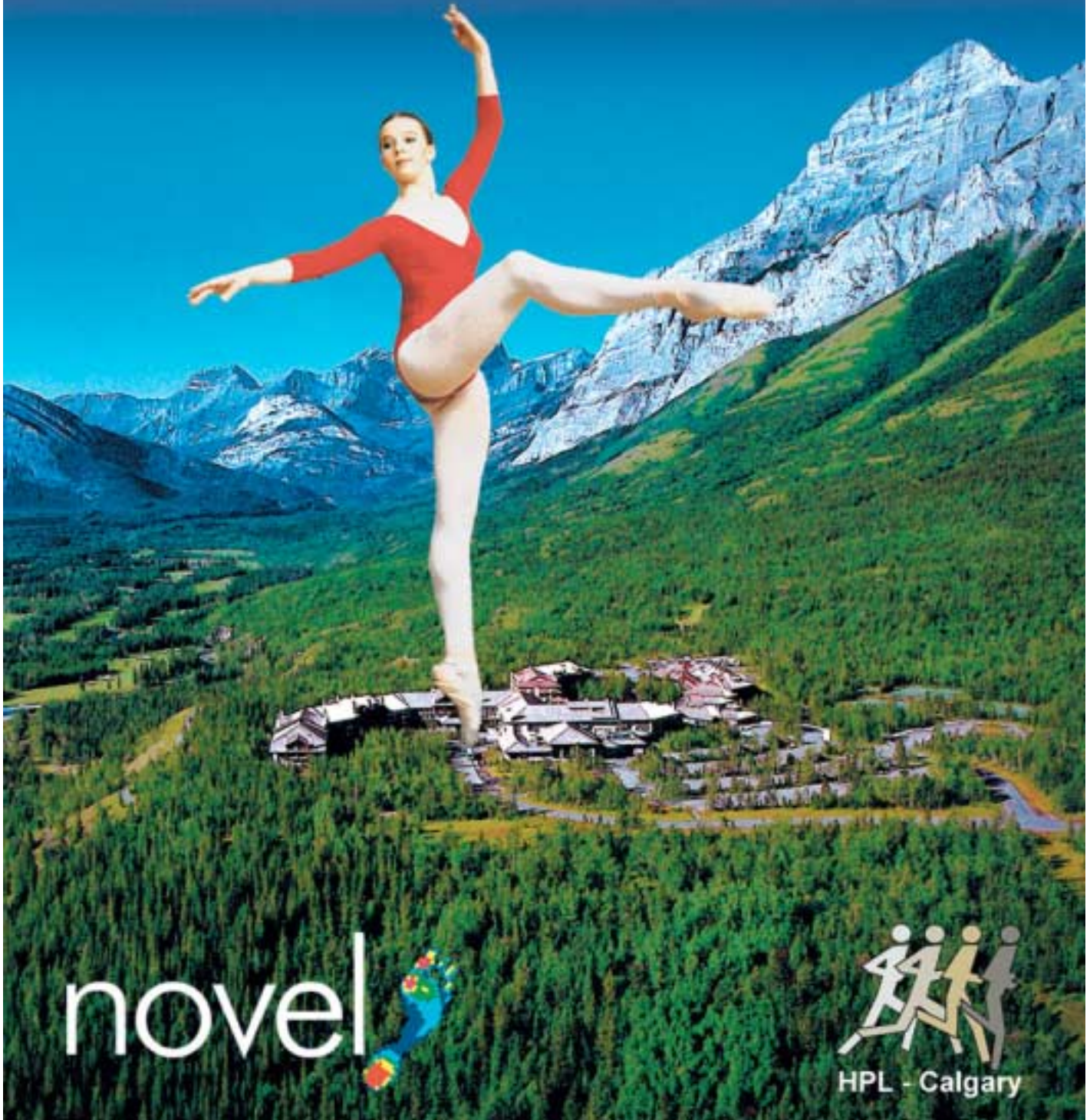


VIII emed scientific meeting
July 31st - August 3rd, 2002
Kananaskis, Alberta, Canada



novel 

The word 'novel' is written in a white, lowercase, sans-serif font. To the right of the word is a small, colorful graphic consisting of a blue shape with several small, multi-colored dots (red, yellow, green, blue) scattered around it.

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ESM2002 Conference Organization

The VIII emed scientific meeting is hosted by the University of Calgary's Human Performance Laboratory and will take place at the Delta Lodge in Kananaskis, Alberta from July 31st – August 3rd, 2002.

This meeting was organized by:

Benno M. Nigg	University of Calgary, Calgary, Canada
Matthew A. Nurse	University of Calgary, Calgary, Canada
Michael Mather	Travel Gallery Inc., Calgary, Canada

with the assistance of

Peter Seitz	novel gmbh, Germany
Axel Kalpen	novel gmbh, Germany
Susan Diekrager	novel electronics inc., USA

This year's emed scientific meeting was made possible with endowments and grants from the following:



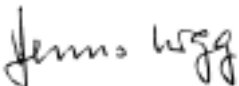
Welcome

As hosts of ESM2002, it is our pleasure to welcome you to the **VIII emed scientific meeting** in Kananaskis, Alberta, Canada.

With guests and participants expected from all five continents, we have strived to ensure that you will experience an excellent **emed** meeting. In the tradition of previous **emed** meetings, this conference will combine two days of scientific presentations with a day of social activities – Western Canadian style. For researchers and clinicians alike, the word “pressure” will give rise to new meaning if it is your first time on the back of a horse as you climb the mountains of Kananaskis, or if you have never been hurdled down a narrow river bed with only an inflatable raft and plastic oar to save you from the rocks ahead.

Participants of this year’s conference have the unique opportunity to share their research and innovations in one of North America’s most beautiful settings. Kananaskis country recently played host to the G8 Summit. The Delta Lodge in Kananaskis provided a forum for leaders of Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, the United States and the European Union to discuss and co-ordinate policy on major global issues. Now it is your turn, albeit without the additional security measures.

It is our hope that the benefits of this conference are realized on both a scientific and personal level. Prosper from the science and learning, and the friends, old and new alike.



Benno M. Nigg
Conference Chair

Matthew A. Nurse
Secretary General

History of the emed scientific meeting

A decade ago **novel** was approached by Professor Leslie Klenerman to provide support for development of an **emed user group meeting** hosted by the University of Liverpool. The inaugural meeting began the following year in Liverpool. At that time, we did not realize that the **emed meeting** would take us to all corners of the world and the tradition would be carried on into the next millennium with the **2000 Millennium Meeting** in Munich, Germany, and then to the **VIII emed scientific meeting** in Kananaskis, Alberta, Canada.

The Liverpool Meeting provided an important exchange of experience and results in pressure distribution measurements. This was the first step in establishing co-operation between the **emed** users and anyone interested in pressure distribution technology. The format of the meeting through scientific and clinical presentations and workshops was used to define pressure distribution measuring as more than a "pretty picture".

After the initial meeting, the **emed user group meeting** became recognized as the **emed scientific meeting** welcoming users of all pressure distribution measuring technology and was scheduled biennially. The meeting has enjoyed the wonderful hospitality of the following locations: Liverpool, Vienna, Flagstaff, Ulm, PennState, Brisbane and Munich.

In 1991, the first **novel award** was presented in recognition of excellence in pressure distribution research. The **novel award** recipient was determined by an international review committee from the fields of biomechanics and medicine. The **novel award** for pressure distribution measurement research continues to be endowed by **novel**.

The **emed scientific meetings** have provided us with an opportunity to learn more about pressure distribution products, applications, and research, meet new and old friends and experience our hospitable host sites.

novel award



novel award

This year, the **novel award** will be presented for outstanding work that makes significant contributions to the field of pressure distribution research.

Papers and oral presentations will be judged by an international panel of experts in the fields of biomechanics and medicine.

The award winning paper will be presented with the **novel award** at the final banquet with a prize in the amount of CDN\$10,000.

The **novel award** is one of the most prestigious awards presented in the biomedical and biomechanical fields. Previous winners of this award are listed below:

Vienna, 1991	Benno Nigg	Canada
Ulm, 1994	Michael Morlock	Germany
Pennstate, 1996	Dieter Rosenbaum	Germany
Tokyo, 1997	Erez Morag	USA
Brisbane, 1998	Margaret Hodge	Australia
Calgary, 1999	Brian Davis	USA
Munich, 2000	Matthew Nurse	Canada

ESM2002 Best Presentation Award

There is nothing that can be said by mathematical symbols and relations which cannot also be said by words. The converse, however, is false. Much that can be and is said by words cannot successfully be put into equations, because it is nonsense. *C. Truesdell*

Dissemination of ideas at conferences and workshops is vital to the scientific community. Scientific research can be presented in a way that both invites the audience to listen, while enthralling them with your ideas.

An award will be presented to the best podium presentation in the amount of \$CDN500.00

ESM2002 Best Poster Award

The decision to allocate poster presentations is not based on the quality of work. Rather, the decision is a function of the number of abstracts submitted for a given topic and the time allotted for the oral sessions. Therefore, poster sessions often contain excellent examples of research in areas that have a lot of activity devoted to them.

An award will be presented to the best poster presentation in the amount of \$CDN500.00

Kananaskis, Alberta

ORIGINS OF KANANASKIS

The local Aboriginal people know the area of Kananaskis as "where the waters meet," which is a translation of the Stoney word, "owzaday", and refers to the confluence of the Kananaskis and Bow rivers.

It has also been recorded that, in 1858, when Captain John Palliser was making his famous survey of the northwestern portion of British North America, he named a mountain crossing Kananaskis Pass after a legendary Indian named Kananaskis.

Kananaskis Country was developed in response to Albertans' concerns that Banff National Park was becoming overcrowded and that affordable outdoor recreation opportunities were no longer available to the average family.

In 1974, the Government of Alberta signaled its first move to set aside land in the area by declaring its intent to establish Kananaskis Provincial Park. The park was later renamed Peter Lougheed Provincial Park in honour of the province's 10th premier. The government responded to Albertans' public recommendations that recreation opportunities in the surrounding region should be also developed and, in 1977 Kananaskis Country was announced.

Kananaskis Country provides outstanding outdoor recreation opportunities in a large, accessible highly attractive landscape, while accommodating a variety of other uses. Kananaskis Country now includes provincial Crown lands, recreational and industrial lease holders, two small private land titles, 13 parks and protected areas, and 54 recreation areas.

Wildlife species such as deer, wapiti, moose, grizzly bear, mountain goat, wolf, cougar, and bighorn sheep thrive in the Kananaskis area. The many different species of birds found there include bald and golden eagles, mountain bluebird, varied thrush, white-tailed ptarmigan, blue grouse, osprey, harlequin duck, Steller's jay, Clark's nutcracker, and American dipper.

Keynote Speakers

Dr. Thomas McPoil

Department of Physical Therapy, Northern Arizona University

Arizona, United States of America

Can plantar pressure data be used to assess the effectiveness of foot orthoses?

Dr. Erich Müller

Institut für Sportwissenschaften der Universität Salzburg

Salzburg, Austria

Pressure distribution analysis in winter sport activities.

Dr. Brigitte von Rechenberg

Veterinaer-Chirurgische Klinik der Universität Zurich

Zurich, Switzerland

What can an electronic mat (novel pliance system) tell us about the well being of horses? Back pain of horses in relation to saddles, medical problems and riding style.

Dr. Dieter Rosenbaum

Universitätsklinikum Münster, Klinik und Poliklinik für Allgemeine Orthopädie

Münster, Germany

Clinical applications of pressure distribution measurements.

novel workshop

This year, **novel** will hold an optional workshop on the morning of Friday August 2nd. This is a chance to see the newest hardware innovations, latest software developments, and learn about advance data collection techniques.

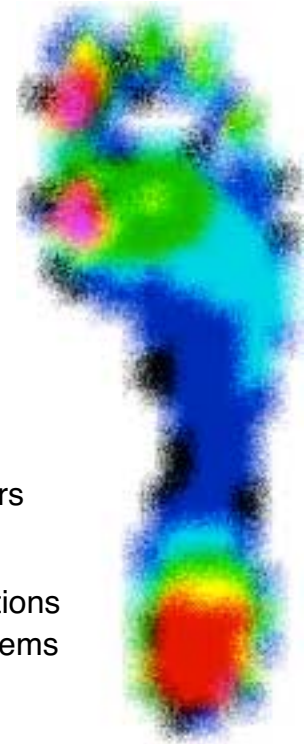
08:30 – 10:00 **novel** Workshop I - Advanced hardware and sensors

- new developments in hardware
- new options, such as PDA and Bluetooth applications
- synchronization options with video and other systems
- new sensors (more flexible sensor layouts)
- sterilization of sensors

10:30 – 12:00 **novel** Workshop II - Advanced data analysis

- designing a project
- data acquisition
- data handling in databases
- data evaluation and handling of results
- creation of html reports
- building queries
- import/export functions to other databases

This is a free workshop for registered participants of ESM2002.



Activities

As has become the tradition at all **emed scientific meetings**, two days of scientific presentations will be complemented with a day of activities – Western Canadian Style.

Conferences and symposia provide an excellent outlet for sharing the latest research ideas and innovations. However, a social day also allows students, professors, doctors and clinicians to put faces to the names that they see in print. And perhaps, to catch a glimpse of colleagues or friends in another environment that will be the foundation for wild tale back home.

The activity portion of this meeting will be centered around Boundary Ranch. Ideally located in the spectacular natural beauty of Kananaskis Valley, Boundary Ranch is perfect to discover the adventure and serenity of a horseback trail ride in to the Rockies. A two hour guided ride travels high above the valley to capture a breathtaking view of the entire Kananaskis area. Watch carefully as you wind your way down around the pond, you may catch a glimpse of our resident moose and her calf sunning in the warm sun. Don't forget your camera!



Or, if the thought of cool mountain water does not make you shiver, then perhaps a 'white water experience' is what you are looking for. Participants will enjoy paddling through the rapids and chutes of the Kananaskis River. All equipment and safety gear supplied along with professional guides. Don't forget your towel!

Finally, for a more relaxing way to enjoy the sheer beauty of the region, an interpretive hike will travel in to one of the many trails in Kananaskis. With any luck, you might just catch a glimpse of one of the many forms of wildlife native to the area.

Transportation to and from Boundary Ranch will be available.

ESM2002 Scientific Program: Thursday August 1st, 2002

Session I: Pathologies and clinical treatment

Chair: Peter Cavanagh

- 8:45 - 9:30 D. Rosenbaum *Keynote Lecture:*
Clinical applications of pressure distribution measurements
- 9:30 - 9:45 J. Woodburn Plantar pressure and footprint analysis in rheumatoid arthritis: A comparison of patients classified by 3-D MRI image analysis of the subtalar and midtarsal joints.
- 9:45 - 10:00 A. Vasarhelyi Partial weight bearing after surgery of fractures of the lower extremity - does it work?
- 10:00 - 10:15 D. Oeffinger Foot pressure and radiographic measurements in the treated clubfoot
- 10:15 - 10:30 A. Kranzl Rehabilitation process after a Chevron osteotomy for hallux valgus correction - A pressure distribution analysis.
- 10:30 - 11:00 Coffee Break**

Session II: 'novel' methods and innovations

Chair: Rebecca Stine

- 11:00 - 11:15 H. Hillstrom Index of pronation
- 11:15 - 11:30 J. Kotovsky A novel microelectromechanical transducer for measuring contact stresses.
- 11:30 - 11:45 A. Cristalli Laser Vibrometer and capacitive matrices: New measurement procedure of hand-arm vibration
- 11:45 - 12:00 I. Spodrina Individual Corrective inserts like part of the treatment for diabetic foot.
- 12:00 - 13:15 Lunch**

Session III: novel awards Finalists I

Chair: Martyn Shorten

- 13:15 - 13:40 M. Mueller Effect of tendo Achilles lengthening on forefoot plantar pressures, ankle motion and plantar flexor power during walking in subjects with diabetes and peripheral neuropathy: A prospective controlled clinical trial.
- 13:40 - 14:05 C. Bertsch Evaluation of early walking patterns by plantar pressure distribution.
- 14:05 - 14:30 D. Wilson Elevated lateral patellar force is related to patellar spin.
- 14:30 - 14:45 Coffee Break**

Session III: novel awards Finalists II**Chair: Martyn Shorten**

14:45	-	15:10	U. Kersting	Changes in knee cartilage volume and serum comp concentration after running exercise related to individual joint loading.
15:10	-	15:35	K. Maluf	Comparison of physical activity and cumulative plantar tissue stress among subjects with and without diabetes mellitus and a history of recurrent plantar ulcers.
15:35	-	16:00	M. Richter	Analysis of joint pressure distribution and joint force during experimental induction of midfoot fractures.

16:00 - 16:15 Coffee Break**Session IV: You'd better sit down for this....****Chair: Jeff Pisciotta**

16:15	-	17:00	B. von Rechenberg	<i>Keynote Lecture:</i> What can an electronic mat tell us about the well being of horses?
17:00	-	17:15	B. Hinz	Study of human-seat interface pressure distribution on car seats.
17:15	-	17:30	R. Mootanah	Evaluation of optimum size of bubble wrap for the preventions of pressure sores.
17:30	-	17:45	D. Hill	Assessing pelvic obliquity in non-ambulatory, neuromuscular scoliosis subjects.
17:45		18:00	T. Kernozek	Boundary loads in finite-element seating models.

18:00 - 19:30 Poster Session**Poster Session : Thursday 18:00 – 19:30**

G. Berschin	The influence of trunk posture and stabilization on foot posture and plantar pressure distribution.
C. Giacomozzi	Peak pressure curve: An effective parameter to detect limited joint mobility and muscular weakness.
F. Hagman	A mathematical model analyzing the motion of the calcaneus from pressure plate measurements.
S. van Horne	Comparison of plantar pressure measurements of elite speed-skaters in an on-ice and laboratory setting.
V. Lebedev	Four years follow-up of diabetes patients with amputations.
E. Lou	Pressure distribution in spinal orthoses.
D. Machado	Evaluation of a female volleyball team regarding anthropometrical foot image, plantar pressure distribution and treadmill walking vertical force parameters.
T. McPoil	The effect of midfoot wedging on plantar surface pain and pressure.
K. Nielsen	Plantar pressure distribution pattern of children in different ages.
A. Vasarhelyi	Dynamic pedography for diagnosis of torsional deformity after intramedullary nailing of femoral shaft fractures.

ESM2002 Scientific Program: Saturday August 3rd, 2002

Session I: Sports

Chair: Mario Lafortune

8:45	-	9:30	E. Müller	<i>Keynote Lecture:</i> Pressure distribution analysis in winter sport activities.
9:30	-	9:45	E. Morag	The effect of heel cupping on heel pressure during soccer activities.
9:45	-	10:00	D. Machado	Characteristics of ground reaction forces, moments and COP during volleyball block jumps.
10:00	-	10:15	T. Smith	The effect of linear density on pressure patterns during bicycle helmet impacts.
10:15	-	10:30	K-A Bowles	Are sports brassieres too tight for active females?
10:30	-	11:00	Coffee Break	

Session II: 'novel' innovation & application

Chair: Julie Steele

11:00	-	11:15	D. Welcome	The application of a novel pliance mat for the measurement of hand-handle coupling force.
11:15	-	11:30	D. Rosenbaum	Will the spatial resolution of pedographic platforms affect plantar pressure patterns of children or adults.
11:30	-	11:45	J. Müller	Is relaxation under the saddle measurable? A study using the pliance system, novel GmbH.
11:45	-	12:00	C. Giacomozzi	Use of an emed system in the design of a sensorized reciprocating gait orthosis.
12:00	-	13:15	Lunch	

Session III: Gait, Posture & Locomotion**Chair: Peter Milburn**

13:15	-	14:00	T. McPoil	<i>Keynote Lecture:</i> Can plantar pressure data be used to assess the effectiveness of foot orthoses
14:00	-	14:15	M. Tanaka	Standing posture maintenance with ankle ROM constraint: A foot pressure study.
14:15	-	14:30	M. Razeghi	The effect of orthoses on the plantar pressure distribution pattern in different foot types.
14:30	-	14:45	R. Weist	Changes of plantar pressure and muscle activity patterns under the influence of fatigue after exhausting treadmill running.
14:45	-	15:00	T. Cahill	Pressure & temporal changes in a running shoe designed to possibly trigger the windlass mechanism.
15:00	-	15:15	S. Dixon	Insoles can increase peak pressures in running shoes.
15:15	-	15:45	Coffee Break	

Session IV: Pathologies and clinical treatment II**Chair: Michael Morlock**

15:45	-	16:00	C. Fritsch	The Neuropool project: A world wide project to develop a database for diabetic foot
16:00	-	16:15	T. Tsvetkova	Patients with multiple sclerosis: How do they walk?
16:15	-	16:30	B. Munro	Effects of rheumatoid arthritis on foot function: Implication for slipper design.
16:30	-	16:45	K. Nielsen	Plantar pressure distribution in children operated on for clubfoot
16:45	-	17:00	Closing Remarks	
18:30	-	19:00	Cocktails	
19:00	-	end	Banquet	Presentation of the novel award

ESM2002 Abstracts:

Thursday August 1st, 2002

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PLANTAR PRESSURE AND FOOTPRINT ANALYSIS IN RHEUMATOID ARTHRITIS: A COMPARISON OF PATIENTS CLASSIFIED BY 3-D MRI IMAGE ANALYSIS OF THE SUBTALAR AND MIDTARSAL JOINTS

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INTRODUCTION

Acquired pes planovalgus deformity in rheumatoid arthritis (RA) is associated with persistent synovitis in and around the tarsal joints of the foot [1]. The aim of this study was to compare plantar pressure measurement (PPM) distribution and selected footprint measurements in RA patients with normal and abnormal rear- and mid-foot architecture as determined by 3-D MRI-based image reconstruction and analysis.

PATIENTS & METHODS

Patients. 23 RA patients with clinical and ultrasound proven arthritis of the subtalar and or midtarsal joints were recruited. Local Research Committee approval was granted for this study. **MRI.** MR images of the ankle to the midtarsal joints of the right foot were acquired on a 1.5 Tesla MR scanner using a 3-D T1-weighted spin-echo sagittal pulse sequence. A custom non-metallic pronation-supination jig was used to orientate the foot in the scanner in subtalar joint neutral position. 3DVIEWNIX software (*Medical Image Processing group, University of Pennsylvania, Philadelphia, Pennsylvania, USA*) was used to reconstruct and analyse in 3-D the calcaneus, cuboid, navicular and talus bones, following protocols for slice-by-slice “live-wire”, segmentation, binary image interpolation, smoothing and surface-rendering. The rear- and mid-foot architecture was defined by 24 geometrical parameters based on normalised 3-D Euclidean distances between geometric centroids, angles subtended at the centroids and angles between the major principal axes for bone pair/triplet combinations [2]. A pattern classification technique using normative data for comparison was used to determine normal and abnormal foot structure in the RA patient cohort. **PPM.** PPM and footprint analysis were conducted using an Emed Platform (*Novel GmbH*). 5 repeated trials of the right foot at a comfortable walking speed were recorded. NovelWin software was used for PPM and footprint analysis. Automasking was used to divide the plantar foot into heel, midfoot and forefoot regions of interest. For each mask, peak pressure- PP (kPa), pressure:time integral- PTI (kPa.sec), peak force- PF (N), force:time integral- FTI (N.sec); contact area- CA (cm²), contact time- CT (ms) were derived. For the full foot the lateral-medial force indices (LAMFI) and later-medial area indices (LAMAI) were calculated. Footprint analysis measured the medial plantar angle (MPA), medial tarsal angle (MTA), sub-arch angle (SAA) and heel-angle (HA), in degrees. **Statistical analyses.** Between group differences for PPM and footprint values were calculated using Student's *t*-test. *P* values less than 0.05 were considered statistically significant.

RESULTS

Pattern classification techniques defined two RA groups with normal- RA-N (*n*=11), and abnormal- RA-Ab (*n*=12) rear- and mid-foot structure. In comparison with RA-N, the RA-Ab group had: **PP**- significantly increased at the medial heel (*P*=0.005), lateral heel (*P*=0.01) and 1st metatarsal (*P*=0.02) masks and decreased at the 4th (*P*=0.01) and 5th metatarsals masks (*P*<0.0001); **PTI**- significantly increased at the medial heel (*P*=0.04), lateral heel (*P*=0.03) and 1st metatarsal (*P*=0.04) masks and decreased at the 5th metatarsal (*P*<0.0001) mask; **PF**- significantly decreased at total foot (*P*<0.0001), medial heel (*P*=0.04), lateral heel (*P*=0.006), midfoot (*P*<0.0001) and the 2nd to 5th (*P*<0.0001) metatarsals masks and significantly increased at the 1st metatarsal (*P*=0.04) mask; **FTI**- significantly reduced at the total foot, the midfoot (both *P*<0.0001) and the 3rd to 5th metatarsals (*P*<0.0001 to *P*=0.03) masks; **CA**- significantly reduced in the full foot mask, the medial and lateral heel masks, the midfoot (all *P*<0.0001) and the 2nd to 5th metatarsals (*P*<0.0001 to *P*=0.03); **CT**- significantly reduced at the midfoot mask (*P*=0.014) and increased at the 1st metatarsal mask (*P*=0.004).

Results for the force and area indices and the footprint measurements are provided in table 1.

Table 1. Force/area indices and footprint variables

Variable	RA-N	RA-Ab	<i>P</i> value
LAMFI	0.07	-0.05	0.014
LAMAI	0.162	0.126	0.430
MPA (deg)	7.00	6.78	0.854
MTA (deg)	145.9	151.7	0.004
SAA (deg)	109.7	106.9	0.792
HA (deg)	12.6	5.1	0.015

CONCLUSIONS

3-D MRI-based analysis differentiated normal and abnormal mid- and rearfoot structure in RA. Patients with abnormal foot-type had significantly different pressure and force distribution and 2-D footprint geometry consistent with a clinical description of planovalgus deformity. PP, PTI, PF and LAMFI measurements showed increased medial loading and off-loading laterally. These techniques will facilitate better understanding of foot structure and function in RA.

REFERENCES

- [1] Woodburn J, Helliwell PS (1996). *Ann Rheum Dis*, 55: 806-810.
- [2] Stindel E, Udupa JK, Hirsch BE, *et al.* *IEEE T Med Imaging* 1999;18:753-63.

PARTIAL WEIGHT BEARING AFTER SURGERY OF FRACTURES OF THE LOWER EXTREMITY – DOES IT WORK?

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INTRODUCTION

Partial weight bearing is a generally accepted principle of rehabilitation following trauma or reconstructive surgery of the lower extremity. In particular, in the early postoperative phase full weight bearing is believed to endanger the stability of the reconstruction and the surgical result. Further, in contrast to non-weight bearing gait, partial weight bearing is known from experimental data to stimulate the osseous healing process.

As such, patients with surgically treated fractures of the lower extremity are advised to maintain partial weight bearing of the operated limb for a minimum of 6 weeks after osteosynthesis increasing the fraction of load bearing according to a certain time schedule. Partial weight bearing is usually trained statically on a weighing machine under control of a physical therapist.

Up to now, no valid data is available whether patients stay within the theoretically given load levels during dynamic partial weight bearing gait.

PATIENTS AND METHODS

We investigated 10 healthy persons, 10 younger patients (< 60 years old) and 10 elderly patients (> 60 years old). Prior to gait analysis, healthy probands were instructed in 200 N partial weight bearing of one limb statically on a weighing machine. Patients with a surgically treated fracture of the lower extremity were investigated at least 3 days after practicing 200 N partial weight bearing gait of the operated limb under the control of a physical therapist.

Pedar mobile system (novel_{gmbh}) is an in shoe gait analysis tool which allows measurements of dynamic sole pressure distributions. Data and statistic analysis were performed with specific software programs (pedar-m Expert 8.2, novel database pro).

Measuring of 3 standardized cycles of partial weight bearing gait was performed on 3 successive days of each proband using pedar mobile system. Analysis of each cycle based on 10 randomly selected steps of the investigated limb during 3 minutes of walking.

RESULTS

Exceeding of the statically pre-tested 200 N partial weight bearing was observed during dynamic measurement in all

groups and every proband. Even healthy persons showed at least a maximum sole pressure of 300 N of the partial weight bearing limb over 5 registered gait cycles. 2 probands reached sole pressure values of 550 N to 650 N during the whole measurement. Maximum sole pressure values of the individuals were constantly reproducible during all cycles and did not decrease with the practice effect.

Profiles of sole pressure distribution showed high interindividual heterogeneity of the partial weight bearing limb in every group. Pressure peaks were observed mainly in the heel and forefoot regions.

Patients of a higher age, a reduced postoperative pain level and better joint motion tended to impose significantly higher loads on their injured limb.

SUMMARY

Pedar mobile system could successfully be applied for analysis of dynamic in shoe pressure and load distribution during partial weight bearing. The study revealed that after surgically treated fractures of the lower extremity the pre-tested static sole pressure of 200 N were regularly exceeded over repeated gait cycles, especially in the elderly.

This study implies that the conventional concept of postoperative partial weight bearing starting from 200 N for a time period of 6 weeks and a stepwise increase of the load level until full weight bearing is not valid during clinical practice.

Based on measurements of dynamic postoperative plantar pressure distribution novel concepts of weight bearing may be developed as an integral of a more aggressive postoperative rehabilitation program.

REFERENCES

- DeVita, P., Hortobagyi, T. (2000). *Age causes a redistribution of joint torques and powers during gait.* J Appl Physiol, **88**, 1804-1811
- Lephart, S. M. et al. (1998). *Proprioception of the ankle and knee.* Sports Med, **25**, 149-155
- Ronsky, J. L. et al. (1995). *Correlation between physical activity and the gait characteristics and ankle joint flexibility of the elderly.* Clin Biomech, **10**, 41-49

FOOT PRESSURE AND RADIOGRAPHIC MEASUREMENTS IN THE TREATED CLUBFOOT

¹Donna Oeffinger, ¹Chester Tylkowski, and ²John Douglas

¹Shriners Hospitals for Children, Lexington, KY contact: doeffinger@shrinenet.org; ²Peninsula Hospital Center, Far Rockaway, NY

INTRODUCTION

Clubfoot is a common pediatric orthopedic deformity. Previous studies have looked at radiographic measurements as a means of assessing treatment outcome. Dynamic foot pressure measures are used to assess outcomes in other foot deformities. To date no study has investigated the relationship of radiographic measurements to angles defined on dynamic footprints in the treated clubfoot deformity. This retrospective study investigated radiographic measures, foot pressure measures and the relationship between the radiographic and foot pressure measures in the treated clubfoot and the uninvolved contralateral foot of 10 subjects with unilateral clubfoot.

METHODS

Talocalcaneal angle (lateral and AP), Calcaneus-2nd metatarsal angle, Calcaneus-1st metatarsal angle Radiographic measurements were taken using the methodology described by Thompson et al. for AP and Lateral films.

Foot pressure data were collected using the Novel EMED platform system. Three trials were collected bilaterally with the subject walking at his/her self-selected speed. Data were analyzed using the Novel Geometry and Lateral area Indices programs. The COPI (Center of Pressure Index) and LAMI (Lateral-Medial Area Index) were calculated from the Lateral area indices program and the 7 angles reported, long plantar, lateral plantar, medial plantar, forefoot, heel, subarch, and hallux angles were calculated using the Geometry program.

Paired t-tests were used to assess the differences between the treated clubfoot and the uninvolved foot. Pearson r correlations were run to assess the correlation between the radiographic measures and the foot pressure measures. Correlations were assessed independently for the uninvolved foot and the treated clubfoot.

RESULTS

Differences in some radiographic and foot pressure measures were seen between the treated clubfoot and uninvolved foot. However, due to the large variability in the small preliminary data set there were no statistically significant differences between the groups for either the radiographic or foot pressure measures ($p \leq 0.05$). Pearson correlations $r > 0.600$ are reported in Table 1.

DISCUSSION:

If successful clubfoot correction has been achieved the treated clubfoot should be near "normal,," The findings from this study support that in our population there were small differences between the treated clubfoot and uninvolved side. However, in this small sample size there was a large variability in the degree of abnormality across the subjects.

This study gives preliminary indication that foot pressure measurements correlate to radiographic measures in the treated clubfoot and uninvolved foot. If the same information can be obtained utilizing a foot pressure assessment as an x-ray then there would be a decreased need for x-rays and decreased radiation exposure for children with clubfeet. These findings could lead to a change in clinical practice.

Future work in this area hopes to establish a means to classify clubfeet, utilize the foot pressure measurements to assess treatment outcomes, degree of correction and progressive recurrence in the clubfoot.

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	Talocalcaneal angle (lateral)		Calcaneus-2nd Met angle		Talocalcaneal angle (A-P)		Calcaneal-1st Met	
	Uninvolved	Treated Clubfoot	Uninvolved	Treated Clubfoot	Uninvolved	Treated Clubfoot	Uninvolved	Treated Clubfoot
Long Plantar angle			-0.692		0.820			
Lateral Plantar angle	0.886					0.966		
Medial Plantar angle			-0.780		0.834			
Forefoot Angle	0.686		-0.693			-0.699		
Heel Angle	-0.732							
Subarch Angle	0.974		-0.679		0.838		0.836	
Hallux Angle								
Foot Progression Angle			-0.674					0.820
Heel Width	-0.848							
Forefoot & Heel Coef.	-0.827		0.922		-0.751			
Coefficient of Spreading						-0.762		
LAMAI		0.764		0.737				
COPI		-0.739		0.688				

TABLE 1: Correlations between the Radiographic and Foot Pressure Measures in the Treated Clubfoot and Uninvolved Foot

Rehabilitation process after a Chevron Osteotomy for hallux valgus correction – A pressure distribution analysis

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INTRODUCTION

Painful hallux valgus is a common clinical problem, especially in women. One of the possibility to correct this depending of the level of deformity is the Chevron Osteotomy. How long it will take to get back the full foot function is quit an important question. So the purpose of this study was to evaluate the rehabilitation process after a Chevron Osteotomy for hallux valgus (HV) correction.

METHODS

68 patients (108 feet) with moderate or severe HV deformity (HV angle greater than 24 degrees) take part in this study. Pressure distribution and x-rays were taken before hallux valgus correction surgery. Two subgroups were created: Patients with Chevron Osteotomy and trochlea resection (n=43 feet) at the toes II-IV (Group A) and patients with Chevron Osteotomy without any additional intervention (group B). Postoperative x-rays were taken one day after surgery. Dynamic pressure distribution measurements (EMED SF, 50 Hz, Novel) were done 6 weeks, 3, 6 and 12 month after surgery. For each foot three acceptable trial were collected. For pressure distribution analysis we divided the foot into 11 regions by using the auto mask program from Novel. Medial and lateral heel, mid foot, 1st metatarsal head (MT), 2nd MT, 3rd MT, 4th MT, 5th MT, big toe, second toe and 3rd – 5th toe. Maximum peak pressure normalized to body weight, contact area and contact time.

RESULTS AND DISCUSSION

Corresponding to the results from the literature we found reduced max. pressure values for the MT1 – MT3 and big toe for the 1st, 2nd and 3rd follow-up check. After 12 month quit a normal distribution under the metatarsal heads were reached.

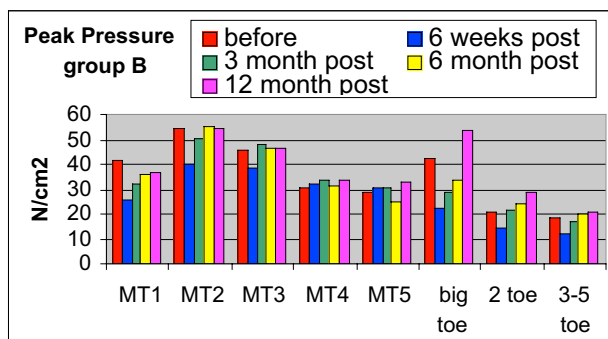


Figure 1: max. pressure values of selected regions under the foot, group B

The region under the big toe showed after 12 month a significant higher max. pressure value as before surgery. Extended contact time for the hole foot except for toe region were seen for 6 week follow-up. For the next follow-ups the contact time decreased to lower values as before surgery. This results were in both groups similar. Differences between the two groups were found under the big toe and MT2 at the 12 month follow-up check. A lower max. pressure value under the big toe compared to the result before surgery and to group B. The second metatarsal has still a significant higher value as before surgery.

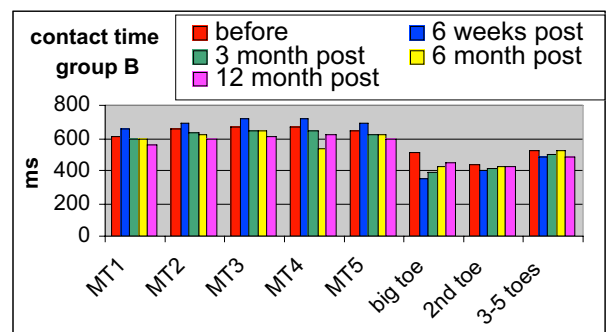


Figure 2: contact time of selected regions under the foot, group B

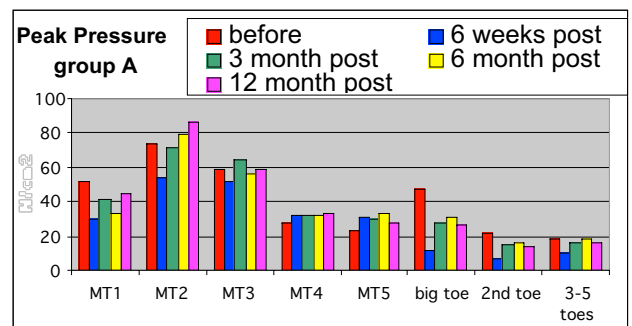


Figure 3: max. pressure values of selected regions under the foot, group A

SUMMARY

The higher peak pressure values under the big toe results from the slightly reduced dorsiflexion at the first metatarsophalangeal joint. A relative long time is needed to reach a quit normal pressure distribution pattern. So further research is needed to see the influence of special treatment (physical therapy,...) on the rehabilitation time.

INDEX OF PRONATION

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INTRODUCTION

The goal was to develop an Index of Pronation that was based upon objective measurements and sensitive to the severity in which an individual exhibits static and dynamic pronation. The concept was derived from previous work (Song et al, 1996) in which a discriminant function was developed to distinguish healthy rectus and pes planus foot types. This was initially accomplished by studying the structure, or pedal architecture, and biomechanical function of the feet of young healthy individuals. This work was advanced to include older diabetic neuropathic individuals (Song et al, 1999) and patients with severe pronation who have collapsing pes valgus feet (Mahan et al, 2001). The basis of this investigation was the observation that patients with clinical evidence of pronation (e.g. a valgus hindfoot, a declinated arch, and/or a varus forefoot) had greater measures of static and dynamic pronatory foot function based upon their clinical severity.

METHODS

Data from the aforementioned investigations were pooled to provide the required information to conduct this study. Each subject underwent a clinical biomechanical exam which included resting calcaneal stance position (RCSP), the forefoot to rearfoot relationship (FF-RF), and the distance between the ASIS to medial malleolus bilaterally. Only a 1° resolution goniometer and a 1 mm resolution tape measure were used. Subjects were excluded if they had greater than 1cm of limb length discrepancy. The remaining subjects were divided a priori into two clinical classifications based upon this information: 'rectus' and 'planus' foot types. The rectus subjects had RCSP values that were +/- 2° from perpendicular to the ground and FF-RF values that were between 0 and 3° of varus. The pes planus subjects had RCSP values ≥ 4° of valgus and/or FF-RF values ≥ 5° of varus. Each subject stood upon a flatbed scanner with a jig that registered the lateral and medial malleolus to the transverse plane of the plantar foot (Song et al, 1996). From this data malleolar valgus index (MVI) values were calculated and observed to increase with greater amounts of hindfoot valgus. Subjects then walked at their comfortable walking speed across a pedobarograph. The concavity of the center of pressure pattern was calculated. The resulting center of pressure excursion index (CPEI) values decreased with greater amounts of foot pronation.

RESULTS AND DISCUSSION

As shown in Figure 1 all of the included subjects (n=90 feet) are summarized in a scattergram. CPEI' and MVI' are the

measures of dynamic (CPEI) and static (MVI) foot function transformed to the centroid of the rectus foot type. The 90% ellipsoid clusters are shown around the rectus (depicted in squares) and planus (depicted in '+' and 'x') foot types. The Pronation Index is calculated in CPEI'-MVI' space as the Mahalanobis distance from the centroid of the rectus population. A foot exhibits pronation if MVI' > 0, CPEI' < 4.6, and the Pronation Index (PI) is greater than 2. This algorithm yields >98% correct classification in comparison to the a priori clinical grouping. Graphically this corresponds to the lower right quadrant of Figure 1 where the more severe the pronation the further the foot is from the rectus centroid.

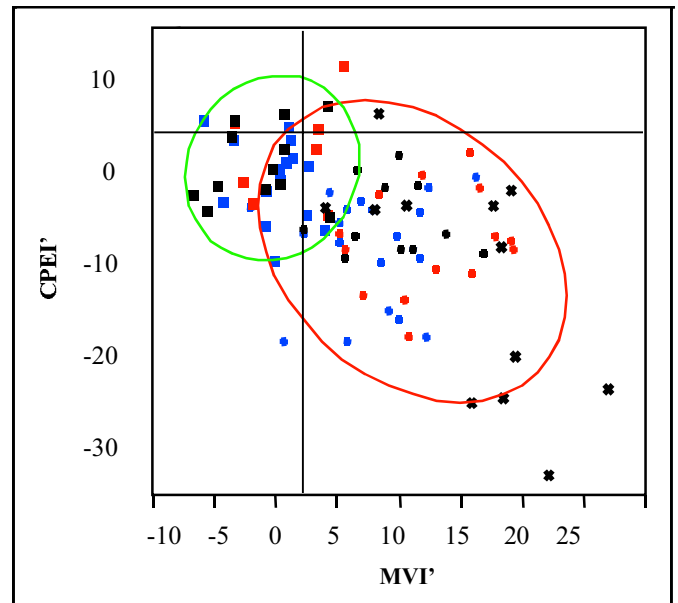


Figure 1: CPEI' and MVI' are measures of dynamic foot function (CPEI) and static foot function (MVI) transformed to the centroid of the rectus foot type. 90% ellipsoid clusters are shown around rectus and planus groups. Note that the rectus foot type data is comprised of young subjects (black squares), older subjects (blue squares), and diabetic subjects (red squares) while the planus foot type data is comprised of young subjects (black +), older subjects (blue +), diabetic subjects (red +), and collapsing pes valgus subjects (black x).

SUMMARY

An Index of Pronation has been developed that is based upon objective measures of static and dynamic foot function and sensitive to the clinical severity of pronation.

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A NOVEL MICROELECTROMECHANICAL TRANSDUCER FOR MEASURING CONTACT STRESSES

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INTRODUCTION

Improved instrumentation for measuring contact stresses has long been desired by many research and industrial groups. One design requirement is minimal total transducer thickness to avoid disrupting the normal contact stress distribution. An additional design requirement is a flexible and extensible transducer that will conform to complex curvatures of various surfaces. The objective of this work was to develop instrumentation that meets these requirements.

METHODS

MicroElectroMechanical System (MEMS) techniques were exploited to design and fabricate micromachined Silicon contact-stress sensors. An individual sensor includes a piezoresistor doped into the surface of a Silicon micro-beam. The beam deflects under load to produce a resistance change in the sensor proportional to the load.

Various individual sensors were tested prior to release from their bulk substrate of origin. This is an intermediate form that is not flexible but is mechanically similar to the final sensor. Sensor resistance was monitored as a function of applied load in a hydraulic materials testing machine. Sensors were subjected to quasistatic, sinusoidally varying compressive loads transmitted through various rubber sheets backed by a polished-flat steel plate.

An array of individual sensors was fabricated with conducting micro-springs (Figure 1). The springs permit flexure and elongation between sensors so that the array can conform to complex curvatures. The micro-springs are arranged in row-column form to allow multiplexed addressing of the array with a minimal wire set.

RESULTS

Typical cantilevered beam dimensions of an individual sensor are 25 μm in width, 15 μm in height and 40 μm in length. These dimensions produce a sensitivity of 288 Ohms/MPa with an imprecision of 1.25% full scale and a 0% bias. This sensor demonstrates a thermal sensitivity of 0.68 Ohms/ $^{\circ}\text{C}$ (if the application demands, then thermal compensation is available) and a maximum load limit of 2 MPa.

Sensors in the array are constructed on 860 μm centers with a total of 64 sensors/array. The array conforms to a spherical curvature of 15 mm radius.

DISCUSSION

To realize a transducer that can measure contact stresses, the Silicon sensor(s) must be potted in an electrically insulating material. The potting material will pose limitations on the dynamic, mechanical performance of the resulting transducer because the potting material typically demonstrates viscoelastic behavior. The potting material thus must be carefully chosen to be appropriate for the application.

Initial testing demonstrates that the design requirements can be successfully achieved. The micromachining process allows minimal transducer thickness and a high density of sensors in an array. Once potted, the total package thickness will be 170 μm or less. Spacing down to 150 μm centers and an increased number of sensors in the array are readily achievable. Finally the array can conform to complex curvatures.

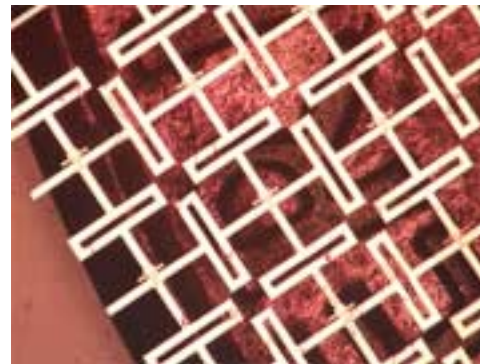


Figure 1: Photograph of a released sensor array shown on a penny for scale. Sensing micro-beams are at wire crossings. Rectangular conducting micro-springs which serve as the wires permit flexure and elongation.

SUMMARY

A novel stress sensor and array of sensors have been fabricated and individual sensors have been evaluated for performance. The technology has the potential to offer improved accuracy over commercially available transducers due in part to the sensor design and in part to the reduced thickness and extensibility of the transducer package. Future work will characterize sensor array performance. If the sensor array can be demonstrated to provide useful information, then this new technology may offer a dramatically improved solution for the experimental measurement of contact stresses.

ACKNOWLEDGEMENTS

The authors thank the Engineering Foundation (NY, NY) and the Stanford Nanofabrication Facility (Palo Alto, CA) User Grant Program for their generous support.

LASER VIBROMETER AND CAPACITIVE MATRICES: NEW MEASUREMENT PROCEDURE OF HAND-ARM VIBRATION.

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INTRODUCTION

Testing of vibrating hand-held tools is needed in order to declare the levels of vibration that tools transmit to the operator. That has a significant impact on user safety and health. Recent studies from CEN point out the large uncertainty, low repeatability and low reproducibility of vibration measurement, with particular reference to hand-held tools. Test results are strongly operator dependent.

The EU funded research Project DOPTTEST, proposed a new measurement technique in order to better quantify and analyse vibration emission by hand-held tools. The innovative sensing technique is a combination of scanning laser Doppler vibrometer (LDV) and capacitive sensor matrixes.

METHODS

A LDV employing He-Ne laser radiation has been used. Tests on subjects, in different points of the hand and with typical skin cosmetics, showed that the laser vibrometer can measure skeleton motion of the hand. To measure the grip force and the pressure distribution at the hand-handle interface, a capacitive elastic sensor matrix has been developed and tested. The sensor matrix consists of 256 sensor elements (size of one element 7.8mmx7.8mm). A test bench has been developed according to the European Standard 8662-5 to evaluate the vibration level of the hydraulic hammer. The LDV head has been mounted over the breaker on a rigid and isolated structure. One breaker handle has been instrumented by the sensor matrix and an accelerometer mounted in compliance with European Standards. Tests have been carried out on 10 young healthy volunteers. They were required to control and apply a total vertical force of about 200 N while they operated the breaker with a different grip force. The following information were acquired during each test: knuckle vibration velocity time history by LDV; handle acceleration time history by accelerometer and LDV; mean pressure values and total grip force by the capacitive matrix; vertical load force exerted by the operator; vascular effects by photoplethysmography and finger skin temperature by thermocouples.

RESULTS AND DISCUSSION

Results (Fig.1) show that at 27.5 Hz (main hammer frequency) exist a correlation between regions of large local contact pressure and low vibration. The subject holding the breaker with a low grip force presents the higher vibration velocity values on all the knuckles. A comparison of pressure maps of different subjects shows that even if a constant vertical load is applied to the handle, the grasp turns out to be rather different. Furthermore the subject is not really able to keep the same grip force.

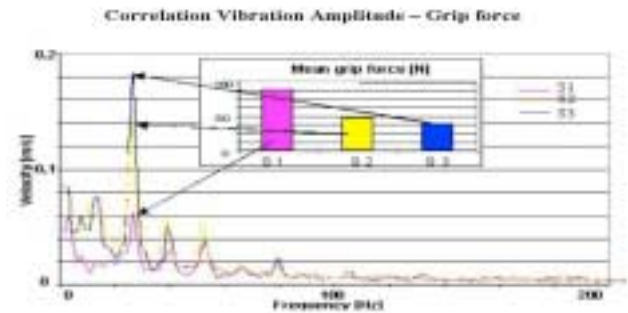


Figure 1: Vibration velocity spectra of index finger knuckle of 3 subjects.

A fairly good correlation of data has been also obtained referring to medical tests. A higher vasoconstriction has been observed when a weak grip is applied (high vibration levels).

SUMMARY

The good correlation between vibration amplitude and grip force, the observation of low repeatability of the grip force values, show the effectiveness of this innovative sensing technique. This measurement helps improving test repeatability and reproducibility and could be of great interest for standardisation purposes.

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INDIVIDUAL CORRECTIVE INSERTS LIKE PART OF THE TREATMENT FOR DIABETIC FOOT.

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INTRODUCTION.

Clinicists and orthotists used different methods for diabetic foot treatment – like doctor's stuff, medical service, operative treatment, various technical aids –as special orthopaedical shoes, destress orthosis, individual insoles etc. Often problems with diabetical foot raise inconstant problems for "healthy,, foot and patients walking style.

Existing methods in most cases avert the damages, but not fully resolve all gait problems.

transmigration. After necessary changes patients gait become more stable, we obtained stance stabilisation, footstep length levelling and decrease of varus position, hasten the process of ulcer healing. In 17 cases diabetic foot ulcers volume decreasing level was 2 till 5 mm; in 4 cases – complete recovery. For more precise individual inserts construction and manufacturing are necessary dynamic pressure data measurements. It also helps to apprise the individual inserts accordance for patients.

METHODS.

Foot damages level was determinate by endocrinologists and podiatrists; by USS.

'Blu – print,,(like simple pressure data) and three dimensional (3 –D) investigation of the foot deformity was introduced from Jan, 2000. Diabetic Foot deformity changes was identified by CadCam system (from Germany company PedCad) and individual corrections was made from 3D view connecting by "blu – print,, in the PC . Adjustment individual inserts manufacturing was produced by computerised carving machine. The spectrum of corrections depends from damages volume of diabetic foot.

SUMMARY.

Individual inserts made by CadCam system are effective in diabetic foot . Inserts done more easily integrated treatment process, decrease pressure in critical areas and prevent from following damages, done walking process more easily.

RESULTS AND DISCUSSION.

From March 2000 till March 2001 28 patients with diabetic foot were investigated. 20 of them had diabetic foot ulcer in regin of metatarsal heads, 4 – at heel region, 4 – at tiptoe region. We receive objective static 3D data from defective diabetic foot. Findings helps to made optimal individual corrective inserts concerning treatment of the diabetic foot. We made various level of recession and used special insoles covering materials like X2 – soft maroon and X2 – medium petrol. For 14 of patients extra corrections was made " by hand,, then the patient start walking and dependence of ulcer

Effect of Tendo Achilles Lengthening on Forefoot Plantar Pressures, Ankle Motion and Plantar Flexor Power During Walking in Subjects with Diabetes and Peripheral Neuropathy: A Prospective Controlled Clinical Trial

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INTRODUCTION

Patients with diabetes mellitus (DM) and peripheral neuropathy develop limited ankle dorsiflexion range of motion (DFROM) that has been associated with high forefoot plantar pressures (PP) and skin breakdown. Total contact casting (TCC) is effective at healing forefoot ulcers, but patients experience a high ulcer recurrence rate. A Tendo Achilles lengthening (TAL) procedure is intended to increase DFROM, reduce forefoot PP, and help heal/prevent forefoot ulcers. Although healing outcomes will be presented, the primary purpose of this study is to determine the effect of a TAL and TCC on forefoot PP, DFROM, and plantar flexor (PF) power during walking compared to TCC alone. A secondary purpose is to determine if the change in PP following TAL is related to a change in DFROM or PF power during walking.

METHODS

Fifty-five subjects with DM who had a recurrent or nonhealing forefoot ulcer, and ≤ 5 degrees of ankle DFROM were randomly assigned to the TCC or TAL group. There were 31 subjects (10 female, 21 males) in the TCC group and 24 subjects (4 females, 20 males) in the TAL group. There were no significant differences in age (57 ± 9 years), body-mass index (31 ± 8), or duration of DM (19 ± 13 years) between groups. A percutaneous (Hoke) triple hemisection technique was used for the TAL procedure and an open-toe TCC with a cast boot was used for the TCC. A subset of patients were tested 3 times; prior to treatment (Pre), after cast removal (Post), and 6 months post-treatment (6mo Post). Forefoot peak PP and pressure time integral (PTI) data were collected barefoot during separate timed walking trials using the EMED pressure mat system. DFROM was measured with the knee extended using a goniometer and during walking using computerized motion analysis (Motion Analysis System 3D). Peak PF power during walking was estimated using inverse dynamics methods. Analysis: A 2 (group) by 3 (times of testing) repeated measures ANOVA was used to determine differences in each variable. t-tests were used for post-hoc comparisons on significant findings. In addition, correlations between changes in plantar pressures, DFROM, and PF power were determined using multiple regression techniques (6 month scores were adjusted for pre and post-test differences).

RESULTS AND DISCUSSION

Twenty-two of 24 (92%) and 28 of 31 (90%) wounds healed in 44 ± 14 days and 42 ± 28 days in the TAL and TCC groups respectively ($p > .05$). During 6 month follow-up, 3 of 21

(14%) and 15 of 24 (60%) patients had ulcer recurrence in the TAL and TCC groups respectively ($p < .005$, χ^2). Forefoot PP and PTI decreased substantially after TAL ($p < .0001$, Table 1). PP returned to its pretreatment level 6 months after surgery, while PTI increased ($p < .002$), but not to its pretreatment level ($p < .001$). PP and PTI did not change across time in the TCC group. DFROM increased as measured with a goniometer ($15 \pm 6^\circ$) or during walking ($9 \pm 5^\circ$) after TAL. The increase in DFROM was maintained at 6-month follow-up in the TAL group. DFROM did not change in the TCC group over time. Peak PF power during walking decreased dramatically after TAL ($p < .00001$). PF power increased at 6-month follow-up ($p < .0002$), but not to its pretreatment level ($p < .001$). PF power did not change in the TCC group over time. Correlations between the change in forefoot PP was .03 with the change in DFROM (goniometer), .11 with the change in DFROM during walking, and .48 with the change in peak PF power over time. Walking speed was not different across groups or time ($p > .05$).

Table 1: Outcomes at Pre, Post, and 6 month (6mo) follow-up

Variables	Group	n	Pre	Post	6 mo	p
PP barefoot (N/cm ²)	TAL	13	89±21	65±26	89±24	.005
	TCC	11	83±21	87±26	97±24	
PTI barefoot (N/cm ² *sec)	TAL	13	22±5	13±4	17±5	<.001
	TCC	11	18±5	19±4	20±5	
DFROM (°) Goniometer	TAL	15	-4±8	11±4	11±5	<.001
	TCC	14	-1±8	1±4	0±5	
DFROM (°) Walking	TAL	14	11±4	20±6	17±4	.005
	TCC	13	11±4	12±6	10±5	
PF power (Nm/sec)	TAL	13	166±101	57±63	114±96	.001
	TCC	13	179±101	168±63	168±96	

SUMMARY

TAL resulted in a dramatic reduction in short-term (<6 months) ulcer recurrence rate, forefoot PPs, PF power during walking, and an increase in DFROM compared to TCC alone. Changes in PPs during 6 month follow-up were more correlated with changes in PF power during walking than with DFROM. Given the excellent reduction in ulcer recurrence with TAL and the invasiveness of surgery, alternative procedures may be investigated that could temporarily reduce the vigor of push-off. Additional research is needed to clarify long term healing rates (>6 months) following treatment with TAL, and how patients adapt to plantar stresses.

ACKNOWLEDGEMENTS

Funded by NCMRR, NIH, RO1 HD36802; PODS II, Foundation for Physical Therapy

EVALUATION OF EARLY WALKING PATTERNS BY PLANTAR PRESSURE DISTRIBUTION

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INTRODUCTION

During the first month of independent walking in childhood foot shape and gait pattern change rapidly. The beginning of bipedal locomotion strongly influences the development of the lower extremity. The development of foot and gait is an individual process, a wide variety of different foot shapes and gait pattern in children of the same age can be found (Fig. 1). In comparison with the adult foot typical differences as for example the physiologic flat foot are obvious (Fig. 2). The differentiation between physiologic and pathologic developments often is difficult. Foot and gait disorders are therefore common problems in paediatric orthopaedics. Reviewing the literature few data about maturation processes of the lower extremity were found, standard values do not exist.

The aim of the present study is the longitudinal evaluation of the development of foot and gait from the first steps of independent walking up to the age of ten years.

METHODS

Up to now, 55 children take part in the investigation. Foot loading characteristics were evaluated initially during their first independent steps. Re-tests are performed every three month during the first year of walking, twice per year until the age of six years, and once a year until the age of ten years. So far, 38 children were followed up for at least one year.

Five dynamic foot prints for left and right feet during barefoot walking were collected by use of the EMED ST4 pressure distribution platform. For analysis the foot prints were divided in five masks (heel, midfoot, forefoot, hallux, 2nd-5th toes). Contact area, force, peak pressure, contact time and impulse were calculated for each mask. Furthermore, Harris mat prints and video clips were collected for each child.

RESULTS AND DISCUSSION

In comparison with the first steps the foot shape demonstrates in the first year of walking an increasing gap at the medial margin of the foot indicating a progress in the development of the longitudinal arch (Fig. 3).

In relation to the foot length the gait line becomes longer indicating the beginning of the initial heel strike during gait

cycle. The roll-over process starts to be modified towards an adult pattern. The analysis of foot loading parameters after the first year of walking compared with the initial steps demonstrates significant changes: Contact area, maximum force peak pressure and impulse are reduced under the midfoot indicating the development of the longitudinal arch. Force and peak pressure for the heel and forefoot masks increased significantly as well as the contact area under the forefoot. The impulse increased significantly in the forefoot and hallux indicating a more pronounced push-off during gait cycle.

The present study demonstrates that significant changes in foot loading characteristics in infants can already be observed after the first months of independent walking. Pedographic measurements can be performed even in very young children.

The results should improve the understanding for maturation processes of the lower extremity. For the future, a database with standard values for foot and gait development in infants can be created.

Further investigations as the three-dimensional movement analysis, electromyographic measurements and evaluation of leg axis and torsion by ultrasound will be added to the project.

SUMMARY

The development of foot and gait in childhood is significantly influenced by physiologic maturation processes. The interpretation of foot and gait disorders in infants is often difficult due to a wide variety of individual changes, scientific data is rare. Pedobarographic measurements as a reliable and sensitive tool are helpful to evaluate foot loading characteristics in order to improve the understanding for age-related maturation processes in foot and gait.

ACKNOWLEDGEMENTS

This project is supported by the German Research Foundation (DFG grant # RO 2146/3-1).



Fig. 1: Foot shape of a child at the beginning of walking



Fig. 2: Harris mat prints indicating the inter-individual differences at the same age

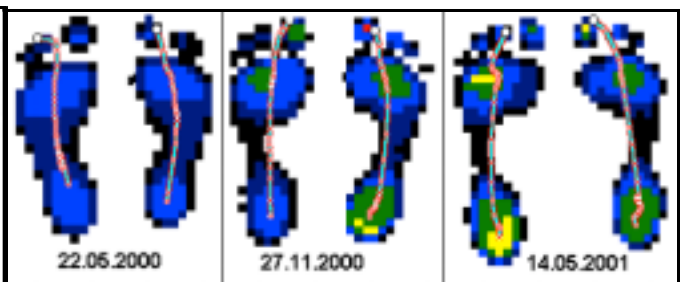


Fig. 3: Individual changes of foot loading patterns (initially and after 3 and 6 months of walking)

ELEVATED LATERAL PATELLAR FORCE IS RELATED TO PATELLAR SPIN

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INTRODUCTION

Patellofemoral pain accounts for 33.2% of all knee disorders in women and 18.1% of all knee disorders in men. It is widely assumed that this pain is caused by abnormally high pressures on the lateral facet of the patella. Surgical procedures and rehabilitation protocols aimed at relieving patellofemoral pain are designed to realign the patella so that a more even distribution of contact pressure is achieved in the joint. It is not clear which features of patellar position and movement must be corrected to relieve high forces and pressures on the lateral patellar facet.

In this study, we sought to answer the following research question: which features of patellar movement are linked to elevated contact force on the lateral patellar facet?

METHODS

Nine unembalmed human cadaver knee joints were tested. Each specimen was flexed in a test rig designed to simulate a continuous loaded squat while allowing unconstrained movement between the tibia and the femur (Figure 1). A motion analysis system (Qualisys, Glastonbury, CT) measured movement of the femur, tibia and patella. Patellar tilt, patellar rotation, and the medial-lateral position of the patella were determined using a sequence-independent coordinate system.

A new technique was used to measure contact force and pressure and determine how they were distributed across the patella. Contact pressure and force distribution were measured with a sensor (Iscan, Tekscan, Boston, MA) fixed to the patella. Prior to loading the specimen, landmarks describing the proximal, distal, medial and lateral orientation of the patella as well as the patellar circumference and ridge were identified. Landmark position and contact mechanics data were merged using a custom computer program to determine the distribution of force and pressure on the lateral and medial patellar facets.

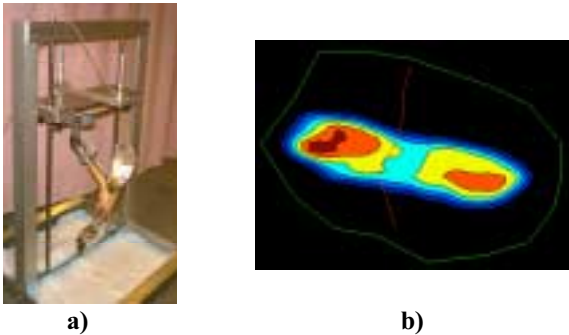


Figure 1: a) Test rig for simulated weightbearing squat and b) sample frame showing pressure distribution on the patella.

Kinematics and pressure distribution were measured for continuous loaded flexion of the knee with different alignments of the extensor mechanism:

- normal alignment (all knees)
- after simulating patellar malalignment by moving the proximal extensor mechanism laterally to create a mean Q-angle increase of 7.5 degrees (all knees)
- after coronal osteotomy to move the tibial tubercle medially in knees with elevated Q-angles (7 knees) or
- after moving the extensor mechanism medially to create a mean Q-angle decrease of 5 degrees from normal (2 knees)

We tested the hypothesis that increased force on the lateral patellar facet is correlated with increased a) patellar tilt b) patellar spin c) patellar flexion d) medial-lateral patellar position with scatter plots and the Pearson correlation coefficient.

RESULTS AND DISCUSSION

	Tilt	Spin	Flexion	M-L Position
Variable range	-12.9°-9.2°	-6.5°-13.1°	-9.9°-4.2°	-4.7 mm - 4.8 mm
Pearson correlation coefficient	0.13	0.52**	0.15	-0.32

Table 1: Correlation between changes in patellar kinematic variables and elevation in contact force on the lateral patellar facet at full extension (** indicates $p < 0.05$).

Patellar spin (varus/valgus angulation) is the only kinematic variable examined that correlates significantly with increased force on the lateral patellar facet at full extension (Table 1).

We tested widely-accepted hypotheses linking patellar movement and contact force distribution by measuring these quantities simultaneously during loaded knee flexion. We found no evidence for the widely-held view that elevated lateral contact force is related to changes in patellar tilt or medial/lateral position. Although limited by the simplified loading applied to our *ex vivo* specimens, the results suggest that diagnostic tests and treatments for patellar malalignment should focus on assessing and changing patellar spin.

ACKNOWLEDGEMENTS

Supported by the a Bristol-Myers Squibb/Zimmer award from the Orthopaedic Research and Education Foundation and the Natural Sciences and Engineering Research Council, Canada.

CHANGES IN KNEE CARTILAGE VOLUME AND SERUM COMP CONCENTRATION AFTER RUNNING EXERCISE RELATED TO INDIVIDUAL JOINT LOADING

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INTRODUCTION

To date no biomechanical rationale has satisfactorily explained the aetiology of overuse running injuries (Nigg, 2001) with the knee joint being the structure of major concern.

Magnetic resonance imaging (MRI) has proven a reliable tool for determining volumetric changes in human knee joint cartilage following single bouts of exercise (Eckstein et al. 1999). Considerable inter-individual variations were reported. Comparing well-trained and inactive athletes did not show notable differences between groups (Muhlbauer et al. 2000).

Cartilage oligomeric matrix protein (COMP) as a blood serum marker was proposed as an indicator for cartilage breakdown during running exercise (Neidhardt et al. 2000).

The aim of this study was to determine changes in knee cartilage volume and serum COMP concentration after a 1 h training run and relating these to individual joint loading parameters.

METHODS

A group of 21 trained subjects had to fulfil an intense 1 h training run. Before and after exercise (20 min and 2.5 h) venous blood was abated. COMP concentrations were determined by an enzyme-coupled immuno-absorption assay (COMP ELISA™ reaction kit, AnaMar Medical).

Before and immediately after the training session the right knee was scanned with a MRI scanner (Philips Gyroscan, 1.0 NT, with extremity coil) using a 3D FFE protocol (fast field echo; 0.3*0.6*2 mm voxel size). Segmentation was conducted semi-automatically following procedures proposed by Eckstein et al. (1999). Cartilage volume was reconstructed three-dimensionally using a customised MatLab routine.

The individual joint loading patterns were determined using a six-segment inverse dynamics model of the lower extremity (Kersting & Böhm, 1999). Subjects had to perform five successful trials crossing a force platform (Kistler) in a laboratory set-up. A pressure distribution system (PEDAR, 100 Hz) was used to distribute resultant GRF to anatomical structures of the foot. Body segment kinematics were recorded by a V icon® system (8 cameras, 240 Hz). The model was used to calculate net joint moments of the right knee (DADS 9.5, CADSI).

RESULTS AND DISCUSSION

COMP levels expressed as percentage of the basal value changed in two different ways (fig. 1). Group1 (n=10) experienced a drop of 19 % while group2 increased by 25 % 20 min post-exercise. After 2.5 h the basal levels were re-established in most subjects.

The changes in knee cartilage volume (total and femoral condyles) mirror the pattern observed for the COMP levels.

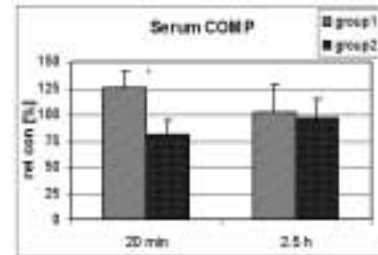


Figure-1: Comp levels after exercise (*: p<.01)

For group1 the cartilage volume did not change notably while for group2 the cartilage volume decreased by 9.2 % post-exercise (fig. 2). Maximum flexion-extension moments at the knee joint did not vary significantly between groups when related to bodyweight. Maximums of constraint moments (rotational and medial-lateral) showed significant (p<.05) differences with greater values for group2.

Increased values of COMP have been shown to occur during and after marathon runs and were also related to osteoarthritis

(Neidhardt et al. 2000). The current study connects the COMP changes directly to quantitative changes in cartilage volume and constraint moments at the knee joint. Though it must be kept in mind that an increase in serum COMP cannot be assigned to overloading of one particular joint.

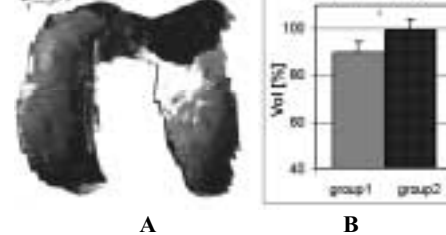


Figure-2: A 3D Representation of a femoral condyle, B Volume after exercise (*: p<.01)

Though it must be kept in mind that an increase in serum COMP cannot be assigned to overloading of one particular joint.

SUMMARY

Strong relationships between biochemical markers for cartilage breakdown and morphometric changes in knee joint cartilage volume were demonstrated. These changes appear to be related to the mechanical loads. Future studies in this direction seem to be helpful in relating mechanical loads to tissue reactions in the human locomotor system.

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ACKNOWLEDGEMENTS

Supported by BISP, grant no. VF 0407/01/10/2001

COMPARISON OF PHYSICAL ACTIVITY AND CUMULATIVE PLANTAR TISSUE STRESS AMONG SUBJECTS WITH AND WITHOUT DIABETES MELLITUS AND A HISTORY OF RECURRENT PLANTAR ULCERS

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INTRODUCTION

Researchers have identified a relationship between elevated plantar pressures and risk of ulceration in patients with diabetes mellitus and peripheral neuropathy (DMPN), suggesting that excessive mechanical stress contributes to the development of neuropathic foot ulcers. Current approaches to the treatment of neuropathic ulcers emphasize the reduction of plantar tissue stress, however, the rate of ulcer recurrence remains high. The purpose of this study is to compare physical activity and estimates of cumulative plantar tissue stress among subjects with DMPN and a history of recurrent plantar ulcers (DMPN+ulcer), subjects with DMPN but no history of plantar ulcers (DMPN), and non-diabetic control subjects (Con).

METHODS

A cross-sectional descriptive study design was used with the following inclusion criteria: All DMPN subjects had been diagnosed with DM and demonstrated a loss of protective sensation as defined by the inability to detect a 5.07 monofilament at 1 or more locations on the plantar foot. DMPN subjects reported no history of foot ulcers, while DMPN+ulcer subjects reported a history ≥ 2 forefoot plantar ulcers. All ulcers were fully healed at the time of testing. Non-diabetic control subjects had never been diagnosed with DM, and demonstrated intact protective sensation.

Groups were matched with regard to age (Con=55.0 \pm 12.3; DMPN=57.8 \pm 7.2; DMPN+ulcer=56.5 \pm 8.0 years), body-mass index (Con=32.3 \pm 8.3; DMPN=32.4 \pm 3.7; DMPN+ulcer=34.8 \pm 8.0 kg/m²), and gender (4 males/2 females per group). Lower extremity circulation was intact for all groups as assessed by ankle arm indices (Con=1.2 \pm 0.1; DMPN=0.99 \pm 0.2; DMPN+ulcer=1.1 \pm 0.3). DMPN+ulcer subjects reported a longer duration of DM compared with diabetic control subjects (DMPN=7.3 \pm 4.9; DMPN+ulcer=20.8 \pm 12.7 years). HbA1c was similar among subjects with DMPN, and was greater than non-diabetic control subjects (Con=5.6 \pm 0.3; DMPN=8.4 \pm 1.9; DMPN+ulcer=8.8 \pm 1.7%).

All subjects wore a step activity monitor (SAM) for 7 consecutive days as they performed their usual activities. The SAM is a 2-dimensional accelerometer used to quantify daily step counts with >98% accuracy and a reliability of 0.95. The Pedar pressure system was used to assess in-shoe plantar pressures. Pressure data were sampled at 50 Hz as subjects walked at their self-selected pace across a 7.5 meter walkway in the shoes they reported wearing most frequently in the home and community. Mean peak pressure (PP) and pressure-time integral (PTI) were calculated for the forefoot region of 3

consecutive mid-gait steps. The mean PTI was multiplied by the mean daily step count to provide an estimate of daily cumulative plantar tissue stress for each subject.

RESULTS

18 subjects have participated in the study to date. Physical activity and estimates of cumulative plantar tissue stress for each group are provided in Table 1 below. Preliminary results suggest the following trends with a current power of 0.60: Peak forefoot pressures are highest for the DMPN group, and lowest for the DMPN+ulcer group (2/6 subjects with DMPN vs. 6/6 subjects with DMPN+ulcer wore prescribed custom insoles during pressure testing). Mean daily step count and cumulative tissue stress are similar among diabetic and non-diabetic control subjects. The DMPN+ulcer group exhibits 47% less activity with 37% lower cumulative tissue stress compared with the non-diabetic control group, and 37% less activity with 43% lower cumulative stress compared with the diabetic control group.

TABLE 1	Con	DMPN	DMPN+ulcer
Mean daily step count (steps/day)	5202 (\pm 2267)	4395 (\pm 1131)	2782 (\pm 1393)
Distance traveled (km/day)	7.51 (\pm 3.39)	5.54 (\pm 2.28)	3.16 (\pm 1.91)
Peak forefoot pressure (N/cm ²)	26.07 (\pm 3.93)	33.80 (\pm 12.80)	20.78 (\pm 8.93)
Daily cumulative stress (MPa*s/day)	352.2 (\pm 126.8)	390.5 (\pm 151.6)	221.7 (\pm 131.1)

DISCUSSION

Preliminary results indicate that subjects with DMPN and a history of recurrent ulcers are less active and experience less cumulative plantar tissue stress than subjects with DMPN and non-diabetic control subjects. These results suggest that ulcer recurrence may be due to a reduced tolerance for plantar loading rather than excessive plantar tissue stress. We speculate that reduced activity following development of a primary foot ulcer may contribute to disuse atrophy of plantar tissues and increase the risk of ulcer recurrence. Research is needed to determine whether strengthening plantar tissues through a progressive return to activity following treatment of primary ulcers can help reduce the incidence of ulcer recurrence, with additional benefits for weight management, insulin sensitivity, and cardiovascular health.

ACKNOWLEDGEMENTS

Funding provided by the Foundation for Physical Therapy and NCMRR 2T32HD07434-08.

ANALYSIS OF JOINT PRESSURE DISTRIBUTION AND JOINT FORCE DURING EXPERIMENTAL INDUCTION OF MIDFOOT FRACTURES

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INTRODUCTION

Among the injuries in the foot region, midfoot fractures are still problematic in both diagnosis and treatment, and result in a high degree of long-term morbidity. Midfoot fractures are uncommon and predominantly occur in car occupants. Force effect (plantar impact, extent of foot compartment deformation) and result (fracture pattern) known. An analysis of the processes *in* the foot during the impact was intended to improve the current foot dummy. An unique method with permanent registration of joint pressure and force distribution in foot joints with a high sampling rate was used during the experimental induction of midfoot fractures.

METHODS

Eleven fresh, unfrozen, unpreserved intact human cadavers [age: 36.8 (16-61) years, gender: male, race: white] were studied 24 to 72 hours after death. In 3 cadavers (5 feet) the setting was determined: entire cadaver fixed on a special tray in supine position, pendulum with bar impactor hitting the foot plantar to the Lisfranc joint (Effective pendulum weight, 50 kg; effective height, 2.3 m; effective energy, 1,130 J). Custom made pressure sensors (Novel, Munich, Germany) were inserted in Chopart joint [consisting of talonavicular (TN) and calcaneocuboid (CC) joint] and ankle (A). The thickness of the sensors was 2 mm, and the sizes were 3 x 3 cm for A, and 2 x 2 cm for TN and CC joint. The sensors contained a rectangular array of 10 mm x 10 mm transducers (Accuracy better than 5%, hysteresis 3%). Due to the size of the single transducers (1 cm²), the joint force could easily be calculated (force of single transducer, 1 N = 0.01 MPa x cm²; force of entire joint, sum of transducers in joint). The sampling rate was 500 per second. The zero hypothesis at the p<0.05 level was that there is no pressure or force difference between ankle versus Chopart joint.

RESULTS AND DISCUSSION

16 feet were measured; midfoot fractures were induced in 11 feet. The maximum pressure that was registered at one of the total 17 sensor transducers (ankle: 3 x 3, TN: 2 x 2, CC: 2 x 2) during one complete testing procedure amounted 1.22 to 2.55 MPa (2.04±0.412). The time after impact of the maximum pressure was 0.005-0.195 seconds (0.067±0.059). The maximum pressure values were measured in 8 (50%) testing procedures at the A, in 7 (44%) at the TN and in 1 (6%) at the CC joint. The maximum pressure at the A (n=8) was situated in the ventral third of the joint in 2 cases, at the central third in 3 cases and at the dorsal third in 4 cases. The maximum pressure in the Chopart joint (n=8) was situated in

3 cases at the dorsal half and in 5 cases at the plantar half. The maximum joint force (maximum sum of all sensor transducers at the same time) amounted from 381 to 1,458 N (947.9±266.7). The maximum force in the Chopart joint (sum of all transducers at TN and CC, n=8) was higher than the maximum force in the A (n=9 transducers) in 10 of 16 (62.5%) testing procedures, and the mean difference amounted to 115.1 N (±425.1 N). The differences between the maximum force in ankle and Chopart joints were not significant (t-test: p=0.519). No differences in the maximum force occurred when comparing the feet with (n=11) or without (n=5) midfoot fractures (Wilcoxon test: p=0.352). The comparison of the first 200 pressure values after impact (i.e. 0 to 0.4 seconds) of all 17 transducers (A, n=9; Chopart, n=8), resulted in significantly higher forces in the Chopart joint than in the ankle (t-test: p<0.001). Those force differences were significantly higher in cases with midfoot fractures (n=11) in comparison to cases without midfoot fractures (n=5) (mixed model analysis of variance of the first 200 pressure values after impact with random effect "cadaver,, and fixed effect "incidence of fracture,, of forces at A and Chopart joint p=0.003). The zero hypothesis was rejected.

At present, pressure sensitive films (Fujifilm Prescale™, Mitsui & Co., New York, NY, USA) are the standard for joint pressure distribution analysis. Those films detect the maximum pressure over a complete testing procedure and are useful for the analysis of static pressure and force. However, the films are unable to detect changing pressure and force. In our crash test model, the maximum pressure and force did not differ between ankle and Chopart joint. Still, the analysis of joint pressure and force over time showed highly significant differences between the joints. A high sampling rate was necessary for the detection of those differences. The forces in the Chopart joint were higher than in the ankle, although the impact direction was almost parallel to the Chopart sensors and perpendicular to the ankle sensor. Those force differences were higher when midfoot fractures occurred. Therefore, we recommend a modification of the foot dummy with a load cell that detects forces in the longitudinal axis of the foot, similar to forces that occurred in the Chopart joint in our crash test model.

SUMMARY

During experimental induction of midfoot fractures, higher forces in the Chopart joint than in the ankle occurred. Those differences were only detectable with a permanent measurement of joint pressure with high sampling rate. For joint pressure and force analysis in a cadaver crash test model, the introduced sensors are better than pressure sensitive films.

STUDY OF HUMAN-SEAT INTERFACE PRESSURE DISTRIBUTION ON CAR SEATS

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INTRODUCTION

The contribution summarises the state of the art concerning pressure measurements at the human-seat interface of automotive seats as a workplace. Quantitative results of a representative number of subjects have not been reported so far with automotive seats. The influences of the seat type, the gender and the individual body dimensions on static pressure distributions at the human-seat and the human-backrest interfaces using different seats should be examined in an experimental study.

METHODS

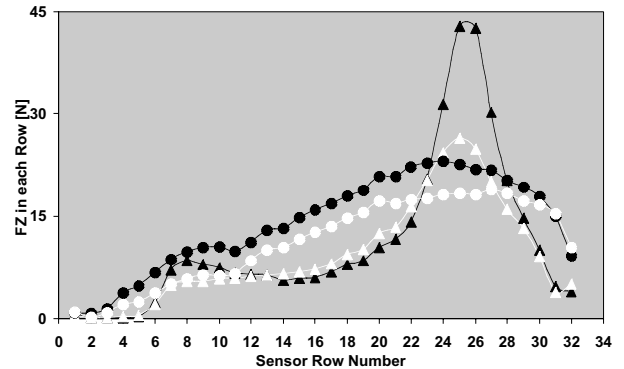
23 voluntary male subjects with body masses (BM) between 58.2 kg and 106 kg as well as body heights (BH) between 160.0 cm and 186.9 cm and 22 female voluntary subjects with BM between 51.5 kg and 84.1 kg as well as BH between 154.0 cm and 175.0 cm were selected for the examinations of pressure distributions at the seat- and backrest-interfaces of 4 seats. For the anthropometric description of the stature relevant parameters were determined in the standing and sitting posture. 3 car seats (S1-S3) from current vehicle models were used and 1 lab seat (S0) with a rigid seat surface and with the backrest of a car seat (Fig. 1). The test subjects sat in a relaxed, leaned and subjectively comfortable posture. Two pressure sensing mats were used for the measurements of the pressure acting perpendicularly on the human-seat interface, each in combination with an analyzer (novel) and a personal computer. The resulting force (FZ), the contact area, and the maximum pressure were calculated. The individual postures were quantified with the motion analysis system Mac reflex (Qualisys).



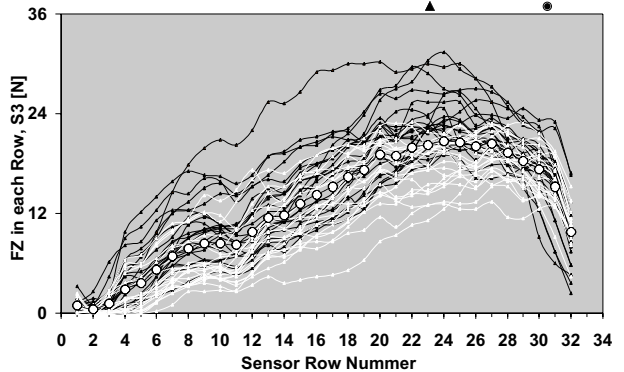
Figure 1: Female (left, S1) and male subject (right, S3) in the tested position

RESULTS AND DISCUSSION

The pressure distributions on the rigid seat pan were significantly different from those on the car seat cushions (Fig. 2). The whole pressure and the maximum pressure was higher for men than for women at the seat- and backrest-interface. The forces FZ, normalized with BM, showed different relations between men and women at the seat and backrest. Regression



equations were derived using the subjects weight and the
Figure 2: Mean values of longitudinal force profiles of male



(black) and female (white) subjects for S0 () and S3 ().
Figure 3: Individual longitudinal force profiles of the S3 for male (black) and female subjects (white) and the mean value (N=52, black line with white circles)

weight-to-height-ratio for men and women to estimate the measured parameters of the pressure distribution at the seat- and backrest-interfaces. The share of body weight acting perpendicularly to the backrest was relatively high (18-19% for men, 21-23 % for women) in comparison with that supported by the seat (46 to 59% for men, 69 to 80% for women). The individual force distributions show a great variability (Fig. 3). The data were discussed and for the hard seat compared with results published by Wu (1998).

SUMMARY

The results hint to the importance of such experimental studies for the seat design and modelling as well as the necessity of further research work during dynamic conditions.

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EVALUATION OF OPTIMUM SIZE OF BUBBLE WRAP FOR THE PREVENTION OF PRESSURE SORES

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INTRODUCTION

Pressure sores are potentially serious complications caused by capillary closure due to extended periods of immobilisation. Capillary blood flow pressure ranges between 22 and 32 mm Hg (Landis, 1930) and when externally applied loads create localised pressure above this level, blood flow is likely to be obstructed and circulation is reduced, resulting in pressure sores. Excessive and prolonged pressure excludes blood from the skin and subcutaneous layers and may cause thromboses, ulcer and necrosis. A variety of products are used in hospitals to reduce pressure sores, but most are very costly. In hospitals, the incidence of pressure ulcers seems to range from 2.7% (Gerson, 1975) to 29.5% (Clarke and Kadhom, 1988). The yearly UK costs of pressure sore treatments have been estimated to be £755 million (West and Priestley, 1994).

Preliminary tests carried out by the authors have shown that (1) jelly pads harbour bacteria and therefore could transmit infections when re-used and (2) bubble wrap is a potential bacteria-free alternative material for the prevention of pressure sores. The aim of this study is to investigate the potential use of more cost effective disposable products, without compromising on efficacy.

METHODS

Different pressure relief products, including jelly pad and different sizes of bubble wrap were used in this study to compare pressures generated when a subject sat on the different products. The X-sensor pressure mapping system, which consists of a thin mat containing grids of miniature force sensors, was placed between the subject and the pressure relief products, one at a time, to electronically record information on pressure distributions. Pressure data were recorded every second for 10 seconds while the subject was sitting on each of the pressure relief products. Each test was repeated five times and the average pressure data was computed. Pressure information for each product was compared.

RESULTS AND DISCUSSION

Average and peak pressure values recorded for the different pressure relief products are shown in figure 1. These results show that 10 mm diameter bubble wrap seems to be more effective than jelly pad and bigger sized bubble wrap.

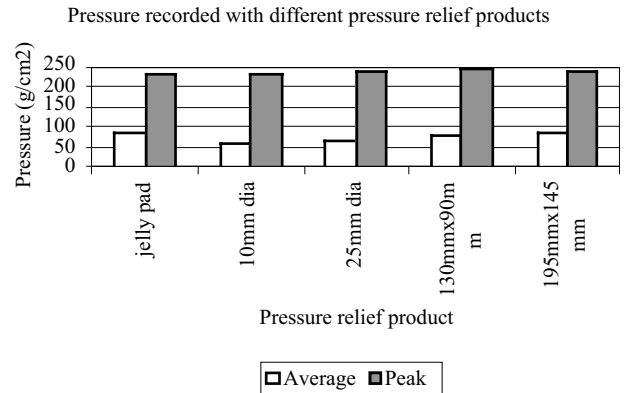


Figure 1: Pressure values associated with jelly pad and different sizes of bubble wraps

The pressure mapping system only records values of normal pressures and does not give any indication of values of shear forces generated. The extent of sideways motion of the bubblewrap indicates low possibility of shear build-up. However, further investigations need to be carried out to evaluate shear forces resulting from the different products.

SUMMARY

Based on the above investigations, we believe that (1) bubble wrap is a potentially more effective product for the prevention of pressure sores than the currently used jelly pad, (2) 10mm diameter bubble wrap gives better results than larger ones. Moreover, bubblewrap is cheap, disposable and is less likely to transmit infections.

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ACKNOWLEDGEMENTS

The authors wish to thank De Puy Int. Ltd., Prof. D. King, Mr P. Ingle Mr. K. Cheah and APU graduate school.

ASSESSING PELVIC OBLIQUITY IN NON-AMBULATORY, NEUROMUSCULAR SCOLIOSIS SUBJECTS

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INTRODUCTION

Non-ambulatory adolescents with neuromuscular conditions often have spinal deformities and pelvic obliquity - the pelvis does not lie perfectly horizontal in the frontal plane. The objectives of surgery are the safe correction of the deformity, with a solid fusion and a balanced spine centered over a level pelvis. The scoliosis correction is the fundamental goal of surgery, with pelvic obliquity being secondary. Pelvic obliquity correction ranges from 50-80% (Gau et al., 1991, Maloney et al., 1990) The goal of this prospective ongoing study is to determine how residual pelvic obliquity affects quality of life.

METHODS

Five (4F, 1M) consecutive adolescent, non-ambulatory, Cerebral Palsy subjects, who had surgery for the correction of scoliosis and pelvic obliquity, had a post-operative follow-up of 2-7 months. The average age at surgery was 14.6±2.6 years. All had posterior instrumentation and fusion with screw fixation to the sacrum. Pelvic obliquity and Cobb angles were measured from sitting pre- and post-operative posterior-anterior radiographs. A force-sensing conductive ink pad (TEKSCAN, Ferguson-Pell et al., 1993) with a grid of sensors was placed on an examination bed. The weight distribution pattern was recorded after two minutes of sitting. Measurements were recorded three times for twenty seconds at 10Hz. The patterns were divided into left and right sides and peak levels were noted on each side. A questionnaire was administered by a research assistant. Questions related only to the spinal deformity and were asked for the time period one year prior to surgery and for the current follow-up visit. Questions included sections on the necessity for hospital admission and treatment, pain, wheelchair use, modifications required for their chair, weight distribution in their chair, pressure sores, and changes in functional ability.

RESULTS

Small sample size and the non-homogeneity of the subjects limited group analysis. The outcome measures of pain, pressure sores, sitting tolerance, and function were not well related to the amount of pelvic obliquity. The ratio of left/right pressure correlated with improvement in pelvic obliquity ($r=0.91$). The following results are of note (Table 1) and:

- Two subjects had less pain post-operatively than pre-operatively, while another two had no pain either pre or post-operatively.
- Three subjects had never had a pressure sore, one had pressure sores in the year before surgery and one had pressure sores post-operatively.

- All subjects felt they sat straighter in their wheelchairs after surgery.
- Three subjects felt they had better balance, while one thought it was worse after surgery.
- Three subjects felt eating/feeding was easier after surgery.
- Two subjects felt they could sit in their wheelchair for longer periods post-operatively, while one felt their ability to sit in place had decreased.
- All subjects sat with more weight on their left side.

Table 1: Radiographic and Pressure Measurements

Measure (PO=Pelvic Obliquity)	Mean (SD)	Range
Pre-Op PO Iliac Crest (°)	10.3(6.1)	3-17
Post-Op PO Iliac Crest (°)	6.0(5.4)	0-11
Change in PO Iliac Crest (°)	4.3(2.2)	2-7
Percent Change in PO	55%(36)	15-100
Pre-Op Cobb (°)	64(9)	55-78
Post-Op Cobb (°)	43(14)	25-63
Change in Cobb (°)	21(10)	15-38
Percent Change in Cobb	33%(16)	19-60
TEKSCAN: Mean Post-op sitting asymmetry Left / Right	1.6(0.4)	1.2-2.0
TEKSCAN: Peak Post-op sitting asymmetry Left / Right	1.5(0.3)	1.1-1.9

CONCLUSION

No conclusive agreement can be made on how residual post-operative pelvic obliquity effects pain, pressure sores, seating requirements, and function, from the literature or the limited results of this study. It is clear however, that there is some positive outcome from surgery that as yet cannot be quantified. Further research, with more subjects, is warranted to enable a conclusive finding on the necessity of surgical correction and the degree of aggression with which the correction should be attacked.

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BOUNDARY LOADS IN FINITE-ELEMENT SEATING MODELS

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INTRODUCTION

Finite element computer models have been used to study the subcutaneous pressures due to the high incidence of pressure ulcers that occur in spinal cord injury patients confined to wheelchairs. The distribution of the weight of the torso on the upper boundary of the model has been treated various ways. In a recent study, the weight of the upper torso was divided into two loads; one applied to the top surface of the IT, and the other as a uniform pressure on the top surface of the buttock (Ragan et al., in press). The ratio of the two loads was adjusted to fit seat interface pressure data. Surprisingly, the loads on the ITs were found to be a small fraction of the torso weight (15%), with the majority of the weight supported by the buttocks. This disagrees with previous studies, where it was assumed that the total upper torso weight should be applied to the IT (e.g. Todd et al. 1994; Dabnichki et al., 1994).

Since these two kinds of boundary assumptions yield very different predictions of the interior pressure, the purpose was to examine how the weight of the upper torso was transmitted to the tissue of the buttocks during seating.

METHODS

The current model is a refinement of the Ragan et al. model and is similar to the mechanical model used by Reddy et al. (1982). The model considered each buttock as a horizontal axisymmetric slab with a radius of 8 cm and width 8 cm with a hemispherical IT situated along the axis. In the current study, a circular bony plate situated on the upper surface of the buttocks simulates the surfaces of the pelvis other than the IT, as shown in the Figure 1 inset. These distances were chosen as effective approximate distances taken from an adult skeleton. The weight of the upper torso is applied uniformly on the upper surface of the pelvis. The buttocks were considered to consist of nearly incompressible "soft" human tissue with a Young's modulus of 47 kPa and a Poisson's ratio of 0.49 (Todd et al., 1994). The minimum distance between the point of the IT and the skin was 1.5 cm before loading. The weight of the upper torso was taken to be 6.5% of the total body weight, and the seat was taken to be a hard, flat, horizontal surface.

RESULTS AND DISCUSSION

The computational model predicted that within the soft tissue, the area of high stress was concentrated within a centimeter or two of the IT with the maximum compressive stress just inferior to the surface of the IT. The seat interface pressures from the model were found to be in good agreement with

pressure mat data obtained with 70 kg single subject sitting in a standardized position on a hard surface, as shown in Figure 1. The pressure data was put into radial form by measuring the average pressure versus radial distance from the axis of the IT for each buttock. The current model confirmed the loading assumptions used in the model considered by Ragan et al. In particular, the pressure at the superior boundary of their model (the dashed line in the inset) agreed with their fit of 0.5 ± 0.1 N/cm², and the total load supported by the IT was found to be only 20% of the upper torso weight. The maximum subcutaneous pressure (3.8 N/cm², directly inferior to the IT) is much lower than the value obtained by Todd et al. (1994) where the upper body load was applied entirely to the IT.

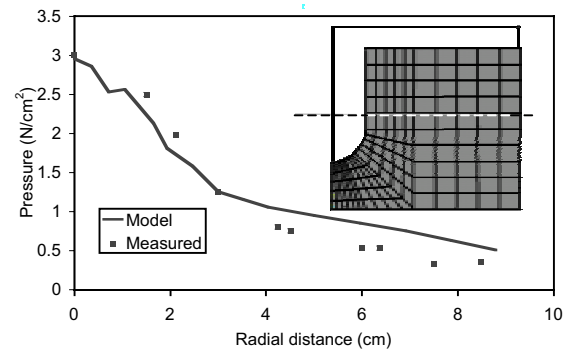


Figure 1: Radial distribution of seat interface pressure. The inset shows the axisymmetric finite element model. The dashed line is the superior boundary of the Ragan et al. model.

SUMMARY

A finite element model was used to examine how the weight of the upper torso is transmitted to the tissue of the buttocks during seating. Although the greatest subcutaneous pressure occurs inferior to the ischial tuberosities, the majority of the weight (80%) is transmitted by other surfaces of the pelvis. Model predictions of seat interface pressures were found to be in good agreement with pressure mat measurements.

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THE INFLUENCE OF TRUNK POSTURE AND STABILIZATION ON FOOT POSTURE AND PLANTAR PRESSURE DISTRIBUTION

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INTRODUCTION

Although it is well accepted that apart from the architecture of the foot and its biomechanical properties, body weight, muscle fatigue and the position of the center of gravity decide on foot posture and plantar pressure distribution no data are available about the influence of trunk posture and stabilization on plantar pressure distribution in bi- and monopodal standing under non-fatigue and fatigue conditions.

METHODS

A group of 39 men and women (aged 26 ± 6 a) with regular different sports activities underwent a defined test procedure: Abdominal muscle strength was tested in prone position. EMG-activity of foot extensor- and flexor muscles together with M. rectus abdominis and m. gluteus were measured simultaneously to the plantar pressure distribution in bi- and monopodal standing under non-fatigue and fatigue (caused by vertical jumping till subjective exhaustion) conditions with and without setting up the pelvis and flexing the lumbar spine by activating both, abdominal and gluteal muscles. Statistic testing included t-Test and product-moment coefficient for correlation.

RESULTS AND DISCUSSION

No correlation was found between abdominal muscle strength, muscle activity (AEMG), and foot pressure distribution in mono- and bipedal standing under all different conditions. However contraction of both, abdominal and gluteal muscles under all conditions do not only correlate with a significant increase of activity of the M. rectus abdominis and m. gluteus but also with a significant increase of activity i.e. of the M. tibialis absolute and relative to the activity of the M. gastrocnemius. The data of plantar pressure distribution showed a corresponding and significant decrease of pressure in

the area the medial arc and partly an increase in the area of the forefoot. Therefore foot posture can be influenced by the posture of the pelvis and thus by different grades of coactivation of extensor and flexor foot muscles which also means an influence on foot stability. It can be assumed that the lack of correlation with abdominal muscle strength is the result of the testing procedure in prone position, which does not include testing of simultaneous coactivation of the back muscles as a precondition of trunk posture control. In addition the increase of pressure in the forefoot can be interpreted as the result of an anterior shift of the center of gravity because of a lack of back muscle coactivation.

SUMMARY

Foot pressure distribution and EMG-activity of foot and pelvic muscles of 39 men and women (aged 26 ± 6 a) were measured in bi- and monopodal standing position under non-fatigue and fatigue condition and with and without activation of the abdominal and gluteal muscles. A significant influence on foot pressure distribution as well as on foot stability was detected by changing the posture of the pelvis which includes the posture of the trunk

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PEAK PRESSURE CURVE: AN EFFECTIVE PARAMETER TO DETECT LIMITED JOINT MOBILITY AND MUSCULAR WEAKNESS

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INTRODUCTION

The analysis of foot loading during gait is mainly focused on the elaboration of plantar pressure distribution, ground reaction force (GRF) and pattern of center of pressure (COP). The use of an accurate measurement device such as the Novel piezo-capacitive platforms allowed the accurate analysis of a further meaningful parameter, the peak pressure curve (PPC).

In this study PPC and its gradient have been studied in order to identify the effects of peripheral diabetic neuropathy on the biomechanics of the gait in terms of limited joint mobility (LJM) of the foot-ankle complex, muscular weakness (MW) of plantar and dorsal flexors, and increased plantar peak pressures (IPP).

METHODS

22 healthy volunteers and 60 diabetic patients have been examined. Even though diabetic patients were previously classified on the basis of presence or absence of neuropathy, in this study they have been re-classified according to the presence or absence of single or simultaneous LJM, MW and IPP.

Joint mobility and muscular functionality were accurately assessed by means of a dedicated device (Giacomozzi et al, 2000). It allows the measurement of angular excursions of the ankle complex in the three anatomical planes, and of torques expressed around the three corresponding axes when exerting maximal voluntary isometric contractions of the leg muscles. Peak values have been identified for each parameter and for each patient. Only data related to the sagittal plane have been considered in this study.

PPCs have been acquired by means of an EMED-ST4 pressure platform (Novel GmbH) inserted at a level in a wooden 5.6m long walkway. Patients were trained and acquired 6 times for each foot while walking barefoot at their natural speed.

4 groups have been formed as follows: A: no alterations; B: MW and IPP; C: LJM and IPP; D: LJM, MW and IPP.

In this preliminary study only 5 cases have been considered for each group. PPCs have been normalized to 100% of the stance phase and resampled over 65 samples. Instantaneous gradient of each PPC has been also calculated based on the finite difference between i^{th} and $(i^{\text{th}} - 1)$ sample. Resampled PPCs and their gradients have been finally averaged inside each group.

RESULTS AND DISCUSSION

Figure 1 summarizes the most interesting results. Vertical GRF has been reported (dotted line) just as a reference of the main stance phases.

As shown in the figure, peak pressure increase is already evident, for each pathologic group, in the early phases of stance, more evident for groups C and D.

As for MW, mainly due to dorsal flexors weakness, its combination with IPP (group B) leads to higher peak pressures for the whole period of contact between metatarsal heads and ground (about 60% of the stance phase). Absolute peak pressure is about 1.5 times the averaged normal peak (group A) and is almost simultaneous with it.

The major effects of LJM associated to IPP (group C) are the early and continuous increase of peak pressure, since metatarsals interact with the ground even from the very first period of stance, and the significant anticipation (10.8% of stance phase) in the occurring of the absolute peak pressure.

As expected, the combination of LJM and MW with IPP (group D) entails a dramatic increase in peak pressure as for both duration and amplitude.

The analysis of gradient of PPC helps in identifying instants in which rapid changes in size of the plantar contact surface cause peak pressure to increase abruptly. As shown in the figure, positive gradients are always greater for pathologic conditions than for normal gait.

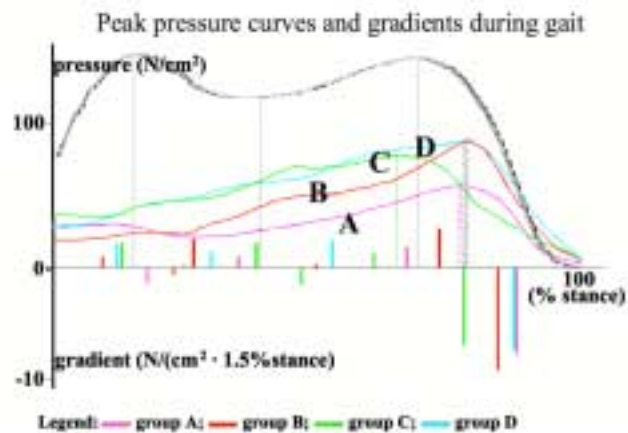


Figure 1: PPCs (curves) and gradients (bars) averaged inside each of the following groups: A: no alterations; B: MW and IPP; C: LJM and IPP; D: LJM, MW and IPP.

This preliminary study proved PPC to be a reliable and effective parameter to discriminate between muscular weakness and limited joint mobility in presence of increased peak pressures. A better quantification of PPC and the establishment of risk thresholds might definitely help in the early detection of risk of ulceration in diabetic patients.

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A MATHEMATICAL MODEL ANALYSING THE MOTION OF THE CALCANEUS FROM PRESSURE PLATE MEASUREMENTS

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INTRODUCTION

In the last decennia of the last century, extensive studies on the lower extremity have been carried out based on data obtained from high-speed cinematography (review: McClay et al., 2000). From these studies, it has been concluded that excessive subtalar pronation is linked to running-related injuries, and that the eversion of the calcaneus is a reliable predictor of the amount of pronation. The present study is not based on cinematography. But, instead, data are obtained from a pressure measurement system as starting point of an analysis of rearfoot motion. For that the pressure distribution should be linked to rearfoot motion requiring a mathematical model. Thus, three-dimensional rearfoot kinematics during heel contact can be simulated. In the presentation, the focus is on the obtained mathematical model and its validation.

MATHEMATICAL MODEL

The mathematical model uses pressure distribution as input to create kinematic output (Hagman et al., 2001), as such it differs from other models found in literature (Morlock et al., 1991; Scott et al., 1993). In the mathematical model the surface geometry of the calcaneus is an unknown parameter. Knowing this geometry and the pressure distribution input, the model calculates the kinematic output. For simplicity, it is assumed that the surface geometry is a sphere locally. Even with this simplifying assumption the results show striking resemblance with the output of high-speed cinematography measurements.

VALIDATION

To validate the output of the mathematical model, Cardan angles describing the kinematics are calculated and compared with the corresponding Cardan angles obtained from cinematographical measurements. Measurements were performed in which pressure data and cinematographical data were obtained simultaneously. Therefore, the left foot motion of five subjects in five trails from heel impact until forefoot contact were analysed.

In the measurements set-up six MCU240 cameras constructed by Qualisys, a footscan pressure plate of 200cm by 40cm constructed by RSscan International, a force plate of 200cm by 40cm constructed by Amti, and a 3D data box constructed by RSscan International were used.

Camera measurements were analysed with Move3D, a software package from the National Institutes for Health. Having being exported to ACII files, the pressure measurements were analysed and validated in the Matlab environment.

RESULTS

A comparison between the collection of Cardan angles obtained from pressure measurements and cinematography measurements has been performed. Results are given in Figure 1, in Figure 1.A both sets of Cardan angles are depicted, in Figure 1.B the difference in each of the angles is presented, and Figure 1.C shows the difference in trend.

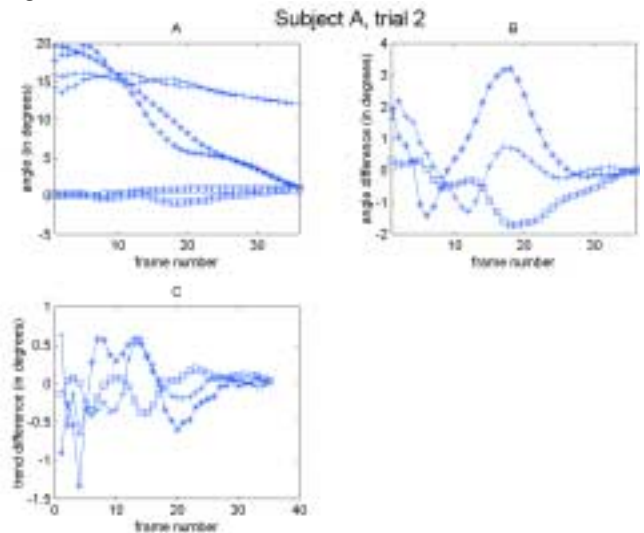


Figure 1: * denote dorsal flexion / plantar flexion, + denote inversion / eversion, _ denote abduction / adduction. In A, the smooth curves denote the model curves and the other curves denote the cinematographical curves.

CONCLUSION

A pressure measurement system enables us to simulate reliably the motion of the calcaneus from heel impact until forefoot contact, even with the simplifying assumption that the surface geometry of the calcaneus is a sphere locally.

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KINETIC COMPARISON BETWEEN AN ON ICE SPEED SKATING PUSH AND A SLIDE BOARD PUSH

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INTRODUCTION

With the introduction of the klapskate the sport of speed skating is at a stage of research that demands more accurate and controlled testing environments. As stated by Houdijk, (2001), “our current simulation models and experimental techniques may not be sensitive enough to test the small, though for skaters relevant, effects of these innovations in klapskate design., The above statement makes reference to some of the problems associated with on-ice testing. The modified slide board apparatus has been introduced to create an in-lab environment where better controls and equipment can be used to study the speed skate push. The conventional slide board has been used for the last 20 years by elite level skaters as a tool for developing proper skating technique (Kandou et. al., 1987). The purpose of the current study is to test the effectiveness of the slide board model in replicating an on-ice skating push.

METHODS

Four subjects participated in the study. Each subject performed four maximal pushes on the slide board. These pushes were then compared to four pushes selected from a maximal skating lap. Force and center of pressure data was collected with the Pedar Mobile system, through insoles placed inside the subject’s speed skates, collecting at 50 Hz.

The modified slide board model consists of a 20 foot by 4 foot melamin sheet with a small block of wood at one end where the subject performs the simulated skating push, from this point the subject will slide along the board until friction stops him/her. The pushing foot is in a speed skate that has a protective low resistance material under the blade, so that the blade and slide board will not be damaged. The contra lateral foot is in a running shoe with a wool sock over top.

RESULTS AND DISCUSSION

The averaged results for force-time and center of pressure (CP)-time data can be seen in figures 1 and 2. The data were normalized to peak force. The error bars represent 95% confidence intervals.

The CP-time curves are very similar throughout the push phase, indicating, the lever arm between the ankle joint and the PP is almost identical between the on-ice and slide board conditions. The force-time curves are very similarly shaped, although the forces tended to be a little higher for the on-ice data. Due to the relatively small sample size it is hard to quantitatively conclude whether skaters actually do produce

smaller forces on the modified slide board apparatus or if there were other factors at play. Because the setup is unique, skaters may need practice on it before they are completely comfortable, and able to produce maximal force. Qualitatively, both an on-ice push and a modified slide board push look almost identical.

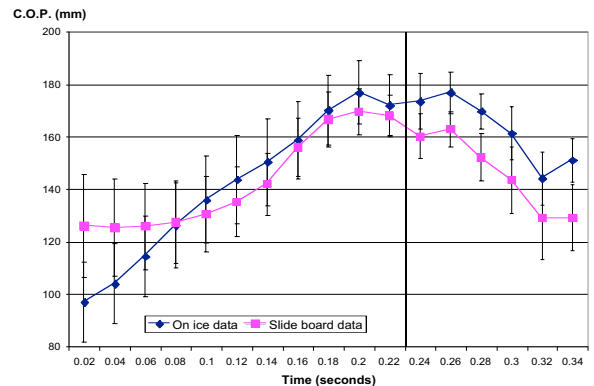


Figure 1: Center of pressure throughout the push phase, averaged for 4 subjects. Vertical line indicates end of push.

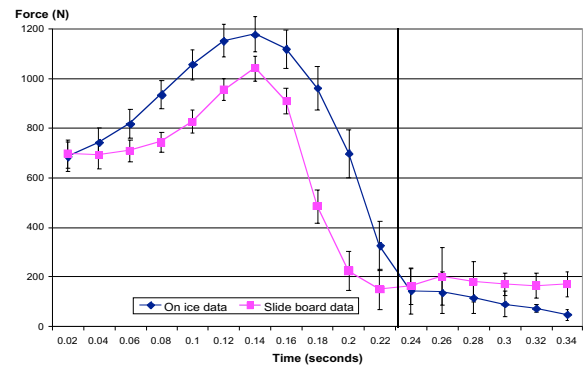


Figure 2: Force throughout the push phase, averaged for 4 subjects. Vertical line indicates end of push.

SUMMARY

This study provides a good indication that the speed skate push can be accurately reproduced on the modified slide board. With the superior kinematic and kinetic data collection equipment that can only be used in-lab the modified slide board has the potential to be a very useful tool in the future investigation of the speed skate push.

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FOUR YEARS FOLLOW-UP OF DIABETES PATIENTS WITH AMPUTATIONS

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INTRODUCTION

Fifty-nine patients with amputations were examined during 1997-2001 years. Ten patients developed plantar ulcers, four patients had new amputations of different level, six patients are dead, and three patients are blind. The purpose of this study is to determine whether it was possible to predict ulcers on the base of dynamics of increasing peak pressure.

METHODS

Eighteen patients, 11 women and 7 men, were selected for current study. The patients had a mean age 59 ± 9 years, duration of diabetes during 18 ± 8 years, and different levels of amputations at the time of first examination. All examined patients were divided in two groups: seven patients without ulcers after first measurement (1st group) and ten patients who developed ulcers between measurements or after the last measurement (2nd group). One patient with 2nd metatarsal head (MH) fracture after last measurement was analysed separately. Plantar pressure distribution measurements were performed with emed-AT-2 system (novel, Germany) using first step protocol. Five dynamic records of each foot were made. Peak pressure (PP) under foot areas was analysed. Automask program was used for definition of toes, forefoot, midfoot and heel areas. Special questionnaire was developed on the base of the questionnaire used in Neuropool study. It includes

ulcer location, month and year of its development, and callus formation. Time diagram of ulcer development, its treatment and amputations were used in understanding the "cause-effect" sequence of ulcer development. ANOVA was used for comparison between groups.

RESULTS AND DISCUSSION

At the 1st measurement PP were significantly higher under 1st MH of left feet and 2nd MH of right feet in 2nd group of patients, PP under 5th MH of left feet were significantly lower. At the last measurement PP under 1st and 2nd MH of left feet, big toe on both feet were greater in the 2nd group. PP measured at the beginning and end of the study are presented in Table 1.

Ulcers were developed under big toe (1), 2nd toe (6), 3rd toe (2), 4th toe (1), 5th toe (1), 2nd MH (1), 3rd MH (1). Location of ulcers under toes was near amputated toe. PP under 2nd and 3rd MH was high before ulcers were developed.

SUMMARY

Peak pressures in the group, that developed plantar ulcers, were significantly higher during the study. However, ulcers were developed not under the areas of high peak pressure. Eighty five percent of ulcers were developed under the toes.

Table 1: Peak pressure (N/cm²) under the foot areas in two groups of patients

Measurement	Foot region	Left/Right	Patients		p
			without ulcers	with ulcers	
First	1 st MH	Left	27.0±16.2	47.7±30.7	0.0004
	2 nd MH	Right	34.4±28.9	38.5±20.1	0.0006
	5 th MH	Left	27.9±20.0	16.4±8.9	0.0005
Last	1 st MH	Left	24.7±15.9	27.4±22.6	0.005
	2 nd MH	Left	22.6±6.9	33.3±16.4	0.0006
	Big toe	Left	15.1±13.7	25.9±17.1	0.02
		Right	13.4±17.4	23.9±18.2	0.01

PRESSURE DISTRIBUTION IN SPINAL ORTHOSES

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INTRODUCTION

The efficacy of brace treatment for children with idiopathic scoliosis has been questioned due to the lack of comprehensive information about wear characteristics. The intent of brace treatment is to prevent further progression of the spinal deformity by applying forces at specific locations and orientations. The goal of this study is to obtain a better understanding of brace mechanics for the treatment of scoliosis. To do this, dynamic measurement during different activities has been recorded.

METHODS

Twelve force transducers (FS01, SenSym Inc.) and one strap-tension transducer were calibrated and inserted into a custom orthotic brace. The brace forces were converted to pressure. The linearity and hysteresis of the force transducer was $\pm 1.0\%$ Full-Scale Span (FSS) and $\pm 0.5\%$ FSS, respectively. The linearity and hysteresis of the strap-tension transducer was $\pm 0.05\%$ FSS and $\pm 0.03\%$ FSS, respectively. Figure 1 shows the locations of the force transducers and the buckle transducer.

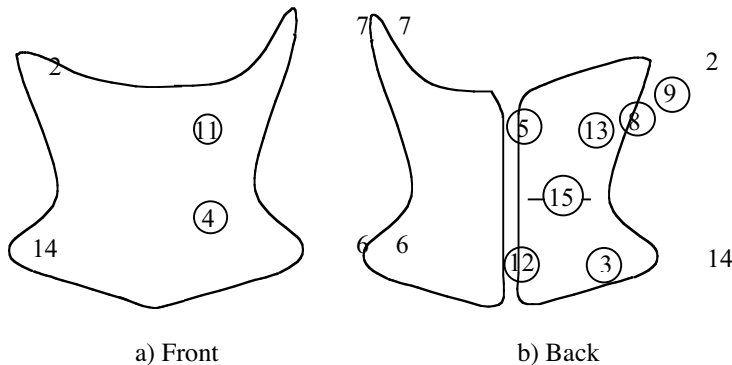


Figure 1. Front and back view of the brace with force (2,3,4,5,6,7,8,9,11,12,13,14) and buckle transducer (15).

LABORATORY EXPERIMENT

All the transducers were tested inside the brace before a subject donned his brace. After a subject wore his brace, two sessions of thirteen activities of standing, left, right, forward and backward bending, sitting, sitting with support, writing, standing with breath-in, supine, left and right sided lying and repeat standing were performed. The purpose of the first session was to allow the brace to seat with the body. Measurements were taken on the second session. At each of the activities, 20 samples were recorded with the sample rate at 0.33 sample/second. The average and standard deviation of the pressure distribution was calculated.

RESULTS AND DISCUSSION

The force applied at the buckle transducer during standing before and after all the activities were $9.1 \pm 2.3\text{N}$ and $8.8 \pm 2.0\text{N}$, respectively. The variations at the measured points were within $\pm 15\%$. This indicated that the measurements were reliable and repeatable. The sagittal and frontal planes components were investigated. Figure 2 shows the resultant pressure (mmHg) applied to the body during standing, sitting and supine. The resultant pressure was higher during sitting and lower during standing. The buckle forces at these three activities were $9.1 \pm 2.3\text{N}$, $36.7 \pm 4.1\text{N}$ and $21.0 \pm 1.9\text{N}$, respectively.

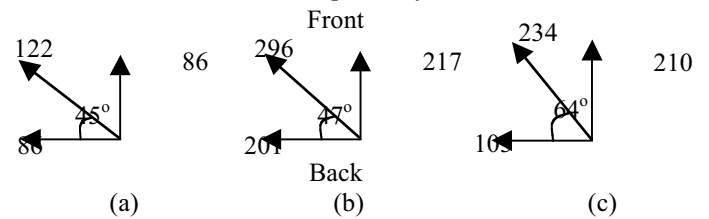


Figure 2 a) Standing b) Sitting, and c) Supine.

During other activities, the buckle force varied from a minimum of $0.2 \pm 0.5\text{N}$ at left sided lying to a maximum of $80.0 \pm 9.6\text{N}$ at forward bending. The pressure on the front side of the brace was relatively low. At location 4, it varied from 5.4 ± 0.5 to $37.4 \pm 17.8\text{mmHg}$; and at location 11, it varied from 1.0 ± 0.6 to $7.2 \pm 4.6\text{mmHg}$. The resultant of these two during standing, sitting and supine were 15.1 ± 3.5 , 20.2 ± 13.7 and $6.6 \pm 1.2\text{mmHg}$, respectively. The sensor at locations 12 and 13 were not exactly perpendicular to the sagittal plane. For standing, sitting, supine positions, the resultant pressure distribution from locations 3, 5, 12 and 13 in the left to right directions were 10.2 ± 4.8 ; 21.4 ± 5.9 and 17.1 ± 4.0 mmHg respectively. The corresponding resultant pressure distribution from locations 3, 5, 12 and 13 in back to front directions were 62.0 ± 11.4 ; $21.72.9 \pm 14.8$; and 142.4 ± 15.5 mmHg, respectively. The corrective components for the right thoracic curve should be mainly from locations 2,6,7,8, 9 and 14. The resultant components of the right to left and back to front directions were 119.4 ± 15.6 and $38.5 \pm 8.2\text{mmHg}$; 216.9 ± 35.2 and $164.5 \pm 19.8\text{mmHg}$; 97.5 ± 7.4 and $65.5 \pm 5.5\text{mmHg}$ during standing, sitting and supine positions, respectively. A higher ratio between right to left and back to front is desirable.

SUMMARY

Posture and activity appear to dramatically alter the mechanical forces applied by the brace. A two-week clinical trial will be conducted to further understand the brace mechanics during daily activities.

EVALUTION OF A FEMALE VOLLEYBALL TEAM REGARDING ANTHROPOMETRICAL, FOOTPRINT IMAGE, PLANTAR PRESSURE DISTRIBUTION AND TREADMILL WALKING VERTICAL FORCE PARAMETERS

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INTRODUCTION

Gait tasks are collected for normative data as well to control any variation that should effect an athlete on his sportive performance. The main goal of this study was however to select highlight biomechanical information for a female volleyball team that should help them during training as well as in preventing injuries and providing better footwear conditions.

METHODS :

Eleven female professional athletes from the Brazilian Superliga Group were evaluated for Lower Limb Anthropometry, Plantar Pressure Distribution (M-Scan System), Footprint Image (Scanning Technique), Vertical Force Parameters during walking at 5 km/h on a instrumented treadmill (Gaitway™).

RESULTS AND DISCUSSION:

The sample main characteristics are presented in the following table. They are all active volleyball players.

Table 1: Mean Values and Standard Deviation for the sample group (n=11)

Age (years)	Height (cm)	Body Mass (kg)	Foot Length (mm)	Foot Width (mm)	Heel Width (mm)
21,73 (3,54)	181,92 (1,70)	72,98 (8,38)	268,51 (15,30)	108,47 (4,87)	63,65 (1,32)

Plantar Pressure Distribution as well as other results should be regarded individually for each athlete.

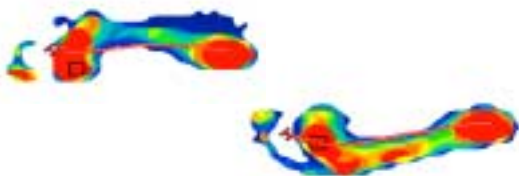


Figure 1: Peak Pressure and COP trajectory during barefoot walking

Anthropometry and Footprint Scanning should be regarded as a alternative for last manufacturing individually.



Figure 2: Scanned Footprints for one athlete.

Plantar Pressure Distribution Parameters as well and GRF should be regarded during establishment of training intensity for prevent the musculoskeletal system to injuries. At the same way this information is essential to define the footwear characteristics needed.

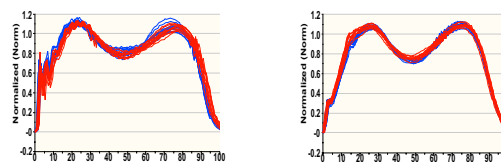


Figure 3: Vertical Component from the Ground Reaction Force, walking at 5 km/h during barefoot (left Side) and shod condition (right side).

Concerning the sports related lower limb control this should be a primary investigation. After this specific motor requirement should be investigated such as landing strategies during jumping for block or attack.

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ACKNOWLEDGEMENTS

To the *Esporte Clube Pinheiros*, São Paulo, SP, Brazil.

THE EFFECT OF MIDFOOT WEDGING ON PLANTAR PLANTAR SURFACE PAIN AND PRESSURE

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INTRODUCTION

Recent research indicates that the soft tissues of the medial longitudinal arch (MLA) undergo minimal change during dynamic activities, such as walking (McPoil & Cornwall, 2002). Although MLA soft tissues may undergo minimal change in contour, patient's still complain of MLA pain when fitted with certain types of foot orthoses. If the soft tissues of the MLA are not undergoing change, then one could hypothesize that the pain felt by patient's is caused by bone movement within the foot that pinches the MLA soft tissues held in check by the foot orthoses. This would be especially true for those patients with excessive bony movement associated with navicular drop. The purpose of this study was to determine if individuals complaining of arch pain when wearing foot orthotics with midfoot wedging have 1) a greater change in navicular drop from neutral standing posture (NSP) to resting standing posture (RSP) or 2) a decreased tolerance for deep pressure on the plantar surface of the foot.

METHODS

Twelve subjects (8 women and 4 men) with no history of lower extremity congenital or traumatic deformity or acute injury 6 months prior to the start of the study consented to participate. The mean age of the subjects was 26.5 years and ranged from 22 to 34 years. Subjects were selected based on the change in navicular height from NSP to RSP with 4 subjects having a minimal change (< than 4 mm) and 4 subjects having maximal change (> than 8 mm) of navicular drop. All 12 subjects were first assessed statically for deep plantar pressure tolerance of both feet using a digital algometer (J-Tech Model # JTU-777) for the following regions: heel, lateral midfoot, medial midfoot, lateral forefoot, central forefoot, and medial forefoot. Each subject then walked on a treadmill while plantar pressures were assessed using the PEDAR insole system and wearing two different foot orthoses with and without midfoot wedging. The foot orthoses were classified using a shore A gauge as soft and Rigid. All subjects walked for 5 minutes on a treadmill at a self-selected speed, prior to pressure data collection. Each subject rated each orthotic condition as painful or non-painful. The five dynamic conditions tested were 1) no orthotic, 2) soft orthotic, 3) rigid orthotic, 4) soft orthotic with wedge, and 5) rigid orthotic with wedge. The mean midfoot wedge height was 10.8 mm. EMED Win software was used to determine dynamic peak pressure (PP) from 8 consecutive footsteps for the same 6 plantar regions as the assessment of static pressures. All subjects used standardized footwear.

RESULTS AND DISCUSSION

Between-trial reliability coefficients for the algometer measurements ranged from .96 to .99 for all 6 plantar regions. The mean static and dynamic peak pressures values are shown in Table 1 by plantar region.

Table 1: Means (\pm SD) for static and dynamic pressures

REGION	PEAK PRESSURE	
	STATIC	DYNAMIC
Heel	656.1 \pm 259.0	172.8 \pm 32.8
Lateral Midfoot	647.8 \pm 248.9	85.7 \pm 13.6
Medial Midfoot	496.1 \pm 162.2	84.6 \pm 38.9
Lateral Forefoot	647.9 \pm 248.9	152.8 \pm 18.8
Central Forefoot	608.9 \pm 261.8	180.3 \pm 6.1
Medial Forefoot	589.1 \pm 197.5	203.8 \pm 21.7

Based on the results of ANOVA, the left and right extremities were not significantly different for either static or dynamic pressures. A series of t-tests indicated that 1) those subjects complaining of arch pain as a result of wearing wedged foot orthoses did not have significantly ($p > .01$) lower static plantar pressures than those subjects not complaining of pain and 2) those subjects complaining of arch pain had a significantly greater ($p < .009$) navicular drop than those subjects not complaining of pain. Although the most common dynamic orthotic conditions producing pain were soft with wedge and rigid with wedge, subjects complaining of pain were not found to have significantly higher dynamic pressures than those not complaining of arch pain.

SUMMARY

The results of this study indicate that individual tolerance levels to deep plantar pressure does not appear to be a factor in whether pain is perceived when wearing foot orthoses wedged in the MLA. Subjects complaining of arch pain as a result of wearing wedged orthotics demonstrate a greater change in navicular drop as measured from NSP to RSP in comparison to those subjects not complaining of pain. These findings support the theory that the foot orthotic induced arch pain is caused by bone movement within the foot that pinches the MLA soft tissues held in check by the foot orthoses.

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PLANTAR PRESSURE DISTRIBUTION PATTERN OF CHILDREN IN DIFFERENT AGES

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PURPOSE OF THE STUDY

To evaluate the plantar pressure distribution in feet of children at the age from five to fifteen.

INTRODUCTION

Plantar pressure was recorded during barefoot walking at self selected speed on a capacitive pressure distribution platform (EMED-AT, 4 sensors/cm²). The pressure platform was built into a five meter long wooden walkway, and from each child five repetitive trials with each foot were collected.

MATERIAL AND METHODS

141 children with no history of foot disability volunteered for this study. A random sample of six age groups were collected (5, 7, 9, 11, 13 and 15 years at the time of investigation). For each pressure measurement trial, seven areas of interest on the foot were identified. The following variables were generated: pressure, force, contact area and contact time. Additionally BMI and lower leg circumference were measured clinically.

RESULTS

The peak pressure showed decreasing values in the lateral forefoot with increasing age, and at the same time increasing values for the medial and central forefoot. In the young age group the peak pressure from the heel region was higher than the one from the big toe, but it changed slowly during growth so the big toe in an adolescent contributed with a higher peak pressure compared to the heel. The peak pressure and maximum force related to the midfoot area and the lateral toes were relatively constant during growth and so was the contact time.

CONCLUSIONS

The plantar pressure distribution pattern in the forefoot during growth changed from a relatively lateral load in a young child to a typical medial load in the teenager. Furthermore, no remarkable differences were seen not even from the midfoot and lateral toes in the years of growth, except for increasing difference between the peak pressure from the heel and the big toe, where the increasing part of the load was related to the big toe.

DYNAMIC PEDOGRAPHY FOR DIAGNOSIS OF TORSIONAL DEFORMITY AFTER INTRAMEDULLARY NAILING OF FEMORAL SHAFT FRACTURES

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INTRODUCTION

Torsional deformities are regularly registered after closed intramedullary nailing of femoral shaft fractures. Range and direction of femoral torsion can be detected by CT imaging comparing the femoral torsion of both femora.

However, the influence of torsional range and direction on the function of human gait is still unclear. To our knowledge, quantitative assessment of gait asymmetry in healed femoral fractures after closed intramedullary nailing has not been performed yet.

PATIENTS AND METHODS

19 patients following isolated femoral shaft fracture treated surgically by closed intramedullary nailing (UFN) were investigated by clinical assessment (Rikli-Schütz-Score) including CT imaging, dynamic pedography and dynamic angular assessment of the sagittal hip and knee angles. Average of follow up time amounted up to 28 months after surgical treatment.

RESULTS

According to CT scans 12 patients had lateral, 6 patients medial torsional deformities, one patient showed a torsional angle difference of 0°. Torsional asymmetries 10° were detected in 5 cases. Torsional range and direction were statistically independent from fracture type, -localization and mode of interlocking.

13 clinical results (58%) were scored „as excellent,, and „good,, applying the Rikli-Schütz-Outcome-Score. Patients with medial torsional deformities had better clinical results than patients with lateral torsional deformities. Altogether, 22% of all torsional deformities could be detected clinically. Clinical outcome and range of torsional deformity did not correlate.

Gait analysis did not show any correlation between change of dynamic sole pressure distribution and the clinical result. A significant shift of sole pressure distribution was observed with patients showing lateral torsional deformities depending on the range of torsion. The angle of foot abduction correlated quite well with the torsional deformity assessed by CT scanning (Pearson $r^2=0,53$).

Dynamic angles of hip and knee movements did not correlate with the range of the torsional angle of the femur.

SUMMARY

Kinetic gait analysis using dynamic pedography is a useful additive tool for diagnosis of the functional result after nailing of femoral shaft fractures which cannot be analysed by clinical or imaging methods.

Dynamic pedography could be used as a screening method for detection of femoral torsional deformities prior to expensive and time-consuming diagnostic procedures.

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THE EFFECT OF HEEL CUPPING ON HEEL PRESSURE DURING SOCCER ACTIVITIES

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INTRODUCTION

The game of soccer requires high levels of dynamic stability. Therefore, soccer shoe outsoles are generally designed with a low profile to keep the athlete close to the ground. For a low profile shoe, the choices for cushioning are limited. During a 90 minute game, soccer players may cover more than 11 km (Bangsbo et al., 1991), mostly running. In addition, there are specific movements such as planting for a kick that involve high peak heel pressure, indicating a need for heel cushioning. These needs are even greater on hard surfaces. The challenge is to design and develop soccer shoes that will provide sufficient heel cushioning without compromising stability.

Cupped heel shoe inserts are commonly used in a variety of clinical, non-surgical applications. The purpose of this study was to evaluate the effect of heel cupping on heel peak pressure during soccer activities

METHODS

Ten active male subjects (180 ± 10 cm & 77.3 ± 8.2 kg) completed 2 running trials (average speed 6.0 m/s) over a 30m dry grass surface, and performed two shots on goal in two shoe conditions: Shoe A was constructed with a flat innersole board, and shoe B with an anatomically contoured innersole board over the heel (cupped heel) and arch regions. Both shoes had identical upper construction and identical outsole plates. The sockliners were removed from the shoes during data collection.

Plantar pressure was collected using the Pedar Mobile in-shoe pressure system at 99 Hz. Peak pressure under the entire foot was measured. This abstract focuses on the heel region. The peak pressures were averaged over all subjects for each shoe condition.

RESULTS

Peak heel pressures were significantly lower in the contoured shoe when planting for a kick ($p < 0.01$) and when running ($p < 0.01$). Peak heel pressures in the support foot during planting were $520 (\pm 97)$ kPa and $443 (\pm 72)$ kPa for the flat and contoured conditions, respectively. The pressure values during running were $285 (\pm 100)$ kPa and $229 (\pm 117)$ kPa for flat and contoured, respectively.

DISCUSSION

A contoured heel design contributed to a reduction of peak pressure during two common soccer movements. It is likely that contouring the heel enhances the ability of the fat pad under the heel to reduce localized load by limiting rapid

displacement of the fat pad under the calcaneal tuberosity and by allowing greater load bearing contact area. This effect was especially evident at higher load levels (e.g., planting for a kick). It seems that a contoured soccer outsole plate could enhance heel cushioning in a low profile manner.

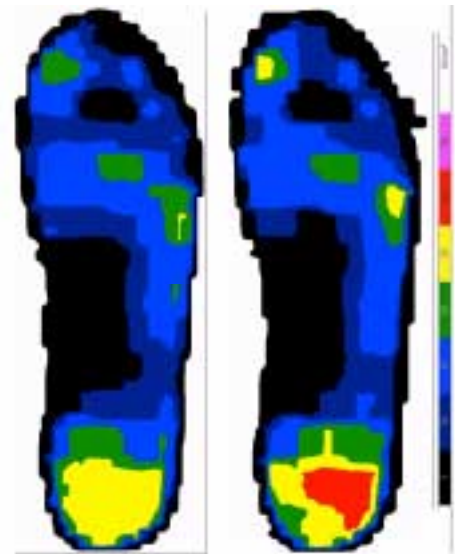


Figure 1. Peak pressures during planting for a kick in a contoured (Left) and flat (Right) innersole board

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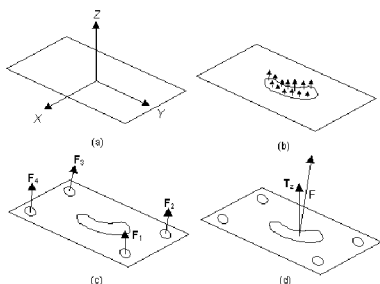
CHARACTERISTICS OF GROUND REACTION FORCES, MOMENTS AND C.O.P. DURING VOLLEYBALL BLOCK-JUMPS

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INTRODUCTION

Strategies to control landing strategies at volleyball should be of interest for injury profilaxy as well as to improve athletes training and performance. The point of application of the ground reaction force on the plate is the **center of pressure (CP)**. All the small reaction forces collectively exert on the surface of the plate at the CP.



METHODS :

Ten male injury-free recreational volleyball players were asked to perform different block jump tasks over two force plates (OR6-5, AMTI, MA, USA). The experimental design controlled seven different block jumps and respectively landing usually performed at volleyball. Each task was performed three times.

RESULTS AND DISCUSSION:

Since the vertical component of the ground reaction force were about 3,3 and 4,5 times the body mass. The highest GRF values, which are discussed here, were obtained during the following block tasks: a) the athlete starts from a position corresponding to the position 4 on the court, with a parallel displacement in relation to the net, swinging the arms to jump (Fig. 1a); b) the athlete starts from a position corresponding to the position 2 on the court crossing the steps during the development, swinging the arms to jump (Fig. 1b).

Figure 1a)

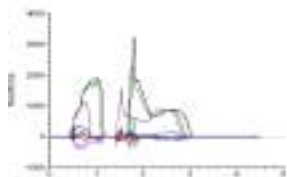
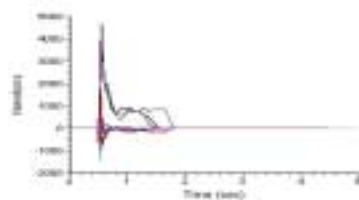


Figure 1b)



The COP was calculated and demonstrated for each block task a different form as well as the torque curves.

Figure 2a)

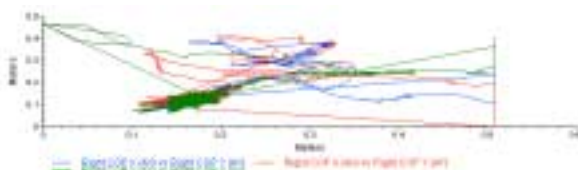
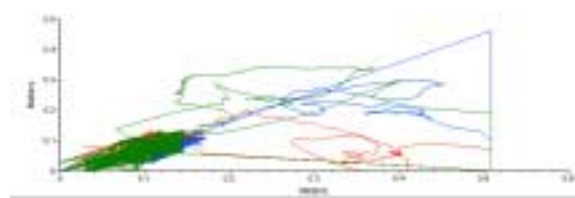


Figure 2b)



Figures 2a and 2b provide information concerning the COPx and COPy displacements. It is to observe that in both cases there is almost no variability for the three performances at small range displacement (between 0,06m and 0,15m). Otherwise there are more variability at bigger COP displacements for both cases. The total COP displacement was smaller for the block jump realized from a position corresponding to position 4 on court than to position 2. It seems to be very important to investigate balance requirements for landing strategies at volleyball block tasks.

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THE EFFECT OF LINER DENSITY ON PRESSURE PATTERNS DURING BICYCLE HELMET IMPACTS

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INTRODUCTION

Head injuries occur as a result of the application of local contact forces and due to inertial loading (Gennarelli, 1987). Assessment of head injury potential associated with inertial loading, however, has been based on acceleration measurements of humanoid headforms. This generalized acceleration does not reflect the magnitude of the local contact pressures applied to the headform during impact or the manner in which protective countermeasures such as helmets distribute these loads over the headform.

In this study a custom pressure sensitive resistive ink transducer was developed to test the hypothesis that localized contact pressure distribution patterns on an anthropometric test headform during bicycle helmet impacts would be significantly different between helmets with different expanded polystyrene (EPS) liner densities.

METHODS

A custom pressure sensitive transducer specifically designed for impact testing was developed and fabricated. The design consisted of 65 individual sensors, each with a sensing area of 31.67 mm², with electrical conducting tracks fitted onto a single sheet transducer (diameter, 15.2 cm). Each transducer was conditioned, calibrated and secured with two-sided tape to an ISO Size E test headform (EN960, 1995).

Identical bicycle helmets in four different EPS densities ranging from 35 kg/m³ to 98 kg/m³ were used for the study. The helmets were impacted at the front left impact location and the right side location using the same flat and hemispherical anvil surfaces used in all international bicycle helmet standards. Drop heights for the 327 impact tests ranged from 0.5 m to 2.0 m in 0.5 m increments. Prior to each test, the helmet was secured to the headform and raised to the appropriate drop height and released. Immediately prior to the impact, a velocity gate provided the driving voltage for the transducer and concurrently triggered the data acquisition system (64 data channels at 7500 Hz per channel). All channels were then calibrated, filtered (1000 Hz low pass) and stored to disk.

RESULTS AND DISCUSSION

The results indicate that pressure distribution patterns during bicycle helmet impacts vary with EPS liner densities. The lowest density of helmet liner produced much lower local sensor pressures on the headform than the higher density liners. Peak contact pressures were significantly lower for the low density helmet liners when compared to the high density helmet liners ($p < .05$). However, at energy levels which must

be considered to be in the range of foreseeable impacts (i.e. 1.5 m), the low density helmet liners were found to fail or “bottom out,, resulting in dangerously high pressures being applied directly to the headform. Figure 1 illustrates how the high pressures are localized over a small area.

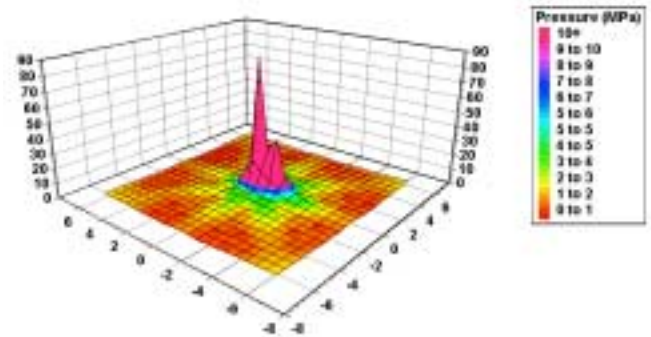


Figure 1: Pressure distribution profile (t = 12 ms after impact) for 1.5 m impact onto hemispherical anvil (x,y = sensor position (cm), z = Pressure (MPa)).

SUMMARY

The integration of resistive ink technology to impact test instrumentation has advanced the understanding of how bicycle helmet liners of different density distribute and transmit local contact pressures during impact. The clear differences in pressure distribution between bicycle helmet liner densities presents a performance trade-off between effective pressure distribution and overall energy absorption. Lower density helmet liners will produce more dispersed pressure distribution patterns but may “bottom out,, whereas the higher density helmet liners will produce more concentrated pressure distribution patterns, but have a much higher upper limit for energy absorption. These trade-offs must be considered in the design of bicycle helmets as well as in the development of appropriate head protection standards.

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ACKNOWLEDGEMENTS

The authors would like to thank the Protective Headgear Manufacturers' Association, Bell Sports Inc., The Head Protection Research Laboratory and American Honda for their support of this project.

ARE SPORTS BRASSIERES TOO TIGHT FOR ACTIVE FEMALES?

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INTRODUCTION

As the female breast contains limited anatomical support, external support, usually in the form of a brassiere, is worn to decrease excessive breast motion and associated breast pain. Although limited research has been conducted in this area, previous studies have shown that sports brassieres are more effective in limiting breast motion and breast pain, compared to standard fashion brassieres (Mason *et al.*, 1999). However, a recent study of young Australian females indicated that only 27% of respondents usually wore a sports brassiere for breast support during exercise. The most popular form of breast support during exercise was the less supportive fashion brassiere. Although cost and fashion-related factors influenced sports brassiere use, 11% of respondents stated that they did not wear sports brassieres during exercise, as they were “too tight around the chest,.. It has been postulated that tighter sports brassieres may impede athletic performance by restricting respiratory function during exercise. As this notion is only speculative, the aim of this study was to investigate if sports brassieres were “tighter, than fashion brassieres and if brassiere design impeded respiratory function during exercise.

METHODS

Ten smaller breasted (A cup) and 10 larger breasted ($\geq C$ cup) healthy active females (23.5 ± 2.5 yrs) were selected for this study, based on professionally fitted brassiere size. After adequate familiarisation sessions the subjects exercised on a treadmill at 70% of their maximal oxygen consumption under three randomly assigned experimental conditions: bare breasted, wearing a fashion brassiere (Berlei “Touched,.) and wearing a sports brassiere (Berlei “UltraSport,.). To assess brassiere “tightness, two custom-designed novel_{gmbh} pliance-sensor pressure strips were attached to the subject’s torso, located directly under the elastic strap of the brassiere gore, during each brassiere condition (see Figure 1). Respiratory volumes were also collected during each trial using standard spirometry techniques. Once each subject had reached a steady state heart rate force, area and pressure data were sampled (50 Hz) for 15 seconds from each sensor strip ($10 \times 1 \text{ cm}^2$ sensors). After completing each trial the subjects were asked to rank their perceived “comfort, of the brassiere using a visual analogue scale. A repeated ANOVA design with one within factor (brassiere design) and one between factor (breast size) was then used to determine if either brassiere design or breast size significantly ($p \leq 0.05$) affected the respiratory, pressure and comfort data.



Figure 1: Novel sensors attached to a subject’s torso

RESULTS AND DISCUSSION

Preliminary results indicate that, for smaller breasted women, sports brassieres imparted significantly more maximal force on the torso of the subjects, in turn, increasing the maximal pressure, and the pressure time integrals. However, this trend was not evident in the larger breasted females, or the respiratory volumes data. This difference in pressure data between the two subject groups may be explained by differences in brassiere construction for the two sizes, despite using the same brassiere make and line for both the A and C+ cupped subjects. Although there was no significant difference between the perceived comfort of the two brassieres, when the subjects were asked which of the two brassieres they would prefer to exercise in, most responded the “sports brassiere,.

SUMMARY

As the causes of breast pain and the consequences of excessive breast motion are not known, brassiere designers need to address structural issues within sports brassiere design that deter active females from wearing them. Although results of the present study indicate that sports brassieres can place more pressure on the torso of some females, there is no evidence to support the notion that “tighter, sports brassieres impede respiratory function during exercise.

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ACKNOWLEDGEMENTS

Thanks to Berlei Australia, the New South Wales Sporting Injuries Committee, and novel_{gmbh}.

THE APPLICATION OF A NOVEL PLIANCE MAT FOR THE MEASUREMENT OF HAND-HANDLE COUPLING FORCE

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INTRODUCTION

The coupling (contact) force of the hand with the handle of a hand-held vibrating tool is known to affect the nature of hand-transmitted vibration and thus the associated health risk. However, reliable methods do not yet exist for quantifying the hand-handle coupling force, specifically for field applications. The coupling force is therefore estimated as the sum of hand feed (push) and grip forces, measured along a specific axis. In this investigation, the application of an *emed* pressure-sensing mat is explored to study the distribution of hand-handle contact pressure, contact force and effective contact area under controlled feed and grip forces.

METHODS

The experiments were performed in the laboratory on a simulated handle that was instrumented to measure the hand grip forces, while a force plate was used to measure the feed force. These inputs were measured simultaneously with the distribution of interface pressure quantified using a Novel Pliance mat. Ten male subjects were employed in the experiments performed with three different handle sizes (30 mm, 40 mm, and 48mm). The subjects applied different combinations of grip force (0, 15, 30, 50, 75 N) and push force (0, 25, 50, 75 N) to the handles and the resulting pressure

distribution was recorded. The measured data provided the hand-handle contact force, location of localized peak pressures and effective contact area as functions of the handle size, grip force and feed force. The data were analyzed to identify relationships between the coupling and the grip and push forces.

RESULTS AND DISCUSSION

The results suggest that a measure of the distribution of contact pressure/force and effective contact area can be obtained using the *emed* pressure sensing mat. The nature of the coupling force between the human hand and a handle, such as that of a hand-held power tool, can thus be effectively investigated. The pressure sensing grid yields a distribution of contact pressure and effective contact area as functions of the hand and handles size. The simultaneous measurements of hand grip and feed forces further permitted a study of relationships between the coupling, grip and feed forces. This initial study revealed that the hand-handle coupling force can be expressed as a linear combination of grip and push forces, where the contribution of the grip force is considerably larger than that of the push force. This force relationship further revealed strong linear dependence on the handle size.

WILL THE SPATIAL RESOLUTION OF PEDOGRAPHIC PLATFORMS AFFECT PLANTAR PRESSURE PATTERNS OF CHILDREN OR ADULTS?

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INTRODUCTION

Pressure distribution measurements are accepted tools for the evaluation of normal and pathologic foot function. Various platform and insole systems are commercially available and may differ with respect to the sensor principle (e.g. capacitive, resistive, piezoelectric) as well as technological aspects like temporal or spatial resolution. The latter aspect has been the issue of previous theoretical considerations (Davis 1996) as well as practical applications (Morlock 1992) and has led to the development of a new high resolution capacitive platform. However, it has not been demonstrated whether the smaller sensors reveal differences in foot loading characteristics and may be especially suitable for the investigation of children's feet. Therefore, the aim of the present study was to compare a standard ST-4 platform with the new ST-9 platform with consideration of potential age effects.

METHODS

Twenty-seven subjects from a wide age range (2 to 33 years) were asked to walk at self-selected speed across two capacitive pressure platforms embedded the floor (Novel ST-4 and ST-9, with 4 and 9 sensors/cm², sensor size 5x5 and 3x3 mm, 50 and 25 Hz data acquisition rate, respectively). Five left and right trials were recorded with each platform. Walking speed was monitored with light gates and kept constant between the two conditions. Plantar pressure patterns were analyzed with respect to peak pressures, forces, impulses and contact areas for 9 regions of the foot (hindfoot, midfoot, metatarsals 1-5, hallux, lateral toes). Comparisons between the two platform conditions were evaluated with the Wilcoxon signed-rank test.

RESULTS AND DISCUSSION

With the higher spatial resolution of the ST-9 platform slightly smaller contact areas were determined (Fig. 1, range 2-11%, significant difference in 7 regions).

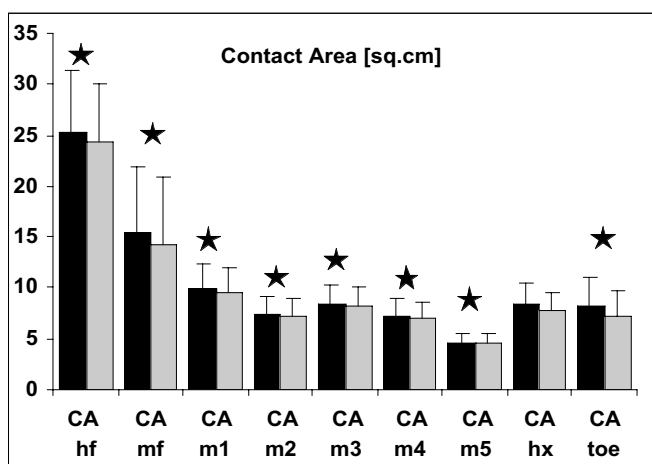


Fig. 1: Contact areas obtained with the ST-4 (black) and ST-9 platform (gray); * = significantly different, $p < 0.05$.

Peak pressure values were generally higher for the ST-9 as compared to the ST-4 platform (Fig. 2, range 2% – 17%, significant for 5 regions). Maximum forces varied depending on the foot region (range -4% – 5%), impulses were slightly smaller for the ST-9 platform (range -10% – 0%).

Correlation analyses did not reveal an age influence on the extent of the differences measured with the two platforms.

The area differences may be explained by the reduced spatial error or the higher accuracy of area calculations that was possible attributable to the smaller sensor size. However, the different temporal resolution of the two systems has to be taken into consideration as well. A lower sampling frequency might prevent the detection of the absolute pressure peak. Therefore, the 25 Hz frequency of the ST-9 platform might even have underestimated the actual pressure peaks so that the differences between the platforms might have been more pronounced if both systems would have recorded with the same sampling frequency.

In conclusion, the results demonstrate that even though there are systematic differences between the two investigated platforms the increased spatial resolution does not reveal a dramatic gain of information even in the feet of small children.

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ACKNOWLEDGEMENTS

Thanks are due to Reising Orthopädietechnik and Novel Munich for providing the ST-9 platform for the measurements.

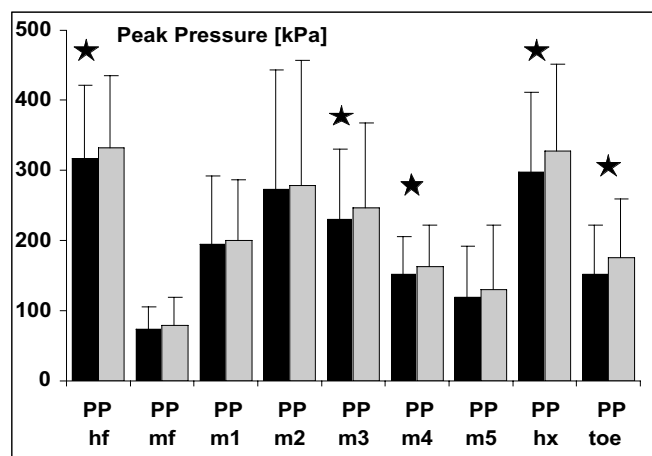


Fig. 2: Peak pressure values obtained with the ST-4 (black) and ST-9 platform (gray); * = significantly different, $p < 0.05$.

**Is relaxation under the saddle measurable?
A study using the pliance system, novel GmbH**

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INTRODUCTION

Man has utilized the horse for thousands of years and today the riding of horses is a still a popular pastime. The well-being and relaxation of the horse under the saddle is the aim of every rider and is dependent on many factors, such as the fitting of the saddle, the riding technique and state of the musculoskeletal system of the horse. Generally, one speaks of relaxation or suppleness if a horse is willing to perform without force from the rider, and answers to the commands of the rider with ease of movement. In addition, a massage, chiropractic or osteopathic therapy, if carried out correctly, will certainly relax the muscles of a horse. However, the unanswered question is if there is an objective and reliable way to measure that suppleness of the horse. The goal of this study was to evaluate if the changes in muscle tone in a horse's back can be measured, and represent a way to assess suppleness. The present study was based on the hypothesis that changes of muscle tone occur after osteopathic or chiropractic therapy, and may be measured with the shape of the contact area and pressure distribution under the saddle. It was also assumed that the pressure sensing pliance system (novel GmbH) has the sensitivity to measure these subtle changes.

METHODS

There were two experimental groups, each of 22 horses of mixed age and gender and all with sore backs. The first group, German Warmbloods, was equipped with English style saddles and measurements were taken before and after osteopathic treatment. The second group, Quarterhorses, was equipped with western style saddles and measurements made before and after chiropractic treatment. The sensor mat (224 sensors) was placed beneath the saddle and in direct contact with the back. The horses were then ridden and pressure measurements taken while standing, at the walk, trot and canter. A clinical back examination was then performed, followed by an examination by an osteopath therapist or a chiropractor, and treated according to their findings. Thereafter, all horses were remeasured with the pliance system and the examinations repeated. Using a scoring system for the degree of back soreness, the findings before and post adjustment were compared and correlated with the changes determined electronically. The analysis of the data was performed with the novel pliance software, using Groupmask evaluation®. Statistical analysis was performed using the ANOVA test for repeated measures for overall differences, and the ANOVA post hoc test for differences

between individual groups. Interaction plots were used to compare the two measurements in individual horses.

RESULTS AND DISCUSSION

Subjectively, the movement and ease of performance improved slightly in the eyes of the riders and the observers after therapy. The scores of the back soreness improved significantly ($P < .05$) in the group treated with chiropractic techniques. Particular changes in surface area pattern and pressure distribution occurred in the group treated with osteopathy such, that the maximum mean pressure values decreased between 0.1 to 0.4 N/cm² overall, whereas the contact area in the middle part of the saddle increased in most instances. However, statistical significance could not be demonstrated ($P > .05$). In the group treated with chiropractic manipulation differences of measured values were also recorded between the first and second measurement, however, in contrast to the osteopathy group, no overall tendency was noted. This could be due to several reasons. All horses had back problems at the time of the initial examination. In addition, the sitting of the saddle was not optimal in all instances and as this could not be altered this could have a negative influence on the results. The difference between groups may also be partially explained by the types of saddle, in that English saddles used in the osteopathy group is much lighter and smaller than the western saddles used in the chiropractic group. Furthermore, different riding styles and abilities of the riders may have influenced the outcome. In conclusion, this study demonstrated that differences in muscle tone may be used to assess suppleness in horses, and the Novel Pliance system is sensitive enough to measure the differences.

SUMMARY

Using the novel pliance system, the distribution pattern of force, pressure and surface area, beneath two types of saddles, was measured in back sore horses prior and after osteopathic/chiropractic adjustment. Measured values are helpful in assessing the suppleness of the horse as a result of changes in muscle tone.

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INTRODUCTION

Paraplegia origins from a severe spinal injury which entails immobility of lower limbs. Paraplegic patients are heavily impaired and lose their locomotor ability. Reciprocating gait orthosis (RGO) is an external mechanic aid which allows the patient to assume and maintain the standing position, and to walk by performing alternate steps. A RGO was instrumented with a set of transducers aimed at recognizing some specific phases of gait; the final target will be to give the patient a bio-feedback, in order to replace the lost sensory feedback of foot-floor interaction. The present study constitutes the final part of the sensorization design, in which a capacitive pressure platform has been used to analyse RGO-supported gait and to accurately relate signals from transducers to each defined contact phase.

Torsion signals and horizontal GRF components showed high inter-subject variability, which rendered them not suitable for a reliable detection of gait phases.

Bar flexion and hip angular excursion were effective in validating the mechanic model, since they resulted to be very similar to the expected curves (minimum flexion at the beginning of the stance phase, maximum flexion at the end).

From their comparison with the vertical GRF component two major findings came out: i) first contact coincides with a sharp decrease of flexion, well identified by the minimum of flexion gradient; ii) last contact coincides with the beginning of hip angle rise. Mean delay of min flexion gradient with respect to the first heel contact was 0.05s; mean delay of hip angle rise with respect to the last contact was 0.04 s. Fig. 2 shows an example of the above curves.

Instrumental set-up

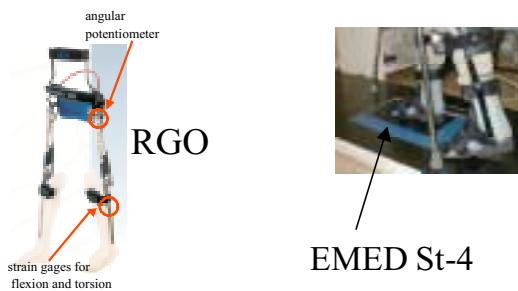


Figure 1: on the left: sensorized advanced RGO; on the right: an instrumented patient stepping over the EMED pressure platform.

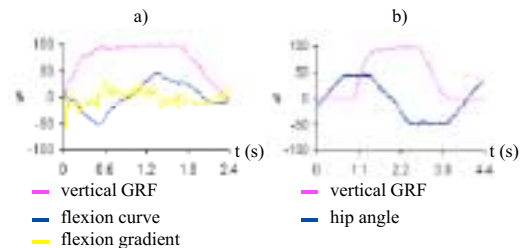
METHODS

An advanced RGO was instrumented with one angular potentiometer, solid with the hip joint, and two full estensimetric bridges mounted to measure flexion and torsion of the leg bar (Fig. 1). Signals were locally conditioned and sampled at 100Hz by means of a commercial A/D converter.

An EMED St-4 pressure platform was used simultaneously with a force platform (Bertec Co.) rigidly fixed just beneath it. Signals from force platform were acquired together with signals from RGO transducers, thus the first heel contact was used as a trigger signal for all measurement instrumentation. Signals from EMED system were acquired at 50Hz and linearly interpolated in order to have 100 samples per second. Force platform also delivered the horizontal components of the ground reaction force (GRF).

RESULTS AND DISCUSSION

8 patients were analysed while walking on a 5.6m long pathway.



Relevant gait signals

Figure 2: identification of main stance phases through RGO transducers. Signals have been normalized to their maximum excursion. Vertical GRF has been synchronized with: a) leg flexion; b) hip angle.

Pressure plantar distribution allowed the accurate study of the correspondence between gait phases and foot contact area. The result is reported in fig. 3, where plantar contact area was subdivided in rearfoot, midfoot and forefoot.

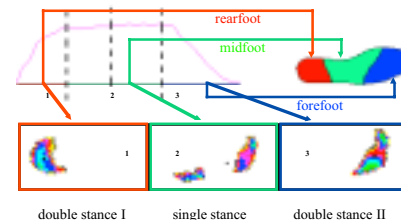


Figure 3: Main phases of RGO gait and the corresponding plantar distribution.

The RGO sensorization design was proved to be effective in identifying some specific gait phases; the acquired signals resulted to be reliable and, apart from bar torsion, showed extremely low inter-subject variability. The accurate reconstruction of interaction times between specific foot subareas and ground will be used as input for a bio-feedback signal to be delivered *on-line* during locomotion.

STANDING POSTURE MAINTENANCE WITH ANKLE ROM CONSTRAINT: A FOOT PRESSURE STUDY

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INTRODUCTION

Ankle foot orthosis (AFO) is an important aid commonly used for the disabled with gait disorder to retrieve the standing and walking activities. It primarily supports the ankle joint at the appropriate position assisting the insufficient ankle joint moment and/or depressing the involuntary ankle joint moment such as in spastic joints. At the same time, such joint support introduces some constraints on the ankle joint movement, but very little attention has been paid for the effects of the ankle joint constraint. This study examines the influence of the range of motion (ROM) constraint by AFO for the standing posture maintenance with the floor translation.

METHODS

Six young healthy males were voluntarily participated and were instructed to stand on the motion platform (MMS-612E2, Mitsubishi Precision, Tokyo, Japan). The forward translation was enforced on the platform with the maximum acceleration of 0.8 m/s^2 for 1.4 seconds. A metal column AFO realized five different ROM conditions on subjects' ankle joints: Case 0 of bare foot without AFO, Case 1 with AFO but no dorsal-plantar ROM constraint, Case 2 with ROM in dorsal direction only, Case 3 with ROM in plantar direction only, and Case 4 with no ROM in dorsal-plantar direction. The motion of lower limb joints were recorded by using the goniometer (M110 and M180, Penny and Giles, Gwent, UK), and the foot pressure distribution as well as the center of pressure (COP) was monitored by the foot pressure sensor (Pedar, Novel, Munich, Germany). The knee joint stiffness was calculated based on the link model in sagittal plane and the resultant reaction force acting on the sole.

RESULTS AND DISCUSSION

The major foot pressure was observed at the thenar eminence region and the heel region. Figure 1 shows the time history of foot pressure contributions in these two regions, and that of the knee joint stiffness. As the result of forward floor translation, the COP went backward first, and then overshoot forward before retrieving the neutral position. The COP trajectory was almost linear in AP direction. Thus, the link model in sagittal plane was used for the knee joint stiffness calculation from the resultant reaction force. At the accelerating floor translation period, the contribution in foot pressure almost vanished in the

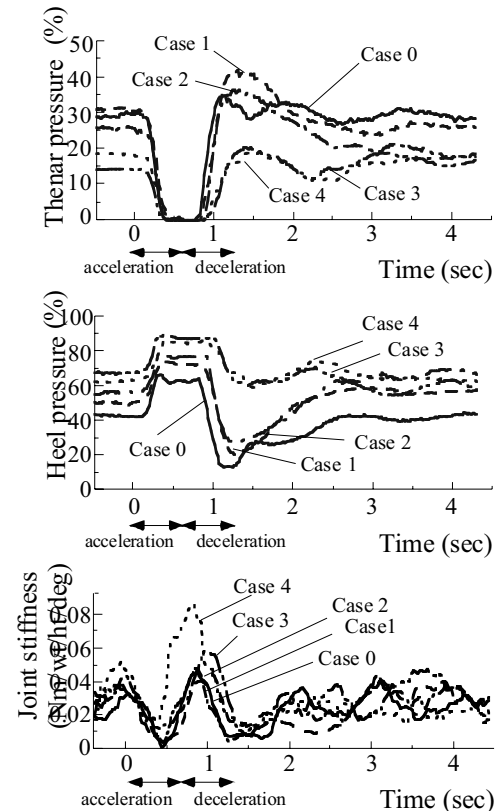


Figure 1 : Foot pressure and knee joint stiffness

thenar eminence region regardless the ROM constraint conditions. However, the increase of the heel region contribution depended on the ROM constraints, and Cases 3 and 4 with no dorsal ROM were different from Cases 1 and 2 with dorsal ROM. This difference was also observed at the both regions during the recovering process of the decelerating floor translation period and the following. The knee joint stiffness was also exhibited some discrepancy between Cases 1 and 2 and Cases 3 and 4 with or without dorsal ROM. These observations suggested us the large influence of the dorsal ROM constraint at ankle joint, and supported the importance of the dorsal flexion on the standing posture maintenance in sagittal plane reported by Mihelj et al. [2000]. Further consideration is expected for the appropriate AFO ankle joint function.

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The effect of orthoses on the plantar pressure distribution pattern in different foot types

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Introduction

Orthoses are often prescribed in the belief that they may reduce or eliminate abnormal or compensatory motion, thus allowing the foot and lower limb to function normally (Bates et.al, 1979). The results of clinical practice are variable and inconclusive (Kilmartin & Wallace, 1994). The mechanism of action of orthoses is poorly understood and their prescription based more on anecdote than science (Razeghi & Batt, 2000). The aim of this study was to compare selected foot pressure measurement variables among subjects who were classified into groups of flat, cavoid, and normal foot configurations based on dynamic foot criteria with and without orthoses during walking and running.

Materials and Methods

45 healthy runners were recruited from running clubs and were classified into flat, cavoid, and normal foot configuration based on criteria of dynamic foot function. Selected plantar pressure variables were compared among groups in each gait condition. Two different orthotic modifications, medial heel posting and heel cushioning, were made and responses to orthoses compared with a group of subjects with normal foot configuration.

Results

Orthotic application did not significantly change the force and pressure distribution beneath the whole of the foot and underneath different regions of the foot. Both orthotic interventions shifted the load in the hindfoot laterally and in the midfoot medially. Similar orthotic modification did not produce the same changes in the normal group. Heel cushioning did not prove to be effective in altering either impact force or pressure beneath the heel.

Conclusion

Small differences found in the selected plantar pressure variables between orthotic and non-orthotic conditions suggest that different intrinsic and extrinsic factors such as individual neuromuscular mechanisms, the type of footwear, and the type of activity appear to play a role in orthotic efficiency. Responses to orthoses appear to be individualised and not predicted by foot type.

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Acknowledgements

The authors would like to thank the Faculty of Rehabilitation, Shiraz University of Medical Sciences, Shiraz, Iran for the financial support of the studentship toward this project. The great help of the Special Trustees of the University Hospital, Nottingham, UK for partially funding the project is acknowledged.

CHANGES OF PLANTAR PRESSURE AND MUSCLE ACTIVITY PATTERNS UNDER THE INFLUENCE OF FATIGUE AFTER EXHAUSTING TREADMILL RUNNING.

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INTRODUCTION

Stress fractures are common running related injuries and often affect the foot, especially the central metatarsals (Matheson 1987, Brukner 1996, Fredericson 1997). Various anthropometric factors have been identified as intrinsic contributions (Korpelainen 2001). Furthermore, rapid changes in the exercise regime are mentioned as extrinsic factors (Lehman 1987). However, the potentially damaging overloading mechanism during sports activities has not been well described yet. Especially, the relation between kinetic and neuromuscular parameters has not been investigated. Therefore, the aim of the present study was to investigate the influence of muscle fatigue on EMG activity and plantar pressure patterns during exhausting treadmill running.

METHODS

Subjects: 30 experienced runners and triathletes (22 men, 8 women). Age 34.5 ± 8.8 years, height 178 ± 8 cm, body mass 69.6 ± 8.9 kg, mileage 61 km/week.

Instrumentation: Capacitive pressure insoles in the left shoe (Pedar Mobile, Novel Munich, 100 sensors, 99 Hz). Surface electromyography (Noraxon Myosystem, 1000 Hz) from 14 muscles of the hip, thigh and shank (left leg only).

Protocol: 8 min. warm-up at moderate speed, running until exhaustion at a speed above anaerobic threshold, 8 min. cool-down. Recording of 20 cycles every 2 minutes.

Parameters: Peak pressure, force, impulse, integrated EMG.

Statistics: Wilcoxon signed-rank-test with $p < 0.05$

RESULTS AND DISCUSSION

The athletes terminated their run at a lactate level of 6.7 ± 1.7 mmol/l and a heart rate of 184 ± 13 beats/min. The pedographic results showed an increase of maximal force, peak pressure and force time integral under the toes, the forefoot, and the medial longitudinal arch during fatigue (Fig. 1). The EMG activity decreased during fatigue especially in the shank muscles (Fig. 2). The changes persisted during cool-down in comparison to warm-up.

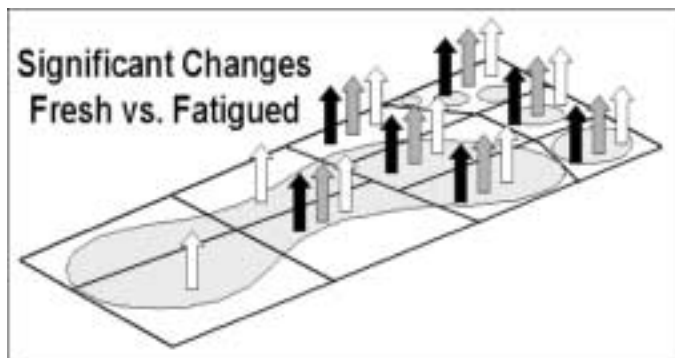


Fig. 1: Significant changes of foot loading parameters after fatiguing running (black: peak pressure, gray: maximum force; white: impulse).

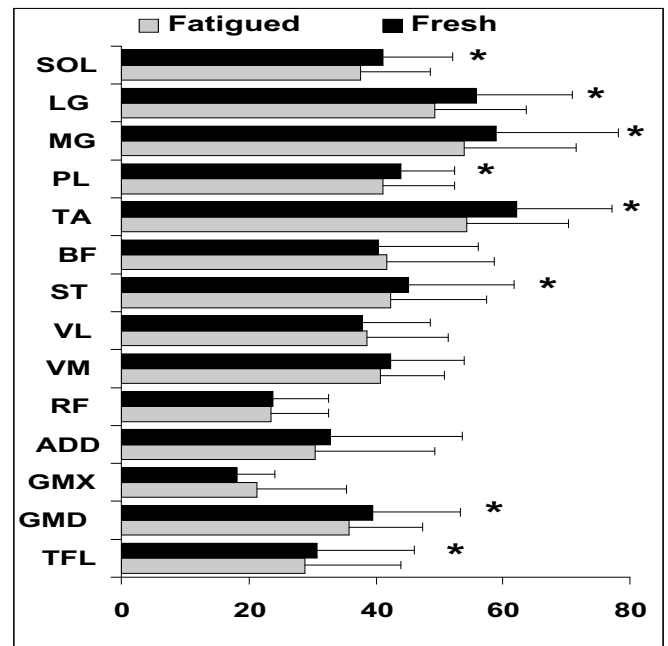


Fig. 2: Mean EMG activity in hip, thigh and shank muscles before (black) and after fatigue running (gray) (* $p < 0.05$) (top to bottom: soleus, lateral & medial gastroc., peroneus longus, tibialis anterior, biceps femoris, semitendinosus, vastus medialis & lateralis, rectus femoris, adductor, gluteus maximus & medius, tensor fasciae latae).

The results demonstrate fatigue-related changes in the plantar pressure patterns during exhausting running that might aid in the understanding of overload injuries in runners. It has to be determined whether the changes are predominantly due to the reduced control during the impact of the landing phase or the push-off. The changes are accompanied by decreased EMG activities that occur predominantly in the shank (and hip) muscles. It has to be noted, however, that no significant correlations between EMG and pressure changes were revealed.

ACKNOWLEDGEMENTS

Thanks are due to the Institute for Sports Medicine, University of Münster (Prof. K. Völker) for the lactate analyses.

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Pressure & Temporal Changes in a Running Shoe Designed to Possibly Trigger the Windlass Mechanism

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INTRODUCTION

A link has been suggested between excessive or ‘abnormal’ pronation (velocity, degree and duration) and overuse injuries in running. There have been plenty of studies on modifications to the rear of the running shoe (varus and valgus wedges) and their effects on rearfoot motion, Milani et al 1995. There have been very few studies on modifications or perturbations to the forefoot of running shoes and their effects on rearfoot motion and changes in temporal parameters.

Medially posted running shoes attempt to control excessive frontal plane motion (calcaneal eversion) during the stance phase as do varus posted orthotics. Frontal plane motion makes up a relatively small percentage (15%) of the total motion of the foot during gait. 70% of the total motion is in the sagittal plane. Recent work by Payne and Dananberg, 1997 have suggested an alternative theoretical framework called the sagittal plane theory explaining the body’s ability to resist forces applied during gait. The sagittal plane theory is based heavily upon the windlass mechanism discovered by Hicks in 1954.

METHODS

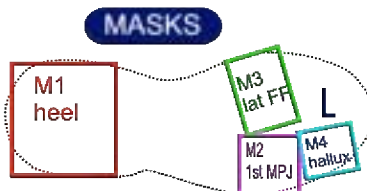
Figure 1: shoe conditions



A running shoe was modified by cutting a 4mm deep window approximately 3.5 cm square directly under the 1st MPJ in the outsole of a size EUR 42.5 running shoe [Figure 1]. 16 healthy subjects (10men & 6 women) all sized EUR 42.5 aged between 20 – 37 mean 22.3 (SD 4.12) and weighing between 65 – 109 kg mean 73kg (SD 11.4). Using the Novel Emed plantar pressure insoles and group analysis software, subjects (all heel toe runners) ran at a speed of 3.6m/s while data was collected for 30 seconds during four trials; control left and right, experimental left and right at a sampling rate of 100hz.

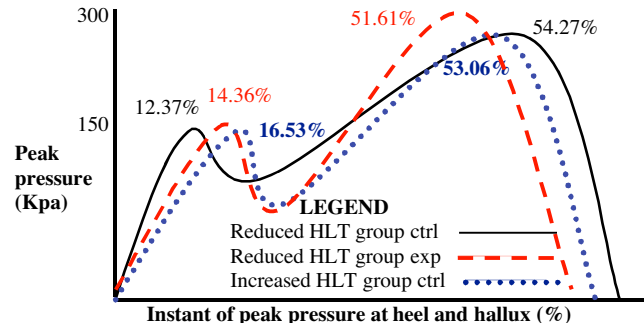
RESULTS & DISCUSSION

Figure 2: placement of masks



Masks were placed over the heel, lateral and medial forefoot and hallux. Parameters chosen for evaluation thought to reveal temporal changes and changes in plantar pressure at the selected regions of interest were; end of ROP (%), contact time (% & ms), peak pressure (Kpa), pressure time integral (Kpa/s) and instant of peak pressure (%) [Figure 2].

Figure 3: trend summary comparing reduced heel lift timing group to increased heel lift timing group; changes in loading rate, peak pressure & 2nd peak timing



Wilcoxon signed ranked tests revealed a statistically significant increase in peak pressure (P .007) at the hallux, a significant decrease in peak pressure at the 1st MP J (P .007) and significant increase in pressure time integral at the hallux (P.037). Trends included an earlier heel lift in 15 of 23 feet evaluated. [Figure 3] The reduced heel lift timing group had a mean heel lift in the control shoe of 67.84%, which was reduced to a mean of 61.65% in the experimental condition. The 8 of 23, which didn’t respond, had a mean control heel lift of 57.26%, which was significantly delayed to 71.93% in the experimental condition.

SUMMARY

Parameters of subtalar joint pronation (velocity, duration and degree) are thought to be very subject specific. One possible explanation for the results might be that the more excessive pronators within the group responded with an earlier heel lift due to an active triggering of the windlass earlier during the stance phase of gait that it would otherwise occurred passively. The ‘non-respond’ group may already have had an ‘optimal’ heel lift timing (57.26%) explaining the opposite response. Further research is merited possibly coupling traditional motion analysis with the use of in shoe plantar pressure data collection to accurately correlate joint motion with changes in pressure and temporal parameters.

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ACKNOWLEDGEMENTS

Shoes for the study supplied by Nike Inc.
Craig Payne, staff and students of La Trobe University, Bundoora, Victoria Australia

INSOLES CAN INCREASE PEAK PRESSURES IN RUNNING SHOES

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INTRODUCTION

Insoles are commonly prescribed for the treatment of overuse injuries such as Achilles tendonitis and anterior knee pain. Reductions in injury have been demonstrated when using these interventions (MacLellan and Vyvyan, 1981). It is commonly claimed that the reported reduction in injury is the result of an increased cushioning of running impacts when wearing insoles compared with footwear alone. However, it has been found that there are no detectable changes in impact forces when insoles are placed in running shoes (Nigg et al. 1988).

A suggested explanation for the finding that impact loading is not reduced when shock absorbing insoles are placed in running shoes is that the shoes already provide adequate cushioning properties prior to the insole being added. Rather than being placed in new shoes, a more realistic use of insoles is in old shoes that the owner feels no longer provide adequate cushioning. It is suggested that the placement of shock-absorbing insoles in old running shoes is more likely to influence peak loads than the placement in new shoes.

The aim of the present study was to compare the peak pressures when running with insoles in new and old shoes. It was hypothesised that the insoles would reduce peak pressures when placed in the old shoes, but that when placed in new shoes they would have no effect.

METHODS

Six female distance runners (mean mass 54 kg; mean weekly mileage 40 miles) were provided with new running shoes (Saucony Jazz 3i). The subjects were asked to wear the shoes for their usual training routine and to stop wearing them on the completion of a total of 300 miles. At a later date, the subjects reported to the laboratory for the recording of pressure measurements.

Pressure data were collected for each subject while running at 3.83 m.s⁻¹ on a treadmill. The influence of two different insole types placed in each subjects' old shoes and in a pair of new shoes was assessed, resulting in six running conditions. Pressure data were recorded at the foot-shoe interface of both feet using an in-shoe pressure system sampling at 500 Hz (footscan®, RSScan, Belgium). For the left and right foot of each subject, average peak values for mask areas at the medial and lateral heel, metatarsal heads and toe were determined over three running steps for each footwear condition. To identify significant differences in group means, a repeated measures ANOVA was used ($p < 0.05$).

RESULTS AND DISCUSSION

Mean group values and standard deviations for peak pressures are presented in Table 1. For insert A, a polyurethane foam, there were no differences in peak pressures across the footwear conditions. However, the use of insole B, a viscoelastic polymer, resulted in a significant increase in peak pressures at the heel in both the new and the old shoe, and additionally the 2nd metatarsal head for the old shoe.

Table 1. Peak pressures for each of the running conditions. Mean values (standard deviation). (*difference from shoe condition, $p < 0.05$).

Foot Area	Medial heel	Lateral heel	2 nd MTP	toe
Old Shoes	34.6 (11.2)	39.9 (11.8)	40.3 (17.7)	38.6 (33.0)
Old Shoes + Insert A	39.8 (24.5)	36.3 (14.7)	46.9 (19.3)	46.0 (31.7)
Old Shoes + Insert B	55.5* (28.9)	58.1* (24.7)	60.5* (18.1)	41.0 (25.8)
New Shoes	35.6 (14.6)	37.7 (15.0)	45.6 (18.2)	40.7 (25.0)
New Shoes + Insert A	30.7 (13.2)	32.5 (10.6)	45.0 (14.8)	32.5 (15.6)
New Shoes + Insert B	51.8* (27.0)	54.3* (22.1)	58.4 (27.8)	32.3 (15.3)

The hypothesis that insoles would have no influence on peak pressures for the new shoes, but would reduce peak pressures when worn in old shoes, has not been supported by the results of the present study. The absence of any detectable influence for insole A agrees with the findings of Nigg et al. (1988), and is likely to be the result of running shoes already providing sufficient cushioning, even after 300 miles. The increase in peak pressures observed for insole B highlights the possibility that the placement of insoles in running shoes can result in an increase in peak loading, rather than the intended reduction.

SUMMARY

The results of the present study suggest that, if a reduction in peak loading is intended, a viscoelastic insole is not an appropriate intervention in running shoes.

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The Neuropool project: A world wide project to develop a database for Diabetic Foot

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INTRODUCTION

The Neuropool project was started to provide an international database that contained information regarding diabetic patient screening and treatment. The aim of the project was to gain a better understanding of the diabetic foot which would allow a physician to predict diabetic foot ulcerations and provide treatment options. The database was to consist of a variety of clinical data and plantar foot pressure measurement data.

METHODS

In collaboration with clinicians and researchers around the world, a prototype of a diabetic questionnaire was developed. The final questionnaire contained a unification of clinical parameters which have been widely used in different standard protocols for diabetic foot assessment. The clinicians and researchers then used the questionnaire to record clinical information about patients. Along with the clinical data, pressure data were also collected. The standardized data collection protocol was based on the CELOS protocol. All pressure data were collected using emed platforms with a spatial resolution of 2 or 4 sensors per cm² and a sampling frequency of 50-70 Hz. The inclusion criterion for the study was a physician diagnosis of diabetes mellitus. Patients with significant macroangiopathy, determined by absent foot pulses, were excluded. Twelve clinical centers worldwide participated in the project.

RESULTS

The resulting current database consists of 760 patients and 6700 plantar foot pressure measurements scanned for completeness, unusual data and/or outliers.

This relational database for diabetic patients contains a variety of information including: personal data, footwear data, daily activity level data (e.g. smoking and alcohol consumption), data relating to systemic diseases (e.g. diabetes types, peripheral neuropathy, retinopathy, nephropathy, rheumatoid arthritis), symptoms of peripheral vascular disease (i.e. the ankle-brachial index), sensitivity disturbances, callus formation and debridement, specification of amputations, ulcerations, deformities (i.e. hallux valgus), measures of joint mobilities and specifications of the skin (i.e. dry skin or swelling and sweating).

Pressure parameters, which have been shown to predict ulcerations, were also included for analysis of the plantar foot pressure measurements. The selected parameters include a foot detection algorithm that automatically provides masking of

anatomical regions of interest (ROI's). Ten ROI's were defined as follows: big toe, the lesser toes, forefoot, midfoot, heel and each of the five metatarsal heads. An automatic calculation and storage of the contact time, force-time integrals, peak pressure and peak pressure-time integral for the ROI's was performed.

SUMMARY

The Neuropool study is an ongoing project and consists of a patient database collected from multiple centers to:

- determine the factors which correlate with high pressure on the plantar surface of the foot
- determine the role that plantar pressure measurements play in early recognition of diabetic neuropathy
- develop an algorithm for predicting ulceration under the diabetic foot using clinical data in combination with pressure distribution measurements

Besides the Neuropool participants, direct access to the Neuropool database by partners will soon be possible using the Internet.

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ACKNOWLEDGEMENTS

We acknowledge the support of research teams contributing data to the Neuropool project and the contribution of Marilyn Lord, Mike Edmonds and Wendy Dodds , King's College Hospital, London, UK
Jim Woodburn, University of Leeds, UK
David Armstrong, University of Texas, San Antonio, USA.
Richard Stess, Veterans Administration Medical Center, USA
Tom McPoil, Northern Arizona University, USA
Peter Cavanagh, Jan Ulbrecht, Pennsylvania State University, USA

PATIENTS WITH MULTIPLE SCLEROSIS: HOW DO THEY WALK?

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INTRODUCTION

Multiple sclerosis (MS) is the most common demyelinating disease of the central nervous system. It usually affects young adults and is characterized by clinical relapses that eventually lead to chronic disability. A variety of MS symptoms may lead to a walking difficulty. Problems with vision, balance, strength, coordination, muscle tone, and sensation can each have an effect on how well a patient is able to walk. The Expanded Disability Status Scale (EDSS) is the most widely used measure of neurological impairment in MS clinical trials. The purpose of this study is to develop approach to assess quantitative changes in the walking of patients with different progression of the disease.

METHODS

Twenty-nine patients, twenty one women and eight men, were examined. The patients had a mean age 34.4 ± 11.1 years, body mass index 21.7 ± 4.4 and EDSS 2.7 ± 1.3 . Nine patients had EDSS equal to 0 or 1.5 (no signs of disability, minimum impairment in functional systems excluding cerebral system) and were accepted as a control group. Plantar pressure distribution measurements were performed with emed-AT-2 (novel, Germany). Five dynamic records of each foot on emed-AT platform were made for each patient. Clinical data were collected using specially developed

questionnaire and novel database pro. novel-projects software was used to calculate peak pressure, contact time, begin and end of contact under anatomic foot areas for each patient and averaged across the patients with the same EDSS. ANOVA was used for comparison between groups.

RESULTS AND DISCUSSION

Contact time was equal to 1110 ± 140 ms for patients with EDSS 0 and 1.5 and was increased to 1278 ± 64 ms ($p < 0.001$) and to 1538 ± 159 ms ($p < 0.0001$) for patients with EDSS equal to 4 and 4.5 correspondingly. Contact time and begin of contact in percent of roll-over-process (%ROP) under metatarsal heads (MH) and toes are presented in table 1.

Contact time is increased because velocity is decreased (35% reduction in velocity was reported by Walker et al., 1999). Increased time of loading lateral forefoot is result of unstable gait the MS patients. Peak pressures equal or greater than 70 N/cm^2 were found at 40% and greater than 90 N/cm^2 – at 25% of patients as a sequence of foot deformities. Loss of sensitivity in concert with increased contact time may be one of the risk factors of foot tissue damage.

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Table 1: Comparison of parameters of roll-over-process.

Foot region	Begin of contact, %ROP			Contact time, %ROP		
	p	EDSS ≤ 1.5	EDSS > 1.5	p	EDSS ≤ 1.5	EDSS > 1.5
3 rd MH	0,002	12±4,6	7,0±6,5	0,2	84,6±5,0	85,8±6,9
4 th MH	<0,0001	12,8±4,0	5,6±6,4	0,002	82,2±5,2	86,0±6,3
5 th MH	<0,0001	14,9±7,2	7,1±6,1	0,007	75,1±6,9	79,4±8,3
Big toe	0,02	18,9±5,1	22,9±18,8	0,01	67,9±13,2	76,5±19,1
2 nd toe	0,002	43,8±12,5	33,3±21,4	0,0003	51,0±14,7	65,2±21,0
Lateral toes	0,005	30,3±24,8	24,3±18,8	<0,0001	50,6±23,4	70,9±20,5

EFFECTS OF RHEUMATOID ARTHRITIS ON FOOT FUNCTION: IMPLICATION FOR SLIPPER DESIGN

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INTRODUCTION

Rheumatoid arthritis (RA) often affects a patient's feet and ankles, leading to reduced muscle strength, restricted joint ranges of motion, distal neuropathy, delayed reaction time, and elevated plantar pressures, particularly under the metatarsal heads (Woodburn & Helliwell, 1996). These conditions contribute to the widespread foot pain and persistent foot deformities characteristic of RA, as well as to abnormal weight bearing, gait disturbance, and footwear difficulties (Woodburn & Helliwell, 1996; Platto et al, 1991). Therefore, slippers are often worn around the home by older women, particularly those with RA (Munro & Steele, 1999), as they lack structure and can mould to the shape of any foot (Marr, 1993). However, slippers tend to become 'sloppy and can provide an insecure base for gait, in turn, creating the potential for the wearer to slip or trip (Marr, 1993). The aim of the present study was to determine the effects of RA on foot function in older women to derive implications for designing safe slippers for wearing around the home.

METHODS

Static and dynamic plantar pressures were sampled (25 Hz) using the emed® AT/4 pressure distribution platform (novel[®] _{gmbh}) for eight older RA women (age = 67.8 ± 7.3 yrs) and eight older unaffected women matched to the RA subjects for age, height and weight (age = 65.3 ± 3.1 yrs). Foot function index (FFI) scores, foot-press reaction time and foot problems were also recorded together with plantar touch sensitivity, assessed at the hallux, 1st and 5th metatarsals, and the heel, using Semmes-Weinstein monofilaments. Ankle plantar flexion and dorsiflexion muscle strength and flexibility were assessed using a manual muscle tester and plastic goniometer, respectively.

Peak pressure (kPa), peak force (N), contact area (cm²), contact time (ms), pressure:time integral (kPa.s), and force:time integral (N.s) data were analysed for 10 plantar masks (PRC) from the maximum pressure print obtained for both static and dynamic trials. A series of independent *t*-tests were used to determine if there was any significant ($p \leq 0.05$) effect of RA on the experimental variables. As there were no significant limb-to-limb differences; all statistical comparisons were completed for the subjects' dominant limbs.

RESULTS AND DISCUSSION

As anticipated with an older population, all but one control subject reported foot problems such as bunions. However, the RA subjects reported significantly greater FFI scores

compared to their unaffected counterparts ($p < 0.01$). The foot problems experienced by the RA subjects appeared to be more severe when compared to the control subjects, contributing to their increased foot pain and greater difficulty when performing daily tasks. Although no significant differences were found between the RA and control subjects for ankle range of motion, reaction time, and plantar sensation, RA subjects had significantly less ankle dorsiflexion ($p = 0.01$) and less plantar flexion ($p = 0.05$) muscle strength compared to the control subjects.

Similar to previous research, RA subjects displayed significantly greater peak forces under the 1st metatarsal head ($p = 0.01$) compared to control subjects under static loading (Woodburn & Helliwell, 1996). However, these differences were not evident during the dynamic trials. Instead, when walking, RA subjects displayed significantly less peak plantar pressure under the 2nd toe ($p = 0.01$), less peak force under the 3rd to 5th toes ($p = 0.02$), and a smaller area under the medial rearfoot ($p = 0.03$). Furthermore, RA subjects displayed high variability in both the pressure and force distribution data. Therefore, it appeared that RA subjects used varying strategies when walking to reduce the dynamic forces and pressures under the metatarsal heads, most of which included an adapted foot loading pattern. Consequently, incorrect and increased ankle and knee joint loading may occur during gait as well as reduced ankle dorsi- and plantar flexion (Platto et al, 1991), perhaps contributing to further strength reductions at the ankle.

SUMMARY

Older women with RA displayed adaptations to their gait which may result from, as well as contribute to, foot pathologies, foot pain, and reduced ankle dorsi- and plantar strength. It is imperative that household slippers are designed taking these factors into consideration to ensure that the slippers themselves do not become a trip or slip hazard for this group of women who have been identified as a high risk group for falls.

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PLANTAR PRESSURE DISTRIBUTION PATTERN IN CHILDREN OPERATED ON FOR CLUBFOOT

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PURPOSE

To evaluate the plantar pressure distribution pattern in children operated on for clubfoot.

INTRODUCTION

Plantar pressure was recorded during barefoot walking at self selected speed on a capacitive pressure distribution platform (EMED-AT, 4 sensors/cm²). The pressure platform was built into a five meter long wooden walkway, and from each child five repetitive trials with each foot were collected.

MATERIALS AND METHODS

Until now 56 children (5-13 years old) with 88 clubfeet have participated in the study. 15 feet were reoperated and therefore excluded for this part of the study. It left 49 children (35 boys, 14 girls) with 73 clubfeet (24 bilateral, 12 right and 13 left) for evaluation. Seven areas of interest on the foot were identified. Pressure, force, contact area and contact time were generated. Foot length, leg length discrepancy and lower leg circumference were measured clinically.

RESULTS

Comparing the normal material following results were found: Peak pressure in all areas of interest were generally lower in all age groups, except for the midfoot area where a higher and more constant pressure in all age groups was seen. The maximum force reacting on the forefoot, was remarkably constant in all age groups with equal load on the medial and lateral side and a constant higher load in the central area. Furthermore the peak pressure in the heel region was decreasing in the years of growth.

CONCLUSIONS

Differences in the plantar pressure distribution pattern in the primarily operated clubfoot compared to a normal material of children in different ages were seen. Compared to this material where a typical change in load and pressure from lateral to medial forefoot in the years of growth were seen, the force reacting on the forefoot in the clubfoot group was equal on the lateral and medial side and did not change during growth. Finally the load related to the heel area decreased in the years of growth which was not seen in the normal material. Plantar pressure and contact area were remarkably higher in the midfoot.

Overview: VIII emed scientific meeting

Wednesday July 31st

18:00 – 21:00 Welcome Reception and Registration.
Gold Ballroom, Kananaskis Conference Center
Drinks and Hors-D'œuvres to be served

Thursday August 1st

Presentations in Silver & Bronze Ballroom, Conference Center
08:45 – 10:30 Session I: Pathologies & Clinical Treatment
10:30 – 11:00 *Coffee Break*
11:00 – 12:00 Session II: 'Novel' methods & innovations
12:00 – 13:15 *Lunch: Pizza Buffet – Fireweed Grill*
13:15 – 14:30 Session III: Novel award presentations
14:30 – 14:45 *Break*
14:45 – 16:00 Session III: Novel award presentations
16:00 – 16:15 *Coffee Break*
16:15 – 18:00 Session IV: You'd better sit down for this.....
18:00 – 19:30 Poster Session – Main Foyer, Kananaskis Conference Center

Friday August 2nd

08:30 – 10:00 **novel** workshop I
Silver & Bronze Ballroom, Conference Center
10:00 – 10:30 *Coffee Break*
10:30 – 12:00 **novel** workshop II
12:00 – 13:15 *Lunch: Box Lunch*
13:30 – 17:30 Activities
White water rafting, horseback riding, or hiking via Boundary Ranch
17:30 – 19:00 *Barbeque Dinner at Boundary Ranch, Kananaskis*

Saturday August 3rd

Presentations in Silver & Bronze Ballroom, Conference Center
08:45 – 10:30 Session I: Sport
10:30 – 11:00 *Coffee Break*
11:00 – 12:00 Session II: 'Novel' innovation & application
12:00 – 13:15 *Lunch: Box Lunch*
13:15 – 15:15 Session III: Gait, posture & locomotion
15:15 – 15:45 *Coffee Break*
15:45 – 16:45 Session IV: Pathologies & Clinical Treatment 2
16:45 – 17:00 Closing Remarks

18:30 – 19:00 Cocktails
19:00 – end *Final banquet and presentation of the novel award.*
Silver & Bronze Ballroom, Conference Center
Music, dancing, and celebration to follow dinner.

Sunday August 4th

10:00 Depart for Calgary