for torsion allows both loads to be measured at the same time. The measuring frequency is 125 Hz. Sensors are placed proximal to metatarso-phalangeal joints I and V (MTP I and V), proximal to the distal interphalangeal joints I and V (DIP I and DIP V) and distal to the processus calcaneus (see Figure 2). Data are transferred wirelessly to a notebook via Bluetooth. The calibration results presented a coefficient of determination of $R^2 > 0.999$ and a linearity factor of almost 1.0 [5].

The measuring insoles were placed in the shoes and cables were affixed to the participants’ legs with flexible Velcro® straps. To avoid distorted results due to fatigue or testing order, the order of shoe conditions tested was randomized. Subjects wore the different test shoes on their right foot. On their left foot, they wore an Adidas Samba with additional height compensation matching that of the offloading shoe being tested. The measuring insoles were worn on both feet. The system requires an initially unloaded state, which was measured with subjects sitting on a raised chair with legs and feet hanging and immobile. The measurements were taken on a Sprin-tex slat belt treadmill (SPRINTEX Trainingsgeräte GmbH, Kleines Wiesental, Germany).

Before data acquisition, participants were given five minutes of familiarization per shoe condition, during which they walked on the treadmill at a self-selected speed (minimum of 2.5 km/h). The velocity chosen by the subject during this period of familiarization was maintained for the following trials. Measurement of bending
and torsional moments was conducted once per shoe condition. For each trial, 30 gait cycles were recorded.

Data processing and evaluation
The curves of bending and torsional moments were recorded at five different measuring points by the veibitoSCIENCE measuring system. The load curves of 30 serial gait cycles (GC) were monitored and mean values were calculated. The point of reference determined automatically by the software was heel strike [3]. Before analysis, the raw data were run through low-pass filter (Butterworth, 10 Hz, second order).

The curves of the bending and torsional moments of the right foot were analyzed for all five measuring points. Besides these load curves, five additional parameters were statistically analysed:
- maximum plantar flexion moment/ Nmm
- maximum dorsal extension moment/ Nmm
- range of bending moments/ Nmm
- alternating load of bending moments/ %
- momentum (absolute value) of bending moments/ Nmm * %

Figure 3 presents a characteristic bending moment curve, including the analysed parameters. The parameter range is an index of the range of motion over an entire gait cycle. The momentum (absolute value) has not been visualised. In this study, the term momentum (absolute value) is used to refer to the absolute value of the bending momentum. This designation is abstracted and not equivalent to the physical quantity momentum. The load over the entire gait cycle can be characterised by considering the parameter momentum (absolute value) of the bending moments.

If there are no moments in the direction of a plantar flexion, the minimum of the dorsal extension moments is shown. The alternating load (AL) is calculated as shown in formula (1). If there is no plantar flexion or dorsal extension moment, then there is no alternating load, either.

\[
AL = \frac{(M_{max} + M_{min})}{2} \times \frac{1}{GC}
\]

A two-sided paired t-test was conducted to detect significant differences \((p < 0.05)\).

Results Curves
The continuous curves present the mean values, the dotted curves present the standard deviation (SD). The blue curves describe the loading in the Relief Dual shoe as a function of the GC and the red curves the loading in the competitor shoe. For each graph, the number of subjects (N) used to calculate the mean value is given.

If there were measurement errors with regards to individual test persons, then \(N < 22\).

Bending moments
The mean bending moment at the heel produces a similar curve in both shoe conditions, with a small SD. The curves first show a dorsal extension moment with a local peak at about 10 – 20% gait cycle, followed by a slow decrease that reaches zero at about 60 – 70% GC. The measurement for the Relief Dual shows a slight plantar flexion moment and an additional plantar flexion moment (Figure 4). Starting from about 40% GC, bending moments at measuring point MTP I show very similar curves with small SDs, whereas the competitor presents considerably higher dorsal extension moments. After heel strike until about 45% GC, a slight plantar flexion moment can be observed in the Relief Dual. By contrast, the competitor presents a dorsal extension moment.

At measuring point MTP V, the bending moment curves differ little and present small SDs. After heel strike, a local maximum occurs at about 10 – 20% GC. At 30 – 40% GC, a local minimum can be observed. At about 60% GC, a conspicuous local maximum occurs, afterwards showing a steep decrease. The dorsal extension moments of the Relief Dual also have considerably lower values in comparison to the competitor at this measuring point. There is no plantar flexion moment for either shoe condition at measuring point MTP V.

Both mean bending moment curves are almost identical at measuring point DIP I. There is a local maximum at about 60 – 70% GC. A relatively high SD exists in the first phase of the gait cycle (until approx. 50%). After the local maximum is reached, both curves show a steep decrease. At this measuring point, both shoe conditions display a dominant dorsal extension moment.

At DIP V, the bending moments of both shoe conditions present a similar curve. The high SDs apparent here are due to the relatively high variations between individual subjects. Bending moments change their direction from a plantar flexion moment to a dorsal extension moment earlier for the competitor (at approx. 55% GC) and as compared to the Relief Dual. Dorsal extension values are slightly smaller for the competitor than for the Relief Dual.

Torsional moments
The mean torsional moment at the heel demonstrates a strongly varying curve with a large SD under both shoe conditions. The measurement taken for the Relief Dual shows a higher inversion moment as compared to the competitor. An inversion moment is dominant in the competitor shoe. High SDs indicate strong variations in the curves of the individual test persons (Figure 4).

The mean torsional moments demonstrate a similar curve, but unlike the bending moments at MTP I, higher SDs occur at this location. In addition,
Mean bending and torsional moments on five sensor regions. Continuous lines present the mean values, dotted lines present the standard deviation. Positive values describe a dorsal extension moment (internal rotation with regard to the central axis of the foot), negative values a plantar flexion moment (external rotation).
the eversion and inversion moments are higher in the competitor shoe than in the Relief Dual.

For both shoe conditions, only an inversion moment can be observed with regards to the torsional moments at MTP V. The curves are quite similar and there is a small SD. The increase in amplitude of the inversion moment is considerably higher in comparison to the Relief Dual.

In contrast to the bending moments, more differences are found regarding the curves of the torsional moments at DIP I. Here, the value of the competitor is significantly higher than that of the Relief Dual. At the other measuring points, there is no significant difference between the two shoe conditions.

At MTP V, the mean values of the maximum dorsal extension moments of the competitor are significantly higher as compared to the Relief Dual. At the other measuring points, no significant difference exists for the dorsal extension moments.

The alternating load value of the Relief Dual is significantly higher than the value of the competitor at the measuring points heel, MTP I and DIP I. Because there is no plantar flexion moment, no alternating load can be determined at measuring point MTP V. At DIP V, no significant difference can be observed between the two shoe conditions.

Discussions

The aim of this study was to evaluate loads acting on the foot during walking in two different offloading shoes with very different shoe designs. The Relief Dual was compared to an offloading shoe that already is indexed in the German register of medical technical aids. The analysis focuses on functional limitation and relief of the forefoot. Bending and torsional loads were measured using the vebitoSCIENCE measuring system.

The curves of the bending loads at the different measuring points are sig-

Table 1 Results of the five compared measuring parameters and the findings of the conducted t-test. Mean value and standard deviation (N=22) presented for each parameter for the Relief Dual and the competitor at all measuring points.
The findings of the bending and torsional measurements show that similar levels of functional stress occur under the two shoe conditions analyzed. However, the Relief Dual offered the advantage of a reduced dorsal extension moment at MTP I and MTP V. The differences between the two shoe conditions especially occur at the measuring points heel, MTP I and MTP V. At DIP I and DIP V, the load curves of both shoes are similar. For the Relief Dual, an additional slight plantar flexion moment can be observed at the heel. Furthermore, the dorsal extension moment is slightly higher at this measuring point. The bending load at the heel is of subordinate importance regarding the question of functional limitation and relief of the foot. At these two measuring points, the dorsal extension moment of the Relief Dual is notably lower than that of the competitor. This implies greater functional limitation and increased relief of the foot. The pronounced occurrence of a plantar flexion moment at MTP I is of lower importance as compared to the reduced dorsal extension moment, because the highest loads at the forefront are observed during terminal stance and can therefore be expressed well by the dorsal extension moment. At measuring point MTP V, only a reduced dorsal extension moment can be observed. The fact that no additional plantar flexion moment was observed implies that the Relief Dual provides better offloading of the forefront.

Interpreting torsional load curves generally only allows conclusions to be drawn on the gait pattern of individual test persons. They also complicate interpretation of the occurring loads.

Due to their lack of relevance to offloading the forefront, the heel parameters will not be discussed any further. At measuring points MTP I and MTP V, seven of the nine load parameters selected differ significantly. For five of these selected parameters, the Relief Dual demonstrates greater relief of the forefront during walking. For two of these parameters, the competitor achieves smaller loads at the forefront. The values of the maximum dorsal extension moment at MTP I and MTP V, of the range at MTP V and of the moment (absolute value) at MTP I and MTP V are significantly smaller for the Relief Dual as compared to the competitor. The competitor presents a smaller maximum plantar flexion moment and an alternating load at MTP I.

At measuring points DIP I and DIP V, the competitor achieves greater relief of the forefront for one of ten values (alternating load at DIP I). For all other parameters, both offloading shoes achieve similar functional limitation and relief of the forefront at these measuring points.

Because of the additional plantar flexion moments of the Relief Dual and the lower alternating loads of the competitor, the competitor achieved comparatively slightly reduced loads at the forefront. However, given that the values of the maximum dorsal extension moment and the momentum (absolute value) of the Relief Dual are significantly smaller than the values of the competitor, it can be assumed that the Relief Dual achieves similar relief of the forefront, and in some cases even greater relief.

Individual walking speed was chosen by each participant during the first measuring condition and remained constant for the second condition. For statistical analysis, a paired t-test insensitive to the effect of interindividual differences in walking speed was used.

For the very same reason, differences in sole stiffness caused by different shoe sizes do not affect the data analysis; the shoe sizes differed from subject to subject, but remained constant for the two testing conditions.

To derive more information on the offloading effects of the two different shoe designs, the plantar pressure distribution should be analyzed as well. It is also important to what extent patients feel familiar with the shoes and how the orthopedic device influences normal gait patterns. Furthermore, to see how offloading shoes influence the gait patterns of bending and torsional stress acting on the foot, additional data should be analyzed, i.e. from the left foot wearing the control shoe, or under control conditions. To date, no information has been published on the influences of bending and torsional loads on the feet of surgery patients wearing offloading shoes.

Conclusions
Although the two shoes investigated had very different designs, there were only minor differences observed between the bending and torsional stress acting on the foot in each shoe design. That said, the offloading effects during walking measured by multidimensional parameters were attributable to demonstrable differences in bending and torsional stress under the two shoe conditions. The significant differences found for MTP I and MTP V suggest that the Relief Dual has a slightly greater offloading effect on the forefront. After this study was completed, the Relief Dual was indexed in the German register of medical technical aids as an offloading shoe. However, to provide a more comprehensive view of stress acting on the foot, plantar pressure must be analyzed in combination with bending and torsional stress measurements in future studies.

Conflict of interest
This study was supported by DARCO (Europe) GmbH. This funding did not influence study design, data analyses and conclusions.

Literature


Analysis of Bending and Torsional Stress on the Foot in Different Offloading Shoes

Original Research Report

Nora Dawin, M.Sc.1,2; Nicole Dirksen, M.Sc.2; Philipp Buss, M.Sc.2; Klaus Peikenkamp, Prof. Dr. habil.2

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For more information about the competitor shoe please contact the author.

Both shoes were offloading shoes. The competitor shoe is indexed in the German register of medical technical aids, which is a precondition for the reimbursement through the health insurance (medical technical aids classification number group: 31.03.03.). The DARCO Relief Dual did not have a medical technical aids classification number at the beginning of this study. The offloading shoes are very different in design. The competitor is a closed model with cushioned interior, featuring a rigid, full outsole with a double-roller. The Relief Dual is an open shoe, which protects the toes, with an extended outsole. The outsole is made of two different materials with a continuous, rigid stiffening sole. Both shoes are fastened to the foot with Velcro.

In total, seven shoe sizes of the Relief Dual (34 female – 48 male) and five sizes of the competitor (37 – 46) were compared. Heel heights of the competitor shoes ranged from 30 – 32 mm and the Relief Dual from 31 – 39 mm.

Bending and torsional insole measurements
The vebitoSCIENCE insole measurement system described above was used to measure bending and torsional stress (5 sensor positions, 125 Hz, 16 bit).

The vebitoSCIENCE measurement system was developed by the Biomechanics Research Laboratory, Münster University of Applied Sciences, Germany. Strain gauges are fixed to a specially shaped flexible layer in the insoles. The purpose of the special shaping is to detect bending and torsional loads independent of the medial and lateral forefoot. Mirror-inverted and interconnected strain gauges can be found on both the upper and bottom surface. The interconnection of the strain gauges into half bridge circuits for bending and full bridge circuits for torsion allows both loads to be measured at the same time. The measuring frequency is 125 Hz. Sensors are placed proximal to metatarsophalangeal joints I and V (MTP I and V), proximal to the distal interphalangeal joints I and V (DIP I and DIP V) and distal to the processus calcaneus (see Figure 2). Data are transferred wirelessly to a notebook via Bluetooth. The calibration results presented a coefficient of determination of $R^2 > 0.999$ and a linearity factor of almost 1.0 [5].

The measuring insoles were placed in the shoes and cables were affixed to the participants’ legs with flexible Velcro® straps. To avoid distorted results due to fatigue or testing order, the order of shoe conditions tested was randomized. Subjects wore the different test shoes on their right foot. On their left foot, they wore an Adidas Samba with additional height compensation matching that of the offloading shoe being tested. The measuring insoles were worn on both feet. The system requires an initially unloaded state, which was measured with subjects sitting on a raised chair with legs and feet hanging and immobile. The measurements were taken on a Sprintex slat belt treadmill (SPRINTEX Traininggerät GmbH, Kleines Wiesental, Germany).

Before data acquisition, participants were given five minutes of familiarization per shoe condition, during which they walked on the treadmill at a self-selected speed (minimum of 2.5 km/h). The velocity chosen by the subject during this period of familiarization was maintained for the following trials. Measurement of bending
Exemplary curve progression for bending moments including illustration of analysed parameters.

and torsional moments was conducted once per shoe condition. For each trial, 30 gait cycles were recorded.

Data processing and evaluation

The curves of bending and torsional moments were recorded at five different measuring points by the vebitoSCIENCE measuring system. The load curves of 30 serial gait cycles (GC) were monitored and mean values were calculated. The point of reference determined automatically by the software was heel strike [3]. Before analysis, the raw data were run through low-pass filter (Butterworth, 10 Hz, second order).

The curves of the bending and torsional moments of the right foot were analyzed for all five measuring points. Besides these load curves, five additional parameters were statistically analysed:
- maximum plantar flexion moment/ Nmm
- maximum dorsal extension moment/ Nmm
- range of bending moments/ Nmm
- alternating load of bending moments/ %
- momentum (absolute value) of bending moments/ Nmm * %

Figure 3 presents a characteristic bending moment curve, including the analysed parameters. The parameter range is an index of the range of motion over an entire gait cycle. The momentum (absolute value) has not been visualised. In this study, the term momentum (absolute value) is used to refer to the absolute value of the bending momentum. This designation is abstracted and not equivalent to the physical quantity momentum. The load over the entire gait cycle can be characterized by considering the parameter momentum (absolute value) of the bending moments.

If there are no moments in the direction of a plantar flexion, the minimum of the dorsal extension moments is shown. The alternating load (AL) is calculated as shown in formula (1). If there is no plantar flexion or dorsal extension moment, then there is no alternating load, either.

\[ AL = 2 \times M_{peak} \times \left( \frac{1}{3} \times GC - \frac{1}{3} \times M_{peak} \right) \]

A two-sided paired t-test was conducted to detect significant differences (p < 0.05).

Results

Curves

The continuous curves present the mean values, the dotted curves present the standard deviation (SD). The blue curves describe the loading in the Relief Dual shoe as a function of the GC and the red curves the loading in the competitor shoe. For each graph, the number of subjects (N) used to calculate the mean value is given.

If there were measurement errors with regards to individual test persons, then N ≠ 22.

Bending moments

The mean bending moment at the heel produces a similar curve in both shoe conditions, with a small SD. The curves first show a dorsal extension moment with a local peak at about 10 – 20% gait cycle, followed by a slow decrease that reaches zero at about 60 – 70% GC. The measurement for the Relief Dual shows a slightly higher dorsal extension moment and an additional plantar flexion moment (Figure 4).

Starting from about 40% GC, bending moments at measuring point MTP I show very similar curves with small SDs, whereas the competitor presents considerably higher dorsal extension moments. After heel strike until about 45% GC, a slight plantar flexion moment can be observed in the Relief Dual. By contrast, the competitor presents a dorsal extension moment.

At measuring point MTP V, the bending moment curves differ little and present small SDs. After heel strike, a local maximum occurs at about 10 – 20% GC. At 30 – 40% GC, a local minimum can be observed. At about 60% GC, a conspicuous local maximum occurs, afterwards showing a steep decrease. The dorsal extension moments of the Relief Dual also have considerably lower values in comparison to the competitor at this measuring point. There is no plantar flexion moment for either shoe condition at measuring point MTP V.

Both mean bending moment curves are almost identical at measuring point DIP I. There is a local maximum at about 60 – 70% GC. A relatively high SD exists in the first phase of the gait cycle (until approx. 50%). After the local maximum is reached, both curves show a steep decrease. At this measuring point, both shoe conditions display a dominant dorsal extension moment.

At DIP V, the bending moments of both shoe conditions present a similar curve. The high SDs apparent here are due to the relatively high variations between individual subjects. Bending moments change their direction from a plantar flexion moment to a dorsal extension moment earlier for the competitor (at approx. 55% GC) as compared to the Relief Dual. Dorsal extension values are slightly smaller for the competitor than for the Relief Dual.

Torsional moments

The mean torsional moment at the heel demonstrates a strongly varying curve with a large SD under both shoe conditions. The measurement taken for the Relief Dual shows a higher eversion moment as compared to the competitor. An inversion moment is dominant in the competitor shoe. High SDs indicate strong variations in the curves of the individual test persons (Figure 4).

The mean torsional moments demonstrate a similar curve, but unlike the bending moments at MTP I, higher SDs occur at this location. In addition,
Mean bending and torsional moments on five sensor regions. Continuous lines present the mean values, dotted lines present the standard deviation. Positive values describe a dorsal extension moment (internal rotation with regard to the central axis of the foot), negative values a plantar flexion moment (external rotation).
the evasion and inversion moments are higher in the competitor shoe than in the Relief Dual.

For both shoe conditions, only an inversion moment can be observed with regards to the torsional moments at MTP V. The curves are quite similar and there is a small SD. The increase in and amplitude of the inversion moment are considerably higher for the competitor in comparison to the Relief Dual, an eversion moment is dominant, whereas the competitor shoe generally demonstrates an inversion moment. This inversion moment is considerably higher in comparison to the corresponding values of the Relief Dual.

Under both shoe conditions, the curves for torsional moments at measuring point MTP V show highly opposite trends (Fig. 4). In the curve for the Relief Dual, an evasion moment is dominant, whereas the competitor shoe generally demonstrates an inversion moment. This inversion moment in the direction of an evasion are dominant for both shoe conditions.

The curves of the bending loads at DIP V show a highly significant difference (p<0.05) as regards the value of the competitor as compared to the Relief Dual. At the other measuring points, there is no significant difference between the two shoe conditions.

The alternating load value of the Relief Dual is significantly higher than the value of the competitor at the measuring points heel, MTP I and DIP I. Because there is no plantar flexion moment, no alternating load can be determined at measuring point MTP V. At DIP V, no significant difference can be observed between the two shoe conditions.

The alternating load value of the Relief Dual is significantly higher than the value of the competitor at the measuring points heel, MTP I and DIP I. Because there is no plantar flexion moment, no alternating load can be determined at measuring point MTP V. At DIP V, no significant difference can be observed between the two shoe conditions.

### Discussions

The aim of this study was to evaluate loads acting on the foot during walking in two different offloading shoes with very different shoe designs. The Relief Dual was compared to an offloading shoe that already is indexed in the German register of medical technical aids. 

The analysis focuses on functional limitation and relief of the foot as well as on bending, torsional and alternating loads. The comparison of the shoe conditions with the Relief Dual and the competitor shows significant differences in the values of the maximum dorsal extension moments and the mean values of the maximum torsional moments. The curves of the bending loads at the different measuring points are sig-

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**Parameter** | **Mean value** | **Standard deviation** | **t-test** (p<0.05) |
---|---|---|---|
### Mb. max. planar flexion /°/Nm | Relief Dual | competitor | Relief Dual | competitor |
Heel | -25 | -7 | 17 | 9 | 0.0003 |
MTP I | -19 | -4 | 25 | 14 | 0.0040 |
MTP V | 2 | 1 | 13 | 16 | 0.4988 |
DIP I | -2 | -1 | 10 | 7 | 0.3990 |
DIP V | -35 | -25 | 43 | 40 | 0.2330 |
### Mb. max. dorsal extension /°/Nm | Relief Dual | competitor | Relief Dual | competitor |
Heel | 195 | 180 | 61 | 60 | 0.4608 |
MTP I | 86 | 115 | 51 | 46 | 0.0074 |
MTP V | 71 | 95 | 38 | 39 | 0.0007 |
DIP I | 160 | 164 | 78 | 69 | 0.8068 |
DIP V | 44 | 50 | 39 | 42 | 0.5056 |
### Range /° | Relief Dual | competitor | Relief Dual | competitor |
Heel | 220 | 188 | 60 | 57 | 0.1053 |
MTP I | 104 | 118 | 44 | 41 | 0.1271 |
MTP V | 70 | 94 | 32 | 34 | 0.0003 |
DIP I | 163 | 165 | 78 | 69 | 0.8805 |
DIP V | 79 | 75 | 32 | 47 | 0.6605 |
### Alternating load /% | Relief Dual | competitor | Relief Dual | competitor |
Heel | 24 | 12 | 17 | 10 | 0.0065 |
MTP I | 38 | 15 | 33 | 22 | 0.0162 |
MTP V | - | - | - | - | - |
DIP I | 11 | 6 | 11 | 6 | 0.0443 |
DIP V | 24 | 36 | 22 | 27 | 0.0932 |
### Momentum values /°/Nm | Relief Dual | competitor | Relief Dual | competitor |
Heel | 5857 | 5300 | 1852 | 1828 | 0.3292 |
MTP I | 2517 | 3155 | 1452 | 1679 | 0.0170 |
MTP V | 1969 | 2860 | 903 | 1294 | 0.0055 |
DIP I | 4387 | 4500 | 2162 | 1928 | 0.7739 |
DIP V | 1565 | 1475 | 984 | 1092 | 0.6799 |

Table 1 Results of the five compared measuring parameters and the findings of the conducted t-test. Mean value and standard deviation (N=22) presented for each parameter for the Relief Dual and the competitor at all measuring points.
The findings of the bending and torsional measurements show that similar levels of functional stress occur under the two shoe conditions analysed. However, the Relief Dual offered the advantage of a reduced dorsal extension moment at MTP I and MTP V. The differences between the two shoe conditions especially occur at the measuring points heel, MTP I and MTP V. At DIP I and DIP V, the load curves of both shoes are similar. For the Relief Dual, an additional slight plantar flexion moment can be observed at the heel. Furthermore, the dorsal extension moment is slightly higher at this measuring point. The bending load at the heel is of subordinate importance regarding the question of functional limitation and relief of the forefoot. At these two measuring points, the dorsal extension moment of the Relief Dual is notably lower than that of the competitor. This implies greater functional limitation and increased relief of the forefoot. The pronounced occurrence of a plantar flexion moment at MTP I is of lower importance as compared to the reduced dorsal extension moment, because the highest loads at the forefoot are observed during terminal stance and can therefore be expressed well by the dorsal extension moment. At measuring point MTP V, only a reduced dorsal extension moment can be observed. The fact that no additional plantar flexion moment was observed implies that the Relief Dual provides better offloading of the forefoot.

Interpreting torsional load curves generally only allows conclusions to be drawn on the gait pattern of individual test persons. They also complicate interpretation of the occurring loads. Due to their lack of relevance to offloading the forefoot, the heel parameters will not be discussed any further. At measuring points MTP I and MTP V, seven of the nine load parameters selected differ significantly. For five of these selected parameters, the Relief Dual demonstrates greater relief of the forefoot during walking. For two of these parameters, the competitor achieves smaller loads at the forefoot. The values of the maximum dorsal extension moment at MTP I and MTP V, of the range at MTP V and of the moment (absolute value) at MTP I and MTP V are significantly smaller for the Relief Dual as compared to the competitor.

The competitor presents a smaller maximum plantar flexion moment and an alternating load at MTP I.

At measuring points DIP I and DIP V, the competitor achieves greater relief of the forefoot for one of ten values (alternating load at DIP I). For all other parameters, both offloading shoes achieve similar functional limitation and relief of the forefoot at these measuring points.

Because of the additional plantar flexion moments of the Relief Dual and the lower alternating loads of the competitor, the competitor achieved comparatively slightly reduced loads at the forefoot. However, given that the values of the maximum dorsal extension moment and the momentum (absolute value) of the Relief Dual are significantly smaller than the values of the competitor, it can be assumed that the Relief Dual achieves similar relief of the forefoot, and in some cases even greater relief.

Individual walking speed was chosen by each participant during the first measuring condition and remained constant for the second condition. For statistical analysis, a paired t-test insensitive to the effect of interindividual differences in walking speed was used.

For the very same reason, differences in sole stiffness caused by different shoe sizes do not affect the data analysis; the shoe sizes differed from subject to subject, but remained constant for the two testing conditions.

To derive more information on the offloading effects of the two different shoe designs, the plantar pressure distribution should be analysed as well. It is also important to what extent patients feel familiar with the shoes and how the orthopedic device influences normal gait patterns. Furthermore, to see how offloading shoes influence the gait patterns of bending and torsional stress acting on the foot, additional data should be analysed, i.e. from the left foot wearing the control shoe, or under control conditions. To date, no information has been published on the influences of bending and torsional loads on the feet of surgery patients wearing offloading shoes.

Conclusions

Although the two shoes investigated had very different designs, there were only minor differences observed between the bending and torsional stress acting on the foot in each shoe design. That said, the offloading effects during walking measured by multidimensional parameters were attributable to demonstrable differences in bending and torsional stress under the two shoe conditions. The significant differences found for MTP I and MTP V suggest that the Relief Dual has a slightly greater offloading effect on the forefoot. After this study was completed, the Relief Dual was indexed in the German register of medical technical aids as an offloading shoe. However, to provide a more comprehensive view of stress acting on the foot, plantar pressure must be analysed in combination with bending and torsional stress measurements in future studies.

Conflict of interest

This study was supported by DARCO (Europe) GmbH. This funding did not influence study design, data analyses and conclusions.

Literature

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