Proceedings

art in science

Dundee, Scotland, July 28 to 31, 2008

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Welcome to Dundee
Welcome to the City of Discovery

Welcome to the Institute of Motion Analysis & Research (IMAR) and the University of Dundee. This international meeting could not have come at a more opportune time as the University is celebrating its 40th Anniversary.

The University of Dundee has been at the forefront in teaching and research in the UK and Europe and has over the last 5 years invested over £50 million on expanding its estate. We have received many awards over the last 2 years: 1st in the UK for Teaching Quality; Best Scientific Workplace in Europe; awarded “Excellent” by the International Student Barometer survey. In June 2008, the Medical School was ranked 1st in the UK according to the Guardian newspaper university league tables.

This is a further accolade to the university being classified among the top 200 universities worldwide. In 1988, when I arrived at the University of Dundee as a postgraduate student, the University had just over 3000 students; we now have over 17,500 students with a turnover of £350 million. Many recent scientific breakthroughs and state-of-the-art facilities have made the University of Dundee an attractive International University which I am proud to be part of.

I never expected the ESM to return to the UK so quickly having been hosted by Jim Woodburn at Leeds in 2004. The aim is to keep this forum ongoing irrespective of where it is being held where old and new friends working in the field of motion analysis towards alleviating pain, correcting deformity and enhancing performance can meet and exchange expertise. I am sure that you will all join me to thank Mr Peter Seitz for his past, current and future support of such events.

The scientific programme will combine 30 oral presentations from over 60 submitted abstracts; a poster presentation session with over 20 exhibitors and 3 workshops for Novel users. We have also organised an exciting Scottish theme-based social programme during your stay with us, including a buffet/dinner at the highest restaurant in the UK at the Cairngorm mountains!

On behalf of the Academic Department of Orthopaedic & Trauma Surgery, IMAR and the University it gives me great pleasure to host the XI ESM; welcome to Dundee, the City of Discovery, and I hope you will enjoy your stay and the special hospitality of Scotland.

Sincerely,

Rami J Abboud
Professor of Education in Biomechanics
Head of Department and Director of IMAR
The ESM 2008 is hosted by the Institute of Motion Analysis & Research (IMAR) in the School of Medicine at the University of Dundee [http://www.dundee.ac.uk/]. From its very beginning the University of Dundee was both inspirational and down to earth; traits that remain its fundamental watermark today. The Nobel Laureate, Seamus Heaney, described the University as an institution “with its head in the clouds and its feet firmly on the ground”. Perhaps the most apt description of the University’s ethos comes from one of its founding father’s, Patrick Geddes, who advised that by “creating we think and by living we learn”.

The University’s origins date back over 100 years to the founding of University College Dundee in 1881. The driving force was a rising demand for the extension of liberal education and the advancement of technical instruction.

Today the University of Dundee has a strong emphasis on the professions, educating more than 70% of its students into the non-business professions - medicine, dentistry, nursing, law and architecture - more than any other Scottish university. It also has thriving arts and science colleges.

With women accounting for over 60% of our student population, the University has long since fulfilled and surpassed the earlier vision of Mary Ann Baxter “promoting the education of persons of both sexes and the study of science, literature and the fine arts”. The above quote translates today to excellence in teaching and research and contributing to the social, economic and cultural life of Scotland.

The high quality of teaching and research at the University, together with the satisfaction ratings of our students, have contributed to a series of high rankings:

- One of the world’s top 200 universities (Times Higher Education Supplement 2007) and the fastest rising Scottish university
- One of the UK’s top 20 universities (Guardian 2008)
- One of the UK’s top 20 for research (Research Fortnight 2008)
- First in the UK for Dentistry (Independent and Guardian 2008)
- First in the UK for Medicine (Guardian 2008)
- Best scientific workplace in Europe according to recent polls of international scientists
- The University has both a 5* rated Medical School and School of Life Sciences, with research expanding from “the cell to the clinic to the community”.
- Since the completion of the £21 million Sir James Black Centre for Inter-Disciplinary Research, the University has a larger medical research complex than the National Institute for Medical Research in London.
- A new £13 million Clinical Research Centre, opened in July 2008, is the latest phase in the development of a holistic research agenda.
- Dundee is also among the UK’s highest generators of per capita research income, much of it focused on medical and life sciences research.

The wider value of the university’s contribution, in terms of its impact upon human lives and society can be seen via the international profile of our teaching and research and the standard of the students on campus today, ready to take their place in shaping and improving the challenges of the 21st century world.
**Venue**
University of Dundee, Scotland

**Workshops**
Institute of Motion Analysis & Research  
University Dept. of Orthopaedic & Trauma Surgery  
TORT Centre at  
Ninewells Hospital & Medical School  
Dundee DD1 9SY  
Tel: +44 (0)1382-496276  
e-mail:imar@dundee.ac.uk

**Conference/ Presentations**
Darcy Lecture and Bonar Hall  
Theatre Tower Building  
University of Dundee  
Dundee DD1 4HN

*Note: The University Campus and Ninewells Hospital are “smoking free” zones (as all public places in Scotland)*

**Host & Conference Chair**
Prof. Rami J Abboud  
University of Dundee  
Institute of Motion Analysis & Research (IMAR)  
University Dept. of Orthopaedic & Trauma Surgery  
Ninewells Hospital & Medical School  
DD1 9SY, Dundee, UK  
e-mail: r.j.abboud@dundee.ac.uk

**Organising Committee**

- Professor Rami Abboud  
- Karla Fretwell  
- Graham Arnold  
- Sadiq Nasir  
- Ian Christie  
- Sven van Sweeden  
- Daniela Jiřová-Enzmann  
- Gabriella Atzori  
- Clelia Berialdi  
- Andrea Kempff  
- Alexander Grahammer  
- Nina Lee
Chairman of the novel award committee
Michael Morlock, PhD, Univ. Prof. Dr. habil. TU Hamburg-Harburg, Denickestr. 15, 21073 Hamburg-Harburg, Germany. e-mail: morlock@tuhh.de


Scientific Committee

Professor Rami Abboud
Head of Department and Director of IMAR
University of Dundee

Dr Weijie Wang
Lecturer in Orthopaedic & Trauma Surgery
Department of Orthopaedic & Trauma Surgery and IMAR
University of Dundee

Dr Carlos Wigderowitz
Consultant Orthopaedic Surgeon
Department of Orthopaedic & Trauma Surgery
University of Dundee

Dr Tim Drew
Lecturer in Orthopaedic & Trauma Surgery
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University of Dundee

Mrs Sheila Gibbs
Senior Clinical Gait Analyst
IMAR
University of Dundee

Scientific Committee

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University of Dundee
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Prof. Benno Nigg
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2500 University Drive N.
T2N 1N4 Calgary, Alberta, Canada
email: nigg@ucalgary.ca

Prof. Julie Steele
University of Wollongong
Biomechanics Research Laboratory
University of Wollongong
Northfields Ave
Wollongong, NSW, Australia
email: julie_steel@uow.edu.au

Dr Weijie Wang
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Lecturer in Orthopaedic & Trauma Surgery
Department of Orthopaedic & Trauma Surgery and IMAR
University of Dundee

Mrs Sheila Gibbs
Senior Clinical Gait Analyst
IMAR
University of Dundee
Workshops

Dr. Axel Kalpen
Professor Rami J Abboud

Graham Arnold
Bharti Rajput
Sheila Gibbs
Sven van Sweeden

Sponsor

Dundee & Angus Convention Bureau

Lord Provost, Dundee City Council

www.novel.de

City of Dundee
The 10th emed scientific meeting held in Bavaria was a superb display of scientific material and a wonderful mix of social and intellectual interaction. This was my first experience at the ESM meeting and with the novel users. I had a wonderful experience!

Axel began the week by giving each novel user the chance to participate in workshops related to pressure measurement. The workshops gave the attendees an opportunity to learn about the new functionalities and to ask questions regarding all novel products.

The next day began in beautiful Bavaria! The day’s agenda was used for scientific presentations and posters. Presentations were given by two keynote speakers and also the presentation and poster novel award winners, Kerstin Bosch and Arne Nagel. Both award winners are from the University of Münster.

After a full day of scientific presentations and discussions everyone relaxed and enjoyed the sunset from the hills of Schliersee. The evening was filled with traditional food and dress from the Bavarian region.

The third day was the Activity Day. Those participants who were very brave chose to go on the 35 kilometer mountain biking tour. Others chose from either the long or short hike. Each activity had spectacular views of the Bavarian Alps. I chose to join the short hike. We had the wonderful Daniela as our guide. She did her best to keep the 30 + people together, but unfortunately some of us gave her a scare by getting too far ahead of the group (sorry Dana!). Everyone was very grateful for each of the novel guides. After a long day everyone relaxed with a gourmet “barbecue” dinner on the island of Wörth. Again the views were beautiful and the conversation stimulating.

The final day of the conference continued the excellent standard of scientific presentation including the remainder of the keynote speakers and novel award presentations. Throughout the day there was much collaboration and discussion based on the research performed and the methods used. Once the scientific aspect of the day ended the evening began with a champagne cocktail hour followed by an exquisite dinner. After dinner was the announcement of the novel award winners by the children of the meeting. Finally the night ended with each participant dancing with the Bavarian dancers.

Of course for some participants the night did not end there, but that is a different story :)!

Thanks to all of those who presented and a special thanks to all of those who spent so many hours organizing the wonderful event!

-by Maria Pasquale from novel INC
5,000 Euro will be presented for the best scientific manuscript in the field of dynamic pressure distribution analysis. Six of these abstracts were nominated for the novel award 2008.

Their authors were requested to send a full length paper until June 15th, 2008, and will present their paper at the meeting in a 25 minutes talk. The paper must be entirely original, not published at the time of the meeting in any journal nor submitted for publication to any journal or book. The paper must describe a scientific study including pressure distribution measurement.

A blind review of papers was conducted by the panel of experts. The novel award 2008 will be presented to the winner at the ESM 2008 banquet evening, Thursday, July 31st, 2008.

Previous Winners (first authors)

- Spitzingsee, 2006: Wolfgang Potthast, Germany
- Leeds, 2004: Joshua Burns, Australia
- Leeds, 2004: Mark Thomson, Germany
- Kananaskis, 2002: Katrina S. Maluf, USA
- Munich, 2000: Matthew Nurse, Canada
- Calgary, 1999: Brian Davis, USA
- Brisbane, 1998: Margret Hodge, Australia
- Tokyo, 1997: Erez Morag, USA
- Pennstate, 1996: Dieter Rosenbaum, Germany
- Ulm, 1994: Michael Morlock, Germany
- Vienna, 1991: Benno Nigg, Canada
ESM Best Presentation award
Will be presented during the closing banquet on Thursday July 31st, 2008.
The award is based on the votes of the committee.
The award winner will receive a prize of 500 Euro.

ESM Best Poster award
Will be presented during the closing banquet on Thursday July 31st, 2008.
The award is based on the votes of the committee.
The award winner will receive a prize of 500 Euro.
**Activity Day**

**Wednesday July 30th 2008**

**Fully day tour visiting**

**Option 1**

**Blair Castle**, the ancient seat of the Dukes and Earls of Atholl. The castle enjoys one of Scotland’s finest settings in the heart of Highland Perthshire. With its roots in the 13th century, Blair Castle’s history extends over some 740 years, during which time it has welcomed countless generations of visitors.

At the gateway to the Grampian Mountains on the route north to Inverness, the location was highly strategic. Today we can enjoy the wild beauty of the surrounding landscape but centuries ago it was a threatening and dangerous place.

**Edradour Distillery** is produced in Scotland’s smallest distillery - and is hand made today as it was over 150 years ago by just three men who are devoted to the time-honoured methods of whisky making. Indeed equipment used at the distillery has remained unchanged since the day the distillery opened and is only just capable of producing commercial quantities. Only 12 casks of whisky are produced a week, making Edradour single malt a rare pleasure for a fortunate few.

Then travel to **Cairngorm Mountain** - Evening Event including dinner in the Ptarmigan Restaurant.

**House of Bruar**

**Option 3**

En route to Loch Morlich the coach will stop at House of Bruar to give delegate the chance to visit the Falls of Bruar, browse round the retail outlet or have a tea/coffee break.

**Loch Morlich Water Sports**

Situated at the foot of the Cairngorm, Loch Morlich is situated right at the heart of the National Park. This beautiful location provides an ideal site for you to enjoy a wide range of activities including

Open Canoeing, Kayaking, Windsurfing, Mountain Biking, Sailing, Woodland Walks, Orienteering, Canoeing

The centre has single kayaks and the larger Canadian style open canoes which take two or three persons. Loch Morlich and the burn, which runs into the loch, are ideal places to enjoy this sport.

**SAILING**

The centre has a fleet of Laser Picos, Toppers and Optimists. The different boats in our fleet offer a range of performance to suit all ages and abilities.

**WINDSURFING**

Stable boards and a full range of specially reduced adult and junior sails. This ensures that the maximum time is spent on the board and not in the water. An introduction on the sandy beach quickly leads to being afloat. Loch Morlich Watersports also offers the following ‘Dry Options’ for Groups

**WALKING, ORIENTEERING, INITIATIVE EXERCISES, MOUNTAIN BIKING**

There are changing facilities at the water sports centre. Fully qualified instructors are on hand at all times.

Then travel to **Cairngorm Mountain** - Evening Event including dinner in the Ptarmigan Restaurant.
Golf Option 4

Burnside course Carnoustie
Responsible Prof. Dr. M. Morlock (morlock@tuhh.de)

Then travel to Cairngorm Mountain - Evening Event including dinner in the Ptarmigan Restaurant.

Cairngorm Mountain Evening Event

Evening Event will include dinner in the Ptarmigan Restaurant and a presentation by Dr Catherine Morduant entitled "CairnGorms: Landscape and Ecology". Eight miles south east of Aviemore and high on the northern flank of Cairn Gorm lies the Cairngorm Mountain Railway.

This funicular railway runs for two kilometers through the Cairngorm ski area. In doing so it climbs 460m to the Ptarmigan top station, 150m below the summit of the mountain. The Cairngorm plateau, mostly above 4,000ft in height, is one of the most rare and fragile environments in Scotland.

However, Cairngorm’s northern corries of Coire Cas and Coire na Ciste have been the location for extensive ski-related development since the opening of the White Lady chairlift here on 23 December 1961.
**Important telephone numbers**

### Dundee

- IMAR (workshops) ☎️ +44 (0)1382 496276
- Bonar Hall (lectures) ☎️ +44 (0)1382 385466
- Prof. Rami Abboud, University of Dundee ☎️ +44 (0)7896093480
- Karla Fretwell, University of Dundee (general enquiries, registration) ☎️ +44 (0)1382 496332
- Tower Building Reception Desk ☎️ +44 (0)1382 388188
- Dundee Police (non emergency) ☎️ +44 (0)1382 223200
- Emergency service (Police, Ambulance, Fire Brigade) ☎️ +44 (0)1382 643242
- Emergency service (Police, Ambulance, Fire Brigade) ☎️ 999
- Edinburgh international airport ☎️ +44 (0)870 040 0007
- Glasgow international airport ☎️ +44 (0)870 040 0008
- National Rails enquiries ☎️ +44 (0)8457 48 49 50
- Taxi in Dundee ☎️ +44 (0)1382 669333
- National car rentals
  - http://www.nationalcar.co.uk/Content/630/uk/Contact-Us
  - Apex City Quay Hotel Dundee ☎️ +44 (0)1382 202 404
  - Hilton Dundee ☎️ +44 (0)1382 229 271
  - Invercarse, Best Western Hotel Dundee ☎️ +44 (0)1382 669 231
  - West Park Hotel Dundee ☎️ +44 (0)1382 229 271
  - Carnoustie Golf Hotel ☎️ +44 (0)1241 411 999

### Munich

- Peter Seitz, novel gmbh ☎️ +49 171 6464612
- Axel Kalpen, novel gmbh ☎️ +49 171 4896669
- Daniela Jiřová-Enzmann, novel gmbh (registration) ☎️ +49 171 6504199
- Alexander Grahammer, novel gmbh (transportation) ☎️ +49 172 8561737

**Events in Dundee & Angus**

You will find the *Tourist Guide* of Dundee & Angus in the conference bag which will be distributed at ESM 2008 registration.
Meeting overview

Monday 28th, July, 2008
Site: Institution of Motion Analysis & Research (IMAR)
New workshops from 13:00

Site: Bonar Hall
Registration from 18:00
Early bird get together 18:00

Tuesday 29th, July, 2008
Site: Darcy Lecture Theatre and Bonar Hall
Registration, coffee and pastries from 08:00
Scientific presentations from 09:00

Site: RRS Discovery Ship
Buffet dinner: civic reception from 18:30
Tour of RRS Discovery ship
Talk by Professor Charles McKean, Professor of history at the University of Dundee

Wednesday 30th, July, 2008
Site: Blair Castle, Edradour Distillery, Ben Vracky, Loch Morlich
Activity day: sightseeing or water sport activity from 09:00
Dinner and evening event in the Cairngorm Mountain from 18:00

Thursday 31st, July, 2008
Site: Darcy Lecture Theatre and Bonar Hall
Registration from 08:30
Scientific Presentations from 09:00

Site: Invercarse Hotel
Scottish-theme Banquet dinner and Ceilidh from 19:45
Novel award ceremony

Invercarse Hotel
Ball room at Invercarse Hotel
### Monday 28th, July, 2008

#### Welcome to ESM 2008

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
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<tbody>
<tr>
<td>13:00 - 17:15</td>
<td><strong>novel Workshops (75 minutes each) at Institution of Motion Analysis &amp; Research</strong>&lt;br&gt;The workshops are consecutive sessions to provide attendees with the opportunity to participate in all three workshops.</td>
</tr>
<tr>
<td>13:00</td>
<td><strong>Workshop I</strong>&lt;br&gt;Basics of Pressure Distribution Measurement and Pedography&lt;br&gt;The following topics will be addressed:&lt;br&gt;– physics of sensors for pressure distribution measurement,&lt;br&gt;– which system (platform, inshoe, sensor mats) is required for which application,&lt;br&gt;– which values are measured and which parameters can be calculated,&lt;br&gt;– basic meaning of measured and calculated parameters</td>
</tr>
<tr>
<td>14:30</td>
<td><strong>Workshop II</strong>&lt;br&gt;Software for the evaluation of pedographic data in the daily clinical routine and in science&lt;br&gt;The following topics will be addressed:&lt;br&gt;– handling of basic patient data in databases,&lt;br&gt;– predefined schemes for analysis of pedographic data in daily routine,&lt;br&gt;– user defined data evaluation,&lt;br&gt;– linking to additional information (pictures, documents) in the databases,&lt;br&gt;– interfaces to other data evaluation software</td>
</tr>
<tr>
<td>16:00</td>
<td><strong>Workshop III</strong>&lt;br&gt;Implementation of Pedography in existing gait labs&lt;br&gt;The following topics will be addressed:&lt;br&gt;– combination of novel systems with other data acquisition systems,&lt;br&gt;– possibilities of synchronization,&lt;br&gt;– software interfaces to control novel programs by third party systems,&lt;br&gt;– common data evaluation and data display</td>
</tr>
<tr>
<td>18:00 - 20:00</td>
<td>Early Bird registration and wine/buffet reception, Bonar Hall, University of Dundee (transportation from IMAR to Bonar Hall after the end of Workshop III; bus departure at 17:45)</td>
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### Tuesday 29th, July, 2008

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>8:00 - 9:00</td>
<td>Registration (coffee &amp; pastry) at Bonar Hall</td>
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<tr>
<td>9:00 - 9:10</td>
<td><strong>Welcome</strong>&lt;br&gt;Sir Alan Langland - Principal &amp; Vice Chancellor&lt;br&gt;Professor Rami Abboud - Conference Chair</td>
</tr>
<tr>
<td><strong>Session 1</strong></td>
<td><strong>Motion</strong>&lt;br&gt;Abboud R J, Institute of Motion Analysis &amp; Research, University of Dundee, Scotland, UK</td>
</tr>
<tr>
<td>9:10 - 10:00</td>
<td><strong>Keynote lecture 1</strong>&lt;br&gt;<strong>Black S</strong>&lt;br&gt;The changing face of anatomy and its role in research and service provision</td>
</tr>
</tbody>
</table>
## Session 2

**Chair**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:12 – 10:24</td>
<td>Correlation between plantar pressure and Oxford foot model kinematics</td>
<td>Stebbins J, Giacomozzi C, Theologis T</td>
</tr>
<tr>
<td>10:24 – 10:36</td>
<td>Relationship between ankle mobility and plantar pressure distribution during gait in diabetic neuropathic patients</td>
<td>Hamamoto A, Onodera A, Gomes A, Sacco I</td>
</tr>
<tr>
<td>10:36 – 10:48</td>
<td>Changes in plantar contact area and gait after chemodenervation in acquired brain injury</td>
<td>Nolan K J, Savalia K K, Yarossi M, Elovic E P</td>
</tr>
<tr>
<td>10:48 – 11:00</td>
<td>Can reductions in bra band pressure increase comfort during exercise in lumpectomy patients?</td>
<td>Gho S A, Steele J R, Munro B J</td>
</tr>
<tr>
<td>11:00 – 11:30</td>
<td>Coffee break</td>
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</tbody>
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### Session 2 Finalist Award I

**Chair**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30 – 11:55</td>
<td>From “first” to “last” steps in life - pressure patterns in three generations</td>
<td>Bosch K, Nagel A, Weigend L, Rosenbaum D</td>
</tr>
<tr>
<td>11:55 – 12:20</td>
<td>Changes in lower extremity loading during cutting movements at controlled slipping velocities and amplitudes</td>
<td>Kersting U G, Bulsink V E</td>
</tr>
<tr>
<td>12:20 – 12:45</td>
<td>High plantar pressures and foot pain: are they contributing to falls in older patients?</td>
<td>Mickle K J, Munro B J, Lord S R, Menz H B, Steele J R</td>
</tr>
<tr>
<td>12:45 – 14:00</td>
<td>Lunch break</td>
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</table>

### Session 3

**Chair**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00 – 14:12</td>
<td>Pressure pattern alterations and foot deformities in diabetes and rheumatoid arthritis</td>
<td>Martelli F, Giacomozzi C, D’Ambroggi E, Uccioli L, Nagel A, Rosenbaum D</td>
</tr>
<tr>
<td>14:12 – 14:24</td>
<td>Follow-up of multiple sclerosis patients with different neurological status</td>
<td>Tsvetkova T, Stoliarov I, Ivko D, Ilves A, Prakhova L, Nikiforova I, Lebedev V</td>
</tr>
<tr>
<td>14:36 – 14:48</td>
<td>The additional value of reporting pressure-time integral results in foot pressure studies on the diabetic foot</td>
<td>Bus S A, Waaijman R</td>
</tr>
<tr>
<td>Session 4</td>
<td>Poster &amp; Coffee</td>
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<tr>
<td>15:00 - 16:00</td>
<td>The effect of the Additional Weight during Pregnancy on Plantar Pressure Distribution of the Female Foot</td>
<td></td>
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<tr>
<td>Hömme A-K, Hennig E M, Hottgenroth J</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brauner T, Milani T L, Sterzing T, Oriwol D</td>
<td>Usage of Discrete Pressure Sensors to Determine Rearfoot Motion During Heel-to-Toe Running</td>
<td></td>
</tr>
<tr>
<td>Miu S, Capris G, Constantin S, Bucur D</td>
<td>Method for assessing the gait energy cost by recording the vertical component of the ground reaction force</td>
<td></td>
</tr>
<tr>
<td>Reed L F, Urry S R, Wearing S C</td>
<td>A preliminary investigation of plantar loads in feet with Hallux Valgus during bipedal and unipedal stance</td>
<td></td>
</tr>
<tr>
<td>Lau H C, Stansfield B, Solomonidis S, Wearing S, Pepper M</td>
<td>Time dependent characteristics of the &quot;Kent&quot; triaxial force transducer system for in-shoe load distribution measurement</td>
<td></td>
</tr>
<tr>
<td>Ribeiro A, de Souza F, Sacco I, João S</td>
<td>Analysis of the plantar pressure distribution in gait during pregnancy</td>
<td></td>
</tr>
<tr>
<td>Aliberti S, Costa M, Sacco I</td>
<td>Loads imposed to the painful leg versus the pain free leg during stair descent in patellofemoral pain syndrome</td>
<td></td>
</tr>
<tr>
<td>Aliberti S, Costa M, Sacco I</td>
<td>Relationship between plantar pressure and patellofemoral pain syndrome during gait</td>
<td></td>
</tr>
<tr>
<td>Bourke G</td>
<td>Pedobarographic examination of three post operative shoes utilised in forefoot surgery</td>
<td></td>
</tr>
<tr>
<td>Gurney J K, Kersting U G</td>
<td>Asymmetry between left and right plantar loading during gait in non-diabetic and neuropathic- diabetic populations</td>
<td></td>
</tr>
<tr>
<td>Prionidis I, Browne T, Taylor M, Mootanah R</td>
<td>An intermittent graduated pneumatic compression boot for the treatment of venous ulcers</td>
<td></td>
</tr>
<tr>
<td>Session 4</td>
<td>Poster &amp; Coffee</td>
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<tr>
<td>15:00 - 16:00</td>
<td>Giacomozi C, De Maiti G, Orlandini D, Raggi M, Rogante M</td>
<td>Assessment of transtibial amputees’ gait in clinical practice: semi-quantitative kinematics to integrate pedar gait analysis</td>
</tr>
<tr>
<td></td>
<td>Dietze A, Mittlmeier T</td>
<td>Kraftsimulator intraoperative pedography (KIOP) - an experience of the clinical application</td>
</tr>
<tr>
<td></td>
<td>Arts M L J, Bus S A</td>
<td>Reliability and validity of in-shoe plantar pressure data measured in neuropathic diabetic patients</td>
</tr>
<tr>
<td></td>
<td>Hillstrom H, Giacomozi C, Lenhoff M, Zifchock R, Vanadurongwan B, Gross D, Mclennan C, Hannan M</td>
<td>Accuracy of the novel emed®-x and Tekscan matscan plantar pressure measurement systems</td>
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<td></td>
<td>Stine R, Hansen A, Tucker K, Boutwell E, Gard S</td>
<td>A Preliminary Study of the Effects of Gel Liner Thickness on In-Socket Residual Limb Pressures in Trans-Tibial Prosthesis Users</td>
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## Tuesday 29th, July, 2008 - cont.

<table>
<thead>
<tr>
<th>Session 5</th>
<th>Biomechanics</th>
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<tbody>
<tr>
<td>Chair</td>
<td>Cornwall M, Department of Physical Therapy and Athletic Training, University of Arizona, USA</td>
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### Keynote lecture 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>16:00 - 16:50</td>
<td>Taylor M</td>
<td>Finite element modeling of the foot: a review</td>
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<tr>
<th>Time</th>
<th>Title</th>
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<tbody>
<tr>
<td>16:50 - 17:02</td>
<td>Changes in foot loading from bipedal to unipedal stance are site specific and highlight the importance of toe function</td>
</tr>
<tr>
<td>17:02 - 17:14</td>
<td>Foot dimensions and plantar distribution parameters of soldiers before and after marching with load</td>
</tr>
<tr>
<td>17:14 - 17:26</td>
<td>Effect of foot orthoses contour on pain perception in individuals with anterior knee pain</td>
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### Evening event

<table>
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<tr>
<th>Time</th>
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<tr>
<td>18:15</td>
<td>Bus depart from Bonar Hall to the Civic Reception at Discovery Ship</td>
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</table>
| 18:30 - 22:30 | Buffet dinner: civic reception  
|            | Tour of RRS Discovery ship  
|            | Talk by Professor Charles McKean, Professor of history at the University of Dundee          |
| 22:30     | Bus depart for hotels Apex, Hilton, Travelodge and West Park                                |

## Wednesday 30th, July, 2008

<table>
<thead>
<tr>
<th>Activity day</th>
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<tbody>
<tr>
<td>9:00</td>
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<td>10:00</td>
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<tr>
<td>18:00</td>
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<tr>
<td>22:30</td>
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</table>
### Session 6  
**Chair**: Steele J, Biomechanics Research Laboratory, University of Wollongong, Australia  
**Keynote lecture 3**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>09:00 - 09:50</td>
<td>Cornwall M</td>
<td>Beyond the diabetic patient: using plantar pressure analysis to study mechanical foot dysfunction</td>
</tr>
<tr>
<td>09:50 - 10:02</td>
<td>Trautmann C</td>
<td>Plantar pressure distribution in fencing shoes</td>
</tr>
<tr>
<td>10:02 - 10:14</td>
<td>Orendurff M S</td>
<td>Metatarsal fracture prevention: can a more flexible boot reduce 5th metatarsal head pressures during sporting maneuvers</td>
</tr>
<tr>
<td>10:14 - 10:26</td>
<td>Strauss D N</td>
<td>Plantar pressure distribution during tennis specific movements performed on the 3 grand slam court surfaces</td>
</tr>
<tr>
<td>10:26 - 10:38</td>
<td>Song J</td>
<td>Can 9 weeks of iyengar yoga alter dynamic plantar pressure?</td>
</tr>
<tr>
<td>10:38 - 10:50</td>
<td>Hetsroni I</td>
<td>Static and dynamic analysis of foot structure in athletes sustaining proximal fifth metatarsal stress fracture</td>
</tr>
<tr>
<td>10:50 - 11:02</td>
<td>Hesslow V</td>
<td>The influence of surface in the medial and lateral foot areas during running on the grass and asphalt</td>
</tr>
<tr>
<td>11:02 - 11:30</td>
<td>Coffee break</td>
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</table>

### Session 7  
**Chair**: McPoil T, Department of Physical Therapy and Athletic Training, University of Arizona, USA  
**Finalists Award II**

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
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<tbody>
<tr>
<td>11:30 - 11:55</td>
<td>Teyhen D S</td>
<td>Dynamic plantar pressure parameters predictive of static arch height index</td>
</tr>
<tr>
<td>11:55 - 12:20</td>
<td>Höhne A</td>
<td>Plantar pressure distribution in gait is not affected by targeted reduced plantar cutaneous sensation</td>
</tr>
<tr>
<td>12:20 - 12:45</td>
<td>Wearing S C</td>
<td>Bulk compressive properties of the heel fat pad during walking: a pilot investigation in plantar heel pain</td>
</tr>
<tr>
<td>12:45 - 14:00</td>
<td>Lunch &amp; Poster</td>
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<tr>
<td>Session 8</td>
<td>Technology</td>
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<tr>
<td><strong>Chair</strong></td>
<td><strong>Rosenbaum D, Movement Analysis Laboratory, University of Muenster, Germany</strong></td>
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</tr>
</tbody>
</table>
| 14:00 - 14:12 | Assessing gait asymmetries using pedobarographic statistical parametric mapping  
| | Pataky T C, Parker D, Goulermas J Y, Crompton R H |
| 14:12 - 14:24 | Comparison of parameters produced by emed and pedar pressure measuring systems  
| | Maliotou D, Theodorou D, Tsvetkova T |
| 14:24 - 14:36 | The feasibility of intra-operative plantar pressure assessment  
| 14:36 - 14:48 | Combination of morphology and plantar pressure distribution in a single graphical presentation for clinical application  
| | Hömme A, Hennig E M |
| 14:48 - 15:00 | Dynamic plantar pressure parameters predictive of foot posture  

**Keynote lecture 4**  
15:00 - 15:50  
Woodburn J  
Foot related impairment and disability in rheumatoid arthritis: plantar pressure measurement and gait analysis

| **Coffee break** |
| 15:50 - 16:20 |

<table>
<thead>
<tr>
<th>Session 9</th>
<th>Rehabilitation</th>
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<tbody>
<tr>
<td><strong>Chair</strong></td>
<td><strong>Bochdansky T, University Teaching Hospital, Feldkirch, Austria</strong></td>
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</table>
| 16:20 - 16:32 | Analysis of plantar pressures in a post-surgical walking boot with and without a contralateral limb length adjustment device  
| | Song J, McDonald P, Kihm C, Nimick C, Heilman B, Zoltick E, Hillstrom H |
| 16:32 - 16:44 | The efficacy of a removeable vacuum cast replacement system in reducing plantar forefoot pressures in diabetic patients  
| | Waaijman R, Arts M L J, Manning E A, Bus S A |
| 16:44 - 16:56 | Plantar pressure results following non-operative treatment for clubfoot  
| | Jeans K A, Karol L A |
| 16:56 - 17:08 | Vacuum cushioned removeable cast walkers reduce foot loading in patients with diabetes mellitus  
| | Nagel A, Rosenbaum D |
| 17:08 - 17:20 | The effect of vibration on bone-cement interface in cemented hip arthroplasty to withstand load transferred between the bone and cement  
| | Talih S, Drew T, Abboud R J |
| 17:20 - 17:30 | Closing remarks: Mr Peter Seitz & Professor Rami J Abboud |
Evening event

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
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<tbody>
<tr>
<td>19:00</td>
<td>Bus pick up from hotels Apex, Hilton, Travelodge and West Park for Invercarse Hotel</td>
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<tr>
<td>19.45 - 00:00</td>
<td>Conference dinner at Invercarse Hotel: Evening organized by Mr Douglas who will give the Selkirk Address at the beginning and address the Haggis. Additionally included a small presentation by Mr Brian Wilton, Director of the Scottish Tartan Authority, on Tartan and to round off the evening a Ceilidh (Scottish Dancing).</td>
</tr>
<tr>
<td>00:00</td>
<td>Bus depart from Invercarse Hotel for the hotels Apex, Hilton, Travelodge, West Park</td>
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</table>
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T1 **KEYNOTE LECTURE:**
THE CHANGING FACE OF ANATOMY AND ITS ROLE IN RESEARCH AND SERVICE PROVISION
Black S

T2 **AN INTEGRATED APPROACH TO THE ASSESSMENT OF DIABETIC PATIENTS GAIT - UNCOVERING THE PIVOTAL ROLE OF MUSCLE DYSFUNCTION IN FOOT ULCERATION**

T3 **CORRELATION BETWEEN PLANTAR PRESSURE AND OXFORD FOOT MODEL KINEMATICS**
Stebbins J, Giacomozzi C, Theologis T

T4 **RELATIONSHIP BETWEEN ANKLE MOBILITY AND PLANTAR PRESSURE DISTRIBUTION DURING GAIT IN DIABETIC NEUROPATHIC PATIENTS**
Hamamoto A, Onodera A, Gomes A, Sacco I

T5 **CHANGES IN PLANTAR CONTACT AREA AND GAIT AFTER CHEMODENERVATION IN ACQUIRED BRAIN INJURY**
Nolan K J, Savalia K K, Yarossi M, Elovic E P

T6 **CAN REDUCTIONS IN BRA BAND PRESSURE INCREASE COMFORT DURING EXERCISE IN LUMPECTOMY PATIENTS?**
Gho S A, Steele J R, Munro B J

T7 **FROM "FIRST" TO "LAST" STEPS IN LIFE - PRESSURE PATTERNS IN THREE GENERATIONS**
Bosch K, Nagel A, Weigend L, Rosenbaum D

T8 **CHANGES IN LOWER EXTREMITY LOADING DURING CUTTING MOVEMENTS AT CONTROLLED SLIPPING VELOCITIES AND AMPLITUDES**
Kersting U G, Bulsink V E

T9 **HIGH PLANTAR PRESSURES AND FOOT PAIN: ARE THEY CONTRIBUTING TO FALLS IN OLDER PATIENTS?**
Mickle K J, Munro B J, Lord S R, Menz H B, Steele J R

T10 **PRESSURE PATTERN ALTERATIONS AND FOOT DEFORMITIES IN DIABETES AND RHEUMATOID ARTHRITIS**
Martelli F, Giacomozzi C, D'Ambrogi E, Uccioli L, Nagel A, Rosenbaum D

T11 **FOLLOW-UP OF MULTIPLE SCLEROSIS PATIENTS WITH DIFFERENT NEUROLOGICAL STATUS**
Tsvetkova T, Stoliarov I, Ivko O, Ilves A, Prakhova L, Nikiforova I, Lebedev V

T12 **PRESSURE PATTERNS IN PATIENTS WITH RHEUMATOID ARTHRITIS: THE RELEVANCE OF A MULTI-CENTRE EXPERIENCE**
Giacomozzi C, Martelli F, Nagel A, Rosenbaum D, Turner D, Woodburn J

T13 **THE ADDITIONAL VALUE OF REPORTING PRESSURE-TIME INTEGRAL RESULTS IN FOOT PRESSURE STUDIES ON THE DIABETIC FOOT**
Bus S A, Waaijman R

T14 **MORNING STIFFNESS INFLUENCES FOOT LOADING PATTERNS IN PATIENTS WITH RHEUMATOID ARTHRITIS**
Nagel A, Kiene B, Peikenkamp K, Hammer M, Rosenbaum D

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| T15 | KEYNOTE LECTURE: FINITE ELEMENT MODELING OF THE FOOT: A REVIEW | Taylor M | 38 |
| T16 | CHANGES IN FOOT LOADING FROM BIPEDAL TO UNIPEDAL STANCE ARE SITE SPECIFIC AND HIGHLIGHT THE IMPORTANCE OF TOE FUNCTION | Urry S R, Reed L F, Wearing S C | 40 |
| T18 | EFFECT OF FOOT ORTHOSES CONTOUR ON PAIN PERCEPTION IN INDIVIDUALS WITH ANTERIOR KNEE PAIN | McPoil T G, Vicenzino B, Cornwall M W | 43 |
| T19 | KEYNOTE LECTURE: BEYOND THE DIABETIC PATIENT: USING PLANTAR PRESSURE ANALYSIS TO STUDY MECHANICAL FOOT DYSFUNCTION | Cornwall M | 44 |
| T20 | PLANTAR PRESSURE DISTRIBUTION IN FENCING SHOES | Trautmann C, Rosenbaum D | 45 |
| T22 | PLANTAR PRESSURE EXPERIENCED DURING TENNIS SPECIFIC MOVEMENTS PERFORMED ON THE 3 GRAND SLAM COURT SURFACES | Strauss D N, Messenger N, Utley A, Brooks P, Miller S | 47 |
| T24 | STATIC AND DYNAMIC ANALYSIS OF FOOT STRUCTURE IN ATHLETES SUSTAINING PROXIMAL FIFTH METATARSAL STRESS FRACTURE | Hetsroni I, Nyska M, Mann G, Segal O, Maoz G, Ben-Sira D, Lifshitz L, Ayalon M | 49 |
| T25 | THE INFLUENCE OF SURFACE IN THE MEDIAL AND LATERAL FOOT AREAS DURING RUNNING ON THE GRASS AND ASPHALT | Tessutti V, Pereira C S, Sacco I | 50 |
| T27 | PLANTAR PRESSURE DISTRIBUTION IN GAIT IS NOT AFFECTED BY TARGETED REDUCED PLANTAR CUTANEOUS SENSATION | Höhne A, Stark C, Brüggemann G-P | 52 |
| T29 | ASSESSING GAIT ASYMMETRIES USING PEDOBAROGRAPHIC STATISTICAL PARAMETRIC MAPPING | Pataky T C, Parker D, Goulermas J Y, Crompton R H | 54 |
T30 COMPARISON OF PARAMETERS PRODUCED BY EMED AND PEDAR PRESSURE MEASURING SYSTEMS
Maliotou D, Theodorou D, Tsvetkova T

T31 THE FEASIBILITY OF INTRA-OPERATIVE PLANTAR PRESSURE ASSESSMENT

T32 COMBINATION OF MORPHOLOGY AND PLANTAR PRESSURE DISTRIBUTION IN A SINGLE GRAPHICAL PRESENTATION FOR CLINICAL APPLICATION
Hömmle A, Hennig E M

T33 DYNAMIC PLANTAR PRESSURE PARAMETERS PREDICTIVE OF FOOT POSTURE

T34 KEYNOTE LECTURE:
FOOT RELATED IMPAIRMENT AND DISABILITY IN RHEUMATOID ARTHRITIS: PLANTAR PRESSURE MEASUREMENT AND GAIT ANALYSIS
Woodburn J

T35 ANALYSIS OF PLANTAR PRESSURES IN A POST-SURGICAL WALKING BOOT WITH AND WITHOUT A CONTRALATERAL LIMB LENGTH ADJUSTMENT DEVICE
Song J, McDonald P, Kihm C, Nimick C, Heilman B, Zoltick E, Hillstrom H

T36 THE EFFICACY OF A REMOVEABLE VACUUM CAST REPLACEMENT SYSTEM IN REDUCING PLANTAR FOREFOOT PRESSURES IN DIABETIC PATIENTS
Waaijman R, Arts M L J, Manning E A, Bus S A

T37 PLANTAR PRESSURE RESULTS FOLLOWING NON-OPERATIVE TREATMENT FOR CLUBFOOT
Jeans K A, Karol L A

T38 VACUUM CUSHIONED REMOVEABLE CAST WALKERS REDUCE FOOT LOADING IN PATIENTS WITH DIABETES MELLITUS
Nagel A, Rosenbaum D

T39 THE EFFECT OF VIBRATION ON BONE-CEMENT INTERFACE IN CEMENTED HIP ARTHROPLASTY TO WITHSTAND LOAD TRANSFERRED BETWEEN THE BONE AND CEMENT
Talih S, Drew T, Abboud R J
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P1 THE EFFECT OF THE ADDITIONAL WEIGHT DURING PREGNANCY ON PLANTAR PRESSURE DISTRIBUTION OF THE FEMALE FOOT
Hömme A-K, Hennig E M, Hottgenroth J

P2 USAGE OF DISCRETE PRESSURE SENSORS TO DETERMINE REARFOOT MOTION DURING HEEL-TO-TOE RUNNING
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P3 THE INFLUENCE OF ORTHOTICS ON PRONATION, IMPACT LOADS AND PLANTAR PRESSURE DISTRIBUTION DURING RUNNING
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P4 METHOD FOR ASSESSING THE GAIT ENERGY COST BY RECORDING THE VERTICAL COMPONENT OF THE GROUND REACTION FORCE
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P5 A PRELIMINARY INVESTIGATION OF PLANTAR LOADS IN FEET WITH HALLUX VALGUS DURING BIPEDAL AND UNIPEDAL STANCE
Reed L F, Urry S R, Wearing S C

P6 TIME DEPENDENT CHARACTERISTICS OF THE "KENT" TRIAXIAL FORCE TRANSDUCER SYSTEM FOR IN-SHOE LOAD DISTRIBUTION MEASUREMENT
Lau H C, Stansfield B, Solomonidis S, Wearing S, Pepper M

P7 ANALYSIS OF THE PLANTAR PRESSURE DISTRIBUTION IN GAIT DURING PREGNANCY
Ribeiro A, de Souza F, Sacco I, João S

P8 LOADS IMPOSED TO THE PAINFUL LEG VERSUS THE PAIN FREE LEG DURING STAIR DESCENT IN PATELLOFEMORAL PAIN SYNDROME
Aliberti S, Costa M, Sacco I

P9 RELATIONSHIP BETWEEN PLANTAR PRESSURE AND PATELLOFEMORAL PAIN SYNDROME DURING GAIT
Aliberti S, Costa M, Sacco I

P10 PEDOBAROGRAPHIC EXAMINATION OF THREE POST OPERATIVE SHOES UTILISED IN FOREFOOT SURGERY
Bourke G

P11 ASYMMETRY BETWEEN LEFT AND RIGHT PLANTAR LOADING DURING GAIT IN NON-DIABETIC AND NEUROPATHIC- DIABETIC POPULATIONS
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P12 AN INTERMITTENT GRADUATED PNEUMATIC COMPRESSION BOOT FOR THE TREATMENT OF VENOUS ULCERS
Prionidis I, Browne T, Taylor M, Mootanah R

P13 WHAT IS THE EFFECT OF A PHYSICAL ACTIVITY PROGRAM ON FOOT STRUCTURE & FUNCTION IN OVERWEIGHT & OBESE CHILDREN?

P14 ASSESSMENT OF TRANSSTIBIAL AMPUTEES’ GAIT IN CLINICAL PRACTICE: SEMI-QUANTITATIVE KINEMATICS TO INTEGRATE PEDAR GAIT ANALYSIS
Giacomozzi C, De Maiti G, Orlandini D, Raggi M, Rogante M
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THE RELATIONSHIP BETWEEN IN-SHOE FOOT PRESSURE DISTRIBUTION AND TIBIAL SHOCK-WAVES

THE EFFECT OF THREE SIMULATED GAIT MODES ON PLANTAR PRESSURE DISTRIBUTION

THE USE OF THE FASTRAK AND PEDAR SYSTEMS FOR CLINICAL EVALUATION OF FINGER PRESSURE DURING WRITING

REPEATABILITY OF THE NOVEL pliance®-x-32 Expert System

KRAFTSIMULATOR INTRAOPERATIVE PEDOGRAPHY (KIOP) - AN EXPERIENCE OF THE CLINICAL APPLICATION
Dietze A, Mittmeier T

RELIABILITY AND VALIDITY OF IN-SHOE PLANTAR PRESSURE DATA MEASURED IN NEUROPATHIC DIABETIC PATIENTS
Arts M L J, Bus S A

ACCURACY OF THE NOVEL emed®-x AND TEKSCAN MATSCAN PLANTAR PRESSURE MEASUREMENT SYSTEMS

A PRELIMINARY STUDY OF THE EFFECTS OF GEL LINER THICKNESS ON IN-SOCKET RESIDUAL LIMB PRESSURES IN TRANS-TIBIAL PROSTHESIS USERS
Stine R, Hansen A, Tucker K, Boutwell E, Gard S
THE CHANGING FACE OF ANATOMY AND ITS ROLE IN RESEARCH AND SERVICE PROVISION

Sue Black

Centre for Anatomy and Human Identification, College of Life Sciences, University of Dundee.

BACKGROUND

There is no doubting that the historical pedigree of human anatomy as an academic subject is almost without parallel. Yet, it has not passed through history without its own scars of war, displaying regular cycles of both growth and recession. Even in very recent years we have witnessed its close-call survival following the major cull on staff, facilities and study time during the later part of the twentieth century. Yet like the phoenix, it refuses to lie dormant and its profile has begun to rise again from the ashes at the beginning of this millennium, as not only the teaching but also the research potential of the subject began to be rediscovered.

Many still view the subject of human anatomy as a rather dead and dull old subject that has seen few significant advances since Vesalius printed his monumental tome on the human form in 1543. However, the aim of this presentation is to demonstrate how misguided is that view and that anatomy is indeed very much alive and kicking and very much more than a dusty forgotten corner for teaching recalcitrant undergraduate medical students.

SURPRISES

The relevance of anatomy to clinical and scientific advances seems too obvious to mention but its influences in the world of forensic investigation, mass fatality events, forensic art, biometric authentication, refugee and asylum seeker status and child protection are perhaps not appreciated and may come as somewhat of a surprise to many.

This presentation will aim to introduce the many varied avenues of involvement for human anatomy and thereby raise awareness of its core position in many areas of research. Perhaps it might even open some doors for a few more collaborators who had not previously considered the relevance of the ancient and noble science of anatomy to the problems of the modern world.
AN INTEGRATED APPROACH TO THE ASSESSMENT OF DIABETIC PATIENTS GAIT - UNCOVERING THE PIVOTAL ROLE OF MUSCLE DYSFUNCTION IN FOOT ULCERATION.

Bharti Rajput (1), Graham Arnold (1), Sheila Gibbs (1), Weijie Wang (1), Lynda Cochrane (1), Graham Leese (2), Rami J. Abboud (1)

1. Institute of Motion Analysis & Research (IMAR), University of Dundee, Dundee Scotland.
2. Consultant Diabetologist, Tayside University Hospitals NHS Trust, Dundee, Scotland.

INTRODUCTION
In the time that it takes to read this abstract, at least one person around the world will have lost part of their foot or leg through diabetic foot complications. Up to 85% of amputations in diabetes are preceded by foot ulcers [1]. Therefore, any positive amputation prevention strategies must involve reducing foot ulcer incidence. Most foot ulcers occur during walking and have been reported to be related to the forces generated during gait [2]. ‘Normal’ gait requires the proper functioning of the musculoskeletal system and the nervous system. The challenge with diabetes lies in the progressive loss of somatosensory sensitivity, proprioception and distal muscle function [3]. Although biomechanical changes in diabetic gait have gained some recognition in the literature, to date, majority of research has focused solely on elevated foot pressures using in-shoe and barefoot foot pressure technology. While foot pressure has demonstrated an important role in the development of especially neuropathic ulcers, foot ulcers still pose a major global healthcare burden. Therefore, much work needs to be done to fully understand the contribution of biomechanical consequences in the development of foot ulcers.

OBJECTIVE
Fundamental studies in human gait should include data from the kinematics, kinetic, electromyography and foot pressure. Although studies exist in exploring these areas separately, no study to date has integrated their measurement for a holistic approach to the assessment of diabetic patient’s gait. It was the aim of this study to therefore conceive a novel method of assessing diabetic gait namely the IMAR system which involved the integrated measurement for the first time of:

- three dimensional kinematics and kinetics (Vicon® 612 and Kistler® force plates)
- Electromyography (EMG)
- Bilateral in-shoe foot pressure (Novel PedAR®)

With a limited amount of literature exploring dynamic muscle activity in diabetic patients, another focus of the study was to further explore this area following on from the work by Abboud et al. in 2000. Abboud et al. in 2000 demonstrated dysfunction in the firing of the Tibialis Anterior muscle during walking in diabetic patients [4]. It was hypothesised that such muscle dysfunction when combined with nerve impairment (as commonly encountered in neuropathic diabetic patients) would amount to forefoot slap and hence higher forefoot pressures followed by ulceration.

METHODS
Data was collected under standardised, repeatable conditions using the IMAR system from 50 type 2 diabetic patients and a comparative control group of 25 healthy volunteers. The activity of three lower limb muscles was measured bilaterally (Tibialis Anterior, Peroneus Longus and Gastrocnemius). In addition, simultaneous in-shoe foot pressure measurements and three dimensional kinematic and kinetic measurements were obtained. It must be noted that this is one of the first studies in this field of research with such number of patients.

RESULTS
Following the processing and statistical analysis of the data, a delay in muscle activity especially in the Tibialis Anterior muscle (~ 60 milliseconds) accompanied by high forefoot pressures under metatarsal heads 2, 3, 4 and 5 was established in diabetic patients. This therefore confirms a disturbed modulating role in lowering the foot to the ground after heel strike. Additionally, all diabetic subjects demonstrated a greater total contact time (P<0.05) also under metatarsals 5, 4, 3 and 2 with a corresponding high impulse value (P<0.05) in the same regions. These findings are a possible indication of the additional contribution of horizontal (shear) forces in foot ulcer development. Most findings worsened on increasing neuropathy.

CONCLUSION & CLINICAL RELEVANCE
An innovative method of assessing the diabetic foot in relation to foot pressure and disturbances of the normal modulating role of various lower limb muscles in gait is presented. We strongly believe that the art of dealing with diabetic foot problems requires a rigorous scientific approach, which is facilitated by this technology.

The confirmation of muscle dysfunction in the diabetic foot is indeed a pivotal finding in the comprehensive understanding of the biomechanics of gait in the diabetic foot.

We are optimistic that future developments from data obtained using the IMAR system will be aimed to explore suitable ways of preventing foot ulcer development. e.g. orthotics and footwear modification.

KEYWORDS
Diabetic foot; Electromyography; Foot Pressure; Gait Analysis; Kinematics; Kinetics; Neuropathy; Ulceration.

REFERENCES
CORRELATION BETWEEN PLANTAR PRESSURE AND OXFORD FOOT MODEL KINEMATICS.

Julie Stebbins (1), Claudia Giacomozzi (2), Tim Theologis (1)

1. Oxford Gait Laboratory, Nuffield Orthopaedic Center, Oxford, UK
2. Istituto Superiore di Sanita, Rome, Italy

INTRODUCTION

Plantar pressure measurement is widely used to assess foot deformity and plan treatment. However, consistent measurement of plantar pressure distribution in the presence of foot deformity is a challenging task. A method to objectively and reliably assess sub-division of foot prints when the whole foot is not in contact with the plate is required. The aim of this study was to provide an objective, comprehensive and clinically relevant measure of foot deformity by correlating pressure measurement with multi-segment foot model kinematics.

METHODS

35 children with hemiplegic cerebral palsy were assessed (19 male, 16 female, age 10.8±3.2 yrs). Each child had 29 markers attached to both legs and the affected foot, according to the Oxford Foot Model (OFM) (Stebbins, 2006). Data were collected with a 12 camera Vicon 612 system (Oxford, UK) and a prototype, piezo-resistive pressure plate (Istituto Superiore di Sanita, Rome, Italy) with a spatial resolution of 5 mm (Stebbins, 2005). The positions of the markers on the foot were superimposed onto the pressure footprint at a time corresponding to mid-stance. The co-ordinates of each marker were then projected vertically onto the footprint (Fig. 1). This provided the means to automatically divide the foot into five sub-sections on the basis of anatomical landmarks, and to correlate pressure findings with the output from the OFM. Peak force and area from each subdivision was correlated with clinically relevant variables from the OFM.

RESULTS

No significant correlation was found between hindfoot varus and the medial/lateral distribution of force at the hindfoot (Table 1). This was presumed to be due to reduced ground contact at the heel. There was only minimal correlation between hindfoot varus and midfoot force and contact area. The force in the midfoot tended to be higher than that of the healthy population, regardless of whether the hindfoot was in varus or valgus. In the case of a varus hindfoot, this was due to weight bearing on the lateral border, while in the valgus hindfoot, it was due to a flattening of the arch. Dividing the midfoot into medial and lateral sections could have shown a more significant correlation. Interestingly, an inverse correlation was found between forefoot supination (in relation to the hindfoot) and lateral force at the forefoot. The direct correlation between hindfoot varus and forefoot lateral loading (0.64) indicates that the hindfoot varus is responsible for increased lateral forefoot loading. Therefore, high loading of the lateral forefoot may not always be attributable to forefoot supination.

<table>
<thead>
<tr>
<th>Foot Model</th>
<th>Pressure Plate</th>
<th>Corr</th>
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</thead>
<tbody>
<tr>
<td>HF Varus</td>
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</tr>
<tr>
<td>HF Varus</td>
<td>Lat:Med heel area</td>
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<tr>
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<tr>
<td>FF/Tibia dorsiflex</td>
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</tr>
</tbody>
</table>

Table 1: Correlation between OFM and pressure plate results. FF=forefoot, HF=hindfoot, Corr=correlation

A significant correlation was found between increased forefoot dorsiflexion and decreased forefoot force as expected.

CONCLUSION

Correlating pressure measurements with multi-segment foot angles provides valuable insight into foot pathomechanics.

REFERENCES

RELATIONSHIP BETWEEN ANKLE MOBILITY AND PLANTAR PRESSURE DISTRIBUTION DURING GAIT IN DIABETIC NEOPLASTIC PATIENTS

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INTRODUCTION

Abnormal forefoot plantar pressure distribution is frequently associated with the pathogenesis of forefoot plantar ulceration in subjects with diabetic neuropathy (DN) (Van Schie, 2005; Zimny et al., 2004). Other factors seem to play an important role in the plantar load distribution mechanism. The ankle stiffness due to diabetic neuropathy result in limited joint mobility (Zimny et al. 2004; Viswanathan et al., 2003; Fernando et al., 1991) and was related to higher plantar loads (Rao et al., 2005; Klaesner et al., 2002). The purpose of the present study was to investigate foot and ankle motion and the influence of its mobility in plantar pressure in two sub-phases of stance in gait: heel-strike and push-off.

METHODS

Fifteen subjects with DN (57±6yrs, 28±4kg/m²) and 22 non-diabetic subjects (CG) (46±11yrs, 25±4kg/m²) participated in this study. Dynamic ankle flexion and extension was obtained at 100Hz with an electrogoniometer. Plantar pressure were acquired at 100Hz with PEDAR-X system during barefoot walking (anti-skid socks) at a self-selected speed. Contact area, peak pressure (PP) and maximum mean pressure (MMP) were evaluated in rearfoot, mid-foot and forefoot during 2 sub-phases of stance: heel-strike and push-off. The 2 groups, 3 foot areas and 2 stance sub-phases were compared using 3 ANOVAs 3-way (2x3x2), followed by Scheffé test (α=5%).

RESULTS

DN subjects presented significantly reduced ankle flexion at heel-strike (p=0.009) compared to CG subjects (CG: 9.8±4.5°; DN: 5.6±4.1°). The foot and ankle movement amplitude (flexion-extension) was significantly smaller in DN during stance phase (p=0.002).

Regarding heel-strike and push-off phase analysis, CG subjects presented significantly larger mid-foot contact area at heel-strike than at push-off phase (Heel-strike: 14.1±3.2cm²; Push-off: 10.7±2.8 cm²), while neuropathic subjects did not present any differences in contact area comparing both stance sub-phases in any plantar areas (Heel strike: 12.8±6.2cm²; Push-off: 10.8±5.2 cm²).

Considering both plantar pressure variables (MMP and PP), DN subjects presented significantly higher loads during push-off phase compared to heel-strike in mid-foot area (PP - Heel-strike CG: 74.1±21.0kPa, DG: 83.5±40.2kPa; Push-off phase CG: 75.7±31.1kPa, DG: 114.0±52.2kPa) (p=0.02). CG subjects showed similar plantar loading values in this region in both sub-phases.

DISCUSSION

DN patients walked using a smaller ankle range of motion at stance phase as well as a smaller ankle flexion at heel strike. This mobility reduction (Mueller et al., 1994) could be associated to the plantar pressure distribution observed in the DN subjects. Plantar pressure results demonstrated that mid-foot plays a different role in subjects with DN receiving higher loads at heel strike probably due to the smaller ankle flexion at this stance sub-phase. Considering the results found by Giacomozzi et al (2003), DN subjects may contact the ground with the most anterior part of the heel and perform their push-off phase before the metatarsal heads completely touch the ground. This fact may justify the higher loads observed in mid-foot in DN subjects confirming an inadequate roll over process of the foot associated to the ankle range of motion reduction at the heel-strike phase.

CONCLUSION

In summary, we found that differences in dynamic ankle range of motion and stiffness make subjects with DN to have an increased plantar loading in mid-foot during gait. Our findings suggest that subjects with DN make the roll over process of the foot shortly during gait producing a heterogeneous plantar pressure distribution in stance phase.

REFERENCES


ACKNOWLEDGMENT

We thank FAPESP (04/09585-2) and CNPq (PIBIC) for the financial support.
Changes in Plantar Contact Area and Gait After Chemodenervation in Acquired Brain Injury.

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Background and Purpose
Mobility impairments are commonly experienced by individuals with Acquired Brain Injury (ABI). Spasticity, often a secondary result of ABI, interferes with function and causes a disturbance in gait. This investigation focuses on lower extremity unilateral spasticity that causes equinovarus or plantar-flexor deformity, which are common in individuals with ABI. Equinovarus foot produces an inadequate base of support leading to an unstable gait (Esquenazi et al. 2006). Individuals with ABI have bilateral differences in limb loading during gait. It is important that any clinical treatment for spasticity in ABI measure how the treatment affects plantar loading and gait on both the affected and unaffected limb. An objective evaluation is needed to precisely evaluate how chemodenervation clinical intervention affects bilateral contact area and how these changes directly affect gait.

Methods
Subjects: Nine individuals (age 51.4 ± 18.1) with ABI related spasticity were recruited for participation. All were at least 1 year post ABI and currently being treated clinically with botulinum toxin, a chemoneurolytic intervention for spasticity.

 Procedures: Subjects performed a 2-Minute Walk Test (2MWT) pre (PrT) and ≤ 6 weeks post (PoT) clinical intervention. During data collection subjects walked for 2 minutes at a self selected pace PrT and ≤ 6 weeks PoT intervention. The primary outcome variables of interest were medial (M) and lateral (L) percent contact area (%CA) on the affected and unaffected limb plantar to the foot. Secondary gait outcome variables included average velocity, step length and cadence during the 2MWT.

Analysis: Collected pressure sensor data were divided into two masks representing M and L contact area on the plantar region of the foot. Percentage of total contact area (cm2) loaded during various phases of the gait cycle (Footstrike-FS, Single support-SS, Double support-DS, and Toe-off) were calculated for analysis using a custom Matlab program. A one-way analysis of variance (ANOVA) was used to test for significant differences in loading and gait outcome parameters.

Results
PrT there was a significant difference in M and L %CA between the affected (53.6%M, 46.3%L) and unaffected limb (46.0%M, 54.0%L) (p<.05) at FS. PoT this effect diminished when comparing the affected (51.6%M, 48.4%L) and unaffected side (51.8%M, 48.1%L). On the affected limb there was significantly (p=.004) increased medial %CA PrT at DS, and this significance (p≤.001) increased PoT. On the unaffected limb there was significantly increased %CA PrT L at FS (p<.001) and SS (p=.004) and medially during DS (p≤.001). PoT on the unaffected limb there was significantly increased L %CA at SS (p=.003) and M at DS (p≤.001). Trends for increases were observed in gait variables: average walking velocity and step length increased and percent time spent in stance on the affected limb increased PoT.

Discussion and Conclusion
The results of this investigation suggest that chemoneurolytic intervention can significantly affect M and L plantar contact area in ABI in both the affected and unaffected limbs. The largest effect of clinical intervention was seen on the unaffected limb. This is particularly relevant because the unaffected limb often has increased weight bearing after ABI. Furthermore, there were trends for increased walking velocity and step length. A limitation of this study is that foot type was not evaluated and should be considered in the future. More research and analysis is needed to fully explore changes in contact area and loading and how these changes affect gait after clinical interventions.

References

Acknowledgements
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CAN REDUCTIONS IN BRA BAND PRESSURE INCREASE COMFORT DURING EXERCISE IN LUMPECTOMY PATIENTS?

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INTRODUCTION
Breast cancer is a prevalent, life-impacting disease. With increasing incidence rates and a growing number of survivors, greater efforts must be directed towards improving the physical functioning and quality of life (QoL) of women living with a diagnosis of breast cancer. Although exercise interventions have been reported to provide these benefits, without the development of adverse events, many impediments to exercise exist (Rogers, 2007).

While several psychosocial or physical capacity impediments to exercise have been investigated, a recent study found that a substantial proportion (70.3%) of women living with a breast cancer diagnosis reported experiencing bra discomfort during exercise (Gho, 2007). Furthermore, bra band “tightness” was an acute cause of this discomfort, particularly for lumpectomy patients. For this reason there exists an urgent need to determine whether it is possible to modify the bra band for post-lumpectomy patients to reduce their exercise-induced breast discomfort caused by band tightness. Therefore, the purpose of this study was to determine whether an innovative bra modification could reduce bra band pressure, and therein the uncomfortable bra band “tightness”, experienced by lumpectomy patients.

METHODS
Three female lumpectomy patients who were large breasted (C+ cup), currently exercising, not undergoing active breast cancer treatment, and who had reported experiencing bra discomfort during exercise, were required to exercise at a consistent self-selected pace on a treadmill under three randomly presented bra conditions: Own bra, Sport bra and Experimental bra. For the Experimental bra condition, a custom-designed sliding fastener was incorporated into a standard sports bra to enable the band to be individually adjusted around the torso, without compromising breast support required during exercise.

Bra band pressure data were collected for 60 seconds during each treadmill trial per condition using a Pilance-c Expert system (Novel Inc, Munich, Germany). Two 10 cm calibrated pressure strips (1 sensor/cm²; 10 sensors; 50 Hz) were secured directly to the subject’s torso, under the affected side band of the bra in each bra condition and then zeroed. The Pilance-c Expert Online program (version 8.2, Novel Inc, Munich, Germany) was then used to mask the relevant sensors in order to calculate mean pressure (N/cm²) for each condition. Band pressure and bra discomfort, quantified using a visual analogue scale (VAS), were analysed to determine whether these outcome variables differed when subjects exercised in the three bra conditions.

RESULTS
Bra band pressure and bra band discomfort were positively correlated in all three bra conditions, whereby high band pressure was associated with greater discomfort (Fig 1). The Experimental bra condition provided the most consistently low pressure readings (<0.50 N/cm²), and also had the overall lowest band discomfort score.

CONCLUSION
This is the first study to provide evidence to show that, irrespective of bra condition, high band pressure was associated with bra band discomfort on the affected side of post-lumpectomy patients. Reducing bra band pressure through innovative modifications can act to reduce bra band discomfort, thereby enabling more women living with a breast cancer diagnosis to enjoy exercise benefits in comfort.

REFERENCES
FROM “FIRST” TO “LAST” STEPS IN LIFE – PRESSURE PATTERNS OF THREE GENERATIONS

Kerstin Bosch, Arne Nagel, Lars Weigend, Dieter Rosenbaum

INTRODUCTION
The human foot has to bear loads during all kinds of bipedal locomotion throughout the whole life. Rapid developmental changes of foot morphology and foot function occur during the first years of walking (Bosch, 2007). Furthermore, disease dependent modifications can also have an influence on plantar loading (Schmiegel, 2008; Giacomozzi, 2002). Therefore, it is reasonable to assume that foot function alters in life (Scott, 2006). However, the main differences between the pressure patterns in young and elder humans have not been well described?
The aim of the present study was to evaluate age-dependent pressure patterns and their differences between new-walkers, 7-year olds, adults and seniors.

METHODS AND MATERIALS
Dynamic foot pressure measurements were analysed in 104 healthy humans of 4 different age groups; each with 26 participants: New-walkers (1.0 yr. ± 0.2); 7-year olds (7.0 yrs. ± 0.4); adults (31.9 ± 2.1); seniors (68.4 ± 3.2). The participants walked barefoot with self selected speed over the emed x platform. Mean values of either 5 left or 5 right foot trials were randomly selected and analysed. The foot was divided in 5 regions of interest (heel, midfoot, forefoot, hallux, toes 2-5). Peak pressure (PP), Maximum force (MF), contact time (CT), contact area (CA) and arch index (AI) were evaluated. Local CT, CA and MF were normalised to total foot values or body-weight.

For statistical analyses the ANOVA (p < 0.05) and the Tuckey-HSD as Post Hoc Test were used.

RESULTS AND DISCUSSION
Significant differences were found for each parameter between almost every age group. As expected, the most significant differences were observed for the new-walkers.

Regarding the heel region significantly lower PP values were seen in the new-walkers in comparison to the others. This is based on the fat pad, a lower body-weight to foot contact area ratio and the non-existing initial heel contact in many new-walkers (Bosch, 2007; Hennig 1991). Scott (2006) found significantly lower pressures under the heel in elderly in comparison to the new-walkers, about 8 times more than in adults and 6 times more than for the 7-year olds. Furthermore, the seniors and new-walkers showed longer loading times in the midfoot and forefoot in contrast to the other age groups. These differences can be explained by step length and foot structure differences (Scott, 2006).

During the roll-over process the midfoot of the seniors was loaded with 87% body weight. This is twice as much as for the new-walkers, about 8 times more than in adults and 6 times more than for the 7-year olds. Furthermore, the seniors and new-walkers revealed longer loading times in the midfoot and forefoot in contrast to the other age groups. These differences can be explained by step length and foot structure differences (Scott, 2006).

The significantly higher PP values under the seniors’ midfoot can be attributed to the decreasing fat pad under the 5th ray. It cannot be ascribed to a flattened arch because no significant differences concerning the AI and the midfoot CA between the seniors and the 7-year olds and adults were found. Only the new-walkers, with their developing arch structure showed a significantly higher AI with a larger relative midfoot CA in comparison to the other groups. Regarding the seniors and the new-walkers the CT, CA, AI and the MF values of a number of foot regions are comparable.

CONCLUSION
Significant differences of pressure patterns were found for every age group. The new walkers showed the most differences in contrast to the others. The less significant differences were found between the adults and seniors. It can be assumed that with increasing age the pressure pattern develops again new-walker characteristics.

REFERENCES

ACKNOWLEDGMENT
We are grateful to the participants for volunteering and the DFG for funding (RO 2146/3-4).
CHANGES IN LOWER EXTREMITY LOADING DURING CUTTING MOVEMENTS AT CONTROLLED SLIPPING VELOCITIES AND AMPLITUDES

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INTRODUCTION

Ankle sprains are the most common injuries across sport games occurring during landing or cutting movements with or without interference of an object or opponent. Although considered to be a minor injury a high proportion of complications and associated costs were stressed by Larsen et al. (1999). Many studies investigated risk factors, such as foot shape or playing surface, among others, as well as the effect of interventions, such as bracing or training. Across these studies contradictory results were presented. Bahr and Krosshaug (2005) concluded this being caused by the fact that the underlying injury mechanisms are not fully understood. Therefore, well controlled epidemiological studies and experiments are needed.

A robotic platform was previously developed allowing for fast and controlled perturbations around four degrees of freedom (van Doornik & Sinkjær, 2007) to a force platform. This device is fast enough to simulate varied amplitudes and velocities of ‘slip’ as found in sports on different surfaces.

The aims of this study were to (1) develop a methodology for quantifying joint loading on a moving force platform and to (2) assess the effect of small, fast slip episodes during ground contact in a change of direction task.

METHODS

To obtain the centre of pressure location for the moving robotic platform (van Doornik & Sinkjær, 2007) an inertia compensation algorithm was developed (MatLab 7.1, The MathWorks). By mounting a time-synchronized high-speed pressure platform (RS Scan, 250 Hz, spatial resolution 2.6 sensors/cm²) on top of the force plate the validity of the algorithm was tested. Pressure data from dynamic trials of three subjects and a series of point loading trials using a loaded rod were used to verify the agreement between the two systems employing geometric calculations and regression techniques (aim 1).

The pressure plate was then removed and twelve subjects were asked to carry out 180 degree cutting movements with or without interference of an object or opponent. Although considered to be a minor injury a proportion of complications and associated costs were stressed by Larsen et al. (1999). Many studies investigated risk factors, such as foot shape or playing surface, among others, as well as the effect of interventions, such as bracing or training. Across these studies contradictory results were presented. Bahr and Krosshaug (2005) concluded this being caused by the fact that the underlying injury mechanisms are not fully understood. Therefore, well controlled epidemiological studies and experiments are needed.

The reference experiments using the pressure platform demonstrated good agreement for the centre of pressure calculations when the platform was resting ($r^2 = 0.988$, mean difference = 2.1 mm) or moving ($r^2 = 0.958$, mean difference = 2.5 mm) when excluding the first and last 5% of contact time from the comparison, respectively.

Maximum horizontal GRF showed only small differences between slip conditions with a slip of 3 cm over 121 ms demonstrating a significantly greater horizontal force maximum than no slip ($p = 0.046$). Vertical GRF decreased significantly with increasing amplitudes of slip ($p = 0.041$). As foot placement and turning technique varied considerably between subjects joint loadings were changed but only the resultant joint moment and force showed significant alterations by a notable reduction for the 3 cm over 242 ms slip condition compared to no slip ($p = 0.033$).

DISCUSSION

A valid method for calculating GRF on a moving force plate was developed. This experimental approach will allow for further insights in how musculoskeletal loading is affected by slips. Results demonstrate that limited amounts of slip affect external GRF and internal loading of the ankle during a change of direction task. Our data indicates the existence of an optimal slip magnitude. It may be possible to create surface-footwear combinations which support this optimum. Such developments may have implications for injury prevention and may be validated using the approach outlined in this paper.

REFERENCES

HIGH PLANTAR PRESSURES AND FOOT PAIN: ARE THEY CONTRIBUTING TO FALLS IN OLDER ADULTS?


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INTRODUCTION

Falls, the leading cause of injuries in older adults, typically occur during ambulation. As such, gait and balance abnormalities are frequently cited as falls risk factors. During normal gait, the foot is the only source of direct contact with the ground and, therefore, it plays a substantial role in maintaining stability and balance.

Foot pain has been found to impair balance and gait in women (Leveille, 1998), and has been shown to be falls risk factor in institutionalised elders (Menz, 2006), however it is unknown whether foot pain is a risk factor for falling in community-dwelling older adults. As foot pain is a common complaint in older adults, it is important to determine whether foot pain is a falls risk factor.

Despite providing detailed information about the function of the foot during gait, dynamic plantar pressures have not been investigated as a falls risk factor. Therefore, the purpose of this study was to determine whether foot pain and/or plantar pressures are associated with falls in the elderly.

METHODS

Three hundred and twelve older men and women aged between 60-90 years were randomly recruited to participate in the study. Subjects completed the Manchester Foot Pain and Disability Index (Garrow, 2004) to assess the presence of foot pain. The subjects then walked across an emed AT-4 pressure platform (25 Hz; Novel gmbh) using the second-step method. Participants were then followed prospectively to determine their falls incidence over 12 months.

Pressure data were analysed for each subject’s dominant foot, using Novel Projects, by dividing each footprint into 10 regions using the Novel mask set. Peak plantar pressures (kPa) and pressure-time integrals (kPa.s; PTI) were calculated for each region.

Each subject was categorised as a non-faller, single faller or multiple faller based on the number of falls experienced throughout the year. Chi-square values were calculated to determine whether the incidence of foot pain differed for each fall category while a one-way ANOVA design was used to determine any significant differences in the pressure variables between the fall groups.

RESULTS

Multiple fallers (n = 36) displayed a significantly higher incidence of foot pain than non-fallers (n = 196; χ²=8.42; p = 0.004). However, there was no difference in foot pain between the single fallers (n = 71) and the other two subject groups. Multiple fallers generated significantly higher peak plantar pressures when walking compared to the single or non-fallers in the heel, midfoot, 2nd toe and total regions of the foot. Multiple fallers also had significantly higher PTIs at the heel, midfoot, 1st MTH, 2nd toe, toes 3-5 and total foot regions than their counterparts (see Figure 1).

Figure 1: Mean (+SD) PTI generated under each masked region. ** multiple and single vs. non-fallers; * multiple vs. single fallers (p ≤ 0.05).

CONCLUSION

The results from this study are the first to confirm that older people who incur multiple falls generate higher plantar pressures during gait relative to single fallers or non-fallers. It is postulated that these high plantar pressures are contributing to the increased foot pain and discomfort suffered by multiple fallers, which, in turn, may cause gait and balance disturbances, predisposing these individuals to falls. Providing interventions to older individuals with foot pain and high plantar pressures may result in reducing their risk of future falls.

REFERENCES

PRESSURE PATTERN ALTERATIONS AND FOOT DEFORMITIES IN DIABETES AND RHEUMATOID ARTHRITIS.

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INTRODUCTION
Cluster analysis of peak pressure curves (PPC) had previously been validated and applied to patients with Diabetes (D, n=97) [1] and Rheumatoid Arthritis (RA, n=90) [2]. The present study aims at investigating potential similarities in pressure patterns associated with these severe pathologies, to gain some knowledge about concurrent foot pathomechanics.

MATERIALS AND METHODS
D and RA patients were examined by means of standardised instrumentation and protocols (EMED ST-4 platform, patients walking barefoot at self-selected speed). Cluster analysis based on a k-means algorithm [1] was applied to time-normalized PPCs. For each pathology, 3 well-separated clusters were identified. In the present study all clusters were superimposed and compared (Fig. 1). The integration of the above results with clinical examination led to the following statements:
- Cluster 1 (D: 53 curves; RA: 41 curves) almost overlapped PPC distribution of controls;
- Cluster 2 (D: 32 curves; RA: 31 curves) grouped patients with quite homogeneous foot structure and biomechanics;
- Cluster 3 (D: 12 curves; RA: 18 curves) included patients with highly variable gait patterns, severe foot deformities, concurrent pathologies.

The present study was focused on D and RA patients included in Cluster 2.

RESULTS
With respect to RA, D patients in Cluster 2 showed the following differences (p<0.05):
- lower peak pressures (735±166kPa vs 885±165kPa);
- longer stance phase (865±150ms vs 797±134ms);
- earlier occurrence of maximum pressure (78.7±7.1% stance vs 82.8±5.8% stance);
- greater contact area at maximum pressure occurrence, both absolute (58.3±12cm² vs 46.7±10.2cm²) and relative (% of maximum area) (52.9±9.5% vs 47.7±9.8%);
- longer loading of the high-load area (>300 kPa), both absolute (388±111ms vs 313±89ms) and relative (45.1±11.0% stance vs 39.6±10.5% stance).

Three foot-types (FT) were identified within each group, all including hammer toes:
- FT1 (Fig. 2): cavus foot, high arch, greater loading of the central metatarsal heads (16 D, 12 RA);
- FT2: evidence of hallux valgus with greater loading of hallux (4 D, 10 RA);
- FT3: cavus and more supinated foot with greater loading of 4th and 5th metatarsal heads (8 D, 1 RA).

DISCUSSION AND CONCLUSIONS
Similarities and differences were found for gait patterns of well characterized D and RA patients, which led to the following hypotheses:
- high peak pressures during propulsion might be due to the dorsiflexion of the toes, which leads to exposure of the metatarsal heads (cause A) – forward shift with respect to sesamoids – and tightening of plantar fascia (cause B).
- If cause A is more evident – majority of RA patients – bony forefoot prominences are more exposed, thus peak pressures are even higher and more localized.
- If cause B is more evident – majority of D patients – the onset of an early and sustained windlass mechanism keeps the foot in a cavus position, with a greater involvement of the metatarsal heads.

Further development of structural changes and onset of plantar ulcers are however strictly related to the individual course of the disease with respect to its duration, severity, treatment and each patient’s overall health status. This issue will be further investigated.

REFERENCES

Fig. 1: Comparison of the results of PPC cluster analysis for D and RA patients.

Fig. 2: Typical cavus foot, with hammer toes.
FOLLOW-UP OF MULTIPLE SCLEROSIS PATIENTS WITH DIFFERENT NEUROLOGICAL STATUS

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INTRODUCTION

Patients with multiple sclerosis (MS) tend to have balance and gait problems. Gait impairments caused by changes in pyramidal (PFS) and cerebellar functional systems (CFS) are one of the main factors of disability.

The aim of this study was to estimate the dynamics of pressure distribution parameters changes in MS patients with different neurological status in time.

METHODS

30 patients (11m/19f, age 39±9 years, BMI 23±4 kg/m2), diagnosed with relapsing-remitting MS according to McDonald’s criteria, were examined twice during 42±16 months. Neurological status of examined patients was characterized with Expanded Disability Status Scale (EDSS) 2.4±1.2, PFS 1.8±0.8, CFS 1.8±0.9. Patients were divided into two groups in relation to estimated EDSS at the first examination: EDSS<3 (without functional limitations) and EDSS>=3 (moderate affected gait). All patients received permanent pathogenetic therapy.

Plantar pressure distributions were performed with emed-AT 25 system (novel, Munich, Germany). Five dynamic records of each foot were made with first step protocol. novel database medical was used to collect clinical and pressure measurement data. Peak pressure (PP), mean pressure (MP), maximum force (MF), pressure-time integrals (PTI), force-time integrals (FTI), contact time (CT) and contact area (CA) were calculated in novel-projects with novel automask for foot, hindfoot, midfoot, five metatarsal heads, big toe, second toe, and lateral toes. Parameters were calculated for each subject and for two groups. The difference in pressure distribution parameters beneath foot areas in two measurements was checked with ANOVA. Significance level was set as p<0.001.

RESULTS AND DISCUSSION

Each group had a specific pressure distribution pattern that varied in time with the degree of disability status. The most significant differences were found beneath hindfoot, midfoot, second-fifth metatarsal heads, and big toe in first group (EDSS<3). In contrast to these patients, the most significant changes were found beneath second metatarsal head and big toe in second group (EDSS>=3).

Increased MP, MF, and FTI beneath the hindfoot; increased PP, PTI and FTI beneath the midfoot; increased MF beneath second metatarsal head; increased MP, MF, and FTI beneath third metatarsal heads; increased PP, MF, PTI and FTI beneath fourth and fifth metatarsal heads, decreased MF beneath the big toe, and increased MP, MF and FTI beneath the foot were statistically significant for two measurements comparison of patients from first group.

Decreased PP and MF beneath second metatarsal head, PP beneath big toe, and decreased contact area were statistically significant in second group.

Positive dynamics of parameters changes (patients with EDSS<3) beneath the hindfoot and second-third metatarsal heads is explained by absence of significant changes in pyramidal functional system during follow-up period. Lateral shift of loading is a result of developing inversion of the foot in neurological deficit caused with the processes in cerebellar functional system. Increasing loading of midfoot reflects the neuromuscular disorders and foot deformities due to the cerebral lesion that modified contact of the foot with ground.

Patients with EDSS>=3 practically did not change the pathologic stereotype of gait during follow-up (most parameters remained stable or minimally progressed). Negative dynamics of loading the second metatarsal head confirms the development of transverse arch in the forefoot due to increased spasticity. It results also in decrease the role of big toe in weight bearing and decrease the contact area of the total foot.

CONCLUSION

These findings indicate that patients with EDSS less than 3 are at minimal risk and patients within the EDSS 3 through 6 are at moderate risk (in receiving the corresponding therapy) of developing important gait limitations after four years of follow-up. Pressure distribution measurements are useful to identify the starting points for follow-up and treatment of MS patients.
PRESSURE PATTERNS IN PATIENTS WITH RHEUMATOID ARTHRITIS: THE RELEVANCE OF A MULTI-CENTRE EXPERIENCE.

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INTRODUCTION

ISS and UKM had been firstly applied cluster analysis methodology to peak pressure curves (PPC) of patients with Rheumatoid Arthritis (RA) [1]. The aim had been to find a reliable means to classify patients by gait pattern alterations rather than on clinical classification [2]. In this preliminary study, a cluster-based screening test is validated on new data from a third collaborating centre (GCU).

MATERIALS AND METHODS

Cluster analysis based on a k-means algorithm [1] had been applied to time normalized PPCs of 90 UKM RA patients [2]. 3 well-separate clusters (K) had been identified (Fig. 1):
- K1 (41 curves): low peak pressure curves, almost overlapping PPC distribution of healthy controls;
- K2 (31 curves): high peak pressures during propulsion;
- K3 (18 curves): abnormal peak pressures even at earlier phases of foot loading acceptance.

SCREENING TEST: median curves and 10-90% percentiles were used. Within each cluster RMSE of the two percentile curves were calculated with respect to the corresponding median curve. The maximum between the two RMSEs was used as the acceptance threshold to classify GCU PPC curves within the corresponding cluster.

74 GCU RA patients were examined by means of same standardized measurement device and protocols as UKM – EMED ST-4 platform, patients walking barefoot at their self-selected speed. The UKM and GCU cohorts were matched (p<0.05) for age, BMI, and walking speed. Median curves were calculated for each GCU patient on 5 time re-sampled trials. A sample of 10 patients was randomly selected for the preliminary validation of the test.

RESULTS

7 out of 10 GCU patients were correctly identified as RA patients: 2 were assigned to K1, 3 to K2 and 2 to K3. One excluded patient had a strongly abnormal PPC (PPC_A), with very high pressures during the first 30% of stance. The remaining two excluded patients showed very similar PPCs (PPC_B), with an overall pattern comparable with K2 but with higher peak pressures during propulsion.

Interestingly, also the curve-by-curve investigation of UKM database detected few occurrences of both PPC_A and PPC_B: PPC_A was found for 6 out of 90 PPCs (2 included in K1, 3 in K2 and 1 in K3; Fig. 2A); PPC_B was found for 3 out of 90 PPCs (1 included in K1, 2 in K2; Fig. 2B).

The number of both PPC_A and PPC_B curves in UKM group was too small to support the hypothesis of a further cluster. Their exclusion from the 90 PPCs dataset did not entail changes in mean and median curves of the three clusters. A certain lowering was instead observed in the 75% and 90% percentile reference curves of K1 and K2.

DISCUSSION AND CONCLUSIONS

Cluster-based screening identified two further RA related pressure patterns, not previously identified in the UKM patients. This collaboration will provide a larger reference database and more comprehensive characterization of RA peak pressure pattern to enable the development of a diagnostic tool for the investigation of RA biomechanics.

REFERENCES

2. Giacomozzi and Martelli, Gait & Posture, 2006
THE ADDITIONAL VALUE OF REPORTING PRESSURE-TIME INTEGRAL RESULTS IN FOOT PRESSURE STUDIES ON THE DIABETIC FOOT

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INTRODUCTION

Elevated peak plantar pressures have since long been associated with the development of plantar foot ulcers in patients with diabetes who have lost protective sensation due to peripheral neuropathy (Veves et al., 1992). As a result, regional peak pressures (PPs) are almost always reported in foot pressure studies in this patient group, whether being pressures measured barefoot for risk assessment or inside a shoe or device for efficacy. Besides peak pressure (PP), the pressure-time integral (PTI) is also often reported as a study parameter since the PTI has also been associated with plantar ulceration in the diabetic foot (Stess et al., 1997). Some authors even consider the PTI a more important factor than the PP in this context (Baumhauer et al., 1997). However, the available literature often seems to suggest that results on PP and PTI are very similar and do not lead to different conclusions regarding the topic of interest, which questions the need to report results on both these pressure parameters in the same study. The aim of this review was to test this hypothesis by assessing the available diabetic foot literature which reports both on PP and PTI results and to determine the additional value of reporting PTI next to PP.

METHODS

The MEDLINE literature database was searched for original articles on PTI in foot pressure studies of patients with diabetes by using a specific search string. The title and abstract of each identified reference were initially assessed for eligibility. Subsequently, full paper copies of each included article were assessed based on the following questions:

1. Were differences found between PP and PTI results?
2. Were the results on PTI discussed?
3. Were the (lack of) differences found between the PP and PTI results discussed and explained?
4. Did the PTI results lead to specific conclusions?

The reporting of the PTI results was considered valuable in this study when a clear difference between PP and PTI results was found and explained, and led to specific conclusions based on PTI results.

RESULTS

Of 71 articles resulting from the baseline literature search, 29 were considered eligible for review. Eleven articles assessed barefoot pressures, 16 in-shoe pressures, and 2 both. In 11 articles the PP and PTI results were not different, in 8 minimally different (i.e. same pattern of results with minimum number of significance differences), and in 10 clearly different regarding the study topic of interest. In 24/29 articles, PTI results were discussed. However, only 10/29 papers discussed the PP vs PTI results. Of these 10 papers only three explained the differences found and reported specific conclusions on the PTI results for which PTI was considered to have additional value next to PP in relation to the primary research topic.

CONCLUSIONS

This review showed that in a majority of articles (66%) none or only minimal differences existed between reported PP and PTI results, leading to similar conclusions regarding the subject of interest under investigation. Additionally, in many articles in which differences were found between reported PP and PTI results, these differences were not discussed or, when discussed, these differences were not explained. This lack of explanation may be associated with a limited or lack of understanding of the factors that mediate PP and PTI and often leaves the reader guessing what the reason for the discrepant results was.

These findings suggest that the additional value of reporting PTI next to PP in diabetic foot studies is small and suggests that, until PTI is demonstrated to be a better predictor of ulceration than PP and the factors relating to gait or footwear that mediate PTI are known, the reporting of only PP is sufficient to draw conclusions regarding the topic of interest.

REFERENCES

Baumhauer et al., Foot Anke Int 18: 26-33, 1997
Stess et al, Diabetes Care 20:855-858, 1997
Veves et al, Diabetologia 35: 660-663, 1992
MORNING STIFFNESS INFLUENCES FOOT LOADING PATTERNS IN PATIENTS WITH RHEUMATOID ARTHRITIS

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INTRODUCTION
Morning stiffness is one of the ACR-revised criteria for the diagnosis of rheumatoid arthritis (RA) [1]. In patients with RA the foot joints are often affected by morning stiffness that is supposed to lead to foot pain and altered foot loading during walking. High plantar pressures are reported to cause foot pain in RA patients [4]. However, to our knowledge no studies investigated the influence of morning stiffness on plantar pressure patterns. The aim of this study was to investigate the influence of morning stiffness concerning foot loading, foot pain and foot function in patients with RA.

METHODS AND MATERIALS
Twenty-five patients with RA (55.8 ± 13.3 years) were included in the study. Plantar pressure measurements were conducted during barefoot walking with a capacitive pressure platform (emed-X, Novel GmbH Munich). The measurements were initially performed during the phase of morning stiffness and were repeated 3 hours later. The pressure patterns were subdivided into ten regions of interest and analyzed with respect to peak pressure, maximum force, contact time, and contact area. Flexibility of the ankle joints was assessed by goniometers.

RESULTS AND DISCUSSION
An increase of maximum force and peak pressure could be seen under the 1st and 2nd metatarsal head after morning stiffness had vanished. This suggests more dynamic walking patterns. Shorter contact times of the foot during roll-over process after morning stiffness may explain the increase in plantar forefoot pressures [2,3]. The flexibility of the talocrural joint was impaired during morning stiffness although these differences were not statistical significant. The lower FFI score after morning stiffness indicated a decrease of foot pain and therefore an increased ability to walk freely. This was accompanied by a higher range of motion of the talocrural joint.

CONCLUSIONS
In conclusion, patients with RA appeared to walk more carefully during morning stiffness due to more pronounced foot pain and limited joint flexibility. After morning stiffness has resolved the roll-over process becomes more dynamic and higher foot loading occurs under the forefoot.

REFERENCES
INTRODUCTION

Computational stress analysis is used extensively in engineering and the most commonly used is the finite element method. Developed in the mid-1950's for the aerospace industry, finite element analysis is a mathematical technique for calculating the stress and strain distribution within complex geometric structures subjected to complex loads. The finite element method has been used in orthopaedic biomechanics for more than 30 years to investigate a wide spectrum of problems particularly with respect to joint arthroplasty. The power of finite element method is the ability to examine the magnitude and distribution of loads, strains, stresses or micromotions anywhere within the structure.

Plantar pressure measurements are a valuable clinical tool for assessing the pathological foot. However, as it is a surface measure, it does not necessarily provide information as to the cause of the problem. In combination with plantar pressure measurements, finite element modeling has significant potential to enhance our understanding of the pathological foot and how best to treat it.

From a modeling point of view, the foot is an incredibly complicated structure, consisting of 28 bony segments and multiple soft tissue structures which have complex interactions with each other, including bone on bone and soft tissue on bone interactions.

TWO DIMENSIONAL MODELS OF THE FOOT

In order to simplify the problem, early finite element studies modeled the foot complex as a two dimensional problem. Various models, of varying complexity, have been developed using this approach. Lemmon et al and later Erdemir et al., have used a 2D model of the isolated 2nd metatarsal bone which representations of the plantar and dorsal soft tissues to examine the influence of therapeutic footwear on plantar pressures. A major limitation of this study was that other bones of the foot were ignored, as were the relevant ligaments. Goske et al developed a transverse 2D model of the heel, again, to examine the influence insole design. The modeled assumed that the bones of the hind foot were a single rigid body and ignored the ligamentous structures.

Actis et al. developed a more complex model, which included the 2nd metatarsal articulating with a representation of the hindfoot and the phalanges, the flexor tendon and fascia and the plantar and dorsal tissue.

All of the above studies reported reasonable correlations with plantar pressure measurements. However, the modeling the foot complex as a two dimensional structure is a significant limitation and this has lead to the development of complex three dimensional models, capable of making direct comparisons with in vitro or in vivo plantar pressure measurements.

THREE DIMENSIONAL MODELS OF THE FOOT

An early three dimensional FE model of the complete foot complex was developed by Chen et al. The model was an idealized representation and many of the bone-bone interactions were assumed to be rigidly connected. The major ligamentous constraints were represented, as were the surrounding soft tissues. Using the model, they were able to produce representative plantar pressure distributions and compare the influence of different insole designs. To date, Cheung and co-workers have produced the most complex FE models. They have used anatomically correct representation of the bones, have assumed articulation for the majority of bone-bone interactions, included over 70 representations of the ligaments connecting the bones, as well as the surrounding fascia soft tissue. They performed a verification study, comparing the predicted plantar pressure measurements with experimental data for the same cadaveric foot. Under similar loading conditions, the model was able to predicted similar distribution and magnitudes as those seen experimentally. In combination with statistical analysis techniques, they went on to investigate the influence of insole design parameters on plantar pressure distribution.
CHALLENGES AND FUTURE DIRECTIONS

The studies to date have shown that the finite element analysis is capable of predicting plantar pressures distribution. By doing so, they give us insight into the parameters that determine load transfer from the bony structures through the fascia. In the long term, this means that there is a tool available to understand the factors in the pathological foot that result in abnormal pressure distributions and potentially how footwear design or surgical intervention could modify this. In order to achieve these goals, models of the pathological foot need to be developed. If this is to become a clinical tool, then methodologies for semi-automated or completed automated generation of FE models need to be developed. Due to the complexity of the models, this will not be a trivial task.

REFERENCES


CHANGES IN FOOT LOADING FROM BIPEDAL TO UNIPEDAL STANCE ARE SITE SPECIFIC AND HIGHLIGHT THE IMPORTANCE OF TOE FUNCTION

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BACKGROUND
Since medio-lateral rolling of the foot plays an important part in maintaining body balance, and impacts on the location of the centre-of-pressure (Hoogvliet 1997), it is likely that plantar load distribution will alter when clinical tests of balance are conducted. While foot pressures have been described for relaxed bipedal stance (Cavanagh 1987) and unipedal stance during perturbation (Tanaka 1996), a systematic investigation of multiple stance postures is not apparent in the literature.

This study, therefore, quantified plantar loading at sites beneath the foot during (1) relaxed bipedal stance, (2) unipedal stance with the eyes open, and (3) unipedal stance with the eyes closed.

METHODS
Thirty-four healthy adults (mean age 35.7±14.2 years, height 168±.09 m, weight 71.7±14.9 kg) were recruited. Subjects with a known history of balance disorders, taking medication likely to affect balance, or with obvious foot deformity were excluded. Informed consent was gained prior to participation.

With their right foot on an EMED platform, volunteers were asked to adopt one of three stance conditions – bipedal stance with eyes open, unipedal stance with eyes open, or unipedal stance with the eyes closed. Plantar pressures were then recorded for 2 seconds. The process was repeated, in a random progression, until five replicates of each test condition had been recorded. The pressure data were masked to define ten sites; (1) medial heel, (2) lateral heel, (3) medial arch, (4) lateral arch, (5) met 1, (6) met 2, (7) mets 3-5, (8) hallux, (9) toe 2, (10) toes 3-5.

Site-specific differences and associations of peak force were determined across conditions using Paired T-tests and Pearson correlation coefficients respectively.

RESULTS AND DISCUSSION
Forces in unipedal stance were significantly greater than in bipedal stance except at site 3, the medial arch, where a trend of reduced loading was observed. Force did not simply double when body weight was exerted through one foot rather than two.

To be precise, the magnitude of change was site specific ranging from 0.6x for the medial arch to 17.5x for the hallux. The toes demonstrated the greatest change, averaging an 11.5 fold increase during unipedal stance. A 2.6 fold increase in load at the lateral arch was also noteworthy and may be a consequence of supinatory rolling with foot tilt, lateral arch depression with increased load, or both.

Loading response to activity was investigated by comparing the site specific loads (within site) across the stance conditions. The bipedal-unipedal eyes open comparison revealed significant within site correlations at each site except site 10 (Toes 3-5). However, correlations at sites 8 and 9 (hallux and toe 2) were weak (0.38 each) compared with sites on the sole (range 0.43-0.87). The bipedal-unipedal eyes closed comparison revealed significant within site correlations at sites 1 to 7 (sole) but not for sites 8, 9 & 10 (toes). Finally, the unipedal eyes open-closed comparison revealed significant within site correlations at all sites (ranging from 0.60 to 0.93).

In unipedal stance, plantar loads at sites 1,2,4-7 (sole) peaked when the eyes were open whereas loads at sites 8,9 & 10 (toes) peaked with eyes closed.

CONCLUSION
Analysis of plantar loading profiles gives three indications of the importance of toe function in maintaining upright posture and dynamic balance;

1. the magnitude of increase in load when changing from bipedal to unipedal stance is far greater for the toes than for other sites
2. there is little or no correlation between bipedal and unipedal toe loading
3. toes are distinctive in exerting peak force during eyes closed conditions.

REFERENCES
Cavanagh et al., Foot Ankle 7:262-276, 1987
Summary (for our benefit only)
1. Forces increase in unipedal stance but not uniformly.
2. The toes show the greatest increase (11.5x average)
3. Lateral arch shows significant/interesting increase (2.6x)
4. Loading patterns are generally similar in bipedal and unipedal conditions but the toes show weak association when eyes are open and no association when eyes are closed
5. The unipedal conditions (eyes open and closed) show strong correlations for all sites.

Questions
1. Is lateral arch rolling with supination or depressing or both?
2. Is toe function instance associated with eye function?

Toe function showed little or no correlation between bipedal and unipedal stance.
FOOT DIMENSIONS AND PLANTAR PRESSURE DISTRIBUTION PARAMETERS OF SOLDIERS BEFORE AND AFTER MARCHING WITH LOAD


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INTRODUCTION

Foot and lower limb problems after long distance marches or marching periods are common among soldiers (Reynolds K L, 1999. Kaufman K R, 2000). Nevertheless, there is less knowledge about the direct effects of long distance marching on the foot. Therefore the purpose of the present study was to investigate the effects of a 25km march with load on foot dimensions and plantar pressure distribution parameters.

METHODS

59 soldiers participated in the study and did a 25km march while carrying an 18kg backpack, an assault rifle and ammunition. Before and after the march plantar pressure distribution and foot dimensions of the right foot of each soldier were quantified. Both measurements were done barefooted with soldiers wearing the 18kg backpack. The measurement of the foot dimensions was performed with an INFOTOF high resolution foot scanner (Software Rev. 1.2). The right foot of each soldier was scanned three times. The following foot dimensions were calculated: foot length (FL), foot breadth (FB), heel breadth (HB), ball girth circumference (BC), instep circumference (IC). The EMED-m/R platform (version 13.3.40) was used to quantify the plantar pressure distribution pattern. Five successful walking trials for the right foot of each soldier were collected. The Cavanagh mask (Cavanagh P R, 1994) was used to define plantar pressure distribution parameters (PDPs) in different sub-areas of the foot (PDPs: contact area (CA), peak pressure (PP), relative load (RL)).

Paired t-test and measurement error calculations were done for statistical analysis of the data.

RESULTS & DISCUSSION

According to the results of the paired t-test all foot dimensions increased significantly from pre to post measurement (Tab. 1). However, pre-post differences of the foot dimension variables can be considered negligible with respect to the measurement error (sw), since none of the foot dimension changes exceeded the 95% confidence bound for repeated measures (2.77·sw) (Tab. 1) (Bland J M, 1996).

These findings indicate that even long distance marching with backpack loading does not lead to relevant deforming or swelling of the feet.

However the PDPs showed changes in various areas of the foot after the march. In the toe area all PDPs significantly decreased (Fig. 1). PP also significantly decreased in the area of the 1st metatarsal head and at the medial heel (Fig. 1). Otherwise PP and RL significantly increased in parts of the forefoot (area from 2nd to the 5th metatarsal head) and in the medial metatarsal area (Fig. 1). The PDP measurements indicate significantly reduced loading of the toe area after extensive marching and a load shift from areas where bone is close to the skin to areas with more tissue under the skin. These findings can be explained as being a consequence of the fatigue of the toe flexor muscles, which are unable to maintain their functionality after several hours of extensive marching. Similar results have been found for plantar pressures after a marathon run (Nagel A, 2007). Future studies should investigate if this effect can be modified by footwear features.

REFERENCES

EFFECT OF FOOT ORTHOSES CONTOUR ON PAIN PERCEPTION IN INDIVIDUALS WITH ANTERIOR KNEE PAIN

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BACKGROUND
Foot orthoses have been described as a possible intervention in the management program for individuals diagnosed with anterior knee pain (AKP) (Saxena, 2003; Gross, 2003). A previous study has reported that a non-molded flat foot orthoses with felt wedges can provide significant pain relief for individuals with AKP (Eng, 1993). No study to date has assessed the effect of a molded foot orthoses in comparison to a flat device on symptoms associated with AKP. The intent of this study was to determine if a molded foot orthoses would affect the pain perceived by individuals reporting AKP.

METHODS
Subjects: Twenty-two individuals, 10 with AKP and 12 with NoAKP participated. Only the right foot was used for analysis. The inclusion criteria for the AKP subjects included a diagnosis of non-traumatic AKP for at least 6 weeks and pain with stair walking or squatting. The average pain rating for the AKP group during activity was 4.3 on a 10 scale. The NoAKP subjects had no history of lower extremity congenital or traumatic deformity, or acute injury 6 months prior to the study. The mean age of the AKP and NoAKP groups were 28 and 29 years, respectively.

Methods: Each subject was first fitted with a pair of Sham and Molded foot orthoses. Adjustments to the molded device were made so they were comfortable walking. The Sham orthoses was 3 mm thick, completely flat, and had the same top cover as the Molded orthoses. The Molded orthoses were contoured to increase contact area in the midfoot and heel regions. Once fitting was complete, subjects’ broke-in each pair orthoses by walking 300 feet. PEDAR pressure sensing insoles were placed in each subject’s shoes and over each pair of foot orthoses, so plantar contact area could be assessed. After the shoe-only condition, the plantar contact area for each pair foot orthoses was measured with the order of testing randomized. Subjects had their dorsal arch height (DAH) as well as ball length assessed. To classify foot type, the Arch Height Ratio (AHR) was calculated by dividing DAH by ball length. After the testing was completed, subjects was asked to wear their orthoses in the reverse order of testing for one week, with a one week “wash-out.” After wearing orthoses for one week, the AKP group was asked to rate the amount of pain or symptom reduction for each orthoses condition. Analyses: For each condition studied, 10 consecutive steps were analyzed to determine plantar surface contact area. A within-subjects ANOVA was used to determine if differences existed between the AKP and NoAKP groups for the variables measured.

RESULTS
Total plantar contact area was significantly increased (p < .05) for the Molded orthoses in comparison to the Sham and shoe-only conditions for both the AKP and NoAKP groups. There was no difference between shoe-only and sham between groups for the two subject groups. The AHR was also not significantly different (p > .05) between the two subject groups. Six out of the 10 in the AKP group reported relief of pain using orthoses, with 4 subjects preferring the Molded orthoses.

CONCLUSIONS
The findings indicate that the AKP and NoAKP groups had a similar foot type based on the AHR. While Molded orthoses provided increased plantar surface area contact, they were preferred by only 4 of the 6 AKP subjects reporting pain relief from using foot orthoses. Four from the AKP group reported that the foot orthoses did not provide any pain or symptom relief.

Previous studies have reported that a non-molded foot orthoses can provide significant pain relief for individuals with AKP. The results of this study demonstrate that while molded orthoses did provide increased plantar surface area and were preferred by the majority of AKP subjects reporting pain relief, 40% of the individuals with the AKP did not have improvement in symptoms using orthoses.

REFERENCES
BEYOND THE DIABETIC PATIENT: USING PLANTAR PRESSURE ANALYSIS TO STUDY MECHANICAL FOOT DYSFUNCTION

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The first documented pedobarographic or plantar pressure study was published in 1982 and utilized a rubber-and-ink apparatus to record maximal pressures across the plantar surface of the foot. Although numerous studies using a similar apparatus were conducted in the early and mid twentieth century, it wasn’t until the advent of the personal computer that electronic apparatus were developed which allowed plantar pressure assessment to become a practical tool for both research and clinical use.

Since its inception, plantar pressure analysis has been used most frequently in the study of the causes, prevention and healing of diabetic foot ulcerations. Dynamic plantar pressure analysis has also been used widely to study those with rheumatoid arthritis. Its application, however to other areas of interest has not been as extensive. One such area is primarily mechanical problems such as overuse injuries of the foot.

For the most part, the plantar pressure research conducted in the Gait Research Laboratory at Northern Arizona University over the past 18 years has focused on using dynamic plantar pressure analysis to better understand musculoskeletal overuse injuries of the foot and ankle. Many of these studies were also designed to answer key questions regarding how it could be used and whether there were limitations in its use.

Much of theory regarding how the foot moves during activities such as walking has come from our observation of the shape and alignment of the foot. Extrapolations and predictions regarding foot movement have then been made based upon the foot’s morphology. This method of deductive reasoning is predicated upon the notion that “Form Dictates Function” and is very common amongst clinicians who treat foot problems. For example, if a patient is observed to have high medial longitudinal arches, it is predicted that their arch will have little or no contact with the supporting surface and they will walk with greater pressures under the lateral aspect of their foot. Although logical, the actual results may be different. See Figure 1.

Like foot motion, predicting plantar pressure patterns during walking can at times be counter intuitive and the results mixed. Using dynamic plantar pressure analysis is further complicated by issues related to methodology and the normally occurring variation of human performance. Attention to those factors that the researcher or clinician has control over are essential to extracting the maximum benefit from dynamic plantar pressure analysis.

REFERENCE


Figure 1: Maximum force during walking for individuals with low, normal and high medial longitudinal arches.
PLANTAR PRESSURE DISTRIBUTION IN FENCING SHOES

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INTRODUCTION
Fencing is a highly dynamic activity with specific and unique loading of the lower extremity. Up to now only a few publications have dealt with this issue. There are a few reports about psychological and medical aspects (2, 3, 4) as well as on biomechanical aspects and performance-related factors in fencing (1). Therefore, the aim of the present investigation was to evaluate plantar pressure distribution patterns in different fencing shoes in fencing-specific movements. These measurements deliver valuable information about the functional performance of the shoes.

METHODS
Measurements were carried out at the Olympic Fencing Center Bonn and the Motion Analysis Lab. A total of 29 athletes participated (19.8±8.7 yrs, BMI 22.7±3.7 kg/cm², 20 males, 9 females, 18 elite and 11 advanced fencers). For the plantar pressure measurements the pedar system was used (Novel GmbH, Munich). The footprint was subdivided into 5 regions of interest: heel, midfoot, forefoot, hallux, toes 2-5. The following parameters were used: contact area (Ca), contact time (Ct), force time integral (Fti), maximum force (Mf) and peak pressure (Pp). The following fencing shoes were compared: Own fencing shoe (OS), Adidas “adistar fencing lo” (FL) and Nike Prototype II (NP). The following movements were performed: walking, jogging, running and fencing specific movements: advance, retreat, advance-lunge.

RESULTS
There were minor differences between the measured parameters regarding the different fencing shoes. The pressure distribution, the ground reaction forces as well as high speed video recordings show that in the advance-lunge the heel makes the initial contact with the fencing piste. The maximum force in the heel region is highest in ‘their’ own fencing shoe (861.3 N), followed by the NP shoe (789.8 N) and the FL (774.4 N). After heel impact the forefoot is loaded in the metatarsals, fore foot (OS = 402.3 N, NP = 447.2 N, FL = 456.4 N) and hallux/toes. The data shows high maximum forces and peak pressures in fencing shoes which originate from the fencing specific movements, especially in the lunge. The OS showed the highest Pp value of 669.1 [kPa], in the heel area followed by the FL-shoes and NP. A significant difference the advance-lunge between NP and FL does not exist in the heel area. The highest differences between Nike and Adidas FL occurred in the hallux region during walking, running and advance-lunge (p < 0.01) followed by the values for Nike (369.9 kPa) and OS (429.4 kPa) during running.

DISCUSSION
The comparison of the three shoes shows that the own fencing shoes caused the highest loading in the lunge which was probably due to the wear of the shoe. The own shoes were between 3 months and 1 year old.

CONCLUSION
The extreme Mf and Pp during fencing activities underline the need for specific cushioning in heel and forefoot region. Especially the shoe of the lunge leg must be well cushioned. More pressure data from other fencing shoe models is needed with regard to other (dynamic) fencing movements in order to obtain further information about shoe design as well as their loading characteristics.

REFERENCES
2. KUCERA, Sportorthop- Sporttraumat. 19; 273-280, 2003

Nike provided financial support and the prototype shoes
METATARSAL FRACTURE PREVENTION: CAN A MORE FLEXIBLE BOOT REDUCE 5TH METATARSAL HEAD PRESSURES DURING SPORT MANEUVERS?


INTRODUCTION
Metatarsal fractures have become an increasing common injury for athletes in sports that involve rapid changes in running speed and direction. Fifth metatarsal (5th ray) fractures have recently sidelined several prominent footballers. High peak pressure at the head of the 5th ray combined with lower peak pressure at the base of the 5th ray has been hypothesized to induce a bending moment on the 5th ray (Orendurff, 2008). This bending moment differential may overload the 5th ray during sprint and cutting maneuvers, leading to both stress fractures and acute fractures. Perhaps a boot designed with greater mid- and outsole flexibility could reduce this 5th ray pressure differential, and protect more athletes from injury during the demanding maneuvers of their sport.

METHODS
Right foot pressures were recorded using a Pedar (Novel, GmbH, München) insole system (99 Hz) on ten male college-aged athletes while they ran a course that included running straight, cutting left, cutting right, accelerating, jumping and landing. Subjects ran the course twice (random order), once wearing a Nike Speed TD, a conventional football boot (STIFF) with a traditional molded cleat outsole (14 cleats) made of thermoplastic polyurethane elastomer, no midsole, and a 4mm ethylene vinyl acetate sockliner; and also wearing a Nike Air Pro Turf, a more flexible boot (FLEX) with a rubber outsole with multiple small traction elements (171 cleats), with an ethyl vinyl acetate midsole, and a 7.5mm ‘zoom’ tensile air sockliner. Course times were within 5% to ensure similar running speeds. Using a videotape, each footstep was matched to a step processed in Emedlink to identify which maneuver was being performed (396 individual steps were processed; some transition steps were disregarded). Seven regions of the foot were evaluated for peak pressure with specific focus on the head and base of the 5th ray, to determine the bending moment differential for both boots across all maneuvers. A repeated-measures 3-way ANOVA (2 boots x 2 regions x 6 maneuvers) with Scheffé’s tests post hoc were used for statistical analysis.

RESULTS

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>5th Base</th>
<th>5th Head</th>
<th>Differential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerating</td>
<td>20.6 ±12.1</td>
<td>48.6±10.4</td>
<td>28.0</td>
</tr>
<tr>
<td>Cut Left</td>
<td>10.7 ± 4.4</td>
<td>12.0 ± 3.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Cut Right</td>
<td>32.3 ± 12.0</td>
<td>27.9 ± 13.8</td>
<td>-4.4</td>
</tr>
<tr>
<td>Take-Off</td>
<td>18.5 ± 7.6</td>
<td>27.8 ± 13.3</td>
<td>9.3</td>
</tr>
<tr>
<td>Landing</td>
<td>19.1 ± 7.0</td>
<td>26.2 ± 11.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Run Straight</td>
<td>12.6 ± 5.7</td>
<td>26.5 ± 9.8 *</td>
<td>13.9</td>
</tr>
</tbody>
</table>

Table 1: Peak pressure (N/cm²) for STIFF and FLEX boots during six maneuvers. * indicates stat sig diff 5th head > 5th base (p<0.003); † indicates stat sig diff STIFF boot > FLEX boot (p<0.001).

DISCUSSION
Accelerating produced the highest peak pressures at the 5th ray head for both boots, but the FLEX boot reduced peak pressure at the 5th ray head by 30%, and the bending moment differential by 54%. Running straight also produced a moderate 5th ray bending moment differential in both boots, but the FLEX boot reduced this differential by 30%. Cutting right, with the 5th ray on the inside on the turn, did produce high 5th ray peak pressures, but trivial bending moment differentials. The flexible boots may have reduced the peak pressures by allowing the foot to conform more during these maneuvers, increasing contact area. These data suggest that a trial of flexible boots might reduce 5th ray bending moment differentials enough to diminish stress and acute fracture risk during typical maneuvers in football.

REFERENCE
PLANTAR PRESSURE EXPERIENCED DURING TENNIS SPECIFIC MOVEMENTS
PERFORMED ON THE 3 GRAND SLAM COURT SURFACES

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INTRODUCTION

Recent epidemiological studies report the general increase in prevalence of lower limb injuries in tennis (Strauss, 2003; Cassell, 1999; Bylak 1998). In part this finding is not entirely unexpected as worldwide participation in tennis continues to grow (LTA, 2007; Francescom, 2005; Cassell 1999) it would therefore be expected that injury levels rise in accordance. However, the rise in lower limb injuries appears disproportionate to other regions.

It has long been established that impact force is at the centre of injury generation (Nigg, 1986). Strauss (2007) identified typical impact forces produced during tennis specific movements will range from 2.44BW to 2.80BW. This is related to movement velocity and is significantly dependent on the hardness of the playing court surface, with acrylic courts eliciting the maximum impact forces.

The distribution of these impact forces about the foot is largely unknown. The aims of this study are (1) to identify typical plantar pressures experienced during tennis specific movements and (2) in vivo assessment of the affect of a change in court surface in relation to the peak pressures experienced.

METHODOLOGY

Seventeen participants (9 male, 8 female, mean age 23.18yrs ±8.78 mean mass 64.81kg ±12.87), all regular tennis players from a mixed range of ability and experience took part in the study. Two tennis specific movements (representing low and high intensity) were performed on grass, clay and acrylic surfaces. Plantar pressure data was collected using the Pedar X (Novel gmbh) system. A seven region mask was established sectioning the foot into the medial and lateral heel, medial and lateral midfoot and medial, central and lateral forefoot.

RESULTS AND DISCUSSION

Plantar pressure was found to be highest in the medial forefoot region for all three surface types under both movement conditions. For the high intensity movement there was a general increase across the foot, with forefoot pressures exceeding 350kPa. It is important to note that these are single cell peak pressures and are not the sum of pressure experienced by the foot at any one instance.

![Figure 1: Peak pressure for the medial forefoot region.](image)

Figure one suggests for low intensity movements there is no significant affect of court surface type. For the high intensity movement there is a significant difference between the acrylic and clay court surfaces. An additional point to note is that the peak pressure difference between the low and high intensity movements are significantly different on the acrylic and grass court surfaces but not for the clay court surface.

Overall injury prevention would advocate a general reduction in plantar pressure. This study suggests the medial forefoot region to be an area of particular interest. The primary source of pressure reduction is suggested to be via specific shoe design for particular surface types.

REFERENCES

LTA http://www.lta.org.uk/Newsroom/FactAndFigures /BSMguid=5d3464ac-ad2c-4268-8176-03aele979828 [accessed on 25 Feb 2007].
CAN 9 WEEKS OF IYENGAR YOGA ALTER DYNAMIC PLANTAR PRESSURE?

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3. B.K.S. Iyengar Yoga Studio of Philadelphia, PA, USA
4. Leon Root, MD Motion Analysis Laboratory, Hospital for Special Surgery, New York, USA

INTRODUCTION
Falls are a serious health risk in elderly females. Thirty percent of individuals over the age of 65 fall every year and approximately 90% of the 240,000 annual hip fractures occur in women 65 years and older in the US (2000). By promoting stretching and strength training, and improving overall awareness of posture and locomotion, a classical Iyengar yoga program is postulated to improve health and wellness in older adults and reduce the risk of falling.

Results from studies investigating various exercise modalities have shown improved performance. Subjects experienced increased peak hip extension and stride length following an 8-week Iyengar Hatha yoga program in 19 elderly females (DiBenedetto, 2005). The purpose of this pilot study was to examine the effects of a 9-week classical Iyengar yoga program on postural stability and gait on elderly females.

METHODS
Employing a single group pre-post test comparison, 24 healthy women aged 59-76 years were evaluated at baseline and following nine weeks (two 90-minute sessions per week) of a structured Iyengar yoga program. Dr. Garfinkel and yoga master BKS Iyengar devised a specific Iyengar yoga exercise program, which consisted of simple non-strenuous poses specifically tailored for the elderly who have had little to no yoga experience. Participants were also instructed to practice particular exercises at home three times per week. This study was approved by the Temple University Institutional Review Board and informed consent was obtained from each participant prior to enrollment.

Plantar pressures were quantified with EMED-X during comfortable walking. Peak pressures and pressure time integrals were calculated for 3 masks; anterior/posterior, medial/lateral, and 10 segment (med/lat heel, med/lat midfoot, metatarsal heads 1-5 and hallux). The difference between baseline and follow-up was assessed using a repeated-measures analysis of variance.

RESULTS
On average, subjects attended 25 hours of mentored training over 9 weeks. Increased loading under the 1st metatarsal head along with a reduction of pressure beneath the 3rd metatarsal head were significantly different statistically, as indicated by the highlighted regions in table 1 and seen in figure 1.

DISCUSSION
The increase in pressure under the 1st met head and the decrease in pressure under the 3rd met head suggest a more efficient walking pattern. Although the study was limited to 9 weeks, results suggest yoga can alter plantar pressures. Additional studies are needed to confirm whether practicing yoga and changes in plantar pressures will prevent falls in elderly women.

REFERENCES
STATIC AND DYNAMIC ANALYSIS OF FOOT STRUCTURE IN ATHLETES SUSTAINING PROXIMAL FIFTH METATARSAL STRESS FRACTURE

Iftach Hetsroni (1,2), Meir Nyska (1,2), Gideon Mann (1,2), Ofer Segal (3), Guy Maoz (1,2), David Ben-Sira (3), Liran Lifshitz (1,2), Moshe Ayalon (3)

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INTRODUCTION
Stress fracture of the proximal fifth metatarsal is a well recognized entity. Non union and re-injury are not infrequent following non operative management (Orava, 1988; Porter, 2005). Biomechanical foot characteristics as lateral overloading in rigid cavus foot have been suggested as contributing factors (Williams, 2001). However, scientific evidence supporting a unique foot structure in professional athletes sustaining this injury is lacking. The purpose of our study was to examine whether static and dynamic variables of foot structure in athletes which sustained this injury are unique and support a biomechanical rationale for the development of this fracture.

METHODS
This study compared three groups: 10 injured feet of 10 soccer players which regained professional activity following unilateral proximal fifth metatarsal stress fracture; 10 contralateral non injured feet of these same athletes; and 20 control feet of 10 healthy non injured soccer players. Static variables of arch height and flexibility were measured, followed by dynamic evaluation of foot loading which was performed using EMED-AT pressure measurement platform.

RESULTS
Static measurements of arch height and flexibility did not reveal significant differences among the three groups. Dynamic variables as contact time, contact area and arch index, evaluated with the EMED system, did not reveal as well significant differences among the groups. However, peak pressures and pressure integral under the fourth and fifth metatarsals of injured athletes were decreased compared with non injured athletes, while pressures under the first metatarsal were increased in the injured population compared with control.

CONCLUSIONS
In the specific population of professional soccer athletes, arch height and flexibility may not play an independent role in the development of proximal fifth metatarsal stress fracture. Reduced pressures under the lateral metatarsals and increased pressures under the medial metatarsal in this population may either play a role in the development of this fracture, or merely reflect a resultant pressure distribution pattern following this injury.

REFERENCES
THE INFLUENCE OF SURFACE IN THE MEDIAL AND LATERAL FOOT AREAS DURING RUNNING ON THE GRASS AND ASPHALT

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INTRODUCTION

Quantifying the occurred loads during running is fundamental to better understand the cause of run injuries. Stefanyshyn (2006) described that a high stiffness or a low deformation of the surface, as well as the ground irregularity, might be considered as causes of acute and/or cumulative injuries. In addition to the type of the chosen surface for running practice, anatomical or mechanical asymmetries that may occur due to the foot contact geometry at the moment of footstrike during running have been also cited as a factor related to the increase of injury incidence in runners. Therefore, the purpose of this study was to investigate plantar pressure asymmetries between medial and lateral areas of plantar surface during running in natural grass and asphalt.

METHODS

Forty-four recreational runners, both sexes, from 18 to 50 years old (36±7yr; 172±9cm; 70±12kg) were evaluated during running on 2 training surfaces: natural grass and asphalt. The Pedar X insoles were placed between runners’ foot and a standard sport shoe. Subjects run at 12km/h for 40m on both surfaces. The speed was assured on each trial by calculating the time to perform the established distance. The contact area (CA), contact time (CT) and peak pressure (PP) were the variables evaluated in: MR – medial rear foot, CR – central rear foot, LR – lateral rear foot, MF – medial forefoot, and LF – lateral forefoot. The Symmetry Index (SI) was calculated according to Robinson et al (1987) (equation 1) for all the variables considering medial and lateral plantar areas and also asphalt and natural grass.

\[
SI = \frac{(X_{\text{grass}} - X_{\text{asphalt}})}{(\sqrt{\frac{1}{2}(X_{\text{grass}} + X_{\text{asphalt}})})} \times 100
\]

where \(X\) is the mean variable for each subject on each surface.

The t paired test was used to compare the asymmetries between surfaces in medial and lateral rear foot and forefoot (\(\alpha=1\%\)).

RESULTS

Figure 1: Differences between lateral – medial regions of rear foot and forefoot for contact area (cm\(^2\)), contact time (ms) and peak of pressure (kPa) on each surface (a: \(p<0.001\); b: \(p<0.01\); c: \(p<0.001\)).

DISCUSSION

The SI for contact area was slightly higher in the rear foot and forefoot on natural grass, and symmetrical between medial and lateral areas, which may have occurred due to the greater complacence of natural grass compared to asphalt. The high SI values for contact time indicated that a less hard surface led up to an increase in contact time in the forefoot, greater at the medial than in lateral area. Peak Pressure SI values were significantly higher in the lateral rear foot and forefoot on asphalt. The harder surface caused loads from 2.3 to 2.8 greater in the lateral than at the medial area in the rear foot and forefoot, respectively. This result may be justified by the shorter contact time presented in the lateral area producing a smaller dissipation of the pressure in that area. Therefore, the surface stiffness may be considered as a determinant factor for this outcome. A lower contact time in asphalt restricts an adequate movement of the rear foot increasing the load in the lateral area during running.

REFERENCES

DYNAMIC PLANTAR PRESSURE PARAMETERS PREDICTIVE OF STATIC ARCH HEIGHT INDEX

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BACKGROUND

Extreme values of static arch height have been associated with increased risk for overuse injury (Kaufman, 1999; Williams, 2001). However, limited knowledge exists on the association between static arch height and dynamic plantar pressure distributions during gait. The primary purpose of this study was to explore which dynamic plantar pressure measurements were associated with arch height. The secondary purpose was to determine if a multivariate model representing the dynamic foot could be used to predict the arch height index (AHI; Williams, 2000).

METHODS

Subjects. One thousand subjects (566 males, 434 females, 30.6 ± 8.0 years, 171.1 ± 9.3 cm, 76.9 ± 14.7 kg) were enrolled in this study. They were predominately active adults who ran 3.1 ± 1.4 days/week and 9.8 ± 8.5 miles/week.

Methods. Arch height at 50% foot length and AHI (Williams, 2000) during bilateral stance was measured. AHI was calculated using both toe-to-heel length and truncated foot length (heel to first metatarsophalangeal joint). Additionally, subjects walked across a capacitive-based pressure platform (emed-x®, Novel Electronics, Inc., St. Paul, MN) using a two-step technique. The dynamic pressure pattern data represented a mean of five steps.

Data Analysis. Force, pressure, area, and time-related dependent measures (20 variables) for ten separate regions of the plantar foot were calculated (Cavanagh, 1994). Geometry of the foot was described with an additional 46 variables, resulting in a total of 246 potential variables for inclusion in the model.

In this exploratory study, a significant Pearson product moment correlation (p < 0.01 and r > 0.3) was used to narrow the number of variables of interest. A hierarchical stepwise backwards regression analysis was performed to determine the most parsimonious set of variables associated with arch height. Area, force pressure, and geometry variables were sequentially entered in four blocks. The dynamic measures used to predict arch height and foot length were used to define a dynamic arch height index (DAHI). Correlation and residual analysis was performed to assess the association between the AHI and the DAHI.

RESULTS

The mean AHI value based on the truncated foot length was 0.339 ± 0.027, while the mean AHI value based on total foot length was 0.249 ± 0.020.

Pearson product moment correlations yielded 39 variables with an r-value > 0.3. The backward stepwise multivariate regression analysis resulted in 19 variables of interest. Thirteen variables were removed from the model based on multicollinearity. The resulting six variable model had an r-value of 0.79 (R²: 0.62, Adjusted R²: 0.62). The residual between the predicted and measured value of arch height was 0.00 ± 0.38 cm. Only 16 of the 1,000 individuals had a residual difference > 1.0 cm.

Variables related to area, force, pressure, and geometry remained in the final model. Greater contact area and area of the medial hindfoot were associated with a lower arch height. An increase in area between the foot axis and gait line was noted in those with a higher arch height. A larger force-time integral (impulse) value for the lateral hindfoot was associated with a higher arch. Finally, greater force and pressure was noted in the lateral forefoot (metatarsals three, four, and five) in those with a higher arch.

DAHI values from the predicted arch height and dynamically measured toe-to-heel foot length yielded a mean value of 0.242 ± 0.019. The mean difference between the computed and predicted AHI values was 0.007 ± 0.004. The correlation between AHI and DAHI values was 0.98.

DISCUSSION & CONCLUSIONS

A multivariate model generated by dynamic plantar foot parameters during gait was able to predict static arch height. This model consisted of variables that appear to be clinically plausible and inform the association between static arch height and dynamic foot posture. Future research should assess which of these variables may be linked to increased incidence of injury in individuals with extreme foot postures.

REFERENCES

PLANTAR PRESSURE DISTRIBUTION IN GAIT IS NOT AFFECTED BY TARGETED REDUCED PLANTAR CUTANEOUS SENSATION

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INTRODUCTION
Plantar ulcers are one severe, painful and costly complication of diabetes mellitus and peripheral neuropathy. The increased plantar pressure is accepted to be one major factor for ulceration. Insensitive skin in consequence of sensory neuropathy avoids adequate pressure and pain sensation and is assumed to play an important role for the increased plantar pressures. Previous studies (hypothermic) tried to experimentally change plantar cutaneous sensation but failed to isolate other sensory systems and motor functions. The purpose of this study was to quantify plantar pressure distribution in gait after targeted reduced plantar cutaneous sensation leaving foot and ankle proprioception and intrinsic foot muscles unaffected.

METHODS
Ten healthy subjects volunteered for the study. Dynamic plantar pressure distribution in gait and sensory perception threshold (SPT) of the plantar foot were determined pre and post sensory intervention. Sensation from the weight-bearing surface of both foot soles was directly reduced through multiple intradermal injections (8-12 each sole) of an anaesthetic solution (mod. Meyer et al. 2004). SPT for pressure touch was quantified with a set of 20 Semmes-Weinstein monofilaments (SWMF) (North Coast Medical, Inc., Morgan Hill, USA) using the one-time-period 4, 2, 1 stepping algorithm with null-stimuli (Dyck et al. 1993). SPT for low (25Hz) and high (200Hz) frequency vibration was measured with a custom-modified HVLab Tactile Vibrometer operating with the Bekesy-method (Institute of Sound and Vibration Research, University Southampton, UK).

Dynamic pressure distribution measurement was acquired by an EMED-x/R platform (100Hz, 4 sensors/cm²), (Novel GmbH, Munich, Germany). Five barefoot gait trials of the right foot at each condition were performed using the third-step method. Ten plantar foot regions were defined for analysis. Data analysis was conducted for contact time, peak pressure, pressure-time integral, maximum force and force-time integral (Novel scientific software).

RESULTS
Plantar cutaneous sensation was significantly reduced at the level of sensory neuropathy for pressure touch (figure 1) and vibration (25/200Hz) after sensory intervention. The post-intervention data were measured following a period of 48±10min (mean±SD) with reduced sensation.

DISCUSSION
No increased plantar pressures or forces at the foot regions occurred after reduction of plantar cutaneous sensation while leaving other sensory systems and motor functions unaffected. If ulceration is related to higher plantar pressures and if higher plantar pressures are not related to reduced plantar cutaneous sensation, other factors must be crucial. It is documented that intrinsic muscle atrophy in consequence of motor neuropathy is present before sensory neuropathy is clinically detected (Greenman et al. 2005). The decreased intrinsic foot muscle capacities and their possible consequences such as limited joint mobility, foot deformity and changes to plantar soft tissue thickness should be related to the pressure increase. Interventions should be initiated early and focus on the intrinsic foot muscle functions.

REFERENCES
BULK COMPRESSION PROPERTIES OF THE HEEL FAT PAD DURING WALKING: A PILOT INVESTIGATION IN PLANTAR HEEL PAIN.

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5. Queensland X-ray, Mater Private Hospital, Australia

BACKGROUND

Altered heel pad properties have been implicated in the development of plantar heel pain. However, the in vivo properties of the fat pad in plantar heel pain remained largely unexplored. Of the few studies conducted, most have used loading parameters that fail to replicate those experienced by the heel pad during gait and, as such, lack ecological validity.

Promising early work, however, in which cine-radiography was used to evaluate the in vivo strain of the heel pad during running (De Clercq et al., 1994), has recently been expanded to include simultaneous measures of the contact pressure beneath the heel (Gefen et al., 2001). By incorporating measures of contact stress, the modified technique affords the ability to estimate geometrically-independent, material properties of the heel pad under the dynamic conditions of walking, thus overcoming the limitations of many previous techniques. The aim of the current study, therefore, was to employ a digital fluoroscope integrated with a capacitance mat transducer system to estimate the viscoelastic properties of heel pad in individuals with and without unilateral plantar heel pain while walking at their preferred pace.

METHODS

Nine subjects with unilateral plantar heel pain (age, 48 ± 13 yrs; height, 1.68 ± 0.11 m; weight, 81.6 ± 10.7 kg) and nine asymptomatic control subjects, individually matched for age, sex and body weight (age, 46 ± 12 yrs; height, 1.67 ± 0.11 m; weight, 80.1 ± 10.4 kg) participated in the study. Subjects with heel pain presented with focal tenderness localised to the plantar fascial enthesis, which was exacerbated by the onset of weight-bearing activity. Exclusion criteria included diffuse or bilateral pain, evidence of inflammatory arthropathy or a history of trauma or foot surgery. The average duration of pain was 9±6 months with a mean ‘first step’ pain score of 4±2 cm on a standard 10-cm visual analogue scale. All subjects gave written informed consent prior to participation in the study, which received approval from the institutional review board.

A pressure platform (EMED-SF, Novel GmbH, Munich, Germany) synchronised with a cine-radiography unit (Shimadzu, Kyoto, Japan) was used to obtain stress-strain data for the heel pad while subjects walked at their preferred speed. The initial thickness and compressive strain of the fat pad were estimated from dynamic lateral radiographs, while the compressive stress was derived from peak pressure data. Principle viscoelastic parameters of the heel pad were estimated from subsequent stress-strain curves.

RESULTS AND DISCUSSION

The ensemble stress-strain curve for subjects with and without heel pain is shown in Figure 1. Paired t-tests revealed no significant difference in heel pad thickness, peak stress and secant or tangent elastic modulus in subjects with and without heel pain. However, the fat pad of symptomatic feet had significantly lower energy dissipation (54 ± 17% vs 68 ± 10%) when compared to asymptomatic feet (P<.05).

![Figure 1: Ensemble stress-strain curves for the fat pad in subjects with and without heel pain (n=9).](image)

Although loading properties remain largely unaltered, plantar heel pain appears to influence the unloading profile of the heel pad and is characterised by reduced energy dissipation when measured in vivo under physiologically relevant strain rates.

REFERENCES

ASSESSING GAIT ASYMMETRIES USING PEDOBAROGRAPHIC STATISTICAL PARAMETRIC MAPPING

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INTRODUCTION

The evaluation of asymmetry is fundamental to clinical gait assessment (Sadeghi, 2000), and pedobarographic asymmetries can provide clinically useful indications (Becker, 1995).

Existing pedobarographic asymmetry metrics are based on segmentation methods which sample on the order of ten pressure values from discrete regions. Here we present an alternative asymmetry metric derived from pedobarographic Statistical Parametric Mapping (pSPM). pSPM is adapted from a highly developed methodology for the spatial analysis of fMRI functional brain images (Friston, 1995).

The purpose of this study was to assess the extent to which pSPM could detect gait asymmetries not evident in traditional asymmetry metrics.

METHODS

Peak pressure images (20 left foot, 20 right foot) were collected from 12 healthy subjects (26.9±8.1 years). The images were registered (Maintz, 1998) using an optimal rigid body transform so that homologous structures optimally overlapped (Fig. 1a, b). Mean images (Fig. 1c, d) were computed, and a statistical ‘T map’ was constructed (Fig. 1e) following Friston (1995). We then defined an asymmetry index (AI) to quantify field differences over the entire foot:

\[
AI = \frac{1}{A} \int \int_{x,y} SPM(T) ; T \in T > t_{Bonf}
\]

where SPM(T) is the 2D T map, A is the contact area, and \(t_{Bonf}\) is the Bonferroni-corrected t threshold.

We also computed a vertical ground reaction force symmetry index after Robinson (1987) and a regional pedobarographic index after Becker (1995) and examined the correlations of the various indices.

RESULTS

Significant differences between the left and right feet were observable in all healthy pedobarographic fields (e.g. Fig. 1e). The SPM-based AI exhibited poor linear correlation with both the ground reaction force and the regional pedobarographic indices (r = 0.250, 0.230, and p = 0.459, 0.496, respectively).

DISCUSSION

The main result is that pedobarographic fields contain asymmetry information that is not captured by either ground reaction force or regional pressure data. These field asymmetries, observable in non-pathological gait, should be considered when assessing the clinical status of involved and non-involved limbs; in cases of non-pathological but significant asymmetry it may be inappropriate to compare involved and non-involved limbs directly.

We are currently in the process of evaluating the proposed asymmetry index on a large sample of metatarsalgia patients with the goal of promoting more robust asymmetry-based clinical assessment.

REFERENCES

COMPARISON OF PARAMETERS PRODUCED BY EMED AND PEDAR PRESSURE MEASURING SYSTEMS

Diamanto Maliotou (1), Despina Theodorou (1), Tatiana Tsvetkova (2)

1. foot-forward, Cyprus
2. novel SPb, Russia

INTRODUCTION
Comparison of pedar in-shoe system with Kistler platform to measure vertical force in healthy subjects was carried out in [1,2]. The aim of this study was to determine the correlation between pressure distribution parameters produced by emed and pedar pressure measuring systems in examination of patients with diabetes mellitus.

METHODS
11 patients, 8 men and 3 women (age 61±11 years), diagnosed with diabetes mellitus: 1 type (1), 2 type (5), 2 type on insulin (5) were selected for this study. Simultaneous data were collected with emed platform system (25 Hz, 4 sensors/cm2) and pedar in-shoe system (50 Hz), novel, Munich, Germany (patients were in casual shoes). novel database medical was used to collect clinical and pressure measurement data. Peak pressure (PP), maximum force (MF), pressure-time integrals (PTI), force-time integrals (FTI), contact time (CT), contact time (%ROP) (CTp), begin of contact (BC), end of contact (EC), contact area (CA), instant of maximum force (IMF) and instant of peak pressure (IPP) were calculated in novel-projects with pedar_standard.msp mask for hindfoot (HF), midfoot (MF), lateral forefoot (LFT) and medial forefoot (MFT), big toe (T1), and lesser toes (T2345). The difference between pressure distribution parameters produced by emed and pedar measurements was checked with ANOVA.

RESULTS AND DISCUSSION
Maximum force (1090±272 vs. 828±542), force-time integrals (959±475 vs. 545±844), instant of maximum force (59±19 vs. 54±17) and instant of peak pressure (75±20 vs. 65±17), as well as contact area (144±23 vs. 133±25) calculated for emed measurements correlated well with that obtained for pedar measurements.

Peak pressure (896±303 vs. 285±124), pressure-time integrals (554±235 vs. 139±82) and contact time (1300±619 vs. 753±189) were significantly lower for pedar. P-values for differences of parameters produced by emed and pedar measurements beneath the foot areas are given in table 1.

Table 1. P-values for differences of parameters (emed vs. pedar) beneath foot areas (* - p<0.001)

<table>
<thead>
<tr>
<th></th>
<th>HF</th>
<th>MF</th>
<th>MFF</th>
<th>LFF</th>
<th>T1</th>
<th>T2345</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>*</td>
<td>.01</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>MF</td>
<td>.01</td>
<td>.08</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.38</td>
</tr>
<tr>
<td>PTI</td>
<td>*</td>
<td>.03</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>FTI</td>
<td>.04</td>
<td>.17</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.66</td>
</tr>
<tr>
<td>CA</td>
<td>29</td>
<td>.05</td>
<td>*</td>
<td>*</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>.003</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>CTp</td>
<td>*</td>
<td></td>
<td>.02</td>
<td>.11</td>
<td>.13</td>
<td>.84</td>
</tr>
<tr>
<td>BC</td>
<td>.55</td>
<td>.22</td>
<td>.70</td>
<td>.58</td>
<td>.45</td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>.01</td>
<td>.02</td>
</tr>
<tr>
<td>IPP</td>
<td>.03</td>
<td>.04</td>
<td>.34</td>
<td>.08</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>IMF</td>
<td>.03</td>
<td>.52</td>
<td>.16</td>
<td>.05</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Peak pressure and pressure-time integral well correlated beneath the midfoot only. Significant increase of maximum force and force-time integral beneath medial and lateral forefoot and big toe; significantly later instant of peak pressure and maximum force beneath the toes; significant increase of absolute contact time beneath all foot areas; significantly later begin of contact and decrease of contact time (in %ROP) beneath the midfoot were found in emed data. Significantly lower values of in-shoe measurement parameters were expected because in-shoe measurements reflect the influence of shoes on pressure distribution. However, loading of forefoot and big toe is sensitive to measurement system. Maximum force and force-time integral beneath the foot, hindfoot and lesser toes well correlated as well as loading of midfoot.

CONCLUSION
emed and pedar measurements produce both different and correlated information about pressure distribution parameters, supplementing each other.

LITERATURE
THE FEASIBILITY OF INTRA-OPERATIVE PLANTAR PRESSURE ASSESSMENT

Scott Ellis(1), Richard Cheng(1), William Aibinder(1), Joe Lipman(3), Glen Garrison(4), Sherry Backus(2), Howard Hillstrom(2), Jonathan Deland(1)

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INTRODUCTION
Clinical experience and radiographic parameters are the mainstay for inter-operative clinical decision making in foot surgery (e.g. flatfoot reconstruction). An intra-operative plantar pressure measurement system was developed that requires the knee to be at 90 degrees of flexion (Richter, 2006). The goal of the current study was to design/prototype an accurate and reliable intra-operative plantar pressure measurement system to guide surgical decision making on patients lying supine with their knees at 0 degrees of flexion.

METHODS
A custom Plance 32 sensor array (Novel, Munich, Germany) with a resolution of 1.85 sensors/cm² (29 rows by 28 columns) was employed. The loading apparatus consisted of an aluminum base-plate which was advanced with a turn screw against the plantar foot using a slide-rail assembly (Figure 1).

Figure 1: Intra-operative plantar pressure system
A custom molded polypropylene cuff grounded the apparatus to the knee at the adductor tubercle. Test pressures ranged from 0 – 6 Bar in increments of 0.5 Bar. Root mean square error (RMSE) between the input and measured pressures was used to assess accuracy. Ten healthy subjects were tested in the apparatus (S_r=24Hz) bilaterally by two separate raters at forces of 25%, 37.5%, and 50% of body weight (BW). The same subjects were then tested in vertical posture (S_r=10Hz) and gait (S_r=100Hz) using the emed-X sensor platform (Novel). Mean average pressures (MAP) for supine, posture, and gait conditions were compared using analysis of variance (ANOVA) with post hoc t-tests.

RESULTS
The sensor was shown to be linear (R²=0.9996) and accurate (RMSE=0.15 Bar). The ICC (2,1) values demonstrated that the sensor was reliable (Shrout, 1979) within a rater for test-retest (0.77-0.93) and for remove and replace (0.64-0.79) conditions as well as between raters (0.69-0.77) with 50% BW being the most reliable. The MAP values were significantly different at each anatomical region across test conditions (supine, vertical posture, and gait) via ANOVA. Post hoc Bonferroni tests found significantly different supine and vertical posture pressures for most plantar regions except the hallux and toes (Table 1). Plantar pressures during gait were significantly larger than those of supine and vertical posture.

<table>
<thead>
<tr>
<th>MAP KPa</th>
<th>R1- Sup</th>
<th>R2- Sup</th>
<th>Posture</th>
<th>Gait</th>
<th>P- Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hallux</td>
<td>12.9 *</td>
<td>12.0 *</td>
<td>16.0 *</td>
<td>58.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2nd toe</td>
<td>8.7 *</td>
<td>9.6 *</td>
<td>7.5 *</td>
<td>31.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3-5 toes</td>
<td>9.0</td>
<td>9.6</td>
<td>2.9</td>
<td>20.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MH1</td>
<td>14.9 *</td>
<td>14.4 *</td>
<td>32.7</td>
<td>70.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MH2</td>
<td>21.8</td>
<td>21.5</td>
<td>40.6</td>
<td>107.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MH3</td>
<td>23.6</td>
<td>23.4</td>
<td>39.4</td>
<td>90.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MH4</td>
<td>20.3</td>
<td>20.2</td>
<td>31.7</td>
<td>59.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MH5</td>
<td>15.4</td>
<td>15.2</td>
<td>20.34</td>
<td>35.5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Midfoot</td>
<td>12.3</td>
<td>12.1</td>
<td>19.7</td>
<td>32.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>M. heel</td>
<td>92.3</td>
<td>92.8</td>
<td>71.4</td>
<td>108.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>L. heel</td>
<td>69.0</td>
<td>69.6</td>
<td>57.7</td>
<td>89.1</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Table 1: Mixed Effect ANOVA – Map (Kpa); * post hoc Bonferroni tests that were not significant

DISCUSSION
The intra-operative pressure measurement system provides an accurate, linear, and reliable method to measure plantar pressure parameters in the supine subject.

REFERENCES
COMBINATION OF MORPHOLOGY AND PLANTAR PRESSURE DISTRIBUTION IN A SINGLE GRAPHICAL PRESENTATION FOR CLINICAL APPLICATION

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Germany, Essen, University Duisburg - Essen, Biomechanics Laboratory

INTRODUCTION

The aim of this project was to create a software tool which enables the user to analyse function and structure of the human foot in a simple way. Foot shape and plantar pressure distribution information provide useful information about the foot function of individuals. For the medical practitioner it would be advantage to have the information from these two useful, but independent datasets as a single graphical representation.

Therefore, a software tool was developed to visualize three dimensional foot scan data simultaneously with pressure distribution information under the foot.

METHODS & RESULTS

A visualization program was developed using MATLAB (Mathworks, Inc.). This software is able to combine foot geometry as well as plantar pressure distribution in one single graphical representation (PressoMorph 1.0).

Plantar pressure was recorded with a pressure distribution platform (Emed ST; Novel Inc.). The morphology of the foot was captured with a three dimensional foot scanner (INFOOT Scanner; IWL Inc.). Both data sets were exported as ASCII files.

After importing these two different data sets into PressoMorph 1.0 internal transformations match the data in geometric dimensions and angular orientations. The reconstructed three-dimensional image of foot morphology and plantar pressure distribution data is linked with a colour coded isobarographic illustration underneath the plantar foot area.

Moreover PressoMorph 1.0 includes some tools which allow the user to rotate the three-dimensional reconstruction of the human foot in all dimensions and enables a more detailed viewing of certain foot areas. Important foot parameters are also displayed on the user interface for further quantitative information. In addition, the current picture can be saved as a picture in JPEG-format. PressoMorph 1.0 also saves the measured data in ASCII - format. This simplifies an import of the data into various statistic programs.

CONCLUSION

This program was developed as a fast and easy way to analyse and judge pathologies, especially for clinical applications. The combination of three-dimensional foot geometry and plantar pressure distribution in one single graphical representation facilitates analyses of function and structure of the human foot in a clinical setting.

Quantitative data on the user interface complete the visual information and various additional software tools allow an evaluation of statistical relationships between morphological and plantar pressure information.
DYNAMIC PLANTAR PRESSURE PARAMETERS PREDICTIVE OF FOOT POSTURE

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BACKGROUND

Extreme foot postures have been associated with an increased risk for overuse injury (Burns, 2005; Cain, 2006). However, limited knowledge exists on the association between observed foot posture in standing and dynamic plantar pressure distributions during gait. The primary purpose of this study was to explore which dynamic plantar pressure measurements were associated with foot posture based on the six variable foot posture index (FPI-6; Redmond, 2006) as the reference criterion. A secondary purpose was to describe the FPI-6 total and subscale scores.

METHODS

Subjects. Participants (n = 1,000, 566 males, 434 females, 30.6 ± 8.0 years, 171.1 ± 9.3 cm, and 76.9 ± 14.7 kg) were predominately active adults who ran 3.1 ± 1.4 days/week and 9.8 ± 8.5 miles/week.

METHODS. FPI-6 (Redmond, 2006) was assessed during bilateral stance and scored from -12 to +12. Foot posture was categorized as: highly supinated (-12 to -5), supinated (-4 to -1), normal (0 to 5), pronated (6 to 9), highly pronated (10 to 12). Moderate interrater reliability was established (n = 60) for assessing foot posture (ICC 2,1: 0.78, SEM: 1.7).

Additionally, subjects walked across a capacitive based pressure platform (emed-x, Novel Electronics, Inc., St. Paul, MN) using a two-step technique. The data from an average of five steps were used to represent the dynamic pressure pattern.

Data Analysis. Descriptive statistics to describe the FPI-6 total and subscale scores were calculated. Force, pressure, area, and time-related dependent measures (20 variables) for 10 separate regions of the plantar foot (Cavanagh, 1994) were calculated. Geometry of the foot was described with an additional 46 variables, resulting in a total of 246 variables that were considered for potential inclusion in the model.

In this exploratory study, a significant Pearson product moment correlation (p < 0.001 and r > 0.2) was used to narrow the number of variables of interest. A hierarchical stepwise backwards regression analysis was performed to determine the mostparsimonious set of variables associated with the foot posture (FPI-6).

RESULTS

The mean FPI-6 value was 3.4 ± 2.9 (-6.0 to 11.0); resulting in the following classification: 13 highly pronated, 220 pronated, 669 normal, 93 supinated, 5 highly supinated. Very few subjects (n ≤ 31) scored a -2 on any of the 6 FPI subscales.

Pearson product moment correlations yielded 45 variables with an r-value > 0.2. The regression analysis resulted in 15 variables of interest. Seven variables were removed from the model based on multicollinearity. The resulting eight variable model had an r-value of 0.59 (R²: 0.34, adjusted R²: 0.34). The residual between the predicted and measured FPI-6 score was 0.0 ± 2.3 on the 25 point scale.

Variables related to area, force, pressure, and geometry remained in the final model. The pronated foot was associated with increased area medial to the gaitline and increased midfoot area relative to total foot area. The pronated foot was also associated with increased maximum force of the lateral midfoot and increased peak pressures of both the first and second toe regions. The supinated foot was associated with higher mean force values in the metatarsal region of rays three, four, and five and higher mean pressure in the region of the first metatarsal. Additionally, the instant of maximum force for the second metatarsal region tended to occur later in those with a supinated foot.

DISCUSSION & CONCLUSIONS

Although the FPI-6 resulted in a normal distribution, the range of values was limited. The limited number of subjects classified as highly supinated warrants further investigation and may require the use of different cut-off values to categorize the foot of a relatively healthy individual.

A multivariate model generated using dynamic parameters associated with the plantar foot during gait was able to predict total FPI-6 scores. The difference between the measured and predicted FPI-6 values was just slightly larger than the interrater measurement error. These variables inform the association between the static and dynamic foot posture. Future research should assess which of these variables may be linked to increased incidence of injury in individuals with extreme foot postures.

REFERENCES

FOOT RELATED IMPAIRMENT AND DISABILITY IN RHEUMATOID ARTHRITIS: PLANTAR PRESSURE MEASUREMENT AND GAIT ANALYSIS

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School of Health & Social Care and the HealthQWest Research Consortium, Glasgow Caledonian University, Glasgow, Scotland

INTRODUCTION
Rheumatoid arthritis (RA) causes inflammation and destruction in the synovial joints. In the foot, symmetrical polyarthritis is associated with tender and swollen joints, tendons and bursae. In persistent disease, progressive joint destruction leads to characteristic features such as forefoot splaying, hallux valgus, claw and hammer toes deformity and pes planovalgus (Figure 1). These problems impact negatively on health related quality of life (Turner et al 2008a).

Figure 1: Typical forefoot deformities in a patient with well established RA.

Joint and soft-tissue inflammation in the foot is painful and alongside other impairments such as joint stiffness and deformity serve to alter the weightbearing capacity of the foot. In many patients, the metatarsophalangeal (MTP) joints are subluxed, exposing eroded metatarsal heads plantarly. Under weightbearing pressure bursae, callus and, albeit less frequently, frank ulceration occur. Disease in the midtarsal, subtalar and ankle joints can be painful and disabling and lead to the development of pes planovalgus.

The impact of RA on the structure and function of the foot can be determined through careful clinical examination combined with special investigations including imaging techniques and gait analysis. Plantar pressure measurement (PPM) is an important component of gait analysis and in the RA patient it reveals valuable information on local stresses at sites of deformity and the ability of the foot to accept and transfer loads effectively during walking (Figure 2).

PLANTAR PRESSURE MEASUREMENT IN RA

This keynote presentation will outline how we systematically approach PPM and analysis in our RA patients in Glasgow. The conceptual and statistical development of standardised protocols for platform and in-shoe data collection, including the development of a ‘core-set’ of pressure variables, will be explained. The analysis techniques will cover;

- The use of masking techniques to ‘isolate’ important functional regions of the foot with specific reference to foot morbidity in RA.
- The selection of pressure variables for analysis within these regions including peak pressure, contact area and time parameters.
- Analysis of the timing and velocity of the Centre of Pressure (COP).
- The utility of foot geometry metrics derived from PPM footprint analysis.

PLANTAR PRESSURE MEASUREMENT AND 3D GAIT ANALYSIS IN RA

This presentation will also describe how combined 3D gait analysis and PPM can be used to study both degraded and adapted gait patterns in patients with RA. Illustrated case series will be used to demonstrate the relationship between kinematic and kinetic changes in the foot and ankle and altered plantar pressure distribution patterns (Figure 3).
A more detailed overview of foot function in RA will be presented. The influence of pain and the characterisation of plantar pressure distribution in antalgic gait will be considered alongside the pressure distribution patterns related to pes planovalgus and metatarsophalangeal joint disease with associated hallux valgus and lesser toe deformities (Semple et al 2007) (Figure 4).

In particular, consideration will be given to the factors, both inflammatory and mechanical, that are associated with disease ‘impact’ in the foot and ankle. ‘Impact’ will be defined and through regression modelling the relative contribution of disease factors (duration and severity); joint inflammation (swollen and tender joint counts); deformity (structural indices); and function (plantar pressure distribution, kinetics, kinematics) to localised impairment and disability will be explored (Turner et al 2008a).

The presentation will summarise new insights on our understanding of foot function in the early stages of disease and how these drive treatment paradigms within a so-called ‘functional therapeutic window of opportunity’ (Turner et al 2006). Here, significant changes in plantar pressure distribution will be shown to occur in patients within the first 12 months of disease, combined with changes to spatio-temporal gait parameters, joint kinematics and kinetics.

Continuing through to end-stage disease, the presentation will show the potentially devastating effects of persistent joint inflammation and destruction on foot structure and function. This will be undertaken using a case series of RA patients with predominant forefoot, rearfoot and combined foot involvement (Turner et al 2008b) (Figure 5). In advanced disease the association between abnormally high pressures and plantar ulceration will be discussed and data presented which examine peak pressures, pressure-time integrals and contact area.

**REFERENCES**

ANALYSIS OF PLANTAR PRESSURES IN A POST-SURGICAL WALKING BOOT WITH AND WITHOUT A CONTRALATERAL LIMB LENGTH ADJUSTMENT DEVICE

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LITERATURE REVIEW

Use of the CAM walker after surgery has become increasingly popular over the traditional cast as patients treated with CAM walkers have shown significantly less edema, tenderness, and joint stiffness after six weeks of immobilization as compared to a standard below knee cast (Pollo, 1999). CAM walkers have incorporated rocker sole designs to accommodate deformities, limit painful joint motion, and reduce plantar pressures, shock, and shear on specific areas of the foot following a wide array of surgical procedures (Brown, 2004). A potential concern is the increase in heel height attributed to CAM walkers as the raised heel on the walker artificially creates a Limb Length Discrepancy (LLD) (Zhang, 2006). CAM walkers, occasionally worn for extended periods, can alter the gait pattern and ground reaction forces during midstance (Zhang, 2006). Clinical sequelae from LLD include limp, low back pain, and hip instability, as well as neurological effects (Sathappan, 2008). The Evenup device was created to reduce the negative impact of the LLD on post-surgical walking, but there has not been any objective evaluation to date.

METHODS

Ten healthy, asymptomatic subjects (7 female, 3 male) were evaluated. The mean age was 24.6 years and the BMI was 22.7 kg/m². Subjects were tested in three conditions: (A) New Balance walking sneakers #574 (NB), (B) NB with the Evenup on the left and CAM walker (DJO Maxtrax Air Walker) on the right, and (C) NB on the left and CAM walker on the right. Subjects walked at a comfortable pace on a treadmill for 3 minutes to accommodate to each shoe condition. Temporal and spatial footfall parameters were measured with GaitMatII™ (E.Q. Inc., Chalfont, PA) at 200 Hz. Dynamic in-shoe plantar pressures were obtained with Pedar-X (Novel, St. Paul, MI) at 50 Hz. Subjects also rated pain during a timed 50 foot walk and half-flight of stair tests. Results were compared with an analysis of variance (ANOVA) at a significance level of 0.05.

RESULTS & DISCUSSION

Weight bearing limb length showed a slight limb length difference: 0.3 cm longer on right for condition A, 0.5 cm longer on the left for condition B, and 0.8 cm longer right for condition C. Significant differences were noted in self-selected walking speed, fast paced walking speed, and half-flight of stair ascent/descent across the shoe conditions. Subjects walked significantly slowly while wearing CAM Walker, condition C worse than condition B. In addition, significant in-shoe plantar pressure distributions were noted in both the ipsilateral (see Figure 2) and contralateral limbs. Seven of the ten subjects preferred to walk with the NB with the Evenup.

Figure 1: Illustration of NB sneakers with Evenup (left) and DJ orthotic CAM walker (right)

Figure 2: Results of the in-shoe plantar pressure of the right foot for 3 shoe conditions are illustrated.

REFERENCES


This study was partially funded by Evenup Corp.
THE EFFICACY OF A REMOVABLE VACUUM CAST REPLACEMENT SYSTEM IN REDUCING PLANTAR FOREFOOT PRESSURES IN DIABETIC PATIENTS

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2. Diabetic Foot Unit, Department of Surgery, Twenteborg Hospital, Almelo, The Netherlands

INTRODUCTION
Pressure reduction or offloading is the mainstay of treatment in diabetic patients with plantar foot ulcers. For this purpose, different devices are used, including total contact casts, removable walking braces, half shoes and forefoot offloading shoes (FOS). All these devices have proven effective in offloading the plantar forefoot region in diabetic patients. A new prefabricated and removable vacuum cast replacement system (VCRS) has been specifically designed to offload plantar diabetic forefoot ulcers. The system incorporates an instantly moldable vacuum cushion to accommodate different foot shapes and a roller outsole configuration. However, little is known about the biomechanical efficacy of this device. The aim of this study was therefore to assess the pressure-relieving effect of the VCRS in the plantar forefoot of diabetic neuropathic patients in comparison with a FOS and a control shoe condition.

METHOD
Fifteen diabetic neuropathic subjects (mean age 58.9 years, body mass 100.8 kg, and height 1.78m) were included and underwent in-shoe dynamic plantar pressure assessment in three footwear conditions, including the VCRS (Vaco®Diaped Plus, Oped Germany), a Rattenhuber Talus (FOS) and a Pulman control shoe. Additionally, the efficacy of two specific biomechanical features of the VCRS, the vacuum cushion and the roller outsole were tested in two additional conditions, namely the standard VCRS with flat vacuum cushion, and the VCRS with flat outsole. Test shoes were worn on the right foot, the own shoe on the left foot. The sequence of tested footwear conditions was randomized. In each condition, patients walked in four trials along a 10m walkway at a standardized walking speed (mean difference 5%) based on a comfortable speed initially measured in the VCRS condition. Peak pressures (PP) and pressure-time integrals (PTI) were calculated for 6 anatomical foot regions, including the heel, midfoot, 1st metatarsal head (MTH1), MTH2-5, hallux and toes. Perceived walking comfort was assessed after completion of each footwear condition using a 10 point VAS score.

RESULTS
In all foot regions, except the midfoot, PPs were significantly lower (by 25-59%) in both offloading footwear conditions when compared with the control shoe (P<0.05, Figure). PTI's were significantly lower (by 37-56%) in all four forefoot regions (P<0.01). The FOS showed the lowest MTH PPs, significantly lower compared with the VCRS condition (P<0.01). However, PTI’s at these regions were not different between offloading conditions. Hallux PP and PTI in the VCRS were significantly lower than in the FOS (P<0.01). Perceived walking comfort was scored significantly higher in the VCRS condition (6.6) than in the FOS (3.4). Pressure results between each of the three VCRS conditions were similar with a significant lower pressure only at the MTHs in the standard VCRS compared with the VCRS with flat outsole.

CONCLUSION
The data showed that the VCRS is effective in its primary goal: offloading the plantar forefoot of at-risk diabetic patients. The FOS is better than the VCRS in offloading the MTH regions and the VCRS is better in offloading the hallux. The vacuum cushion did not prove additionally effective in forefoot offloading. The roller outsole provided additional offloading in the MTH regions. Based on the combined PP, PTI and comfort results, the VCRS seems a useful alternative for the FOS for offloading the diabetic plantar forefoot and may prove beneficial in treatment of plantar foot ulcers in future studies.
PLANTAR PRESSURE RESULTS FOLLOWING NON-OPERATIVE TREATMENT FOR CLUBFOOT

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INTRODUCTION

Two types of non operative (NonOp) treatment are being utilized to manage clubfoot at our hospital: Ponseti casting and the French Physiotherapy method (Richards, 2007). Early kinematic results show that 47% of CAST feet and 67% of PT feet have normal ankle motion at 2 years of age (El-Hawary, in press). A closer look at the plantar pressure data shows residual deformity in these same feet including: increased midfoot pressure in the CAST feet and decreased heel and medial forefoot pressure and contact area in the PT feet (Jeans, 2007).

Patients identified as having residual kinematic deformity (equinus and increased dorsiflexion (DF) during mid stance) have not been studied. Are there pedobarograph markers that correlate to these kinematic findings?

METHODS

Plantar pressures were collected on 102 toddlers with 151 clubfeet treated NonOp. Data were collected and analyzed using the Emed System and software (Novel, Munich, Germany). Due to the age of the patient group (2+3 years of age), no attempt was made to control the number of lead-up steps, however, no fewer than two were taken prior to data collection. At least five trials were collected and reduced to one representative trial. The PRC automask was primarily used to assess medial and lateral differences in the hindfoot and midfoot regions. Some masks were edited when the data was indeterminate. Regions of interest include: medial/lateral hindfoot, medial/lateral midfoot, 1st/2nd ray forefoot and the lateral forefoot (Figure 1). Plantar pressure measures include: Contact Area - % of the total area (CA%), Max Force %BW (MaxF), Mean Force %BW (MF) and Contact-Time %roll-over-process (CT). Eighteen age-matched controls were used for comparison. Statistical analysis included t-tests with p set at 0.05.

RESULTS / DISCUSSION

Eleven feet were identified as having residual equinus following NonOp treatment. They were found to have decreased MaxF, MF and CT in the medial heel, while all variables were significantly greater in the lateral midfoot and forefoot regions. The 1st/2nd ray area was found to have decreased CA%, MaxF and MF than normal.

The DF group (n=47) was found to have significantly greater: CA%, MaxF, MF and CT in the lateral midfoot, MaxF, MF and CT in the medial midfoot, and CT in the lateral forefoot. All variables were found to be decreased in the 1st/2nd ray region compared to normal.

This lateralization of the CA, timing and force across both the equinus and the DF groups, does not help differentiate between the two residual deformities. The decrease in MaxF and MF in the both the medial and lateral heel regions and the decrease in CT% in the medial heel in the equinus group may be significant markers in identifying residual equinus in these NonOp clubfoot patients.

A more extensive analysis needs to be done to identify other markers that may help us differentiate patients who have residual foot drop, or have been over corrected which may be an indication of calcaneus gait.

REFERENCES

VACUUM CUSHIONED REMOVABLE CAST WALKERS REDUCE FOOT LOADING IN PATIENTS WITH DIABETES MELLITUS

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INTRODUCTION
Diabetes mellitus is one of the most frequent diseases worldwide and the number of patients is expected to increase dramatically in the next years. Plantar ulceration is a major complication in diabetic patients and can lead ultimately to amputation [1,2]. Pressure relief of the wound is important to provide healing in plantar ulcers [3]. Therefore, removable cast walkers are used as a treatment option to allow wound healing in plantar ulceration.

The aim of this study was to investigate the pressure relieving effects of two vacuum orthoses in patients with diabetes mellitus.

METHODS AND MATERIALS
Twenty patients with diabetes mellitus were included. Exclusion criteria were the use of walking aids, further systemic diseases and severe foot alterations (Wagner degree one or higher). Plantar pressure distribution was measured with capacitive sensor insoles (Pedar-X, Novel GmbH, Germany) during walking in two vacuum orthoses (VACOdiaped (high-cut design) and VACOdiaped-Plus (low-cut design)) and a standard shoe as reference condition. Statistical analysis was conducted with Friedman tests and paired Wilcoxon tests.

RESULTS AND DISCUSSION
The results revealed significant differences in plantar pressure distribution between the three walking conditions (Fig. 1 + 2). An increase of contact area could be seen in the midfoot for both vacuum orthoses. Maximum force and peak pressures showed a reduction of the hindfoot and forefoot and an increase on the midfoot area during walking with both vacuum orthoses. The gait line in both vacuum orthoses was shortened in comparison with walking in the standard shoe.

CONCLUSIONS
The pressure-relieving efficacy of the vacuum orthoses could be demonstrated in this study. Removable cast walkers seem to be an alternative solution to total contact casts especially when patient compliance is improved by applying it as a non self-removable cast walker [4].

REFERENCES
The effect of vibration on bone-cement interface in cemented hip arthroplasty to withstand load transferred between the bone and cement

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BACKGROUND
At least 50,000 hip replacement operations take place each year in Britain. The Swedish Hip Registry quotes a success rate of 94.6% for 10 years. Aseptic loosening, that is, loosening in the absence of infection, is the most common reason for failure (75.7%). It is caused by debonding at the cement interface, eventually leading to fractures in the cement mantle. This can occur between the prosthetic stem and the cement or more usually between the cement and the femoral cancellous bone. The cement and the bone form a mechanical bond referred to as microinterlock, which affects the mechanical properties of the composite structure, such as the strength and resistance to fatigue failure. Optimizing microinterlock is therefore desirable.

AIM AND OBJECTIVES
The purpose of our study is to analyse the effect vibration has on the bone-cement interface in total hip replacement, as well as on the flow and properties of polymethylmethacrylate bone cement.

MATERIALS AND METHODS
A model was developed to approximate the conditions under which a cemented total hip replacement would be performed. This was then used to compare the cement microinterlock induced under normal and mechanically vibrated conditions. Twenty-two separate tests were carried out, ten were performed without vibration, nine were vibrated at a frequency of 36Hz, and three at 16Hz frequency. Four sets of data were taken out of each experimental run: the cement microinterlock, the depth of penetration of cement, the quality of cement and the force needed to insert the stem. A mould was also designed to enable us to correlate the results found in a computational fluid dynamics model of cement flow under vibration. A simple device to impart mechanical vibration to a prosthesis has been developed.

RESULTS
The maximum depth of penetration of cement was achieved when the stem was not subjected to vibration. However in total hip replacement loads are transferred between the bone and cement predominantly by shear at the interface. The depth of penetration of the cement into the trabecular structure is less important than the total area undergoing shear at the interface. We observed an increase in this area with vibration. Vibrating the prosthesis as it is inserted into the cement also significantly lowered the force needed for insertion. All the cement mantles were subjected to X-ray examination. The vibrated mantles showed a decrease in air bubbles. But there was wide variability between tests and this change was not statistically significant; however we concluded vibration was not detrimental to quality of the cured cement.

CONCLUSION
Our results indicate that vibration of the femoral stem has a positive effect on the cement-bone interface and that vibrating the prosthesis during insertion into the cement significantly lowers the force needed for insertion. Evidence presented here and from previous studies suggests mechanical vibration of an implant during cemented joint replacement has a beneficial effect on the cement bone interface.

KEYWORDS
Aseptic loosening; Polymethylmethacrylate; Microinterlock.
THE EFFECT OF THE ADDITIONAL WEIGHT DURING PREGNANCY ON PLANTAR PRESSURE DISTRIBUTION OF THE FEMALE FOOT

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INTRODUCTION
Several authors have shown that there are physiological changes in foot morphology during pregnancy. Over this period of time the female foot increases in length and width, in foot volume, but it decreases in foot height. (Wetz, 2006). Nyska et al. (Nyska, 1997) found that pregnant women have higher plantar pressure values and higher forces in dynamic situations. Additionally, pregnant women show a bigger contact area during standing than non-pregnant women. All of these studies, however, have been looking for differences between pregnant and non-pregnant women with different body mass. It is of interest to know, whether other factors than the increase in body weight during pregnancy has an effect on foot function. Hormonal changes, for example, influence ligament strength and could cause an additional lowering of the longitudinal arch of the foot. The purpose of this study was to look for differences between a pregnant women group and a non-pregnant control group, both being similar to each other in age, weight, height and body mass index.

SUBJECTS & MATERIALS
We measured the right foot of twenty healthy pregnant women (age 29.7 ± 5.4 y; weight 78.3 ± 10.7 kg; height 167.1 ± 7.2; BMI 28.1 ± 3.6 kg/m²; week of pregnancy 36.4 ± 2.5) and twenty healthy non-pregnant women (age 27.4 ± 3.9 y; weight 77.8 ± 12.2 kg; height 166.2 ± 5.85; BMI 28.1 ± 3.6 kg/m²). The data were collected using a capacitive pressure distribution platform with a resolution of 4 sensors/cm² (Emed ST, Novel Inc.). Plantar pressures under the right foot were recorded during half body weight standing. Furthermore, pressures under the foot were measured during walking across the platform using a two-step-procedure and contact with the right foot. The plantar pressures were evaluated for ten anatomical areas under the foot (PRC-Mask, Novel Inc.).

RESULTS
There were significantly to highly significantly increased values for relative loads, force-time-integrals, contact areas and peak pressures for the non-pregnant women during half body weight standing and walking. Walking speed was not controlled. However, comparable foot contact times suggest that walking speed was similar between the two groups.

CONCLUSION
Compared to the pregnant women, non-pregnant weight matched women showed increased foot contact areas, higher force-time-integrals, relative loads and peak pressure values during standing and walking. The increased loads of the non-pregnant group were primarily focussed in the midfoot area below the longitudinal arch. It appears that the long term effect of an increased body weight on foot architecture has a bigger effect than the short term additional weight in women during pregnancy. This also suggests that hormonal influences do not have a large effect in modifying the foot loading behaviour during pregnancy.

REFERENCES
INTRODUCTION

Pronation in distance running is often linked to overuse injuries like PFPS and achilles peritendinitis. Rotation of the hind foot from the supinated position at touch down to pronation during early stance phase induces a load shift from lateral to medial (Hennig & Milani, 2000). However, an algorithm to determine pronation parameters by using plantar pressure distribution has not been identified yet. Hagman et al. (2001) used a mathematical model to build a relationship between pressure plate data and 3D rearfoot motion, but no biomechanical validation was reported. Range and velocity of rearfoot motion (Nigg et al., 1987) as well as plantar pressure distribution (Hennig & Milani, 2000) depend on running velocity. The goal of this study was to calculate an algorithm to determine the range of rearfoot motion (TPR) and maximum pronation velocity (MPV) using plantar pressure distribution data of eight discrete sensors under the heel. Additionally, the dependency of this algorithm on running velocity was analyzed.

METHODS

41 runners (26.1±5.3yrs, 71.5±7.8kg), known to be heel-toe runners, were in the subject pool: 19 served for the algorithm calculation, whereas 13 different runners were used for its validation. The influence of running velocity on the validity of the algorithm was tested with 17 subjects. Eight discrete piezoceramic pressure transducers were fixed around the heel area of a TPU chassis slightly inclined. As a reference for rearfoot motion an electrogoniometer was used (Milani & Hennig, 1995). Five repetitive trials at standardized running velocity of 3.5m/s (±0.1) were performed. Maximum (max) and time of this maximum (tmax) of each pressure signal were used as independent variables in Multiple Regression Analyses, whereas goniometer data served as dependent variables. With the determined regression coefficients, TPR and MPV were calculated for each trial and compared to the goniometer data (Fig. 1). In a following study the velocity dependency of the algorithm (calculated at 3.5m/s), was analyzed by applying the regression coefficients to pressure data captured at four different running speeds (2.9, 3.2, 3.8, 4.1m/s(±0.1)).

RESULTS & DISCUSSION

Pressure distribution was successfully used to determine TPR (∅=13.1° (±3.7), ∅error=1.4°, R²=.77,) and MPV (∅=366°/s (±91), ∅error=40.3°/s, R²=.66). The combination of the variables max/tmax resulted in higher regression coefficients. The validation study showed higher mean errors and low correlations (TPR ∅error=4.7°, R=.49; MPV∅error= 168.2°/s, R=.38). At higher velocities, better correlations coefficients were achieved compared to slower conditions (TPR: R=.58 to R=.79; MPV: R=.54 to R=.73).

CONCLUSION

Rearfoot motion was determined by pressure sensors. Nevertheless, improvement of the algorithm (e.g. sensor placement) may lead to better results.

REFERENCES


ACKNOWLEDGEMENT

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THE INFLUENCE OF ORTHOTICS ON PRONATION, IMPACT LOADS AND PLANTAR PRESSURE DISTRIBUTION DURING RUNNING

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INTRODUCTION
Orthotics are often recommended as an additional possibility to reduce excessive rearfoot motion during running. There are controversial results in the literature whether orthotics are really helpful in fulfilling this function.

The purpose of this study was to examine the effect of custom made and commercially available prefabricated orthotics on pronation, impact loads and plantar pressure distribution in two different footwear conditions.

METHODS
19 experienced runners with the same shoe size ran in 6 different footwear conditions (randomized order) across a Kistler force platform at a speed of 3.3 m/s. In each of two shoe models, a neutral shoe (Nike Air Pegasus) and a stability shoe (Nike Air Zoom Elite), the regular insole (RI) and two orthotic conditions were tested. One custom made orthotic (CO) was designed by an orthopedic shoemaker with the goal to reduce pronation in the two given shoes. Six different arch heights orthotics were created through heat molding of commercially available Spenco Orthotic Arch Supports (SO). Based on the background of pronation reduction and comfort all subjects were asked to choose their favorite orthotic from the six available modalities. Using an electrogoniometer and an uniaxial accelerometer at the tibia, foot pronation and tibial acceleration of the right leg were recorded. Using single piezoceramic pressure transducers (HALM, Germany) plantar pressures were measured under 7 anatomical locations (medial and lateral heel; lateral midfoot; 1st, 3rd and 5th metatarsal heads; hallux). Statistical comparisons were carried out using an ANOVA with post hoc t-tests (p<0.05).

RESULTS
Compared to the regular insole (RI) and the spenco orthotic (SO), the custom made orthotic (CO) reduces maximum pronation significantly in the stability shoe (p<0.05). In the neutral shoe CO decreases maximum pronation compared to SO (p<0.05). Similar results were found for the pronation velocity. The Spenco orthotic reduces neither maximum pronation nor pronation velocity.

Figures 1 & 2: Maximum Pronation and Loading Rates for Regular Insole (RI), Custom Made (CO) and Spenco Orthotic (SO) in a neutral and a stability shoe

The custom made orthotic is characterized by significantly higher loading rates compared to the regular insole (p<0.05). In the stability shoe as well as in the neutral shoe the custom made orthotic shows lower peak pressures under the medial heel and the lateral midfoot (p<0.05).

DISCUSSION
The orthotics had different effects for the two footwear conditions. The custom made orthotic reduced pronation and pronation velocity but also showed increased loading rates. The Spenco Orthotic did not reduce rearfoot motion but also increased loading rate. Therefore, the custom made orthotic was better able to achieve a reduction in rearfoot motion. However, some subjects found the CO condition less comfortable than either RI or SO.
METHOD FOR ASSESSING THE GAIT ENERGY COST BY RECORDING THE VERTICAL COMPONENT OF THE GROUND REACTION FORCE

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SUMMARY

The paper intends to present the results of a research concerning the assessment of the gait energetic cost by measuring the vertical component of the ground reaction force. A mathematical algorithm was proposed and a portable equipment was designed that has resistive force transducers, mounted in an “overshoe” covering. The method and the equipment were validated by comparing the experimental results with those got using the PEDAR system – Novel Germany.

1. INTRODUCTION

The gait energetic cost takes place in muscles, that act in order to do a work of the COM (center of mass), to balance the limbs relative to the COM and to support the body weight. The external work is the work done by the external forces – mainly at the ground – to rise and accelerate the COM, and the internal work is the one associated to the limbs movement relative to the COM (Griffin, 2003). The method proposed in the paper estimates both the external work - by measuring the vertical component of the ground reaction force - and the internal work – through the algorithm proposed by A.E. Minetti (Minetti, 1992).

2. DESCRIPTION

2.1 The description of the CALORCRO equipment

The CALORCRO equipment, as the result of the research, consists of two “overshoe” coverings each of them wearing 10 resistive force transducers, two electronics blocks for the conditioning of the signal, a block for the data acquisition system with microcontroller and a specialized software.

2.2 Description of the mathematical model that evaluates the energy cost

a) The power $P_z$ is evaluated based on the work which is generated by the total vertical ground reaction force $f_z [N]$ using the corresponding vertical acceleration. Every subject was asked to walk for at least 20 steps. Among these steps, for the evaluation of power were used those that gave an average value of the measured vertical forces which has a minimum deviation compared to the weight of the subject.

$$G = \frac{\sum f_z}{n}$$  \hspace{1cm} (1)

b) Afterwords the power $P_y$ consumed for the forward moving is evaluated, by considering three stages of a step: stage 1, the double support; stage 2, single support, before to the moment when the vertical ground reaction force reaches a minimum value, stage 3, single support, between stage 2 and the end of the single support stage.

c) The internal Power $P_{int}$ was evaluated using Minetti’s relation. The total power results from the addition of the external power, considering the vertically and forwardly directed movements, and of the internal power:

$$P_{tot} = P_z + P_y + P_{int} [W]$$  \hspace{1cm} (2)

2.3 Description of the validation method

For the validation of the proposed method the CALORCRO software was equipped with a function that automatically takes the files with the extension „fgt”, generated while measuring with the PEDAR system. The acquired data from both equipments were compared and the energetic cost was evaluated using the algorithm proposed by the authors. Moreover the energetic cost was directly measured with the portable equipment for the indirect calorimetric measurement COSMED K4b2.

3. RESULTS

In order to validate the method for the evaluation of the gait energetic cost, measurements have been done using both healthy subjects and patients, who were simultaneously wearing the PEDAR equipment and the equipment for the indirect calorimetric measurement COSMED k4b2.

4. CONCLUSIONS

The mathematical model we proposed for the evaluation of the gait energetic cost was verified through comparing the results obtained by applying this algorithm to the data measured by the PEDAR system and the results of the direct measurement of this energetic cost using the device COSMED k4b2.

REFERENCES

A PRELIMINARY INVESTIGATION OF PLANTAR LOADS IN FEET WITH HALLUX VALGUS DURING BIPEDAL AND UNIPEDAL STANCE

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2. Institute of Health & Biomedical Innovation, Queensland University of Technology & Queensland Academy of Sport, Queensland, Australia
3. Bioengineering Unit, University of Strathclyde, Glasgow, Scotland

BACKGROUND
Hallux valgus is known to be an independent risk factor for falls (Koski 1996, Lord 2003) and, in older people, its presence has been shown to impair balance (Menz 2001). Moderate to severe hallux valgus deformity is also associated with impaired gait patterns in elderly people (Menz 2005) and may increase the risk of falling when walking on uneven terrain. Menz et al, acknowledged that plantar pressure assessment of hallux valgus has been reported relatively widely but point out that the findings to date fail to contribute to a clearer understanding of balance, instability and falls (Menz 2005). That earlier foot pressure studies have tended to focus on the effects of foot surgery may, in part, account for this situation. Whatever the reasons, a study of load distribution through the hallux valgus foot during tasks requiring bipedal and unipedal balance is indicated.

This is a pilot study to quantify plantar loading of the hallux valgus foot during (1) relaxed bipedal stance, (2) unipedal stance with the eyes open, and (3) unipedal stance with the eyes closed.

METHODS
Nine healthy adults (mean age 43.8±12.6 years, height 1.72±0.08 m, weight 71.3±14.7 kg) with grade 2 or 3 hallux valgus on the Manchester scale (Garrow 2001), were recruited. Subjects with a known history of balance disorders or taking medication likely to affect balance were excluded. Informed consent was gained prior to participation.

With their right foot on an EMED platform, volunteers were asked to adopt one of three stance conditions – bipedal stance with eyes open, unipedal stance with eyes open, or unipedal stance eyes closed. Plantar pressures were then recorded for 2 seconds. The process was repeated, in a random progression, until five replicates of each test condition had been recorded. The pressure data were masked to define ten foot-sites; (1) medial heel, (2) lateral heel, (3) medial arch, (4) lateral arch, (5) met 1, (6) met 2, (7) mets 3-5, (8) hallux, (9) toe 2, (10) toes 3-5.

Site-specific differences and associations of peak force were determined across conditions using paired t-tests and Pearson correlation coefficients, respectively.

RESULTS AND DISCUSSION

Forces in unipedal stance were significantly greater than in bipedal stance except at site 3, the medial arch, although the same trend was evident. The magnitude of increase was site specific ranging from 1.3x for the lateral heel to 14.9x for the hallux. The toes demonstrated the greatest change, averaging a 10.6 fold increase during unipedal stance. Two other sites demonstrated noteworthy increases during unipedal stance; the lateral arch (2.5x) and the first metatarsal (2.3x). Preliminary analysis of the data indicates that first metatarsal load correlated with medial heel load during unipedal stance with eyes closed and could, therefore, be associated with pronatory rolling of the foot. Similarly, the increased load at the lateral arch with unipedal stance may be a consequence of supinatory rolling. Further investigation of this behaviour with simultaneous kinematic analysis is indicated.

In unipedal stance, plantar loads at sites 1-7 (sole) peaked when the eyes were open whereas loads at sites 8, 9 & 10 (toes) peaked when the eyes were closed.

REFERENCES
Koski K et al, Age Ageing 25:29-38, 1996
TIME DEPENDENT CHARACTERISTICS OF THE “KENT” TRIAXIAL FORCE TRANSUDER SYSTEM FOR IN-SHOE LOAD DISTRIBUTION MEASUREMENT

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4. Electronic Engineering Department, University of Kent, Canterbury, UK

BACKGROUND

Razian and Pepper (1998) described the development of a triaxial piezoelectric force transducer, measuring 13 x 13 x 2.7mm, to simultaneously quantify the 3D force under any location of the plantar surface of the foot within an in-shoe environment. However, limited characterization of this device has been presented in the papers (Razian and Pepper, 1998, 2003). This study attempts to provide further characterisation of the transducer-and-amplifier system.

METHODS

A series of normal (Z-axis) loading regimes were applied to the transducer via a materials testing machine (5800R, Instron®, USA) (Figure 1). Figure 2a illustrates one of the sequences used with two 20 sinusoidal cycles (±20N) at 1Hz separated by a 10s hold. Additional input loadings were implemented including: step input and hold; rapid single load and unload (‘impulse’); and continuous sinusoidal cycles. All loading sequences began with a 10s load hold at nominal zero load and finished with a 40s hold with three repetitions of each sequence.

RESULTS

Figure 2 illustrates a typical loading sequence and system voltage output. As with all piezoelectric systems, exponential decay was apparent in the system output. The average time constant was 12 s for the vertical Z-axis, and 10 s and 8 s for X and Y axes (shear crosstalk), respectively. The average crosstalk between Z→X and Z→Y axes was 4.5% and 4.1%, respectively.

DISCUSSION

The response was typical of a piezoelectric transducer/charge amplifier system. As shown in Figure 2 the cyclic signal decayed with a time constant of 12s. However, despite this decay, peak-to-peak signals were proportional to the applied force. The time-dependent response reflects the pass band characteristics of the charge amplifier whose high pass frequency response of 0.01Hz will result in a time constant of 15 s. In order to minimise the effect of any static loading, measurements should be taken after approximately 4 time constants (about 1 minute).

REFERENCES

ANALYSIS OF THE PLANTAR PRESSURE DISTRIBUTION IN GAIT DURING PREGNANCY

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INTRODUCTION
Some anatomical and physiological changes in woman body during pregnancy are the increase in body mass, spine adjustments, and center of gravity modification. These musculoskeletal adjustments result in changes of the gait, which can cause greater overloads on the plantar surface. However, one of the clinical and scientific propositions in this regard is still very contradictory since some autores reported an increase of plantar pressure on the heel and lateral edge of the foot, while Ribas and Guirro reported no change of these variable dynamometries. There are not longitudinal studies which investigate the changes of the plantar overloads during the pregnancy. Therefore, the purpose of this study was to evaluate the plantar pressure distribution during the gait over the gestational period.

MATERIALS AND METHODS
Six women (n = 12 feet), with age of 30 to 40 years (32 ± 3 y) and weight gain in average total of 10,28±1.36kg, were evaluated, always in the last month of each trimester of pregnancy. The exclusion criteria were: diabetics, body mass index > 30, risk pregnancy, musculoskeletal diseases prior (rheumatism, arthritis and osteoarthritis), deformities feet, neurological and cognitive problems. It was used insoles of the PEDAR-X system (Novel) for measurement of the plantar pressure distribution (PPD) at 100 Hz, during the barefoot gait with self-selected cadence. Contact area (AC), contact time (CT), pressure peak (PP) and pressure integral (IP) were evaluated in five areas of the foot (lateral and medial rearfoot, midfoot and lateral and medial forefoot). In the statistical analysis was verified the normality of variables by Shapiro Wilk test. After verifying the equality between the right and left feet by the student t-test, was carried out for any author. However, there is a necessity of confirming our results with an increase of the sample for best conclusions about the gait of pregnancy.

RESULTS
There was a significant decrease in PP on the medial rearfoot from the 1st to 3rd and from the 2nd to 3rd trimester. There was also a significant increase of the CA on the lateral rearfoot from the 2nd to 3rd trimester and on the midfoot from the 1st to 3rd trimester. It was observed a significant increase of the CT on the midfoot and on the medial and lateral forefoot from the 1st to 3rd trimester. The variable PI showed no significant differences. These results are demonstrated in table 1.

DISCUSSION
This study showed a decrease in PP in the rearfoot and an increase in CA and CT during pregnancy. The results of the PP disagree of Nyska et al. and Goldberg et al., which found an increase in the PP of the rearfoot only in some trimesters. Moreover, Ribas and Guirro, in cross sectional study of a single trimester, found no change in the PP. A possible explanation for the findings of this study is that pregnancy move the center of gravity more laterally to compensate the weight gain, carrying out a heel initial contact more cautious. The increase in CA of the midfoot and in the lateral rearfoot, is explained by the attempt to minimize the plantar overloads, which also was observed by some autores. The readaptation during the gait led to an increase in the CT in the midfoot and forefoot, representing a longer foot rollover process. Bird et al. discusses that the rollover is longer in order to maintain the balance during gait. This study becomes relevant because it is a longitudinal tracking, which was not carried out for any author. However, there is a necessity of confirming our results with an increase of the sample for best conclusions about the gait of pregnancy.

CONCLUSION
In order to minimize the overloads on the locomotor system during the gait, the pregnancy readapts the support phase over the gestational period.

REFERENCES

Table 1 - Statistical results of the DPP variables of the foot areas in each trimester of pregnancy.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Area</th>
<th>Trimester</th>
<th>Mean (sd)</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td>PP (KPa)</td>
<td>Medial</td>
<td>1</td>
<td>314,4±87,9</td>
<td>0,026</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>318,6±104,4</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>3</td>
<td>315,8±108,5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rearfoot</td>
<td>1</td>
<td>260,4±104,4</td>
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</tr>
<tr>
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<td>2</td>
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<td>CA (cm²)</td>
<td>Lateral</td>
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<td>3</td>
<td>20,5±5,2</td>
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<td>CT (ms)</td>
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</tr>
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<td></td>
<td></td>
<td>3</td>
<td>642,7±54,1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forefoot</td>
<td>1</td>
<td>555,2±113,6</td>
<td>&lt;0,001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>623,7±113,6</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>3</td>
<td>624,7±113,6</td>
<td></td>
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</tbody>
</table>
LOADS IMPOSED TO THE PAINFUL LEG VERSUS THE PAIN FREE LEG DURING STAIR DESCENT IN PATELLOFEMORAL PAIN SYNDROME

Sandra. Aliberti, Mariana. S.C. Costa, Isabel C.N. Sacco

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INTRODUCTION

Patellofemoral Pain Syndrome (PFPS) is one of the most common injuries of the knee\(^1\). Nevertheless, the rationale basis for its rehabilitation remains unclear\(^2\). Investigating the loading patterns in the symptomatic and asymptomatic leg during a demanding task that is usually related to an increasing of symptoms may provide guides in the compensatory strategies adopted by the subjects with PFPS. The aim of this study was to compare plantar pressure distribution during the stance phase of stair descent between painful and pain free leg in subjects with unilateral PFPS.

PATIENTS AND METHODS

17 volunteers (10 women, 34 feet) with diagnose of unilateral PFPS (30±7 years old, 65±13kg, 167±10cm) served as subjects for this study. 47,1% had the left side affected and 52,9% had the right one. Plantar pressure distribution during the stairs descending condition (stair with five steps constructed using Brazilian Association of Technical Rules standardization) was measured using Pedar X System at 100 Hz. Contact area, peak pressure and pressure-time integral were calculated in 6 areas: medial, central and lateral rearfoot, midfoot, medial and lateral forefoot. Plantar Pressure data were compared between sides using ANOVA three-way for repeated measures followed by Newman-Keuls test.

RESULTS AND DISCUSSION

Both sides produced the same contact area (p>0.05). As shown on table 1, the painful leg presented lower peak pressures at medial forefoot and lower pressure-time integral at medial and lateral forefoot when compared to the pain free leg.

Pressures under the forefoot during the descending stairs condition reach about 80% of body weight as this is the first region of the foot to make contact with the steps\(^3\).

Table1. Means (±SD) of the foot regions statistically different in peak pressure and pressure-time integral between painful and pain free.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Foot Region</th>
<th>Painful leg</th>
<th>Painfree leg</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>Medial Forefoot</td>
<td>316.8±68.2</td>
<td>374.8±108.5</td>
<td>.031</td>
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<tr>
<td>PP</td>
<td>Lateral Forefoot</td>
<td>245.5±62.4</td>
<td>278.1±64.2</td>
<td>.000</td>
</tr>
<tr>
<td>PTI</td>
<td>Medial Forefoot</td>
<td>139.7±34.7</td>
<td>157.3±36.2</td>
<td>.039</td>
</tr>
<tr>
<td>PTI</td>
<td>Lateral Forefoot</td>
<td>109.0±35.1</td>
<td>128.1±37.7</td>
<td>.025</td>
</tr>
</tbody>
</table>

Finding lower peak pressures at the forefoot in the painful leg suggests that these subjects tend to diminish the loads imposed to the painful leg at the weight acceptance, when the knee is under an eccentric flexion with a great demand of quadriceps muscle. It is in agreement with a study that found a reduced knee extensor moment during downstairs condition in subjects with PFPS\(^4\). Besides that, lower pressure-time integrals in the forefoot, confirms that the subjects with PFPS spend less time loading the painful leg probably to avoid increasing symptoms.

SUMMARY

Subjects with unilateral PFPS decrease the loads imposed to the painful leg compared to the pain free leg at the ground during stairs descending task.

REFERENCES

2. La Botz M. Physician and Sportsmedicine32 : 22-29, 2004

ACKNOWLEDGEMENTS

Thanks to FAPESP (2005/03803-0) for the financial support.
RELATIONSHIP BETWEEN PLANTAR PRESSURE AND PATELLOFEMORAL PAIN SYNDROME DURING GAIT

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INTRODUCTION

Our hypothesis is that Patellofemoral Pain Syndrome (PFPS) may be related to a greater contact area and pressures at the medial portions of the feet, based on the fact that this dysfunction can be linked to an excessive pronation of the rearfoot\(^1\) as well as an excessive medial rotation of the hip\(^2\). These kinematic alterations may lead consequently to an increase in plantar pressures over medial regions during gait. The purpose of this study was to investigate the relationship of plantar pressure distribution with PFPS at the stance phase of gait.

METHODS

74 volunteers served as subjects for this study: 30 (26 women) with PFPS diagnosis (PFPS) (30±7yr, 63±12kg, 165±9cm) and 44 (39 women) asymptomatic subjects (CG) (30±8yr, 60±11kg, 165±9cm). Plantar pressure distribution during gait (10 meters walkway, cadence between 100 and 112 bpm) was measured using Pedar X System at 100 Hz. Both legs (88 feet) in control group and the painful leg (30 feet) in PFPS group were analyzed. Contact area, peak pressure and pressure-time integral were evaluated in 6 plantar regions: medial (MR), central (CR) and lateral (LR) rearfoot, midfoot (M), medial (MF) and lateral (LF) forefoot. Groups and plantar areas were compared using 3 ANOVAs two-way (2X6) followed by Newman-Keuls post hoc test (\(\alpha=.05\)).

RESULTS AND DISCUSSION

Both groups were equal for pressure - time integral (\(p>0.05\)). Statistical tests did not confirm effect of areas or groups for pressure-time integrals. Therefore, ANOVA detected an effect of the group independent of plantar areas for peak pressure (\(p=0.040\)): PFPS subjects presented lower peak pressures (240.6±34.6kPa) compared to CG (255.7±34.2kPa). This suggests that these subjects decrease loads imposed to the feet probably to avoid increasing the symptoms and is in accordance to Powers et al\(^3\) study that found lower ground reaction forces in subjects with this syndrome during gait.

<table>
<thead>
<tr>
<th>Areas</th>
<th>PFPS</th>
<th>CG</th>
<th>(p^3)</th>
</tr>
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<tbody>
<tr>
<td>MR</td>
<td>12.2±3.5</td>
<td>10.5±3.5</td>
<td>.048</td>
</tr>
<tr>
<td>CR</td>
<td>17.1±1.9</td>
<td>16.6±2.1</td>
<td>.565</td>
</tr>
<tr>
<td>LR</td>
<td>5.80±3.6</td>
<td>6.49±3.2</td>
<td>.404</td>
</tr>
<tr>
<td>M</td>
<td>18.96±3.4</td>
<td>16.44±6.1</td>
<td>.013</td>
</tr>
<tr>
<td>MF</td>
<td>34.14±3.1</td>
<td>34.52±4.1</td>
<td>.649</td>
</tr>
<tr>
<td>LF</td>
<td>24.46±2.2</td>
<td>22.80±3.6</td>
<td>.046</td>
</tr>
</tbody>
</table>

\(^3\)Newman-Keuls p-values. *Represent significant differences.

There was also an effect of area and groups in contact area (\(p=.018\)). PFPS subjects showed significantly larger contact areas in the medial rearfoot, midfoot and lateral forefoot as shown in table 1. These results suggest that subjects with PFPS have a greater medial excursion of the foot at the initial stance (at heel strike) and a lateral excursion in late stance. A recent study\(^4\) confirmed a roll over process of the foot more on the lateral side in PFPS subjects during gait, which is in line with our findings at the forefoot. On the other hand, these authors observed a heel strike in a less pronated position in individuals with PFPS, while our findings suggest that a greater medial excursion of the rearfoot can be related to this syndrome.

Our findings confirm our initial hypothesis that this dysfunction may be related to an increase in contact area at medial portions of the feet at the initial contact during gait.

SUMMARY

PFPS is related to a greater medial excursion at rearfoot and greater lateral excursion at forefoot during gait. Besides that, these subjects decrease loads imposed to the feet possibly to reduce symptoms.

REFERENCES


ACKNOWLEDGEMENTS

Thanks to FAPESP (2005/03803-0) for the financial support.
PEDOBAROGRAPHIC EXAMINATION OF THREE POST OPERATIVE SHOES UTILISED IN FOREFOOT SURGERY.

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ABSTRACT

The use of post operative shoes is becoming more routine following surgery for forefoot disorders especially hallux valgus. They enable weight bearing whilst protecting the correction from deformity. They also decrease pain in the postoperative period and can be used as unloading devices in the treatment of diabetic neuropathic ulceration.

Three shoes are tested for forefoot unloading using the Pedar (Novel) Pedobarograph in-shoe pressure measuring system. The shoes tested were a flat rubber sole shoe (Darco), Orthowedge Shoe (Darco) and a new Heel Walker shoe of my own design. Patients who were 2 – 6 weeks following forefoot surgery were tested in each shoe whilst walking at a self-determined speed down a long corridor. Each patient was asked to walk in such a way that they experienced the same amount of pain with each trial.

Pressure and force measurements for the total foot as well as masks of hind, mid and forefoot were studied.

Both the orthowedge and heel walker shoes showed significantly more unloading of the forefoot with increased loading of the hindfoot. Maximum pressure, pressure-time integrals and force parameters were all significantly reduced in these shoes indicating increased protection from deforming forces. The heel walker showed slightly more favorable parameters and anecdotally was more comfortable than the Orthowedge shoe.

Heel walker and Orthowedge shoes are recommended in the postoperative period following forefoot surgery to protect against deforming forces. They also significantly unload the forefoot so may be used in diabetics but should be used with caution as they transfer the pressure to the hindfoot, which may be susceptible to damage from excess pressure.
ASYMMETRY BETWEEN LEFT AND RIGHT PLANTAR LOADING DURING GAIT IN NON-DIABETIC AND NEUROPATHIC-DIABETIC POPULATIONS

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2. Center for Sensory-Motor Interaction, Aalborg University, Denmark

INTRODUCTION

It still remains unclear whether an asymmetry exists between feet in terms of plantar loading during gait. While some studies have shown symmetry between feet (Segal et al., 2004), or have assumed symmetry as if it was a given (Hayafune et al., 1999, Hills et al., 2001), others have found asymmetry between feet (Brown et al., 2004, VanZant et al., 2001).

As yet, no research has been conducted investigating asymmetries in the plantar loading characteristics exhibited by neuropathic diabetics. As previously mentioned research has found asymmetries between feet in normal populations, it is reasonable to ask whether an asymmetry will be present in a neuropathic population. Therefore the objective of this study was to investigate asymmetries in plantar pressure variables during gait in a neuropathic population as well as a non-diabetic control group.

METHODS

A total of 46 subjects gave informed consent to participate in this study. These 46 were further divided into two groups; 36 healthy controls (8 male, 28 female, age 54.4 +/- 12.8, BMI 28.1 +/- 4.7) and 10 neuropathic-diabetics (6 male, 4 female, age 63.4 +/- 9.9, BMI 31.2 +/- 5.8). Neuropathy status was identified using the Semmes-Weinstein 5.07 monofilament.

Plantar pressure was evaluated using a Novel EMED-AT system (Novel GmBh, Munich, Germany). Plantar pressure data were collected at a frequency of 50Hz during walking at a self-selected speed. Following a familiarisation period, five trials+ were collected for each foot (Hughes et al., 1991).

Plantar pressure data were analysed using Novel software, in which the foot was divided into 10 regions. Pressure parameters investigated were peak pressure (kPa), maximum force (N), contact time (s), pressure-time integral (kPa.s), force-time integral (N.s), instant of peak pressure (% contact time) and instant of maximum force (% contact time).

An intra-subject statistical analysis was performed for each participant using an independent T-test. Significant asymmetry between feet was established by \( p = <0.05 \).

RESULTS

Figure 1 shows the percentage of participants in each group who exhibited asymmetry at a given region for peak pressure. Significant asymmetries were present in both non-diabetic and neuropathic-diabetic populations for all parameters. For example, 69% of neuropathic participants had an asymmetry at the hallux, with the asymmetry ranging in magnitude between 31 - 470 kPa.

DISCUSSION

Asymmetry was present in both populations, with asymmetry prevalence being region- and parameter-dependent. For both groups, the greatest incidence of asymmetry tended to occur in distal regions.

In terms of clinical significance, the magnitude of peak pressure asymmetry in neuropathic participants in regions such as the hallux (31 - 470kPa), medial forefoot (10 - 148 kPa) and lateral forefoot (7 - 220 kPa) is significant, since these areas are the most frequently ulcerated in these populations.

The primary finding from this research is that asymmetry between feet is highly prevalent in both non-diabetic and neuropathic-diabetic participants. These asymmetries cannot solely be explained by a pathological condition, since non-diabetic participants also showed a high prevalence of asymmetry. These asymmetries should be taken into consideration when designing experiments and analyzing plantar loading parameters.

REFERENCES

Brown et al. (2004), Arch Phys Med Rehabil, 85, p81-86.
Hayafune et al. (1999), Foot, 9, p88-92.
Segal et al. (2004), Foot Ank Int, 25(12), p926-933.
AN INTERMITTENT GRADUATED PNEUMATIC COMPRESSION BOOT FOR THE TREATMENT OF VENOUS ULCERS

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2. Consultant Vascular Surgeon, Mid Essex Hospitals NHS Trust
3. Biomechanist, Department of Biological Sciences, University of Essex, Colchester, Essex
4. Senior Lecturer, Department of Bioengineering, Anglia Ruskin University, Chelmsford, Essex

INTRODUCTION

Ulceration of the lower limb affects 1% of the adult population and 3.6% of people older than 65 years. Prevalence increases with age to about 20/1000 in people aged over 80 years (Wollina 2006). Leg ulcers are debilitating and painful and greatly reduce patients’ quality of life. Ulcer healing has been shown to restore quality of life (Briggs 2007).

Lower limb ulceration tends to be recurrent, and the total annual cost of leg ulceration to the NHS has been estimated at between £294-650m which represents 1-2% of the total healthcare expenditure. Much of this cost is accounted for by community nursing services; district nurses spend up to half of their time caring for patients with ulcers (Morell 1998).

Following an extensive review of the literature, there is evidence that intermittent pneumatic compression (IPC) may reverse some of the damaging effects of chronic venous insufficiency (CVI) and, by improving venous return and reducing edema, enhance ulcer healing, although there is limited supporting evidence for this conclusion (Mani 2008).

TECHNOLOGY AND METHOD DESCRIPTION

IPC devices comprise of chambers which are periodically inflated with air to a preset pressure and duration. These devices are used to aid the return of venous blood from the lower limb to the heart. The proposed device uses the weight of the patient during walking to inflate the air chambers around the lower leg. This raises the pressure and aids vascular return. The benefit to the patient of a wearable device is compliance with treatment leading to an improvement in their condition.

We are introducing a new form of IPC device consisting of the already existing multi-chambered foot and calf element, but, in addition the pumping mechanism for the necessary inflation is incorporated in the sole. The latter can be a combination of two separate mechanical pumps that they only require mechanical energy to function while the patient ambulates.

The advantages are patient autonomy (smaller size of the device) and hence improved mobilization, cost-effectiveness (simpler construction, no need for electricity or power source) and the ability for the device to be used for longer periods of time.

A mechanically powered air pumping mechanism placed below the heel and/or the forefoot can inflate a multi chambered boot during the phases of loading response and push-off during the gait cycle. The length of the boot should allow it to cover the calf. The inflation should be sequential and graduated starting from the foot. The chambers are connected to each other through small valves. As the patient walks a “wave” of pressure inflates the chambers moving towards the knee expelling the venous blood proximally. After all chambers are inflated they are allowed to deflate and the cycle can start from the beginning.

This boot allows the patients to be mobile while having their treatment; it is easy to wear compared to the existing compression hosiery and provides a closer to the normal physiology of the "calf muscle pump" solution to the problem of the CVI.

REFERENCES


Mani et al, Cochrane Database of Systematic Reviews 2008 Issue 1, 2008.


WHAT IS THE EFFECT OF A PHYSICAL ACTIVITY PROGRAM ON FOOT STRUCTURE & FUNCTION IN OVERWEIGHT & OBESE CHILDREN?

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2. Discipline of Paediatrics and Child Health, University of Sydney, NSW, Australia
3. Faculty of Education, University of Wollongong, NSW, Australia
4. School of Education, University of Newcastle, NSW, Australia

1. INTRODUCTION

It has been speculated that the higher peak pressures typically generated beneath the feet of overweight/obese children may result in excessive discomfort of these children’s developing feet (Mickle et al. 2006, Dowling et al. 2001), in turn, acting as a deterrent to them participating in physical activity. Apart from perpetuating the cycle of obesity via decreased energy expenditure, physical inactivity in young children can restrict opportunities for these children to develop basic motor skills and, possibly, proper musculoskeletal development. We postulated that an intervention designed to improve fundamental movement skill (FMS) performance in overweight and obese young children may influence development of the children’s base of support, the feet, during locomotor skills. Therefore, the aim of the present study was to examine the effects of a FMS intervention program on foot structure and function in young overweight and obese children.

2. METHODS

Forty five overweight/obese consenting children (age = 7.7 ± 1.2 yr) were randomly assigned to one of three intervention groups: a FMS program, a dietary education program (active control group) and a combined FMS+diet program. The three interventions involved 10 weeks face-to-face (1/week) followed by program maintenance up to 6 months. Variables characterising the children’s obesity (body mass index; BMI), FMS proficiency (gross motor quotient; GMQ, locomotor and object-control skills), and foot structure (arch height and midfoot fat pad thickness) and function (dynamic plantar pressures) were quantified pre-intervention and at 6 months follow-up (post-intervention). Midfoot plantar fat pad and arch height during static weight-bearing were quantified using a Sonosite® 180PLUS ultrasound system. An emed AT-4 pressure platform (2-step method) was used to quantify plantar pressure distributions.

3. RESULTS

No significant between-group differences were identified for any of the independent variables. However, significant pre- and post-intervention differences were evident in body mass for the FMS group, BMI for the dietary group, and height and forefoot pressure distribution for all groups. Although two-way repeated measures ANOVA indicated a significant main effect of height growth over the 6 months, no significant interactions between time and intervention programs were identified for any of the foot parameters or FMS outcomes. All children improved their FMS skills from pre- to post-intervention, except the dietary group who reduced their object-control performance over the 6 months. Only the combined FMS+diet group displayed a significant improvement in all motor skills (Table 1).

4. DISCUSSION & CONCLUSION

Subject growth during the 6-month program was accompanied by corresponding increases in plantar pressures as the children’s increased body mass was not accompanied by significant changes in plantar contact area. Although the children generally improved their FMS performance by way of the intervention, foot structure or function did not appear to be altered via the 6 month FMS program. However, effects of the FMS intervention are currently being monitored at 12- and 24-month follow up to determine possible effects of changes in the children’s motor performance on foot structure and function, including plantar pressure distributions.

5. REFERENCES


Table 1. Group characteristics at baseline and six months

<table>
<thead>
<tr>
<th></th>
<th>Diet (n = 12)</th>
<th>FMS (n = 13)</th>
<th>FMS+diet (n = 21)</th>
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<tbody>
<tr>
<td>Mass (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>47.7</td>
<td>47.9</td>
<td>46.9</td>
</tr>
<tr>
<td>Post</td>
<td>48.7</td>
<td>44.6</td>
<td>45.6</td>
</tr>
<tr>
<td>Height (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>1.40</td>
<td>1.43</td>
<td>1.38</td>
</tr>
<tr>
<td>Post</td>
<td>1.42</td>
<td>1.34</td>
<td>1.38</td>
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<tr>
<td>Fore1 P (kPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>165.5</td>
<td>195.3</td>
<td>161.7</td>
</tr>
<tr>
<td>Post</td>
<td>194.3</td>
<td>172.4</td>
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<tr>
<td>Fore2 P (kPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>288.3</td>
<td>270.6</td>
<td>293.2</td>
</tr>
<tr>
<td>Post</td>
<td>320.7</td>
<td>253.7</td>
<td>273.4</td>
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<tr>
<td>Mid P (kPa)</td>
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</tr>
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<td>Pre</td>
<td>66.4</td>
<td>78.2</td>
<td>65.6</td>
</tr>
<tr>
<td>Post</td>
<td>73.3</td>
<td>74.5</td>
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</tr>
<tr>
<td>Fore1 C (cm²)</td>
<td></td>
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<tr>
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<td>11.9</td>
<td>17.1</td>
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<tr>
<td>Mid C (cm³)</td>
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<td>Post</td>
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<tr>
<td>Arch ht (mm)</td>
<td></td>
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<tr>
<td>Pre</td>
<td>22.4</td>
<td>23.4</td>
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<tr>
<td>Post</td>
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<tr>
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</tr>
<tr>
<td>Post</td>
<td>65.7</td>
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<tr>
<td>Pre</td>
<td>3.08</td>
<td>3.25</td>
<td>3.62</td>
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<tr>
<td>Post</td>
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<tr>
<td>Pre</td>
<td>2.92</td>
<td>2.75</td>
<td>3.15</td>
</tr>
<tr>
<td>Post</td>
<td>3.62</td>
<td>3.52</td>
<td>4.57</td>
</tr>
</tbody>
</table>

Pre = baseline, Post = 6 months, Fore1 = 1st metatarsal head, Fore2 = 2nd metatarsal head, Mid = medial midfoot, P = pressure, C = contact, ht = height, significant difference (p < 0.05)
ASSESSMENT OF TRANSTIBIAL AMPUTEES’ GAIT IN CLINICAL PRACTICE: SEMI-QUANTITATIVE KINEMATICS TO INTEGRATE PEDAR GAIT ANALYSIS.

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INTRODUCTION

Even though a complete restoration of gait symmetry in transtibial amputees is desired, some alterations still remain even after patient’s rehabilitation. These might be acceptable unless they entail damages to the whole locomotor system [1]. Main aim of this study was the delivery of reliable instrumentation and procedures to support the clinician’s prescription of suitable shoes and/or plantar orthoses for preventing excessive loading of the healthy foot. Main requirements for the semi-quantitative kinematic (SQK) system hereby described were easiness of use, low cost and, most important, extremely low impact on both patient and operator.

MATERIALS AND METHODS

The calibrated Pedar Expert System was used to collect data from 25 transtibial amputees and 50 matched healthy volunteers. Individuals were examined with standardized sport shoes and regular shoes, at both natural and fast speed. Some patients were also tested with custom plantar orthoses. Data from Pedar were averaged over the five central steps for each foot; attention was paid to peak forces and pressures, relevant timing, and intra-subject ratios. For each individual, videos were recorded in the frontal plane and synchronized to Pedar. The SQK analysis was performed on one representative double step per trial. For each frame of the step the edge of the walking subject was detected by using the Canny algorithm [2] and manually processed by building up the vectorial body mask (Fig. 1). 4 frames of interest were processed: the first (1PP) and second (2PP) peak of pressure and the first (1FP) and second (2FP) peak of force. A dedicated software package was developed at ISS for video and image processing.

RESULTS

Work is still in progress. As a preliminary finding from Pedar, asymmetry indices for healthy people were always <10% as for both force and pressure. Reliability of the SQK system was tested. Percentual repeatability error ranged from 0.7 to 2.2%.

As an example of SQK applicability, a single case is here reported. The left step of a right amputee was observed while walking fast with sport shoes without (A) and with (B) plantar orthoses. Mean Pedar data for B showed a significant reduction of 1PP (23%) and 2PP (33%), a 8% decrease of 1FP and a 7% increase of 2FP, a comparable walking speed. The fourth left step was selected in both cases and named ALS and BLS respectively. Qualitatively (Fig. 2), masks highlighted that during propulsion a longer and wider right step was executed with orthoses. The consequent higher acceleration explained the Pedar resulting higher peak force. Trunk polygons area ratios between 1PP and 2PP quantitatively confirmed the greater BLS forward progression (1.20 for ALS, 1.26 for BLS).

Fig. 2: Gait data of ALS and BLS during propulsion.

DISCUSSION AND CONCLUSION

The proposed SQK methodology seems to be an interesting tool to complete Pedar gait analysis in clinical practice without any impact on the patient. In the reported case, it helped to verify that suitable plantar orthoses significantly reduced peak pressures under the healthy foot without compromising the overall gait kinematics.

REFERENCES

1. Michel V, Chong RK. Exp Brain Res. 2004
A comparative study between blades and studs in football boots


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BACKGROUND
Injuries in football are very common and have a number of contributing factors. Many people accuse blades, a relatively new innovation in football boot design, for promoting injury. However, no publication or study has been found comparing the blade and conventional stud designs.

AIM
This study aimed to compare biomechanically some of the differences between bladed and studded football boots. Two similar boots, differing only in cleat design (Adidas® F30.6 TRX SG and the F50.6 TUNIT) were tested using the Novel Pedar®-X in-shoe pressure measuring system.

MATERIALS AND METHODS
Measurements were taken on 29 amateur football or rugby players who were asked to perform three trials of each of two actions: a straight run and cutting at a 60° angle in each boot design on artificial turf. For 12 of the participants additional data were recorded as they walked straight down the synthetic turf. Contact area, contact time (normalised to a percentage of foot fall), force-time integral, instant of peak pressure (normalised to a percentage of foot fall), peak pressure and pressure-time integral were analysed between boot design, action and trial. The data were analysed over 11 clinically relevant areas of the foot: medial and lateral heel, lateral midfoot, first, second, third, fourth and fifth metatarsal heads, hallux, second digit and digits three to five. Repeated measures analysis of variance was used to examine the effects of boot type (Blade or Stud) and activity (Straight or Slalom or Walk) on each foot parameter.

RESULTS
Pressure values were generally greater for the studded boots than bladed boots in all trials and across all the areas of the foot. Peak pressures and pressure-time integrals were marginally greater over the fourth metatarsal head in blades. Over the fifth metatarsal head force-time integrals were also slightly greater for blades. This suggests that studs could be overall potentially more harmful, and blades potentially more harmful over the lateral metatarsal heads in the football boots tested.

CONCLUSION
The values recorded were all within the normal variation for plantar pressures and so no clinical difference was discovered between the boots tested. Therefore, neither boot design could be concluded to be substantially more dangerous than the other in this context.

KEYWORDS
Pedar; Football boots; Blades; Studs.
The relationship between in-shoe foot pressure distribution and tibial shock-waves


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BACKGROUND
While work has been carried out to investigate tibial shock-waves and in-shoe pressure independently, no attempt has been made to correlate the two. A decrease in the magnitude of shock-wave experienced is expected to be beneficial as overloading of the functional capacity of natural shock-absorbers may result in degenerative diseases such as osteoarthritis.

AIM
The aim of this study is to investigate the relationship between in-shoe pressure distribution and tibial shock-waves when walking and running. If evidence for such a relationship is found, attempts will be made to quantify it and represent the relationship with a transfer function.

MATERIALS AND METHODS
Healthy subjects walked and ran on a treadmill at 1.12, 2.91, and 3.80 m.s\(^{-1}\) while synchronised data collection of in-shoe pressures and tibial shock was carried out using the Pedar\(^{\text{®}}\)-M system and accelerometers respectively. A custom-written computer program was used to extract data from the initial contact phase of both measurements. The initial contact phase was identified using the in-shoe pressures, and the peak extracted values were used in the analysis. A model of tibial shock was produced using in-shoe pressure, speed, age, true leg length, foot length, and foot width.

RESULTS
A positive correlation between tibial shock and in-shoe pressure was found \((r=0.304, \ P<0.001)\). Correlations were also identified between speed and in-shoe pressure \((r=0.662, \ P<0.001)\), and speed and tibial shock \((r=0.523, \ P<0.001)\). The tibial shock model produced can account for 33.7% of the variation in peak tibial shock at initial contact.

CONCLUSION
This study found a positive correlation between in-shoe pressure and tibial shock. It also confirmed the positive correlation between speed and in-shoe pressure, and speed and tibial shock. The tibial shock model demonstrated that shock is dependent on numerous factors, and cannot be predicted using in-shoe pressure data alone. An accurate model of tibial shock may be produced if the key variables shock is dependent on and their corresponding relationships were found.

KEYWORDS
Pedar; Accelerometers; In-shoe pressure; Tibial shock waves; Treadmill.
The effect of three simulated gait modes on plantar pressure distribution


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BACKGROUND
Walking is one of the most common movements of the body involving complex biomechanics in the lower limb especially in the foot. The act of walking is usually evaluated by gait analysis. This form of analysis is useful in choosing the best treatment modality, predicting outcome of the treatment, or to determine whether maximal recovery has occurred during rehabilitation.

AIM AND OBJECTIVES
The purpose of our study was to analyse the pressure and force distributions over the bearing areas of the foot during three modes of gait, normal gait (NG), forefoot gait (FG) and sidefoot (SG) gait. The objectives were to divide the whole foot-sole into 10 areas (with corresponding masks) hallux, second-third toe, fourth-fifth toe, first metatarsal, second-third metatarsal, fourth-fifth metatarsal, medial mid-foot, lateral mid-foot, medial heel and lateral heel; to calculate and analyze the plantar pressure distribution over the defined areas during the respective three modes of gait NG, FG, SG.

MATERIALS AND METHODS
Eighteen subjects were evaluated with an age range of 25-48 years. The right foot of each subject was studied. The exclusion criteria used for screening were subjects with no lower limb injury, any surgery on their feet at any time in their life, congenital or acquired deformities of the feet, use of walking aids and any current condition affecting the gait. The Pedar® in-shoe system was used to record the dynamic measurements of pressure on the plantar surface of the foot during NG, FG and SG. The ten masks were created using the Creation of Any Masks software.

RESULTS
Contact area, maximum force, peak pressure, maximum mean pressure, contact time, pressure-time integral and force-time integral were analysed. The forefoot recorded significantly higher temporal and pressure parameters in FG due to the decrease of the total contact area in comparison to NG. FG showed higher temporal and pressure recordings in the forefoot area but lower recordings in lateral midfoot and hindfoot areas in comparison to SG. There was no significant difference in the total contact area between SG and FG. On the other hand, SG showed higher pressure recordings in lateral metatarsal and lateral midfoot areas due to the decrease in the total contact area in comparison to NG.

CONCLUSION
In FG, there is a shift of maximum force and peak pressure from the hindfoot and midfoot areas to the forefoot. In FG, the peak pressure and maximum force were significantly high in the forefoot area especially under the metatarsal head areas, which may result in tissue damage in the form of callosities or ulceration. The hallux showed similar pressure data pattern as in FG and NG.
In SG the pressure and force were shifted from the medial areas to the lateral areas. Lateralised pressure distribution decreases the ability of walking. This type of gait is similar to the gait of patients with club-foot deformity.
FG and SG should be corrected as soon as possible to achieve the normal plantar pressure distribution. This study will be helpful in the clinical decision making like establishing diagnosis, monitoring various deformities of the foot, determining surgical intervention and assessing sports injuries of the foot and ankle.

KEYWORDS
Pedar; Simulated gait modes; Plantar pressure.
The use of the Fastrak and Pedar systems for clinical evaluation of finger pressure during writing


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BACKGROUND
The hand is an indispensable part of human form, function and communication, capable of intricate, expressive articulation and is a finely tuned instrument with specialized inter-dependent functioning of its component parts. It is designed to handle a vast array of tasks ranging from fine motor manipulations to powerful work. The adaptability and versatility of the hand can be seen in the delicacy and accuracy with which an eye surgeon operates, the quick touch discrimination of a blind Braille reader, the dexterity of a violinist, the timing of a tennis player, or the power and work capacity of manual labourers. Various techniques have been used for biomechanical analysis of the hand while performing different types of task. However, there are no studies concerning the evaluation of finger pressure and range of motion of the hand during writing.

AIM
The purpose of this study was to develop an enhanced biomechanical protocol to evaluate finger pressure in relationship to the range of motion of the hand for clinical use and examine the repeatability of the set-up.

MATERIALS AND METHODS
Twenty-five healthy volunteers with no previous history of trauma, surgery to the dominant upper extremity, writing problems or any other disease were recruited. Twenty-four were males and one was female. The ages of the group ranged from 29 to 52 years. The Pen Sensor S2060 was used in conjunction with the Pedar® system to measure Contact Area (CA, cm²), Peak Pressure (PP, kPa), Maximum Mean Pressure (MMP, kPa) and Contact Time (CT, s) of the thumb, index and middle fingers during a writing task on two occasions seven days apart. In addition, the Range of Motion (RoM, °) of the hand in Azimuth, Elevation and Roll were recorded using the Fastrak® system. Descriptive measures of parameters (minimum, maximum, mean and standard deviation) were calculated. Repeatability was investigated using limits of agreement (LoA), coefficient of repeatability (CR) and coefficient of variation (CV).

RESULTS
All measures of repeatability provided similar assessments and CV has been selected for the presentation of the results. CV was less than 50% in 12 of the 16 Pedar® cases and all three Fastrak cases (79% overall). All values were less than 81%. The lowest values, indicating the strongest repeatability, were in CT and CA. Values across the four regions of the hand (index finger, middle finger, thumb and total) were similar for these two variables. CV was highest in PP and values varied across the hand, with the highest occurring under the index finger. CV was lowest for the thumb and the total area in both PP and MMP. CV was highest for the thumb in MMP. Minimum and maximum recorded on the two days for each area of the hand mostly were comparable. In Fastrak®, while there were no significant cases of bias at the 5% level, the difference between repeated readings of Roll was close to significant (P=0.07). Agreement was good and repeatability was comparable in Elevation, Azimuth and Roll (mean CVs 25.21, 22.1 and 23.4, respectively). Values of RoM were higher in Elevation than Azimuth and Roll (means 25.1, 18.4 and 16.8, respectively). Minimum and maximum values of measurements recorded on Days 1 and 2 were comparable.

CONCLUSION
A new protocol was devised using the Pen Sensor S2060, Pedar® and Fastrak® systems. This was easy to set up and took no more than ten minutes to record the finger pressures and range of motion of the hand during writing. The results also indicated that the repeatability of the systems is satisfactory for clinical and research use. It needs further evaluation before using it as a biomechanical tool in assessing repetitive strain injuries of the hand.

KEYWORDS
Pedar; Fastrak; Finger pressure; Repetitive strain injuries.
Repeatability of the Novel Pliance®-X-32 Expert System


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BACKGROUND
One of the determinants of pressure sore risk has been the seat-interface pressure. Many pressure mapping systems are available with varying accuracy, reliability and repeatability.

AIM
This study was aimed to assess the repeatability of the Novel Pliance®-X-32 Expert seat-interface pressure mapping system.

MATERIALS AND METHODS
Ethics committee approval was obtained. Thirty four healthy volunteers participated in the study. Each participant sat on three different interfaces (ninian canvas, foam cushion and evazote sag compensator with foam cushion) of standard UN18A (Lomax® mobility Ltd.) wheelchair for five minutes each. The same was repeated after one week. Order of seating was randomized using a Latin square design. A real time pressure-map was recorded for various variables including contact area, peak pressure, maximum mean pressure, mean force and area, maximum force and contact time by a pre-calibrated Pliance-mat and this map was divided into seven zones; whole map (Zone 1), left buttock (Zone 2), right buttock (Zone 3), left buttock-thigh area (zone 4), left ischial tuberosity (zone 5) right buttock-thigh area (zone 6) and right ischial tuberosity (zone 7).

RESULTS
The Pliance system was most repeatable for evazote sag for almost all the variables, followed by foam cushion. The difference between the conditions was highly significant (p<0.001) in all the seven zones. The difference between the two sittings was significant for some variables such as maximum force, mean area and mean force. Sandwiching the evazote sag compensator between the foam cushion and the ninian canvas although subjectively increased the comfort level, did not prove beneficial in either pressure distribution or reduction.

CONCLUSION
Novel Pliance®-X-32 Expert System is probably the most repeatable seat-interface pressure mapping system available for clinical use. For each variable, the pattern of distribution is vital than the actual values.

KEYWORDS
Pliance; Seat-interface pressure; Pressure mapping system; Repeatability.
KRAFTSIMULATOR INTRAOPERATIVE PEDOGRAPHY (KIOP) – AN EXPERIENCE OF THE CLINICAL APPLICATION

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Introduction

Recently intraoperative pedography (KIOP) was introduced with the goal to objectively guide and assist the surgeon in corrective foot and ankle surgery for the patient’s benefit. A validation trial for the device was performed and plantar pressure distribution results were found to be comparable to other well accepted static pedography methods (Richter et al, 2006). In patients with hallux valgus deformity among other pathologic findings the transfer-metatarsalgia of the distal midfoot rays and the associated non or reduced weight bearing of the first metatarsal head are in surgical focus for correction and are considered to be pedographically detectable. Therefore, they are clinically relevant criteria to assess the extent of surgical correction and to estimate the impact on the individual’s clinical outcome (Michael et al, 2007).

Methods

From November 2007 onwards six patients (age, all female) with a clinical manifest hallux valgus deformity underwent corrective surgery in our hospital. As operative treatment a tarso-metatarsal (TMT I) arthrodesis of the first ray, an arthrosynthesis of the first metatarsal-phalangeal (MTP I) joint and a medial capsule and soft tissue reefing in MTP I joint (Lapidus-Mann Procedure) was performed. Preoperatively a physical exam, bilateral standardised weight-bearing foot x-rays, the American Orthopaedic Foot and Ankle Society Score (AOFAS), Visual Analogue Scale Foot and Ankle (VAS FA), Short form 36, standard dynamic pedography (EMED®, Novel Inc., Munich, Germany) and a KIOP (PLIANCE®, Novel Inc., Munich, Germany) measurement under anaesthesia were performed. Intraoperatively, a second KIOP analysis before wound closure was undertaken and plantar pressure distribution compared with the initial findings of the treated foot. On the base of intraoperative plantar pressure distribution assessment the operating surgeon stated whether KIOP analysis was relevant or not in deciding the final foot correction. Subsequently KIOP data were edited and transformed in an emed comparable format and further processed.

A clinical and dynamic pedography follow up evaluation of up to one year after operation and evaluations on further patients are planned to assess the predictive value of KIOP for functional outcome and its clinical sufficiency.

Results

All six Patients met criteria for operative hallux valgus treatment. For all cases pre- and intraoperative KIOP analysis was available and analysed. In each case’s operation a qualitative change in static forefoot pressure distribution from the pre- to intraoperative KIOP measurement was observed. After format transfer of the KIOP data to compare it with dynamic emed data prior to operation, the forefoot pressure achieved during intraoperative static force application was not sufficient for quantitative analysis.

Discussion and Conclusion

Intraoperative pedography has proven to be of objective guidance for corrective foot and ankle surgery in patients with manifest hallux valgus deformity. Low forefoot peak pressures in pre- and intraoperative evaluations only allowed qualitative comparison. Although no alteration of the arthodesis resulted from the KIOP measurements in the studied cases, the operative correction analysis was sufficient with regard to the optional surgical revision. A standardised KIOP protocol ensures constructive application of the device and avoids hardware difficulties.

As such intraoperative pedography seems to be an objective implement able and therefore useful method to control operative correction results by the mean of plantar pressure distribution. Its value for the estimation of functional and clinical operation outcome remains to be further studied and analysed.

References

Reliability and validity of in-shoe plantar pressure data measured in neuropathic diabetic patients

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Introduction

In-shoe dynamic plantar pressure assessment is frequently used to evaluate therapeutic footwear in at-risk diabetic patients since high plantar pressure is a major risk factor for ulceration. When measuring in-shoe pressure data, subsequent steps in a number of walking trials are often collected in order to obtain a representative estimate of the true pressures in a patient. However, guidelines for the required minimum number of steps to obtain reliable and valid in-shoe pressure data are not available for this patient population. In healthy subjects, Kernozek et al. (1996) found that a minimum of eight steps were required for reliable pressure data. Neuropathic diabetic patients may require more steps because their gait is more variable due to loss of protective sensation. The aim of this study was to determine the number of steps required for reliable and valid in-shoe foot pressure data in diabetic patients with peripheral neuropathy.

Methods

Eighteen neuropathic diabetic patients (12 men) with a mean age of 55.8 years underwent in-shoe plantar pressure assessment (Novel Pedar-X system) while walking in multiple trials at a comfortable speed along a 10m walkway in a laboratory setting wearing therapeutic footwear. Speed was controlled between trials (+5%). A minimum of 20 midgait steps per foot were collected. Peak pressure (PP) and pressure-time integral (PTI) were calculated for each of 6 anatomical foot regions per foot.

To assess reliability, Intraclass Correlation Coefficients (ICC) were calculated for each incremental number of steps starting with two. An ICC>0.90 was considered acceptable. To assess validity, Limits of Agreement were calculated for each region based on 95% confidence intervals of the differences in mean PP and PTI measured between each incremental number of steps and 20 steps (reference protocol). The ratio of the 95% CI and the mean PP or PTI for 20 steps (=Coefficient of Variation (CoV)) was calculated and considered acceptable when smaller than 10% in all regions.

Results and Discussion

For both PP and PTI, only 2 steps per foot were required to obtain excellent reliability scores (PP: ICC>0.98, PTI: ICC>0.94) for all regions. These scores were probably so high with few steps made because subsequent steps within a single walking trial were entered in the statistical model and because the inter-subject variability of mean PP and PTI was large (ΔPP=314 kPa, ΔPTI=84.9 kPa) which affects ICC calculations.

The CoV for both PP and PTI was high with 2 steps and therefore PP and PTI were not representative of the mean pressures measured with 20 steps (Figure). With more steps added to the calculation, the mean and range in CoV decreased and reached levels <10% for all foot regions at 12 steps. This number is larger than calculated for healthy individuals, which may be due to an inherently larger gait variability in neuropathic patients.

To reach acceptable CoVs, fewer steps were required for the rearfoot than forefoot, which shows that PP and PTI are less variable in more proximal regions of the foot.

Conclusions

This study showed that a minimum of 12 steps per foot were required to obtain representative and reliable in-shoe dynamic plantar pressure data in diabetic neuropathic patients wearing therapeutic footwear.

References

Kernozak, TW et al, Foot Ankle Int. 17:204-9, 1996.
ACCURACY OF THE NOVEL EMEDEX AND TEKSCAN MATSCAN PLANTAR PRESSURE MEASUREMENT SYSTEMS.

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INTRODUCTION
The ultimate goal of this investigational team is to determine the validity of making plantar pressure measurements with emed-X (Novel: Munich, Germany) and MatScan (TekScan; Boston, Ma, USA) systems during both posture and locomotion. Construct validity requires that a system is both accurate and reliable. To be reliable is necessary but not sufficient because it is possible to be repeatably wrong. This abstract evaluates the accuracy of both plantar pressure measurement systems.

METHODS
All sensors of the emed-X (and MatScan) were excited simultaneously at regular discrete values ranging from 0 to 850 KPa with a bladder-based calibrator/tester (Figure 1). Short term (Figure 2) and long term loading profiles were selected to approximate the temporal loading characteristics of locomotion and posture. The measured pressure values obtained by each plantar pressure measurement system sensor were compared to the applied pressure values recorded by the transducer (Greisinger model GDH 14AN) of the calibrator/tester. The root mean square error (RMSE) was calculated across all sensors and across all load levels at baseline and follow-up.

RESULTS
When using the TekScan MatScan default equilibration (300KPa – single point method) after the factory recommended calibration (scaled to a test subject’s body weight) the system saturated between 250 and 300KPa. This did not improve using any of the other factory equilibration files associated with the mat. The procedure that did yield more appropriate maximum pressure magnitudes was to build a new equilibration file at 500KPa using the bladder testing system (Figure 1). Then using the same bladder, an equivalent force (500KPa x sensor area (cm^2)) was applied to serve as the calibration. Note that all of the MatScan accuracy results were obtained with this ‘special calibration’ procedure so that it was possible to obtain results that spanned full scale.

Table 1 – Total Accuracy Results

<table>
<thead>
<tr>
<th>Pressure 0–850KPa</th>
<th>Baseline</th>
<th>1 Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RMSE</td>
<td>%FSE</td>
</tr>
<tr>
<td>EmedX</td>
<td>13.22</td>
<td>1.56</td>
</tr>
<tr>
<td>MatScan</td>
<td>49.53</td>
<td>5.83</td>
</tr>
</tbody>
</table>

Total accuracy, for both the ascending and descending portions of the loading profile was excellent for Novel emed X as evidenced by the baseline RMSE of 13.22 KPa (1.56% FSE). TekScan MatScan accuracy for the same loading profile was 49.93 KPa (5.83% FSE). Drift was minimal for both systems as indicated by the similarity of the error values at 1 month. Note that the MatScan had errors as high 21% FSE without the ‘special calibration’ due to saturation. The concern is that this procedure is not the standard protocol described in the TekScan manual and user access to a calibrator/tester such as Figure 1 may be limited.
A PRELIMINARY STUDY OF THE EFFECTS OF GEL LINER THICKNESS ON IN-SOCKET RESIDUAL LIMB Pressures IN TRANS-TIBIAL PROSTHESIS USERS

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INTRODUCTION
Polliack et al. (2000) pointed out that measuring pressure at the interface between the residual limb and the prosthetic socket could provide valuable information in the process of socket fabrication, modification, and fit. Two studies (Seelen et al., 2003 and Dou et al., 2006) investigated pressure distribution at the residual limb/socket interface using 6mm gel liners. Dou examined pressure during walking on stairs and slopes rather than level walking. Seelen studied the effects of prosthesis alignment on pressure distribution. The purpose of this preliminary study is to examine the effects of gel liner thickness (3mm and 9mm) on residual limb pressures.

METHODS
Three men with unilateral trans-tibial amputations agreed to participate in the study and signed IRB-approved consent forms. Mean (+ standard deviation) age was 53 ± 12 years, mean weight 92 ± 15 kg, and mean height was 177 ± 9 cm. Sockets for both gel liners were made for each subject using a CAM system developed in our laboratory called Squirt Shape. All other prosthetic components were the same for all subjects. A gait analysis was performed with the person walking at his normal self-selected speed for each gel liner condition. Mean walking speed across all subjects and conditions was 1.26 ± 0.10 m/sec.

Prior to each gait evaluation, 6cm x 3cm pressure sensors (Pliance, Novel Electronics, Inc.) were placed over the patellar tendon region, the fibular head, and the anterior distal tibia. Pressure data were synchronized with the motion data. All pressure data were recorded at 120 Hz.

RESULTS
Maximum pressures for each sensor matrix averaged over multiple gait cycles are shown in Figure 1. Pressure over the patellar tendon area was either reduced with the 9 mm liner or did not exhibit a change. Pressure over the fibular head was reduced in all subjects using the 9mm liner. Pressure over the anterior distal tibia did not change appreciably between the 3mm and the 9mm liner.

CONCLUSIONS
The liner thickness affected pressures at some locations on the residual limb but not all locations. This study is currently ongoing with additional subjects.

REFERENCES

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