International Conference on Ambulatory Monitoring of Physical Activity and Movement

Conference Book

Editors:
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Welcome

Dear ICAMPAM participants,

In 1992 the department of Rehabilitation Medicine of Erasmus MC started its first project in the area of ambulatory activity monitoring. Back then we could perform ambulatory measurements for maximally 1 hour, the computer time for data analysis was about that long, and we had to deal with many hardware and software problems. Since then, enormous progress has been made in ambulatory activity monitoring, both in research and applications. Systems have become smaller, more powerful and energy efficient, and are nowadays much more user-friendly and widespread used.

However, we realized that ambulatory monitoring still did not have its own platform. When it did receive some special interest, it was generally a small part of a discipline-specific conference. Consequently, those working in the field of ambulatory activity monitoring missed the opportunity to meet each other and share ideas and possible solutions. About two years ago we explored the need for a conference dedicated to this topic. Everyone we asked responded enthusiastically: "… it really is THE moment for such a conference". This supported our own ideas and has resulted in the ICAMPAM conference held in Rotterdam May 21-24 2008.

Organizing a first conference of this type is both challenging and demanding. From the beginning we knew that we wanted to offer a scientific conference of high standard, with renowned speakers, an open procedure of abstract submission, with as many participants as possible from all over the world, the involvement of related companies, and all this embedded in an excellent conference and social environment. We hope that we have succeeded: there is an excellent program consisting of 12 invited lectures, 45 oral presentations and about 100 poster presentations; over 200 participants will attend; several companies are present or are supporting the meeting; and we think that ICAMPAM will also be enjoyable. It has taken considerable effort to do all this, but it was worth it. Of course we hope you will agree with us at the end of the conference!

We would like to thank the many people involved in organizing this conference. First of all the Organizing Committee: Rita van den Berg, Herwin Horemans, Henri Hurkmans, Joke Tulen, Fabienne Schasfoort, Janneke Haisma and Marian Michielsen, who have done a marvelous job. We would also to thank Angelique Janssens and Margo Vreeburg who are the key persons of the conference office, and Mirjam van der Linden for her administrative support. Another important group is the Scientific Committee: they generated valuable suggestions and ideas, reviewed more than 170 abstracts, and will play an important role during the meeting. Of course we also thank the sponsors of this conference and the exhibitors. We do realize that some courage is needed to participate in a conference which is without history.

Indeed, no history so far. However, one of the topics for discussion will be "the future". What do you need, what are you waiting for? Will you be interested in a second edition of ICAMPAM? Do you think we need some type of network or global society? We would like to discuss this with you at the end of the conference, but hopefully also during ICAMPAM.

We wish you all an interesting, exciting, as well as very enjoyable conference.

Hans (J.) B.J. Bussmann	Henk J. Stam
Conference chair	Chair Dept. of Rehabilitation Medicine Erasmus MC

Committees

Scientific Committee

Kamiar Aminian	Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
Chris Baten	Roessingh Research & Development, Enschede, The Netherlands
Rita van den Berg-Emons	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Hans Bussmann	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Uli Ebner-Priemer	Central Institute of Mental Health, Mannheim, Germany
Ulf Ekelund	Institute of Metabolic Science, Cambridge, UK
Andrea Giordano	Centro Medico di Riabilitazione, Veruno, Italy
Janneke Haisma	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Jaap Harlaar	Free University, Amsterdam, The Netherlands
Herwin Horemans	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Henri Hurkmans	Physical Therapy, Erasmus MC, Rotterdam, The Netherlands
Nigel Lovell	University of New South Wales Sydney, Australia
Masaaki Makikawa	Ritsumeikan University, Japan
Chris Nester	Salford University, Salford, UK
Gearóid Ólaighin	National University of Ireland, Galway, Ireland
Jean Paysant	Institut Régional de Médecine Physique et de Réadaptation, Nancy, France
Fabiënne Schasfoort	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Henk Stam	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Joke Tulen	Psychiatry, Erasmus MC, Rotterdam, The Netherlands
Gitendra Uswatte	University of Alabama, Birmingham, USA
Peter Veltink	University of Twente, Enschede, The Netherlands
Greg Welk	Iowa State University, Ames, USA
Klaas Westerterp	University of Maastricht, Maastricht, The Netherlands
Luc van der Woude	Free University, Amsterdam, The Netherlands
Wiebren Zijlstra	University Medical Centre Groningen, Groningen, The Netherlands

Organizing Committee

Rita van den Berg-Emons	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Hans Bussmann (chair)	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Janneke Haisma	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Herwin Horemans	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Henri Hurkmans	Physical Therapy, Erasmus MC, Rotterdam, The Netherlands
Marian Michielsen	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Fabiënne Schasfoort	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Henk Stam	Rehabilitation Medicine, Erasmus MC, Rotterdam, The Netherlands
Joke Tulen	Psychiatry, Erasmus MC, Rotterdam, The Netherlands

Sponsors

The Organizing Committee gratefully acknowledges the support of the following sponsors:

Venue

General
The Beurs-WTC is the prestigious location for the ICAMPAM conference. The building and its environments are the setting for a scintillating variety of shops, the Beurs-WTC Business Center, the Beurs-WTC Conference Center, the WTC Club Rotterdam and the WTC Art Gallery. The technical facilities in the Beurs-WTC are of excellent quality. The Beurs-WTC Conference Center is located in the business centre of Rotterdam and is accessible by both public transport and car. Car parking facilities are available in the direct environment of the WTC, and for public transport the metro station Beurs is just outside the building. See for Floor Plan page 13.

Rotterdam Hall
The scientific part of the conference – oral and poster presentations – will take place in the Rotterdam Hall of Beurs-WTC.

Shipping Hall
Coffee breaks, lunches and the commercial exhibition will be held in the Shipping Hall, adjacent to the Rotterdam Hall. Also the Speakers' Corner is located in this Hall.

Penn Room I
The workshops during the lunch slot on Thursday and Friday will be held in Penn Room I.

Penn Room II
Penn Room II is the Speakers' Ready Room.

Van Mees Auditorium
The van Mees Auditorium is the workshop location on Wednesday.

Address details
Beurs-WTC Congres Center
Beursplein 37
P.O. Box 30099
3001 DB ROTTERDAM

Rotterdam

The city that is so unlike Holland's other cities. Located on the mighty Maas River. One of the world's biggest ports. City with outstanding architecture and delightful culture. City with an abundance of attractions, festivals and museums. A swinging, young city culture and excellent shopping facilities, restaurants and cafes. Whatever your interests are, whatever you want to do, Rotterdam is sure to pleasantly surprise you! Please contact the registration desk if you need further tourist information.

Registration

Registration desk
The registration desk is located in the Beurs-WTC Shipping Hall, and will be open at:

Wednesday May 21	14:00 – 17:30
Thursday May 22	7:30 - 17:30
Friday May 23	8:00 - 18:00
Saturday May 24	8:00 - 14:00

The registration desk will also be open in the City Hall of Rotterdam during the welcome reception (Wednesday May 21, 18:00 – 19:30).

Registration fee
The registration fee for the meeting includes the following:

- Participation in the conference
- Welcome reception at City Hall Rotterdam
- Social program on Thursday
- Conference bag
- Coffee breaks
- Lunches
- The conference proceedings and abstracts book
- Optional: Participation in the conference dinner on Friday evening

Instructions for Speakers

A speakers' ready room, available every day throughout the meeting, will be provided for speakers. The speakers' ready room is located in Penn Room II.

Presentations must be in MS PowerPoint format (.ppt), suitable for use with Windows XP. Presentations prepared in PowerPoint 2007 must be saved as an earlier version.

Please provide your presentation(s) to the audio-visual assistant in the speakers' ready room on CD, DVD or memory stick. The presentation will be downloaded on a computer from the organization. This has to be done before the session preceding the speaker's session. E.g. a presentation in session 3 must be provided to the assistant before session 2. Speaker's in the first session of a day must upload their presentation before the end of the previous day.

Speakers are requested to check their presentation after uploading their file. This is especially important when using embedded files, e.g. video films or other not PowerPoint files.

Speakers may not use their own computer for their presentation.

Presentations will be shown using LCD projection only. There will be no facilities for 35 mm or overhead transparencies.

Each presenter must make him/herself known to the chairpersons on time, i.e. during the break before the session. The chairpersons will be available on the presentation floor during the last 15 minutes of the break.

Speakers are informed about their time slot. It is essential to stay within that time slot, and session chairs will strictly prevent speakers from exceeding the time slot. The time slot includes at least 5 minutes (keynote speakers) or 2 minutes (other speakers) for questions or discussion.

The discussion time during a session is limited, and several people from the audience will not be able to pose their questions. Therefore, directly after their session speakers are requested to go to the "Speakers' Corner" in the Shipping Hall. At the "Speakers' Corner" people from the audience ones more will have the opportunity to contact speakers.

Speakers are requested to enter the presentation floor during the discussion time of the previous speaker.

Instructions for Poster Presenters

Posters should be mounted by the beginning of the first coffee break on Thursday at 10:20 and dismantled at the end of the conference. So posters will be displayed during the whole conference. Upon registration please check the final program for poster board number that has been allocated. Please use the board with the same number.

Scheduled moments for poster viewing are the coffee breaks in the morning and afternoon. Poster presenters are expected to stand at their poster for informal discussion during minimally 2 of the 4 coffee breaks. So a schedule has been made that half (Part I) of the presenters stand at their poster on Thursday, and the other half (part II) on Friday. But of course it is encouraged to stand at the poster too at other moments, e.g. during lunch or on the other days.

Poster Award

During Thursday and Friday, each poster will be visited and assessed by people from the Poster Award Committee, consisting of people from the Scientific and/or Organizing Committee, and chaired by Rita van den Berg. The best poster will be awarded during the conference closing.

Accreditation

Accreditation for the International Conference on Ambulatory Monitoring of Physical Activity and Movement being held in Rotterdam, The Netherlands May 21-24, 2008 has been requested from the European Accreditation Council for Continuing Medical Education (EACCME). This EACCME is an institution of the European Union of Medical Specialists (UEMS), http://www.uems.net/.

To receive accreditation, participants have to report themselves present at the registration desk during every day that they participate in the conference. Furthermore, participants have to complete at the end of the conference program the evaluation form which can be found in the conference bag. Completed evaluation forms can be returned at the registration desk. Each medical specialist should claim only those hours of credit that he/she actually spent in the educational activity. EACCME credits are recognized by the American Medical Association (AMA) towards the Physician's Recognition Award (PRA). To convert EACCME credit to AMA PRA category 1 credit, contact the AMA.

All faculty and other speakers at this scientific event are aware of, and have agreed, to sign the UEMS/EACCME disclosure form, and have disclosed any potential conflict of interest that they may have.

Workshop information

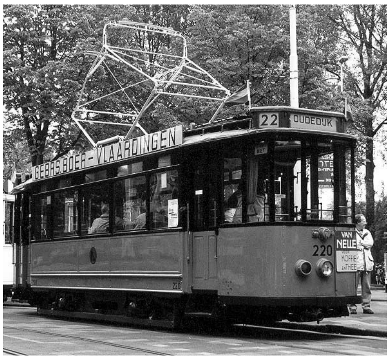
During the conference several workshops will be held. Workshops are scheduled on Wednesday afternoon and during the lunch slots on Thursday and Friday. We encourage you to visit these workshops, although they are no part of the Scientific program of ICAMPAM. See for more detailed information the chapter "Workshops" (page 40).

Social Program

The official start of the conference will be on Wednesday evening with a welcome reception at the beautiful City Hall of Rotterdam.

After this reception, you will have plenty of time to enjoy a nice dinner at one of many fine restaurants in the city center. And maybe afterwards you will join us at our **Conference Café 'Dudok'** (address: Meent 88) where you will find the most famous apple pie of Holland. Here you can meet other participants of the conference. This café will be the meeting point during ICAMPAM.

Thursday afternoon: A tour on a historic tram



At the end of an, no doubt, interesting conference day, we will take you for a tram ride through the city of Rotterdam. Lijn 10 keeps the history of the tram of Rotterdam alive and kicking. Trams from 1931 take you on a tour along ultramodern buildings, the exuberant city centre and historic parts of town. During the 80 minutes tour you will get a good picture of the present and past of Rotterdam. After the tour you can make your own arrangements.

Friday evening: Conference dinner at the Zalmhuis
The conference dinner is optional and you need to sign in and pay for it (€ 85,-) through the registration form. Registration for the Conference dinner is possible till 12:00 on Friday.

On Friday evening we would like to invite you to the conference dinner in Restaurant the Zalmhuis which is situated directly at the river Maas.

Instead of going to the Zalmhuis by bus, we will take you there by boat so that you get the chance to see something of what Rotterdam is all about and famous for; the water, the architecture, the bridges and it's harbour!

We will board at Leuvehaven and welcome you aboard one of the ships of the Spido line. While enjoying your drink, you will have the opportunity to discover and admire the old and the new of the city of Rotterdam. It offers you a unique chance to see Rotterdam from the waterside and to get acquainted with the rich architecture of the city of Rotterdam.

We will sail to Hotel New York, the former head office of the 'Holland-Amerika lijn' and the Northern Island.

Off course you will see the Swann, the most famous and beautiful bridge of the Netherlands and the Willems Bridge. After about an hour we will sail underneath the Van Brienenoord Bridge and tie up at the Zalmhuis.

At the Zalmhuis we will have a wonderful evening in the **Grand Salle**, which is situated on the highest floor of the building, so that you will have a splendid view of the river Maas and on the Van Brienenoord Bridge. After an enjoyable evening with a delicious dinner and music we will take you back to your hotel by bus. The bus drives along 5 hotels in the centre of Rotterdam to drop you off. *Dress code for the evening is smart.*

If you don't want to join us at the Zalmhuis, but you would like the boat tour, it's possible to sign in only for the boat tour there and back for € 25,-

General Information

Badges
Upon registration you will receive a personal badge and the conference bag, which includes the abstracts book with the final program and practical information about Rotterdam. Please wear your badge at all times during the conference and the social events. The following badge colors can be recognized:

Local organizing committee	blue
Invited speakers & Scientific Committee	red
Participants	white
Exhibitors	orange
Assistants	green

Certificate of attendance
A certificate of attendance is included in your conference bag, which will be handed out to you at the registration desk.

Cloakroom facilities
A cloakroom is situated next to the Shipping Hall (foyer).

Currency, banking, and payments
The Netherlands is member of the European Monetary Union, thus its currency is the Euro. Bankomats are everywhere and especially in Metro stations and certainly in all tourist areas. Most banks are open on Monday from 1 to 4 pm, on Tuesday to Friday from 9 am to 4 pm. They are closed over the weekends and on public holidays. Visa, MasterCard and American Express credit cards are widely accepted at major hotels, shops and restaurants in the larger cities. Service charges are included in your bill for most services. It is common to tip a waiter in a restaurant after a satisfactory meal.

Disclaimer
All best endeavors will be made to present the program as printed. However, the Organizing Committee and Conference Organization reserve the right to alter or cancel, without prior notice, any arrangement, timetable, plan or other item relating directly to the meeting for any cause beyond its reasonable control.

The Organizing Committee and Conference Organization accept no liability for personal injuries or loss, of any whatsoever, or loss or damage to property either during or as a result of the meeting.

Electricity
The electrical supply in The Netherlands is 220 volts.

First Aid
If a delegate requires first aid, please contact the registration desk.

Internet facilities
Internet facilities are not – or very limited – provided by the organization. However, Beurs-WTC has a wireless internet facility ("KPN HotSpots"). Participants with their own laptop with a Wi-Fi network card can buy an entry card with a login code. The costs for a one-day card are €17,50, for a one-week card €27,50. It is also possible to pay online by credit card via the login page. Online the costs for a one-day card are €15,95, and for a one-week card €24,95. Visit the Registration Desk for more information.

Language
The official language at the ICAMPAM meeting is English. No translation arrangements will be made.

Lost property
Enquiries regarding lost or found items can be made at the registration desk.

Messages
Messages for delegates can be delivered at the registration desk. Notification of messages will be displayed on the message board next to the registration desk. Please check the board daily and pick up your messages.

Photocopies
A photocopy service is located at the reception desk of the WTC. Charges for photocopies are to be paid in cash.

Registration desk
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Wednesday May 21	14:00 – 17:30
Thursday May 22	7:30 - 17:30
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Saturday May 24	8:00 - 14:00

The registration desk will also be open in the City Hall of Rotterdam during the welcome reception (Wednesday May 21, 18:00 – 19:30)

Smoking
In the WTC smoking is prohibited by law.

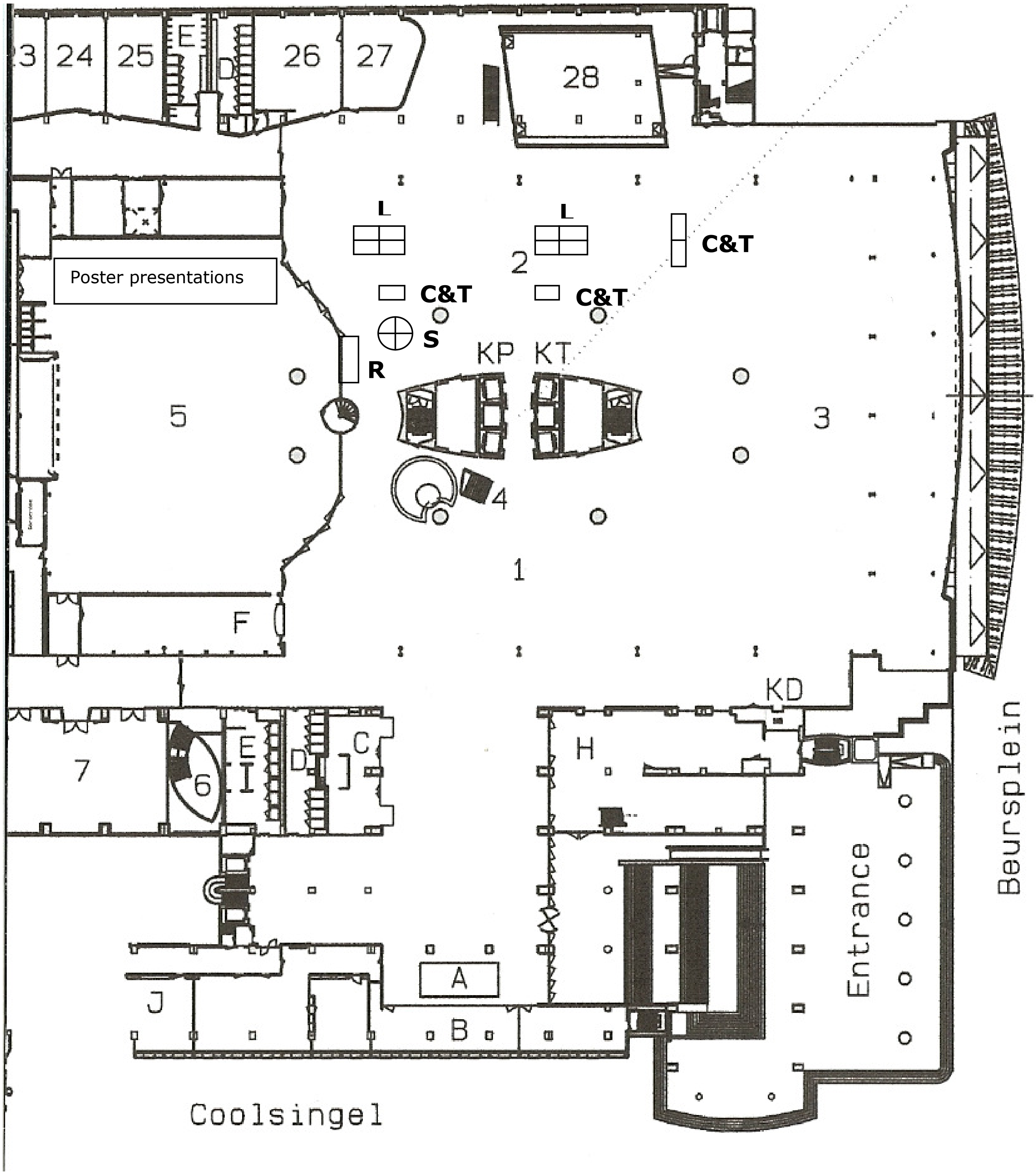
Shopping
Shops in Rotterdam are open on Monday from 11 am to 5:30 pm, on Tuesday, Wednesday and Friday from 9 am to 5:30 pm, on Thursday from 9 am to 9 pm, and on Saturday from 9 am to 5 pm. Major shops in the center are also open on Sunday from 12 am to 5 pm.

Speakers' corner
The discussion time during a session is limited, and participants will not be able to pose their questions. Therefore, directly after their session speakers will to go to the "Speakers' Corner" in the Shipping Hall. At this "Speakers' Corner" people from the audience ones more will have the opportunity to contact speakers.

Speakers' ready room
During meeting hours there are computers and technical assistance available for speakers in the speakers' ready room (Penn room II). See for further information: "Instructions for speakers" (see page 7).

Telephone
The country code for The Netherlands is 0031. Each telephone number in The Netherlands has an area code (the area code for Rotterdam is 10), and an individual number. Emergency calls: 112.
Please note: Mobile phones must be switched of during the presentations!

FLOOR PLAN - World Trade Center



2	**= Shipping Hall / Exhibition grounds**	**A**	**= WTC reception**
5	**= Rotterdam Hall**	**C and D**	**= Toilets**
26	**= Penn Room I**	**F**	**= Cloakroom**
27	**= Penn Room II**	**L**	**= Lunch buffet**
28	**= Mees Auditorium**	**C&T**	**= Coffee and Tea**
R	**= Registration desk**	**S**	**= Speakers' Corner**

ICAMPAM Evaluation Form

Evaluation Form

International Conference on Ambulatory Monitoring of Physical Activity and Movement
May 21-24, 2008; Erasmus Medical Center Rotterdam, The Netherlands

The Local Organizing Committee would really appreciate to have your opinion about this conference. Please be so kind to fill out this form and hand it in at the registration desk upon departure. Information from evaluation forms is used to design and improve future conferences.

In case you have no opinion on a particular part of the conference, please leave the check boxes for that part open.

!! For receiving accreditation credits, please insert your name and institution here !!

Name: …………………………………………………………………………………………

Institution: ……………………………………………………………………………………….

How did you hear about this conference?

□ advertisement magazines
□ colleague
□ emailings ICAMPAM
□ emailing societies/other
□ events calendar magazines
□ events calendar websites
□ flyer ICAMPAM
□ newsletter societies/other
□ press release
□ website ICAMPAM

□ other

Scientific program

	excellent	*good*	*average*	*below average*	*poor*
Invited speakers	□	□	□	□	□
Free papers	□	□	□	□	□
Poster presentations	□	□	□	□	□
Workshops	□	□	□	□	□
Panel discussion	□	□	□	□	□

Social program / Optional bookings

	excellent	*good*	*average*	*below average*	*poor*
Welcome reception	□	□	□	□	□
Conference café	□	□	□	□	□
Conference dinner party	□	□	□	□	□
Historic tram	□	□	□	□	□

Overall

	excellent	*good*	*average*	*below average*	*poor*
Scientific level conference	□	□	□	□	□
Facilities conference center	□	□	□	□	□
Audio visual facilities	□	□	□	□	□
Catering	□	□	□	□	□
Website www.icampam.org	□	□	□	□	□
Program and abstracts book	□	□	□	□	□
Abstract submission procedure	□	□	□	□	□
Registration procedure	□	□	□	□	□
Hotel reservation procedure	□	□	□	□	□
Conference organization	□	□	□	□	□
Location Rotterdam	□	□	□	□	□
Overall score ICAMPAM 2008	□	□	□	□	□

Comments & suggestions

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Thank you for sharing your opinion with us!

Program: general information

ICAMPAM is structured according three types of presentations and 11 main topics. You will recognize the 11 topics in the session titles of the oral program and in the ordening of the poster presentations.
In general, each oral session consists of one or two keynote lectures followed by 3 to 5 free oral papers. Poster presentations are also grouped according to their topic, and posters within the same topic will be located in the same poster area. Presenters will stand at their poster on specific days: for topic 1 & 3 (Part I) on Thursday, for the other topics (Part II) on Friday.

The structure of different types of presentations and topics is also represented in the codes of all presentations and abstracts.

First character: type of presentation:
K: Key note lecture
O: Oral presentation
P: Poster presentation.

Second character: topic number:
1: Physical activity: measurement & general issues
2: Medical & public health applications I
3: Gait and 3D kinematic analysis outside the lab
4 : Medical & public health applications II
5: Balance and falls
6: Ergonomics and Occupational Health
7: Data processing & analysis
8: Energy expenditure
9: Remote monitoring
10: Psychology & miscellaneous
11: “What's next?”

Third character: presentation number within topic & type of presentation

See the back cover page for the time table

Overview program

Wednesday May 21

Workshop session W-1

Mees Auditorium

W-1-1 AMBULATORY MONITORING OF PHYSICAL ACTIVITY AND MOVEMENT: THE ROTTERDAM STORY (15:00-16:00)

Chair: Rita van den Berg - Emons

W-1-2 FALL DETECTION NETWORK (16:00-17:30)

Chairs: Kamiar Aminian & Wiebren Zijlstra

Thursday May 22

Conference opening (8:15-8:30)

Hans (J) B.J. Bussmann & Henk J. Stam

Session 1: Physical activity: measurement & general issues (8:30-10:20)

Chairs: Greg J. Welk & Rita (H) J.G. van den Berg-Emons

Invited speakers (8:30-9:20; 2*25')

K-1-1 ASSESSMENT OF PHYSICAL ACTIVITY WITH ACCELEROMETERS
Klaas R. Westerterp
Maastricht University, the Netherlands

K-1-2 NEW FRONTIERS IN PHYSICAL ACTIVITY ASSESSMENT WITH PATTERN RECOGNITION TECHNOLOGY
Greg J. Welk
Iowa State University, Ames, USA

Free papers (9:20-10:20; 5*12')

O-1-1 INCREASING OUR UNDERSTANDING OF PEDOMETER REACTIVITY: WHAT FACTORS ARE INVOLVED?
Clemes SA
Loughborough University, Dept. of Human Sciences, Loughborough, Leicestershire, UK

O-1-2 PEDOMETRY – A VALIDATION STUDY
Müller C
Motion Analysis Lab, Orthopaedic Department, University Hospital Muenster, Germany

O-1-3 ACTIVITY MONITORING: THE MONITOR AS A SOURCE OF ERROR
Stott NS
Department of Paediatric Orthopaedics , Starship Children's Hospital, Auckland, New Zealand

O-1-4 VALIDITY AND RELIABILITY OF PEDOMETERS AND ACCELEROMETERS IN CHILDREN AND ADOLESCENTS
de Vries SI[1,2]
[1] TNO Quality of Life, Department of Physical Activity and Health, Leiden, The Netherlands, [2] Body@Work, Research Centre Physical Activity, Work and Health, TNO-VU University Medical Centre, Amsterdam, The Netherlands

O-1-5 MOTION SENSOR OUTPUT AT HIGH RUNNING SPEEDS IN CHILDREN – THE A-CLASS PROJECT
Graves L[1, 2]
[1] Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK, [2] The REACH (Research into Exercise, Activity and Child Health) Group, Research Institute for Sport and Exercise Sciences, Liverpool JMU, Liverpool, UK

Coffee break & poster presentations Part I (10:20-11:00)

Thursday May 22

Session 2: Medical and public health applications 1 (11:00-12:25)

Chairs: Henk J. Stam & Jean Paysant

Invited speaker (11:00-11:25)

K-2-1 AMBULATORY ACTIVITY MONITORING: ADDED VALUE IN MEDICINE
Henk J. Stam
Dept. of Rehabilitation, Erasmus University Medical Center Rotterdam, the Netherlands

Free papers (11:25-12:25; 5*12')

O-2-1 WALKING ACTIVITY IN CHILDREN WITH THE STEPWATCH3™
Bjornson KF[1,2]
[1] University of Washington, [2] Children's Hospital & Regional Medical Center, Seattle, WA 98105 USA

O-2-2 THE ASSOCIATION BETWEEN FUNCTIONING IN A LABORATORY AND DAILY LIFE FOR LOW BACK PAIN PATIENTS
Huijnen IPJ
Department of Clinical Psychological Science, Maastricht University, Maastricht, The Netherlands

O-2-3 CHANGES IN PHYSICAL ACTIVITY DURING AND AFTER INPATIENT REHABILITATION IN PERSONS WITH SPINAL CORD INJURY
van den Berg-Emons HJ
Department of Rehabilitation Medicine, Erasmus Medical Center, Rotterdam, The Netherlands

O-2-4 CUEING TRAINING IMPROVES AMBULATORY WALKING ACTIVITY IN PATIENTS WITH PARKINSON'S DISEASE: THE RESCUE TRIAL
Lim I
VU University Medical Center, The Netherlands

O-2-5 AMBULATORY MONITORING IN LARGE MULTI-SITE REHABILITATION TRIALS: LESSONS FROM EXCITE
Uswatte G
University of Alabama, Birmingham, USA

Lunch (12:25-14:00)

Workshop session W-2 (12:30-13:55)

Penn Room I

W-2-1 PAM: PAM ACTIVITY MONITOR (12:30 – 13:10)

W-2-2 ORTHOCARE: THE STEPWATCH ACTIVITY MONITOR (13:15 – 13:55)

Thursday May 22

Session 3: Gait and 3D kinematic analysis outside the lab (14:00-15:25)

Chairs: Peter H. Veltink & Chris Baten

Invited speaker (14:00-14:25)

K-3-1 ADVANCES IN AMBULATORY 3D ANALYSIS OF HUMAN MOVEMENT
Chris Baten
Roessingh R&D, the Netherlands

Free papers (14:25-15:25; 5*12')

O-3-1 OUTDOOR GAIT ANALYSIS USING INERTIAL AND MAGNETIC SENSORS – PRELIMINARY VALIDATION
Ferrari A[1,2]
[1] INAIL Prosthesis Centre, Research Area, Vigorso di Budrio (Bo), [2] DEIS, University of Bologna, Italy

O-3-2 GAIT ANALYSIS USING WEARABLE SENSORS
Picerno P
Department of Human Movement and Sport Sciences, IUSM, Rome, Italy

O-3-3 CENTER OF MASS MOVEMENT ESTIMATION USING AN AMBULATORY MEASUREMENT SYSTEM
Veltink PH
Institute for BioMedical Engineering (BMTI), University of Twente, Enschede, The Netherlands

O-3-4 VALIDITY OF THE DYNAPORT GAITMONITOR FOR THE ASSESSMENT OF PROSTHETIC GAIT
Houdijk H[1,2]
[1] Heliomare Research and Development, Wijk aan Zee, The Netherlands, [2] Research Institute MOVE, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands

O-3-5 OBTAINING BASIC GAIT CHARACTERISTICS WITH MINIMAL INSTRUMENTATION: POSSIBILITIES AND PITFALLS
Zijlstra W
Center for Human Movement Sciences, University Medical Center Groningen, The Netherlands

Coffee break & poster presentations Part I (15:25-16:05)

Thursday May 22

Session 4: Medical and public health applications 2 (16:05-17:05)

Chairs: Gitendra Uswatte & Herwin Horemans

Free papers (16:05-17:05; 5*12')

O-4-1 QUANTIFICATION OF ASYMMETRICAL MOVEMENT IN CHILDREN
Vander Linden DW
Eastern Washington University, Spokane, WA, USA

O-4-2 PHYSICAL ACTIVITY DURING PROLONGED WALKING: INFLUENCE OF DISTANCE AND GENDER
Eijsvogels TMH
Dept. of Physiology, Radboud University Nijmegen Medical Center, the Netherlands

O-4-3 USE OF AMBULATORY ACCELEROMETRY TO ASSESS THE SIT-TO-STAND MOVEMENT
Janssen WGM
Dept. of Rehabilitation Medicine, Erasmus MC, Rotterdam, the Netherlands

O-4-4 PHYSICAL ACTIVITY IN DUTCH SCHOOL CHILDREN WITH CEREBRAL PALSY
Dallmeijer AJ
Dept Rehabilitation Medicine, VU University Medical Center, Amsterdam, The Netherlands

O-4-5 COMPLIANCE OF PHYSICAL ACTIVITY GUIDELINES IN A WORKING POPULATION USING AN OBJECTIVE MONITORING TECHNIQUE
Chastin SFM
School of Health and Social Care, Glasgow Caledonian University, Glasgow, UK

Historic Tram Tour (17:15)

Friday May 23

Session 5: Balance and falls (8:30-10:20)

Chairs: Kamiar Aminian & Wiebren Zijlstra

Invited speakers (8:30-9:20; 2*25')

K-5-1 AMBULATORY SYSTEMS FOR MONITORING PHYSICAL ACTIVITY, GAIT & BALANCE: TECHNOLOGICAL ISSUES IN FALL PREVENTION IN THE ELDERLY
Kamiar Aminian
Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

K-5-2 USE OF A HOME TELECARE SYSTEM AND AMBULATORY MONITOR FOR MOVEMENT CLASSIFICATION AND ASSESSMENT OF FALLS RISK IN THE ELDERLY
Nigel Lovell
University of New South Wales, Sydney, Australia

Free papers (9:20-10:20; 5*12')

O-5-1 CHARACTERIZATION OF DYNAMIC PATTERNS OF POSTURAL SWAY USING ACCELEROMETRY
Lamoth CJC
Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands

O-5-2 AUTOMATED QUANTIFICATION OF MISSTEPS AND NEAR FALLS: ALGORITHM DEVELOPMENT AND PRELIMINARY RESULTS
Hausdorff JM[1,2,3]
[1]Laboratory for Gait & Neurodynamics & Movement Disorders Unit, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel, [2]Dept Physical Therapy, Sackler School of Medicine, Tel-Aviv University, Tel-Aviv, Isarel, [3]Division on Aging, Harvard Medical School, Boston, MA, USA

O-5-3 A FALL DETECTOR INCORPORATED INTO A CUSTOM VEST FOR THE ELDERLY
Bourke AK[1,3]
[1] Department of Electronic and Computer Engineering, University of Limerick, Limerick, Ireland, [3] NCBES, National University of Ireland, Galway, Ireland

O-5-4 LONGITUDINAL BIOMARKERS OF STANCE POSTURE AND GET-UP-AND-GO PARAMETERS IN PARKINSON'S DISEASE
Horak FB
Neurological Sciences Institute and Dept. Neurology, Oregon Health and Science University, Portland, Oregon, USA

O-5-5 THE USE OF WEARABLE INERTIAL DEVICES TO DETECT POSTURAL CHANGES IN EARLY PARKINSON'S DISEASE
Chiari L
Biomedical Engineering Unit, Department of Electronics, Computer Science & Systems, University of Bologna, Italy

Coffee break & poster presentations Part II (10:20-11:00)

Friday May 23

Session 6: Ergonomics and occupational health (11:00-12:25)

Chairs: Alex Burdorf & Masaaki Makikawa

Invited speaker (11:00-11:25)

K-6-1 STRATEGIES FOR ASSESSMENT OF POSTURE AND MOVEMENT AT THE WORKPLACE
Alex Burdorf
Erasmus University Medical Center Rotterdam, the Netherlands

Free papers (11:25-12:25; 4*15')

O-6-1 VALIDATION AND APPLICATION OF INCLINOMETERS (TRIAXIAL ACCELEROMETERS) FOR MEASURING POSTURES AND MOVEMENTS AT THE WORKPLACE
Hansson G-Å
Occupational and Environmental Medicine, University Hospital, Lund, Sweden

O-6-2 DIRECT MEASURES FOR EXPOSURE ASSESSMENT OF MSD PHYSICAL RISK FACTORS FOR COMPUTER USERS
Dennerlein JT
Harvard School of Public Health, Boston, MA USA

O-6-3 THE ABILITY OF COMPUTER ACTIVITY RECORDINGS TO ESTIMATE MECHANICAL EXPOSURES DURING OFFICE WORK
Richter JM
Department of Neuroscience, Erasmus MC, Rotterdam, the Netherlands

O-6-4 MYOTEL: ADRESSING MOTOR BEHAVIOR IN NECK SHOULDER PAIN BY ASSESSING AND FEEDBACK SEMG IN THE DAILY (WORK) ENVIRONMENT
Vollenbroek-Hutten MMR
Roessingh Research and Development, Enschede, The Netherlands

Lunch (12:25-14:00)

Workshop session W-3 (12:30-13:55)

Penn Room I

W-3-1 MCROBERTS: GAIT VARIABILITY AND RISK OF FALLING (12:30 – 13:10)

W-3-2 AMBULATORY MONITORING OF PHYSICAL ACTIVITY AND MOVEMENT: THE ROTTERDAM STORY (13:15 – 13:55)

Friday May 23

Session 7: Data processing & analysis (14:00-15:25)

Chairs: Malcolm Granat & Andrea Giordano

Invited speakers (14:10-14:30)

K-7-1 LONG TERM FREE LIVING PHYSICAL ACTIVITY DATA: WHAT DO WE DO WITH IT?
Malcolm Granat
School of Health & Social Care, Glasgow Caledonian University, Glasgow, UK

Free papers (14:30:15:25; 5*11')

O-7-1 A COMPARISON OF DIFFERENT FEATURE GENERATION METHODS IN ACTIVITY CLASSIFICATION
Goulermas JY
Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, UK

O-7-2 ACTIVITY MONITORING IN TRANSFEMORAL AMPUTEES: ADDED VALUE OF POPULATION-SPECIFIC SETTINGS
Giordano A
Bioengineering Service, 'Salvatore Maugeri' Foundation, Clinica del Lavoro e della Riabilitazione, IRCCS, Veruno, Italy

O-7-3 GAIT ASSESSMENT SYSTEM OF THE ELDERLY USING PORTABLE ACCELERATION MONITOR DEVICE
Makikawa M
Dept. of Robotics, Faculty of Engineering and Science, Ritsumeikan Univ., Kusatsu, Japan

O-7-4 CONTINUOUS RECOGNITION OF DAILY PHYSICAL ACTIVITIES USING A SINGLE TRIAXIAL ACCELEROMETER
Yin B
Philips Research, Biomedical Sensor Systems, Eindhoven, The Netherlands

O-7-5 IMPROVED ESTIMATION OF STARTING TIMES OF HUMAN ACTIVITIES USING HIDDEN MARKOV MODELING BASED ACTIVITY CLASSIFICATION?
Wassink RGV[12]
[1]Roessingh Res. & Dev., Enschede, The Netherlands, [2]Biomedical Signals & Systems, University of Twente, Enschede, The Netherlands

Coffee break & poster presentations (Part II) (15:25-16:05)

Friday May 23

Session 8: Energy expenditure (16:05-17:30)

Chairs: Klaas W. Westerterp & Søren Brage

Invited speaker (16:05-16:30)

K-8-1 ISSUES AND ADVANCES IN AMBULATORY MEASUREMENT OF ENERGY EXPENDITURE
Søren Brage
Institute of Metabolic Science, Cambridge, UK

Free papers (16:30-17:30; 5*12')

O-8-1 RESTING HEART RATE IMPROVES ENERGY EXPENDITURE PREDICTION FROM ACCELEROMETER COUNTS
Plasqui G
Maastricht University, The Netherlands

O-8-2 PHYSICAL ACTIVITY ENERGY EXPENDITURE OF SEDENTARY ADULTS VIA HEART RATE, ACCELEROMETRY AND A BRANCHED ALGORITHM
Browning RC
Center for Human Nutrition, University of Colorado, Denver, USA

O-8-3 VALIDATION OF SENSEWEAR ARMBAND DURING WHEELCHAIR PROPULSION
Wouda MF
Sunnaas Rehabilitation Hospital, Oslo, Norway

O-8-4 VALIDITY OF A SEISMIC ACCELEROMETER FOR ESTIMATING ENERGY EXPENDITURE UNDER SEDENTARY CONDITIONS
van Hees VT[1,2,3]
[1] Human Biology, University Maastricht, [2] Human Movement Sciences, VU University Amsterdam, [3]McRoberts B.V., The Hague

O-8-5 VALIDATION OF THE SENSEWEAR PRO ARMBAND ALGORITHMS IN CHILDREN
Calabró MA
Iowa State University, Ames, IA, USA

Boat Tour and Conference Dinner (19:00)

Saturday May 24

Session 9: Remote monitoring (8:30-10:10)

Chairs: Hermie Hermens & Nigel Lovell

Invited speakers (8:30-9:20; 2*25')

K-9-1 TOWARDS MONITORING MOTOR RECOVERY IN SUBJECTS POST STROKE VIA WEARABLE SENSING TECHNOLOGY
Paolo Bonato
Spaulding Rehabilitation Hospital/Harvard Medical School, Boston, USA

K-9-2 TOWARDS REMOTE MONITORING AND REMOTELY SUPERVISED TRAINING
Hermie Hermens
Roessingh R&D, the Netherlands

Free papers (9:20-10:00; 3*13')

O-9-1 COMBINED ACTIVITY MONITOR AND WEB-SERVICE TECHNOLOGY FOR IMPROVING PHYSICAL ACTIVITY
Goris AHC
Philips Research, Care & Health Applications, Eindhoven, The Netherlands

O-9-2 ADDING EMBEDDED INTELLIGENCE TO A REALTIME WEARABLE REMOTE MONITORING SYSTEM: EXPERIENCES WITH MAGIC
Meriggi P
Polo Tecnologico – Biomedical Technology Department, Fondazione Don Carlo Gnocchi Onlus, Milano, Italy

O-9-3 SENSORPHONE: WIRELESS MONITORING VIA THE MOBILE TELEPHONE
Vlaskamp FJM
Vilans, Hoensbroek, The Netherlands

Coffee break (10:00-10:40)

Saturday May 24

Session 10: Psychology & miscellaneous (10:40 – 11:45)

Chairs: Uli Ebner-Priemer & Joke Tulen

Invited speaker (10:40-11:05)

K-10-1 AMBULATORY ACTIVITY MONITORING IN PSYCHOLOGY AND PSYCHIATRY
Uli Ebner-Priemer
Central Institute of Mental Health, Mannheim, Germany

Free papers (11:05-11:45; 3*13)

O-10-1 ACCELEROMETRY TO ASSESS MOTOR ACTIVITY DURING SLEEP IN ADULTS WITH ADHD OR TOURETTE'S DISORDER
Tulen JHM
Department of Psychiatry, Erasmus MC, Rotterdam, The Netherlands

O-10-2 TIME ASPECTS OF COMPUTER USE ACROSS ONE YEAR EXPOSURE: METRICS AND EMPIRICAL FINDINGS
Slijper HP
Department of Neuroscience, Erasmus MC, Rotterdam, The Netherlands

O-10-3 DIFFERENT ACTIVITY SENSORS FOR SLEEP DETECTION
Virkkala J[1,2]
[1]Sleep Laboratory, Brain Work Research Center, Finnish Institute of Occupational Health, Helsinki, Finland, [2]Department of Clinical Neurophysiology, Pirkanmaa Hospital District, Tampere, Finland

Saturday May 24

Session 11: Panel discussion: “What's next?” & Conference closing (11:45-13:00)

Chairs: Henk J. Stam & Hans (J) B.J. Bussmann

Lunch (13:00-14:00)

Overview poster presentations part I

Presentation Thursday May 22

Topic 1: Physical activity: measurement & general issues

P-1-1 MONITORING MOBILITY RELATED ACTIVITIES IN OLDER PEOPLE; SYSTEMATIC REVIEW
de Bruin ED[1,2]
[1] Institute of Human Movement Sciences and Sport, D-Biology, ETH Zurich, Switzerland, [2] Department of Rheumatology and Institute of Physical Medicine, University Hospital Zurich, Zurich, Switzerland

P-1-2 MONITORING OF PHYSICAL ACTIVITY USING ACCELEROMETERS AND PEDOMETERS AND POSSIBILITY TO CHANGE PHYSICAL ACTIVITY BEHAVIOR USING INDIVIDUALIZED FEEDBACK
Sigmund E
Center for Kinanthropology Research, Palacky University, Olomouc, Czech Republic

P-1-3 DIURNAL MOTOR ACTIVITY EVALUATED BY WRIST AND BACK ACTIGRAPHY: A WITHIN SUBJECT COMPARISON OF RAW SIGNALS
Raymann RJEM
TNO Defence, Security and Safety, Soesterberg, the Netherlands

P-1-4 ASSESSMENT OF PHYSICAL ACTIVITY IN DAILY LIFE IN MUSCULOSKELETAL PAIN: A REVIEW OF THE LITERATURE
Verbunt JA[1,2]
[1] Rehabilitation Foundation Limburg, Hoensbroek, [2]Maastricht University, Maastricht, the Netherlands

P-1-5 ACTIVITY TYPE AS A DETERMINANT OF ACTIVITY LEVEL
Bonomi AG[1,2]
Philips Research, Care&Health Applications, Eindhoven, the Netherlands, [2]Maastricht University, Department of Human Biology, Maastricht, the Netherlands

P-1-6 POTENTIAL OF MOBILE MONITORING OF PHYSICAL ACTIVITY TO IMPROVE HUMAN HEALTH: RESULTS OF AN INTERNATIONAL EXPERT PANEL WORKSHOP
Daumer M[1,2]
[1]Sylvia Lawry Centre for Multiple Sclerosis Research, Munich, Germany, [2]Trium Analysis Online Gmbh, Munich, Germany

P-1-7 AMBULATORY MOVEMENT MONITOR REQUIREMENTS
McNames J[1,2]
[1]APDM, Inc., Portland, Oregon, USA, [2]Biomedical Signal Processing Laboratory, Portland State University, Portland, Oregon, USA

P-1-8 WHAT DOES THE "LEFT" HAND TELL US?
Papastefanou G
Gesis Leibniz Institute for Social Science, Mannheim, Germany

P-1-9 INTERINSTRUMENT RELIABILITY OF RT3 ACCELEROMETER AT DIFFERENT LEVELS OF PHYSICAL ACTIVITY IN CHILDREN AND ADOLESCENTS
Vanhelst J[1,2]
[1]EA 3925, IFR 114, IMPRT, Hôpital Jeanne de Flandre, et Université Lille 2 Droit et Santé, France, [2]Laboratoire R.E.L.A.C.S, EA 4111, Université du Littoral Côte d'Opale, Dunkerque, France

P-1-10 A TOOL FOR GEOSPATIAL ANALYSIS OF PHYSICAL ACTIVITY: PHYSICAL ACTIVITY LOCATION MEASUREMENT SYSTEM (PALMS)
Patrick K
Department of Family and Preventive Medicine, University of California, San Diego, CA, USA

P-1-11 PHYSICAL ACTIVITY RECOGNITION IN CHILDREN BY TWO UNI-AXIAL ACCELEROMETERS

Ruch N
Swiss Federal Institute of Sport SFIS, Magglingen, Switzerland

P-1-12 TEST-RETEST RELIABILITY OF THREE DAY ACTIVITY MONITORING IN PARTICIPANTS WITH STROKE

Mudge S
Department of Surgery, University of Auckland, Auckland, New Zealand

P-1-13 TEST-RETEST RELIABILITY OF THE STEPWATCH ACTIVITY MONITOR IN HEALTHY PARTICIPANTS

Mudge S
Department of Surgery, University of Auckland, Auckland, New Zealand

P-1-14 RELATIONSHIP OF THE ACTICAL TO THE STEPWATCH ACTIVITY MONITOR IN HEALTHY PARTICIPANTS

Mudge S
Department of Surgery, University of Auckland, Auckland, New Zealand

P-1-15 MONITORING OF DAILY ACTIVITY LEVELS AND PROSTHETIC WEARING TIMES IN TRANS-TIBIAL AMPUTEES USING SUCTION SOCKETS

Tang KT
University of Strathclyde, Glasgow, UK

P-1-16 AN INVESTIGATION OF THE CONSTRUCT VALIDITY OF FREE-LIVING PHYSICAL ACTIVITY AS A MARKER OF FUNCTIONAL ABILITY IN PEOPLE WITH CHRONIC LOW BACK PAIN

Granat M
School of Health and Social Care, Glasgow Caledonian University, Glasgow, UK, G4 OBA

P-1-17 SLEEP SCORED WRIST AND BACK ACTIGRAPHY: A COMPARISON

Raymann RJEM
TNO Defence, Security and Safety, Soesterberg, the Netherlands

P-1-18 RECOGNITION OF MILITARY SPECIFIC ACTIVITY CLASSES USING HEARTRATE- AND ACCELERATION MONITORS

Wyss T
Swiss Federal Institute of Sports Magglingen, Switzerland

P-1-19 VALIDITY OF A BODY WORN SENSOR SYSTEM AS A MEASURE OF STEP COUNT DURING WALKING IN FRAIL OLDER ADULTS

Stene G[1,2]
[1]Dept. of Neuroscience, Norwegian University of Science and Technology, Trondheim Norway, [2]Dept. of Cancer Research and Molecular Medicine, Norwegian University of Science and Technology, Trondheim, Norway

P-1-21 DEVELOPMENT OF A LOCATION AND MOVEMENT MONITORING SYSTEM TO QUANTIFY PHYSICAL ACTIVITY

MacLellan G
School of Health and Social Care, Glasgow Caledonian University, Glasgow, UK

P-1-22 ACTIVITY RECOGNITION USING ELECTROOCULOGRAPHY: READING WHILE SITTING, STANDING AND WALKING

Ward JA
Embedded Interactive Systems, Computing Department, University of Lancaster, Lancaster, UK

P-1-23 EVALUATION OF A LABORATORY TO RECREATE OUTDOOR ENVIRONMENTS INDOORS

Childs CR
Accessibility Research Group, Department of Civil, Environmental and Geomatic Engineering, University College, London, UK

P-1-24 APPLICATION OF THE SPEED SENSOR ON PERCIVED DISTANCE FOR THE SIGHT AND HEARING HANDICAPS

Sato T
Lab.Human Factors, Jissen Women's University, Tokyo, Japan

P-1-25 FROM THE SENSORS TO FEATURES: WHAT OPTIMIZES THE RECOGNITION OF PHYSICAL ACTIVITY?

Rumo M
Physical Activity and Health Branch, Swiss Federal Institute of Sports, Magglingen, Switzerland

P-1-26 MULTI-SENSOR PLATTFORM FOR ACTIVITY MEASUREMENTS

Diemer R
Institute for Realtime Computersystems, Technische Universität München, Munich, Germany

P-1-27 RECOGNITION OF DAILY LIFE ACTIVITIES - A SENSOR NETWORK PROSPECT

Sorel A
M2S Laboratory, University of Rennes 2 - ENS Cachan, Avenue Charles Tillon - 35044 Rennes, France

P-1-28 DETECTION OF GAIT AND POSTURES IN OLDER ADULTS AND PATIENTS WITH PARKINSON'S DISEASE: ACCURACY OF AN ACCELEROMETRY BASED METHOD

Dijkstra B
Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen

P-1-29 GAIT & POSTURE DETECTION IN DAILY LIFE BASED ON ONE 3D ACCELEROMETER

Van Lummel RC
McRoberts, The Hague, the Netherlands

Topic 3: Gait and 3D kinematic analysis outside the lab

P-3-1
RELIABILITY OF AMBULATORY MONITORING TO EVALUATE GAIT CHARACTERISTICS OF DIABETIC PATIENTS

Allet L[1,2]
[1]University Hospital, Geneva, Switzerland, [2]Department of Epidemiology University and Caphri research school, Maastricht, the Netherlands

P-3-2 REAL-TIME GAIT EVENT DETECTION USING A BIAXIAL ACCELEROMETER

Rodriguez-Uria J
Multisensor Systems Research Unit, Department of Electrical Engineering, University of Oviedo

P-3-3
THE VALIDITY AND FEASIBILITY OF THE TELEMETRY MONITORING SYSTEM FOR POSTURAL AND LOCOMOTION PATTERNS

Lee HK
Department of Biomedical Engineering; Yonsei University, Wonju, Gangwondo, Republic of Korea

P-3-4 THE DEVELOPMENT OF A CLINICAL GAIT ANALYSIS SYSTEM

O'Donovan K
Digital Health Group, Intel Corporation

P-3-5 RELATIONSHIP BETWEEN ACCELEROMETRIC SIGNALS FROM BODY-MOUNTED SENSORS AND CENTER OF PRESSURE FROM A FORCE PLATE DURING QUIET STANCE

Mancini M
Biomedical Engineering Unit, Department of Electronics, Computer Science & Systems, University of Bologna, Italy

P-3-6 VALIDATION OF AN AMBULATORY GAIT MONITOR IN PATIENTS WITH PARKINSON'S DISEASE

Speelman AD
Department of Neurology and Parkinson Center Nijmegen (ParC), the Netherlands

P-3-7 VALIDATION OF AN ACCELERATION BASED GAIT TEST TO FOLLOW UP TKA PATIENTS

Senden R[1,2]
[1]University Maastricht, Faculty of Health Medicine and life sciences, Maastricht, the Netherlands,[2]Atrium Medical Center, Dept Orthopaedics & Traumatology, Heerlen, The Netherlands

P-3-8 GAIT FUNCTION OF TOTAL HIP ARTHROPLASTY PATIENTS: ANALYSIS OF PREFERRED SPEED WALKING ALONE IS NOT ENOUGH.

Van den Akker-Scheek I
Department of Orthopaedics, University Medical Center Groningen, University of Groningen, the Netherlands

P-3-9 RELIABILITY OF A BODY-FIXED SENSOR GAIT ANALYSIS PROTOCOL FOR EVALUATING GAIT FUNCTION IN PATIENTS WITH HIP OSTEOARTHRITIS

Reininga IHF
Department of Orthopaedics, University Medical Center Groningen, University of Groningen, The Netherlands

P-3-10 CENTER OF PRESSURE DYNAMICS IN PARKINSON'S DISEASE PATIENTS WITH FREEZING OF GAIT: FAILED POSTURAL ADJUSTMENTS?

Hausdorff JM[1,2,3]
[1]Movement Disorders Unit, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel ; [2]Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel; [3]Harvard Medical School, Boston, MA, USA

P-3-11 LONG-RANGE CORRELATIONS IN GAIT DATA OF COPD PATIENTS

Annegarn J
Department of Human Movement Sciences, Faculty of Health Medicine and Life Sciences, Nutrition and Toxicology Research Institute Maastricht (NUTRIM), Maastricht University, Maastricht, The Netherlands

P-3-12 NORMAL GAIT ANALYSIS USING AN ORIGINAL ANALYZING STRAP

Nica A
Department of Physical and Rehabilitation Medicine, University of Medicine "Carol Davila" Bucharest, Romania

P-3-13 FEASIBILITY AND VALIDITY OF THE ACTIVITY MONITOR IN CHILDREN WITH CP

Horemans HLD
Department of Rehabilitation Medicine, Erasmus MC, University Medical Center Rotterdam, Rotterdam, the Netherlands

P-3-14 ESTIMATION OF TRAJECTORY OF HUMAN CENTER OF GRAVITY DURING GAIT USING A TRI-AXIAL ACCELEROMETER AND THREE GYRO SENSORS

Komoto K
Graduate School of Science and Engineering, Ritsumeikan University, Kusatsu, Japan

P-3-15 OUTDOOR GAIT ANALYSIS USING INERTIAL AND MAGNETIC SENSORS: PART 1 - PROTOCOL DESCRIPTION

Garofalo P
DEIS, University of Bologna, Italy

P-3-16 SENSING DYNAMIC INTERACTION WITH THE ENVIRONMENT

Veltink PH
University of Twente, Institute for BioMedical Technology (BMTI), Enschede, the Netherlands

P-3-17 INERTIAL-BASED APPROACH FOR 3D EVALUATION OF ACL-DEFICIENT KNEE JOINT DURING GAIT

Aminian K
Ecole Polytechnique Fédérale de Lausanne (EPFL-LMAM), Lausanne, Switzerland

P-3-18 ANTICIPATORY SWING FOOT KINEMATICS DURING BIPEDAL LOCOMOTION

Block EW
Department of Clinical Neurosciences and Hotchkiss Brain Institute, University of Calgary, Canada

Overview poster presentations part II

Presentation Friday May 23

Topic 2: Medical & public health applications I

P-2-1 THE METABOLIC COST OF TWO AMPUTEES WALKING OUTDOOR WITH THE 'POWER KNEE' PROSTHESIS
Cutti AG
INAIL Prosthesis Centre, Research Area, Vigorso di Budrio (Bo), Italy

P-2-2 PHYSICAL ACTIVITY IS RELATED TO HEALTH-RELATED QUALITY OF LIFE IN ADOLESCENTS AND YOUNG ADULTS WITH SPINA BIFIDA
Buffart LM
Department of Rehabilitation Medicine, Erasmus MC, University medical center, Rotterdam, the Netherlands

P-2-3 AMBULATORY ASSESSMENT OF THE MOTOR STATE IN PARKINSON'S DISEASE IN REAL DAILY LIFE
Keijsers NLW[1,2]
[1]Sint-Maartenskliniek, Research Development & Education, Nijmegen, The Netherlands, [2]Department of Biophysics, Institute for Neuroscience, Radboud University, Nijmegen, the Netherlands

P-2-4 ACCELEROMETERY-BASED ACTIVITY MONITORING FOR UPPER LIMB PROSTHESIS EVALUATION
Kenney LPJ
Centre for Rehabilitation and Human Performance Research, University of Salford, Salford, UK

P-2-5 UPPER-LIMB ACTIVITY PROFILE OF STROKE PATIENTS
Vega-Gonzalez A
Department of Physiology, Faculty of Medicine, National Autonomous University of Mexico, Mexico City 04510, MEXICO

P-2-6 MULTI-DAY PHYSICAL ACTIVITY MONITORING IN PEOPLE WITH CEREBRAL PALSY
Tang KT
University of Strathclyde, Glasgow, UK

P-2-7 OBJECTIVE ASSESSMENT OF MOBILITY OF THE SPINAL CORD INJURED IN A FREE-LIVING ENVIRONMENT
Dall PM
School of Health & Social Care, Glasgow Caledonian University, Glasgow, UK

P-2-8 MEASURING PHYSICAL ACTIVITY IN AMBULATORY CHILDREN WITH SPINA BIFIDA: FROM DIARY TO PHYSICAL ACTIVITY MONITOR
de Groot JF
[1]Department of Pediatric Physical Therapy and Exercise Physiology, University Medical Center Utrecht, the Netherlands. [2]Research Group Lifestyle and Health, University of Applied Sciences Utrecht, the Netherlands

P-2-9 FREQUENCY OF THE SIT TO STAND TASK IN FREE LIVING ADULTS
Dall PM
School of Health & Social Care, Glasgow Caledonian University, Glasgow, UK

P-2-10 PHYSICAL ACTIVITY PATTERNS OF PATIENTS AFTER ROTATIONPLASTY DUE TO MALIGNANT BONE TUMORS
Müller C
Motion Analysis Lab, Orthopaedic Department, University Hospital Muenster, Germany

P-2-11 ACTIVITY LEVEL IN PATIENTS WITH LUMBAR SPINAL STENOSIS BEFORE AND AFTER DECOMPRESSIVE SURGERY
Winter C
Department of Orthopedics, University Hospital of Muenster, Germany

P-2-12 DAILY PHYSICAL ACTIVITIES OF PATIENTS WITH CHRONIC LOW BACK PAIN, ASSESSED WITH ACCELEROMETRY

van Weering MGH
Roessingh Research and Development, Enschede, the Netherlands

P-2-13 HOW AN AMBULATORY MONITORING SYSTEM MIGHT DESCRIBE FRAILTY IN ELDERLY PERSONS

Martin E
Service of Geriatric Medicine, CHUV & CUTR Sylvana, 1066 Epalinges, Switzerland

P-2-14 EVERYDAY PHYSICAL ACTIVITY IN ADULTS WITH BILATERAL SPASTIC CEREBRAL PALSY

van den Berg-Emons HJG
Department of Rehabilitation Medicine, Erasmus University Medical Center, Rotterdam, The Netherlands

P-2-15 EFFECT OF REHABILITATION ON DAILY PHYSICAL ACTIVITY, PHYSICAL FITNESS AND FATIGUE IN LIVER TRANSPLANT RECIPIENTS

van Ginneken BTJ
Department of Rehabilitation Medicine, Erasmus University Medical Center, Rotterdam, the Netherlands

P-2-16 EFFECT OF BOTULINUM TOXIN TREATMENT ON ACTIVITY LEVEL OF PATIENTS WITH SPASTIC HEMIPARESIS AFTER STROKE

Jelsma NG
Heliomare Rehabilitation Centre, Wijk aan Zee, The Netherlands

P-2-18 PILOT STUDY- PHYSIOLOGICAL DATA RECORDED REMOTELY FROM INDIVIDUALS WITH SPINAL CORD INJURY (SCI) DURING NORMAL DAILY ACTIVITIES

Nunn A[1,2]
[1]Victorian Spinal Cord Service, Austin Health, Heidelberg, Vic., Australia, [2]Monash University Centre for Biomedical Engineering, Clayton, Vic., Australia

P-2-19 ORTHOPAEDIC OUTCOME ASSESSMENT WITH ACCELEROMETER ASSESSED STAIR CLIMBING

Grimm G
AHORSE Foundation, Atrium Medical Center Orthopaedic Research & Education, Heerlen, the Netherlands

P-2-20 EFFECT OF C-LEG ON LOCOMOTOR CAPACITY AND PERFORMANCE IN TRANSFEMORAL AMPUTEE

Paysant J
Institut Régional de médecine physique et de Réadaptation, Nancy, France

P-2-21 THE ASSOCIATIONS BETWEEN FUNCTION, CAPACITY AND PERFORMANCE OF THE UPPER-LIMBS FOLLOWING STROKE

Michielsen ME
Department of Rehabilitation Medicine, Erasmus Medical Center, Rotterdam, the Netherlands

Topic 4: Medical & public health applications II

P-4-1 THE HABITUAL PHYSICAL ACTIVITY OF WARD-BASED AND DAY-HOSPITAL ELDERLY PATIENTS

Grant PM
School of Health & Social Care, Glasgow Caledonian University, Glasgow, UK

P-4-2 MONITORING OF THE BODY CORE TEMPERATURE WHILE DOING SPORT

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P-4-3 PHYSICAL ACTIVITY PATTERNS IN NORMAL WEIGHT AND OBESE ADULTS USING ACTIVPAL PHYSICAL ACTIVITY MONITOR

Tully MA

Health and Rehabilitation Sciences Research Institute, University of Ulster, Northern Ireland

P-4-4 THE ASSOCIATION BETWEEN SKIN TEMPERATURES AND CARDIAC AUTONOMIC RESPONSE IN YOUNG HEALTHY SUBJECTS
Li Y
iDAPT Technology R&D Team, Toronto Rehabilitation Institute, Toronto, Canada

P-4-5 PHYSICAL ACTIVITY MONITORING IN AFRICAN SUB-SAHARAN RURAL AREAS
Aminian K
Laboratory of Movement Analysis and Measurement, Ecole Polytechnique Federale de Lausanne, Switzerland

P-4-6 BODY COMPOSITION IS ASSOCIATED WITH HABITUAL PHYSICAL ACTIVITY IN DAILY LIFE AS MEASURED USING A TRI-AXIAL ACCELEROMETER
den Hoed M
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P-4-7 MARKERS FOR MITOCHONDRIAL DENSITY AND FUNCTION CORRELATE POSITIVELY WITH HABITUAL PHYSICAL ACTIVITY IN DAILY LIFE
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P-4-8 DIFFERENCES IN THE DYNAMICS OF TRUNK ANGULAR VELOCITY DURING DAILY LIFE WALKING AS A MARKER OF PHYSICAL FRAILTY
Aminian K
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P-4-9 MONITORING OF PHYSICAL ACTIVITY AND AUTONOMOUS NERVOUS SYSTEM FUNCTIONS IN PERSONS WITH MUSCULOSKELETAL DISORDERS
Lyskov E
University of Gevle, Gevle, Sweden

Topic 5: Balance and falls

P-5-1 IS TURNING DURING WALKING AN AUTOMATED MOTOR TASK, OR IS IT A COMPLEX COGNITIVE ACTION?
Hausdorff JM[1-3]
[1]Movement Disorders Unit & Parkinson Center, Department of Neurology, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel, [2]Department of Physical Therapy, Sackler Faculty of Medicine, Tel-Aviv, Israel, [3]Division on Aging, Harvard Medical School, Boston, USA

P-5-2 AMBULATORY MONITORING OF PLANTAR PRESSURE FOR DETECTING DIFFICULTY OF WALKING ON ICE
Dutta T[1,2]
[1]University of Toronto, Toronto, Canada, [2]Toronto Rehabilitation Institute, Toronto, Canada

P-5-3 WEARABLE INERTIAL SENSORS DETECT ANTICIPATORY POSTURAL ADJUSTMENTS PRIOR TO STEP INITIATION IN EARLY PARKINSON'S DISEASE
Mancini M[1,2]
[1]Biomedical Engineering Unit, Department of Electronics, Computer Science & Systems, University of Bologna, Italy, [2]Neurological Sciences Institute, Oregon Health & Science University, Beaverton, OR, USA

P-5-4 WIRELESS ACCELEROMETRY FOR MOTOR CONTROL QUANTIFICATION
Giordano A
Bioengineering Service, 'Salvatore Maugeri' Foundation, Clinica del Lavoro e della Riabilitazione, IRCCS, Veruno, Italy

P-5-5 BALANCE SKILL STATUS OF FOUR TO SIX YEAR OLD PRE-SCHOOL CHILDREN
Cools W
Department of movement education and sport training, Faculty of Physical Education and Physiotherapy (LK/BETR) Vrije Universiteit Brussel, Belgium

P-5-7 FOOT-WEAR DEPEND ACCELERATION MEASUREMENTS OF A FALL PREVENTION SYSTEM BASED ON A WEARABLE SENSOR

Endo H
Information Networking Lab, Graduate School of Engineering, Seikei University, Musashino, Tokyo, Japan

P-5-8 CLINICAL EVALUATION OF THE VIBROTACTILE LABYRINTHINE SUBSTITUTION SYSTEM (VLS) FOR PATIENTS WITH SEVERE VESTIBULAR FUNCTION LOSS

Janssen MJA[1,7,8]
[1]Department of Biomedical Engineering, University Hospital Maastricht, the Netherlands, [7]Department of ENT, Division of Balance Disorders, University Hospital Maastricht, the Netherlands, [8]School for Mental Health and Neuroscience, University Maastricht, the Netherlands

P-5-9 THE DISCRIMINATING POWER OF SWAY PARAMETERS IN STANCE TASKS

Janssen MJA[1,2,3]
[1]Department of Biomedical Engineering, University Hospital Maastricht, the Netherlands,
[2]Department of ENT, Division of Balance Disorders, University Hospital Maastricht, the Netherlands,
[3]School for Mental Health and Neuroscience, University Maastricht, the Netherlands

Topic 6: Ergonomics and Occupational Health

P-6-1 MOUSE AND KEYBOARD INTERACTIONS IN COMPUTER BEHAVIOR

Slijper HP
Department of Neuroscience, Erasmus MC, Rotterdam, the Netherlands

P-6-2 PIMEX, AN APPLICATION WHICH MAKES PHYSICAL LOAD VISIBLE

Beurskens-Comuth PAWV
Arbo Unie, Business Unit South-east, Venlo, the Netherlands

Topic 7: Data processing & analysis

P-7-1 A MODEL-BASED APPROACH FOR AMBULATORY MEASUREMENT OF MOTOR SYMPTOMS IN PARKINSON'S DISEASE

Le Cavorzin P[1,2]
[1] Universitary Research Unit "Basal Ganglia and Behaviour" (URU 425), University of Rennes 1, Rennes, France, [2] Rennes-Beaulieu Rehabilitation Institute, Rennes, France

P-7-2 A METHOD FOR PERSONAL POSITIONING AND ACTIVITY MONITORING IN 3D INDOOR UTILIZING WEARABLE SENSORS AND MAP KNOWLEDGE

Ohtaki Y
[1] Graduate School of Medicine and Engineering, University of Yamanashi, Kofu, Japan

P-7-3 AUTOMATIC ACTIVITY RECOGNITION FOR TECHNOLOGY-SUPPORTED STROKE REHABILITATION

Winter S
Philips Research Europe, 52066 Aachen, Germany

Topic 8: Energy expenditure

P-8-1 ACCELEROMETER BASED DETECTION OF PHYSICAL ACTIVITY IN CHILDREN AND ADULTS

Terwee CB
EMGO Institute, VU University Medical Center, Amsterdam, the Netherlands

P-8-2 DOES ACCELEROMETER PLACEMENT AFFECT METABOLIC ENERGY EXPENDITURE ESTIMATION IN NORMAL WEIGHT AND OBESE SUBJECTS?

Kenney LPJ
Centre for Rehabilitation and Human Performance Research, University of Salford, Salford, UK

P-8-3 COMPARISON OF COMBINED PHYSICAL ACTIVITY MEASUREMENT DEVICES: A BRIEF REVIEW

Moy KL
University of California, San Diego, Department of Family and Preventive Medicine, San Diego, USA

P-8-4 PHYSIOLOGIC RELEVANCE OF OPTIMIZED BRANCHED ALGORITHM ANALYSES IN ESTIMATING ENERGY EXPENDITURE

Browning RC
Center for Human Nutrition, University of Colorado, Denver, USA

P-8-5 ALTERNATIVE APPROACH FOR PRESENTING DATA OF ENERGY COST OF WALKING

Brehm MA[1,2]
[1] VU University Medical Center, Amsterdam, The Netherlands, [2] MOVE Institute for Human Movement Research, Amsterdam, The Netherlands

Topic 9: Remote monitoring

P-9-1 COMPARISON OF SENSOR CONFIGURATION IN TELE-HEALTH APPLICATIONS ON CLASSIFICATION OF BEHAVIOR

Keijsers NLW
St. Maartenskliniek, Research, Development & Education, Nijmegen, the Netherlands

Topic 10: Psychology & miscellaneous

P-10-1
WRIST-ACTIGRAPHY TO ASSESS DISTURBED REST-ACTIVITY PATTERNS IN DELIRIUM AFTER CARDIAC SURGERY

Tulen JHM
Department of Psychiatry, Erasmus MC, Rotterdam, the Netherlands

Workshops

Wednesday May 21

Workshop session W-1 (Mees Auditorium)

W-1-1 AMBULATORY MONITORING OF PHYSICAL ACTIVITY AND MOVEMENT: THE ROTTERDAM STORY (15:00-16:00)
Chair: Rita van den Berg - Emons

The Department of Rehabilitation of Erasmus University Medical Centre has activity monitoring as research focus since 1992. The central topic is the "Activity Monitor", an accelerometry-based instrument that allows objective and long-term measurement of body postures and motions during normal daily life. The AM has been used in many patient populations (e.g. heart failure, total hip/knee surgery, Cerebral Palsy, Spinal Cord Injury, amputation, meningomyelocele, stroke, chronic pain, liver transplantation, children with Prader Willi Syndrome). Further development and validation focused on measuring arm-hand usage (CRPS-1, stroke), measuring physical (cardiovascular) strain during daily life, and on quantification of movement patterns (walking, sit-to-stand transition). In this workshop the characteristics and possibilities of the Activity Monitor will be demonstrated, illustrated by examples from own research.

W-1-2 FALL DETECTION NETWORK (16:00-17:30)
Chairs: Kamiar Aminian & Wiebren Zijlstra

Detection of falls in real life is of utmost importance for initiating immediate care services and for the further study of factors underlying these falls. Algorithms for fall detection are generally devised with simulated falls and at present few data are available that describe real life fall patterns. Recording real fall data is difficult and having a common database should be helpful for researchers working on real life fall patterns. This workshop aims to discuss issues regarding fall detection and possibilities to create a network in scientific community for archiving real fall patterns.

Thursday May 22

Workshop session W-2 (Penn Room I)

W-2-1 PAM: PAM ACTIVITY MONITOR (12:30 – 13:10)
This workshop will tell you everything about the Pam device: its fundamentals, why its technology is unique, validations, practical use in research. The Pam Activity Monitor is a small, light, accurate, versatile and affordable monitoring device that can help you perform studies with larger groups of subjects. We look forward meeting you in our interactive workshop! (Pam is called Kam in the US).
www.pam.com/us/product/ and www.mykamunity.com

W-2-2 ORTHOCARE: THE STEPWATCH ACTIVITY MONITOR (13:15 – 13:55)
This workshop will introduce you to the StepWatch Activity Monitor (SAM), a powerful, unobtrusive and easy-to-use instrument that records the number of strides taken each minute for extended periods of time with greater than 98% accuracy regardless of gait style, gait speed, and body composition. The SAM software analyzes levels and patterns of activity, providing insight into the functional dimensions of ambulatory capacity and behavior. The SAM is used extensively in research and clinical applications worldwide. A bibliography of peer-reviewed literature and a summary of published accuracy results will be available.

Friday May 23

Workshop session W-3 (Penn Room I)

W-3-1 MCROBERTS: GAIT VARIABILITY AND RISK OF FALLING (12:30 – 13:10)
The aim of the workshop is to inform you about the use of accelerometry based methods to analyse gait in order to estimate risk of falling. The topics are:

- Clinical use in the Fall Clinic (Dr. Jos van Campen)
- State of the Art (Dr. Jeff Hausdorff)
- Reproducibility of gait variability in frail elderly (Prof. Dr. Ivan Bautmans)
- Practical demonstration of the DynaPort (McRoberts)

W-3-2 AMBULATORY MONITORING OF PHYSICAL ACTIVITY AND MOVEMENT: THE ROTTERDAM STORY (13:15 – 13:55)
See W-1-1

Keynote Lectures

K-1-1
ASSESSMENT OF PHYSICAL ACTIVITY WITH ACCELEROMETERS

Klaas R. Westerterp
Human Biology, Maastricht University, Maastricht, The Netherlands

Physical activity can be defined as muscular contractions to perform body postures and –movements. Accelerometers are promising tools to assess physical activity in terms of frequency, duration and intensity, under free-living conditions. To test the validity of accelerometers for movement registration, energy expenditure as measured with indirect calorimetry is used as a reference. Thus, the doubly labelled water technique for the measurement of total energy expenditure under free-living conditions has become the gold standard for the validation of accelerometers. However, so far few accelerometers have been tested against doubly labelled water. Inter-individual variation in energy expenditure is mainly a function of differences in body size and physical activity. To evaluate the validity of an accelerometer for movement registration, one has to keep in mind that studies do not always mention the contribution in explained variation of total energy expenditure by accelerometer output, after inclusion of subject characteristics for the estimation of the contribution of body size. Determinants of physical activity, as derived from observational and intervention studies with doubly labelled water validated accelerometers are presented.

Klaas Westerterp is professor of Human Energetics at Maastricht University, where he coordinates the bachelor and master programme Metabolism and Nutrition. Among his present fields of interest in research are energy metabolism and body composition, with special emphasis on observations in daily living conditions using accelerometers and labeled water. He was from 1997 to 2003 a member of the Editorial Board of the British Journal of Nutrition. From 1999 to 2005 he was head of the Department of Human Biology. Currently, he is PhD dean of the Faculty of Health, Medicine and Life Sciences. He is member of the FAO/WHO/UNU Expert group on Human Energy Requirements.

K-1-2

NEW FRONTIERS IN PHYSICAL ACTIVITY ASSESSMENT WITH PATTERN RECOGNITION TECHNOLOGY

Gregory J. Welk
Iowa State University, Ames, USA

Obtaining accurate assessments of physical activity under free-living conditions has proven to be a challenging problem. This session will provide a perspective on future technologies that offer promise for improving the accuracy of physical activity measures. Emphasis is placed on three relatively new devices that utilize pattern-recognition technology to more accurately detect physical activity and improve predictions of energy expenditure (Actiheart, Sensewear armband and the IDEEA monitor). The Actiheart monitor integrates data from an accelerometer and a heart rate monitor and employs branch chain algorithms to provide more accurate estimates of PA. The SenseWear Armband is a multi-channel monitor that integrates data from two accelerometers, two heat related sensors and a galvanic skin response sensor. The the Intelligent Device for Energy Expenditure and Activity (IDEEA) uses a multipoint accelerometer-based neural network to determine body posture allowing more precise determinations of energy expenditure. The presentation will summarize advantages and disadvantages of the different approaches and review recent work examining the validity of these different pattern recognition approaches. Implications for future developments will also be discussed.

Gregory J. Welk is an Associate Professor with the Department of Kinesiology at Iowa State University. Dr. Welk completed his master's degree (MS) at the University of Iowa and his doctoral work (Ph.D.) at Arizona State University. Prior to coming to ISU, Dr. Welk worked at Eastern Michigan University and the Cooper Institute for Aerobics Research. His research interests focus on the assessment and promotion of physical activity in both children and adults. He has published numerous studies on the validation, interpretation or utility of different physical activity assessment techniques including accelerometry-based activity monitors, pedometers and various self-report measures. He also edited a comprehensive book titled '*Physical Activity Assessment for Health Related Research*' that is used as a reference book on the topic of physical activity assessment research. His work on physical activity promotion has been focused on understanding the interacting influences of schools, communities and parenting variables on children's interest and involvement in physical activity. He has been involved in large school based trials aimed at promoting physical activity and has recently focused his work on community-based participatory research through his involvement in the Story County Healthy Lifestyle Taskforce. Professionally, Dr. Welk serves as the Scientific Director of the *FITNESSGRAM* youth fitness program for the Cooper Institute. A major responsibility with this position is to develop and validate assessment and promotion strategies for use in the software program. He is also a co-author of a popular fitness and wellness text known as Concepts of Fitness and Wellness published by McGraw Hill. He is an active member of the American College of Sports Medicine (ACSM), the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD), the Society for Behavior Medicine (SBM), and the Society for Public Health Education (SOPHE).

K-2-1
AMBULATORY ACTIVITY MONITORING: ADDED VALUE IN MEDICINE

Henk J. Stam
Department of Rehabilitation, Erasmus Medical Center Rotterdam, the Netherlands

Activity monitoring has been used in many clinical studies including patients with chronic pain, spinal cord injury, amputation of the leg, spina bifida, heart failure, cerebral palsy, knee or hip arthritis, liver transplantation, Guillain Barré Syndrome, stroke, and CRPS-I. In this presentation a selection of the most relevant findings from a clinical perspective will be presented.

In most studies we found low or moderate relations between actual objective activity and other measurement tools such as performance in a movement laboratory (capacity) or subjective/perceived activity such as questionnaires. Generally the studies on patients confirm that testing in a movement laboratory or with questionnaires cannot be used to determine what patients actually do when they are not supervised and in their own environment. Adding the results of activity monitoring to measurements of capacity and subjective/perceived performance has given us more insight in how and on what level certain interventions and therapies affect a patient.

Henk J. Stam MD PhD FRCP, is a specialist in rehabilitation medicine and Professor at Erasmus University Medical Center, Rotterdam, the Netherlands. He is involved in research activities related to ambulatory activity monitoring since more than 15 years. Henk Stam is past president of the European Society of Physical and Rehabilitation Medicine and editor of the Journal of Rehabilitation Medicine.

K-3-1
ADVANCES IN AMBULATORY 3D ANALYSIS OF HUMAN MOVEMENT

Chris Baten
Roessingh Research & Development, Enschede, the Netherlands

An overview will be presented on state of the art of technology and methods of ambulatory 3D analysis of human movement based on optimal motion sensor fusion. Sensor fusion promises robust and accurate 3D motion capture by combining strenghts of, and guarding against weaknesses of, the individual sensor types. Fully wearable methods delivering detailed 3D kinematics and kinetics are the result. Strenghts and weaknesses of current methods will be disscussed as well as future opportunities. Practical examples will illustrate current applications and developments in health care, ergonomics and sports."

Chris Baten currently holds a position as program manager of the 'Ambulatory 3D analysis of human movement' program at Roessingh Research and Development, Enschede, Netherlands. He is coordinator of the dutch FreeMotion consortium of 10 internationally established research groups and innovative companies researching ambulatory methods and applications of 3D analysis of human motion (www.freemotion.tk) and current president of section on '3D Analysis of Human Movement' of the International Society of Biomechanics' and chair of the upcoming 3DMA-'08 conference (www.3DMA-08.org).

K-5-1

AMBULATORY SYSTEMS FOR MONITORING PHYSICAL ACTIVITY, GAIT & BALANCE: TECHNOLOGICAL ISSUES IN FALL PREVENTION IN THE ELDERLY

Kamiar Aminian
Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

The objective of this lecture is to address the potential relevance of ambulatory monitoring for mobility assessment in older people. After introducing background information about factors leading to disability and frailty in the elderly population, the importance of body fixed sensors for measuring human function will be outlined. Then, the lecture discusses the application of ambulatory techniques for long-term monitoring of daily physical activity, assessment of motor performance such as gait and balance control, fall risk evaluation and fall detectors. Examples are given how these techniques can become clinically relevant, particularly in the context of fall interventions for older people.

Kamiar Aminian is currently Professor of medical instrumentation in the Interfaculty Institute of Bioengineering of EPFL (Swiss Federal Institute of technology) and head of the Laboratory of Movement Analysis and Measurement. He received the Electrical Engineering degree in 1982 and the PhD degree in biomedical engineering in 1989 from EPFL. He is teaching in the area of electronics, sensors and instrumentation, medical devices, biomechanics and sports. His research interests include system integration and bio-inspired sensors fusion for ambulatory monitoring, biomechanics of human movement, gait and physical activity monitoring, orthopedics engineering and sports, as well as clinimetrics in elderly and neurology.

Dr Aminian is the inventor of Physilog® system for ambulatory monitoring of gait and physical activity, owner of 4 patents in the field of movement analysis based on inertial sensors and author of more than 200 publications in international journals, conference proceedings and book chapter. He is member of IEEE, ISB, ESB, ESMAC, ISPGR and reviewer of several engineering and biomechanics journals.

Regarding aging population, he is member of two EU networks (Profane and Mobex) active in fall prevention, and involved in several EU and national projects: developing a system to improve walking and mobility in older persons (SMILING, 7th Framework Programme EU), investigating the relationship between gait performance and fear of falling in fall-prone elderly persons admitted to rehabilitation care and in the general population, and validation of physical activity questionnaires.

K-5-2

AN AMBULATORY TRIAXIAL ACCELEROMETER SYSTEM FOR IMPLEMENTATION OF A DIRECTED ROUTINE IN FALLS MANAGEMENT

Nigel Lovell
Graduate School of Biomedical Engineering at University of New South Wales, Sydney, Australia

In developed countries, a third of people aged 65 or over fall each year, with falls being one of the leading causes of hospitalization in this age group. As such, with a rapidly ageing population, methods to evaluate falls risk and identify specific deficits in functional ability are becoming increasingly relevant. This paper proposes a directed-routine (DR) based methodology, using a waist-mounted triaxial accelerometer (TA) to facilitate the evaluation of falls risk and to detect early changes in functional ability. Preliminary evaluation of the DR in 45 elderly patients will be provided along with details of various algorithmic developments.

The TA has an in-built Bluetooth wireless and communicates with a data portal, which is used to save the DR data as well as event data related to falls and stumbles. The telehealth system that supports the acquisition and analysis of this remotely acquired data will also be described.

Nigel Lovell is currently a Professor at the Graduate School of Biomedical Engineering at University of New South Wales. His research and development work has covered areas of expertise ranging from biomedical instrumentation, biological signal processing, neurophysiology and physiological modeling. His principal research interest has been on the design of an electronic vision prosthesis and on the design of appropriate technology for managing chronic disease. He has published 300+ journal articles, books, chapters, patents, refereed proceedings and abstracts. He has been awarded over $20 million in research, consultancy and infrastructure funding in his career.

K-6-1

STRATEGIES FOR ASSESSMENT OF POSTURE AND MOVEMENT AT THE WORKPLACE

Alex Burdorf
Department of Public Health, Erasmus MC, Rotterdam, The Netherlands

Musculoskeletal disorders have been recognised as a major cause of sickness absence and disability in many (occupational) populations. For almost all of these disorders there is ample epidemiologic evidence for a strong association with mechanical load factors such as manual materials handling, frequent bending and twisting, and repetitive movements. However, quantitative exposure-response relationships are, in general, not available.[Burdorf et al., 1999] In important reason for the lack of these much-needed relationships is a poor characterization of the actual patterns of exposure to these risk factors. In musculoskeletal research, either researchers present very detailed information on postures and movements on a limited number of subjects with to little consideration to the specific exposure metric that is associated with an increased risk on occurrence of musculoskeletal disease, or researchers rely on subjective judgements or observations in epidemiologic studies that define risk factors at crude levels without disentangling the essential information on frequency, duration, and level of mechanical load.

In recent years direct measurement techniques have become increasingly available to study patterns of mechanical load at the workplace. These direct measurement techniques vary from inclinometers to record postures and movements, force gauges to measure exerted forces, to electromyographic registration devices to assess muscle activity. Direct measurements often focus on specific components of mechanical load and, thereby, have to be integrated with other measurements. In epidemiologic studies, direct registration of exposure data as a function of time prompts for analytical methods, which reduce the available amount of data into a limited number of essential parameters but still sufficiently capture the exposure patterns. Mathiassen and Winkel [1991] have proposed an exposure variation analysis whereby level, duration, and frequency of the exposure are summarized in a data matrix. With novel multi-level regression analysis techniques it is possible to evaluate differences in exposure patterns, taking into account the core elements.[Jansen et al., 2001] This apporach will be illustrated by a study among nurses, office workers, and cleaners in nursing homes. An inclinometer was attached to the trunk at L2-L3 and for 8 hours the angular position of the trunk in the sagittal plane was continuously recorded with a frequency of 16 Hz. The exposure frequency as well as the percentage of trunk postures in a particular angle for a particular time are presented in each cell of the matrix. The analysis clearly demonstrates the nature of the work activities among nurses in comparison with the office workers and cleaners. The nurses and cleaners spent more work time in trunk flexion over 30% and higher than office workers, but the movements of nurses are much more dynamic than amng cleaners with shorter durations in particular positions. This matrix analysis also illustrates that the often adopted measure of exposure of percentage worktime with 20 degrees flexion does not discriminate between these three occupational groups whereas larger angular flexion shows clear differences.

The introduction of continuous measurement techniques in workplace studies requires requires considerable resources in terms of equipment, competence and time. For example, studies assessing upper trapezius EMG amplitude in ergonomic evaluations are, in general, conducted in small groups, rarely exceeding 15 subjects. Since a large EMG amplitude variability within and between subjects performing occupational tasks is a common finding, small intervention studies are at the risk of suffering from critically low statistical power, i.e. an insufficient ability to detect statistically significant differences in exposure. Analyses of power and optimal allocation of measurement resources are widely accepted study design tools, giving guidance to the necessary investment of measurement resources to reach an acceptable chance of success in a planned study, as well as to an efficient use of these resources. So far, however, these tools have been only sporadically discussed in the context of application of continuous measurement techniques in workplace studies. The consequences of variation in exposure will be demonstrated by a study of cyclic assembly work, using the normalized EMG-amplitude and 10-, 50-, and 90-percentiles of the cumulative amplitude distribution as exposure measures of interest.[Mathiassen et al., 2002] The study population consisted of 8 subjects with full-shift measurements on 4 days per subject, allowed the estimation of exposure variability between subjects, between days, and within days. On basis of this information, the precision and power of different data collection strategies were explored. A sampling strategy comprising four registrations of about two min each (i.e. four times two work cycles) for one day per subject resulted in coefficients of variation on the 10-, 50-, and 90-APDF-percentiles of 0.44, 0.31, and 0.29 respectively. The corresponding necessary number of subjects in a study aiming at detecting a 20 percent exposure difference between two independent groups were 154, 78, and 68, respectively ($p \leq 0.05$, power 0.80). Multiple measurement days per subject would improve power, but only to a marginal extent beyond four days of recording. Increasing the number of recordings per day would have minor effects. Bootstrap resampling of the present data revealed that estimates of variability and power were associated with considerable uncertainty. The present results in combination with an overview of other occupational studies showed that common-size investigations using trapezius EMG are at great risk of suffering from insufficient statistical power when attempting to detect even a substantial intervention effect.

The examples presented above demonstrate that the application of continuous measurement devices certainly contributes to a better understanding of patterns of postures and movements at the workplace. However, decisions made about the allocation of measurements will largely determine the results of the exposure assessment. Insight into exposure variability, although often ignored, is a necessary tool for designing any study at the workplace.

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Alex Burdorf (1958) was trained as an occupational hygienist and epidemiologist at the University Wageningen in The Netherlands. After his move to the Erasmus University Rotterdam, he started projects on a variety of work-related disorders, such as reproductive disorders and musculoskeletal disorders. He received his PhD in 1992 on assessment of physical load in epidemiological studies on musculoskeletal disorders. He is currently appointed as associate professor in occupational health at the Erasmus University Rotterdam, responsible for a research group on occupational health. Research includes etiological studies on musculoskeletal complaints as well intervention studies on ergonomic improvements in the workplace. One of his main areas of interest is exposure assessment at the workplace, primarily addressing determinants of mechanical load and strategies for an optimal design of exposure assessment strategies. In the past years, he has worked as visiting scientist at Sahlgren Hospital in Goteborg, Harvard School of Public Health in Boston, and Liberty Mutual Research Center in Hopkinton, USA.

K-7-1

LONG TERM FREE LIVING PHYSICAL ACTIVITY DATA: WHAT DO WE DO WITH IT?

Malcolm Granat
School of Health & Social Care, Glasgow Caledonian University, Glasgow, UK

Monitoring free-living physical activity produces large volumes of data, which are typically reduced to basic outcome measures of simple totals for each parameter such as total acceleration counts or step number. This ignores the inherently information rich nature of continuous collected data. The relative importance of the information and outcomes that can be generated by this rich data resource are often context (e.g. disease state or treatment paradigm) specific. This talk will focus on methods for extracting clinically relevant outcomes from the pattern of free-living physical activity and the illustration of these outcomes using data from a range of studies undertaken by ourselves and collaborators. These patterns are analysed in terms of cadence patterns, sedentary behaviour, cadence variability and walking patterns as an indicator of household or community activity. This talk would draw on free-living physical activity data collected from hundreds of individuals, over seven-day periods, in a variety of clinical and work-related populations.

Professor **Malcolm Granat** is Associate Dean of Research at the School of the Health and Social Care. Malcolm obtained his PhD in Bioengineering, in 1990, at the University of Strathclyde, Glasgow and subsequently worked there as a postdoctoral research fellow, lecturer and reader. He moved to Glasgow Caledonian University in January 2004. His research has principally been concerned with the development of functional electrical stimulation based systems for the restoration of movement in neurological conditions. In addition he has developed methods and novel instrumentation for quantifying free-living activity.
Malcolm has received research funding in excess of £2M from a variety of funding bodies including EPSRC, MRC, EU, Chief Scientist's Office and a variety of medical research charities. He has published over 60 peer reviewed journal papers and over 100 conference papers.

K-8-1

ISSUES AND ADVANCES IN AMBULATORY MEASUREMENT OF ENERGY EXPENDITURE

Søren Brage
MRC Epidemiology Unit, Cambridge, United Kingdom

It is generally accepted that physical activity plays a major role in the aetiology of obesity, type 2 diabetes, cardiovascular disease, and some cancers. Yet, surprisingly little is known about the physical activity levels of the general population, something which could otherwise inform primary, secondary, and tertiary intervention strategies. This lack of knowledge at population level stems from the difficulty in the assessment of physical activity during free-living, a highly complex behaviour. Nonetheless, recent advances in monitoring technology have greatly enhanced our ability to objectively assess aspects of physical activity, which may compliment the subjective survey tools used so far. Although there are several important parameters for describing physical activity behaviour by means of objectively assessed biosignals, the most popular metric is physical activity energy expenditure (PAEE) and in particular its first time-derivative, physical activity intensity (PAI). Currently, it is not possible to directly measure PAI during prolonged periods of free-living but PAEE is reasonably accurately assessed with the doubly-labelled water (DLW) technique. The DLW method does not provide information about activity intensity and it is still very expensive, so population-based studies and surveys must resort to more indirect methods. Wearable sensors, such as accelerometers and heart rate monitors, have gained popularity and countries like the US and Canada have now incorporated objective monitoring into their national surveys. A key question is how to maximise validity of the activity estimate, whilst at the same time maintaining a high degree of feasibility for such study settings. For the estimation of PAI, there are several important stages one must go through to get from the phenomenon being measured to the phenomenon of interest being estimated. These stages include:

- the degree to which the sensor captures the phenomenon being measured,
- the extent to which measurement noise is successfully removed from the true biosignal,
- data reduction before data storage,
- post-processing,
- feature extraction from the raw data, and finally
- the selection of an appropriate inference model.

Examples of features of the raw data could be the mean signal value (common for accelerometry) or the frequency (common for ECG-based heart rate monitors) in a local time window ("epoch"). In order to advance the field, it is essential to ensure transparency in this process, so that the consequence of decisions made at each of those stages may be appropriately evaluated.

In this talk, accuracy of the distal estimate of energy expenditure resulting from this process using acceleration and/or ECG as input signals will be evaluated against indirect calorimetry as the criterion.

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K-9-1

TOWARDS MONITORING MOTOR RECOVERY IN SUBJECTS POST STROKE VIA WEARABLE SENSING TECHNOLOGY

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More than 700,000 people are affected by stroke each year in the United States [1]. Strokes affect a person's cognitive, language, perceptual, sensory, and motor abilities [2]. More than 1,100,000 Americans have reported difficulties with functional limitations following stroke [3]. Recovery from stroke is a long process that continues beyond the hospital stay and into the home setting. The rehabilitation process is guided by clinical assessments of motor abilities.

Accurate assessment of motor abilities is important in selecting the best therapies for stroke survivors. These assessments are based on observations of subjects' motor behavior using standardized clinical rating scales. The accuracy and consistency of observational assessments may vary greatly across clinicians [4]. Wearable sensors could be used to provide more accurate measures or could be used in addition to observational clinical tools. Wearable systems have the ability to measure motor behavior at home and for longer periods than could be observed in a clinical setting. Herein we report results from a pilot study suggesting that wearable systems equipped with accelerometer sensors could be used to predict clinical scores of motor abilities subjects post stroke.

Twenty-three subjects who had a stroke within the previous 2 to 24 months were recruited for the study. Each subject was evaluated by a clinician using standardized clinical motor performance scales, including the Fugl-Meyer Assessment of Sensorimotor Recovery after Stroke, Chedoke-McMaster Stroke Assessment, Wolf Motor Performance Test, the Wolf Functional Ability Scale, and the Reaching Performance Scale. These scales measure dimensions of upper limb motor behavior including movement quality, stage of motor recovery, use of compensatory movement strategies, and the ability to perform functional tasks. Experiments were performed at Spaulding Rehabilitation Hospital. Subjects provided informed consent approved by the hospital's ethical committee. Accelerometers were positioned on the sternum and the affected (i.e. hemiparetic) arm. A single-axis accelerometer was positioned on the sternum. Two-axis accelerometers were positioned on the upper arm and forearm respectively. A two-axis accelerometer was positioned on the dorsal aspect of the hand. Finally, single-axis accelerometers were positioned on the tumb and index finger. Sensor data was recorded using the Vitaport 3 (Temec BV, The Netherlands) ambulatory recorder, which was worn on the waist. Subjects performed multiple repetitions of tasks requiring reaching and prehension, selected from the clinical scales. The tasks included reaching to close and distant objects, placing the hand or forearm from lap to a table, pushing and pulling a weight across a table, drinking from a beverage can, lifting a pencil, flipping a card, and turning a key.

The accelerometer data was digitally low-pass filtered in Matlab with a cutoff frequency of 15 Hz to remove high frequency noise. Both this low-pass filtered and a high-pass filtered version of the data were utilized in the analysis. The high-pass filtered version of the data was derived in an attempt to isolate actual acceleration components from gross postural adjustments. A 1 Hz cut-off frequency was used for this purpose. The signals were marked manually during testing using a 5 V pulse. The marks were used to segment the data by task through an automated software procedure based on threshold detection of the manual markings. Manipulation tasks such as card flipping were also segmented within the task using a touch sensor. They were segmented into a reaching epoch, a manipulation epoch, and a release/return epoch. Subjects performed between 10 and 20 repetitions of each task, resulting in an average of more than 100 segments for each subject. The following features were extracted from each epoch of accelerometer data for later analysis: 1) mean value of the low pass filtered data, 2) root-mean-square value; 3) dominant frequency, 4) ratio of energy in 0.2 Hz bin around dominant frequency to total energy (measure of periodicity), 5) range of auto-covariance; 6) root-mean-square of the derivative of acceleration (i.e. jerk), 7) dominant frequency of the jerk time series, 8) ratio of energy in 0.2 Hz bin around dominant frequency of jerk to total energy (measure of periodicity), 9) peak speed, 10) jerk metric of each channel – the negative RMS jerk, normalized by peak velocity value, 11) approximate entropy (nonlinear measure of complexity), 12) accelerometer output corresponding to the starting position of the subject (mean of first 1/8 s), 13) correlation at zero lag between selected pairs of accelerometer time series, 14) peak correlation within a 1 s window between selected pairs of accelerometer time series, and 15) lag time of the peak correlation between selected pairs of accelerometer time series.

For the analyses reported in this abstract, we built models to predict the Wolf Functional Ability Scores (FAS). The FAS score provides a measure of the subject's quality of movement on a task-by-task basis. The scores capture factors such as smoothness, speed, ease of movement, and amplitude of the compensatory movements. This scale ranges between 0 and 5. One score is given for each task and is based on one repetition that the subject performs at maximum speed.

We trained 3 classifiers to predict the Wolf FAS scores. The three classifiers were based on the Simple Logistic, J48 and Random Forest techniques. The Simple Logistic algorithm is a variation of the logistic regression approach. It iteratively matches the best feature to the residue of the data model, basically performing a logistic regression in a stepwise (forward) fashion. This is the simplest classifier that we thought could model the dataset at hand. J48 is the Weka version of Quinlan's decision tree model. This approach has been shown to be effective in a variety of classification problems similar to the one herein considered and therefore we decided to test its performance. The Random Forest approach is a further development of decision trees. We chose to test this technique because it is suitable for datasets with low feature-to-instance ratio.

The results herein summarized were obtained by means of a 10 fold cross-validation approach using 10 different seed values. The results for each classifier (i.e. above-mentioned methods) were taken as an average for the prediction performance over 10 seed values. We found that random forests outperform Simple Logistic and J48 algorithms. The average prediction error across all the subjects recruited in the study was different from task to task. Therefore, we compared the range of prediction error values achieved with each of the techniques adopted for the study. The Simple Logistic approach led to a prediction error of the Wolf FAS scores that ranged from approximately 2 % to about 23 %. The J48 technique resulted in a prediction error ranging from approximately 9 % to about 34 %. Finally, the Random Forest approach showed a prediction error between about 1 % and approximately 13 %.

The results summarized in this abstract are very encouraging as they indicate that features derived from accelerometer data recorded during performance of functional motor tasks can be used to predict the output of a clinical scale (Wolf FAS) aimed at capturing quality of movement in stroke survivors. It is therefore conceivable that a wearable system equipped with just a few accelerometers could be used to assess functional capability in individuals post stroke via monitoring in the home and community settings. If further studies confirmed our preliminary findings, it would be possible to propose the use of wearable technology to monitor motor recovery in individuals post stroke undergoing rehabilitation. This approach could in turn lead to a new methodology to assess the effectiveness of different rehabilitation intervention on a subject-by-subject basis and potential facilitate the adjustment of rehabilitation strategies.

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His research work includes wearable technology and its applications in physical medicine and rehabilitation, electromyography, and biomechanics of movement. He has developed intelligent signal processing tools for investigating problems in neurophysiology and artificial intelligence systems for the analysis of data recorded using wearable sensors.

K-9-2
TOWARDS REMOTE MONITORING AND REMOTELY SUPERVISED TRAINING

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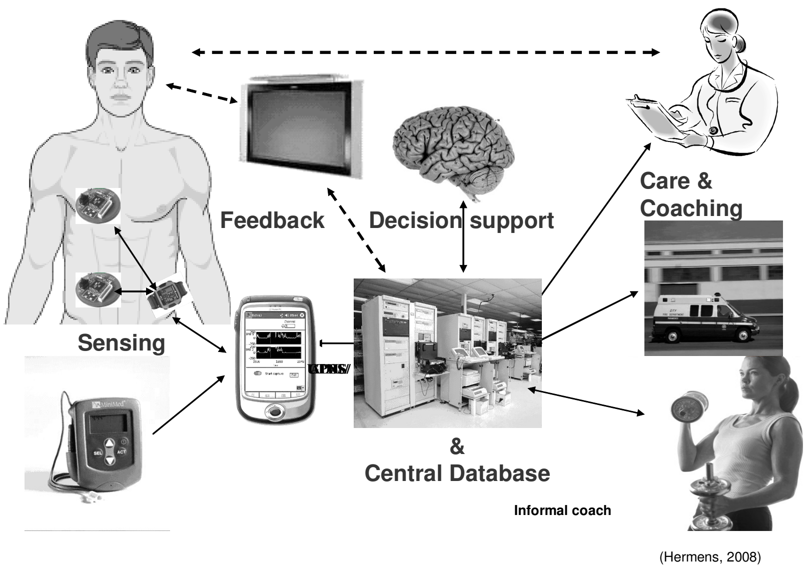
The growing number of elderly and people with chronic disorders in our western society puts such pressure on our healthcare system that innovative approaches are demanded to make our health care more effective and more efficient. One way of innovation of healthcare can be obtained by introducing new services which enable less pressure on the intramural health care and support a more independent living and self efficacy of patients. Two of such services are Remote monitoring and remotely supervised training (RMT).

Remote monitoring enables freedom to the patient with the assurance that assistance is possible whenever required. Remotely supervised treatment enables efficient and effective user-centred training anywhere and anytime with an intensity not feasible in an intramural setting. It is our vision that remote monitoring and remotely supervised treatment applications will become very important for patients (safety, more in control, convenience), health care insurances (efficiency, cost reduction) and healthcare service providers (more effective, innovative).

A schematic drawing of the main components and the information exchange pathways are shown in the figure below. RMT systems are in general quite complex, requiring dependable end-to-end systems integrating ambulant sensing of relevant biosignals and context information, an M-Health platform for a secure data transport and storage and a backend system with appropriate decisions support with respect to both technical and clinical aspects. Another key element is the feedback of the information (dotted lines), which is essential for the subject and the care providers to learn from the data and to make the appropriate decisions.



During the past years considerable knowledge and experience is being gained with the research and development of such smart systems. In parallel, experience is gained with respect to the implementation of RMT systems in a clinical environment and how to assess its potential benefits. Examples concern:

Activity monitoring in low back pain: the daily activity patterns of patients with chronic low back pain have been assessed, indicating a similar amount of total daily activity compared to healthy subjects but with a different distribution over the day. The results clearly show in general a higher activity level in the morning and lower activity levels in the afternoon and evening. This provides a starting point for treatment: restore the balance in acivity pattern by providing adequate personalised feedback

Monitoring of spasticity: continuous monitoring of muscle activity patterns by means of surface EMG measurement, in subjects with a spinal cord lesion provides insight in the magnitude and distribution of spasticity over the day. It gives direct objective and quantitative information during which activities and during which part of the day spasticity is most hindering the activities of daily living and as such it provides valuable information to optimise the drug delivery to decrease spasticity.

Myofeedback in subjects with neck-shoulder and low back pain. An ambulatory myofeedback treatment was developed which involves measurement of the muscle activation of neck/shoulder muscles and providing feedback by means of vibration when relaxation in these muscles is insufficient. Clinical trials showed that this treatment works well but to make the treatment more efficient, a service is set-up to enable remote monitoring of the muscle activation patterns and remote consultation. As a first step in the development of a myofeedback treatment for low back pain, low back muscle activation patterns are monitored. Based on the patterns a specific ambulatory feedback program is being developed to normalise the muscle activation patterns

Post rehabilitation home training (EC project HelloDoc). A modular system was developed to enable a wide range of upper extremity exercises at home, which can be monitored at a distance. In an international study it was shown that the effects were very similar to the traditional intramural treatment. There was also a clear indication that subjects who train more, do improve more. This underlines the potential that with this kind of training, the patient is in the driver seat and can significantly influence the results of his training.

Regarding the present status of remotely supervised treatment one could state that until now the focus has been on the technical realisation of the sensing and transportation part of it. The development of a backend system with an appropriate decision support system is still in its infancy as well as models how to organise these services and how to make them profitable. Probably most important is to gain more experience in this area in a realistic healthcare setting. Our experience gained in the past years in a rehabilitation setting, has learned us that this is a way forward with great potential to increase both the quality of treatment as well as its efficiency. It requires however a step-by-step approach with a strong and continuous involvement of a multidisciplinary team to guarantee a successful implementation.

Hermie J. Hermens did his master in biomedical engineering at the University of Twente, the Netherlands. His PhD was on surface EMG simulation, processing and clinical applications. Currently, he is Professor in neuromuscular control of human movements at the University of Twente and cluster manager in the area of non-invasive neuromuscular assessment at Roessingh Research and Development. Since last year he also coordinates a research group focused on remote monitoring and remotely supervised training.
He is (co)-author of over 100 peer reviewed scientific journal publications and 8 scientific proceedings/text books. He co-ordinated three European projects and participated in over 15 other international projects in the area of surface EMG, functional electrical stimulation and Information and Communication Technology. He is fellow and past president of the International Society of Electrophysiology and Kinesiology (ISEK), editor in chief of the JBMR and coordinated the Seniam group leading to the first surface EMG recommendations.
His present research is focused on normal and impaired motor control, with applications in chronic pain, stroke and work related disorders and combining ambulatory measurement technology with ICT to enable remote monitoring and training.

K-10-1
AMBULATORY ACTIVITY MONITORING IN PSYCHOLOGY AND PSYCHIATRY

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Even though behavior is central to psychology and encompassed in nearly every definition of psychology, the assessment of physical activity and movement is rare in psychology. Even worse, in most psychological studies behavior is assessed by questionnaires, whereas ambulatory assessment of activity, posture and movement are extraordinary exceptions. There are only a few psychologists working with ambulatory activity monitoring. Their main interest is not crucially different to that of other researchers in this field. They investigate the amount of physical activity in obesity, validate new devices, develop algorithms for automated posture detection, or they investigate the discrepancies between reported physical activity and physical activity measured by electronic devices. What might be specific for a psychological approach to activity monitoring is the question if behavior (physical activity, posture, movement) is related to or determined by setting variables or by psychological phenomena like mood, emotions or personality. Such psychological approaches in activity monitoring will be exemplarily presented, encompassing: a) basic research studies on the association between physical activity and mood or personality; b) studies investigating physical activity in psychiatric patients to gain a better understanding on diagnosing, characterizing and optimizing treatment; and c) studies assessing behavior and physical activity as confounding variable in psychophysiology.

<u>The association between physical activity and mood</u>

Numberless studies propose a positive relation between physical activity and mood. However, most studies relied on subjective ratings of activity. Unfortunately, there is converging evidence, that self-reports of physical activity and objective measurement of physical activity are only moderately associated. More recent studies examined the within-subject association between physical activity and mood using technical devices: accelerometers for physical activity and electronic diaries for hourly ratings of affect. Findings revealed that positive affect was significantly associated with preceding physical activity episodes, suggesting that daily physical activity episodes modulate mood. Associations between mood and behavioral pattern are also of interest in disorders defined by activity pathologies, like Parkinson. Even though a neurological disorder, psychological research has helped to understand how tremor activity is affected by emotional and behavioral events.

<u>Physical activity in psychiatric patients</u>

Even though psychiatric disorders are called mental disorders, they do encompass physical activity as major symptoms. Up to 48 disorders in the Diagnostic and Statistical Manual of Mental Disorders have physical activity level as an inclusion or exclusion criteria. Prominent examples are attention deficit/hyperactivity disorder (ADHD), schizophrenia (disorganized or catatonic behavior), major depression (psychomotor retardation or agitation), or bipolar disorders (psychomotor agitation during manic episodes). Studies using objective measurement of physical activities to describe or to differentiate disorders and to evaluate treatment effects exist, but are a minority. However, there are good arguments to rely on ambulatory activity monitoring. For example, hyperactivity in children with ADHD has shown to be situation-specific in some studies: Heightened activity has especially been found during structured school tasks and not during playtime events. Other studies suggest that hyperactivity of children with ADHD appears to be more characteristic by the relative absence of quiescent periods than to the presence of periods of extreme activity. Such specific pattern is less likely to be revealed by self-reports. Current approaches to use ambulatory actigraphy as feedback system to modify motor excess with ADHD are promising.

<u>Behavior and physical activity as confounding variable in psychophysiology</u>

One difficulty encountered in the investigation of physiological indices in ambulatory monitoring studies has been the control for interfering conditions. The assessment of physical activity and posture is necessary for teasing apart emotional and physical influences. The work of Myrtek and colleagues on interactive monitoring of additional heart rate was exemplary in this regard. Heart rate and physical activity was continuously monitored in daily-life and heart rate increases caused by physical activity were eliminated on-line. The remaining additional heart rate, assumed to indicate emotional activation, was used to trigger an electronic diary, which in turn asked for momentary activity, situation and emotion.

Although not yet a main stream procedure, ambulatory activity monitoring especially in combination with the simultaneous assessment of emotions, mood or physiological variables might be a promising approach not only for psychology.

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Abstracts Oral Presentations

O-1-1
INCREASING OUR UNDERSTANDING OF PEDOMETER REACTIVITY: WHAT FACTORS ARE INVOLVED?

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INTRODUCTION

Pedometers are increasingly being used to objectively measure free-living ambulatory activity, however the impact of wearing a pedometer, and recording daily step counts, on participants' activity level has received little attention. If activity changes as a result of wearing the pedometer, defined as reactivity, this could affect the validity of pedometer-determined activity data. Only when participants are unaware that their activity levels are being monitored (termed covert monitoring) can a true investigation into reactivity be undertaken [1]. In the only study to date employing covert monitoring, Clemes et al. [2] reported an increase in mean daily step counts of 1845 steps/day when participants wore an unsealed pedometer and recorded their daily steps in an activity log, relative to the covert condition. Suggested mechanisms for this increase included: (1) participants knowledge that they were wearing a pedometer; (2) the feedback obtained from the visible display; and (3) the requirement to record daily step counts in an activity log. The aim of the current study was to add to the understanding of pedometer reactivity, in relation to the factors highlighted above, by investigating the presence of reactivity, if any, in response to wearing sealed and unsealed (with and without step count recording) pedometers.

METHODS

On the first visit to the laboratory 63 participants (41 female, 22 male: age = 23.6±9.6 years, BMI = 22.7±3.0 kg/m^2), blinded to the study aim, were provided with a sealed pedometer (New Lifestyles NL-1000) and informed that it was a 'Body Posture Monitor' (covert monitoring condition). Participants wore the pedometer throughout waking hours for 1 week. Upon return to the laboratory, stored step counts were downloaded and participants were informed that the device was a pedometer. Participants wore the pedometer under three more conditions, each having a duration of 1 week. These conditions included wearing a sealed pedometer (sealed condition), wearing an unsealed pedometer (unsealed condition), and wearing an unsealed pedometer and recording daily step counts in an activity log (diary condition). The order of participation in each condition was balanced across participants. Mean daily step counts recorded during the 4 conditions were compared using a repeated measures ANOVA, with gender as a between-subjects variable.

RESULTS

There was a significant overall effect of condition ($p<0.001$) (covert monitoring = 8408±2595 steps/day; sealed condition = 8832±2845 steps/day; unsealed condition = 9220±3299 steps/day; diary condition = 9669±2717 steps/day), with Bonferroni corrected post hoc analyses revealing that mean daily step counts were significantly higher in the diary condition than those reported during both the covert (1273±1963 steps/day) and sealed (803±1954 steps/day) conditions (both $p<0.008$). No significant gender effects were observed ($p=0.36$). A significant day-of-the-week effect was present in all conditions, with step counts recorded on a Sunday being significantly lower, by approximately 2500 steps/day, than those reported on Monday through to Saturday ($p<0.001$).

DISCUSSION

The greatest increase in step counts occurred in the diary condition, suggesting that reactivity to pedometers is greatest when participants are requested to wear an unsealed pedometer and record their daily step counts in an activity log. It is suggested that the requirement to record daily step counts may heighten participants awareness of their overall activity resulting in modifications to activity levels. Little differences were observed however between the covert and sealed conditions.

CONCLUSIONS

The current findings have validity implications for short term pedometer studies investigating habitual free-living activity that require participants to provide a daily log of their step counts. Further research is required to determine the duration of this reactivity effect. For a true estimate of habitual activity, if appears that reactivity is not a major threat to validity when step counts are measured using sealed pedometers.

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O-1-2

PEDOMETRY – A VALIDATION STUDY

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INTRODUCTION

In the last years various kinds of motion sensors designed for the assessment of daily physical activity became available. Compared with accelerometers and ADL-Monitors, pedometers are inexpensive devices allowing for describing physical activities in terms of step counts. Researchers should be aware that models may differ regarding the step detection mechanism and therefore sensitivity, accuracy and validity [1]. Therefore, the aim of this study was to compare the step counting accuracy of eight pedometers.

METHODS

Eight pedometers (Omron WS Pro, Oregon Scientific, AudioStep, Newgen Medicals, Sportline, Tchibo TCM, HiTrax Walk, SO202, retail price range from 3€ to 45€) and one accelerometer (StepWatch Activity Monitor SAM, Cyma, USA) were validated on a 400 m-track at three different speeds (self selected speed [sss], slow walking, fast walking). Direct observation served as criterion measure. All motion sensors were worn by 16 children (9.9 ± 0.4, BMI ranging from 14.2 to 22.0) and 18 young adults (24.6 ± 2.4, BMI ranging from 17.2 to 31.5). Statistical analysis was performed using Wilcoxon signed rank test.

RESULTS

Children	50m/min	80m/min	Sss	Young Adults	50m/min	100m/min	sss
Omron WS Pro	1.4	0.5	0.4	**Omron WS Pro**	2.3	0.3	0.7
Newgen Medicals	6.6	1.0	1.2	**HiTrax Walk**	7.0	1.9	2.0
HiTrax Walk	7.5	2.0	2.3	**SAM**	5.1	4.0	2.7
SAM	6.3	2.9	4.1	**Sportline**	24.2	2.0	2.0
Sportline	25.8	5.4	4.9	**Newgen Medicals**	24.7	1.8	5.4
Tchibo TCM	32.9	3.2	6.5	**AudioStep**	27.2	7.3	7.5
Oregon Scientific	55.2	4.7	12.0	**Tchibo TCM**	40.2	3.6	7.7
SO202	53.2	8.5	11.5	**Oregon Scientific**	48.3	3.0	14.4
AudioStep	57.2	40.8	48.3	**SO202**	32.3	17.6	19.5

Tab. 1: Mean differences [%] for motion sensors compared with direct observation on a 400 m-track; under- and overestimations were adjusted by using absolute deviations.

DISCUSSION

The Omron WS Pro pedometer achieved an excellent result in this study. Even at slow walking speed (50 m/min) this piezoelectric device provided more accurate step counts in children and young adults than the accelerometer, which is in contradiction to previous findings [2]. On the other hand, the performance of other pedometers (e.g. Oregon Scientific, AudioStep, SO202) was not acceptable with respect to accuracy at slower walking speeds.

CONCLUSIONS

Pedometers may vary in their data output due to different instrument sensitivity thresholds and subsequent accuracy. Forces/accelerations of less than 0.35 Gs (very slow walking or shuffling) are not likely to be detected [3]. The Omron Walking Style Pro seems to be well adjusted for slower and faster walking speeds in young adults and even in children. Because of its purchase price of under 50 € this pedometer can be considered as an alternative to more expensive accelerometer-based sensors.

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O-1-3

ACTIVITY MONITORING: THE MONITOR AS A SOURCE OF ERROR

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INTRODUCTION

Activity monitoring in a natural environment provides many advantages. However it is important to understand the sources of error, including those that are intrinsic to the measuring device.

METHODS

To quantify errors during monitoring with the StepWatch™ Activity Monitor, separate monitors were attached to the right and the left legs of a single subject and calibrated to detect all steps. Nine days of continuous activity monitoring were then carried out with data collected from both monitors simultaneously.

RESULTS

The difference in total step counts between the right and left legs for single day monitoring ranged from 2 to 361 steps during the nine-day monitoring period. This represented 0.02% to 6.36% of the total step count per day. Combining the data set for the nine days gave a variation in step count between the two sides of 549 steps (0.9% of the total step count). Bland Altman analysis of the nine separate 24 hour monitoring periods showed that the differences in the number of steps/ minute detected for the right versus the left leg were between 0 to 4 steps for 95% of measures. However, for 5% of measures, the differences between detection of steps for the left and right legs were from 4 to 22 steps. At lower activity levels, [a cadence of 4-60 steps/minute], the absolute differences in the detected steps/minute between the two legs were higher (up to 22 steps). At higher activity levels, [above a cadence of 60 steps/minute], the differences in the number of steps/minute detected were less (up to 12 steps).

DISCUSSION

Measurement of total step count using the StepWatch™ Activity Monitor shows good internal consistency with a difference of only 1% between independent monitors on different limbs over a prolonged monitoring period and up to 6.4% over 24 hours. However, activities involving low numbers of steps/minute were associated with greater variability between the independent monitors. This could be a reflection of inaccuracies in the monitors themselves, meaning steps are being incorrectly detected, or it could mean that each leg does not show the same level of activity throughout the day.

CONCLUSIONS

We conclude that potentially higher levels of inaccuracy are seen in gait involving non-continuous stepping or low numbers of steps per day. This has implications for activity monitoring in patient populations with decreased walking ability and / or endurance.

O-1-4

VALIDITY AND RELIABILITY OF PEDOMETERS AND ACCELEROMETERS IN CHILDREN AND ADOLESCENTS

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INTRODUCTION

In the past decades, motion sensors have evolved from simple mechanical devices to three-dimensional accelerometers. Because many children and adolescents have difficulties in accurately recalling their physical activities, motion sensors are being used with increasing regularity. The purpose of the present study was to systematically review published evidence on the validity, reliability, and feasibility of motion sensors used to assess the amount of physical activity in healthy children and adolescents (2-18 yr).

METHOD

A systematic literature search was performed in PubMed, Embase, and PsycINFO in October 2004 and 2007. The clinimetric quality of five pedometers (Digi-Walker, Pedoboy, Walk4Life, Sun TrekLINQ, StepWatch Activity Monitor), five uni-axial accelerometers (ActiGraph, LSI, Caltrac, Actiwatch, Actical), one two-axial accelerometer (BioTrainer), and five three-axial accelerometers (Tritrac-R3D, RT3, Tracmor2, Active Tracer, Mini-Motionlogger) was evaluated and compared using a 20-item checklist.

RESULTS

In 2004, there was strong evidence for a good reliability of the Caltrac in adolescents (12-18 yr), a poor reliability of the Digi-Walker in children (8-12 yr), a good validity of the ActiGraph in children and adolescents (8-18 yr), and a good validity of the Tritrac-R3D in children (8-12 yr). The quality of the described studies (n = 35) was modest (mean = 6.4 ± 1.6 out of 14 points) [De Vries et al., 2006]. In 2007, 38 new studies were identified. Preliminary analyses show that the quality of the new studies is still modest (6.2 ± 1.4 points). Considerably more information is available on the reliability and validity of the Digi-Walker. More results of the update will be available before May 2008.

DISCUSSION

Sixteen motion sensors were evaluated and compared on their clinimetric properties. This is the only review of motion sensors to take the quality of the studies into account. There are still a number of pedometers and accelerometers of which the clinimetric properties in certain age groups are unknown.

CONCLUSION

It can be concluded that the ActiGraph accelerometer is the most studied motion sensor in children and adolescents. There is extensive evidence for a good validity, reliability, and feasibility of the ActiGraph in healthy children and adolescents (validity: 3-18 yr; reliability: 4-18 yr). Because the technology of motion sensors is still improving, we can expect models continuing to change. Researchers and practitioners are encouraged to report the clinimetric properties of new devices, although not without improving the quality of the reported information.

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O-1-5

MOTION SENSOR OUTPUT AT HIGH RUNNNING SPEEDS IN CHILDREN – THE A-CLASS PROJECT

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INTRODUCTION

Despite previous investigations reporting a plateau in activity counts from uniaxial accelerometers at high running speeds in adults [1] only one reported study has investigated this levelling-off phenomenon in a small sample of children [2]. The aim of this study was to establish activity counts for the ActiGraph accelerometer in children during treadmill walking and running, and to determine at what speed and output levelling-off occurs.

METHODS

One-hundred forty-three children (85 girls, 58 boys; mean (SD) age 10.3 (0.3) yrs) completed a discontinuous, incremental exercise test to volitional exhaustion, which involved walking (4 and 6 $km \cdot h^{-1}$) and running (8, 10, 12, and 14 $km \cdot h^{-1}$ or until exhaustion). Participants exercised at each speed for 3 minutes with 30-s rest between stages, and then walked for 5 minutes at 3.5 $km \cdot h^{-1}$ following exhaustion. Activity counts were measured throughout over 5-s epochs by an ActiGraph accelerometer (GT1M) on the right hip. For complete stages the first and last six data points were removed for analysis. For incomplete stages at least 2 minutes of recording was required, with the first and last three data points removed. The effects of speed on the ActiGraph were investigated using repeated measures ANOVA, with statistical significance set at $P \leq 0.05$.

RESULTS

ActiGraph output increased significantly across speeds 3.5 (1384 (415) cpm; n=143), 4 (1768 (506) cpm; n=143), 6 (3597 (870) cpm; n=143), 8 (6546 (1323) cpm; n=143), and 10 $km \cdot h^{-1}$ (6937 (1344) cpm; n=125). Following peak at 10 $km \cdot h^{-1}$ counts declined across 12 (6870 (1268) cpm; n=45) and 14 $km \cdot h^{-1}$ (5814 (368) cpm; n=3). There were no significant differences in ActiGraph output between 8, 12 and 14, 10 and 12, and, 10 and 14 $km \cdot h^{-1}$ ($P \geq 0.140$). The output plateau for boys was lower ($P \leq 0.001$) and more pronounced in running compared to girls.

CONCLUSIONS

Levelling-off of ActiGraph activity counts occurred at approximately 7000 cpm, which was lower than the 8000 cpm reported in an age matched sample during field validation [2]. This may be due to treadmill exercise altering movement mechanics. The plateau in counts is largely attributable to the levelling-off and subsequent decrease in vertical displacement of the body at fast speeds. If a researcher intends to use uniaxial accelerometers to estimate time spent engaged in moderate-to-vigorous physical activity, this plateau will not have a major impact.

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O-2-1

WALKING ACTIVITY IN CHILDREN WITH THE STEPWATCH3™

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INTRODUCTION

Pilot data in children suggest the StepWatch3™ is a valid and reliable measure of ambulatory activity in children [1]. Recently the precision and accuracy of the StepWatch3TM as compared to other ankle assessed accelerometers has been reported in lean and obese adults [2]. The goal of this project was to define the range and variability of walking activity levels in typically developing children ages 2-15 years as measured by the StepWatch3™.

METHODS

Participants included 420 children 2 to 15 years of age. Thirty boys and 30 girls were enrolled in each of seven age groups of two year increments. Each subject wore the StepWatch3™ for all awake hours during for seven consecutive days. Height, weight, and leg length were recorded. Five days of walking activity were analyzed (four school days and one weekend day). Regression analysis examined the relationships of age, sex, leg length, and calculated BMI to percentage time in high, medium, and low activity levels, total activity, and sustained bursts of step activity for 1, 20, and 60 minutes.

RESULTS

Single leg steps/day averaged 9,509 (sd 2,461) for 2-3 year olds while 14-15 year olds walked 7,050 (sd 3,223). Average time in medium activity levels was 37% (sd 4) for 2-3 year olds with 14-15 years olds at 29% (sd 5), while high activity levels averaged 15% (sd 5) and 11% (sd 6) of all active time respectively. Peak steps/min for a sustained 20 min effort for 2-3 years olds averaged 44 (sd 8) steps and 38 (sd 10) for ages14-15 years. Peak 60 minute effort was 32(sd 6) and 25(sd 9) steps/min respectively while one minute peak effort was 72(sd 6) and 59(sd 6) steps. Significant correlations were found between age and all walking activity variables. With increasing age, both boys and girls showed a significant decline in percentage of time active, percentage of time in medium and high levels of activity, and peak activity index (peak activity for a single minute), and in endurance, cardiovascular and accumulated peak effort (peak activity for continuous 5, 20, 30, and 60 minute effort).

DISCUSSION

These results describe the first normative walking activity data for children with the StepWatch3™. With increasing age, typically developing children show progressively less overall activity and have less endurance and lower peak efforts of activity. At all age groups, boys exhibit on average higher levels of activity than girls. This correlation appears to be independent of leg length and BMI changes.

CONCLUSIONS

Interventions for musculoskeletal problems of children are intended to positively affect functional activity of children on a daily basis. This study characterizes the intra and inter-age group variation of daily walking activity for typically developing boys and girls with the StepWatch3™ providing baseline normative ambulatory activity against which to compare children with disability and measure the impact of interventions. Further documentation of precision and accuracy in children as well as ability to predict energy expenditure in daily life is needed.

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O-2-2

THE ASSOCIATION BETWEEN FUNCTIONING IN A LABORATORY AND DAILY LIFE FOR LOW BACK PAIN PATIENTS

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INTRODUCTION

In pain research physical performance tests are often used to identify patient's performance in a daily life situation. In some patients, however, performance in a laboratory setting may be influenced by both their ability to accurately predict activity-related pain and their fear of injury. As a result, the association between physical performance in a laboratory setting and in daily life situation may be influenced. The objective of this study is to test the association between physical performance in a laboratory setting and physical performance in daily life in both patients with an accurate and inaccurate pain prediction.

METHODS

As to physical functioning in a laboratory setting, 124 sub-acute low back pain patients performed a strength measurement test of the quadriceps muscle. Test outcome, pain expectations before the test, experienced pain during the test and fear of injury were measured. Furthermore, all patients wore an accelerometer (RT3) during one week to assess their physical activity level in daily life. Patients with either an accurate or in-accurate pain prediction were identified, based on the discrepancy between predicted and experienced pain. In a regression analysis, the outcome of the strength measurement was tested against age, gender, fear of movement and mean physical activity level in daily life.

RESULTS

In patients who can correctly predict their pain, physical activity in daily life contributes significantly to the explanation of the physical performance in the lab ($\beta = 0.272$, $p < 0.05$). In addition, in patients that had an inaccurate pain prediction, fear of movement ($\beta = -0.553$, $p < 0.01$) instead of physical activity in daily life ($\beta = 0.181$, not significant) contributes significantly in explaining the physical performance in the laboratory.

DISCUSSION / CONCLUSION

In patients who can correctly predict their pain, the outcome of a physical performance task in a laboratory setting seems to be a good indicator for the physical activity level in daily life. However, for patients with an inaccurate pain prediction fear of movement seems to interfere with physical performance. As a result of this, for these patients, a prediction of their level of physical functioning in daily life based on the result of a laboratory-bound physical performance task seems inadequate. Further research is needed to get more insight in the underlying mechanisms.

O-2-3

CHANGES IN PHYSICAL ACTIVITY DURING AND AFTER INPATIENT REHABILITATION IN PERSONS WITH SPINAL CORD INJURY

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INTRODUCTION

Persons with a spinal cord injury (SCI) are often restricted in their performance of everyday physical activities. As a consequence, persons with SCI are, more than the able-bodied population, at risk of developing a hypoactive lifestyle, with possible detrimental effects on physical fitness, social participation, and quality of life. Furthermore, a hypoactive lifestyle can increase the risk of developing secondary health problems such as cardiovascular disease and diabetes. The aim was to assess the change over time in physical activity level after a spinal cord injury, its determinants, and the extent of hypoactivity 1 year after discharge from the rehabilitation center.

METHODS

We included 40 persons with SCI. Physical activity level, as indicated by duration of dynamic activities (ie, wheelchair driving, walking, cycling, noncyclic movement) per day, intensity of everyday activity, and intensity of wheelchair driving, were measured with an accelerometry-based activity monitor during 2 consecutive weekdays in the rehabilitation center or in the person's home.

RESULTS

Random coefficient analyses demonstrated that duration of dynamic activities, intensity of everyday activity, and intensity of wheelchair driving increased during inpatient rehabilitation at rates of 41%, 19%, and 34%, respectively ($P<.01$). Shortly after discharge, there was a strong decline (33%; $P<.001$) in duration of dynamic activities. One year after discharge, this decline was restored to the discharge level, but the duration of dynamic activities was low in comparison with levels in able-bodied persons and persons with other chronic diseases. Sex, level of lesion and completeness of lesion were determinants of the change in different outcome measures of the physical activity level after discharge.

CONCLUSIONS

Physical activity level increased during inpatient rehabilitation, but this increase did not continue after discharge and remained distinctly subnormal. Subpopulations had a different change over time in physical activity level after discharge.

O-2-4
CUEING TRAINING IMPROVES AMBULATORY WALKING ACTIVITY IN PATIENTS WITH PARKINSON'S DISEASE: THE RESCUE TRIAL

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INTRODUCTION
In the Rescue trial, patients with Parkinson's Disease (PD) received cueing training in their own home to improve gait and gait related activities [1]. In order to objectively assess changes in functional activity related to walking activity monitoring (AM) was applied in the home environment.

METHODS
Design and procedures: A multi-centered, single-blind, randomized trial with cross-over design was carried out in 3 European countries. All participants received 9 training sessions in 3 consecutive weeks, at home. Different rhythmic cues were provided to train gait- and gait-related activities using a rhythmical cueing device developed specially for this purpose.

Measurements: AM was carried out at baseline, 3, 6, and 12 weeks in the patient's homes. The Vitaport ® activity monitor (Temec Instruments B.V., Kerkrade, NL) was used to record the postures and motions of subjects during each assessment day. Day of the week and time of day were kept identical. The system consisted of a set of 5 piezo-resistive, dc-coupled accelerometers connected to a portable data-logger. Three were mounted on the chest and one accelerometer was mounted on the lateral side of each thigh.

Data analysis: Postures and motions were classified as static activity and dynamic activity, using Vitagraph ® software. Dependent variables were: % dynamic activity, % static activity, % sitting, % standing, % walking, number of walking periods > 5 sec (W>5s) and number of walking periods > 10 sec (W>10s).

Statistics: Random coefficient analysis was used to investigate effects of cueing intervention on % of activity, sitting and standing. Count variables (W >5 s and W>10s) were analyzed by using a Poisson distribution in the random coefficients model. Besides intervention, covariates time and carry-over-effects were included in the regression model. Each hypothesis was tested with a two-tailed analysis and 0.05 as the level of significance.

RESULTS
153 patients, 88 male, 65 female, median age 67, median Hoehn and Yahr stage 2,5, were monitored for 276 (+/- 74) minutes a day. A total of 147 patients completed all 4 monitoring sessions. There was no difference between baseline values for all variables when comparing early and late intervention groups. An overall intervention effect was found for: dynamic activity (+4%, $p<0.01$), static activity (-3%, $p<0.01$), walking (+4%, $p<0.01$), W>5s (+3%, $p<0.05$) and W>10s (+3%, $p<0.01$). The increase in walking activity amounted to about 10-15 minutes for an average registration period of about 5 hours. Intervention effects were limited to the 3 weeks of intervention. All intervention effects declined significantly from 6 to 12 weeks.

DISCUSSION
Rhythmic cueing training applied in patients own home environment significantly improves walking activity as recorded by activity monitoring. Dynamic activity significantly increased with a corresponding decrease in static activities. These results are consistent with the improvements seen in other gait-performance measures, such as walking speed, step length, Posture and Gait score as well as improvements in balance performance and fear of falling[1].

CONCLUSIONS
This trial showed that three weeks of rhythmical cueing training applied in patients own home environment significantly improves the level of dynamic activities related to walking as recorded by AM. However, treatment effects were significantly reduced after the intervention period, pointing to the need for supplementing therapy with permanent cueing devices and follow-up.

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O-2-5

AMBULATORY MONITORING IN LARGE MULTI-SITE REHABILITATION TRIALS: LESSONS FROM EXCITE

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Ambulatory monitoring of physical activity has become increasingly sophisticated, and several reliable and valid instruments have been developed. To date, most applications in the area of physical rehabilitation have been restricted to small scale trials. To the best of my knowledge, the Extremity Constraint-Induced Therapy Evaluation (EXCITE) trial represents the first use of ambulatory monitoring in a large, multi-site trial in physical rehabilitation. This randomized controlled trial tested the efficacy of Constraint-Induced Movement therapy or CI therapy for rehabilitating more-impaired arm use in stroke survivors between 3-9 months post-event with mild to moderate upper-extremity hemiparesis (N = 222). A reliable and valid accelerometry system developed by Uswatte and coworkers was used to measure treatment-related changes in spontaneous more-impaired arm movement outside the laboratory. To this end, all participants wore an accelerometer (Manufacturing Technologies Inc., Fort Walton Beach, FL; Model 71256) on each arm before and after treatment and at 1-year follow-up. Participants who received CI therapy immediately had a significant increase in the ratio of more-impaired to less-impaired arm accelerometer recordings after treatment, $p < .05$. Participants who received usual and customary care first did not have a change in this ratio after an equivalent time. This measure, i.e., the ratio, has been shown in previous work to be strongly correlated with self-reports of more-impaired arm use in daily life. Notably, accelerometry data were invalid or missing from 23% of participants at baseline. Reasons for these missing data and possible methods for increasing the proportion of valid accelerometer records in future trials will be discussed.

O-3-1

OUTDOOR GAIT ANALYSIS USING INERTIAL AND MAGNETIC SENSORS - PRELIMINARY VALIDATION

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INTRODUCTION

Main hesitations to include optoelectronic gait analysis in clinical practice concern: 1) the unnatural way a person normally walks in unfamiliar environments, like laboratories; 2) the necessity to acquire short and separated walking trials, due to the small measuring volume, and 3) the difficulty to identify the most representative gait cycles among those acquired. A new protocol was proposed (OutWalk, [1]) based on MTx sensors (Xsens Technologies, NL) which allows to perform outdoor 3D kinematic data collection and real-time processing, of hundreds of consecutive gait cycles. The aim of this work was to compare OutWalk with the CAST protocol used with an optoelectronic system, considering their ease-of-use, accuracy and reliability.

METHODS

A 26 years old subject participated in the experiments. Firstly, he was acquired indoor with the CAST protocol, and then outdoor with OutWalk, while walking at his natural speed. With both protocols, the 3D kinematics of hip, knee and ankle were analyzed. Indoor, 7 walking trials of 1 gait cycle each were collected with a Vicon 460 (Oxford Metrix, UK). Outdoor, 3 walking trials of up to 40 gait cycles each, automatically segmented with [2], were acquired with the sensors. For the analysis, we selected the outdoor trial closer in speed with the mean velocity of the 7 indoor gait cycles. A 26 gait cycles trial was then chosen. The repeatability of gait cycles intra-system and the inter-system correlation were assessed by analysing, respectively: 1) the maximum RMSE between every possible couple of cycles, and 2) the Pearson moment (*r*) between the mean of the 7 CAST and the mean of the 26 OutWalk cycles.

RESULTS

The maximum RMSEs for hip, knee and ankle sagittal kinematics were 5°, 7° and 4° for CAST (over 7 cycles) and 5°, 5° and 6° for OutWalk (*over 26 cycles*). *r*, resulted .997, .990, .955 for hip, knee and ankle respectively. Kinematic plots can be found at: www.inail-starter.org/AnMovEngRep.html

DISCUSSION / CONCLUSIONS

While with OutWalk the acquisition and analysis of 100 gait cycles required about 20min, the same operations with CAST on just 7 cycles required about 3 hrs. Results showed excellent intra-system repeatability and inter-system correlation. This proves that OutWalk is a promising tool to measure the walking patterns of the daily-life and to investigate the role of the central pattern generator in controlling the spontaneous walk.

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O-3-2

GAIT ANALYSIS USING WEARABLE SENSORS

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INTRODUCTION

Clinical gait analysis is traditionally performed using stereophotogrammetric systems (SP) which are accurate but constrain the execution of the motor task in the laboratory space. An alternative for capturing 3D movement data consists in using wearable inertial and magnetic sensors (MARG). A MARG module can furnish as output the orientation of the geometrical axes of its housing (TF), with respect to an earth-fixed global frame (GF). High resolution joint angular kinematics requires the determination of anatomical frames (AFs) rigidly associated with the bony segments involved in the movement. In previous studies involving inertial sensors, the axes of the AFs have been determined measuring both gravity during upright posture and rotation axes during movements occurring in anatomical planes [1]. Relevant drawbacks are: movement planes and posture are subjective and joint impairment may produce axes that are not consistently related with bone anatomy. To comply with requirements of repeatability and consistency with bone anatomy, a gait analysis protocol, in which AFs are defined from the identification of anatomical landmarks (ALs), was proposed. In addition to the kinematic quantities, spatio-temporal parameters were also provided.

METHODS

The AFs were determined with respect to the TF by means of a calibration device, hosting a MARG sensor, which allows to measure the direction of lines connecting selected ALs (Fig. 1). The anatomical calibration yielded the time-invariant calibration matrix $^{TF}R_{AF}$. One subject was involved in the experiment. Four MARG sensors (MTx, Xsens) were strapped on the pelvis, thigh, shank and foot. A definition of AFs, based exclusively on superficial ALs, was adopted. Inter- and intra-examiner precision of the methodology was assessed with six examiners. Data were collected during an upright posture and a level walking trial using the MARG sensors and SP simultaneously. Joint kinematics was estimated using the Cardan convention. Initial and final foot contact were estimated using foot's gyroscope as suggested by [2], whereas spatial parameters were computed from the foot horizontal acceleration using a 'zero-velocity' technique.

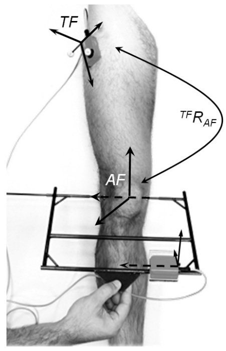

Fig. 1.

RESULTS

Inter-examiner repeatability of the MARG anatomical calibration was evaluated computing the upright posture angles dispersion (*sd*). The discrepancy between the joint kinematics during walking, as estimated with MARG sensors and SP, was expressed in terms of *rmse* between the curves aligned with respect to their mean values (Table 1, Fig.2). Stance and swing phase were 55.5% and 44.5% of the stride duration (1,3 s) respectively. The error on the estimated stride length was equal to 1.5%.

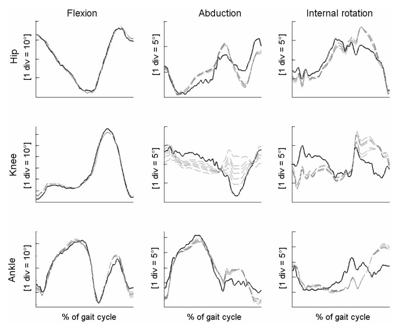

Fig. 2. Joint kinematics relative to one gait cycle estimated with MARG sensors (six dashed grey lines: six anatomical calibrations) and SP (solid black line).

DISCUSSION

Flex/Ext angles obtained with the MARG sensors were very close (*rmse*<2°) to those estimated using traditional stereo-photogrammetric techniques. Differences were found for the in/ex rot. (1.8°<*rmse*<3.6°) which was also the less repeatable among the posture angles.

Table 1.

	hip			Knee			Ankle		
[deg]	Fl/Ex	Ab/Ad	In/Ex	Fl/Ex	Ab/Ad	In/Ex	Fl/Ex	Ab/Ad	In/Ex
Sd	1.8	2.4	6.6	2	1.1	7.3	1.5	1.5	1.6
rmse	0.8	1.5	1.8	1.9	2.8	3.6	1.2	2.2	3.5

CONCLUSIONS

Virtually, the proposed protocol for gait analysis has no spatial and environmental constrains. In terms of information content joint angles were similar to those obtained using SP and no less repeatable. Limitations are: the presence of ferromagnetic disturbances can jeopardize the measurements. Of course, relevant kinetic analysis requires the use of a dynamometer.

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O-3-3

CENTER OF MASS MOVEMENT ESTIMATION USING AN AMBULATORY MEASUREMENT SYSTEM

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INTRODUCTION

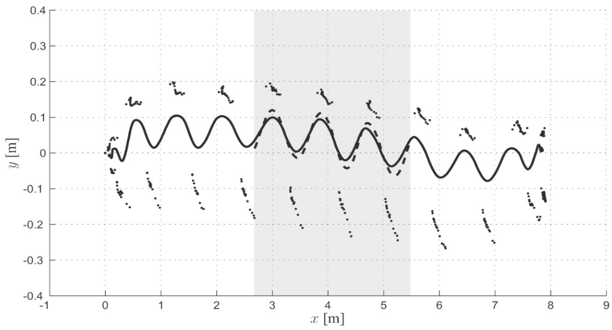
Traditionally, human body movement analysis is done in so-called 'gait laboratories', where several gait variables are estimated by Traditionally, human body movement analysis is done in so-called 'gait laboratories', where several gait variables are estimated by measurement systems such as optical position measurement systems, EMG or force plates. A major drawback of these systems is their restriction to the laboratory environment. Therefore research is required for the development of measurement systems to perform these measurements in an ambulatory environment. An important variable to characterize human walking is the Center of Mass (CoM), an imaginary point at which the total body mass can be assumed to be concentrated. Several methods exist for CoM estimation, of which the segmental kinematics method and the double integration of ground reaction force method are the most important ones. The objective of this study is to estimate the CoM trajectory using an ambulatory measurement system which fuses Center of Pressure (CoP) trajectory with double integrated acceleration obtained from Ground Reaction Force (GRF) data. The accuracy of the ambulatory system is verified by comparing it to an optical reference system based on the segmental kinematics method

METHODS

The measurement system consists of an orthopaedic sandal with two six-degrees-of-freedom force/moment sensors beneath the heel and the forefoot. Moreover, an inertial sensor is rigidly attached to each force/moment sensor. Fusion of CoP with double integrated GRF data is based on a frequency domain method. A detailed description of the method can be found in [2].

RESULTS

The figure on the right shows a top view of the CoM trajectory of a stroke patient estimated by the ambulatory (solid) and reference system (dashed). Moreover, the CoP on either side of the CoM is indicated by the dots. The root-mean-square difference between the CoM magnitudes estimated by both measurement systems averaged over 100 trials was 0.025 ± 0.007 m (mean ± standard deviation).



CONCLUSION

This study has shown the possibility to estimate CoM movement using an ambulatory measurement system. The accuracy was verified by a comparison with an optical reference system. The results are comparable to those described in literature [1].

ACKNOWLEDGEMENT

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O-3-4
VALIDITY OF THE DYNAPORT GAITMONITOR FOR THE ASSESSMENT OF PROSTHETIC GAIT

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INTRODUCTION

The DynaPort GaitMonitor (McRoberts, The Netherlands) is an ambulant, accelerometry-based measurement system that has been shown to be a valid method for detecting spatio-temporal parameters (STP's) in normal gait [1-2]. However, detection algorithms within this system have been designed for normal gait and it can be questioned whether they are valid for the altered gait pattern of people walking with a lower limb prosthesis. In this study the validity of the DynaPort GaitMonitor for the assessment of spatio-temporal parameters of prosthetic gait was investigated.

METHODS

Fourteen subjects with a lower limb amputation at various levels participated in this study. Each subject walked at self selected walking speed in a straight corridor over six different distances between 25 and 40 m. Trunk acceleration was measured using the DynaPort MiniMod (McRoberts, The Netherlands). From these acceleration data STP's were derived using the GaitMonitor software. Average STP's and STP's for each separate leg were also derived from video recordings (25 Hz) that were made during each trial. The relation between STP's derived from the GaitMonitor and video was analysed using Pearson's correlation (r) and Bland Altman's limits of agreement (LoA= mean difference ± 1.96 sd).

RESULTS

The number of steps (r= 0.99, LoA= -0.241 ± 1.776 steps), average step time (r=0.95, LoA=0.0023 ± 0.02 s), average step length (r=0.97, LoA= -0.0003 ± 0.04), walking speed (r=0.97, LoA =0.0115 ± 0.073 m/s) were detected well using the accelerometry data. Step times of both unaffected and prosthetic leg separately differed largely between GaitMonitor data and video data with r=0.70, LoA = 0.04 ± 0.05 s for the prosthetic leg and r=0.67, LoA=-0.04 ± 0.09 s for the unaffected leg. For the prosthetic leg the accelerometer generally detected shorter step times than those derived from video and for the unaffected leg accelerometer detected longer step times.

DISCUSSION

Correlation between the average gait parameters obtained with video and the GaitMonitor was high and comparable with the results of previous performed studies on normal and pathological gait [1-3]. It can therefore be concluded that the DynaPort GaitMonitor can be used to detect average gait and stride parameters in prosthetic gait. However, detection of step time of both legs separately was less successful. The specific gait pattern of prosthetic gait leads to incorrect heel strike detection of one of both legs resulting in a systematic overestimation of the step time of one leg and underestimation of the other. Therefore, gait symmetry could not be assessed correctly using de DynaPort GaitMonitor.

CONCLUSIONS

It was found that the number of steps, average step time, step length and walking speed were detected well with similar confidence intervals compared to normal gait. However detection of the heel strike of the separate prosthetic and unaffected leg was less reliable so that gait symmetry could not be monitored adequately. Heel strike detection algorithms should be adapted to prosthetic gait in order to improve detection of step parameters for the separate legs.

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O-3-5

OBTAINING BASIC GAIT CHARACTERISTICS WITH MINIMAL INSTRUMENTATION: POSSIBILITIES AND PITFALLS

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Available motion sensing methods allow for ambulatory assessment of locomotion. As a general rule, the use of multiple 3D hybrid sensors and complex sensor configurations on the body offer optimal analytical solutions. However, practical considerations may necessitate the choice for as few sensors as possible. A priori knowledge of movements of specific body segments during the gait cycle can simplify both data acquisition and further analyses since it allows an educated choice for sensor location and the analysis of specific movement characteristics. Based on a priori knowledge, a sensor placement on either the foot or the lower trunk seems suitable as a single sensor approach for obtaining basic gait characteristics.

This contribution focuses on possibilities to obtain basic gait characteristics based on motion sensing on the dorsal side of the pelvis, approximately at the height of the body's center of mass. Based on inverted pendulum approaches the linear movements of the pelvis can be predicted from spatio-temporal gait parameters [1], thus the latter gait parameters can be determined from motion sensing on the pelvis [2, 3]. Such a single sensor approach comes with advantages as well as disadvantages, therefore, an analysis of possibilities and limitations is relevant. This contribution will identify possibilities and (some) limitations of a single sensor approach. In addition, it will address the kind of sensing (i.e. acceleromery and/or angular velocities) which is needed for obtaining specific gait parameters.

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O-4-1

QUANTIFICATION OF ASYMMETRICAL MOVEMENT IN CHILDREN

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INTRODUCTION

Children with developmental delays may present with asymmetries of postures and movement that may lead to a later diagnosis of hemiplegic cerebral palsy. Although standardized motor assessments have items that require symmetrical movement to receive credit for that item, the evaluation of symmetry is subjective, based upon the examiner's judgment' [1]. Physical therapy and occupational therapy interventions are often designed to improve symmetry of use of lower and upper extremities, but again, the documentation of improvement is typically based upon observation alone. The purpose of this preliminary study was to determine if activity monitors using a piezo-electric accelerometer could be used to quantitatively document differences in symmetry of use of left and right extremities during typical activities in preschool aged children with developmental disabilities.

METHODS

Seven children from 23 months to 4.5 years, all identified as children with developmental delays, participated in this study. Four Actical Activity Monitors were attached to the right and left wrist and right and left ankle of the children for 2.5 hours while they attended a preschool classroom specifically designed for children with special needs. Children participated in their regularly scheduled preschool activities during the time the monitors were worn. These activities included, but were not limited to individual instruction on specific cognitive or speech deficits, fine-motor tasks, gross-motor tasks, circle time for stories and music, and snack time. The activity counts were averaged as counts/minute over the 3 days children wore the monitors.

RESULTS

Activity counts for the upper extremities ranged from 319 to 2079 counts/min, while activity counts for the lower extremities ranged from 186 to 1045 counts/min. Asymmetries ranged from a 0.03% to 19.93% difference in the upper extremities and from a 0.17% to 13.05% difference in the lower extremities. 2 of the 7 children exhibited more than a 5% difference in upper and lower extremity activity. This activity asymmetry was consistent with the clinical presentation of movement in these two children.

DISCUSSION

Data from the activity monitors on all four extremities of children with developmental delay for a period of at least 3 days were able to be used to quantify magnitude of movement asymmetry. These findings were consistent with the clinical findings of an experienced physical therapist who provides intervention to these children.

CONCLUSION

Accelerometers such as the Actical Activity monitors can be used to quantify the amount of movement in limbs of preschool age children as well as to quantify the extent of the asymmetries of movement that may be present. These data could be used to help identify those children who would benefit from physical or occupational therapy intervention. Such monitors might also be useful in documenting changes in movement symmetry as a result of intervention.

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O-4-2

PHYSICAL ACTIVITY DURING PROLONGED WALKING: INFLUENCE OF DISTANCE AND GENDER

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INTRODUCTION

The Nijmegen-4-day-Marches is the largest athletic event in the world with yearly 40.000 to 48.000 participants. Despite the popularity of walking as a leisure activity, little is known about the physical activity during prolonged walking exercise. To examine walking time, number of steps, energy expenditure and average METs during the Nijmegen-4-Day-Marches.

METHODS

57 volunteers (22-81 years) participated in the study and walked 30 (n=16, 63% men), 40 (n=22, 60% men) or 50 km (n=19, 47% men) per day for 4 consecutive days. Subjects wore a SenseWear Pro Armband™ on the right arm, that estimated energy expenditure and average METs using an algorithm developed by the manufacturer.

RESULTS

The SenseWear Pro Armband™ had a 100% success rate of data retrieval. The average daily walking time was 7:04, 8:35 and 10:47 (hh:mm) for 30, 40 and 50 km, respectively. Accompanying number of steps was 40.693, 48.112 and 60.131, respectively. Walking time as well as number of steps per day were both significantly different among the distances ($p<0.001$). Average estimated energy expenditure was 10.0 MJ for 30 km (0.33MJ/km), 14.0 MJ for 40 km (0.35MJ/km) and 18.9 MJ for 50 km (0.38MJ/km) and significantly differed among all distances ($p<0.05$). Average METs was significantly different ($p=0.007$) between 30 km (4.87) and 50 km (5.36), but not with 40 km (5.20). Furthermore, distance interacted with days for walking time, number of steps, energy expenditure and average METs. Women needed more time and a higher number of steps to accomplish their distance than men ($p<0.05$). In addition, average energy expenditure was lower in women ($p<0.001$) while average METs was not significantly different between women (5.12) and men (5.19).

CONCLUSIONS

This study represents the first report on physical activity during prolonged walking. Results clearly show that physical activity depends on the walked distance (30, 40 or 50km) and that walking time, number of steps and energy expenditure are different between men and women.

O-4-3

USE OF AMBULATORY ACCELEROMETRY TO ASSESS THE SIT-TO-STAND MOVEMENT

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INTRODUCTION

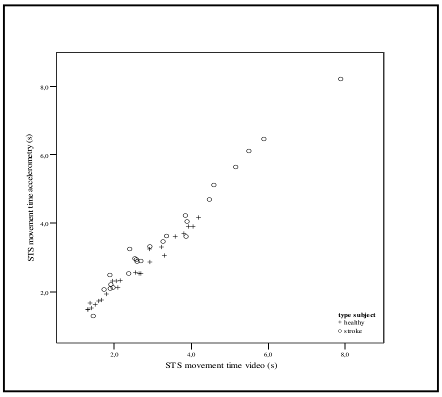
The Sit-to-Stand (STS) movement is an important skill and refers to the change in posture from sitting to standing. Body-fixed sensors, such as accelerometers, allow prolonged ambulatory measurements in a subject's own environment. Accelerometry is a method of interest for assessing STS movement outside a movement lab and/or during daily life, and it potentially provides data on the duration of this movement, balance control, and on the number of STS movements. The aim of the presentation is the provide examples of these possibilities in stroke patients.

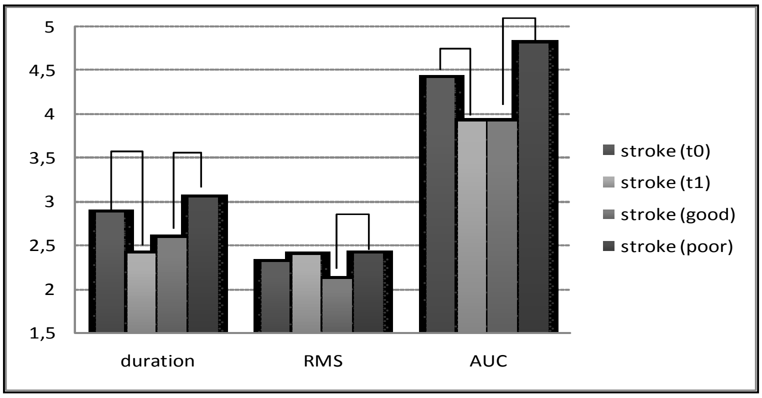
METHODS

Several studies were performed in which a Vitaport-based Activity Monitor (AM) has been used. This AM is based on body-fixed accelerometers, attached at the trunk (measuring in 3 directions) and upper legs (sensitive in the sagittal plane while standing). In study I (n=12) the validity of the AM was tested to quantify STS movement duration, based on the leg signal and the sagittal trunk signal. In study II (n=31) we studied its sensitivity to change and discriminative ability in assessing balance control, with additional data from the transversal trunk signal. The number of STS movements in daily life was one of the topics of study in a prospective longitudinal study (III) in 50 subjects with stroke.

RESULTS

In study I we found a close relationship and a strong agreement between the results of accelerometry and a reference method based on a video system [1]. (see Fig. 1) The transversal trunk signal appeared in study II to be able to discriminate between patients with poor and good balance control, and between patients in different phases of recovery (Fig. 2)[2-4].





In our prospective cohort study (study III), the number of STS movements increased from 11,0 (sd 11,9) / 8 hr shortly after stroke to 17,7 (sd 19,3)/ 8 hr 3 months after stroke and 16,6 (sd 13,6)/ 8 hr 1 yr after stroke.

DISCUSSION & CONCLUSION

Accelerometry is a promising technique to provide data on the quantity of the STS performance during daily life, but also quantitative data on the quality or movement pattern of the STS movement in a patients own environment. Further research is needed to provide insight into the capability of accelerometry to provide quantitative data on balance control during daily life facing environmental balance challenges. Its use is of interest for researchers evaluating daily life effects of disorders hampering the STS movement.

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O-4-4

PHYSICAL ACTIVITY IN DUTCH SCHOOL CHILDREN WITH CEREBRAL PALSY

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INTRODUCTION

Cerebral palsy (CP) is the most common disorder encountered in pediatric rehabilitation, resulting in impaired motor function and concomitant limitations in performance of daily life activities. As a result of their motor impairments children with CP are at risk for developing an inactive lifestyle. Low physical capacity levels are likely to develop as a consequence of inactivity, resulting in an even more inactive life. To avoid the appearance of such a vicious cycle, children should be encouraged to be physically active. The purpose of this study was to determine the daily physical activity by level of motor involvement and age in ambulant school children with cerebral palsy, and to investigate its relationship with lower limb muscle strength and anaerobic capacity.

METHOD

Eighteen children (5 girls) with CP who were all attending a school for disabled children participated in the study. They were aged 9 to 12 years, and were able to walk without walking aids (Gross Motor Function Classification System [GMFCS] level 1 [n=10] and 2 [n=8]). Six children had a unilateral involvement. Physical activity was measured with the StepWatchTM, an accelerometer that can be attached with a strap or elastic cuff to the ankle, and measures continuously the number of steps over time. StepWatch measurements have proven to be accurate in children with CP [1]. All children wore the StepWatch continuously for a period of seven days. Registrations of four or five complete days, including one weekend day, were analysed. The daily physical activity level was expressed as the total number of steps per day, percentage of time children were active at a moderate and high activity levels (%active), and percentage of time children were inactive (%inactive). Lower limb muscle strength was measured as the six repetition maximum on a leg press, and anaerobic capacity was measured in a 20-s full out sprint on a cycle ergometer.

RESULTS

Data of one child (11 yr old boy, GMFCS I) was omitted because only incomplete days were recorded. Analysis of the remaining 17 children showed a significantly higher total number of steps per day in children with GMFCS level I (4681±1425) compared to II (3445±1022, p=0.003), when adjusted for age. Older children showed a lower total number of steps per day (p=0.020). GMFCS and age explained 47% of the variance. For %active, GMFCS and age explained 49% of the variance, while no significant relationship was found for %inactive (p=0.081). A significant relationship was established between lower limb strength and %active (r=0.64, p=0.006), while only a trend was found for its relationship with anaerobic capacity (r=0.46, p=0.07).

DISCUSSION/ CONCLUSIONS

This pilot study shows that physical activity in ambulant Dutch children with CP, who are able to walk without walking aids, is related to the level of motor involvement, when adjusted for age. Results were in agreement with earlier findings in children with CP in the USA [1]. All calculated physical activity parameters were considerably lower than previously reported in healthy children [2]. Although step count is suggested to be indicative of level of physical activity in healthy children, it remains to be investigated to what extent this also accounts for children with CP, because an evident elevated energy expenditure is present in the latter group due to a reduced motor control. Future studies should further investigate the relationship between strength, anaerobic capacity and physical activity in a larger study group, addressing the question whether improved strength and anaerobic capacity will result in higher levels of physical activity.

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O-4-5

COMPLIANCE OF PHYSICAL ACTIVITY GUIDELINES IN A WORKING POPULATION USING AN OBJECTIVE MONITORING TECHNIQUE

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INTRODUCTION

In 2007 the American College of Sports Medicine (ACSM) updated their recommendations for physical activity [1]. The purpose of these guidelines is to give a "clear and concise health message". According to the ACSM the minimum amount of recommended daily activity in terms of walking is 30 min of brisk walking on five days of the week, which can be accumulated in bouts of 10 min. In this study, we surveyed the compliance with the guidelines of a working population over a week, using an objective activity monitoring technique.

METHODS

Participants were postal workers recruited from offices in Glasgow, UK. Each participant wore an accelerometer based free-living physical activity monitor (activPAL, PAL Technologies, Glasgow)[2], continuously for seven days. The ACSM defines brisk walking as walking at 6.4 km/h or 5 MET. According to Tudor-Locke et al. [3] this corresponds to a walking cadence of 123±4.9 steps/min. We selected a relaxed cadence threshold 10% below this mean value. Compliance with the physical activity guidelines was assessed in terms of the total time each day spent walking at or above that cadence threshold in bouts longer than 10 min. The duration criteria of the guidelines were then relaxed, assessing the total time accumulated per day, without any restriction on bout length.

RESULTS

We report on a subsample of 59 postal workers (10 f; mean age 40). None of the participants walked at or above the cadence threshold, for longer than 30 minutes, in bouts of at least 10 minutes on at least 5 days per week. Thus none of the participants met the ACSM recommendations for physical activity [1]. The maximum number of days on which the criteria were met was four (n=2), while 61% of participants (n=36) did not meet the criteria on any day of the week. Relaxing the criteria that walking should be accumulated in bouts of at least ten minutes, 25% (n=15) walked above the threshold cadence for an average of more than 30 min per day.

DISCUSSION

Compliance with the ACSM guidelines as they stand was non-existent in this sample. However, when we omit the restriction that brisk walking activity must be accumulated in bouts of 10 minutes, we found that one quarter of the population actually exceeded 30 minutes per day. This probably illustrates the issue that in an urban environment there are frequent events, such as stopping to cross a road, which require individuals to temporarily cease walking. This raises the question of what constitutes an acceptable short break in walking bouts, an aspect that is not considered by the current guidelines.

CONCLUSIONS

This study demonstrates that working individuals did not meet the recommended ACSM activity guidelines for walking, even though 25% of the participants accumulated a daily average of more than 30 min at a brisk pace. This highlights that individuals tended to walk briskly in bouts shorter than 10 min. There is a need for a clearer and more practical definition of what constitutes brisk walking in the guidelines to produce a truly "clear and concise health message".

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O-5-1

CHARACTERIZATION OF DYNAMIC PATTERNS OF POSTURAL SWAY USING ACCELEROMETRY

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INTRODUCTION

Recent studies on postural control have shown that variability of body sway during quiet standing contains valuable information to characterize changes in postural control by age, pathology, skill, and task difficulty. Increased regularity and decreased local stability and complexity of postural sway dynamics have been reported for a variety of pathological conditions including stroke patients [1], sport related contussio [2], Parkinson's disease [3], and children with Cerebral Palsy [4]. These changes are considered indicative of a less flexible and efficient postural control. In contrast, experts in balance skills, such as gymnastics and dancers, are characterized by less regular and locally more stable patterns sway patterns, which, in a similar vein, may be interpreted as indicative of a more efficient postural control and greater behavior flexibility. The presents study aims to examine, using accelerometry, if postural efficiency of three populations that differ only in terms of their athletic skills are characterized by qualitatively different dynamic patterns.

METHODS

Three groups of 22 subjects with different levels of athletic skill participated: regular students who did not participate in sport activities for more than 3 hours a week, physical education students pursuing a teacher degree and who were mainly involved in ball games, and students who were specialized in gymnastics. Body sway was measured with a tri-axial accelerometer (DynaPort®MiniMod, McRoberts BV, The Hague, The Netherlands) attached to the trunk near the centre of mass. Data were recorded during tandem stance with eyes open, eyes closed, and while standing on foam. Time series of anteriorposterior and mediolateral accelerations were analyzed. Differences in postural control were quantified by the magnitude of the variability, the mean power spectrum, and by studying dynamics patterns of postural sway using measures of regularity (sample entropy, long range correlations) and local stability (largest Lyapunov exponent).

RESULTS

A significant effect was found for condition; standing with eyes closed and on foam increased the magnitude of variability. Standing with eyes closed decreased regularity but increased local stability, whereas standing on foam had an opposite effect ($p < 0.001$) With more gymnastic skills accelerations of posture became less variable, less regular and more stable, indicating a more efficient postural control ($p<0.01$).

DISCUSSION

The results indicate that dynamic measures for quantifying acceleration patterns discriminate groups of subjects with different balance skill characteristics. This finding lends further support to current approaches in posturography that rest on the assumption that variability analysis in terms of the underlying structure offers tools that are capable of detecting subtle differences, i.e., due to task manipulation or skill, pathology, and learning history, and henceforth may be used for directing interventions.

CONCLUSIONS

Quantifying the dynamical structure of postural sway using an ambulant accelerometer based system can contribute to the development of a diagnostic measurement device that is capable of identifying and localizing loss of balance control in stance during controlled and daily life conditions.

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O-5-2
AUTOMATED QUANTIFICATION OF MISSTEPS AND NEAR FALLS: ALGORITHM DEVELOPMENT AND PRELIMINARY RESULTS

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INTRODUCTION

A new method for automatic detection of missteps is presented. While much research has been devoted to the automatic detection of falls, currently, most investigations of falls rely on self-report to determine fall frequency. This approach is far from ideal. For example, it suffers from a lack of objectiveness, relies on the memory of the subject, and typically requires long-term follow-up to obtain meaningful data. The long-term goal of the research is to develop a new approach to the study of falls by quantifying not just falls, but missteps (or near falls), measures that should serve as a sensitive and objective marker of fall risk.

METHODS

We examined the gait of 10 young adults and 5 community-dwelling elderly subjects. Subjects wore a tri-axial accelerometer (Dynaport, McRoberts Inc.) on the pelvis as they walked on a treadmill under fast, slow and normal paces. Missteps were induced by placing obstacles on the treadmill. Visual analysis and self-report were used to define missteps (i.e., loss of balance which did not produce a fall). 5 second epochs were examined. Measures included the maximum acceleration amplitude (Max), the maximum acceleration derivative (Maxdiff), the maximum peak to peak acceleration amplitude (Maxp2p)- defined as the difference between the maximum and minimum acceleration amplitudes, and the maximum peak to peak acceleration derivative (Maxp2pdiff)- defined as the difference between the maximum and minimum acceleration derivatives. We checked single and multiple parameter combinations for misstep indicators, the latter were checked for passing the threshold for all indicators (state "and"), and passing the threshold for at least one indicator (state "or").

RESULTS

We observed 21 misstep intervals (group 2), and 668 other intervals (group 1) consisting of 592 normal intervals, 18 stops, 30 stepovers (stepping over obstacles), and 28 kicks. We compared between group 1 and 2. The best "single parameter" indicator for a misstep was the vertical maxp2pdiff which had a sensitivity of 85.7% and specificity of 88.0%. The best 2-parameter indicator for an abnormal step was the "or" combination of the vertical maxp2pdiff along with the vertical max with sensitivity of 85.71% and specificity of 90.12%. All of the acceleration derived measures clearly showed higher values during a misstep.

DISCUSSION / CONCLUSIONS

Questions remain about the relationship of these acceleration-derived measures to falls and near falls, however, these preliminary results suggest that a tri-axial accelerometer can successfully identify abnormal steps, in particular a misstep. Quantification of missteps may reduce the time required to assess fall risk and also has the potential for improving the objective evaluation of this important clinical outcome.

O-5-3

A FALL DETECTOR INCORPORATED INTO A CUSTOM VEST FOR THE ELDERLY

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INTRODUCTION

Falls in the elderly are a major problem for society. On average, one in every three adults, 65 years old or older, falls each year [1]. A serious consequence of falling is the "long-lie", this is remaining on the ground or floor for more than an hour after a fall [2]. The long-lie is a marker of weakness, illness and social isolation and is associated with high mortality rates among the elderly [1]. A fall detection system and algorithm, incorporated into a custom designed garment has been developed which will automatically detect falls and potentially reduce the incidence of the "long-lie".

METHODS

A fall detection system consisting of a tri-axial accelerometer, microcontroller, battery and Bluetooth module was developed. This sensor is attached to a custom designed vest, designed to be worn by the elderly person under clothing. The fall detection algorithm was developed using research carries out by Bourke et al [3]. In the algorithm, the subject's orientation is also monitored to determine if a fall followed by a "long-lie" had occurred. The vest was developed using feedback from elderly subjects donning, wearing and doffing a prototype vests and subsequently filling in a questionnaire. The re-designed vest and fall algorithm was tested using young healthy subjects performing normal activities of daily living (ADL) and falls onto crash mats, while wearing the vest and sensor. The full system was later tested using 8 elderly subjects wearing the system over the course of 2 weeks, for 8 hours a day. Two teams of 4 elderly subjects wore the sensor system for 1 week each.

RESULTS

Results from the young health subject's, show that falls can be distinguished from normal activities with a sensitivity of 98.75% and a specificity of 98.6%, from a total data set of 240 falls and 150 normal ADL. Over 380 hours of monitoring was recorded over the course of the two weeks from the elderly subjects during normal daily activity. In this time no actual falls occurred, however the system registered a total of the 19 false positives.

DISCUSSION

Through incorporating the fall sensor into a vest that can be worn by the elderly, it is considered that greater compliance with wearing and using a fall detection system will be achieved. During the long term trial involving the 8 elderly subject's, 19 false positives occurred. This indicated that further development of the fall-detection algorithm is required. Also following feedback from the elderly subject's further development of the vest is required to make it more comfortable, breathable and easier to don and doff. Further development of the system will include a more accurate fall-detection algorithm, more comfortable vest, lighter and smaller sensor as well as, mobility monitoring and energy expenditure measurement.

CONCLUSIONS

A fall detection system incorporated into a custom designed garment has been developed which will help reduce the incidence of the long-lie, when falls occur in the elderly population.

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O-5-4

LONGITUDINAL BIOMARKERS OF STANCE POSTURE AND GET-UP-AND-GO PARAMETERS IN PARKINSON'S DISEASE

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INTRODUCTION

Clinical trials of neuroprotective interventions for Parkinson's disease (PD) are lacking accurate, quantitative biomarkers for longitudinal testing of posture and gait that are sensitive to change, even in early stages of the disease. An expert, consensus workshop in Portland predicted that inertial sensors could be used to identify stable and sensitive parameters characterizing postural sway, postural transitions, and gait parameters in untreated PD.

METHODS

Thirteen, untreated subjects with PD (UPDRS motor 23.2 ± 10.6) and 13 age-matched controls (61 yrs old) were tested at baseline, 3-, 6-, and 12-months. A Physilog® portable data-logger [1] with 7 inertial sensors (on chest, forearms, thighs and shanks) recorded three trials of an extended, 6-meter, Get-Up-and-Go task to automatically identify postural transitions (sit-to-stand, turning, stand-to-sit) and gait parameters with and without a cognitive task (counting backwards by threes). An Xsens portable data-logger with 3 inertial sensors (on C-7, L-5, and thigh) recorded 2-minute trials of quiet stance with eyes open, eyes closed, and eyes closed with the cognitive task.

RESULTS

Subjects with early PD showed increased postural sway variability, at higher frequencies, with less smoothness than controls during quiet stance. Although the total Get-Up-And-Go time did not differ between groups (17 vs 15 sec), subjects with PD showed slower turning velocities, slower cadence, slower arm swing speed and arm asymmetry, and longer duration of sit-to-stand. Posture and gait differences between subjects with PD and controls were not increased with eyes closed or a secondary cognitive task. Differences between groups in all parameters were stable or increased across time as PD progressed.

DISCUSSION

These studies show, for the first time, that linear accelerations at the waist can substitute for forceplate measures to quantify postural sway in stance and that even subjects with early PD show postural sway abnormalities. Our new, automatic algorithm to quantify performance of the GET-UP-AND-GO task also identified several sensitive biomarkers for early deficits in parkinsonian gait and gait transitions. We found that even an early stage of PD is associated with measurable differences in posture and gait but without effects of dual task interference.

CONCLUSIONS

Inertial devices can provide accurate, stable, sensitive biomarkers for longitudinal testing of posture and gait in untreated PD. Current clinical scales of parkinsonism are not sensitive to problems with balance and gait so inertial devices can provide important, quantitative measures using simple tasks in the clinic or home such as standing still with eyes open and getting out of a chair, walking, and turning.

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O-5-5
THE USE OF WEARABLE INERTIAL DEVICES TO DETECT POSTURAL CHANGES IN EARLY PARKINSON'S DISEASE

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INTRODUCTION

While several studies have shown that subjects with advanced Parkinson's disease (PD) exhibit abnormal sway during quiet standing [1], abnormalities of postural sway associated with early symptoms of PD have not been reported. Measures provided from inertial sensors mounted on different body segments can, in principle, represent a good tool to quantify spontaneous, multisegmental body sway and to disclose slight changes in postural coordination. We hypothesized that inertial devices could provide sensitive measures of postural function in early PD.

METHODS

We examined 12 PD and 12 healthy, age-matched control subjects. PD subjects were newly diagnosed and were not taking any medications. Two-minute trials were performed with subjects staying on a force platform (AMTI). Three conditions were evaluated: eyes open, eyes closed, eyes closed with a concurrent cognitive task consisting in counting backward aloud in multiples of seven. Subjects wore 3 MTX Xsens (49A33G15) sensors, mounted with Velcro belts laterally on the thigh, and in the middle of the posterior trunk, at the levels of L5 and C7. We evaluated multisegmental sway (sway area and jerk) and compared the information provided by inertial sensors and the force platform.

RESULTS

Smoothness of lower trunk and leg displacements is clearly compromised in early PD compared to controls in all conditions tested, while it is not compromised at the cervical level. Mean sway amplitude at the trunk and legs is also larger in PD than controls during quiet standing with eyes open. Visual deprivation and dual task induced a significant increase in sway amplitude and increase in variability in all sway parameters in both groups.

DISCUSSION / CONCLUSION

Our results confirm that postural control is affected in early PD and show that postural sway is more compromised at the thigh and lower trunk than at cervical level. It seems that even simple conditions as eyes open, without the need of a Visual deprivation or of a concurrent cognitive task, reveal changes in body sway associated with early stages of PD. Wearable inertial sensors provided sensitive measures of postural alterations in early PD and added new insight into multisegmental posture control, compared to traditional force platform posturography. Inertial sensing of quiet stance posture will facilitate posturography measures in the home and clinical environments.

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O-6-1

VALIDATION AND APPLICATION OF INCLINOMETERS (TRIAXIAL ACCELEROMETERS) FOR MEASURING POSTURES AND MOVEMENTS AT THE WORKPLACE

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INTRODUCTION

Extreme and constrained postures, as well as repetitive movements, are known risk factors for work-related musculoskeletal disorders. In this field there is an urgent need for valid quantitative exposure data. For performing whole-day recordings at the workplace we have developed systems, comprising body-mounted transducers, dataloggers and software, for electromyography, goniometry and inclinometry. This abstract presents inclinometry applied to the head, upper back, neck and upper arms.

METHODS

Inclinometers (i.e. triaxial accelerometers) were built from uniaxial accelerometers [1]. We developed a software for: (1) calibration of the individual accelerometers; (2) transformation of the co-ordinate system from that of the inclinometer to that of the body segment; (3) transformation of the acceleration vector from Cartesian to spherical co-ordinates; (4) calculating of forward/backward and sideways angles; (5) deriving forward/backward and sideways angular velocity, as well as a generalized angular velocity.

(A) To evaluate the accuracy and precision of the inclinometers, they were tested, in a jig [1].

(B) To evaluate the between-days and between-subjects variation, six women performed three standardized tasks, all of them repeated on three different days [2]. Variance components were derived for the 10^{th}, 50^{th} and 90^{th} percentiles of the angular and the angular velocity distributions.

(C) To elucidate the variety in exposure, postures and movements were recorded for the head, upper back, neck and upper arms, for more than 40 various types of work, as well as breaks. On average, the recording duration was 2.5 hours and 10 subjects were recorded for each type of work.

RESULTS

(A) The angular error of the system is small (1.3°), the reproducibility is high (0.2°), and the inherent angular noise is small (0.04°), and independent of the orientation of the body segment. Under quasi-static conditions, the angular velocities can be derived from the inclinometer data.

(B) For angles, the average between-days variability was 3.4°, and the between-subjects variability 4.0°. For velocities, the between-days variability was 8% and the between-subjects variability 22%.

(C) There was a great contrast, for both postures and movements, between different types of work, even within categories, as e.g. "repetitive industrial work".

DISCUSSION / CONCLUSIONS

Rotation round the line of gravity can not be recorded by inclinometry. Three (not two) orthogonally mounted accelerometers are required to obtain a low angular error that is independent of the orientation of the body segment. Recording of a reference position, and a position indication the forward direction, enables a co-ordinate transformation to the co-ordinates of the body segment, which permits an arbitrary mounting of the transducer. Spherical co-ordinates, e.g. inclination/elevation of the upper arm, and the forward/backward and sideways angles for the head, facilitate the presentation and interpretation of the data. During dynamic conditions, the acceleration in the X, Y and Z directions are still valid, while an error may be introduced when data are interpreted as inclination. The relative angle between two body segments can be derived; e.g. neck flexion as head minus upper back flexion. Measures, characterizing the variation over time, in postures and movements, may be derived. Inclinometry provide valid and essential data.

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O-6-2

DIRECT MEASURES FOR EXPOSURE ASSESSMENT OF MSD PHYSICAL RISK FACTORS FOR COMPUTER USERS

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INTRODUCTION

Prolong duration of computer use is the most consistent risk factor identified for computer-related musculoskeletal disorders; however, there is strong evidence supporting postural components. (Gerr et al., 2006). There is debate among researchers and practitioners whether simple static postures or the more dynamic repetitive motions are associated with MSD outcomes. For example, Serinia et al. (1999) measured in the laboratory setting that the velocities and accelerations of the wrists were similar to those observed in high risk industrial jobs. Unfortunately, little field data exists on the direct measures of dynamic components due to the complex nature of the direct measures. Therefore, our goal is describe a field system and present preliminary data combining our direct measures of posture with our direct measures of computer activities to estimate the dynamic components associated with computer users.

METHODS

We have developed a system that continuously and directly measures wrist posture, keyboard typing force, and mouse grip force. We utilize a portable data logger and electrogoniometers for wrist posture, a custom designed strain-gauged force plate to measure typing forces, and a modified MicroSoft mouse with embedded strain gauges to measure the forces of the thumb. In the laboratory we measured 30 subjects to determine the difference in wrist dynamics between keyboard and mouse intensive tasks. The wrist posture was recorded at 20 samples per second and were then filtered and digitally differentiated to determine wrist velocity and acceleration values.

In addition we have developed an integrative program that directly measures the duration and characteristics of each keystroke, mouse movement, and mouse button activation. In the field, we measured the mouse and keyboard usage patterns of 20 office workers for a half day (four hours). From the directly measured keyboard and mouse activities we determined the duration of mouse, keyboard and computer usage for these 20 office workers and then calculated a time-weighted average for the acceleration of the wrist during the observational period.

RESULTS & DISCUSSION

Wrist accelerations were significantly higher during keyboard activities (291 deg/s/s) compared to mouse activities (67 deg/s/s). See Dennerlein and Johnson (2006) for details. A range of mouse and keyboard use existed among the 20 field participants (Figure 1). The calculated time-weighted averages for wrist acceleration were not strictly co-linear with computer duration (Figure 2). These data suggest that the variability of computer duration and of the dynamic component can be considered potential independent factors in the epidemiology of computer risk factors, thus providing an opportunity to explore hypotheses related to static and dynamic postures and MSD outcomes.

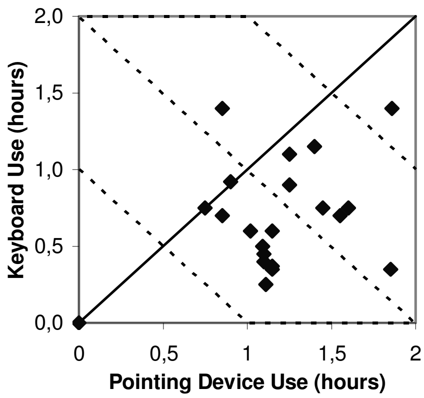

Figure 1: Usage duration patterns (N=20)

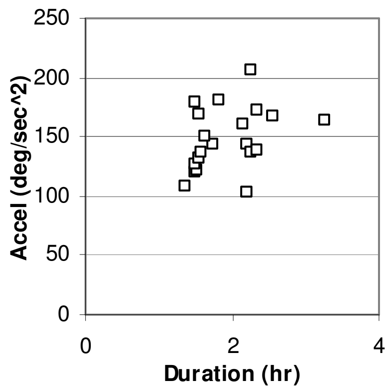

Figure 2: Wrist acceleration values (N=20)

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O-6-3

THE ABILITY OF COMPUTER ACTIVITY RECORDINGS TO ESTIMATE MECHANICAL EXPOSURES DURING OFFICE WORK

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INTRODUCTION

The monotony and lack of variation in computer use have been associated with the occurrence of musculoskeletal disorders (CANS) at the workplace [1]. Thus, in order to reduce the risk of complaints, interventions often focus on introducing pauses. The efficacy of such an approach relies on the assumption that physical exposure during pauses is different from exposure during computer work. This assumption has however never been tested rigorously. In this study we assessed whether there were indeed differences in exposures during episodes of computer and non-computer use. To this end we compared activity of arm and shoulder muscles across a working day. Computer and non-computer work episodes were identified by implementing a temporal criterion (threshold) that specifies the amount of time two subsequent computer events can be separated, while the time in between is still classified as continuous computer work [2]. By varying the threshold we were able to compare exposures using both strict and lenient criteria. Specifically, we calculated the threshold for which the exposure contrast was maximal. This parameter is important since it represents the time span over which muscle EMG during computer work is most dissimilar from EMG during non-computer work.

METHODS

Fifteen office workers with non-specific CANS and 15 gender-, age- and job-matched controls were measured during a normal working day performing their normal work tasks at their own work station for at least 5 hours. Usage of input devices was measured using registration software, while a telemetric system recorded activity from wrist extensor and flexor and trapezius on both sides of the body. EMG data was filtered and down-sampled to 8 Hz, normalized to a sub-maximal reference load and synchronized (off-line) with the registration software. Computer and non-computer work episodes were identified using temporal thresholds, ranging from 2 to 960 seconds. EMG activity was averaged across all work and non-work episodes and compared using a contrast measure [2]. The (threshold of) maximal exposure contrast was calculated per muscle and subject. Median values and interquartile ranges (IQR) across all subjects and subgroups (CANS versus non-CANS and different job functions (secretaries, researchers, managers) were calculated, as well as one-way ANOVA's to test for differences between subgroups and muscles.

RESULTS

For all thresholds mean exposure (EMG) during non-computer work was higher than exposure during computer work. Consequently, the highest exposures during computer work were found at the highest threshold. The thresholds at maximum contrast (averaged over body sides) were 8.5, 9.3 and 15 seconds for extensor, flexor and M. trapezius respectively (IQR 124, 85 and 43 sec, differences were non-significant). Contrast values between computer and non-computer episodes (possible range: 0-1) were low. Across muscles the averaged maximal values ranged between 0.03 and 0.07 (IQR range 0.02-0.08). Small but significant differences existed in threshold and contrast values between subgroups.

CONCLUSION

For office workers, very low contrast values were found between computer work and non-computer work. This indicates that physical exposure during non-computer work (including pauses) is quite similar to physical exposure during computer work. This might explain the finding that only limited evidence was found for the effectiveness of adding breaks to computer work for treatment of CANS [3].

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O-6-4

MYOTEL: ADRESSING MOTOR BEHAVIOR IN NECK SHOULDER PAIN BY ASSESSING AND FEEDBACK SEMG IN THE DAILY (WORK) ENVIRONMENT

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INTRODUCTION

Subjects with chronic pain differ in motor behavior especially with a decreased ability to relax their muscles. As subjects are often not aware of this, feedback on the absence of muscle relaxation during daily activities might be of potential. A myofeedback system has been developed that assesses muscle relaxation in an ambulant way during daily activities and provides continuous feedback to the subject. Positive effects were shown in several studies in subject with neck-shoulder pain[1]. To improve access to the service and increase its efficiency, the system was further developed into a tele-treatment system (RSMT). With this system, subjects can view their muscle activation patterns on a PDA. Besides, the PDA automatically sends the data via GPRS to a secured sever, which is remotely accessible for the therapist, anytime and anywhere. This enables remote (e-)counseling. The objective of this study was to examine the RMST on technical efficacy for clinical use and explore changes in clinical outcome.

METHODS

Ten female workers suffering from work related neck-shoulder pain participated. Subjects received the RMST for four week. In addition they noted their activities and pain intensity. Weekly counseling sessions of 30 min with a therapist took place. Technical efficacy for clinical use was assessed by logging technical failures of the system and examining the hours of sEMG data available at the server. A questionnaire, based on the Technology Acceptance Model, was used to assess satisfaction. Clinical outcomes used were pain and disability.

RESULTS

Results show that in 78% sufficient sEMG data during daily activities were available at the server to make an assessment of muscle activation patterns. Subjects reported high satisfaction with the usefulness and ease of use of RMST. However, they were less satisfied with the technical functioning of the system. Eighty percent of the subjects reported a reduction in pain intensity and disability directly after RSMT.

DISCUSSION / CONCLUSION

The RMST was technically feasible, subjects were satisfied and the clinical changes tended to be slightly better compared to myofeedback provided *in vivo*. Nevertheless, the technical performance and the ease of use need to be optimized. Further evaluation, which will be performed in 4 different countries in the E-ten MyoTel project (www.myotel.eu), should be large scale clinical trials with outcomes defined on multiple endpoints like quality and costs.

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O-7-1

A COMPARISON OF DIFFERENT FEATURE GENERATION METHODS IN ACTIVITY CLASSIFICATION

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INTRODUCTION

Techniques for recognising activities from acceleration data normally operate with short windows of sensor data which are characterised by a small number of features. Previous studies have employed a wide range of features, from simple descriptive statistics, to frequency domain measures and, more recently, wavelet-derived parameters [1]. However classification accuracy can be strongly influenced by the choice of features. Therefore, this study aimed to compare classification accuracy between a number of different feature generation methods. Furthermore, as accuracy can also be influenced by the attachment site, a comparison was also made between three different accelerometer placements.

METHODS

17 subjects (mean BMI=23.4) took part in the experiment. Each subject performed a range of activities which included walking, stair ascent/descent, jogging, running, hopping and jumping. Tri-axial accelerometer data was collected using three separate units, mounted on the sacrum, thigh and ankle. Following collection, the data was segmented into two-second consecutive blocks, each associated with a particular activity. A range of features were then derived to characterize each block of data, including simple statistical measures, spectral measures and five different wavelet methods. For each feature generation method, a nearest neighbor classifier was constructed and cross validation used to determine the between-subject classification accuracy. This process was repeated for each accelerometer and for different accelerometer combinations.

RESULTS

Classification accuracies varied considerably across the different feature generation methods and for the different accelerometers. On average the frequency-based methods performed best (61-99%), followed by the simple statistical methods (66-92%) with the wavelet-derived features giving the lowest classification accuracy (29-59%). In general the ankle-mounted accelerometer outperformed the thigh and sacrum-mounted units for the simple statistical measures but the sacrum-mounted unit performed better with the wavelet methods.

DISCUSSION

Wavelet techniques have been used successfully to determine transition times between different activities [1]. However this study showed that wavelet-based features may be less effective for activity classification than standard frequency-domain features.

CONCLUSIONS

The results of this study suggest that good classification accuracy can be obtained using simple descriptive statistics or simple FFT coefficients to characterize accelerometer data. Furthermore, in some applications, classification accuracy may be improved by using an ankle mounted sensor.

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O-7-2

ACTIVITY MONITORING IN TRANSFEMORAL AMPUTEES: ADDED VALUE OF POPULATION-SPECIFIC SETTINGS

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INTRODUCTION

Activity monitoring (i.e. detection, classification and measurement of movement for long periods in non-specific environments) in leg amputees could provide information not only on the subject's general mobility status, but also on the effectiveness of prosthetic interventions. While previous studies demonstrated the feasibility and validity of the detection and classification of physical activities in the daily life in subjects with a transtibial amputation [1], in this study we examined the added value of modifying pre-set settings in the analysis software in subjects with an amputation at the transfemoral level.

METHODS

Signals coming from 4 uniaxial accelerometers, 2 on the trunk and the others on each upper leg, were stored on a Vitaport 3 recorder. The recorded data was analyzed by a classification algorithm, based on angular, frequency and motility features derived from each accelerometer [2], which provides an estimate of the subject's motor activity, identifying postures and a number of major movements. 10 subjects with transfemoral amputation enrolled in the study. The instrument was applied to the subjects that were asked to perform a test track (comprising walking, stair climbing and descending, sitting and standing). An operator was following the subjects while videorecording their performance. The recorded data were analyzed with 1) the standard Knowledge Base (KB), containing the pre-set settings for posture and motion detection, and with 2) the modified KB, containing modified settings based on data from a previous study [3], but taking into account the side of the amputation

The accuracy of the motor identification process was determined by comparing the video recordings and the output of the automatic classification procedure based on the standard and modified KB.

RESULTS

		Correct classification %	
	Video (s)	Standard	Modified
Sitting	793	95.8	99.0
Standing	879	97.6	99.8
Walking	2455	80.9	99.0
Climb	374	72.5	99.2
Descend	249	67.5	93.6
Unclass.	-	17.1	1.9

The table presents the classification performance of the standard and modified procedure in detecting 5 main postures/activities; in the first column are their durations, as determined by video recordings, which have been used as reference. It is also presented the amount of motor activity/posture that the procedure was unable to classify in any category.

DISCUSSION

The modified KB leads to a considerable improvement in the detection of body postures and movements. Especially the settings related to the angular feature of the legs were markedly different between the standard and modified KB.

CONCLUSIONS

The results indicate that adapting the pre-set KB settings improves the validity of posture and movement detection. This suggests that creating population-specific KB's is demanded, especially in cases of strongly altered motor patterns.

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O-7-3

GAIT ASSESSMENT SYSTEM OF THE ELDERLY USING PORTABLE ACCELERATION MONITOR DEVICE

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INTRODUCTION

Now most advanced countries has become an aging society, and it is worried about how to keep health of the elderly. In this study a portable gait assessment system with a triaxial accelerometer has been developed [1] and its application for a quantitative assessment of gait in the elderly was examined.

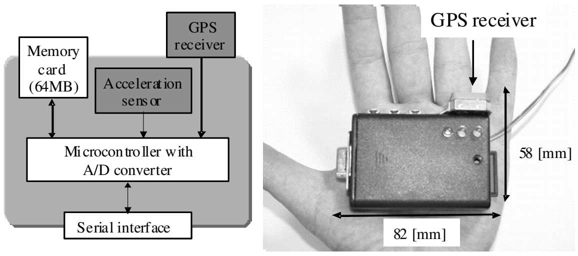

Fig.1 Portable physical activity monitoring unit

METHODS

The portable device was fixed to the lower back of the subject, and the subject was asked to walk around a test course at a voluntary speed. The activities performed on the test course include standing up, normal walking, fast walking, and walking over a barrier. Subjects are 402 elderly people (78.2±8.5 yo) of 20 facilities in Shimane Pref., who have received long-term care insurance services and they were under nursing health services, such as expert place nursing, walking training, power rehabilitation, fall prevention training, and pool training. Gaits in these elderly people were measured three times every three months. The measured acceleration was converted into relative velocity and relative displacement of the center of gravity.

Four evaluation indices, i.e., physical activity, stability, symmetry, and average speed were calculated; the 1st index is the average walking velocity. Here walking distance is fixed to 5 m, information from the acceleration sensor was used to decide the start and stop time. The 2nd index is the stability, and this index was calculated as the ration between average displacement amplitude during straight walking and walking over barriers The 3rd index is the energy consumption. The 4th index is the symmetry of right and left step. if the subject is suffered from stroke or hemiplegia, he/she is expected to show asymmetry. To get this symmetry autocorrelation of acceleration waveform of up/down direction was calculated and symmetry was calculated as the ration between 2nd and 3rd peak of the autocorrelation function.

RESULTS

Fig. 2 shows a part of monitoring results; walking speed of the elderly has decreased with the passage of time. Stability deteriorated with the required nursing level. The groups of needing care level 1 and 2 have decreased the energy consumption. There were some groups that symmetry had improved. The results reveal that both the stability and walking speed decreased after six months under nursing services.

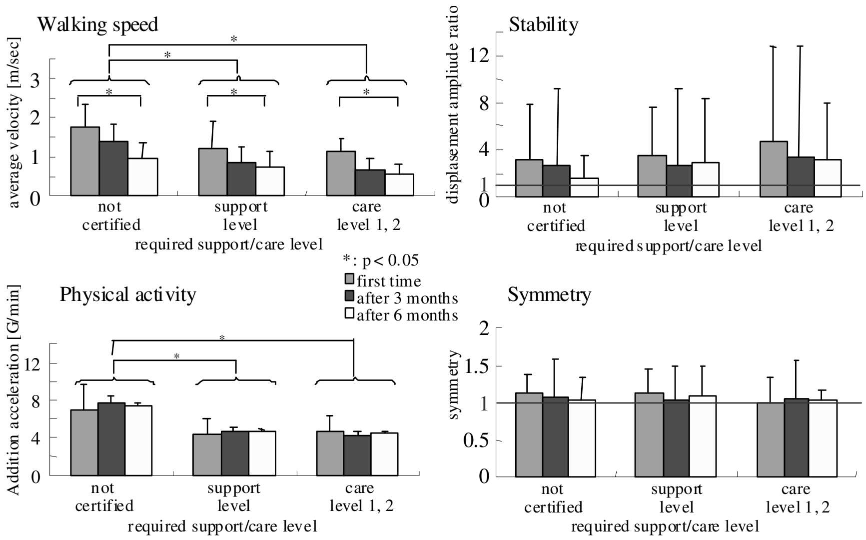

Fig.2 Change in gait abilities of the elderly at each support/care level.

DISCUSSION & CONCLUSIONS

In this study we tried to get some parameters of physical activities by an acceleration sensor, that is, the energy consumption, a trajectory of human body center of gravity and walking velocity. Besides these parameters walking pitch can easily be detected and also rough behavior, like standing, walking, running, getting on a vehicle or lying can be identified from the acceleration data.

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O-7-4
CONTINUOUS RECOGNITION OF DAILY PHYSICAL ACTIVITIES USING A SINGLE TRIAXIAL ACCELEROMETER

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INTRODUCTION

Providing people with their daily physical activity information, such as activity types, durations and intensities, can help to maintain a proper physical activity level so as to prevent chronic diseases and unhealthy conditions having correlation with inactivity. This paper reports the first results of a feasibility study on activity recognition using body acceleration data [1] collected with a single triaxial accelerometer and under unsupervised and naturalistic conditions. Recognition is performed on continuously recorded data traces instead of isolated activity events, which brings it closer to a practical use. The work is part of the healthy living program, developed by New Wellness Solutions (NWS), based on the combination of the Tracmor sensor (triaxial accelerometer of Philips Research [2]) and a web-service where people can monitor their own physical activity levels and get personalized feedback and coaching.

METHODS

12 healthy subjects (7 male and 5 female) were asked to wear the Tracmor on the lower back for ~24 hours (from noon to noon not during sleeping), so that their normal daily activities could be continuously recorded. An activity diary was requested as well for the purpose of validation. Walking, running, cycling, driving and sport activities (such as football, table tennis) were chosen as target activities for recognition since they are typical daily activity types and largely related to physical activity levels. The data were offline processed by the continuous activity recognition (CAR) algorithm developed based on a decision tree. The subjects were split into two groups: 9 in the group A and 3 in B, and the classifier employed in CAR was trained with a set of labeled activity segments sampled from the data of A. The performance was evaluated by applying CAR on the continuous 24-hour data traces of A and B respectively, which indicated the recognition capability of the algorithm on known subjects but unknown data, as well as on completely unknown subjects.

RESULTS

For the evaluation on A, both recall and precision rates exceeded 80%, among which for running and cycling recalls and precisions of >90% were reached. For the set B, no running and sport were reported by the algorithm in accordance with a zero occurrence of these two in annotation; the lowest recall (69%) was seen in walking, and for the rest at least a recall of 77% was obtained; the precision rates were all above 82%. Among misclassified activities, substitutions were hardly observed, deletions and insertions in most cases were <10%, and the rest was from under- or over-filling (under- or over-estimating of duration).

DISCUSSION

Recognition worked well on unknown data of known subjects in A, and dropped in performance on unknown subjects data in B, mainly in recall (by ~10%). The drop, however, was largely attributed to under-filling and over-filling that are considered as less severe misclassification types compared to others, especially in event-based activity recognition. Misclassified activities may result from too short durations for a chosen time resolution (e.g., in walking), high complexity and diversity (e.g., for sport), disturbances from uninterested activities in continuous data traces, and etc.

CONCLUSIONS

A continuous activity recognition (CAR) algorithm was developed, using data measured by a single waist-mounted traxial accelerometer. With negligible substitutions and limited deletions and insertions, the results of CAR indicated a good feasibility of recognizing activities from continuous real life data. Future work will be carried on for further improving its recognition performance towards a real implementation.

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O-7-5

IMPROVED ESTIMATION OF STARTING TIMES OF HUMAN ACTIVITIES USING HIDDEN MARKOV MODELING BASED ACTIVITY CLASSIFICATION?

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INTRODUCTION

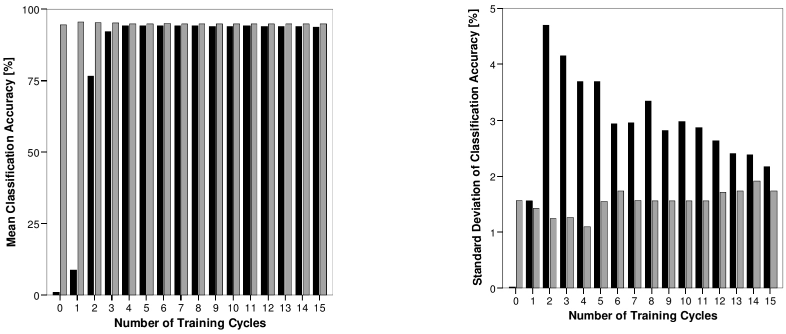
Automated classification of human activities should help the researcher, or the physician, with the interpretation of data, as it will automatically label, or subdivide, large quantities of data. In a previous study, a novel activity classifier based on Hidden Markov Models (HMMs) was successfully implemented and tested on ambulatory obtained of human activities [1]. However, the estimated starting times of the activities were not accurate. Here, the addition of timing information to perform isolated activity training as initialization of the HMMs is proposed to more accurately estimate the starting times of activities.

METHODS

Acceleration and angular velocity data was collected at 25 Hz with sensors attached to the subjects back at the level of the S4 and the C7 vertebrae. The subject was directed through an alternating series of activities, consisting of four different ways of lifting a crate (from left, from right, stooping and squatting), putting the load down, walking, standing and sitting. Five measurements of ~10 minutes containing ~120 activities were registered. In a time consuming process a description file, containing the activities and the accompanying starting times, was created by hand. 30 minutes of data and the description file were used to train 5-state forward connected HMMs over 15 training iterations. The HMMs were initialized using isolated activity training. Training and testing set were chosen five times from the 5 measurements. Classification accuracy and estimated starting times of the resulting activity classifier were compared with the classification accuracy and estimated starting times of the original activity classifier.

RESULTS

Initialization with isolated activity training did not significantly influence classification accuracy. However, good classification performance was already achieved with no additional training (Fig 1). Furthermore, the standard deviation of the resulting classification accuracy was almost twice as small after 5 training cycles. Decrease in error of the estimated starting time of activities was achieved. Without initialization the absolute estimation error was 619 ± 1041 msec. Initializing the HMMs resulted in an absolute estimation error of 212 ± 206 msec.



Figuur 1: Mean classification accuracy (left) and standard deviation of the classification accuracy (right) of the activity monitor per training cycle. Light bars are the results of the initialized activity monitor, dark bars of the plain activity monitor.

DISCUSSION/ CONCLUSIONS

Increased preparation time before the activity monitor can actually be trained is a drawback of the proposed method. All starting times have to be manually labeled. On datasets of 30 minutes this involves 360 activities. Major advantage is gained regarding the estimated starting times of activities. Classification accuracy does not increase. Therefore, isolated activity training is only advised if an estimation of the starting times of activities are required as an output of the activity classifier.

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O-8-1

RESTING HEART RATE IMPROVES ENERGY EXPENDITURE PREDICTION FROM ACCELEROMETER COUNTS

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INTRODUCTION

Given the high cost of doubly labelled water, other field techniques are being applied to estimate free-living total energy expenditure (TEE). We recently reported that the tri-axial accelerometer for movement registration (Tracmor) explained 83% of the variation in doubly labelled water assessed TEE using body weight, height, age and counts. The combination of heart rate (HR) registration and accelerometry has been proposed to improve estimates of energy expenditure. Here we investigated whether HR in addition to accelerometer counts contributes to the prediction of energy expenditure.

METHODS

29 healthy subjects between the ages of 18 and 40 wore the Tracmor for 15 consecutive days. Tracmor output was summed for the three axes and was defined as activity counts per day (ACD). Heart rate was registered simultaneously over 1 week. Average HR was calculated and resting HR was defined as the lowest HR observed. TEE was measured with the doubly labelled water method. Sleeping metabolic rate (SMR) was measured during an overnight stay in a respiration chamber and activity-related energy expenditure (AEE) was calculated as [(0.9 x TEE) - SMR].

RESULTS

Using multiple regression analysis with backward selection, average HR or HR above resting (HR-resting HR) did not improve the explained variation in TEE or AEE based on body weight, height, age and ACD as independent variables. However, using the same subject characteristics, resting HR was negatively correlated with AEE and TEE and increased the explained variation from 81% to 84% and from 83% to 85% for AEE and TEE respectively.

DISCUSSION

Not average but resting heart rate was related with AEE and TEE. Resting heart rate is related to physical fitness with a high resting heart rate corresponding with low physical fitness. The observed negative correlation suggests a higher TEE for fitter subjects, presumably because of a higher physical activity.

O-8-2

PHYSICAL ACTIVITY ENERGY EXPENDITURE OF SEDENTARY ADULTS VIA HEART RATE, ACCELEROMETRY AND A BRANCHED ALGORITHM

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INTRODUCTION

Devices that measure both heart rate and accelerometry are currently used to estimate physical activity energy expenditure (PAEE) [1]. Recently, branched analytic techniques have been used to improve the accuracy of these PAEE estimates [2]. The purpose of this study was to assess the accuracy with which heart rate, accelerometry and a branched algorithm (BA) can estimate PAEE within a sedentary population.

METHODS

Sedentary men (n=8) and women (n=8) performed a treadmill calibration protocol, during which heart rate (HR), accelerometry (ACC), and PAEE were measured. HR-PAEE, and ACC-PAEE regressions were then used in each of five analytic models to predict PAEE from ACC and HR data collected during a subsequent daily-living protocol. PAEE was measured during both the calibration and daily-living protocols via indirect calorimetry. The root mean square error (RMS) between model-predicted daily-living PAEE, and measured daily-living PAEE, was taken to indicate the accuracy achieved by each of the five analytic models.

RESULTS

Among both men and women a post hoc optimized BA best predicted criterion PAEE, with group calibration resulting in improved precision vs. individual calibration. The RMS indicated error was 13% of the mean PAEE among women and 17% among men. When BA parameters that had been post hoc optimized for women were applied to the men's data, and vice versa, the branched algorithm still outperformed (RMS = 24-34% of mean PAEE) simple regression models.

DISCUSSION

Post-hoc optimized branched algorithms appear superior to other popular analytic techniques for predicting PAEE from HR and ACC. Further, branched algorithm analyses involving group calibration are more accurate than analyses involving individual calibration – a characteristic that affords the branched technique greater applicability than other analytic models.

CONCLUSIONS

Our findings demonstrate that simultaneous measurement of HR and ACC, analyzed with an optimized branched algorithm, improves prediction of free-living energy expenditure among sedentary adults. Additionally the process of algorithm optimization does not exhibit marked sex-specificity among sedentary men and women.

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O-8-3

VALIDATION OF SENSEWEAR ARMBAND DURING WHEELCHAIR PROPULSION

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INTRODUCTION

Wheelchair users are at risk of developing a hypoactive lifestyle, with possible detrimental effects on physical capacity. There is a need for a valid and easy-to-use device that can monitor energy expenditure of wheelchair users accurately. Several accelerometry-based activity monitors have been developed to assess daily life activity and its use in clinical research has increased exponential. The Activity Monitor (AM) has proven to be a valid instrument to provide objective information on quantitative aspects of mobility-related activities, including wheelchair propulsion [1]. This device consists of several sensors and a portable data recorder around the waist, which makes it cumbersome and unnatural to wear continuously. SenseWear Armband (SWA) is a valid instrument to assess energy expenditure of able-bodied persons during several forms of exercise [2]. SWA is a small device that is easily applicable, but its validity during wheelchair propulsion is unknown.

METHODS

10 healthy subjects (6 males, 4 females) were recruited. Each subject performed 6 tests, which consisted of wheelchair propulsion on a treadmill at different workloads (dependent on angle and speed). During the tests, SWA registered continuously energy expenditure (EE) in kcal/min. Oxygen uptake (VO2), re-calculated as kcal/min, was measured continuously as reference method. Comparisons of the methods were explored by scatter-plots and analysed using a mixed model approach.

RESULTS

The SWA strongly and significantly overestimated the energy expenditure (overall mean 6.3 (SD 1.4)), as compared to the O2 measurements (overall mean 4.4 (1.6)). The discrepancy was most pronounced for the lowest work load, mean 5.4 (1.7) compared to 2.5 (0.4), whereas the highest work load displayed a better agreement, mean 6.7 (0.9) compared to 6.3 (0.6). The scatter-plot shows the relationship between the two measure methods (fig.1)

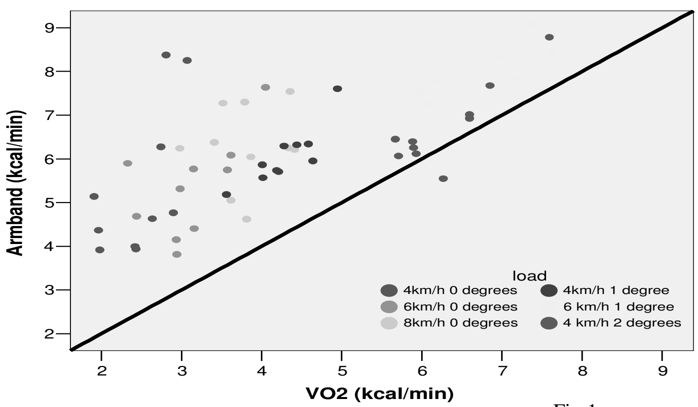

Fig.1

DISCUSSION

The SWA overestimates energy expenditure which was most significant at lower work loads. In addition, there was a large variation in measurements with the SWA at the lower workloads. The daily life activities of wheelchair users consist of a great amount of motion in arms, but often at low work loads. One can assume that energy expenditure measured with the SWA over a longer period, will be drastically overestimated and is inaccurate.

CONCLUSION

The use of SWA to quantify daily life activities among wheelchair users is not recommended. The authors recommend a new algorithm, adjusted to wheelchair users, so the SWA can estimate their energy expenditure accurately.

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O-8-4

Validity of a seismic accelerometer for estimating energy expenditure under sedentary conditions

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INTRODUCTION

Physical activity monitors show difficulties in assessing energy expenditure related to sedentary physical activities. No literature was found proving the validity of a physical activity monitor under sedentary conditions (non-exercise). Exercise bouts are normally added to the validation experiment to improve resemblance with daily life [1]. By doing so the validity of the physical activity monitor under sedentary conditions is mixed with its validity under exercise conditions. Recently an algorithm was developed to detect the type of physical activity (PA), based on a tri-axial seismic accelerometer (DynaPort*MiniMod*, McRoberts B.V., The Hague). Commercially available physical activity monitors able to detect the type of PA use sensors at multiple locations on the body and connected by wires. One location for sensing makes the new system more convenient for the subject. Piezoelectric acceleration sensors are commonly used in physical activity monitors. Seismic acceleration sensors are believed to be more sensitive for slow movements. In static situations a seismic acceleration sensor yields information about inclination which can be used for posture detection [2].

METHODS

The model was validated over 23h intervals in a respiration chamber, furnished as a hotel room without exercise equipment. Subjects were fifteen healthy women (age: 22.1 ± 2.0 years, BMI: 24.0 ± 4.0 kg · m^{-2}). The accelerometer was attached to the lower back with an elastic belt. Raw data was stored (100 Hz) and processed on a computer afterwards. To calculate movement intensity (MI) the three raw signals were band-pass filtered (ω_0: 0.2 – 10 Hz) and then combined by taking the root of the summed squared values. Average MI value per second was used for further calculations. To determine the relation between MI and activity-related energy expenditure (AEE) standardized physical activities were performed in laboratory. AEE (kJ min^{-1} kg^{-1}) was calculated from total energy expenditure (TEE) and sleeping metabolic rate (SMR) as [(TEE x 0.9) – SMR]. Measurement data was used to derive four linear regression equations, one for each detectable type of PA: lying, sitting, standing and walking. In the final model the detected type of PA per second was used to determine which one of the four regression equations should be applied to the MI value. AEE (kJ min^{-1} kg^{-1}) was then predicted using MI and the specified regression equation. Within-subject validity was assessed by comparing 30 minute averages. Between-subject validity was assessed by comparing 23h averages. A radar system was used as a reference for PA assessment.

RESULTS

Significant correlations were found between AEE_{30min} (kJ · min^{-1} kg^{-1}) and model predictions: r^2 = 0.81 ± 0.06 ($p < .00001$, for all subjects). R^2-values for the model were significantly higher compared to radar counts (r^2 = 0.70 ± 0.07) and MI (r^2 = 0.74 ± 0.06) ($p < .01$). Variation in energy expenditure between subjects (AEE_{23h}) was best explained by model predictions, see table. The standard error of the estimate (SEE) of AEE_{23h} prediction by the model was 0.054 W kg^{-1}.

Table: Correlation coefficients (r^2) for radar, MI and the model and SEE (W kg^{-1}) for the model

		AEE_{30min}	AEE_{23h}
Radar	r^2	0.70 ± 0.07‡	0.12 NS
MI	r^2	0.74 ± 0.06‡	0.58*
Model	r^2	0.81 ± 0.06‡	0.69**
	SEE	0.141 ± 0.025	0.054

NS: not significant, *: p < .01, **: p < .001,
‡ < .00001 for all

DISCUSSION

This is the first study showing a significant relation between accelerometer output and energy expenditure related to sedentary PA. Despite the small range in measurement values the average explained variation in AEE_{30min} by the model was 81%. The type of PA significantly improved the prediction of energy expenditure. In the current study only young women were included, other populations will have to be studied in the future. An expansion of the types of PA accounted for could perhaps improve the model.

CONCLUSION

A seismic accelerometer is a valid tool for estimating energy expenditure related to sedentary physical activities in healthy young women.

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O-8-5

Validation of the SenseWear Pro Armband algorithms in children

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INTRODUCTION

The Sensewear Pro Armband (SP2) has been previously shown to be a valid and practical tool to assess energy expenditure under free-living conditions. However, the validation of the device in children has been evaluated in only one previous study [1]. The results revealed significant underestimation for all activities tested. The propriety SP2 algorithms were developed primarily with an adult sample so it is not surprising that the results may not be accurate in this population. The purpose of this study was to assess the validity of new proprietary algorithms that were developed specifically from children's data.

METHODS

Twenty one healthy children (14 boys, 7 girls), averaging 9.4 (±1.3) years of age, participated in different activities while being monitored with the SP2 and a metabolic analyzer (TrueMax 2400, ParvoMedics, UT, USA). The activity protocol lasted 41 minutes and included: resting (lying down), coloring (sitting), playing computer games, walking on a treadmill (2, 2.5 and 3mph) and stationary bicycling.

RESULTS

With the original algorithms, the SP2 was found to overestimate EE by 32%. Results with the newly developed algorithms yielded much better results. There were no significant differences in overall estimates of EE across the 41 minute trial (error = 1.7%). The average absolute difference in EE estimates for the various activities was 13%. The EE differences (kcal/min) using the new algorithms were 0.23, -0.21, 0.03, 0.06, -0.06, -0.09 and 1.14 for resting, coloring, computer games, walking on a treadmill (2, 2.5 and 3mph) and biking, respectively. Resting in a supine position and biking were the only two activities were EE estimations were significantly different ($p<0.001$). Results were similar among genders, with mild differences observed. Individual correlations were conducted across the 41 minute-trial and the average min-min correlation was 0.70.

DISCUSSION

The application of children-specific algorithms appears to be a necessity in order to enhance the accuracy of energy expenditure estimation by the SenseWear Pro Armband in children during different activities.

CONCLUSIONS

When children-specific algorithms were applied, the SenseWear Pro Armband provided accurate estimates of energy expenditure for different activities, compared to indirect calorimetry.

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O-9-1

COMBINED ACTIVITY MONITOR AND WEB-SERVICE TECHNOLOGY FOR IMPROVING PHYSICAL ACTIVITY

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INTRODUCTION

Insight in own physical activity behavior can be a first step to create awareness amongst people and to possibly increase physical activity. New Wellness Solutions (NWS) developed a 12 week lifestyle activity program consisting of an activity monitor based on the Tracmor (tri-axial accelerometer of Philips Research) and a web-service where people can monitor their own activity levels and get personalized feedback and coaching. In measuring the energy expenditure, the accuracy of the NWS activity monitor is comparable to the Tracmor [1], which has been validated with doubly labeled water. Here we describe the first results of a field trial to test the usability of this lifestyle activity program that aims at increasing the level of physical activity of the participant.

METHODS

The NWS activity monitor is a small tri-axial accelerometer (3 by 3 cm), which can be worn unobtrusively on the body. The number of blinking LED's on the device indicates the personal activity score of that day. The web-service shows activity levels of the individual, provides feedback, activity plans and suggestions and has a community space where participants can compare, anonymously if desired, their activity data with data of other members of their community. The usability of the lifestyle activity program and NWS activity monitor was tested in a randomized controlled user's trial (300 employees), with a questionnaire in week 3 of the trial and by measurements of physical activity over time. The intervention group (n=212) wore the activity monitor and got personalized feedback and coaching by the web-service during 12 weeks. In the control group physical activity was measured in week 1 and week 12 with no intervention in between.

RESULTS

The first results showed that 70% of the users agreed with the statement that the device was easy to wear (8% neutral, 18% disagreed). More than 75% of the users found the lifestyle activity program encouraging, fun to do and useful to increase awareness. Data of the first 5 weeks of the trial showed that the initially inactive participants (physical activity level: total energy expenditure / resting energy expenditure <1.7 in the assessment week, week 0) improved their activity energy expenditure significantly with 10% ($P<0.05$) in the first two weeks and were able to maintain this higher activity level up to 5 weeks. The activity level of the active participants (physical activity level >1.7 in week 0) remained unchanged during the first 5 weeks.

DISCUSSION

The Tracmor was recently reviewed as the most accurate device for the measurement of overall daily energy expenditure and could serve as a good reference method to compare the NWS activity monitor with [2]. A certain level of accuracy is required for the user to review his/her daily activity behavior and to see the effect of small steps in changing physical activity behavior. At the end of the trial in January 2008, analysis of the full data set will reveal if participants were able to maintain their increased activity level and would like to continue using the lifestyle activity program.

CONCLUSIONS

First results showed that initially inactive participants were made aware of their low activity level and were able to increase their activity energy expenditure with 10% with the combined activity monitor and web-service technology.

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O-9-2

ADDING EMBEDDED INTELLIGENCE TO A REALTIME WEARABLE REMOTE MONITORING SYSTEM: EXPERIENCES WITH MAGIC

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INTRODUCTION

Since 2003 we have been developing a new textile-based wearable system, named MagIC [1], for the unobtrusive recording of cardiorespiratory and motion signals during spontaneous behavior. Initially our target was to create a compact and comfortable solution for our cardiovascular patients during their rehabilitation activities. By the time, given the reliability and versatility of the systems, we have been using MagIC in different demanding applications [2, 3]. In this abstract we report some recent experiences, including the use of more sophisticated real-time algorithms.

METHODS

The MagIC system is composed of a vest, including textile sensors for ECG and breathing frequency detection, and a portable electronic board for motion assessment, data storage and remote transmission to PDA. The latter can visualize and analyze the information acquired and possibly re-transmit them via WiFi or GPRS/UMTS to a remote monitoring station or a server. The PDA software also provides embedded intelligence (EI) to the system: at the moment, it allows the real-time assessment of several cardiovascular variables of importance, though a sophisticated analysis of the ECG signal coming from the MagIC vest, reported to the user via an intuitive and compact representation obtained by a radar plot. Moreover, this software also provides an intuitive graphical representation of the motion signals related to the tri-axial accelerometer, as well as an automatic posture classification (APC) and a quantification of the level of activity of the subject. Some of the potential use of such EI are very interesting: to provide the user with higher level feedback or warnings about her/his conditions independently from the online connection to a supervisor, and, on the other hand, once its reliability would be completely verified, to trigger alarm or simply to communicate smaller amount of data from the wearable system to the remote monitoring station.

RESULTS

The system, without the EI part of the software, has been used quite intensively in the recent past, with more than a hundred different subjects, including kids, cardiac patients, parachutists, alpinists, and crew of military jet during training flight. On average the recorded signals were readable (namely, adequate to detect beat-to-beat RR intervals, breathing frequency and instantaneous 3D accelerations) for more than 95% of the time. The garment was adequately comfortable in the vast majority of the test performed, and the wearing of the system did not interfere with the activities of the subjects, neither in parachutists while performing aerial acrobatics during the free fall or with a military airplane (during maneuvers with vertical accelerations ranging from +6.1g to - 3.7g). For the embedded intelligence part of the system, we had positive feedback about the heart rate variability (HRV) algorithms and the graphical representations related to them, while the APC correctly detects the posture in around 90% of the cases (in normal living conditions).

DISCUSSION

The MagIC system was proven to be well adequate for the vital signs monitoring in normal conditions up to medium physical activity. Also, attention has been paid to the graphical representation of the information related both to the tri-axial accelerometer and the HRV variables. However, at the moment, the reliability of the APC algorithm is still an issue that will require further investigations.

CONCLUSIONS

In this abstract we briefly reported our recent experience in using the MagIC system; even though further investigations are needed, the preliminary results regarding the use of EI are positive and promising.

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O-9-3

SENSORPHONE: WIRELESS MONITORING VIA THE MOBILE TELEPHONE

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INTRODUCTION

The combined application of sensors, with modern IT services and wireless networking leads to new ways of working and innovative applications. SensorPhone is a novel wireless and personalized health monitoring system. It uses the mobile telephone for the transmission of data from sensors, worn by of ambulant clients, who continue their daily activities while monitored. The project objective is to develop and validate a health service centered around the collection, transmission, analysis and client feedback of motion and heart rate data. SensorPhone is developed by Vodafone Group R&D, Maastricht Instruments and Vilans. The project is partly funded by the Dutch Ministry of Economic Affairs.

METHODS

SensorPhone comprises a body-worn wireless 3-D accelerometer, a heart rate sensor, a standard mobile telephone, and a data acquisition and analysis unit (DAA). The DAA collects and forwards data wirelessly to the mobile telephone, which transmits the data to a secure web database. Special software stores incoming client data, and generates graphs depicting movement and heart rate. Fitness trainers access client data and give feedback and advice, which is sent as a message to the mobile telephone and to a personal webpage. The client views graphs and messages from the trainer. Field trials ran from March to December 2007. During the trials 22 persons (among them 10 overweight and 4 obese) used the SensorPhone equipment and website. Participants used SensorPhone for 4 weeks and received professional guidance and feedback. The research questions are: (1) Does SensorPhone perform satisfactorily when used by clients and trainers? (2) Is the measured data relevant for a training programme? (3) Is SensorPhone user-friendly?

RESULTS

Clients used SensorPhone 4 hours a week, on average, mainly during exercise outside the fitness centre. The trials indicate that reduction of size and weight and increased battery life should be goals for technical development. The information presented to the user on the mobile phone and web site needs to be simplified. Trainers are enthusiastic about SensorPhone's versatility, but it is also clear that integration in a training programme requires further development.

DISCUSSION

The current SensorPhone prototype is a complex device, with different sensors (heart rate, movement), different data links (Zigbee, Polar, Bluetooth, GSM, Internet) and different user interfaces (phone, DAA, web application). The complexity of the prototype makes the system vulnerable to system failure.

CONCLUSIONS

The application developed in the SensorPhone project has obese patients and overweight clients as a user group, but the same platform can be applied with different sensors, different user groups and different care concepts. SensorPhone can be used for medical purposes, exercise and sport purposes, and for research purposes. SensorPhone opens the door for new care concepts. In these concepts clients are directly involved in therapy and receive immediate feedback on their performance. The perspective of SensorPhone in care is promising.

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O-10-1

ACCELEROMETRY TO ASSESS MOTOR ACTIVITY DURING SLEEP IN ADULTS WITH ADHD OR TOURETTE'S DISORDER

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INTRODUCTION

Attention-Deficit Hyperactivity Disorder (ADHD) and Tourette's Disorder (TD) are neuropsychiatric disorders that frequently present with sleep problems. Disturbance of sleep in ADHD and TD as quantified by means of electrophysiological data may be related to or caused by the disinhibition and dysfunction in regulation of motor functions in ADHD and TD. To clarify the role of behavioural disturbance during sleep, we used accelerometry to objectively investigate body postures, postural transitions and motility during sleep of adult patients with ADHD or TD and healthy controls.

METHODS

Fifteen adults with ADHD, 18 with TD, and 38 healthy controls participated in an ambulatory study in their home environment. Both patients and controls were drug-free at the time of the study. Ambulatory recordings of daily activities were made during weekdays for a consecutive period of two days. Motor activity was measured by five 5 g uni-axial piezo-resistive accelerometers (placed on the sternum and upper legs). The signals were recorded on a Vitaport2™ digital portable recorder and analyzed with a kinematic software package [1]. The following output measures were computed per patient during the sleep period: time in bed, static activities (lying, sitting and standing), dynamic activities (walking and general non-specific movements), body motility, and number of body transitions per hour.

RESULTS

The time spent in bed during the night was significantly longer in the ADHD group as compared to the control group ($p<.01$). The groups showed no significant differences regarding the proportions of time spent in static postures or doing dynamic activities. However, both the ADHD and TD group showed about 1.5 times more motor activity than the controls during the static postures in general and during the lying positions specifically (all p-values $<.01$). The number of body transitions per hour did not differ between the groups.

DISCUSSION/ CONCLUSIONS

ADHD and TD both are conceptualized as disorders characterized by disinhibition of motor function. Sleep disturbances form an essential part of their symptoms. We observed a significant increase in body motility during static activities (particularly lying) in both patient groups versus the controls. Our data provide a firm basis that behavioral restlessness during the sleep period may contribute to the reported sleep disturbances in both patient categories.

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O-10-2

TIME ASPECTS OF COMPUTER USE ACROSS ONE YEAR EXPOSURE: METRICS AND EMPIRICAL FINDINGS

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INTRODUCTION

Time aspects of biomechanical exposure are believed to be a risk factor for musculoskeletal disorders. This is particularly relevant to extensive computer use, since usage patterns are characterized by prolonged periods of low loads with little variation and little opportunity for recovery [1]. While computer-related disorders often develop gradually over extended periods of time very few studies have assessed exposure accordingly, i.e. consecutively recording for days or months. Recently, computer software has been developed [2] which allows exposure registrations for very long periods of time. This creates the need for metrics that can pick up time aspects of computer use across different time scales (days, weeks and months). The present study investigated patterns of computer, mouse and keyboard use in 96 computer users across one working year. The following questions were asked: 1.What patterns of periodicity are found across one year recording? 2. Can the characteristics of a working day be predicted on the basis of recordings from previous days? 3. Can the mean exposure across a year be predicted from recorded computer use of a few consecutive days?

METHODS

When analyzing opportunities for recovery in a time line of exposure is "work" and "non-work" episodes need to be discriminated. To this end, we implemented a temporal criterion that specifies the amount of time two subsequent data points can be separated in time, while the time in between is still classified as continuous work [2]. On the basis of this discrimination criterion, the duration of the working day, the summed duration of the episodes, the number of episodes, and the variability of the episode duration were used to describe the distribution of exposure *within* a work day (for total computer use, mouse and keyboard use separately). To analyze the work pattern *across* days the distributions of the duration of blocks (in days) of consecutive working and non-working days, were calculated. For all variables, coefficients of variation across subjects and across days within subjects were calculated as basic measures of dispersion. Day-to-day autocorrelation functions were calculated as a measure of dependence, and empirical re-sampling of data was applied to assess the reliability of the daily exposure measures.

RESULTS

Exposure variability between subjects was larger than the variability between days within subjects, indicating that substantial systematic differences existed between subjects in the population. With respect to the research questions: 1. The days on which the computer was not used were very variable across computer users, this masked seasonal variability for the whole group. At the end of the year a decrease in the number of work days occurred. However, those that were working showed an increase in the work duration. Weekend use of the computer was characterized by extensive keyboard use (as compared to the work week). Within day variability of episode durations was very large (mean < interquartile range) and skewed towards small episode durations. 2. Since the day-to-day autocorrelations ($r = 0.1\text{-}0.2$; non significant) were low, the exposure of a working day could not be predicted from the recordings of previous days. 3. In order to estimate mean exposures across a year with good precision (± 10% error, including 90% of individuals), more than 60 consecutive days would need to be monitored.

CONCLUSIONS

Time aspects of computer usage across a working year were characterized by considerable exposure variability within and between days, as well as between individuals. Some seasonal differences in exposure were found. Autocorrelation between exposures across days was low, and considerable measurement periods are necessary to arrive at precise estimates of individual mean exposure across a working year.

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O-10-3

DIFFERENT ACTIVITY SENSORS FOR SLEEP DETECTION

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INTRODUCTION

Actigraphy is an established method for studying sleep-wake patterns. Usually activity sensors (actigraphs) are placed on the wrist of non-dominant hand. In this study five different activity sensors were compared to study the role of different activity sensor types in sleep epoch detection.

METHODS

Eleven females (age 20-54) were recorded using polysomnography (PSG) after baseline night once during daytime sleep and once during nighttime sleep. Recordings were scored according to standard R&K criteria using EEG, EOG and EMG. Five activity sensors were used: a two-axis accelerometer placed over sternum (Embla N7000 patient unit), SenseWear Pro2 on right arm (mean absolute difference of longitudinal acceleration was analyzed), a multichannel mattress sensor (VTT Matsense), and two activity sensors on left wrist (Camntech Wristsense and Polar activity recorder). Sampling rates and e.g. filter characteristics were different for each sensor. In this study, the mean "activity" values during the 30 s epoch and during the 10 surrounding epochs were used for logistic regression analysis [1]. Leave-one-out cross-validation was conducted by fitting the used logistic regression for each subject by using the data of the remaining ten subjects. This process was repeated eleven times. Sleep was detected using the threshold p-value>0.5.

RESULTS

A total of 16402 epochs were analyzed, out of which 89.7% were visually scored as sleep. Epoch by epoch agreements for each sensor were:

	Embla patient unit		SenseWear Pro2		Matsense		Wristsense		Polar activity	
	Wake	Sleep	Wake	Sleep	Wake	Sleep	Wake	Sleep	Wake	Sleep
PSG Wake	458	1236	383	1311	552	1142	399	1295	199	1495
PSG Sleep	195	14513	185	14523	468	14240	222	14486	130	14578
Agreement		91.3%		90.9%		90.2%		90.8%		90.1%
Cohens' Kappa		0.35		0.30		0.36		0.31		0.17
Sensitivity		98.7%		98.7%		96.8%		98.5%		99.1%
Specificity		27.0%		22.6%		32.6%		23.6%		11.7%

CONCLUSIONS

Use of activity sensors for the separation of wakefulness and sleep involves some limitations [1]. Relatively similar results were obtained using very different sensors and sensors placement. The Polar wrist activity sensor, made to distinguish between a broad spectrum of daily activities (not sleep), had the lowest specificity. The overall low specificity underlines a major problem with activity-based sleep estimates: the devices were unable to detect periods of wakefulness without movement. Innovations should focus on this problem. However, actigraphs remain valuable because they allow for multi-day recordings and for the characterization of sleep-wake rhythms and tremor [2, 3].

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Abstracts Poster Presentations

P-1-1

MONITORING MOBILITY RELATED ACTIVITIES IN OLDER PEOPLE; SYSTEMATIC REVIEW

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INTRODUCTION

Valid outcome measures are needed for the assessment of physical activity and/or physical functioning in aged individuals. Use of wearable motion sensing technology offers important advantages over conventional methods. The aim of this systematic review is to identify the actual state of the application of wearable systems for monitoring mobility related activity in older populations. Questions asked were: Which technologies and applications have been used? With which results have technologies been applied? What are identified feasibility and adherence aspects of such technologies? What is the clinical relevance of this technology?

METHODS

PubMed (Medline since 1990), Ovid (Biosis, Cinahl), and Cochrane (Central) and reference lists of all relevant articles were searched. Two authors independently reviewed the relevant randomised and non-randomised trials systematically. Quality of selected articles was scored and study results were summarized and discussed.

RESULTS

227 abstracts were considered. After application of inclusion criteria and full text reading, 42 articles were taken into account in a full text review. Twenty of these papers evaluated walking with step counters, other papers used varying accelerometry approaches for obtaining overall activity measures (n=16), or for monitoring changes in body postures and activity patterns (n=17). Six studies explicitly mentioned feasibility and/or compliance aspects. Eight studies presented outcome evaluations of interventions.

DISCUSSION

The available studies in older populations predominantly use step counters, and to a lesser extent combinations of different sensors (accelerometers and gyroscopes). Duration of application varies between a few minutes in reliability type studies and every 24-hour period for 1 year. A number of studies can be regarded as validation approaches, other studies are focusing on the relation between mobility measures and other variables. Despite the obvious clinical relevance of the available methods, only few of the available papers directly present clinical studies. Identified feasibility and adherence aspects of BFS technology mainly relate to the reliability of the various devices in unsupervised measurement settings and acceptance of the devices by the various studied populations. Some devices show low acceptance when attached to certain body parts or clothing, e.g. hip or shoes, which impedes measurements.

CONCLUSION

Evidence-based clinical applications of these methods (e.g. for fall prediction and outcome assessment) are in need of (further) development. Available literature does not yet show examples of training balance or mobility based on the use of wearable systems for movement analyses over longer durations. At present, therefore, the use of wearable systems for monitoring movement activities in people aged over 65 years has not yet reached its full potential.

P-1-2

MONITORING OF PHYSICAL ACTIVITY USING ACCELEROMETERS AND PEDOMETERS AND POSSIBILITY TO CHANGE PHYSICAL ACTIVITY BEHAVIOR USING INDIVIDUALIZED FEEDBACK

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INTRODUCTION

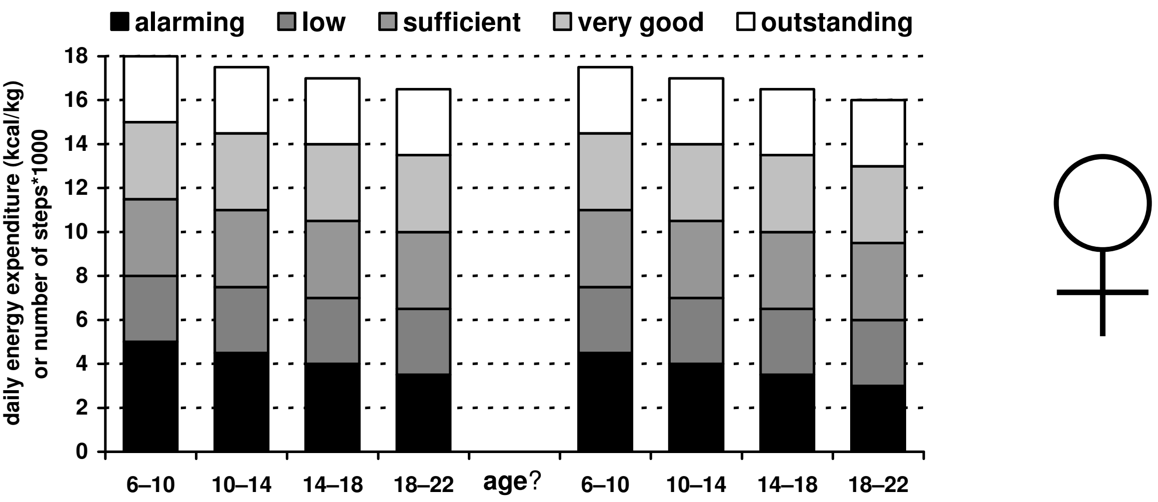
Accross Europe, pedometers and accelerometers both with displays and without displays are used to monitor physical activity (PA) in children and youth in terrain. The benefits of this type of monitoring are the most accurate estimates of PA patterns available in participants in their natural conditions. The aim of the study is to explain the methods of weekly PA monitoring in terrain using pedometers and accelerometers and the possibility to change physical activity behavior using individualized feedback.

METHODS

The methods of PA monitoring in terrain using Caltrac accelerometer, Omron pedometer, and individual recording sheets (FITT characteristics of PA) were originally standardized at the Faculty of Physical Culture at Palacky University in Olomouc in the 90s of the 20th century. At present, applied even forms of these methods are being used with ActiGraph accelerometers (trialling ActiTrainer) and Yamax pedometers. A specially created software allows recording data from the devices, their analysis and creating of an individualized feedback. Feedback provides graphs on the level of PA on weekdays and weekend days, at school, in spare time and recommendations for healthy behavior. It functions as an effective motivational tool for the participants to perform more PA [Figure 1 - example].

RESULTS

The recommendations suggested reflect the decrease in PA along with age in children and youth and the differences between genders [Figure 1 - example].



DISCUSSION

Weekly monitoring allows to compare PA on weekdays and weekend days, at school and in spare time. The devices with display seem to be more suitable since they provide direct information on PA to the participants who can thus immediately influence their PA level.

CONCLUSIONS

Using accelerometers and pedometers in PA monitoring provides good information on PA patterns to formulate health-oriented recommendations and to create PA intervertions.

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P-1-3

DIURNAL MOTOR ACTIVITY EVALUATED BY WRIST AND BACK ACTIGRAPHY: A WITHIN SUBJECT COMPARISON OF RAW SIGNALS

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INTRODUCTION

Wrist actigraphy is useful for measurement of rest-activity patterns and is considered to be the best option to measure sleep when the gold standard polysomnography is difficult to obtain [1]. However, the placement of a sensor on the wrist might hinder a subject during a daily routine at work, especially in case of soldiers on duty. For monitoring rest-activity patterns and other physiological signals in soldiers on duty, a centrally located sensor (i.e. on the torso) is preferred. We tested whether the movement in the wrist is related to the movement at the back.

METHODS

In thirteen subjects without sleep-complaints movement of the back and the non-dominant wrist was simultaneously and continuously recorded for 23 hours using Actiwatches (Cambridge Neurotechnology Ltd, UK). Time series of raw actimetry data, sampled at 60 seconds intervals, were analyzed using both correlation and regression analyses.

RESULTS

First, motor activity was significantly affected by the sleep-wake cycle. Overall the motor activity recorded at the wrist more pronounced as compared to motor activity of the back. Wrist and back movements were very modestly related (r=0.27) and the best correlation was found when applying a time lag of 10 minutes (wrist before back, r=0.34). Regression analyses applied on the time lagged data set revealed that the movement of the wrist only accounted for 11.2% of the variance in movement of the back. At individual level r=0.70 and R^2=0.49 were the best predictions.

DISCUSSION

The relation between back movement and wrist movement is rather weak. For rest-activity measurement recordings at the wrist are better indicators than recordings at the back. This is in agreement with earlier work from Middelkoop and coworkers [2], that compared wrist, ankle and trunk actimetry. The use of back movement recordings for motor activity-based sleep-wake scoring remains to be evaluated. An approach of using (linearly transformed) back movement data on wrist movement based scoring algorithms seems unsuccessful, since the weak relationship. Since the relation between wrist and back movement is not linear, new algorithms need to be developed to motor activity-based sleep-wake scoring.

CONCLUSIONS

The relation of central (back) and peripheral (wrist) movement is weak. Although a more central recording of movement for rest-activity monitoring is wanted in certain occupational environments, it is doubtful whether central movement signals, with a smaller range as compared to peripheral movements, are suitable for rest-activity monitoring in general and particularly sleep-wake state.

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P-1-4

ASSESSMENT OF PHYSICAL ACTIVITY IN DAILY LIFE IN MUSCULOSKELETAL PAIN: A REVIEW OF THE LITERATURE

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INTRODUCTION

In pain rehabilitation, increasing interest has been shown in physical activity instead of disability assessment in order to present a patient's remaining functional abilities regardless pain. However, at this moment, no structured information on different assessment methods for physical activity in musculoskeletal pain is available. The objectives of the current study were twofold, firstly to identify assessment instruments for the level of physical activity in daily life in patients with musculoskeletal pain and secondly to review psychometric properties of the instruments identified.

METHODS

A systematic search was conducted directed to identify instruments for physical activity assessment in chronic musculoskeletal pain including the following literature databases: Medline, Cinahl, Embase and PsycINFO. Two reviewers selected and reviewed all identified articles independently. In case of disagreement, a third reviewer participated. A structured analysis of different aspects of assessment of daily life activities (quantitative/qualitative, length of assessment interval, activity pattern registration etc.) and the psychometric properties was performed for all instruments.

RESULTS

In all, 42 articles derived from the literature on musculoskeletal pain were included in the review. Thirty-four different assessment instruments for physical activity were identified; fourteen questionnaires, ten dairies and ten instruments based on movement registration. Six accelerometers and four activity monitors were identified. Only, 10 out of the total number of 34 instruments contained full or partial information regarding pain specific psychometric properties.

DISCUSSION / CONCLUSION

At this moment, for quantitative assessment of physical activity, movement registration seems to be favoured based on its higher degree of objectivity in comparison with self-report. Self-report, however, is still preferred in qualitative studies. At the moment, a combination of self-report and movement registration could be recommended to represent both qualitative and quantitative aspects of physical activity in musculoskeletal pain. Taken together more research is needed to evaluate psychometric properties of instruments measuring physical activity in musculoskeletal pain.

P-1-5

ACTIVITY TYPE AS A DETERMINANT OF ACTIVITY LEVEL

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INTRODUCTION

In past studies personal activity level has been investigated using accelerometers worn on the body measuring activity counts [1]. Accelerometers have also been used in combination with recognition algorithms to define type and duration of physical activity [2]. Those accelerometers based methods were used in this study to investigate which types of daily activity were the main components of the activity level.

METHODS

Subjects were 30 healthy male and female adults (age 25-55 years). The individual physical activity was measured with a tri-axial accelerometer (Tracmor, Philips Research) for one week. The selected sampling frequency of the acceleration signal was 20 Hz. The number of counts (integrated and rectified sum of squared acceleration values) was recorded every minute for the entire monitoring period. The averaged number of counts per day was used to define the individual activity level. The recognition of activity type was computed using decision tree models to classify 6 types of activities. The decision tree provided an evaluation of the type and duration of activities based on attributes (features) of the measured acceleration. The types of activity recognized were: lying, sitting, standing, walking, running and cycling. Daily duration of every type of activity was measured. The intensity of every type of activity was calculated defining the corresponding average counts per minute. The association between activity type and activity level was assessed calculating the Pearson correlation coefficient between duration of activity type and daily activity counts.

RESULTS

The following activity types are ordered from the highest to the lowest daily duration: lying, sitting, standing, walking, cycling and running. Static activities (lying, sitting, and standing) covered most of the daytime. In average less than 15% of the day was occupied by dynamic activities (walking, running, and cycling). The highest intensity activity type was running followed by walking, cycling, standing, sitting and lying. Running activities generated the highest number of counts per minute, while walking, cycling and static activities were characterized by a progressively lower number of counts. Walking had the highest association with activity level followed by running, cycling, standing, sitting and lying.

DISCUSSION

Both duration and intensity of activity type played a role in the determination of the association between activity type and activity intensity. Walking was the main determinant of the activity level. Although running provided the highest number of counts per minute the limited daily duration resulted in a reduced association to the activity level. Lying and sitting appeared to be inversely associated to activity level.

CONCLUSIONS

Although a relatively small part of the day was spent walking and that the corresponding activity intensity was smaller than the intensity of running, the walking activity type represented in the average subject the best determinant of activity level.

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P-1-6

POTENTIAL OF MOBILE MONITORING OF PHYSICAL ACTIVITY TO IMPROVE HUMAN HEALTH: RESULTS OF AN INTERNATIONAL EXPERT PANEL WORKSHOP

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INTRODUCTION

Physical activity (PA) is a critical outcome parameter for measuring the efficacy of treatment and rehabilitation for many chronic diseases, as well as often being a therapy in its own right. That it is not as widely or systematically used for this purpose can be attributed to two related factors. First, PA is less likely to be applied within a controlled medical care environment, but instead incorporated within the patient's daily routine. For this there are almost no standardized ways for prescribing and controlling either the dosing or the effects of the PA treatment. The Robert Bosch GmbH, Trium Analysis Online GmbH, and the Sylvia Lawry Centre are partnering in an evaluation of the usefulness of various telemedicine devices to monitor physical activity that may be able to overcome these problems. The "actibelt" [1] is an example of such a device, being a belt with a high-tech buckle carrying high-precision 3D-acceleration sensors that allow for the continuous, unobtrusive long-term monitoring of physical activity in the course of daily life. Data storage, transmission, analysis and reporting are done with a flexible web-based backbone of customised, partially automated services. This allows supervising physicians to determine compliance with the subscribed "dose" of treatment with physical activity and to monitor the short- and long-term evolution – deterioration or improvement – of disability, gait and movement disorders.

METHODS

A literature review [2,3] was carried out to prepare a "long list" of diseases and health conditions classified within the ICD with a known relationship to PA, from which a "short list" was extracted based on information about the expected impact of an improved control of PA as treatment and/or outcome. During a one-day workshop on Dec 7, 2007 in Munich, clinical experts, physiotherapists, basic scientists, and representatives from health insurance companies discussed the following questions: how should PA be measured? What are the most relevant aspects of PA? Should other biosignals be coupled with PA? What are the roadblocks – technological, financial, psychological – preventing the wide-spread increased adoption of PA as therapy and outcome for chronic disease? What are key projects? The workshop focused on a number of disease areas including Multiple Sclerosis, Parkinson's disease, Obesity/Diabetes in children, Asthma, COPD, Cardiovascular Diseases, Dementia, and Osteoporosis. PA for persons with prostheses is also an important health intervention, which affects health outcomes.

RESULTS / CONCLUSION

From the various presentations it became clear that there exists a serious problem in monitoring the long-term evolution of disability in a wide range of chronic disabling diseases, in particular MS and Parkinson's disease – an essential element for assessing the long-term effect of drug treatments. An unobstrusive, easy-to-use system like the actibelt could improve outcome assessments both within and outside a clinical setting. Additional biosignals could give further information, e.g. heart rate, ECG, oxygen consumption, even if at the cost of reduced usability. COPD, but also osteoporosis, obesity and high-tech protheses for limb replacement, are prototypical examples of disease conditions where PA plays a dual role as highly effective treatment and highly sensitive outcome measure. In other disease conditions the efficiency of PA as treatment and/or prevention plays a more dominant role, such as in cardiovascular disease. Projects to evaluate the technology of mobile accelerometry in the context of an international multi-center clinical trial and in pilot trials are ongoing in MS, Parkinson and COPD. Two large European projects have in the meantime been selected for funding within the 7th European Framework Program FP7, one in cardiovascular disease (NETSIM) and one in Osteoporosis (VPHOP). Interdisciplinary work involving all key players and stakeholders of the health care sector and the development of telemedicine service centres will be necessary to exploit the high potential of physical activity to improve human health – both as treatment and as outcome measure.

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P-1-7

AMBULATORY MOVEMENT MONITOR REQUIREMENTS

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INTRODUCTION

Research in ambulatory movement monitoring is accelerating. This is due in part to advances in low-power microelectronics and micro-electrical-mechanical systems (MEMS). It is now possible to conduct studies with small, low-power, wearable sensors that include accelerometers, gyroscopes, and magnetometers. Despite these advances, most commercially available research systems do not meet the needs of researchers who wish to conduct studies lasting for more than 1 day. Current ambulatory monitoring systems can be divided into three categories: computer-tethered, unit-tethered, and untethered. *Computer-tethered systems* connect the sensor directly to a computer. These systems are not practical for ambulatory settings. *Unit-tethered systems* connect the sensors to a central recording unit that is typically worn around the waist. This unit typically houses the memory, batteries, and wireless communications circuits. Currently, these systems are the most widely available and have been used the most in published studies. These systems are too cumbersome and difficult to use in an at-home study, the battery life is too short, and the wires connecting the sensors to the central recording unit may be hazardous during normal daily activities. *Untethered systems* combine the batteries, memory, and sensors in single stand-alone units. Currently there are no commercially available untethered units. The closest systems are activity monitors, which typically record from a single-axis accelerometer and record coarse measures of overall activity at intervals of 1-60 s. These do not have sufficient bandwidth, memory, or sensors for precise movement monitoring needed for most studies. Cleveland Medical Devices (Cleveland, OH) makes two unit-tethered systems, the KinetiSense and Kinesia devices. These systems include triaxial accelerometers and gyroscopes with bandwidths of 0-15 Hz, but lack magnetometers. The central recording units are small enough to be worn on the wrist. The sensors are small enough to be attached to the central recording unit so that the system can act as an untethered system. This system can record data continuously, includes an event marker button, and can store data on an on-board memory for up to 12 h. However, this system is too large and heavy to be worn continuously during multi-day trials and requires a technician to offload the data after 12 hours of recording.

DISCUSSION

The next generation of systems for ambulatory movement monitoring will need to be smaller, less obtrusive, and more user-friendly to support the needs of researchers to conduct multiple-day studies. These systems must record raw sensor data for offline analysis at bandwidths >15 Hz. We propose a complete list of functional requirements for these systems. The functional requirements include size, weight, operating duration, sensors, an easy-to-use daily charging system, sensor bandwidth, device synchronization, display, user interface, reliability, data transfer, memory, and accuracy requirements.

P-1-8

WHAT DOES THE "LEFT" HAND TELL US?

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INTRODUCTION

Greatest potential as well as greatest challenge of ambulatory monitoring is real-time measurement in everyday life activities. Still, most devices for collecting data on movement, even being miniaturized, are obtrusive extensions to an individual's normal daytime outfit. They acquire cables, tape-fixed sensors and external housings for the microprocessor, memory, battery etc. In our study a new embedded computing device, the smartband, is used for ambulatory assessment. In a standard trivial, elastic sweatband sensors and datalogger are integrated unobtrusively. The smartband can be weared at wrists or ankles. Mostly unobtrusive it seems to be weared at the wrist of the non-active hand, which in most cases is the left hand. Besides triaxial acceleration also pattern and force amplitude of the pulswave is measured at different sampling rates. So, additional to acceleration values, also changes in pulsforce are reflecting independent measures of everyday physical movement. In two studies we are comparing the acceleration data with pulsforce data over 24 hours, to examine, to what extent both measures are equivalent for detecting different intensities of circadian movment. A further inspection of the wristband indicated movement patterns is done by comparing the acceleration and pulsforce data with movement data, as they are measured simultaneously by a GPS-Logger.

P-1-9

INTERINSTRUMENT RELIABILITY OF RT3 ACCELEROMETER AT DIFFERENT LEVELS OF PHYSICAL ACTIVITY IN CHILDREN AND ADOLESCENTS

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INTRODUCTION

Accelerometers are validated instrument for assessing physical activity especially in children. However their reliability could vary according to the level of physical activity (PA). The aim of this study is to evaluate the interinstrument reliability of RT3 accelerometer at different levels of PA.

METHODS

Sixty healthy subjects (thirty boys, thirty girls), aged 10-16 years, were recruited to participate in the study. Subjects were worn two accelerometers on the right hip. Accelerometers were synchronized and data were recorded every minute, during 9 levels of 15-minute physical activity that varied in intensity from sedentary (i.e., TV watching, reading, playing video game) to vigorous (i.e., running on a treadmill at different speed level). Interinstrument coefficient of variation was assessed using the formula CV = standard deviation of the measure × 100/mean of the.measure).

RESULTS

Interinstrument coefficients of variation (CV) varied from 4%, to 74%. Intensity of physical activity strongly influence interinstrument CV. Indeed, CV was 44% to 74% in sedentary, 7% to 47% in light activity, 5% to 6% in moderate activity, and 4% for vigorous activity.

DISCUSSION

Our study is the first assessing interinstrument reproductibility in a RT3 triaxial accelerometer in children and adolescents during of typical physical activities in free-living conditions. This study shows a poor interinstrument reliability of RT3 accelerometers specially for low level of PA. This could lead to significant error in assessing PA in sedentary children in usual condition of life. Similar results have been shown by Powell *et al*. using the same triaxial accelerometer [1]. During this study, one person performed six activities (rest, walk, run, and sit-stand position). The intermonitor CV was < 6% during locomotive activities, while it increased to 8-25% during sit-stand [1]. In another study, the same authors tested also the interinstrument reliability using a vibration table. Interinstrument CV decreased as vibration frequency increased (21.9% to 26.7% at 2.1 Hz, 6.3 to 9% at 5.1 Hz, and 4.2 to 7.2 at 10.2 Hz) [2]. The poor reliability of the RT3 accelerometer may be explained by the fact that this device has a wide frequency range (2.0 – 10.0 Hz) and dynamic range of 0.05-2.00 g [2], allowing small movement to be detected, but with a wide range of variation.

CONCLUSIONS

This discrepancy could account for difference in measuring PA in usual condition of life in subject with low physical activity pattern.

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P-1-10

A TOOL FOR GEOSPATIAL ANALYSIS OF PHYSICAL ACTIVITY: PHYSICAL ACTIVITY LOCATION MEASUREMENT SYSTEM (PALMS)

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INTRODUCTION

The central role of places in which physical activity (PA) is done is now widely recognized, so it is important to measure both activity and its location. The aim of this research is to develop and refine a suite of sensors and supporting software to capture, store, and analyze PA and energy expenditure (PAEE) data in free living humans from a geospatial perspective. To date there is no systematic way for researchers to simultaneously collect PAEE by either combined heart rate and motion (HR+M) sensors or accelerometers and location data by global positioning systems (GPS). These objective measures, combined with optional concurrent ecological momentary sampling of psychosocial correlates of PA via a cell phone platform will provide significant advantages over currently available measures. Understanding how PAEE varies by location is essential to exposure biology researchers interested in gene-environment interactions as well as researchers exploring how environmental factors such as the built environment, crime, the availability of recreation facilities, or terrain influence PA.

METHODS

Begun in November 2007, the project is comprised of four phases:

I. Specify, build, and bench test the portable data collection device using a cell phone platform for ecological momentary assessment of psychosocial data, a HR+M monitor or accelerometer, and a highly accurate GPS device. b. Develop data-server and web-server software that supports downloading and integration of data existing and well-established GIS systems (e.g., ArcGIS)

II. Usability and field data capture testing on the system among a multiethnic sample of adolescents (age 12-20), adults (21-60), and older adults (61+); n=45

III. Use data Captured in Phase II to develop new, and validate currently used, methods of data modeling and visualization appropriate to PAEE and geospatial research. Based on user feedback improve the tools and software for use in Phase IV

IV. Field test the use of the entire system in free-living adolescents, adults, and older adults (n=45) and test the utility of the sytem as a support to resaerch on geospatial aspects of PAEE

DISCUSSION

This project is supported by the NIH Genes, Environment, and Health Initiative (GEI), a collaboration between geneticists and environmental scientists to identify how gene-environmental interactions influence health. The PALMS project is one of seven GEI-funded studies with the objective of improving measures of diet and physical activity.

P-1-11

PHYSICAL ACTIVITY RECOGNITION IN CHILDREN BY TWO UNI-AXIAL ACCELEROMETERS

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INTRODUCTION

Children generally miss the cognitive abilities to report their physical activities exactly by questionnaires and interviews. Therefore, objective instruments that are simple in use are required to survey physical activity behaviour in this population. The aim of this study was first to establish and validate an observational system to the data of two accelerometers worn on hip and wrist. Secondly, a classifier system should be applied to the accelerometer data that would recognize the mode of children's activities.

METHODS

Data of 21 children (age: 10.7±1.3 y, weight: 39.8±10.1 kg, height: 1.5±0.1m) was used to train a classifying system, whereas data of 20 different children (age: 10.7±0.9 years, weight: 38.0±6.3 kg, height: 1.5±0.1 m) was used to test this system. Both groups were provided with two accelerometers and were asked to attach one of the devices to the wrist and the other to the hip. These devices measure accelerations with a sampling rate of 30/s. Accumulated accelerations were stored each second to the flash memory of the device. Three to four blocks of video recordings were simultaneously accomplished during 3 h at school and 3 h in their leisure time at home and in a regular visited leisure time activity away from home. Each second of video data was labelled as one of nine different activities (stationary, walking, running, jumping, acrobatics, biking, horseback riding, crawling, kickboarding) by researchers. A published compendium was used to assign the respective energy expenditure to the video sequences. The energy expenditure based on the video data was compared to synchronised mean acceleration data to validate the observation method. The classifying system was trained by video-labelled accelerometry data of the first group of children and tested by data of the remaining group of children. A system consisted of three different classifiers, such as Nearest Neighbour (NN) (k=10), Normal Density Discriminant Function (NDDF) and a classifier containing visually determined linear borders. Relative errors of the classifying systems were calculated to determine its quality.

RESULTS

Corrected R of the regression between mean wrist and hip accelerometry data and mean energy expenditure calculated for observed activities by according energy expenditure levels was 0.771. Mean relative error of the three classifiers were 40.0±10.2% (Nearest Neighbour), 51.1 ±8.3% (NDDF) and 35.1±10.2% (visual classifier). Overall error after voting was 35.0±11.0%. The system was able to classify 93% of stationary, 69% of walking, 75% of running and 71% of jumping activities correctly. The other activities were mainly recognised as 'not assigned' activities or walking.

DISCUSSION

Activity classes used during video analysis were found to be valid, when compared to accelerometer data. Overall recognition rate was lower than in another study, where 70.9% of the time was classified correctly using quadratic discriminant analysis and 80.8% using a hidden Markov model [1]. This might result from the different numbers of analysed activity categories used in the two studies. However, recognition rate of walking was higher in the present study than in both methods of the study mentioned above. To our knowledge, this is the first classification system that is able to recognize children-specific activities of different intensities with reasonable overall and low specific error rates.

CONCLUSIONS

As it is crucial for children-specific objective devices to be easy to apply, a simple accelerometry-based system was developed that contains valid activity classes and recognises most common activities of different intensities with low error rates.

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P-1-12

TEST-RETEST RELIABILITY OF THREE DAY ACTIVITY MONITORING IN PARTICIPANTS WITH STROKE

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INTRODUCTION

The aim of this study was to examine the test-retest reliability of the StepWatch Activity Monitor (SAM) outputs (total step count, peak activity index, sustained activity indices of 1, 5, 20, 30, 60 minutes, steps at high, medium and low stepping rates) over two 3 day periods at least a week apart in participants with chronic stroke.

METHODS

Forty participants more than six months post stroke, mean gait speed of 0.67 m/s (range 0.12 to 1.42), were recruited. The SAM was calibrated for each participant, who then wore the device on the non-paretic limb for 3 consecutive days 1 week and the same 3 consecutive days either 7 or 14 days later.

RESULTS

The participants took 6247±4439 steps per day (range 1108 to 20137 steps). The coefficients of variation (CV) for SAM outputs between the means of the two 3 day periods were 6.8 to 37.6%. Intraclass correlation coefficients were high for all SAM outputs (ICC=0.926-0.989). However, Bland Altman analysis showed that only 4 outputs had 95% limits of agreement from session 1 to session 2 that were less than 40%. These were total step count (37.8%), highest activity in 1 minute (23.0%), highest activity in 5 minutes (38.6%) and peak activity index (highest step rate over 30 non-continuous minutes) (29.8%).

DISCUSSION

Busse et al have previously reported CV of 12.0 to 47.1% and ICC of 0.82 to 0.95 for participants with neurological conditions using a 7 day monitoring period with the SAM1. Our test-retest reliability results over 3 days of monitoring compare favourably to their results.

CONCLUSIONS

Test-retest reliability of the monitoring over a 3-day period appears to be at least as reliable as a 7-day monitoring period with the SAM for individuals with stroke.

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P-1-13

TEST-RETEST RELIABILITY OF THE STEPWATCH ACTIVITY MONITOR IN HEALTHY PARTICIPANTS

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INTRODUCTION

The aim of this study was to investigate the test-retest reliability of the StepWatch Activity Monitor (SAM) total step count over two 3-day periods at least a week apart in healthy participants.

METHODS

Thirty participants aged between 18 to 49 years were recruited. The SAM was calibrated for each subject, who then wore the device on the right leg for 3 consecutive days 1 week and the same 3 consecutive days either 7 or 14 days later.

RESULTS

The participants took 7674 ± 2942 steps per day (range 2671 to 13057 steps). The coefficient of variation (CV) for total step count between the means of the two 3 day periods was 15.1%. The intraclass correlation coefficient was 0.874. The 95% limits of agreement (LOA), calculated from Bland-Altman analysis, was 28.7%. A breakdown of groups showed that there was less variation for those who were employed (CV 9.1%; 95% LOA 17.8%) compared to students (CV 17.9%; 95% LOA 34.5%) and those who were unemployed (CV 20.0%; 95% LOA 39.5%). Similarly there was less variation for those who were tested on weekdays (CV 11.7%; 95% LOA 20.3%) compared to those tested over a weekend (CV 16.3%; 95% LOA 30.5%).

DISCUSSION

Busse et al investigated test-retest reliability of the SAM in 10 healthy participants over a 7-day period. They reported a CV of 8.0% and ICC of 0.891. Overall our results show poorer test-retest reliability over 3 days, however the groups who were employed and those who were tested on weekdays are less variable and compare favourably with this previous work.

CONCLUSIONS

Test-retest reliability of the SAM over 3 days appears to be at least as reliable as 7 days under certain conditions. Employment and testing days may impact variability and hence reliability.

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P-1-14

RELATIONSHIP OF THE ACTICAL TO THE STEPWATCH ACTIVITY MONITOR IN HEALTHY PARTICIPANTS

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INTRODUCTION

The aim of this study was to compare the relationship between the output of the StepWatch Activity Monitor (SAM) step count and the Actical activity count in healthy individuals during two standardised walking tests.

METHODS

Participants aged between 18 and 25 years were recruited. The SAM was calibrated for each participant, and worn above the left lateral malleolus. The Actical was calibrated simultaneously and mounted on the participant's waistband at the level of the left iliac crest. The participants then completed the 6 Minute Walk Test (6MWT) and the Incremental Shuttle Walk Test (ISWT) in randomised order. Agreement between monitors for each test was assessed using Pearson's Correlation Coefficient.

RESULTS

Twenty-nine participants completed both walking tests. During the 6MWT, the participants covered an average of 710 ± 90 m, the mean SAM measured step count was 634 ± 70 steps and the mean Actical activity count was 28560 ± 7981. Agreement between the SAM and Actical was poor (r = -0.016). During the ISWT, all participants attained the highest level, so each individual covered 1020 m. The mean SAM measured step count was 1167 ± 81 steps and the mean Actical activity count was 38341 ± 8610. Agreement between the SAM and Actical during the ISWT was also poor (r = -0.176).

DISCUSSION

The lack of agreement between the SAM and Actical is a concerning finding as the activities measured were both discrete walking tasks. Movement of the Actical during the tests was noted by some participants and may have contributed to the lack of agreement. The accuracy of the Actical has been questioned previously [1,2]. Previous work indicates that the SAM is a reliable and valid measure of walking activity [3].

CONCLUSIONS

Lack of agreement between the SAM and Actical raises some issues about validity of the Actical activity monitors as a measure of walking activity.

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P-1-15

MONITORING OF DAILY ACTIVITY LEVELS AND PROSTHETIC WEARING TIMES IN TRANS-TIBIAL AMPUTEES USING SUCTION SOCKETS

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INTRODUCTION

Observations and gait analysis may be carried out in a laboratory environment to determine gait quality [1]; and questionnaires may be used to find amputees' daily activity levels. However, information obtained from questionnaires could be subjective and therefore daily activity monitoring with a worn device would be preferable with elimination of recall bias [2]. Two devices based on the activPAL™ (PAL Technologies Ltd, Glasgow, UK), were designed to monitor trans-tibial amputees' prosthetic wearing times and activity levels in a free-living environment. The aim of this study was to evaluate the two devices, the pressure monitor and force monitor and to develop an algorithm, which would automatically detect static (with and without prosthesis) and dynamic events with associated step counts.

METHODS

For the first study 8 subjects, aged 47-71, with mature unilateral trans-tibial amputations were included. The pressure monitor was attached to the suction valve of the socket to record socket pressure. For the second study 5 unilateral trans-tibial amputees, aged 47-65 years, participated. The force monitor was designed with a force sensitive resistor (FSR) (Flexiforce, Tekscan, USA) used as the sensing element placed at the stump/socket interface. In both studies, the subjects were asked to don their prosthesis and performed activities such as sitting, standing, walking, stairs climbing and sitting without the prosthesis, whilst being video recorded. An algorithm was written using Matlab (Mathworks Ltd.) to analyze the signals automatically to allow posture classification and step count.

RESULTS

Figure 1 shows an example of the pressure profile recorded using the pressure monitor for one of the amputees. Certain features of the pressure profiles were consistent across all of the subjects. A signal analysis code was implemented and the following results achieved: 90.8%, 92.3%, 91.6% and 95.6% accuracy for static events without prosthesis (doffed state), static events with prosthesis (sit or stand), dynamic events and step counts respectively. Force data also showed repeatable patterns. Threshold levels for upright and non-upright activities could be distinguished in each subject and cyclical signals could be identified within the upright events. When the prosthesis was not being worn, zero interface pressure was recorded. A signal analysis code was implemented and the following results were found: 95.0%, 92.8%, 90.1%, 98.7, 94.3% for the accuracy of doffed state, sitting, standing, walking and step counts respectively.

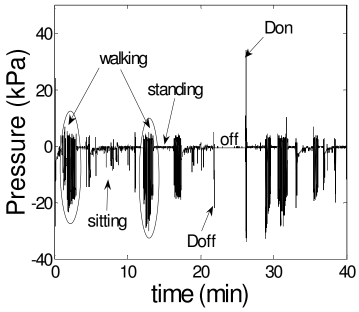

Figure 1. A pressure profile recorded for a trans-tibial amputee performing different activities.

DISCUSSION

Both suction socket pressures (socket pressure measurement) and interface pressures (force monitor) contained repeatable signal components that could be interpreted as activity. This allowed the automatic detection of static and dynamic events. The signals were reproducible across all subjects. The interface pressure measurement using the force monitor allowed more complete determination of posture.

CONCLUSIONS

This study demonstrated that both the interface and socket pressures could be used to reliably quantify static and dynamic events and step detection for trans-tibial amputees using suction sockets.

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P-1-16

AN INVESTIGATION OF THE CONSTRUCT VALIDITY OF FREE-LIVING PHYSICAL ACTIVITY AS A MARKER OF FUNCTIONAL ABILITY IN PEOPLE WITH CHRONIC LOW BACK PAIN

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INTRODUCTION

The aim of the study was to investigate the construct validity of free-living physical activity (PA) monitoring as an objective outcome measure of functional ability in people with chronic low back pain (CLBP). Levels of known difference validity, convergent validity and responsiveness to change were assessed.

METHODS

A sample of 38 individuals (25F, 45±11 years) with CLBP was recruited. These individuals were assessed in terms of free-living PA level, self-reported functional ability and physical performance testing (PPT). Known difference validity was investigated by comparing healthy participants (n = 15, 12F, 39±11) to those with with CLBP, to identify if free-living PA level differed between the groups. Known difference validity was further investigated by examining the change in free-living PA for the participants with CLBP following therapeutic intervention. Convergent validity was investigated by exploring the correlations between free-living PA and self-reported functional ability and physical performance testing (PPT) at a single point in time. Convergent validity was further assessed by looking at the correlation between the changes in all three outcome measures following a therapeutic intervention. The responsiveness of free-living PA to change was assessed using effect-size statistics.

RESULTS

The individuals with CLBP were less active than the group of matched controls and the free-living PA levels of the individuals with CLBP increased following the therapeutic intervention. These findings provide evidence of known difference validity. At a single point in time, relatively weak but statistically significant relationships between free-living PA and both self-reported functional ability and PPT were identified. There was a similar relationship between change in free-living PA and change in self-report and PPT over time. These findings demonstrated evidence of convergent validity. Free-living PA responsiveness to change was small to moderate.

DISCUSSION

This study found evidence of construct validity of free-living PA level as a marker of functional ability in individuals with CLBP. The weak relationships between free-living PA level and both self-reported functional ability and PPT, suggest that they all measure related but distinct components of the functional ability construct. Using all three measures may produce a more comprehensive assessment of functional ability in this patient group. The responiveness to change of free-living PA was lower than for self-reported fucntional abiltiy and PPT. A limitation of this study was the small sample size and the collection of different forms of validity evidence from the same individuals.

CONCLUSIONS

Measurement of free-living PA level may be a useful adjunct to current methods of functional ability assessment in people with CLBP and this may facilitate a more comprehensive assessment of the functional ability construct.

P-1-17

SLEEP SCORED WRIST AND BACK ACTIGRAPHY: A COMPARISON

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INTRODUCTION

Wrist actigraphy is considered to be the best option to measure sleep when the gold standard polysomnography is difficult to obtain [1]. When monitoring for days in an operational field setting, the wrist as location for rest-activity measurement is less preferred. A wrist sensor might hinder a subject during a daily routine at work, especially in case of soldiers on duty. A centrally located sensor (i.e. on the torso) is favored, since this location offers the opportunity to monitor multiple physiological parameters from a singe location. However, the movement-pattern of the trunk is not comparable to the movement-pattern of the wrist, with less motor activity at trunk level [2]. Hence we tested whether motor activity-based sleep-wake scoring based on back activity data is comparable to either motor activity-based sleep-wake scoring based on wrist activity.

METHODS

In twelve subjects without sleep-complaints movement of the back and the non-dominant wrist was simultaneously and continuously recorded for 23 hours using Actiwatches (Cambridge Neurotechnology Ltd, UK). Data was analyzed and automatically scored using Actiwatch Sleep & Activity Software V 5.32 (Cambridge Neurotechnology Ltd, UK). Bed time and Get up time were recorded via the marker button on the Actiwatch and using diaries. Sleep scored data (i.e Sleep-start, Sleep-end, Actual-sleep-time, Sleep-efficiency and Immobile-minutes) were analyzed using both correlation and regression analyses.

RESULTS

Sleep-wake scoring based on wrist and back movements were highly related. Wrist and back based scoring of Sleep-start, Sleep-end, Actual-sleep-time and Immobile-minutes were very strongly related (r=0.95, r=1.00, r=0.92 and r=0.94 respectively). For Sleep-efficiency the relation was less strong (r=0.50).

DISCUSSION

Although the relation between the raw signal of back movement and wrist movement is rather weak, sleep-wake scoring based on wrist and back movements were highly related. The approach of using raw back movement data on wrist movement based scoring algorithms seems successful. However, both Sleep-start and Sleep-end are highly dependent on the input of the Bed time and Get up time, and hence the high correlation is rather biased. Moreover, the tested population was sleeping in their optimal home environment and did not report any disturbed sleep. The validity of back motor activity-based sleep-wake scoring in a more sleep disturbing field setting remains to be evaluated.

CONCLUSIONS

Sleep-wake scoring based on wrist and back movements were highly related. The algorithm of Actiwatch Sleep & Activity Software processes the raw signal of back movements even without any transformation in such a way that the sleep scoring is highly comparable to wrist based scoring. The validity of back motor activity-based sleep-wake scoring in a more sleep disturbing field setting remains to be evaluated.

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P-1-18

RECOGNITION OF MILITARY SPECIFIC ACTIVITY CLASSES USING HEARTRATE- AND ACCELERATION MONITORS

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INTRODUCTION

For physical demanding occupations, like military service, an accurate description of job requirements is needed to establish physical selection standards and adaptations in training and work conditions. The aim of the present study is to validate a feasible and objective method to register daily physical activities of soldiers. In the method to be validated, classes of physical activities shall be recognized based on step frequency, heart rate and acceleration.

METHODS

33 recruits (20.9 ± 1.0 y) performed the isolated activities walking, walking with backpack, running, lifting and lowering loads, carrying loads and digging for five minutes each, while wearing a heart rate (Suunto Smartbelt, Suunto, Fantaa, Finland) and two acceleration and step monitors (GT1M, Actigraph, Fort Walton Beach, USA). One GT1M was placed on the hip and one on the backpack. The data of 15 subjects (recording rate: 0.5 Hz) were used to train an activity classifier (decision tree) that assigned the data of each minute to a respective activity class. The developed classifier was validated by the data of the remaining 18 subjects. In order to estimate the accuracy of the activity classifier during daily military service, activities of 9 subjects (20.6 ± 0.8 y) were recorded in situ over 90 minutes. The data was labeled using direct observation, retaining the starting time of every activity with an accuracy of 1s. This was conducted for each soldier individually by the same researcher.

RESULTS

The overall recognition rate of the test data from isolated activities was 87.5%: 95% for walking, 95% for walking with backpack, 85% for running and 76% for demanding material handling activities (lifting and lowering loads, carrying loads and digging were combined in one class because the data were similar). 33% of carrying loads was incorrectly registered as walking. That explained 7% of 24% incorrectly recognised activity "demanding material handlings", the remaining 17% were not classified (null class). Direct observed in situ data and classifier data did not differ significantly for the activity classes demanding material handling, inactivity and the null class. Only the time spent in the class walking and running was significantly underestimated *(table 1)*. The classes walking, walking with backpack and running were pooled for this analysis, as the numbers of observations in each of those classes were small.

Activity Class	Observed [min]	Recognised [min]	Difference [%]	(T-Test) p	(Correlation) r
Walking and Running	80.5	57.0	-29.2%	0.033	0.951
Physical Demanding Material Handling	106.7	113.2	6.1%	0.738	0.802
Inactivity	144.6	121.1	-16.3%	0.080	0.927
Null Class	462.1	502.6	8.8%	0.171	0.944

Table 1: Total time spent in 3 different activity classes observed over 90 Minutes daily military service of 9 recruits, estimated with an activity classifier using heartrate, accelaration and step frequency.

DISCUSSION

The accuracy of the classifier indicates that step frequency, heart rate and acceleration can be used to recognise reliably isolated activities among group of soldiers. The registration of the total time spent in specific activity classes during daily military service by the used sensors and the activity classifier was accurate, except for the class "walking and running". The finding indicates that walking with slow steps was not registered by the step monitors and therefore not recognized by the activity classifier based on step frequency, acceleration and heart rate data. However, walking at low intensity is not a relevant for the physical selection standards in armies.

CONCLUSIONS

It is possible to register time spent in relevant daily physical activity classes in groups of soldiers with an activity classifier based on step frequency, heart rate and acceleration.

P-1-19

VALIDITY OF A BODY WORN SENSOR SYSTEM AS A MEASURE OF STEP COUNT DURING WALKING IN FRAIL OLDER ADULTS

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INTRODUCTION

New technology has made it possible to objectively measure gait by use of small body worn sensors. So far such systems have only been validated in healthy persons and patient groups with slightly reduced walking capacity. Frail older adults are characterised with asymmetric and slow walking speed. The aim of this study was to test the recognition and accuracy of step count of a uni-axial accelerometer in frail older adults against video recordings.

METHODS

A cross sectional comparative study design was used. The sensor (ActivPAL®) was used to count steps in 10 participants (5 inpatients from geriatric unit and 5 from stroke unit). This was the first 10 out of a total of 45 participants (complete data analysis to be finalised in February 2008); 5 women: mean age 87 ±3,16 yrs and 5 men: mean age 72,2 ±5,17 yrs. The Active PAL sensor was attached to the participants' right thigh. All participants used their usual walking aid during testing. 6 needed additional support. Participants walked back and forth on a 5m level surface at three instructed slow, preferred and fast walking speeds, in addition to three 4 steps and three 8 steps walking sequences. Step count derived from the ActivPAL sensor was compared with observations based on 2D video camera recordings. Absolute percentage of agreement was calculated using the Bland Altman method. Absolute percentage error of step count was calculated as ((sensor – observation)/observation) x 100).

RESULTS

Mean slow speed was 0,32 ± 0,06 m/s, preferred was 0,46 ± 0,86 m/s and fast speed was 0,66± 0,10 m/s. Table 1 and figure 1 demonstrate low agreement between video observations and step count from the ActivPAL sensor. The error was largest for the slowest instructed walking and the shortest sequences.

Instructed walking speed	Observed step count mean (SD)	Sensor step count mean (SD)	Mean diff. %
5 m slow	17.00 (2.98)	8,3 (3,43)	48,82
5 m preferred	14.10 (2.76)	9,0 (0,94)	63,83
5 m fast	12.75 (2.74)	8,88 (1,81)	69,61
4 steps preferred	5.55 (0.69)	1,33(0,83)	24,02
8 steps preferred	9.22 (0.37)	4,13(2,33)	44,85

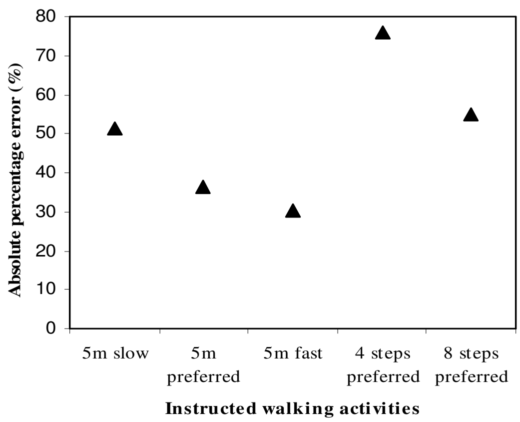

Table 1. Agreement for step number between observation and the activPAL sensor
Figure 1. Standard error for the activPAL sensor (right) in various instructed walking activities

CONCLUSION

The results from this small sample indicate problems with using the ActivPAL sensor for step count measurement in frail older adults using walking aids while walking short distances. This population is characterised by walking short walking distances at a slow speed, hence it is important to develop robust methods for recognising gait in these individuals.

P-1-21

DEVELOPMENT OF A LOCATION AND MOVEMENT MONITORING SYSTEM TO QUANTIFY PHYSICAL ACTIVITY

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INTRODUCTION

An activity monitor can be used to gain a greater understanding of people's activity patterns in everyday life**.** By augmenting the output with concurrent location data it is possible to derive additional detail including number of trips outdoors, duration, distance, gradients, and proportion of travel by vehicle. An integrated system could therefore provide data to assess the effectiveness of attempts to increase activity and indicate where barriers to increased activity may exist, particularly those caused by the external environment. The aim of this study was to test the system with a small number of participants to determine its usability during data collection, the ability of the software to analyse the collected data, and the suitability of the information provided from the users' perspective.

METHODS

Participants were recruited from an exercise group in Scotland. Location data was collected using a Bluetooth GPS device and mobile phone. Activity measurement was achieved with a separate lightweight device incorporating an accelerometer, which classifies activity as sitting/lying, standing or walking, provides step counts and derived energy expenditure. Both sets of data were collected simultaneously over a period of one week

RESULTS

The GPS and activity data were successfully collected and then combined and processed using software developed as part of this project to produce activity related daily values including distance walked and travelled by transport, exercise duration, and energy expenditure. Individual reports were created to display these values along with route maps and weather information. These reports were able to assist participants in understanding whether they were sufficiently active during the test period.

DISCUSSION

The results demonstrated the feasibility of collecting and synchronising location and activity information, and showed that the combined data allows a number of additional measures of relevance to the participants' activity related aim to be obtained. In addition to informing the participants about their activity levels this information could be used to enable them to obtain advice from the exercise group organisers or health professionals.

CONCLUSIONS

The system was capable of providing measures which could offer objective feedback on progress against activity targets. These could demonstrate if daily activity is at an appropriate level based on current guidelines [1]. They could also indicate where further improvements are required, and identify the barriers to achieving these activity goals.

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P-1-22

ACTIVITY RECOGNITION USING ELECTROOCULOGRAPHY: READING WHILE SITTING, STANDING AND WALKING

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INTRODUCTION

One of the richest sources of information on our activities is the movement of the eyes. The paths that our eyes follow as we carry out specific activities also reveal much about the activities themselves [1]. Reading is one such activity. We read in a wide variety of situations, e.g., on computer screens at work, ads. and signs in public, and books read at home or while traveling. In this work we use wearable electrooculography (EOG) as a novel sensing approach to recognize reading during typical situations: sitting at a desk, walking along a corridor, walking on a street, standing at a tram stop and riding a tram. Earlier work on this problem has been exclusively desk based and relied on (often bulky) visual sensors [2].

METHODS

We conducted a series of experiments using 8 subjects wearing EOG electrodes attached around their eyes. The subjects were asked to follow a predefined route, which aimed to simulate, as realistically as possible, a typical journey to and from work. Three runs of the route were made, each lasting about 17 minutes. In two of the runs, subjects were asked to read a section of text; the other run was used as a control, with no reading. An assistant followed each subject and made annotations of whether he or she was reading, and of their current activity (sitting, standing or walking). The EOG data was recorded using a "Mobi" reader from Twente MSI and a laptop carried in a backpack. Off-line feature extraction and classification ("reading" or "not reading") was done using a method based on string matching.

RESULTS

Over the total dataset size of 20485 seconds (48% of which involved "reading" activity), we were able to achieve a true positive rate (tp) of 71% with false positive rate (fp) of 11.6%. By breaking the results down to the three categories we achieved reading recognition rates during the activities of standing (tp=72%, fp=9.2%), sitting (tp=82%, fp=13.2%) and walking (tp=64.9%, fp=11%).

DISCUSSION

Though the recognition rates for reading while sitting were high – as would be expected – we were surprised to note that results of reading while walking was not as bad as might be expected. On closer analysis we discovered that much of the errors encountered were in fact related to poor timing of the annotations – during walking this could be as much as 10% of the total time.

CONCLUSIONS

This study indicates that EOG can be an effective sensing modality for recognizing reading activities during common ambulatory situations. Based on these preliminary results, and the datasets we have collected, we believe that eye movements may prove a useful clue to recognizing more general activities.

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P-1-23

EVALUATION OF A LABORATORY TO RECREATE OUTDOOR ENVIRONMENTS INDOORS

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INTRODUCTION

Two limitations of ambulation studies in outside environments are the difficulty of controlling environmental conditions and comparing results between different environments. A laboratory has been designed to fill the gap between real life studies and motion analysis laboratories that cannot represent real life environments. This paper presents the laboratory; how the environment is controlled; the measurement tools used; discusses how it can be used; and raises questions for how it could be improved.

METHODS

The facility consists of a reconfigurable modular platform, lighting and sound systems. The modules can be rearranged to any shape covering up to $82m^2$. Each individual module surface (1.2m side) can be set level, as steps (±250mm) or sloped (up to 1:5), with the surface material and condition changed as required. It is possible to attach objects to represent street furniture and to soak the platform to recreate wet and slippery conditions. With the laboratory walls and floor painted black, the lighting system allows control over luminescence from daylight to darkness including localised lighting, for example, streetlights. Light colour and intensity can be accurately and repeatedly controlled. An ambisonic sound system can recreate any required sound, for example, high street shops or train stations and dynamic noise, such as passing trains, traffic or aircraft. The measurement equipment currently includes digital video, a position scanner [1], eye-gaze tracking device [2] and heart rate monitors [3]. Object location is measured by two laser scanners using eye safe infrared beams. A proximity protocol defines individual objects. The eye-gaze tracking device can track where people are looking as they complete tasks.

RESULTS

Surface material, condition and topography, lighting and sound can all be accurately and repeatedly controlled. Body position can be measured to ±5cm. Gaze can be tracked in most situations, but there may be inaccuracies when looking at near and distant objects. The facility has been used to examine; pedestrian density at constrictions; pedestrian interactions with environmental features such as steps, slopes and other obstacles under different lighting conditions; embarkation and disembarkation capacities for different vertical and horizontal gaps; and visually and mobility impaired people’s ability to detect and follow pavement delineators. Detailed data about personal interactions have been gathered and analysed to interpret the impacts of how different features affect individuals and what this might imply for the design of pedestrian environments.

CONCLUSIONS

The physical environment can accurately recreate useful test spaces within the limits of $82m^2$. However, even though $82m^2$ is a larger area than that available in most laboratories, however much space you have, it never seems to be enough; hence for longer experiments, a repeated circuit is required. The currently used measurement tools need to be augmented and tested in comparable outdoor conditions. This is a flexible, controllable, and most importantly, safe, environment to test people’s capabilities in recreated street environments.

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P-1-24

APPLICATION OF THE SPEED SENSOR ON PERCEIVED DISTANCE FOR THE SIGHT AND HEARING HANDICAPS

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INTRODUCTION

As for Japan, advance of an aged society is expected. It is estimated if it will reach to 40% in 2055. It becomes the aged society, not regard a kind of aged to all the population in the world of elderly people. Moreover the present number of physically handicapped persons is about 3,520,000 people. It is becoming a social problem to increase of crossing movement in accident for old persons, sight and hearing handicaps. It was desired that to develop of technical assistance for preventing traffic accident elderly peoples and sight and hearing handicaps. Especially it was causes an accident consciousness of the vehicles that approach from backward causes an accident. The hearing- hearing handicaps person cannot recognize the information of sound from vehicles. It was inquired that the system has the back consciousness during walking. The purpose of this study was to investigate the backward consciousness capability and to evaluate the distance detection sensors.

METHODS

Four kinds of sensor were tested for this study. There were commercial products for distance measured sensor: millimeter wave radar, the 24GHz band microwave, infrared rays and optoelectronic switch. Each sensor was attached to ten quite standing subjects and it was verified whether approach or away of a subject's back body would be smoothly detectable. It examined also in walking whether the car, which approaches from backward without hearing information, would be detectable.

RESULTS

The major findings that: there was much multi-pass effects in any experimental conditions. Every sensor has technical glitch. The millimeter wave radar for car products was heavy equipment for human body. It is not suitable for walking person. The infrared rays were difficult to detecting of backward some extent area. That is too strong directly wave to scan the backward area. The optoelectronic switch was very simple reaction but that was not showed the distance on coming up car or human body. The microwave was easily modified detection distance from 100m to 10m. And it was also changed detection backward area by three type antenna (horn antenna, patch antenna and parabola antenna). The microwave with two channels was able to distinguish approach or away, and slow speed measurement with digital signal processor and amplifier circuit.

DISCUSSION

The experimental data and settings indicates that the microwave sensor is most suitable for wearable device, detection capillarity and flexibility area. The application system, which detects the approaching object from backward to the quite standing subjects, is informed comparatively easily. Meanwhile all sensors was not precious detect of backward approaching car or walking man during subject walking. It is possible to get of moving speed from 0 to 0.46m/sec. Then the microwave sensor is most convenient for human moving perception. In the dual doppler microwave oscillation system was applied to discernment of a phase. Future it is necessary to analyze the signal source acquired by the material of reflective backward objects. It will be possible to compute the threshold, which can recognize for the sight and hearing handicaps whether the man is approaching or the car is approaching.

CONCLUSIONS

It is important for an aged society to secure safe walking environment in especially disabled person. The microwave with improved speed sensor was able to detect backward approaching cat and walking man. his is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section. This is the conclusion section.

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P-1-25

FROM THE SENSORS TO FEATURES: WHAT OPTIMIZES THE RECOGNITION OF PHYSICAL ACTIVITY?

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INTRODUCTION

In Future, miniaturized sensors and wireless sensor networks will make it possible, to collect and interpret biomechanical and physiological data, in order to recognize classes of activities that significantly effect metabolic rate. In the present study the use of accelerometers, gyroscope, earth magnetic field sensors and heart rate monitors for activity recognition have been investigated. In particular, the following questions were of interest: Which of the mentioned sensors are the most valuable? Where should they be placed for high recognition rate? How does the frequency of the raw signals effect recognition rate and what is the minimal length of the sliding window in which the extracted features still discriminate between activities.

METHODS

14 Subjects (7 women, 7 men, age: 37.93 ± 15.11 y, weight: 71.8 ± 11.9 kg, height: 1.74 ± 0.07 m) had to perform several activities out of 7 activity classes (resting, sitting activities, standing activities, walking, running, biking and intensive non-cyclic activities typically in sports activities). Datasets were recorded using 3-dimensional accelerometer, gyroscopes and earth magnetic field sensors (MTx, Xsens Technologies B.V., Netherland) on 9 different parts of the body (arms, wrists, knee, ankles and hip), with a frequency rate of 100 Hz. Simple features such as mean, energy, variance and frequency entropy were extracted from the signals using a non-overlapping sliding window of 1 sec. For each single feature the error probability of a minimal error rate classifier were computed from normalized histograms of feature values conditioned by the classes. The features were than ranked and scores were distributed for sensors and their placement according to if they contributed to well discriminating features. For the best combination of sensors and placements several new pairs of features were tested for their capacity to discriminate PA classes using a maximum likelihood classifier. Furthermore, the effect of low-pass filtering of the signals and of feature extraction using different window sizes was also tested, using the same classifier.

RESULTS

For all classes: 36% of the best performing features were extracted from signals recorded above the knee, 24% from signals recorded at the ankle and 18% from signals recorded at the upper arm. 64% from the best performing features for the resting class were extracted from signals recorded at the upper arm. For standing activities, sitting activities walking, biking and running the largest percentage of features were extracted from the knee (56.44%, 34.34%, 47.17%, 39.47%, 41.51%, respectively). 33% of the best performing features for sports activities were extracted from signals recorded at the hip. 74% of the best performing features were extracted from accelerometer signals. Much less of the best discriminating features were extracted from gyroscopes, earth magnetic field sensors and the heart rate monitor (16%, 8%, 2%, respectively). For a maximum likelihood classifier the following optimizations have been found: For resting activities a recognition rate of over 97% has been achieved, when at least the lowest 30% of the frequency range of the signal had been retained, independent of window size. When using the lowest 30% of the frequency range of the signal and using a window size of 6 sec the error rate could be minimized to 4% for sitting activities, 3% for standing activities and 1% for walking and biking. For a recognition rate of 95% for sports activities the lower 40% of the frequency range was needed as well as a window size of 7 sec. Using the lowest 30% of the frequency range and a 6 sec window a recognition rate of 93% was achieved.

CONCLUSIONS

Features extracted from accelerometers mounted above the knee and at the upper arm are sufficient to discriminate 7 classes of activities that effect metabolic rate. The accuracy of a maximum likelihood classifier can be increased, by retaining only the lowest 30% of the frequency range of a 100 Hz signal. Furthermore a window size of 6 sec is sufficient for a recognition rate of at least 93%.

P-1-26

MULTI-SENSOR PLATTFORM FOR ACTIVITY MEASUREMENTS

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INTRODUCTION

The acquisition of different (vital-) parameters like pulse, position, motion, step duration resp. stepping frequency or body temperature is not a problem anymore. But many difficulties come along, if data has to be recorded not only simultaneously but even synchronized and under mobile conditions. Most of commercial purchasable measurement devices are able to collect data from only one sensor and store it locally on a memory card. But if data from different sensors should be correlated, the increment value could not be ignored. In this article we present first results obtained by a newly created sensor platform collecting data from several sensors and transmitting it via a mobile device to an internet server. The system was tested during a "super marathon" (running distance 72,7 kilometers) and the "Munich City Running".

METHODS

In our approach we built a multi-sensor platform to record data from the following sensors: accelerations at the vertebra of the loin in all three dimensions, skin temperature, body core temperature, pulse and position via GPS. The acceleration data was measured with a sampling frequency of 128 Hz, the others with one sample per second. The acceleration data was used to determine the step duration of each single step and the resultant stepping frequency. This data interpretation was done on the mobile device and then the result was transmitted to the server-platform. The raw data was stored locally on SD-Card for further offline analysis. We got data from seven runners in parallel and spectators were able to watch them online superimposed to the position, which was displayed on a Google-Maps window.

RESULTS

Our main goal was to demonstrate, that our new sensor platform can be worn without any disturbance, even under inappropriate circumstances and that the whole technological chain from the sensors up to the display is working. An impressive result provides the step duration resp. stepping frequency derived from acceleration data. In combination with position (GPS) and variation in altitude, it is obvious, that the stepping frequency increased, while the running speed decreased. Another interesting result is the combination of body core temperature and acceleration data. At the beginning of the physical effort, in evidence of the acceleration data, the body core temperature was first decreasing, and after a certain time, when the physical effort was constant, the temperature raised and stayed afterwards at a constant level.

DISCUSSION

These results have to be verified again during other marathon running resp. supplemented by measurements at other sports. The results are very simple at first glance, but now there is the technical base to explore further correlation between these data. The collected data and the analysis of it confirm obvious issues and demonstrate the correctness of the data.

CONCLUSIONS

These first results are very promising and demonstrate the usability of the new sensor platform including the body core temperature sensor, pulse and acceleration. The big challenge will be to identify new, calculated parameters by correlating and combining the raw data now available.

P-1-27

RECOGNITION OF DAILY LIFE ACTIVITIES - A SENSOR NETWORK PROSPECT

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INTRODUCTION

Accelerometers offer a non intrusive and low-cost solution to quantify physical activity (PA) level, but most commercialized systems provide a rough approximation based on activity counts. Moreover, few of them enable PA recognition during daily life, which is an important issue to evaluate quality of life. Based on a simple PA classification, some previous works [1] thus assessed postures and motions for long-term (>24h) measurement periods during daily life by means of an activity monitor comprising accelerometers. Unfortunately such a system do not allow yet to evaluate a large population in real-time. In this work, we propose a new method that minimizes the data flow transmission in order to set up an ambulatory monitoring device that could be integrated into a sensor network. This presentation is focused on postures and locomotion activities recognition, on velocity prediction, and on energy expenditure (EE) estimation.

METHODS

Our algorithm comprises three main steps: 1) local features extraction, 2) hierarchical PA recognition, 3) EE estimation. In order to build up the database, three 3D wireless accelerometers placed at wrist, hip and ankle recorded postures and locomotion activities of 8 non sedentary men. To evaluate the reliability of PA recognition, a test group of 7 other men with similar morphology was also recorded. For each experimental data set, 3s time windows were extracted and manually labelled among PA classes, to be used in a learning analysis. This analysis allowed to build up the following classification algorithm. First, simple temporal and spectral features were extracted to reduce the signal dimension and thus to reduce the transmitted data rate. Then, PA were classified according to a hierarchical tree whose nodes differentiate current activities in sub-activities. Inside dynamic activities, the classification uses principal component analysis on all extracted features [2]. To date, the tree comprises 8 postures (various standing, sitting and lying postures) and transitions, and a range of velocity (0-14km/h) for locomotion activities (walk, run, stairs climbing). From an indirect calorimetry system, regressions were finally established to assess EE for each PA.

RESULTS

Results showed more than 98% of all PA were recognized in laboratory conditions. No misclassification occurred for dynamic PA. Nevertheless, the standard deviation between treadmill speed and estimated speed were 0.38 km/h at 3km/h and 0.47 at 5km/h for walking, and 0.42km/h at 7km/h and 0.52km/h at 10km/h for running. Moreover, among stand and sit postures, less than 5% of misclassifications were quantified, principally when legs were moving. Based on PA classification, early results on EE estimation indicate better correlations when taking inertia due to PA transitions into account.

DISCUSSION

In this study, we could present promising results for PA classification and EE estimation during moderate intensity level. Nevertheless, in order to take into account highest intensity levels, we currently work on the coupling with other physiological indices such as heart rate. At the same time, we work on additional morphological inputs in the algorithm (mass, gender, body mass index...), and on a larger database. These improvements may therefore enable to extend the approach to any subjects, and any daily life activities.

CONCLUSION

First of all, this work is meant to be methodological. Promising results obtained in this study will serve as a basis for the implementation of a sensor network which aims at monitoring a large population in real time. Indeed, features extraction divides the data flow by more than 100 when compared to a rough transmission.

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P-1-28

DETECTION OF GAIT AND POSTURES IN OLDER ADULTS AND PATIENTS WITH PARKINSON'S DISEASE: ACCURACY OF AN ACCELEROMETRY BASED METHOD

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INTRODUCTION

Practical devices that can accurately measure daily activities in real life situations enable objective evaluation and optimization of interventions. The aim of this research was to examine the accuracy of an accelerometry based method (DynaPort MicroMod (DM)) when used for the detection of gait episodes and number of steps (study 1) (c.f. [1,2] and basic activities (walking, standing, sitting and lying, study 2) in a group of older adults and patients with Parkinson's disease (PD).

METHODS

In study 1, the DM-system, consisting of a single tri-axial accelerometer placed at the lower back was evaluated against the results of two pedometers (Yamax Digi-Walker SW-200 (YD)) worn on each hip and video observation. Twenty older adults and 32 PD patients walked straight line trajectories of different lengths at different speeds and while doing secondary tasks in an indoor hallway. In study 2, the same subjects wearing the DM performed the basic activities first in a prefixed order and subsequently during 3 minutes in which the subject was free to act in a simulated 'home-environment' that was set-up in a laboratory room. A correct identification of the activities was evaluated against video observation.

RESULTS

Study 1: The DM's mean accuracy to measure walking duration was 89.3% for the older adults and 88.9% for the PD patients. Mean accuracy of the DM for step detection was 92.6% for the older adults and 93.1% for the PD patients. The DM detected step activity least accurately when subjects walked a distance of 3 meters (79.9% in older adults, 81.6% in PD patients). The left YD was more accurate than the right YD. The left YD detected mean values of 93.2% steps for the older adults and 88.9% for the PD patients. Accuracy of the pedometers decreased at lower velocities (83.8% in older adults, 75.1% in PD patients).

Study 2: Preliminary results of the data of 5 older adults and 4 PD patients show that the DM's mean accuracy for detecting the basic activities walking, standing, sitting and lying when performed in a fixed order was respectively 69.4%, 72.5%, 19.4% and 75.6% for the older adults and 70.2%, 86.6%, 41.3% and 81.4% for the PD patients. The DM's mean accuracy values when the subjects were free to act were respectively 81.7%, 50.1%, 47.7% and 70.2% for the older adults and 84.6%, 40.7%, 67.2% and 79.8% for the PD patients.

DISCUSSION

A low mean walking velocity could explain the lower step detection accuracy of the DM when walking 3 meters. Acceleration signals may have been too small for automatic detection by the algorithm. A slower and shuffling gait pattern of the PD patients could have caused insufficient up-and-downward movement of the spring mechanism of the pedometer to register steps. Since activities of short duration often remain undetected, the presently reported accuracy of the identification of daily activities seems to be influenced by performance duration of activities.

CONCLUSION

Accelerometry and pedometry are both practical methods for assessing gait activity in controlled circumstances, but an accelerometry based method allows for more accurate detection of steps in patients with PD. Furthermore, the presented data show a reasonable to good accuracy for detecting daily activities like walking and lying, but the identification procedure of standing and sitting needs to be improved. Further analysis of the data of all subjects is in progress.

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P-1-29

GAIT & POSTURE DETECTION IN DAILY LIFE BASED ON ONE 3D ACCELEROMETER

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INTRODUCTION

Only few systems are available for long term monitoring (24 hours and longer) of postures and motions during daily life. With minimal two instrumented body segments (e.g. trunk and upper leg) the main postures and dynamic activities (e.g. walking) can be identified [1]. A disadvantage of such a multi-sensor approach is the risk of damage to cables and connectors, discomfort for the subject wearing the instrumentation, and complexity and risk of failure for the investigator. Within the context of an EC funded STR project (SensAction-AAL [2]), a single sensor monitoring approach was developed. This abstract presents the first results of a cross-validation study in healthy subjects, which compares the results of this new single sensor approach to a validated commercially available multi-sensor approach [3].

METHODS

The DynaPort ADL-Monitor (DAM) is used as gold standard. The new system (DynaPort MoveMonitor) consists of three orthogonally placed piezo-capacitive acceleration sensors in a small and light housing (51x84x8.5 mm, 45 gram with lithium polymer battery included). It measures accelerations in a range of ±2g with a resolution of 1 mg and stores raw data on a memory card with a sample frequency of 100 Hz. The accelerometer was inserted in the neoprene belt of the DAM and positioned on the lower back near the body's centre of mass. Four healthy subjects were asked to wear the system continuously for 24 hours. Measurements were done during a normal working day without any protocol. The software of the ADL-Monitor and the new software (MoveMonitor) analyzed the raw data without manual interference. The addition to the method is the detection and classification of postural transitions. The output of the software is an event-list with the duration of all periods of locomotion and posture (sitting, standing and lying) with a resolution of 1 second for the ADL-Monitor and 0.01 second for the MoveMonitor. A Matlab program was developed to compare the output from the two systems. Agreement per second was detected and sensitivity, specificity and error were calculated. The error is the absolute difference between the actual duration assessed by the gold standard and the duration assessed by the new algorithm.

RESULTS

The sensitivity is between 74.7 and 91.2% (Table 1). The specificity is between 90.0 and 99.1%. The error is between 0.2 and 7.6%.

Table 1 Sensitivity, specificity and error of the four 24 hour measurements

	Sensitivity	sd	Specificity	sd	Error	sd
Lying	91,2%	7,5%	97,7%	1,1%	3,7%	3,6%
Sitting	74,7%	9,4%	93,2%	5,8%	5,8%	4,7%
Standing	88,0%	2,7%	90,0%	2,5%	7,6%	2,0%
Locomotion	83,0%	3,0%	99,1%	0,3%	0,2%	0,2%

DISCUSSION

The advantage of comparing two wearable systems is that there is no influence of an observer. The classification of sitting and standing should be improved. It is expected that the detection of walking and very slow walking (shuffling) is better in the MoveMonitor. This is based on the visual inspection of the raw signals. Future studies have to further confirm validity of the method.

CONCLUSIONS

Good agreement in activity classification was found between a double and a single segment system. A single unit 3D seismic accelerometer is a promising system to classify two main activity categories: locomotion and postures. The location near the centre of mass, the storage of raw data and the high resolution of the signals enables detection of other relevant parameters. The system is unobtrusive and the subject has low awareness of being assessed. This new method is a crucial step forward in simplifying the instrumentation.

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P-2-1

THE METABOLIC COST OF TWO AMPUTEES WALKING OUTDOOR WITH THE 'POWER KNEE' PROSTHESIS

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INTRODUCTION

The 'Power Knee' (PK; Össur, IS) is the first commercial knee prosthesis for above-knee amputees (AKAs) in which an electromechanical actuator actively flexes and extends the joint, 'mimicking' the kinetics of the sound side. Being the potential benefits for AKAs followed by a consistent increase in costs (more than 80.000€), it seems essential to objectively evaluate the pros and cons of the PK in comparison with reactive knees, in real-life conditions. The aim of this work was therefore to assess if the PK allows reducing the Net Metabolic Cost of outdoor walking (NMC) compared to a C-leg knee (Otto-Bock, GE).

METHODS

Two K4, traumatic, monolateral AKAs, named hereinafter A and B, 31 and 26 year-old respectively, participated in this study. By the time of tests, A and B had been using a C-leg for 6 years and the PK for more than 6 months. Three NMCs were measured for each subject and prosthetic knee using a portable Cosmed K4b^2 (Rome, IT) gas analyzer, through 3 walking trials at different speeds, performed on an athletic track, 110m long. For each subject, the 3 NMCs with the PK were measured after 7 days of consecutive use the prosthesis, while the 3 NMCs with the C-leg after 3 days. During the test day of each prosthesis, the seated VO_2 [mL/(Kg*min)] of the subject was firstly measured. Then the subject was asked to complete the 3 trials, walking back-and-forth the track at a self-selected slow, normal and fast speed, respectively. During each trial, the VO_2 was monitored in real-time; after the subject had reached 1 minute of aerobic steady state, the trial was stopped and the mean VO_2 over the minute was computed. For each trial, the NMC was then computed by subtracting the seated from the walking VO_2 and dividing the difference by the trial speed.

RESULTS

The NMCs for subject A was higher with the PK compared to the C-leg: +62%, +34%, +15% for the slow, normal and fast speed, respectively. The NMC for subject B with the PK was lower for the slow speed (-7%), but higher for the normal and fast speeds: +9% and +7, respectively.

DISCUSSION AND CONCLUSIONS

Since treadmills modify AKAs' energy expenditure [1], outdoor tests are essential to obtain realistic comparisons of different prostheses. From the results, the PK does not seem to decrease the NMC outdoor: analysis of the outdoor gait symmetry and EMG activity are underway to shed light on the possible causes. No other outdoor studies on the PK are available for comparison.

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P-2-2

PHYSICAL ACTIVITY IS RELATED TO HEALTH-RELATED QUALITY OF LIFE IN ADOLESCENTS AND YOUNG ADULTS WITH SPINA BIFIDA

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INTRODUCTION

Persons with chronic conditions such as spina bifida (SB) have low levels of physical activity compared to the general population. This may have serious consequences for health and quality of life. The study aimed to describe whether the level of daily physical activity was associated to health-related quality of life (HRQL) in adolescents and young adults with SB.

METHODS

Fifty-one persons (51% males) aged between 16 and 30 years participated, of whom 55% were wheelchair dependent. HRQL was measured with the Short Form 36 (SF-36). Additionally, the physical component summary (PCS) and mental component summary (MCS) were calculated. Results of the 8 domains of the SF-36 were compared with those of a Dutch reference population. Physical activity was measured with an accelerometry-based activity monitor and expressed in minutes per day. Relations were studied using logistic regression analyses adjusted for gender and ambulatory status, and in case of significant univariate relations, also for age and educational level.

RESULTS

Participants had poorer HRQL than the reference population on the domains physical functioning and general health ($p< 0.05$). Role limitations due to physical problems, vitality and social functioning tended to be lower in persons with SB ($0.05< p \leq 0.08$). We found no significant differences between SB participants and the reference population on the domains bodily pain, role limitations due to emotional problems and mental health. Average PCS score was 43.1 (9.1) and average MCS score was 55.0 (9.7). Adjusted for gender, ambulatory status and educational level, persons with SB who were more physically active had higher PCS scores (OR = 1.03; $p = 0.02$) and tended to have higher MCS scores (OR = 1.02; $p = 0.06$).

CONCLUSION

In adolescents and young adults with SB, who in general have low levels of physical activity, we found that both ambulatory and non-ambulatory persons who were more physically active had better physical and mental HRQL. Encouraging persons with SB to become more physically active seems to be important for their HRQL, but needs to be confirmed in longitudinal studies.

P-2-3

AMBULATORY ASSESSMENT OF THE MOTOR STATE IN PARKINSON'S DISEASE IN REAL DAILY LIFE

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INTRODUCTION

After several years of levodopa treatment, an increasing number of patients with Parkinson's disease (PD) show fluctuations in motor response and levodopa induced dyskinesias [1]. Self-report of the motor-state in diaries has several limitations and can be troublesome or even unreliable. Therefore, automatic ambulatory assessment of the motor state and motor fluctuations would be highly useful in the management of PD and in the evaluation of surgical and pharmacological interventions. Recently, we developed a method that could distinguish between "on" and "off" states [1] and a method to assess the severity of dyskinesia in daily life [2]. In these studies patients performed about 35 functional daily life activities in a home-like laboratory situations. The purpose of this study was to combine and test both methods in real daily life.

METHODS

Twelve patients were continuously measured for 1-3 days, using 6 triaxial accelerometers. The accelerometers were placed at 6 different positions on the body: on both upper arms, on both upper legs, on the trunk (top of sternum), and on the wrist of the most affected side. Patients noted their motor state in a diary every 15-minute as a reference for the automatic detection. The previously developed methods [2,3] were used to automatically assess the motor state of a patient. The "on" and "off" state were distinguished based on the percentage peak frequencies above 4Hz [2]. Subsequently, the previously developed neural network was used to distinguish between dyskinesia and desired "on" state without dyskinesia [3].

RESULTS

Patients' classifications and automatic classification matched in 85% of the 15-minute periods. Several patients classified dyskinesia, whereas the accelerometer data showed a clear 4-7Hz Parkinsonian tremor indicating misclassification by patients. In addition, patients classified 15-minute periods as dyskinetic, whereas patients did not move a lot. Ten of the twelve patients had at least one misclassification. The important parameters percentage movement and percentage peak frequencies above 4Hz were significantly different between motor states.

DISCUSSION

The participating patients suffered from motor fluctuations and dyskinesias and were well known by the neurologist for many years. Moreover, patients were only selected for this study when they were able to accurately describe relevant motor states and symptoms of PD. Therefore, the misclassification by 10 of the 12 subjects was surprising and suggests that the performance of the classification system is even better than the 85% agreement between automatic classification and classification by the patient.

CONCLUSIONS

The results suggest that the method could be operating successfully in unsupervised ambulatory conditions in real daily life. The misclassification by patients indicated the advantage and the need for automatic assessment of the motor state.

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P-2-4

ACCELEROMETERY-BASED ACTIVITY MONITORING FOR UPPER LIMB PROSTHESIS EVALUATION

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INTRODUCTION

The evaluation of upper limb prostheses' functionality relies on either self-reporting by amputees or lab-based evaluation [1]. Activity monitoring has yet to make a major contribution to the problem, probably as a result of the kinematically redundant arm and highly dextrous anatomic hand, which make the relationships between upper limb motion and task completion extremely complex. However, following trans-radial amputation, the upper limb loses degrees of freedom, and the anatomic hand is replaced with a much less dextrous prosthetic hand. This introduces additional physical constraints, which may reduce the complexity of the relationship between upper limb motion and task completion, thus making upper limb activity monitoring feasible. This study investigated the feasibility of using a machine learning technique to classify upper limb activities of trans-radial prosthesis users from arm-located inertial sensors.

METHODS

Two subjects with trans-radial amputation, who were myoelectric prosthesis users, were recruited for this study. Each subject walked along a 10-metre pathway and then performed one of a set of 5 bi-manual tasks on a table that was placed at the end of the pathway. This sequence was repeated until all tasks were performed 15 times. Kinematic data of the amputated side upper arm, prosthetic forearm, prosthetic hand, and contralateral side non-amputated forearm were captured by a motion capture system (Vicon). The acceleration of the prosthesis and limb segments, as well as the extent of prosthesis hand opening (index finger-thumb distance) throughout the test session were calculated from the kinematic data. The data were labelled as walking, transition and manipulation phases. The labelled data were divided randomly into 2 sets: 8 in the training set and 4 in the testing set. A Multi-Layer Perceptron neural network was used as the classifier.

RESULTS

The neural network was able to classify correctly all 5 tasks and distinguished them from other motion phases (walking and transition) when it was trained and tested on data from the same subject (100% accurate). However, when it was trained on data of one subject and tested on data of another subject, the classification accuracy dropped (80%). The classification accuracy was insensitive to motion input of the contralateral side non-amputated arm.

DISCUSSION

The neural network classifier performed very well under laboratory conditions in which the tasks were highly controlled and the data were all collected on a single visit. It remains to be seen how sensitive the tool is to day-to-day changes in upper limb motion and how well it performs under less controlled, more realistic conditions.

CONCLUSION

This study suggests that movement patterns of upper limbs in amputees tend to be characteristic enough to be recognised by a neural network. The accuracy of recognition dramatically increases when the neural network is personalised.

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P-2-5

UPPER-LIMB ACTIVITY PROFILE OF STROKE PATIENTS

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INTRODUCTION

Recently there has been great interest in the objective measurement of free-living upper-limb activity [1]. For a range of motor impairments and disabilities problems in performing activities of daily living (ADL) have been expressed in terms of upper-limb movement and non-movement [2]. Furthermore, an important outcome in rehabilitation involves gaining accurate and objective information about the individual's performance of the motor tasks most critical to that person's everyday life. To date, there is little information on the measurement of free-living upper-limb use of stroke patients who have been discharged from a rehabilitation programme. The aim of this study was to quantify the free-living upper-limb activity profile of stroke patients using a novel body-worn instrument [3].

METHODS

Twenty-nine chronic stroke patients participated in this study. A device which continuously recorded the movement and vertical position of the wrist relative to the shoulder (the Strathclyde Upper Limb Activity Monitor, SULAM [2]), was worn by all participants for 8 hours a day while they carried out their normal activities. Participants were recruited from hospitals in the Glasgow area. The inclusion criteria for stroke patients were patients with upper limb impairment, at least one year post stroke, discharged from all rehabilitation interventions and with limited use of the affected upper limb (2.5 or lower on the Motor Activity Log). The outcome measures provided by the SULAM quantified the total upper-limb usage and the vertical range (relative to the shoulder) in which that movement occurred.

RESULTS

The unaffected upper-limb was active, on average, twice more than the affected upper-limb ($p<0.01$). For both upper-limbs most of the movement was performed in the vertical range waist to chest. Bimanual movement was found to occur mainly below the chest level whereas unimanual movement occurred predominantly above the chest level. The maximum displacement above shoulder was larger for the unaffected upper-limb than for the affected upper-limb ($P<0.01$).

DISCUSSION

The unaffected upper-limb showed a greater amount of movement in the ranges chest-to-shoulder and shoulder-to-head than the affected upper limb. For this group of stroke patients, in the home environment, there was a reduction in both the amount of movement of the affected upper-limb and the vertical range of movement of that upper-limb. This suggested that this group of stroke patients had either adopted compensatory strategies to cope with ADL or had learned to not use the affected upper-limb. The unaffected upper limb demonstrated more movement in the vertical ranges above the level of the chest, which suggested a dependency on the unaffected upper limb for specific tasks requiring the wrist to be moved above this level. Such tasks could be associated with grooming and feeding.

CONCLUSIONS

This study shows evidence of the actual use of the upper-limb of stroke patients in their own free-living environment. The increased use of the unaffected arm and decreased bimanual movement, suggested a dependency on the unaffected upper-limb and that compensatory strategies were used to perform daily activities. The study showed that this technique could be used to monitor and assess upper-limb therapy.

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P-2-6

MULTI-DAY PHYSICAL ACTIVITY MONITORING IN PEOPLE WITH CEREBRAL PALSY

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INTRODUCTION

The population of people with cerebral palsy (CP) has varying levels of mobility impairments [1] and one of the primary aims of clinical interventions in CP is to maintain and improve walking ability. Therefore knowledge of activity levels will provide critical information about the success of the clinical intervention. There is limited information pertaining to the mobility of people with CP in their free-living environments [2] and typically no routine monitoring of activity levels is performed. The activity monitor (activPAL™, PAL Technologies Ltd, Glasgow, UK) is a small, 50x35x7mm and lightweight (20g) self contained unit designed to monitor free-living activity. The aim of this study was to determine daily physical activity levels of children with CP. An integral part of this study was the evaluation of the activity monitor in a laboratory-based environment in children with CP.

METHODS

10 subjects with the condition of CP (3 girls and 7 boys; age 5-17 years; 7 diplegia and 3 hemiplegia) were recruited. A laboratory based evaluation study was carried out before the subjects wore the device in a free-living environment. The activPAL was attached to the right thigh of each participant during a gait analysis session. They were asked to walk, stand and sit for different periods of time, whilst being video recorded. Subjects then wore the device during waking hours (except for water based activities) for 7 consecutive days during their normal daily life.

RESULTS

For the laboratory based evaluation study, it was shown that the activity monitor could detect sitting/lying, standing, walking and the number of steps with average accuracies of 96.4%, 94.2%, 92.1%, 97.3% respectively. Fig 1 shows the range of activity levels for the 10 subjects for the 7 days periods, indicating the average stepping time, quiet standing time and number of steps per day.

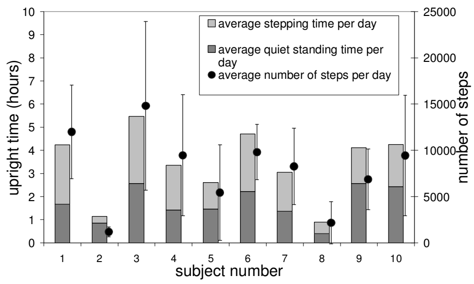

Figure 1: Average quiet standing time, stepping time and number of steps per day over 7 consecutive days for 10 subjects

DISCUSSION

The evaluation study verified good agreement between video and the activPAL data. However, it was noticed that for specific children who had greater mobility impairment such as severe crouch gait, the accuracy decreased as misclassification occurred between standing and walking. The evaluation study was laboratory based, involving short intervals of each activity. This may have increased the proportion of time spent in transition between activities compared with daily life. We therefore believe that the values achieved in the evaluation will be under estimates of accuracy of the device in the community/home environment. For the community based study, the device could distinguish the less active household walkers (e.g. subject 2 and 8) from the more active community walkers who took on average over 5000 steps per day.

CONCLUSIONS

The activPAL may be used to classify activity level in people with CP and therefore may provide valuable information on the rehabilitation progress and mobility status of children with CP by identifying the daily activity levels of the individual in their free-living environment.

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P-2-7

OBJECTIVE ASSESSMENT OF MOBILITY OF THE SPINAL CORD INJURED IN A FREE-LIVING ENVIRONMENT

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INTRODUCTION

The aim of rehabilitation after Spinal Cord Injury (SCI) is to optimise function, and to facilitate mobility and reintegration into the community. Options for the objective assessment of wheelchair mobility in the free-living environment are currently limited [1]. The purpose of this study was to assess the feasibility of continuously monitoring wheelchair and upright mobility in a free-living environment in the SCI population.

METHODS

An existing, commercially available, activity monitor (activPAL™, PALtechnologies, Glasgow, UK), intended for assessing ambulatory physical activity, was used on the wheel of a wheelchair. The analysis software was adapted to provide outcome measures of time spent moving in the wheelchair, distance travelled, and overground speed. The monitor was assessed on three groups of participants, recruited from the Queen Elizabeth National Spinal Injuries Unit, Glasgow, UK: individuals with a SCI who were wheelchair dependent (n=7); individuals with SCI who used the wheelchair in conjunction with upright mobility (n=7); and asymptomatic non-wheelchair users (n=5). Monitors were attached to the wheelchair wheel (to assess wheelchair mobility) and/or the thigh (to assess upright mobility) as appropriate. Data was collected continuously for a week for participants with SCI who were wheelchair dependent, and for a single day for the other two groups of participants.

RESULTS

Over the course of a week, the participants with SCI who only used a wheelchair for mobility moved in the wheelchair for between 4 and 13 h each day, travelling a distance of between 7 and 35 km, at an average overground speed of between 0.43 to 0.88 ms^{-1}. The daily variation of mobility within this group of participants was considerable. Displaying the mobility information on an hourly basis, allowed details of the activity pattern to be assessed. During a single day, mean total mobility was 70% higher for participants with SCI who used a wheelchair and upright mobility (1.7±0.7 h), compared with those who only used a wheelchair for mobility (1.0±0.5 h). Participants in the asymptomatic, non-wheelchair using group, clearly engaged in mobility activities for longer periods (6.3±1.3 h) than both groups of participants with SCI.

DISCUSSION

Despite the large inter-individual differences between participants with SCI, a 70% difference in time spent in mobility activities was reported. This suggested that the technique could be used to assess differences between sub-groups of the of the SCI population for population or intervention studies. The data collected was continuous and could be analysed for any time period (e.g. hourly), allowing an investigation of the pattern of mobility, which could be used to investigate differences in, for example, changes in routine, health status, or environment, on the mobility of an individual.

CONCLUSIONS

This study has shown that the proposed monitoring system, can be used to measure overall mobility across a broad spectrum of the SCI population. In addition to time spent moving in a wheelchair, outcome measures of distance travelled and overground speed were reported. Detailed information can be obtained regarding the type and pattern of mobility, which could be used to evaluate interventions, or to inform decision making in rehabilitation.

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P-2-8

MEASURING PHYSICAL ACTIVITY IN AMBULATORY CHILDREN WITH SPINA BIFIDA: FROM DIARY TO PHYSICAL ACTIVITY MONITOR

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INTRODUCTION

Ambulatory children with Spina Bifida (SB) are at risk of developing a hypoactive lifestyle. Earlier studies have reported lower levels of physical fitness and physical activity in both children and young adults [1, 2]. Physical activity monitors (PAM) commonly used to measure physical activity level (PAL) in both adults and children. In preparation of developing a PAM for future research in ambulatory children with SB, we were interested in knowing (1) the level of physical effort during functional ambulation in these children (2) which daily activities were most common and (3) the level of perceived effort during these daily activities was perceived in ambulatory children with SB.

METHODS

Twenty-three ambulatory children with SB visiting the SB clinic in Wilhelmina Children's Hospital participated in this study. Objective physical effort or strain was calculated as percentage of maximum heart rate (%HR_{max}) and oxygen uptake (%VO_{2max}) during a 6 minute walking test (6MWT). HR_{max} and VO_{2max} were measured during a treadmill test. Daily activities and perceived level of effort were measured using the physical activity diaries from Bouchard. Descriptive statistics were used to analyze the data.

RESULTS

%HR_{max} during the 6MWT was 74.5% with significant differences between normal and community ambulators (69.3% vs. 91.2%). %VO_{2max} showed similar results, with 59% for the group as a whole and significant differences between the normal and community ambulators (52% vs. 83.3%). Analysis of the physical activity diaries showed the most common activities to be walking and sedentary activities. Several activities were given higher METS values than expected.

DISCUSSION

Considering the high level of physical effort during the 6MWT, more everyday activities should be included for similar analysis. Daily physical activity was measured using Bouchards's diaries. While analysis of these diaries showed interpretation of the results to be quite difficult and at times ambiguous, it still gives a more detailed picture than questionnaires regarding PAL. The diaries did show that certain activities were rated much higher than the expected METS level.

CONCLUSIONS

In both objective and subjective measurements physical effort during functional tasks was high in ambulatory children with SB. Our group is now in the process of developing protocols for more precise measurements of PAL in ambulatory children with SB. We are developing a method which consists of a PAM combined with heart rate monitoring to not only look at the type but also the intensity of PAL. We have started validation of the most common activities e.g. walking, sitting activities and biking.

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P-2-9

FREQUENCY OF THE SIT TO STAND TASK IN FREE LIVING ADULTS

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INTRODUCTION

The sit to stand (STS) task is not only critical to functional independence [1], but has a high mechanical load [2]. Consequently, training the STS movement is a common feature of rehabilitation programmes. Knowledge of the daily frequency of the STS movement could inform rehabilitation goals and content, but this has rarely been examined. To date only McLeod et al. [3], in 1975, have investigated this, reporting an average of 92 daily STS transitions in nine healthy young participants. Data was extrapolated from 50 hourly samples taken across the nine participants. The purpose of this study was to report data on the daily frequency of the sit to stand (STS) movement in a healthy, independently living, adult population, using an objective monitor that recorded continously for a week.

METHODS

Sixty-eight healthy, free-living, ambulant adults (21 female; mean age 40 ± 8 years) were recruited from the general population. An activity monitor (*activ*PAL™, PAL*technologies*, Glasgow), reported free-living activity for each subject for 7 consecutive days. The average number of STS transitions per day was calculated from the whole data collection period. Fifty-three subjects were separated by employment type into office based and outdoor workers. These sub groups were compared using a two-sample t-test.

RESULTS

Participants performed a mean of 62 (± 21 1SD) STS movements every day, with large individual differences [range 33 to 124]. Office workers performed significantly ($p=0.023$) more STS movements (68) than those employed in an outdoor occupation (54).

DISCUSSION

The data presented represents the first report of the frequency of the STS movement in a healthy population derived from contionuous data collected across the entire day. Fewer STS movements were recorded than previously reported [1]. This may reflect general changes in lifestyle and work patterns; however comparisons should consider the small samples involved in the original study and methodological differences. McLeod et al allowed subjects to select hourly data collection periods, which may have, unintentionally, resulted in an over reporting of the total number of STS movements performed in a day. The higher number of STS transitions in office workers compared to outdoor worker may reflect the working environment, where periods of sitting at a desk are interjected with short periods of upright activity moving around the workplace. This kind of detailed information on the STS movement could inform rehabilitation programmes across a range of populations. Future studies may consider collecting data from older populations, where the STS movement is often problematic [4].

CONCLUSIONS

Based on continuous activity monitoring over 7 days in 68 participants the average adult performs the STS movement 62 times every day, with office workers performing significantly ($p=0.023$) more than outdoor workers. This information could benefit rehabilitation by providing greater, and more detailed information, on the daily volume of STS movements.

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P-2-10

PHYSICAL ACTIVITY PATTERNS OF PATIENTS AFTER ROTATIONPLASTY DUE TO MALIGNANT BONE TUMORS

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INTRODUCTION

Rotationplasty is a unique surgical procedure in which the ankle is converted into the knee after shortening and 180° external rotation of the limb [1]. Its application focuses on children and adolescents treated for a bone tumor of the femur. Since Fuchs et al. [2] showed that gait parameters of patients with rotationplasty were comparable with the healthy population and Hillmann et al. [3] found that 85% of their investigated patients with rotationplasty regularly engaged in sports activities, the aim of this study was to investigate whether the daily physical activity patterns in this patient group will reach a 'normal' level or whether their former disease and the surgical procedure will show a persisting limiting effect.

METHODS

For the objective assessment of physical activity the StepWatch Activity Monitor (SAM) was used. It is an ankle-worn, uniaxial accelerometer with a storage capacity of up to two months. 9 female and 9 male patients (23.3 ± 10.6 yrs) wore the accelerometer for at least seven days, including workdays and weekend days. A control group was matched by gender and age (9 female and 9 male participants, 23.3 ± 10.8 yrs). The Mann-Whitney U-Test was used for nonparametric comparisons between both groups.

RESULTS

Mean duration of data collection was 10.1 consecutive days for the patient group and 12.4 for the control group, respectively. The patient group took 10417 ± 5427 gait cycles per day, while the control group accumulated 13350 ± 4076 gait cycles each day (* p=0.027). Seven patients exceeded 10000 steps, four of them 12500. Only one patient took less than 5000 steps/d. 24.2% of daily steps in the patient group were of moderate intensity (> 40 gait cycles per minute), while 1.2% were of high intensity (> 60 gait cycles).

DISCUSSION

According to Tudor-Locke's subsumption of pedometer-determined physical activity, individuals taking less than 5000 steps/d can be classified as "sedentary", with 10000 steps or more as "active" [4]. In the present sample of patients, only one fell into the sedentary category while seven can be considered as active or even highly active. Although the surgical treatment for rotationplasty is a severe intervention, the patient group – on the average – met the recommendations for an active lifestyle, which originally are used for healthy individuals. However, a large standard deviation reflects the wide distribution of the individual outcome and ambulatory behavior in both groups.

CONCLUSION

Rotationplasty provides a good functional outcome, so that general recommendations for physical activities (10000 steps per day) can be complied. The surgical treatment of a bone tumor with a rotationplasty even allows most patients to engage in sports activities.

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P-2-11

ACTIVITY LEVEL IN PATIENTS WITH LUMBAR SPINAL STENOSIS BEFORE AND AFTER DECOMPRESSIVE SURGERY

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INTRODUCTION

One of the most common symptoms of lumbar spinal stenosis is the neurogenic claudication, characterized by leg pain and heavy legs after (extended) walking [1]. The maximum possible walking distance or step counts can be used to determine the patients' state of health [2]. Normally patients approximate their walking capacity in questionaires. This subjective assessment was shown to be inaccurate [3]. Therefore, the aim of this study was to objectively quantify the activity level by step counting in patients with lumbar spinal stenosis before and after surgery in order to assess possible improvements after treatment.

METHODS

In total, 47 patients (23 male, 24 female, average age 69.2±7.0 years) where measured with the Step Activity Monitor (=SAM; Cyma Inc., Seattle, USA) for seven days, before surgery as well as 3 and 12 months after surgery. Clinical outcome was assessed with different questionnaires (SF 36, Oswestry Disability Index, Roland Morris Score and Visual Analog Scale). A control group of 20 healthy subjects (10 male, 10 female, average age 69.7±8.8 years) was measured with the same device.

RESULTS

Patients took significantly more gait cycles per day at the three (13.7 %) and twelve month follow-up. (20.5 %) ($p<0.02$). All clinical outcomes improved significantly at both post surgery measurements ($p<0.02$). No significant differences appeared between the two post surgeries measurements. The control group showed significantly more gait cycles per day compared to the patients at any measurement ($p<0.01$).

	Before surgery (n=47)	3 month follow-up (n=47)	12 month follow-up (n=44)	Control group (n=20)
Gait cycles/day	3578 ± 1608	4145 ± 1977	4495 ± 1778	6626 ± 1451

Table 1: Mean gait cycles per day at the different measurements

DISCUSSION

The significantly improved level of activity in patients showed that patients functionally benefit from surgery even though they do not regain a normal activity level as compared to the control group. Clinical data showed a greater improvement but did not correlate with functional results indicating that patients with less pain are not necessarily more active. Some patients show markedly improved activity levels whereas others remained constant or even reduced their activity levels. Different surgical procedures as well as possible comorbidities must be considered before drawing further conclusions.

CONCLUSIONS

The SAM is an appropriate tool for the activity assessment in this patient group. To evaluate the overall outcome of surgery, further factors must be considered.

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P-2-12

DAILY PHYSICAL ACTIVITIES OF PATIENTS WITH CHRONIC LOW BACK PAIN, ASSESSED WITH ACCELEROMETRY

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INTRODUCTION

Different theoretical models consider the development and maintenance of chronic low back pain (CLBP) have in common that they all predict changes in the daily activities, although the direction of change may differ between or within these models (hypo- versus hyperactivity). The objective of the present study was to investigate these changes, using accelerometers to obtain a quantitative measure of the activity patterns over the day.

METHODS

A cross-sectional study was performed in 30 patients and 20 controls. Daily activities were assessed by measuring body movement with a tri-axial accelerometer that was worn for seven consecutive days during waking hours in their own daily environment (in-doors and out-doors). Differences in activity level between patients and controls were investigated as well as differences over days and day parts. Besides the influence of work status on activity pattern over the day was investigated.

RESULTS

Results show that the overall activity level of patients (mean 0.73; sd 0.44) is not significantly different from those of controls (mean 0.70; sd 0.46) neither were the differences between days within both groups. However, patients show compared to controls a significantly different activity pattern over the day with significantly higher activity levels in the morning ($p=0.000$) and significantly lower activity levels in the evening ($p=0.007$). Work status had no influence on the activity patterns as no significant differences in activity patterns were found between leisure time and working time as well as between patients with different work status.

DISCUSSION

The overall activity levels are not different in CLBP patients compared to controls, but the distribution of activities over the day differs significantly. Work status doesn't seem to influence the differences found in activity pattern between patients and controls.

CONCLUSIONS

The fact that patient with chronic low back pain are at an overall level not less active but do show a difference in distribution of activities over the day suggests that a treatment focusing on balancing this activity pattern could be of potential. A treatment worthwhile to explore might be an ambulant activity based feedback treatment in which subjects receive feedback about their daily activities multiple times a day.

P-2-13
HOW AN AMBULATORY MONITORING SYSTEM MIGHT DESCRIBE FRAILTY IN ELDERLY PERSONS

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INTRODUCTION

A robust definition [1] of frailty in elderly persons is based on 5 criteria, including physical components, walking performance, cognition and affective status. Parameters taking into account simple physical activity measures, such as number of transitions and time spent lying or sitting might give important information about frailty. The aim of this study was to compare physical activity measured by an ambulatory monitoring system among populations with different frailty status.

METHODS

Participants were recruited among community-dwelling persons aged 65 years or more, and among patients admitted to a post acute rehab facility. Participant frailty status was assessed using questionnaires and measures of physical activity were performed using the ambulatory monitoring system Physilog® over a 2-day recording. Posture allocations (lying, sitting, standing) and walking periods were classified based on kinematics of trunk segment detected by an inertial sensor [2].

RESULTS

Participants (N=70, mean age 77.0±7.0, 57% women) were divided into 3 groups, fit (0 criterion of frailty), pre-frail (1 or 2 criteria), and frail (3 to 5 criteria). There was a monotonic and statistically significant trend in most of physical activities features along the three groups. More detailed study showed that this effect was mostly due to differences between frail population and others, while the difference between fit and pre-frail participants did not reach significance. Sensitivity analysis showed that most pre-frail participants (15/20) had only 1 criterion of frailty, which probably explains the lack of significant difference when compared to fit group.

DISCUSSION

These results show the effectiveness of long-term ambulatory monitoring of physical activity in elderly populations and the possibility to detect differences according to frailty status. Although the difference between fit and pre-frail groups did not reach statistical significance, the monotonic trend observed along the three groups tends to indicate that we witness a real effect partly hided by insufficient statistical power.

CONCLUSION

These findings suggest that ambulatory monitoring could provide an objective way to describe frailty status. They also suggest that early stage of frailty might be detected with such a technique, but further studies would be necessary to confirm this potential.

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P-2-14

EVERYDAY PHYSICAL ACTIVITY IN ADULTS WITH BILATERAL SPASTIC CEREBRAL PALSY

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INTRODUCTION

Many adults with cerebral palsy (CP) return to rehabilitation care with increasing symptoms such as pain, contractures and fatigue. These symptoms may lead to difficulties in performing daily activities and consequently to a hypoactive lifestyle. The hypoactive lifestyle may in turn lead to more symptoms. Furthermore, hypoactivity increases the risk of cardiovascular disease and may affect health-related quality of life. Information regarding the level of everyday physical activity (PA) in adults with CP is scarce. The aim of the study was to quantify the level of everyday PA in adults (aged 25 to 45 years) with bilateral spastic CP. A secondary aim was to determine whether personal and disability-related characteristics are determinants of the level of everyday PA.

METHODS

Fifty-six adults with bilateral spastic CP (mean age 36.4 ± 5.82 years) participated of which 62% was male. About half of the participants had a diplegia, and most participants (73%) had a good level of gross motor functioning (Gross Motor Functioning Classification System level I or II). Level of everyday PA was measured with an Activity Monitor (AM), based on long-term ambulatory monitoring of signals from body-fixed accelerometers. Measurements were performed on two consecutive weekdays in the home setting. Both stationary activities (e.g. lying, sitting and standing) and dynamic activities (e.g. walking, running, cycling, wheelchair propulsion and non-cyclic movements) were registered. Main outcome measures were the duration of dynamic activities (composite measure, as percentage of a 24-hour period) and average body motility (in g, is representative of the intensity of daily activity). Results in the adults with CP were compared with data of gender- and age-matched (± 5 years) able-bodied controls.

RESULTS

The duration of dynamic activities in the adults with CP was 8.1 ± 3.7%, which corresponds with one hour and 56 minutes of dynamic activities per day. The duration of dynamic activities in men was 7.9 ± 3.5% and in women 8.4 ± 4.1% (p=0.62). Mean motility was 0.020 ± 0.007.No differences were found between men and women (p=0.49). In comparison with able-bodied controls, women with CP had a significantly shorter duration of dynamic activities (8.4% for CP versus 12.2% for controls, p=0.00); for men the difference with healthy controls was not significant (7.9% versus 9.4%, p=0.11). With regard to body motility, both men (0.019g for CP versus 0.027g for controls, p=0.00) and women (0.021g versus 0.028g, p=0.03) with CP had significantly lower values than able-bodied controls. Adults with CP with better gross motor functioning had a significantly higher duration of dynamic activities (p=0.00) and higher body motility (p=0.00) than those with worse gross motor functioning. No differences were found for other personal and disability-related characteristics.

DISCUSSION

Compared with able-bodied controls, adults with bilateral spastic CP have low levels of everyday PA. Furthermore, adults with better gross motor functioning have a higher level of everyday PA than those with worse gross motor functioning.

CONCLUSIONS

These results suggest that adults with bilateral spastic CP and particularly those with worse gross motor functioning, are at risk for developing a hypoactive lifestyle.

P-2-15

EFFECT OF REHABILITATION ON DAILY PHYSICAL ACTIVITY, PHYSICAL FITNESS AND FATIGUE IN LIVER TRANSPLANT RECIPIENTS

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INTRODUCTION

Fatigue is one of the major problems after LTx [1]. Recent studies in liver transplant recipients indicate that a low level of daily physical activity and physical fitness is associated with fatigue after liver transplantation (LTx) [2,3]. The purpose of the study was to evaluate the effects of supervised exercise training combined with counseling on daily activity in fatigued liver transplant recipients on daily physical activity, physical fitness, and fatigue.

METHODS

A total of 18 fatigued liver transplant recipients, aged 51.0 ± 9.9 years (time since LTx 7.5 ± 4.4 years), participated in a 12-week rehabilitation program. The program consisted of supervised exercise training twice weekly for one hour and counseling on daily activity. Daily physical activity, physical fitness and fatigue were assessed before and after this 12-week program. Daily physical activity was measured using an accelerometry-based Activity Monitor (AM) and the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD). Physical fitness was measured using a maximal cycle ergometer test (cardiorespiratory fitness), a knee extensor and flexor muscle strength test (neuromuscular fitness) and measurement of body mass index. Fatigue was measured using the Fatigue Severity Scale (FSS).

RESULTS

After the rehabilitation program, there was no change in daily physical activity as indicated by the AM (percentage dynamic activities during a 24-hr period was PRE 10.3% and POST 9.6%, p=0.95) or the PASIPD (PRE score 15.5 and POST score 16.6, p=0.25). Cardiorespiratory fitness was significantly increased with 6.4% (p=0.01) and neuromuscular fitness with 4.8-16.4% (p<0.05). There was no effect on body mass index. After the rehabilitation program, patients reported less severe fatigue than before the program (FSS POST 4.70 and FSS PRE 5.33, p=0.01). Effects on fatigue were not associated with effects on physical fitness or daily physical activity.

DISCUSSION

The 12-week rehabilitation program was not effective in improving daily physical activity in fatigued liver transplant recipients. This may be explained by the rather high level of daily physical activity (in general population about 12%). However, we found improvements in physical fitness and a reduction in fatigue, but these improvements were not related with each other.

CONCLUSION

The 12-week rehabilitation program, consisting of supervised exercise training combined with counseling on daily activity, was effective in improving physical fitness and fatigue, but had no effect on daily physical activity in fatigued liver transplant recipients.

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P-2-16

EFFECT OF BOTULINUM TOXIN TREATMENT ON ACTIVITY LEVEL OF PATIENTS WITH SPASTIC HEMIPARESIS AFTER STROKE

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INTRODUCTION

Botulinum toxin treatment is frequently used in people with spastic hemiparesis after stroke in order to decrease muscle tone and spasms. The effect of this treatment at the level of the muscle has been demonstrated previously [1,2]. However, until now, the effect of this treatment on the activity level of the patient is unknown. The aim of the current study is to investigate the effect of botulinum toxin treatment on the activity level of people with spastic hemiparesis after stroke.

METHODS

Five men and three women with a spastic hemiparesis after stroke (mean age 47 (37-59) years), who where scheduled to receive botulinum toxin treatment (Botox ©, Allergan) in muscles of the affected leg, participated. Measurements were performed on two instances: before the intervention (T1) and nine weeks after the intervention (T2: when the effect of the botulinum toxin is supposed to be maximal). The primary outcome measure was the level of daily activity. This activity level was measured using the DynaPort ADL monitor [3] (McRoberts, The Netherlands) for a period of 24 hours. From these data the relative time spend on lying/sitting (sedentary), standing and locomotion was derived. In addition, the movement intensity (average acceleration) was calculated. Secondary outcome measures were walking velocity, step length and symmetry (determined during a 20m walk test, using the DynaPort MiniMod (McRoberts, The Netherlands)) and general health (measured using the SF-36 questionnaire). The non-parametric Wilcoxon test was performed to detect statistical significant differences over time. Level of significance was set at p=0.05.

RESULTS

A statistical significant difference was found on the relative sedentary time (T1:83%, T2:78%, p=0.028), relative standing time (T1:12%, T2:16%, p=0.028) and on movement intensity (T1:0.051m/s^2, T2:0.066m/s^2, p=0.043). Sedentary time decreased whereas standing time and movement intensity increased. No statistical significant difference was found on locomotion time. No statistical significant differences were found on walking velocity, step length, walking symmetry and general health. Although, a borderline effect was found on the sub-item general health of the SF-36 (p=0.054).

DISCUSSION

Activity level of the subjects changed significantly after treatment with botulinum toxin: the subjects were less involved in sedentary activities (sitting or lying) and spent more time standing. In addition, movement intensity increased which means that more vigorous movements were made, although walking velocity was not found to increase. No effect was found on time spent on locomotion. Possibly, some periods of walking movements were to short or were of too low an intensity to be classified as walking and appeared as standing time in the analysis. Because the standing time and movement intensity increased, it could be concluded that the subjects became more active after treatment. This, however, had no clear effect on the experienced general health (SF36).

CONCLUSION

Activity level of people with spastic hemiparesis after stroke increased after treatment with botulinum toxin.

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P-2-18

PILOT STUDY- PHYSIOLOGICAL DATA RECORDED REMOTELY FROM INDIVIDUALS WITH SPINAL CORD INJURY (SCI) DURING NORMAL DAILY ACTIVITIES

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INTRODUCTION

Monitoring a range of physiological parameters in SCI patients during extended periods of daily activity and during therapy through the rehabilitation provides evidence of marked physiological changes but raises a no of practical issues. A totally portable system can provide a clinically useful monitoring system for SCI to study the behaviour of physiological parameters during rehabilitation and change over time and allows it to be prescribed and optimised to match the individual patient's needs. Issues affecting our study will be illustrated in the most compromised tetraplegic (n=4) group compared to paraplegic (n=4) and controls (n=2) each with > 4 separate studies of about 4 hours over the months of recovery.

METHODS

A"Siesta" 32-channel portable Lightweight digital datalogger (Compumedics, Melbourne, Australia) developed for sleep research studies with 32 channels, 16 bit physiological onitoring..Sensors/transducers (HR, resp rate, oximetry, temp, accelerometers, EMG) can be interfaced with the "Siesta"and recording of any desired signal is possible giving flexibility to evolve new sensors with generic export of data. Studies at rest, prescribed reproducible activities, therapy and normal activities.

RESULTS

Some examples of o*bservation of traces and export and manipulation in excel 30 sec traces pushing a wheelchair. C*yclical movement of both upper limbs the plus increase in abdominal breathing and HR (ECG and oximetry) which remains stable.

Smoking pattern shown by R dominant upper limb holding cigarette and L UL lighting (measured with accelerometers) followed by a deep inspiration (respiratory bands) and increase in HR.

Progressive tilt is a reproducible stress with significant changes from baseline, a fall in systolic 120 - 60 a diastolic to 75 - 40 MmHg. BP and pulse pressure with a rise in pulse 50 - 110 beats per min. A limit is reached in this test at 60 degrees tilt when inability to compensate and symptoms of hypotension stop the test and return to recumbency is followed by an overshoot and return to baseline.

Post Prandial 11 minutes a*fter a meal* the pulse rises to 30 % > baseline with the exercise of digestion and associated autonomic/vascular changes.

More sophisticated analysis export to MATLAB.eg HR variability.[1] Tilt table measurements are reproducible and provide base data.No apparent difference noted at baseline rest state an inability to respond to stress and maintain BP with each tilt at 15 and 30 degrees .Consistently the parasympathetic NS response (Hi frequency) shows some response with a lesser sympathetic nervous system NS response (Lo frequency). *Group data* useful to confirm individual changes. Eg.% HR change from baseline during tilt which is greatest in the tetraplegic group 100% compared to paraplegics 70% and normal (controls) 10%.

DISCUSSION

Some Issues to be raised: Rigid protocol to ensure reproducibility vital. Need to look at the whole time line and activities logged at each epoch/s and to focus in on the appropriate baseline and period of change for that activity. Artefact often indicates but obscures signals with filtering helpful.

Age, health before and after injury, SCI level of injury and degree of completeness determines measured function. Standard Baseline Trace allows comparison against which each activity measured.

Real / normal activity data increases uncontrolled variables and difficulty of measurement but reveals greater physiological variation. Given variables use individual as own control and look at change with stressors from baseline and then compare consistent response patterns. Percentage change from baseline is most useful. [1]Autonomic dysfunction particularly variations in pulse and blood pressure are a major feature

CONCLUSIONS

Above studies of SCI patients to be described noting accurate setup, protocols, baseline measures, logging of activity, reproducible measurement and careful interpretation affect the design and use of these sensor systems. Significant changes in physiology, presumably autonomic are demonstrated particularly in the early phases, at higher levels of SCI and importantly in the ambulatory setting during activity.

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P-2-19

ORTHOPAEDIC OUTCOME ASSESSMENT WITH ACCELEROMETER ASSESSED STAIR CLIMBING

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INTRODUCTION

Classic orthopaedic outcome scoring systems suffer from subjectivity, pain dominance and ceiling effects. The diagnosis and postoperative monitoring of the younger or more demanding orthopaedic patients ('millennium patient') requires function to be measured beyond the capacity of these scores. Current options are video based gait analysis systems, force platforms and but all are not suitable for routine clinical application because of their high costs and complexity demanding designated space, personnel and long set-up times.

Inertia based motion analysis using accelerometers is cheap, quick and easy to operate in the clinical environment making it feasible for routine follow-up. Accelerometer derived motion parameters have been clinically validated for gait in subjects with knee pathologies [1,2] but walking was identified as not demanding enough to distinguish finer functional differences. Stair climbing is a more demanding activity of daily life that may produce more sensitive parameters.

This study investigates whether a stair climbing test with accelerometer derived motion parameters in a group of healthy subjects is clinically feasible and valid to distinguish between demographic differences.

MATERIALS AND METHODS

The ascending and descending of stairs was measured in 46 healthy subjects (19m/27f, no orthopaedic pathology) with a mean age of 39 years (range: 21-74) using a triaxial accelerometer (range: ±2g, f: 100 Hz, size: 62x41x18 mm; weight: 53g;) attached with a belt to the sacrum. Two sub-groups were compared: young group (15m/16f; mean age 25; range 21-38) and old group (4m/11f; mean age 67; range 54-74). Other values recorded were height, weight, BMI, leg length and dominant side. Subjects ascended and descended five stairs two times at preferred speed (no handrails allowed). Motion parameters were derived from acceleration peak detection algorithms in Matlab 7.1 (Mathworks, USA): average step time up and down (t_{up}, t_{down}), the difference between the average step time up and down (t_{up}-t_{down}), irregularity up and down (irr_{up}, irr_{down}) defined as the difference between maximum and minimum step times, and asymmetry up and down ($asym_{up}$, $asym_{down}$) defined as the difference between the step times of the dominant and non-dominant leg. Group comparison were performed using the t-test and correlation using Pearson`s R ($p<0.05$).

RESULTS

Avg. step times were slightly higher ascending (t_{up}=606ms) than descending (t_{down}=575ms, $p<0.05$, Fig. 1), a difference seen in most individuals (39/46). The step time difference between ascending and descending was 31ms with a sign. difference between the young (t_{up}-t_{down}=47ms) and elderly group taking on average more time to descend (-7ms). All subjects with descending times ≥20ms slower than ascending (6/46) were in the elderly group ($p<0.05$, Fig 1). Irregularity was nearly equal ascending (142ms) and descending (140ms) and not different between age groups. Also asymmetry did not show large differences between stepping up or down or between age groups. However, asymmetry revealed that steps with the dominant leg were of equal or faster speed than the non-dominant leg in 43/46 cases ascending and 39/46 cases descending ($p<0.05$). The parameters were not significantly correlated to other demographic parameters such as gender, height or BMI.

[ms]	Avg	SD	Min	Max	Young	Old
t_{up}	606 *	63	470	743	590	638*
t_{down}	575 *	91	428	843	544	645*
T_{UP}-T_{DOWN}	31	55	-155	103	47	-7*
Irr_{up}	142	51	50	260	140	140
Irr_{down}	140	51	50	250	130	150
$Asym_{up}$	49	35	2	138	50	40
$Asym_{dow}$	39	29	0	113	30	50

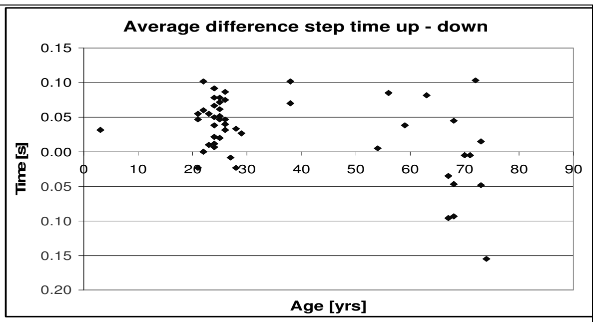

Fig. 1: Stair climbing parameters [ms] overall & per age group (* p<0.05, R). Difference step time up-down vs. age (L).

DISCUSSION

Avg. step times up were higher than step times down as expected by the difference in energy expenditure. Individuals with slower step times down were all elderly indicating that a loss of balance, coordination, strength, proprioception or fear of falling compensates the benefits of an energetically less demanding movement. This parameter may be powerful to detect general or bilateral orthopaedic pathologies such as osteoarthritis. Asymmetry clearly identified the strength of the dominant leg indicating its potential as a powerful parameter to detect and monitor unilateral pathologies such as in knee arthroplasty. With a total test duration of <30s and sensitive parameters, the accelerometer assessed stair test seems a functional test suitable for routine clinical follow-up complementing classic scores.

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P-2-20

EFFECT OF C-LEG ON LOCOMOTOR CAPACITY AND PERFORMANCE IN TRANSFEMORAL AMPUTEE

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INTRODUCTION

The plus-value of microprocessor controlled knee is demonstrated in lab conditions. Despite the satisfaction of C-Leg users, the amputees aren't more active with C-Leg [1].

Aim:To compare the walking characteristics of active transfemoral amputee by C-Leg versus Conventional knee, both in semi-natural controlled conditions and in daily life conditions.

METHODS

- Randomized crossover design
- Microprocessor controlled C-Leg knee *versus* non-microprocessor conventional knee
- 8 adults, post-traumatic transfemoral amputee, daily user of well-fitted prosthesis, active in professional or vocational daily activities.
- Semi-natural conditions: asphalt normal and fast walking, grass, slope up and down, stairs up and down
- Natural conditions: 12 hours monitoring during a weekday
- Outcome measures: Prosthetic Profile Amputee – Locomotor Capacity Index, Houghton scale, Quebec User Evaluation of Satisfaction with assistive Technology
- Accelerometry monitoring Vitaport: step rate, walking speed, heart rate response, Physiological Cost Index, duration of activities.

RESULTS

- High level with both prosthesis for PPA-LCI and Houghton scale.
- Semi-natural conditions: significative improvement with C-Leg for QUEST, PPA-LCI (uneven ground, stairs), Walking Speed and Physiological Cost Index (fast walking, grass, slope and stairs down)
- Natural conditions: no difference (C-Leg versus Conventional) in locomotor performance during daily life monitoring.

CONCLUSION

First, microprocessor controlled knee improve locomotor capacities and metabolic efficiency just in exigent conditions. Patient needs must be precisely analysed before microprocessor medical prescription.

Second, these results exhibit the dissociation between capacity (semi-natural conditions) and performance (natural conditions) [2]. The hypothesis of an avoidin behaviour in front of exigency is discussed.

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P-2-21

THE ASSOCIATIONS BETWEEN FUNCTION, CAPACITY AND PERFORMANCE OF THE UPPER-LIMBS FOLLOWING STROKE

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INTRODUCTION

50% of all stroke survivors are left with serious impairments in their upper-limb function. The ICF distinguishes (among others) the following domains in which impairments can occur: function, capacity and performance [1]. Little is yet known about the exact relationship between impairments in these domains. This is partly due to the lack of objective measurements tools for performance. The Stroke-Upper Limb Activity Monitor (Stroke-ULAM) is a recently designed tool that measures actual arm/hand use for a longer period of time with the use of accelerometry [2]. The aim of the present study was to use the Stroke-ULAM to gain more insight in the relationship between actual performance and function and capacity.

METHODS

17 stroke patients participated in this study. All patients wore the Stroke-ULAM for at least 12 hours. The ratio of the level of usage of the affected arm compared to the level of usage of the non-affected arm (proportion) was used as outcome measure. Furthermore, level of function was assessed by means of the Brunnstrom Fugl-Meyer Assessment (BFMA) and level of capacity by means of the Action Research Arm Test (ARAT). Outcome measures consisted of correlation coefficients between scores on each of the used measurement tools. Subsequently, logarithmic and linear curve fitting methods were used to asses the nature of the relationship between actual performance, function and capacity.

RESULTS

Strong correlations were found between actual performance and both function (r = 0.761) and capacity (r = 0.758). Logarithmic curve fitting explained more variance compared to linear curve fitting for both relationships (72% vs. 58% variance for actual performance and function, and 66% vs. 57% variance for actual performance and capacity) (see also Figure 1).

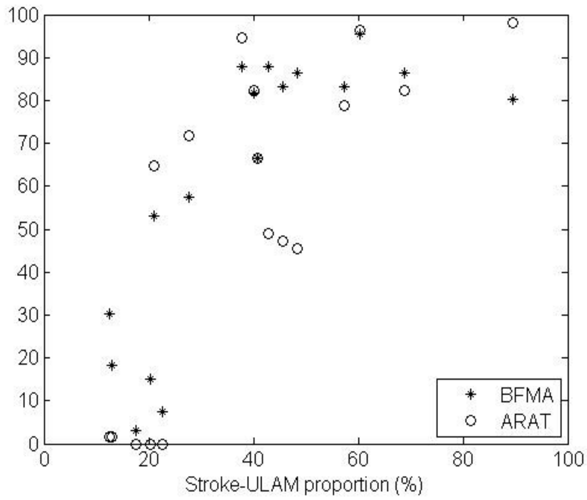

Figure 1: scatterplot of the relationships between Stroke-ULAM, BFMA and ARAT

DISCUSSION

Although actual performance, function and capacity of the upper limbs following stroke are strongly related, they do no seem to progress similarly following the course of rehabilitation. It appears that function and capacity need to reach a certain threshold-level before actual performance increases.

CONCLUSIONS

The main finding of the present study was that even though actual performance and function and capacity of the upper limbs following stroke are strongly related, this relationship is not of a linear nature. In planning as well as in evaluating the effect of post-acute rehabilitation programs aimed at hand function it is pivotal to understand that there is no one-to-one relation between function, capacity, and actual performance. The findings of the present study stress the importance of incorporating outcome measuring in all domains of functioning following a rehabilitation intervention.

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P-3-1

RELIABILITY OF AMBULATORY MONITORING TO EVALUATE GAIT CHARACTERISTICS OF DIABETIC PATIENTS

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INTRODUCTION

Activities in daily life require, among others, adequate ambulation in varying surroundings [1]. A precise portable measurement system would permit objective evaluation of gait parameters [2]. The aim of this study was a) to investigate the reliability of gait parameters measured with the Physilog® in diabetic patients walking on different surfaces (tar, grass, and stones) b) to identify the measurement error (precision) c) to identify the minimal clinical detectable change.

METHODS

Methods: 16 patients with Type 2 diabetes were measured twice within 8 days. After clinical examination, patients walked, equipped with a Physilog®, on the three aforementioned surfaces. Analysis: ICC's and Bland and Altmann plots were reported along with the standard error of measurements (SEM) and minimal clinical detectable change (SDC).

RESULTS

Results: ICC's for each surface were excellent (> 0.938) for within and good to excellent (0.503 to 0.958) for between measurements. The coefficient of variation (CV) was lower than 5% for most of the parameters. Bland and Altman Plots, SEM and SDC showed precise values, distributed around zero for all surfaces.

DISCUSSION

Our results are comparable with those that were recorded for gait analysis on a level surface using other measurement instruments (e.g GaitRite®, minisun IDEEA®). Irregular surfaces were shown to influence gait parameters[1], therefore these results are of great clinical interest.

CONCLUSIONS

The Physilog® provides reliable gait data. The small measurement error and the values of the minimal clinical detectable change promote its use for the evaluation of gait parameters in diabetic patients. Further studies should investigate the effect of different surfaces on gait parameters, in healthy and diabetic populations.

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P-3-2

REAL-TIME GAIT EVENT DETECTION USING A BIAXIAL ACCELEROMETER PLACED ON THE TRUNK

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INTRODUCTION

The aim of this work is to develop an algorithm for the real-time detection of the initial contact (IC) gait event, by using only a biaxial accelerometer placed on the trunk. Methods exist that are carried out post data capture [1], but they require non-causal filtering techniques not directly applicable to real-time applications, such as FES, pedestrian tracking or activity monitoring. Mansfield et al. proposed a procedure to detect the IC events [2], but the method does not provide the instant at which the event occurred, i.e. the event was not identified in the signal. The method presented detects IC events in real-time with mean delays of 80 ms and accuracy over 98 per cent, enabling us to estimate on-line gait related magnitudes such as step length or walking velocity.

METHODS

Measurements were taken from a group of 13 people with an MTx accelerometer from Xsens attached to the trunk. A total number of 2125 steps were computed, and IC events were manually determined by visual inspection of the antero-posterior acceleration signal. The original antero-posterior acceleration signal is filtered using a linear phase 2 Hz filter. Zero crossings of the filtered signal (from positive to negative) are used to look for the peak of the original signal corresponding to the IC event [1]. This search takes into account the expected delay introduced by the filter. Further heuristic data processing techniques avoid misdetections caused by undesired zero crossings and/or noise peaks.

RESULTS

A total 97.8 per cent of the IC events (2078 steps) were detected in the exact sampling period as marked. The rest (47 steps) were also detected, but in a different instant. Only one inexistent event was wrongly detected. Detection of the events is made with mean delays ranging from 55 ms. to 134 ms. dependent on the subject. The following table resumes the results per individual (*cd*: correct detection, *md*: misdetection caused by no-detection or by a detection with bad timing, the last specified in parentheses).

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13
cd	154	150	178	160	140	147	162	171	146	171	169	156	174
md	0	14(3)	1	0	4(4)	0	16(15)	0	0	0	0	2(2)	10(9)

DISCUSSION

The algorithm presented provides a method to detect IC events in real time based on COG accelerometry. The real-time objective leads to the need of dealing with a noisy not-prefiltered signal. The problems that arise due to the variability and noise of the signal were identified and a solution was proposed. The obtained results show that the accuracy of the method when identifying the instant of the event in the signal could suffice for applications that need to calculate step related parameters like step length in real-time. Further work including the detection and identification of the end contact event would permit the assessment of additional parameters like single and double support percentage.

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P-3-3
THE VALIDITY AND FEASIBILITY OF THE TELEMETRY MONITORING SYSTEM FOR POSTURAL AND LOCOMOTION PATTERNS

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INTRODUCTION
Optimal monitoring of postural and gait deviations are important clinical markers for falling. Traditionally, optoelectronics equipments, which are expensive and labor-intensive, have been primarily used to determine postural and gait deviations by computing center of gravity (COG) trajectory and spatiotemporal parameters [1, 2]. We developed a portable and inexpensive monitoring system and examined the validity and feasibility of this system.

METHODS
Four healthy young adults (age, 22.7±2.5 years; height, 178.6±7.6 cm; weight 74.6±6.3kg) participated in this study. A six optical camera motion capture system (VICON, Oxford metrics Ltd., UK) and a piezoresistant accelerometer (CXL02LF3, Crossbow, US) were concurrently used to acquire motion data at 120Hz sampling rate while the subjects walked on the 6m long walkway at their self-selected speed at the motion analysis laboratory. The accelerometer signals were preprocessed by the 60th-order FIR low pass filter with a cut-off frequency of 5Hz to compute the spatiotemporal parameters and then the inverse problem theory are used for estimation of the COG displacement during walking. Analysis procedure to assess results of the accelerometer data was illustrated Fig. 1. Correlation statistics were used at $P<0.05$.

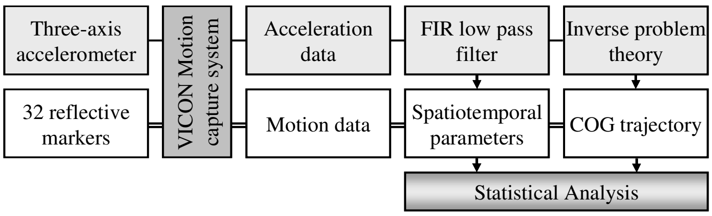

Fig.1 Analysis procedure to assess the data acquired by the accelerometer

RESULTS
The Pearson correlation coefficients (*r*) were 0.84-0.90 for spatiotemporal parameters and 0.87 for COG measurement, respectively. These results suggest that our gait monitoring system was valid and suitable for monitoring qualities of postural deviation and locomotion patterns.

DISCUSSION
This preliminary study addresses that the monitoring system was comparable to the conventional motion analysis system in measurements of postural deviation (determined by COG displacement) and spatiotemporal patterns in normal subjects. Our findings provide clinical insights when designing portable and inexpensive equipments for gait assessment and intervention.

CONCLUSIONS
The present experiment demonstrated the validity and feasibility of the monitoring system by comparing with the conventional system. We demonstrated that our system is valid and useful to monitor postural and gait parameters. Further studies are needed to optimize signal processing technique so as to precisely monitor minute changes or deviations for clients with postural and gait dysfunction.

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P-3-4

THE DEVELOPMENT OF A CLINICAL GAIT ANALYSIS SYSTEM

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INTRODUCTION

An in-home diagnostic tool, which is capable of the early detection of degenerative diseases associated with increased risk of falling, would allow for early intervention for falls prevention. Diagnosis could be made based on the identification of characteristics associated with gait as well as other physiological features such as heart rate and blood pressure. Currently there is no systematic understanding of the optimal sensor configuration for such a system. The aim of this study was to develop a system for use in a clinical setting which could be used to unobtrusively capture gait parameters and physiological data. The platform is being used to evaluate 300 subjects over a 3 year period in a clinical setting. The study will allow for the determination of which sensors are critical in the development of a ubiquitous device to be used for the detection of physiological characteristics that indicate a predisposition to falling and will also provide technology validation for in-home trials.

METHODS

The gait analysis platform comprises of the following major components; software application providing capability for data acquisition, data processing and graphical user interface for clinicians, body worn sensors (physiological/kinematic), pressure sensitive floormat and video capture. The software application is developed using the BIOMOBIUS biosignals software application development environment [1]. The body worn sensor capabilities are provided by the SHIMMER wireless sensor platform, which communicates using the Bluetooth radio stack. The SHIMMER kinematic sensors incorporate tri-axial accelerometer and gyroscope technology and are used to extract the temporal parameters of gait [2]. The SHIMMER ECG sensor is used to capture 3-lead ECG from which it is possible to determine heart rate and heart rate variability. The floor-mat technology used in the gait analysis platform is based on Tactex Control Inc. floor sensors. The floor sensor measures pressure under the foot and can be used to detect the location and timing of each footfall, as well as pressure changes under the foot during gait. Video capture is provided through the use of three webcams. As well as providing the clinicians with the capability to retrospectively review footage of the trial the video data may also being used in the development of algorithms to extract gait parameters from raw video data. Each of the individual components of the gait analysis platform has been clinically validated.

RESULTS

The spatial parameters of gait derived from the system were found to be accurate to within 1 cm while the temporal parameters of gait were found to be accurate to within 0.04 seconds. ECG R-wave peak-to-peak detection with accuracy of 0.02 seconds can be derived from the system.

DISCUSSION

Results indicate that the system has been validated such that the parameters extracted from the system are of clinical value. EMG and GSR measurements have also been successfully acquired using the SHIMMER platform. Current work is focusing on the integration of this sensor technology into the gait analysis platform as well deriving the spatial parameters of gait using the SHIMMER kinematic sensors.

CONCLUSIONS

A platform, which allows for unobtrusive multimodal sensor data capture has been developed. The system provides for in depth physiological analysis during gait while only requiring a basic set-up procedure. Use of the platform in a clinical setting will provide direction for the development of a ubiquitous device suitable for in-home use for the early detection of increased risk of falls. To date the platform has been used to evaluate a clinical cohort of 100, which includes both fallers and non-fallers.

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P-3-5

RELATIONSHIP BETWEEN ACCELEROMETRIC SIGNALS FROM BODY-MOUNTED SENSORS AND CENTER OF PRESSURE FROM A FORCE PLATE DURING QUIET STANCE

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INTRODUCTION

Natural sway and corrective surface reactive forces during stance are important signs of postural function and can be quantified with force plates. Force plates are typically embedded in the ground and used in a laboratory setting. This type of postural measurement system is ecological since it places minimum constraints on subjects, although its current setup and costs do not currently make this a viable solution for a home environment. New sensor technologies and assemblies, or measurement algorithms, need to be developed before surface forces can be used to measure sway outside a laboratory. The aims of the present study were to determine whether it is feasible to use wearable inertial devices instead of force plate measures to quantify spontaneous body sway, and to validate with a biomechanical model this methods.

METHODS

Ten subjects (24.4±2.6 years) weared 3 MTX Xsens (49A33G15) sensors, mounted by means of Velcro belts on the posterior trunk, one about L5 level, an other about C7, and lateral on the right thigh. They stayed on a force platform in a comfortable position with arm crossed for 2 minutes keeping eyes open. Data were acquired and then synchronized at 50 Hz. We performed a correlation analysis in time domain between center of pressure (COP) displacement and acceleration signals at different levels: trunk, thigh and C7, both in antero-posterior (AP) than in medio-lateral (ML) directions. We derived the Newton-Euler equations of body motion approximated as an inverted pendulum, pivoting around the ankle. In this way we obtained a simplified linear equation, valid for small angles and low frequency, to estimate COP from measured acceleration at the thigh level and anthropometric characteristics of the subject (from Winter anthropometric tables [1]). Then, we calculated the correlation and the root mean square error (RMSe) between the COP measured from the force plate and COP estimated with the model.

RESULTS

Accelerometric signals behave similarly to the COP. The combination COP-L5 and COP-thigh accelerations showed the highest correlation both for AP and ML directions (0.7 $<r<$ 0.8). The COP estimated, despite the simplifications, revealed a strong accord with the measured COP (see figure 1). The RMSe between COP estimated and measured was of the order of 2 millimeters.

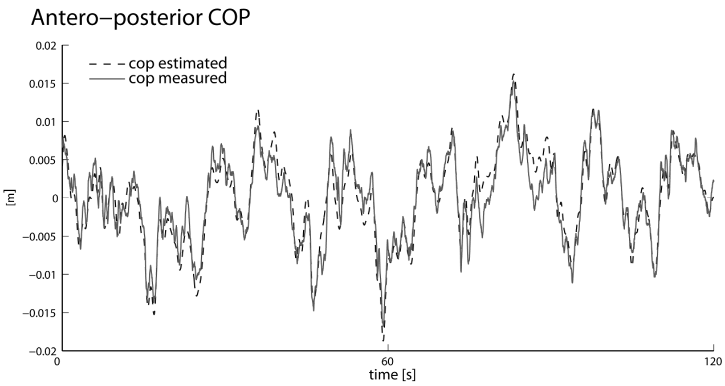

Figure 1

DISCUSSION AND CONCLUSION

Results obtained on the acceleration signals confirmed that we are able to reproduce the same amount of information carried by a force platform by means of the wearable inertial units. Body accelerations signals might substitute for force plate COP signals to assess body sway, and preliminary results suggest that this methods could be validated by a biomechanical model. Wearable inertial sensors could be used outside the laboratory environment, are less expensive, and may be helpful for remote monitoring in elderly or persons with balance disorders.

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P-3-6
VALIDATION OF AN AMBULATORY GAIT MONITOR IN PATIENTS WITH PARKINSON'S DISEASE

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INTRODUCTION

Ambulatory gait monitors can be used to measure the quantity of gait in the patients' own home environment. The objective of this study was to validate an ambulatory monitoring system (Dynaport Minimod (AGM)) as a tool to asses walking distance in patients with Parkinson's disease (PD). In Study A, the estimation of short and long walking distances measured with the AGM were compared with the actual walking distance. In Study B, patients and partners were asked to wear the AGM during two days to examine the day-to-day variance.

METHODS

Study A: Thirty-four patients walked trajectories of ten, twenty meters and a variable distance between twenty and twenty-even meters. Ten patients and partners walked a trajectory through a public building. Mean difference between the measured distance with the AGM and the actual distance were calculated.

Study B: Forty-three patients wore the AGM during two days at home. The number of walking periods, total walking time and total walking distance were calculated. Correlations between day one and two were calculated for each parameter.

RESULTS

Study A: The results are presented in table 1. The AGM overestimated the trajectories of ten meters, the variable distance and the long distances. The distance of twenty meters was underestimated. Study B: The correlation between day one and two for total walking distance was 0.55, for total walking time 0.5, and for the number of trajectories 0.6.

	Measured distance	**AGM**	**Mean difference**	**95 % Limits of agreement**	**Pearson's correlation**	**P**
	Mean (sd)	Mean (sd)				
Study A						
Distance 10 m	10.4 (0.2)	10.5 (0.8)	-0.044	-1.4 – 1.3	0.36	0.716
Distance 20 m	20.4 (0.1)	20.0 (0.8)	0.400	-1.03 – 1.8	0.38	0.003
Variable distance	25.2 (1.8)	25.3 (2.6)	-0.038	-3.7 – 3.6	0.69	0.911
Long distance						
PD-Patients	866.1 (258.6)	984.1 (290.5)	-118.0	-387.5 – 151.5	0.88	0.024
Partners	847.7 (246.5)	905.3 (260.3)	-57.7	-291.1 – 175.7	0.89	0.160

CONCLUSIONS

The mean systematic difference between the actual distance and the estimated distance is about 10% for the actual distance. There is a large variation around the systematic difference, therefore the 95% limits of agreement are considerable.

P-3-7

VALIDATION OF AN ACCELERATION BASED GAIT TEST TO FOLLOW UP TKA PATIENTS

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INTRODUCTION

The currently used patient assessment scores like the KSS suffer from subjectivity, a low ceiling effect and pain dominance. Previous studies have shown that accelerometers are reliable tools to analyze gait objectively and to distinguish between different knee pathologies [1]. However its use in a follow up study has never been reported before. This study investigates whether the acceleration based gait test is able to monitor patients.

METHODS

Twenty four Total Knee Arthroplasty (TKA) patients (11 men, 13 women, avg. age: 72yrs, weight: 85kg, height:1.69m) were monitored for 3 months after surgery. Classic subscores (KSS; Womac; VAS; PDI) as well as a gait test were measured preoperative, at 2 weeks, 6 weeks and 3 months postop. Gait was analyzed using a triaxial accelerometer fixed to the sacrum while walking 6 times 20m at preferred speed. Movement parameters like step frequency, step time, vertical displacement, asymmetry and irregularity were calculated based on a peak detection algorithm. Speed and step length were scaled for height. Correlations between scores were tested using Pearson' R and changes with regards to pre-op were evaluated using repeated measurements ANOVA ($p<0.05$).

RESULTS

The subjects included were a representative group of TKA patients, showing preoperative KSS and Womac values of respectively 57 and 54. The classic scores were all significantly correlated. Several gait parameters (like frequency and vertical displacement) correlated significantly with the KSS, PDI and VAS, with most significant correlations between gait and the KSS function subscore. No correlations were shown between any of the gait parameters and the Womac (sub)scores. Differences in recovery were shown: two weeks after surgery the classic scales reached equal (VAS, PDI, KSS) or better values (Womac 24% improvement) compared to preoperative, while all gait parameters remained worse than preoperative. At 6 weeks all classic scales showed significant improvements (42 to 63%) compared to pre-op, while the gait parameters only just reached pre-op levels. Beyond 6 weeks, the standard scales improved only slightly and almost reached a plateau at 3 months, while gait continued to improve without showing a plateau.

DISCUSSION

A certain degree of redundancy between the classic scores is demonstrated by the significant intercorrelations. The results show that the KSS function scores gives the most objective reflection of a patient's functional state. The fact that no correlations were shown between gait and Womac indicates that the Womac is not capturing objective changes in gait, as has been reported before using another functional test [2]. The differences in post-op recovery profile between the gait test and standard scales shows that pure function needs more time to adapt to normal levels than the classic scores. E.g. the cadence for TKR patients improved from 101 steps/minute pre-op and 83 steps/minute two weeks post op to 105 steps/minute at 3 months postoperative, while healthy subjects score 120 steps/min. The improvements in standard scales at 2 weeks post-op can be due to patient's satisfaction and the ability to move without pain, while the ways they perform activities like walking remains less adequate. For instance patients 2 weeks after surgery walked with smaller step length leading to higher energy consumption per distance resulting in a faster fatigue, which can be a limiting factor in daily life.

CONCLUSIONS

Ambulatory measurement of gait is a valid method to follow up patients. The results indicate that it should be combined with classic scales because they cover different dimensions of surgical outcome.

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P-3-8

GAIT FUNCTION OF TOTAL HIP ARTHROPLASTY PATIENTS: ANALYSIS OF PREFERRED SPEED WALKING ALONE IS NOT ENOUGH

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INTRODUCTION

Gait before and after total hip arthroplasty (THA) is often determined by walking at preferred speed. However gait function comprises more than just walking at preferred speed. The objective is to describe recovery of gait after THA based on the assessment of spatio-temporal gait parameters determined with an ambulatory system whereby an extended test protocol is used.

METHODS

Sixty-three patients (mean age 62.0 (±12.6) years, mean BMI 26.4 (±3.3) kg/m^2, 43 women) participating in a short-stay program for primary unilateral THA were assessed preoperatively and at 6 weeks and 6 months postoperatively. The spatio-temporal gait parameters walking speed, step length, step duration and variability coefficient (VC) were determined with an ambulatory system using accelerometers. The test protocol contained walking at different speeds, walking while performing an additional cognitive task as a means to determine (recovery of) gait automaticity, and an endurance test.

RESULTS

Patients improved significantly over time on all gait parameters; however, the extent and speed of recovery of gait parameters was different for each test part. The relation between walking speed and step length showed systematic improvement when analyzed over a range of speeds (Fig 1). At 6 months, the VC of the additional cognitive task part was comparable with the preferred walking VC. The endurance test results could be predicted from the results of preferred walking.

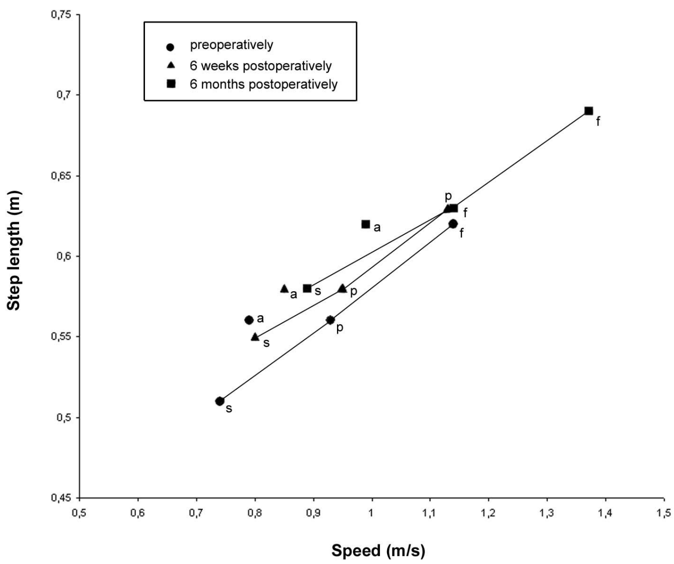

Figure 1. Relation between speed and step length preoperatively and 6 weeks and 6 months postoperatively.

Legend:
a: walking with additional task test part
f: fast-walking test part
p: preferred-walking test part
s: slow-walking test part

DISCUSSION

The results of the study demonstrated that the test protocol provided added value over measurement of only preferred speed. Six weeks after surgery, the results of walking at a preferred speed indicate a very small increase in walking speed and step length, and a small decrease in gait variability (VC). A larger increase in speed and step length is first seen after 6 months. In contrast, already after 6 weeks, the speed – step length relationship during walking at different speeds demonstrates a small but consistent increase in speed and step length (see Figure 1). As for the additional task test part, already after 6 weeks, gait variability is reduced and at 6 months no longer differ from the variability that can be expected based upon chosen gait speed.

CONCLUSION

The assessment of the recovery of gait function requires more than only the assessment of "normal" walking. Particularly, an analysis of walking at different speeds and walking while performing an additional cognitive task demonstrate different aspects of gait recovery after THA.

P-3-9

RELIABILITY OF A BODY-FIXED SENSOR GAIT ANALYSIS PROTOCOL FOR EVALUATING GAIT FUNCTION IN PATIENTS WITH HIP OSTEOARTHRITIS

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INTRODUCTION

Functional limitations of patients with hip osteoarthritis are determined by pain and a decreased hip abductor moment, which may result in abnormal trunk movements in the frontal plane like a Duchenne limp. Spatio-temporal gait parameters such as walking speed, step duration and trunk movements can be determined from body-fixed-sensors (BFS) on trunk segments [1]. Also, assessment of gait function requires more than assessment of 'normal' walking. Analysis of gait on different walking speeds and walking while performing an additional cognitive task demonstrate different aspects of gait function of patients with hip osteoarthritis [2]. Aim of this study was to assess intra-session reliability of a gait analysis protocol for assessment of gait function in patients with hip osteoarthritis.

METHODS

Gait analysis was performed on patients on their day of admission to the hospital for a total hip arthroplasty. Triaxial accelerations and angular velocities of the upper trunk and pelvis were measured with 2 BFS units, attached between the Posterior Superior Iliac Spines and just beneath the 7th cervical vertebrae. Spatio-temporal gait parameters (e.g. walking speed, step duration) were determined from forward pelvic accelerations. Range of Motion was calculated by subtracting the minimum angle from the maximum angle of the pelvis and thorax segments and the trunk. Patients were instructed to walk on a slow, preferred and fast speed back and forth along a 20m corridor. Patients also walked at preferred speed while performing an additional cognitive task. Intraclass correlation coefficients (ICCs, 2-way mixed) between the outcome parameters of the back and forth walks were calculated.

RESULTS

Included in this study were 11 female and 4 male patients with a mean age of 57.7 years (SD 11.0), a mean body mass of 74.7 kg (SD 14.1) and a mean height of 171.8 cm (SD 7.9). For both spatio-temporal and angular parameters, ICCs were the lowest for the test part 'walking at slow speed' (0.79 – 0.88) (table 1). ICCs for the parameters for the other test parts ranged from 0.90 to 0.98.

Table 1. Intraclass Correlation Coefficients (ICCs) for walking speed, step duration and Range of Motion (ROM)

Test part	Walking speed ICC (95% CI)	Step duration ICC (95% CI)	ROM Pelvis ICC (95% CI)	ROM Thorax ICC (95% CI)	ROM Trunk ICC (95% CI)
Slow speed	0.79 (0.47-0.92)	0.88 (0.67-0.96)	0.82 (0.50–0.95)	0.82 (0.53-0.94)	0.87 (0.64-0.96)
Preferred speed	0.98 (0.92-0.99)	0.97 (0.92-0.99)	0.94 (0.80–0.98)	0.92 (0.79-0.97)	0.95 (0.86-0.98)
Fast speed	0.98 (0.93-0.99)	0.98 (0.95-0.99)	0.98 (0.92–0.99)	0.90 (0.73-0.97)	0.97 (0.92-0.99)
Cognitive task	0.94 (0.82-0.98)	0.94 (0.81-0.98)	0.95 (0.87–0.98)	0.97 (0.87-0.99)	0.97 (0.92-0.99)

DISCUSSION

ICCs were the lowest for the test part 'walking at slow speed'. This may be caused by the fact that walking at slow speed is more difficult and painful for patients with hip abductor weakness, because of a longer stance phase and longer weight bearing on the affected hip. ICCs for the other test parts were high (0.90 - 0.98).

CONCLUSION

This gait analysis protocol shows good intra-session reliability, with ICCs ranging from 0.79 to 0.98 for all outcome parameters and test parts.

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P-3-10

CENTER OF PRESSURE DYNAMICS IN PARKINSON'S DISEASE PATIENTS WITH FREEZING OF GAIT: FAILED POSTURAL ADJUSTMENTS?

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INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative disease with myriad symptoms, the most prominent of which affect gait and movement. Freezing of gait (FOG) is a symptom of PD in which the patient is unable to initiate or continue normal forward motion and feels as if the feet are glued to the ground. FOG can be a debilitating symptom and correlates with adverse measures of quality of life, increased risk of falls, and higher rates of nursing home admission. While several aspects of FOG have been studied, the underlying pathophysiological mechanism is unclear. Simultaneous recordings of force magnitude and center of pressure (COP) dynamics during a freezing episode while walking have not been previously analyzed.

METHODS

30 subjects with PD performed three 2-min. walks back and forth along a 20m corridor, with a 180º turn at each end while "on" anti-parkinsonian medicaitons. Three subjects experienced 20? FOG episodes while turning during the experiment. All participants wore piezoelectric force-sensitive insoles (Pedar-X, Novel, Germany) that use an array of sensors to measure the forces under the feet. Forces were sampled at 100Hz, saved on a portable recording unit, and then transferred to a computer for offline analysis. Analyzed data included the dynamics of force magnitude (in Newtons) and the location of the COP under each foot.

RESULTS

During FOG episodes, several features of the force and COP dynamics were consistently noted. FOG episodes were characterized by a rapid, alternating pattern of weight shifts from foot to foot at a frequency of 2-4 Hz, with or without foot lifting. Whereas the occurrence of FOG was accompanied by a shift of the COP to the anterior part of the foot, the termination of the episode was marked by a posterior weight shift. Thus, freezing ended only when all of the bodyweight was borne by one foot, with the COP in a relatively posterior position, at which time a normal weight rolling and toe off pattern was initiated. This gradual backward COP shift, superimposed on the back-and-forth weight shifts between the legs gave freezing episodes a characteristic signature. Freezing episodes clinically characterized by shuffling gait also displayed the same pattern of progressive backshift of the COP as that seen in those without foot lifting. In contrast, a pattern of oscillatory weight-shifts was never observed during turns without freezing.

DISCUSSION

FOG is believed to be associated with impairments in frontal lobe function, which contributes to deficits in movement initiation and motor planning. Initiating a step from quiet standing is known to require a movement called an anticipatory postural adjustment (APA), which entails a weight shift to one side together with a backwards shift of the COP, followed by a forward weight rolling motion that generates the forward momentum for gait initiation. Surprisingly, similar weight oscillations as observed in our study occurred in a different study where healthy adults were subjected to a sudden weight perturbation requiring a stabilizing step, but were instructed only at the very last moment whether to step with the right or left foot. Similar to the abovementioned research, we attribute the oscillatory pattern to multiple, unsuccessful APAs of an unknown origin, that fail to generate an adequate momentum and thus lead either to very short foot lifting (shuffling) or no lifting at all (feet "glued" to the ground). This situation may occur because turning often disrupts the rhythmic right-left pattern of gait. It is possible that a deficit in motor planning forestalls the subconscious decision about which foot to move next, and that the observed pattern of multiple failed APAs reflects a compensatory strategy effected during this delay.

CONCLUSIONS

A characteristic pattern of force and COP dynamics was observed during FOG episodes. This pattern closely resembles multiple failed APAs. Further study of this phenomenon may help illuminate the pathophysiologic mechanisms of FOG and, ultimately, lead to the development of new strategies for preventing or shortening freezing of gait.

P-3-11

LONG-RANGE CORRELATIONS IN GAIT DATA OF COPD PATIENTS

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INTRODUCTION

Analysis of quantitative gait data is challenging. In particular, if ambulatory patients are monitored over prolonged periods of time the need for data reduction is critical. A recent approach to deal with the information in times series of gait parameters is the detrended fluctuation analyses (DFA) method [1]. It provides insight in long-range correlations in gait by a single scaling exponent α. It has been shown that due to central neurological diseases, time series fluctuations become more uncorrelated. Furthermore, changes in α have been associated with gait unsteadiness in the elderly. Although α does not alter in patients with peripheral limitations [2], it is not conclusively known if α can also reflect control processes of other physiological systems. Therefore we had a closer look at the fractal dynamics of gait in chronic obstructive pulmonary disease (COPD) patients, a population that suffers from reduced muscle function and pulmonary dysfunction.

METHODS

Subjects (12 healthy subjects and 15 COPD patients) walked continuously as far as possible within six minutes. Stride interval fluctuations were derived from left and right heel strikes measured with a tri-axial accelerometer attached to the trunk. Subsequently time series of stride times were processed with the DFA method to derive α, which is the slope of the line relating the average fluctuation F(n) and the box size n on an log-log plot. In addition a fourth order polynomial fit was used to explore the contribution of the stride time fluctuation around the trend (root mean square error (rmse)) and the slope of the trend (difference in amplitude) to α.

RESULTS

The COPD patients differed significantly ($p<0.01$) from healthy subjects in age (COPD 63.7 yrs±3.9; healthy 33.3 yrs±2.3), distance walked (COPD 499m±23; healthy 662m±27) stride frequency (COPD 0.95 strides/second±0.08; healthy 1.08 strides/second±0.08) and α (COPD 0.89±0.12; healthy 0.72±0.14). The average rmse of the healthy subjects did not differ significantly ($p>0.1$) from COPD patients (COPD 2.22±1.42; healthy 2.22±0.83). The higher α in the COPD patients was caused by a significant ($p>0.05$) higher average slope of the trend (COPD 0.039±0.019; healthy 0.023±0.012).

DISCUSSION

These results show different long-range correlations in COPD patients compared to healthy subjects. Compared to the α in fast walking healthy subjects in other studies (α=1.0) [3], the α in this study was lower (0.7). This might indicate that the context in which subjects are measured can also influence long-range correlations. In our study the COPD patients and healthy subject walked in identical experimental environments. Therefore we suggest that the physiological impairments of COPD patients, like pulmonary limitations or muscle weakness, was the main determinant of the observed differences in α. When patients need to change gait speed (and thereby stride times) because of their limitations, these changes can be expressed in higher slopes in the trend causing a higher scaling exponent.

CONCLUSION

This study shows that different long-range correlations can exist between healthy subjects and patients who do not suffer from central neurological diseases, which indicates that also reduced muscle function and pulmonary dysfunction can influence α. Further investigation is needed to explore the underlying mechanism of the fluctuations in the time series of the stride times.

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P-3-12

NORMAL GAIT ANALYSIS USING AN ORIGINAL ANALYZING STRAP

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INTRODUCTION

The human gait has traditionally been studied subjectively through visual observations. By combining advanced measurement technology and biomechanical modeling, human gait can now be objectively done. Gait analysis research and development is an ongoing activity, with new models and methods evolving.

METHODS

We study a group of 24 patients (14 women and 10 men) who were following an ambulatory treatment for different diseases in the Ambulatory of the IIIrd Rehabilitation Clinique from Bucharest between 1 October and 31 December 2007. We included in the study group only patients with normal gait and normal cardiovascular parameters. The analyzing strap we used for this study is a prototype designed by Romanian researchers: AGILE - GAIT 95 System. We chose to take into account few parameters from the total pressure curve, forward gait curve and laterality analyzing curve: number of steps, gait speed, laterality, and average footsteps pressure, tossing and weight center variation.

RESULTS

We tried to identify parameters for normal gait analysis using this new AGILE - GAIT 95 System: 4 steps on the strap, average gait speed 4.23 seconds +/- 0.07, average laterality: 21.3 +/- 0.5 cm, average footsteps pressure 67.5 +/- 0.8 kgf, tossing: 5 +/- 0.5 cm, weight center variation: 3.9 +/- 0.9 cm.

DISCUSSION

Our results have been compared with the published data regarding normal gait analysis and the system software must be improved to a more accurate detection of footsteps pressure and weight center variation. We need to continue analyzing more patients to obtain statistical significant values for gait analysis parameters and to enlarge the number of these parameters in order to be able to analyze pathological gait for different types of pathology from a rehabilitation point of view: neurological/aftertrauma/rheumatological/before and after spine surgery/non surgical spine pathology.

CONCLUSIONS

It is our first time to present to an international forum our data obtained during our first study in the domain of gait analysis using a Romanian gait analyzing strap **AGILE - GAIT 95 System** in the Ambulatory of the IIIrd Rehabilitation Clinique in Bucharest.

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P-3-13

FEASIBILITY AND VALIDITY OF THE ACTIVITY MONITOR IN CHILDREN WITH CP

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INTRODUCTION

Many studies have reported on the limitations in physical functioning (activities) in children with Cerebral Palsy (CP), such as decreased gait function and higher energy expenditure [1]. Only few studies have reported on actual physical performance. These studies indicate that children with CP who have neurological impairment are less physically active compared to able-bodied children [2,3]. However, quantification of performance in a daily environment, specified towards certain activities is still lacking. Specified data can be useful to determine the effects of treatment on daily life functioning more precisely. The activity monitor (AM), developed at Erasmus MC and based on accelerometry, can measure a number of activities in adults. However, it has not yet been used to register activities of young children. Children, especially those with CP, walk and act differently than adults. The aim of the present study was to study the feasibility and validity of the AM when used to register several activities in young children with CP.

METHODS

Validity of the activity monitor was tested in 15 children with CP (8 boys, 7 girls; mean age: 7,6 years, range 5-11; hemiplegia: 7, diplegia: 8; gross motor function scale: score I: 7, score II: 6, score III: 2). A standardised activity protocol was administered in the children's daily environment, containing the following activities: lying, sitting, crawling, standing, walking, walking stairs, cycling, running. Each activity was performed for at least 30 seconds continuously, and was performed twice if possible. Activities were recorded with the AM and were video taped. Children were allowed to use orthoses and other aids when necessary to perform an activity.

RESULTS

A neoprene vest was designed to make wearing of the data logger and 4 accelerometers more comfortable. Criteria were defined to detect crawling. All children were able to perform the activities. One child (6 years, hemiplegia, GMFCS I) was excluded from the analysis because of wrong placement of 2 sensors. The AM was able to detect lying, sitting, crawling, standing, and cycling 95-100% correctly. After individual adjustment for 6 children (softwarematic) of the angle of the accelerometers attached to the leg, walking was detected 100% correctly in 10 children, and 80-94% correctly in 4 children. After adjusting the criteria in the knowledge base, running was detected 100% correctly in 8 children, 95% in two children and 71-88% in four children, respectively. Walking stairs was for the greater part detected as walking, cycling or general movement. Adjustments to the software did not improve the detection.

DISCUSSION

The performance of the youngest children (age 5 and 6) was noticeably influenced by the weight of the data logger. For longer term measurements wireless sensors are recommended. Individual adjustments for walking were necessary because of the extent of equino gait with flexed hips and knees. Standard angle adjustment of the leg sensors, based on preceding walking trials, might be necessary. The criteria for running were adjusted because step frequency is higher and movement intensity is lower in children compared to adults. However, in some children, running looked the same as walking and was therefore difficult to distinguish. The activity monitor was unable to detect walking stairs to an acceptable level. This is probably because the pattern of walking stairs is close to walking and the performance of walking stairs varied tremendously among children (sideways, step by step).

CONCLUSIONS

When worn in a vest, the AM is a feasible instrument to register physical activities short term in children (>6 years) with CP. However, for longer term measurements a smaller, light weighted and wireless system is recommended. The AM is valid to register most physical activities. Individual adjustment is necessary to detect walking and running correctly. Attention should be paid to the detection of walking stairs, which can not yet be detected acceptably.

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P-3-14

ESTIMATION OF TRAJECTORY OF HUMAN CENTER OF GRAVITY DURING GAIT USING A TRI-AXIAL ACCELEROMETER AND THREE GYRO SENSORS

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INTRODUCTION

Quantitative assessment of gait is necessary in rehabilitation of the elderly or postoperative patients. Previously we proposed a new gait assessment method using a tri-axial accelerometer set on the back waist of the subject [1]. In this study, we studied to estimate the trajectory of human center of gravity during gait and going up / down stairs using a tri-axial accelerometer and three gyro sensors. This estimated trajectory is expected to assess the gait ability quantitatively.

METHODS

The trajectory can be obtained theoretically by integrating the acceleration twice. However, the estimated trajectory is far from true one because of the sensor's swing according to the body motion and its offset. It is assumed that the observational error by body motion and sensor's offset is almost constant. The observational error is estimated by using the start and end point. Five healthy men (23.0 ± 1.2 y.o.) participated in experiments and walked 5 [m] level walking on flat corridor and up/down on stairs.

RESULTS

The results of gait experiments showed that the trajectory of human center of gravity could be estimated within 4%, estimated trajectories of stair's experiments were similar to stair's form. Examples of estimated trajectory of gait and stair experiment are showed in Fig.1.

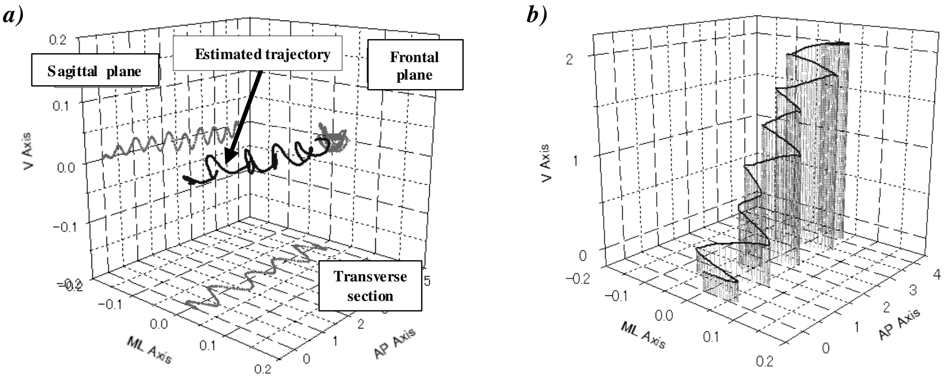

Fig. 1. Estimated trajectories of gait and stair experiment

DISCUSSION AND CONCLUSIONS

It was confirmed that no significant difference of the estimated accuracies between subjects. Results showed that the trajectory of human center of gravity could be estimated within 4%, and the new estimation method proved to be successful. According to the results, it suggests that this estimation method may be of value for quantitative assessment of gait.

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P-3-15

OUTDOOR GAIT ANALYSIS USING INERTIAL AND MAGNETIC SENSORS: PART 1 - PROTOCOL DESCRIPTION

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INTRODUCTION

The MTx (Xsens Technologies, NL) is a low-cost, portable and wearable motion analysis system allowing outdoor acquisitions. The MTx consists of sensing units (SUs) - which are lightweight boxes - integrating 3D accelerometers, gyroscopes and magnetometers. The information from these sensors is 'fused' by the MTx to provide, in real-time, the orientation of the technical System of Reference (SoR) defined for each SU with respect to a global SoR. The MTx can provide the same orientation information an optoelectronic system provides about clusters of markers, but none about SUs position. Being interested in the lower-limb joint kinematics, it means that the usual protocols based on landmarks tracking (e.g. CAST or Plug-In Gate), cannot be directly applied, and different protocols must be defined. The aim of this work was to propose such a different protocol following the example of [1], to measure trunk-pelvis, hip, knee and ankle kinematics with the MTx system.

METHODS

To describe the trunk-pelvis, hip, knee and ankle kinematics we defined anatomical SoRs for thorax, proximal and distal pelvis, proximal and distal thigh, shank and foot. The anatomical SoRs of distal thigh and shank were based on the estimation of the functional axis of rotation of the knee.

RESULTS/ DISCUSSION

The protocol developed was based on the three steps described below.

1) SU positioning on the subject. One SU is placed on each segment with double-sided tape. For the thorax, the SU is positioned on the flat surface of the sternum, with the SU z axis exiting from the body. For the pelvis, the SU x axis is aligned with the posterior superior iliac spines. For the thigh, the SU is just placed on its proximal lateral side. For the shank, the SU x axis is aligned with the fibula, 7cm above the lateral malleolus. For the foot, the SU is positioned on the top of shoes over the mid-foot.

2) Definition of anatomical SoRs by means of a static acquisition. A static acquisition is performed with the subject standing in up-right posture. The thorax SoR is obtained starting from the sagittal plane defined by the gravity line and the SU z axis. The proximal pelvis SoR is computed from the frontal plane defined by the gravity line and the SU x axis. The distal pelvis and proximal thigh SoRs are assumed to be coincident with that of the thorax during the static trial.

3) Definition of distal thigh, shank and foot SoRs based on knee axis of rotation. The subject is asked to perform a pure flexion-extension task remaining seated on a couch. The shank SoR is defined based on the x SU shank axis and the estimated knee flexion-extension axis. The distal thigh and foot SoRs are finally aligned with the shank SoR based on the static acquisition of point 2). The protocol presented here is novel in the literature since no others have measured the full 3D joint kinematics of the lower-limb using such a simple protocol, requiring just one static acquisition and one functional movement.

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P-3-16

SENSING DYNAMIC INTERACTION WITH THE ENVIRONMENT

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INTRODUCTION

Study of the dynamic interaction with the environment and loading of the human body is important in ergonomics, sports and rehabilitation. This paper presents a method to estimate power transfer between the human body and the environment during short interactions and relatively arbitrary movements using a combination of inertial and force sensing.

METHODS

Power transfer between two bodies is given by: $P = \vec{F} \cdot \vec{v} + \vec{M} \cdot \vec{\omega}$ (1) Performed work follows by integrating power over time. Angular velocity $\vec{\omega}$ can be measured using rate gyroscopes, velocity $\vec{v}$ can be estimated from accelerometers after rotation to the inertial coordinate system, subtraction of gravitational acceleration, integration and applying adequate start and end conditions. Force $\vec{F}$ and moment $\vec{M}$ can be sensed by a 6 DOF force/moment sensor system [1] (Figure 1).

Figure 1. Experimental setup of a handle connected to a mass load, with 3D inertial and force/moment sensors

RESULTS

An example result is shown in figure 2. The mass is transferred from the ground to a 75 cm high table, accounting for a potential energy change of 69 J. The estimated performed work in this case is 70 J.

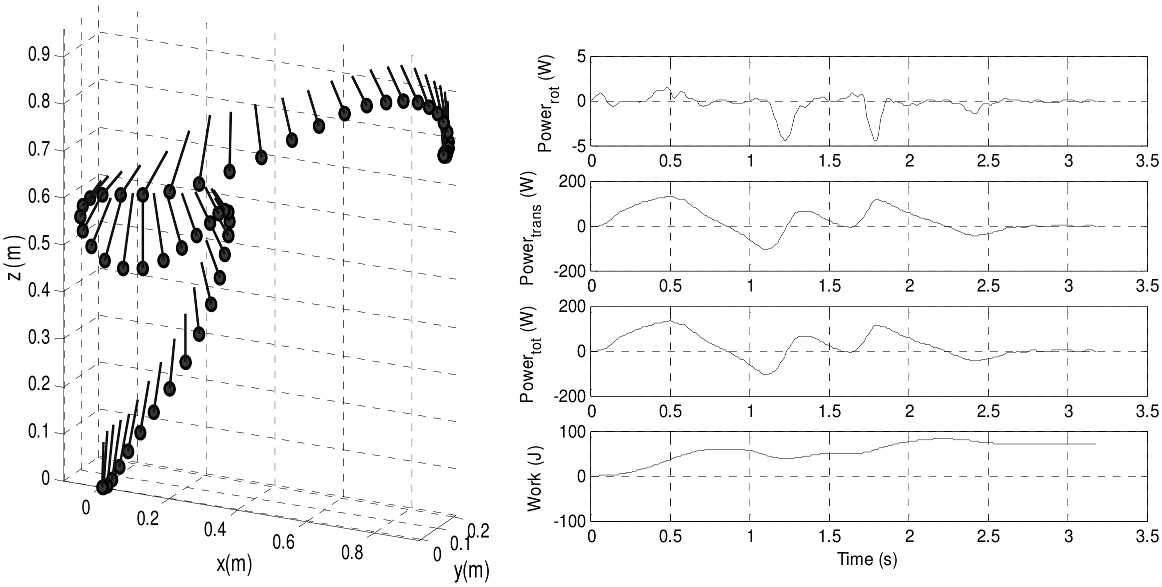

Figure 2. Example measurement
Left: reconstructed position and force directions; Right: Estimated power transfer and work done

DISCUSSION

The presented method also allows partial characterization of the dynamic characteristics of unknown loads.

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P-3-17

INERTIAL-BASED APPROACH FOR 3D EVALUATION OF ACL-DEFICIENT KNEE JOINT DURING GAIT

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INTRODUCTION

Although anterior cruciate ligament (ACL) reconstruction restores a normal anterior-posterior laxity, it seems now established that it does not prevent chrondral lesions. Consequently, nowadays surgeons agree that classical evaluation tools are not sufficient and dynamical analyses are required. Though several *in lab* motion capture systems can conduct 3D analyses; none can be used routinely in clinical practice. Alternatively, inertial-based systems were designed to provide affordable and easy-to-use evaluations *outside the laboratory*. Particularly, an ambulatory device to measure the 3D knees joint kinematics was recently proposed and assessed [1]. Here, the suitability of this system for the quantification of knee joint function change following ACL reconstruction was evaluated.

METHODS

Five young patients with an ACL rupture (range: 16-32 y.o.) were included in this study. They participated at three evaluations: before and two times (5 and 14 months) after reconstruction. The evaluations consisted in a clinical examination and in a 30 m walk. For the gait analysis, Physilog® system (BioAGM, CH) including two sensors units (3D gyroscope and 3D accelerometer) fixed on the thigh and shank segments was used to estimate segments' orientation. The system was calibrated according to Favre et al. [2], and provided reliable 3D joint angles as well as the range of motion of each angle (ROM). The symmetry index (difference in ROM between injured and controlateral knee relative to the average ROM of both knees) was used to compare the function between both knees of a subject. A *zero* index indicates an identical ROM for both joints, while a *negative* or *positive* value indicates a decreased or an increased ROM for the injured knee.

RESULTS

Exaggerate laxities were noticed at baseline for the injured knee, whereas normal values were observed after the surgery. The activity levels were low at the first follow-up, and indicated participations in high demanding sports 14 month after the surgery. Table 1 reports the mean symmetry indexes obtained for all patients at the three evaluations.

Table 1: Symmetry indexes in the three planes

	Sagittal	Frontal	Transvere
Baseline	-17	16	23
5 months	-1	24	-4
14 months	1	13	9

DISCUSSION

As expected, the clinical examinations reported a better laxity control and joint perception following the surgery. In accordance with the literature gait analyses confirmed the change in the sagittal plane after an ACL rupture and the symmetry recovery after the surgery. It showed also asymmetry in abduction/adduction, but without tendency. Finally, this study well underlined the change in the transverse plane after an ACL rupture and its persistence after the surgery.

CONCLUSION

This first use of an inertial-based system for the 3D function evaluation of ACL-deficient and -reconstructed knees reported very promising results. Moreover, it showed the efficacy of such ambulatory system to improve the understanding and the treatments of ACL-deficient patients. Although the results were interpreted with caution due to the small number of patients, the observations agreed with the literature.

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P-3-18

ANTICIPATORY SWING FOOT KINEMATICS DURING BIPEDAL LOCOMOTION

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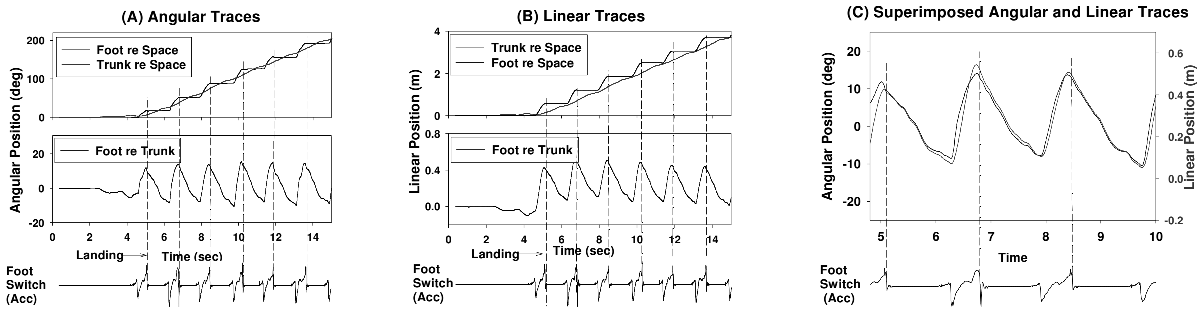
INTRODUCTION

In the early 1970s GMJ & DW [1] demonstrated that anticipatory, rather than reflex, motor action permits a smooth landing from a vertical step to the ground. Here we investigate anticipatory control strategy in the horizontal linear and angular components of swing foot landing during locomotion round a curved trajectory.

METHODS

A subject is asked to walk round a visible circle of one meter radius. An inertia sensing system, NeuroExplore I^{TM} consisting of accelerometers and gyroscopes attached to a wireless PDA, records linear acceleration and angular velocity of the foot as well as angular velocity of the trunk. A vertical accelerometer attached to the same foot acts as a foot switch yielding touchdown. All signals are sampled at 200 Hz.



RESULTS

Figure 1: One subject's derived traces (integrations and transforms applied to raw signals) of both linear and angular foot and trunk positions and their timing with respect to foot landing. Figure (C) superimposes a subset of the angular and linear foot positions re trunk (centre traces of Figures (A) and (B)).

DISCUSSION

We have previously shown [2] that, when stepping round on the spot, the rotating swing foot tends to be stabilized relative to space just prior to landing. Here we show that if adding a forward linear component to the gait, as when following a curved trajectory, the forward linear component is not only stabilized re space but is also tightly synchronized with the angular component (Figure (C)).

CONCLUSIONS

The specifications of our wireless inertia sensing system proved adequate for our purposes. We found that a) there is a strong tendency for anticipatory stabilization of both angular and linear swing foot movement components to occur just before landing, and b) these two components are tightly synchronous throughout. We infer these features favour minimal jolt on landing.

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P-4-1

THE HABITUAL PHYSICAL ACTIVITY OF WARD-BASED AND DAY-HOSPITAL ELDERLY PATIENTS

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INTRODUCTION

Physical inactivity has major health implications for the mortality, morbidity and quality of life of the elderly, and an increasing proportion of the healthcare budget worldwide is utilised by the elderly population. The main goal of rehabilitation programmes designed for the elderly is to maintain functional independence and, in addressing this goal, physical activity is encouraged by physiotherapists. The level of habitual physical activity amongst the elderly is generally considered to be low, however, it has not been extensively analysed and described. The aim of this study was to quantify and compare, over an extended time period, the physical activity of two groups of elderly people receiving physiotherapy treatment.

METHODS

Participants were recruited from a West Glasgow hospital. Group 1 were community-dwellers who attended a day hospital once a week (n=10; 2 male; age 72.2 ± 6.9 years [all values mean ±1SD]) and group 2 were in-patients from a rehabilitation unit (n=10; 2 male; age 80.7 ± 6.9 years). Daytime habitual physical activity was assessed over a week using the *activ*PAL™ activity monitor (Pal Technologies, Glasgow). The monitor, attached to the anterior aspect of the participants' thigh, recorded continuously the postures of sitting/lying, standing and walking. An independent t-test was used to compare the mean time spent upright (standing and walking) between 08.00 and 20.00 hours in the two groups. The number of sit-to-stand transitions and the differences in sedentary patterns between the groups were examined.

RESULTS

There was a significant difference ($p<0.05$) in upright time between the groups; day hospital patients stood or walked for 23% of the day (168 ± 76 minutes) whereas in-patients were upright for only 9% of the day (63 ± 30 minutes). The difference in daily sit-to-stand transitions between groups was also significant (day hospital 54 ± 28; in-patients 32 ± 11). Activity patterns were compared and it was found that the sedentary time of day hospital patients predominantly comprised a large number of short bouts of sitting (< 30 minutes). In-patients spent the majority of the day in sitting periods lasting in excess of an hour.

DISCUSSION

This study measured objectively the habitual physical activity of two separate groups of patients who had all been referred for physiotherapy to improve mobility. By analysing patterns of activity it may be possible to implement tailored interventions which would be more effective in meeting mobility goals. This information has implications for the design and delivery of rehabilitation programmes aimed at maximising and maintaining independence in the elderly. Consideration has not been given to the differences in ages and underlying pathologies between and within the groups.

CONCLUSIONS

This method of analysis of habitual physical activity was able to quantify the levels of activity and the patterns of activity in a frail elderly population. This showed a clear difference in both the overall levels and patterns of activity between the two care settings.

P-4-2

MONITORING OF THE BODY CORE TEMPERATURE WHILE DOING SPORT

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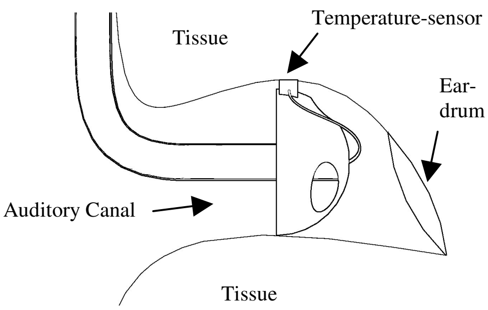
INTRODUCTION

The continuous, non-invasive measurement of the body core temperature under mobile conditions is quite a challenge for monitoring technology. Even though many different temperature measurement technologies exist nowadays, it is still considered very difficult to monitor temperature during physical work or exercise due to motion artifacts [1]. Until now, it was nearly impossible to non-invasively monitor the body core temperature of sportsmen [2]. We whish to report a new body core temperature measurement system which is capable of continuously monitoring the temperature in the presence of bodily motion, even during a competition of half-marathon runners.

METHODS

The site of measurement is the outer auditory canal. A special mechanical device has been designed to position one or more tiny temperature-sensitive resistors onto the wall of the auditory canal applying an unnoticeable well defined attachment pressure. The analog processing is based on a classic 4-wire-resistance read out technology. The resistance values relating to temperature values are then converted to digital values. These are passed through via Bluetooth to the user's mobile phone. Here, the data are stored and can be forwarded to any other place or device, e.g. to a server. This innovative body core temperature measurement system was tested in practice at a half-marathon-running in combination with other parameters: from seven runners, the body core temperature as well as heart rate, position and acceleration were measured during the event.



RESULTS

In nearly any case, the body core temperature of the runners fell during the intital 20 minutes by about 1°C after the running started. Then a rise occurred by about 1.2°C to an elevated level, where the temperature stayed during the remaining competition. Immediately after the running finished, the body core temperature rises abruptly within few minutes by up to 1°C. Eight minutes after the end of physical stress the body core temperature has returned back to the starting level.

DISCUSSION

This experiment as well as a large number of laboratory tests showed three results:

- Firstly, the measurement of the body core temperature is now possible, under mobile conditions, even during sport.
- Secondly, the measurement of the body core temperature is now possible continuously. This can be considered a new physiological parameter with a wide range of applications.
- Thirdly the sensor is quite unobtrusive and easy to wear.

CONCLUSIONS

Given its high accuracy and low susceptibility to motion artifacts and the good wearing comfort, a continuous, mobile body core temperature measurement system could be the basis for a better insight into a poorly understood physiological parameter if it comes to the course of body temperature in everyday-life, during occupational efforts, rehabilitation, hospital use, during sleep, driving a vehicle, in house and cross country conditions, training, sport, just to name a few.

P-4-3

PHYSICAL ACTIVITY PATTERNS IN NORMAL WEIGHT AND OBESE ADULTS USING ACTIVPAL PHYSICAL ACTIVITY MONITOR

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INTRODUCTION

Rising levels of obesity is an increasing concern worldwide. To target individuals with tailored interventions, it is important to accurately describe physical activity (PA) patterns. The activPAL PA monitor records time spent in different postures, number of postural changes, number of steps and cadence. The current study aims to compare PA patterns of normal weight and obese individuals using the activPAL PA monitor.

METHODS

Following informed consent, 20 normal weight (body mass index (BMI) 20-24.9 kg/m^2) and 8 obese (BMI >30 kg/m^2) staff and students of the University of Ulster were fitted with an activPAL PA monitor in a standardised position on the thigh. After 7 days, monitors were returned and data downloaded to a computer. Data was transformed to the average per day and described using mean±SD. Between group comparisons were performed using one-way ANOVA and Kruksal-Wallis for normally and non-normally distributed data respectively.

RESULTS

18 normal weight (BMI 22.8±0.95 kg/m^2) and 8 obese participants (BMI 37.93± 3.92 kg/m^2 completed the study. No significant differences were found between the normal weight and obese groups in the percentage of time spent sitting/lying (77.5%±0.05 vs. 79%±0.07), standing (15.6%±0.04 vs. 14.6%±0.6) or walking (6.8%±0.01 vs. 6.4%±0.01), or in the number of steps per day (8513.57±2019.27 vs. 7202.79±2037.6). There were significantly more postural changes per day from, sitting to standing, in normal weight group (54.76 vs. 43.82, p=0.04). Analysis of number of steps taken at each cadence level revealed that normal weight participants took significantly more steps at the faster walking speeds (110-120 steps/min 1606.89±748.41 vs 911.39±613.13, p=0.03; 120-130 steps/min 1494.86±1121.61 vs. 489.32±531.35, p=0.03; 130-140 steps/min 407.56±445.17 vs. 67.75±71.38, p=0.003; 140-150 steps/min 95.40±73.20 vs. 10.96±11.82, p=0.004).

DISCUSSION

Differences were found in the number of postural changes and the number of steps taken at faster walking speeds between normal weight and obese participants. Previous research has shown that overweight and obese individuals spend less time in moderate and vigorous activity [1]. The results of the current study indicate that this may in part be accounted for by a slower cadence, suggesting that future research should target walking speed and not amount in future PA programmes for obese individuals.

CONCLUSIONS

The results indicate that obese individuals take less postural changes per day and engage in a slower speed of walking, suggesting that this is where future research may be targeted.

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P-4-4

THE ASSOCIATION BETWEEN SKIN TEMPERATURES AND CARDIAC AUTONOMIC RESPONSE IN YOUNG HEALTHY SUBJECTS

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INTRODUCTION

Recording of heart rate variability (HRV), a noninvasive and convenient measure of cardiac autonomic function, has been used as an indicator of cardiovascular health. The death rate due to cardiovascular disease is known to be higher in winter than in other seasons [1]. Several studies have indicated that increases and decreases in HRV can be examined to illuminate the underlying mechanisms that produce a given cardiovascular response to changes in skin temperature. The present study was designed to examine the association between skin temperature and the cardiovascular response of HRV during cold exposure in healthy young subjects.

METHODS

The participants of this study were five male and four female student volunteers. Heart rate data was collected using an ambulatory monitoring vest (LifeShirt®, VivoMetrics, Inc., Ventura, CA, USA) set to record continuous R-R interval data at 200 Hz. Baseline data were collected for 15 minutes at room temperature between 20.5°C and 23.6 °C (RT) while the participants adopted a standing position. Participants then put on a winter coat and pair of fleece gloves and slowly walked 5 m to a temperature-controlled room (ambient temperature between -5°C-0°C), where they stood for 15 minutes. HRV was evaluated in time and frequency domains: RMSSD (root-mean square of successive RR interval differences), low (0.04–0.15 Hz) and high (0.15–0.40 Hz) frequency power in normalized units (LFnu and HFnu) and LF/HF-ratio [2]. During the experimental trials, ambient temperature and skin temperatures (STs) at seven sites (forehead, right forearm, lower back, right dorsal hand, right anterior thigh, right shin, and right dorsal foot) were recorded at 7.5 Hz.

RESULTS

At room temperature, the HFnu and RMSSD was 17.6 and 27.3 ms, respectively, then increased significantly to 31.6 and 45.0 ms, respectively, throughout cold exposure ($p<0.01$). The LF/HF ratio decreased significantly from 5.7 (at room temperature) to 2.6 due to cold exposure ($p=0.003$). At room temperature, the skin temperature at the forehead was moderately related to HFnu ($r=0.71$), LFnu ($r=-0.71$) and LF/HF ratio ($r=-0.69$) ($p<0.05$). The decease of ST at the thigh due to the cold exposure was moderately related to RMSSD ($r=0.69$), HFnu ($r=0.67$) and LFnu ($r=-0.67$) ($p<0.05$). The STs at the forehead and the thigh decreased 6.48°C and 3.48°C, respectively, due to the cold exposure. There was no significant relationship between the STs at other sites and the HRV parameters.

DISCUSSION

Our data demonstrated an acute increase in ambulatory RMSSD and HFnu, the indices of cardiac parasympathetic modulation, as a response to cold exposure. Physiological explanations for the increased parasympathetic tone induced by the cold exposure could be due to cold stimulation of the face. However, the ST at forehead was related to HRV at room temperature but not during the cold exposure. It is of interest to notice that the HRV indices were associated with the ST at thigh instead of the ST at forehead.

CONCLUSIONS

The results of the study show that HRV is in fact sensitive to changes of skin temperature. While the present study was conducted on young healthy participants, the study design and equipment used may serve as a protocol for further research with the elderly population. The LifeShirt proved to be an efficient and non-invasive tool in measuring HRV that could be easily used in an outdoor ambulatory study. Thus, this study demonstrates the human autonomic response to cold and may shed light on the relationships among the physiological response, the cardiovascular health and the intervention of increased clothing in the cold.

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P-4-5

PHYSICAL ACTIVITY MONITORING IN AFRICAN SUB-SAHARAN RURAL AREAS

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INTRODUCTION

The spontaneous physical activity of daily living is a major factor of the quality of life as well as a fundamental determinant of disability. Although objective quantitative physical activity data is, to some extend, available for people living in western countries, there is no such information regarding low-income countries. In developing countries, the assessment of physical activity is difficult and relies almost only on questionnaires. We postulate that the quantitative analysis of the *daily life physical activity patterns* can significantly contribute to a better understanding of the inter-dependence between *poverty, disease, disability* and *working capacity.* This pilot study was conducted in a rural area of Tanzania to evaluate the technical and operational feasibility of long-term physical activity recording under the specific constrains that prevail in African sub-Saharan rural areas.

METHODS

We have designed a waterproof ambulatory physical activity monitoring device composed of a data-logger, batteries and a 3D inertial sensor (accelerometers, gyroscopes) fixed on the trunk. Physical activity was monitored under real-life conditions during 5 consecutive days (12 hours per day) in 10 healthy subjects (5 males, 5 females, age=28±9) from a population of farmers of the Ifakara region, Tanzania. A multi-dimensional analysis of physical activity parameters including both descriptive statistics and advanced nonlinear analysis of physical activity time-series allowed to quantify *posture metrics* (i.e. time spent lying, sitting, standing, walking, number of postural transitions), *gait metrics* (i.e. number of steps, cadence) [1] and *nonlinear metrics* (i.e. fractal scaling exponents quantifying the dynamics of physical activity time-series) [2]. Nonlinear fractal analysis of defined physical activity time-series (e.g. sequence of walking periods, sequence of posture allocation, time of activity-rest transitions) allow to quantify the temporal dynamics of long-term recorded activity patterns and reveals features which can distinguish healthy from chronic disease (pain) conditions [2].

RESULTS

Because we expected physical activity to be gender-dependent, we conducted a comparative analysis in 5 women and 5men. Men showed a higher physical activity than women as the *time percent spent walking* and the total *number of steps* were higher for men (22.4 ± 5.3% and 73344 ± 17502, and 14.2 ± 6.4% and 41808 ± 12237 respectively. Similarly, the *maximal period of continuous walking* and the *percent of walking periods superior to 5 minutes* were 1553 ± 179sec and 1.93 ± 0.95% for men compared to 494 ± 233sec and 0.24 ± 0.2 respectively for women. However, physical activity parameters which can be associated with working tasks showed comparable figures for the two groups. As an example, the *time percent spent in activity* (walking & standing) and the *time percent spent in intense movements* (i.e. trunk angular velocity superior to 100 degree/sec) were similar in men 60.2 ± 5.4% and 4.5 ± 2.7%, and women 59.8 ± 10 % and 4.8 ± 2.2% respectively. The nonlinear analysis shows that the fluctuations of physical activity patterns display fractal temporal organization characterized by power law decaying temporal correlations. These results support a recent hypothesis which suggests that under normal healthy conditions, a number of physiological signals, including physical activity, display complex fractal organization in their fluctuations [2].

CONCLUSIONS & PERSPECTIVES

We advocate that objective, detailed and long-term measurement of physical activity can be achieved under real life conditions in developing countries. Based on other results, we plan to use this activity monitoring to assess behavioral changes related to disorders such as cancer, HIV, chronic pain, diabetes and arterial hypertension, as well as the impact of specific treatments.

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P-4-6

BODY COMPOSITION IS ASSOCIATED WITH HABITUAL PHYSICAL ACTIVITY IN DAILY LIFE AS MEASURED USING A TRI-AXIAL ACCELEROMETER

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INTRODUCTION

Activity related energy expenditure is the most variable component of total energy expenditure and thus an important determinant of energy balance. The aim of this study was to determine whether body composition is related to habitual physical activity in daily life (PA_{DL}).

METHODS

Subjects were healthy, young adults (54 men, 80 women; aged 21 ± 2 years; BMI 22.0 ± 2.4 kg•m^{-2}). PA_{DL} was measured for a period of 2 weeks using a tri-axial accelerometer for movement registration (Tracmor). Using Tracmor output, the proportion of time subjects were physically active at a low, moderate and high intensity (%Low, %Moderate and %High respectively) was determined. Physical activity during work, leisure time and sports was quantified using the Baecke questionnaire. Percentage body fat (%BF) was determined by underwater weighing and deuterium dilution according to Siri's three-compartment model.

RESULTS

The subject characteristics body mass, height and gender together explained a substantial part of the variation in %BF (R^2 = 0.75, SEE = 4.0%). Adding PA_{DL} to the model further increased the explained variation in %BF with 4% (R^2 = 0.79, SEE = 3.7%, $P<0.0001$). In analogy, %BF was negatively associated with %Moderate and %High and positively with %Low ($P<0.01$ for all). A positive association was observed between PA_{DL} and the number of daylight hours during the measurement period (seasonality) in men ($P<0.0001$) but not in women ($P>0.05$). When analyzing the association between %BF and PA_{DL} for both genders separately, a significant association was observed solely in women ($P<0.0001$). In men, an association between %BF and PA_{DL} was observed when taking seasonality into account ($P<0.05$) or when only men with a consistent year round degree of participation in sports were included ($P<0.05$).

DISCUSSION

%BF was significantly associated with PA_{DL} when taking body mass, height and gender into account. More specifically, %BF was negatively associated with physical activity with a higher intensity than upright standing. In men, this association was observed after taking seasonality into account. This was probably due to the fact that men were participating more in season bound sports than women. Indeed, when repeating the analysis for men with a consistent year round degree of participation in sports, i.e. those either not participating in sports or doing so for at least 9 months per year, a significant association was found between %BF and PA_{DL} without adjusting for seasonality.

CONCLUSION

Evidence was found for an association between body composition and habitual physical activity in daily life in both men and women. The results suggest that %BF was negatively associated with physical activity in those with a consistent year round level of physical activity. Moreover, Tracmor assessed physical activity improves the estimate of BF%.

P-4-7

MARKERS FOR MITOCHONDRIAL DENSITY AND FUNCTION CORRELATE POSITIVELY WITH HABITUAL PHYSICAL ACTIVITY IN DAILY LIFE

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INTRODUCTION

Physical exercise training is a powerful tool to maintain or improve mitochondrial density and function (mitochondrial capacity) in both healthy subjects and diseased states like type II diabetes and obesity. This study aimed to determine whether mitochondrial capacity is also associated with habitual physical activity in daily life (PA_{DL}).

METHODS

PA_{DL} was measured during 2 periods of 14 days using a tri-axial accelerometer for movement registration (Tracmor) in non-exercising healthy, young (age 20 ± 2 years) subjects (31 women, 7 men). Using Tracmor output, the proportion of time subjects were physically active at a low, moderate and high intensity was also determined. The capacity of classic markers for mitochondrial density, i.e. the capacity of citrate synthase (CS) and succinate dehydrogenase (SDH), as well the capacity of cytochrome c oxidase (COX) and β-hydroxyacyl-CoA dehydrogenase (HAD) was determined in homogenized muscle biopsy samples obtained from the M. Vastus Lateralis.

RESULTS

CS, SDH and COX were positively associated with PA_{DL} ($P<0.05$, 95% CI: $1.3 \bullet 10^{-4}$ to $2.2 \bullet 10^{-3}$; $P<0.05$, 95% CI: $1.1 \bullet 10^{-5}$ to $9.9 \bullet 10^{-5}$ and $P<0.05$, 95% CI: $7.5 \bullet 10^{-6}$ to $3.6 \bullet 10^{-4}$ respectively) and HAD tended to correlate positively with PA_{DL} ($P=0.06$, 95% CI: $-2.2 \bullet 10^{-5}$ to $1.1 \bullet 10^{-3}$). These associations were independent of gender, age and body mass index (BMI). Stratifying the population based on the intensity of the activities performed indicated that SDH and COX were associated with PA_{DL} irrespective of the intensity of the activities performed. CS on the other hand was only associated with PA_{DL} in subjects spending more time, i.e. more than 8 minutes per day, on high intensity physical activity. HAD was only associated with PA_{DL} in subjects spending less time on low intensity physical activity.

DISCUSSION

In general, a sedentary lifestyle does not result in positive associations with mitochondrial capacity, whilst an active lifestyle does. The intensity of the activities performed influenced the association with PA_{DL} differently for different markers of mitochondrial capacity. Interestingly though, spending an average of only 8 minutes per day on high intensity physical activity already resulted in positive associations between CS and PA_{DL} in healthy young subjects. Whether or not the positive association between mitochondrial capacity and PA_{DL} persists in populations at risk for developing type II diabetes and obesity remains to be tested. More importantly, it should be examined if spending 8 minutes per day on high intensity physical activity accompanied by a high level of PA_{DL} suffices to maintain or improve proper mitochondrial capacity in populations at risk for developing type 2 diabetes and obesity.

CONCLUSION

An active lifestyle within the range of activities of normal daily life is associated with a higher mitochondrial capacity than a sedentary lifestyle and thus a more active lifestyle may help to maintain or improve mitochondrial capacity.

P-4-8

DIFFERENCES IN THE DYNAMICS OF TRUNK ANGULAR VELOCITY DURING DAILY LIFE WALKING AS A MARKER OF PHYSICAL FRAILTY

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INTRODUCTION

Loss of physical function is common in older people and is often linked to general frailty. Avoidance of activities as a result of fear of falling often promotes this loss. Recently, an ambulatory device was used to objectively measure physical activities during daily life and to investigate whether frailty could be linked to the avoidance of activities in every day life [1]. Walking is a key component of mobility as well as many activities necessary for independent living. Walking function can be characterized using measures that provides either *global* (i.e. total daily amount, frequency and duration of walking episodes) or more *specific* (i.e. gait speed, distance, stride length, variability) quantitative information. Although these latter measures correlate well with physical function (chronic pain, frailty, disability) [2][3], assessment of these parameters is difficult in long term monitoring among frail older people since recording usually require additional lower-limbs fixed sensors [2]. The aim of this study was therefore to investigate whether daily life walking pattern could be characterized with information about trunk angular velocity using a single sensor among subjects with various health and functional status.

METHODS

Daily life activity was monitored during two consecutive days, 7 hours each day, using a light portable data logger (Physilog®) including a 3D inertial sensor (accelerometers and gyroscopes) fixed on the trunk. Four groups of subjects were enrolled in the study: a) *Young* (n=23, age=32y±8); b) *Fit old* (n=23, age=73y±5); c) *Pre-frail old* (n=17, age=75y±5); d) *Frail old* (n=31, age=82y±6). The three latter categories were defined according to the presence of 0, 1-2, and 3 or more frailty criteria according to Fried's definition [4]. The dynamics of trunk angular velocity during automatically detected walking periods [5] was assessed using a *symbolic dynamics* approach. The basic principle of symbolic dynamics is to transform a time-series data (in this case the norm of trunk angular velocity) into a series of binary sequences/symbols using a context dependent symbolization procedure. In our approach, the construction of symbolic sequence was done by quantification of *activity intensity* during walking. The norm of the angular velocity was compared with a fixed threshold (*th*=50 deg/s) and samples superior or equal to *th* were set to 1 (higher intensity), while samples inferior to *th* were set to 0 (lower intensity). The symbolic sequence was then characterized by (1) the percent of symbols '1' associated with the time percent of 'high intensity walking' and (2) the complexity of the symbolic sequence (i.e the spread of intense trunk angular velocities over the recorded walking pattern) quantified with the *symbolic Shannon entropy*.

RESULTS

The time percent of vigorous walking was 2.23±0.51, 1.8±0.62, 1.75±0.558 and 0.48±0.44 for the groups of young, fit, pre-frail, and frail old subjects, respectively. Calculated entropy values were 0.15±0.028, 0.13±0.036, 0.12±0.038 and 0.041±0.032 for young, fit, pre-frail, and frail old subjects, respectively. All between-groups differences were statistically significant ($p<0.01$) except for differences between pre-frail and frail older subjects ($p>0.05$). These results suggest that increasingly frail health status is associated with a progressive loss of intensity and complexity of body movements during daily life walking. Clinically, this could be illustrated by the increased prevalence of stiffened gait pattern and decreased body flexibility observed in frailer subjects.

CONCLUSIONS

Quantification of trunk movement intensity during daily life walking activity was able to discriminate subjects with different level of physical frailty. Future studies will evaluate other methodologies to quantify aspects of daily activities, and their relationship with specific measures of gait as well as validated clinical scores.

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P-4-9

MONITORING OF PHYSICAL ACTIVITY AND AUTONOMOUS NERVOUS SYSTEM FUNCTIONS IN PERSONS WITH MUSCULOSKELETAL DISORDERS

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INTRODUCTION

Chronic musculoskeletal disorders (MSD) present a significant medical and social problem. Several clinical studies reported involvement of the autonomous nervous system in manifestation of MSD, with primarily differences in resting parameters and additionally in affected reactivity to laboratory stressors. Longitudinal monitoring of heart rate variability might provide better information about balance in autonomous regulation in patients with MSD [1-3]. However there exist difficulties in interpretation of some effects which are related to stress, working loads and spontaneous physical activity. The aim of the present study is to assess the basic ANS regulatory indicies, stress perception and physical activity in persons with MSD. We hypothesize that MSD is associated with progressive autonomous involvement, including impaired sympathetic-to-parasympathetic balance that related to peculiarities in physical activity patternsis the introduction section.

METHODS

Subjects. 17 subjects with MSD (pain and other symptoms of muscle discomfort in neck and/or shoulder areas that they perceived related to physical loads and observe at least during 6 weeks during last 6 months) and gender/age matched symptom-free subjects has participated in study. Examination consisted of a session of laboratory tests and 24+ hours ambulatory monitoring of heart rate variability and physical activity on separate day. The laboratory part started around 9.00 a.m and included recordings of ECG, arterial blood pressure and muscle blood flow in resting conditions and in response to sustained handgrip, cold pressure and deep breathing tests of autonomous functioning. IDEEA (Intelligent Device for Energy Expenditure and Activity) system of data acquisition and analysis was used to identify different types of physical activity and heart rate. The system monitors body and limb motions constantly through five sensors attached to the chest, thighs and feet. The output characterized specific type, duration, estimated intensity (speed of walking and running) of daily activities in second by second basis. At our request, export of heart rate variability data (RR inter-beat intervals) was available for complementary analysis.

Ambulatory monitoring started in one of the working day soon after laboratory examination between 15.00 and 18.00 depended on participant's schema. Participants were instructed to go about their usual activities and return to the laboratory next day, after 24 hours (e.g. after next day work shift) or any convenient for them time later during the day. This schedule aims to minimize effects of preparation and ambulatory measurements per se on spontaneous behaviour during working shift. Participants will be provided with paper and pencil diary in which they will regularly mark perceived stress and energy.

RESULTS

Ongoing analysis indicates usefulness of posture and motion characteristics such as percentage of the Lie, Recline, Sit, Stand, Walk and Run conditions during the Evening – Night – Day and Transition periods to characterize patients with musculoskeletal disorders in context of possible aberration in the autonomous regulation. Analysis will be completed to the beginning of the conference.

CONCLUSION

The ambulatory monitoring of physical activity and movement might facilitate interpretation of aberration in autonomous nervous system in patients with MSD.

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P-5-1

IS TURNING DURING WALKING AN AUTOMATED MOTOR TASK, OR IS IT A COMPLEX COGNITIVE ACTION?

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INTRODUCTION

Previous work has suggested that as locomotion circumstances become more challenging (e.g., obstacle course, dual tasking during walking, DT), the reliance on cognitive function increases. We evaluated the effects of DT on gait during turns to determine whether this common task is relatively automated (i.e., unaffected by DT) or not. To this end, we developed a method for automatic detection of turns based on force sensitive insoles.

METHODS

213 community-living, relatively healthy older adults (mean age: 76.6± 5.8: range: 70-90 yrs, 128 women, Berg Balance test scores > 45) walked for 2 minutes at a self-selected pace, back and forth along a 25 meter-long corridor, including 180º turns at each end. This task was also repeated under DT conditions (serial 7 subtractions). Subjects wore force sensitive insoles. To quantify the stride-to-stride consistency of the walking pattern, we calculated the stride time variability (coefficient of variation) and swing time variability during the steady state portion of straight-line-walking and during the turns. Turns were identified by using a low pass filter on the stride time series derivative. The maximum peaks of the filtered signal were marked as turns. Each gait segment (turns as well as straight-line-walking) consisted of 7 strides.

RESULTS

Stride time variability (mean ± SE) during turns was significantly higher (p<0.006) in DT (15.1±1.02%), as compared to no DT (11.58±0.76%). During straight-line-walking, variability values were 3.72±0.69% and 3.11±0.57% for DT and no DT, respectively (p=0.49). The effect of DT on stride-time variability was significantly larger (p<0.008) during turns (ΔCV: 3.52±0.89%), as compared to straight-line-walking (ΔCV: 0.61±0.62%). Similar results were obtained for swing time variability.

DISCUSSION AND CONCLUSIONS

Turning is apparently more sensitive to the effects of DT on gait than straight-line-walking. The lack of significance of stride variability in DT compared to no DT in straight-line-walking could be explained by the short gait segment examined. This finding supports the idea that turns require more attention and cognitive resources than straight-line-walking and may help explain why turns are associated with falls among the elderly. Further, the results suggest that automatic detection of turns from force sensitive insoles is feasible.

P-5-2

AMBULATORY MONITORING OF PLANTAR PRESSURE FOR DETECTING DIFFICULTY OF WALKING ON ICE

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INTRODUCTION

Icy surfaces are the cause of many serious slip and fall injuries each winter [1]. However, it is difficult to quantitatively assess the impact of ground conditions on a pedestrian's gait pattern in the real world. This paper discusses a pilot study which evaluates a method for such an assessment using pressure sensitive insoles which record plantar pressure distribution. It can be hypothesized that people walk more "flat-footed" when walking on slippery surfaces such as ice. This change in gait pattern may be detected using measurements of plantar pressure distribution.

METHODS

4 healthy subjects (3 female, between the ages 19-35) were asked to walk on two different surfaces in a simulated outdoor environment where the temperature was held constant at -5°C in a "cold-room". Subjects were asked to walk back and forth 10 times along a 4m long walkway in the cold-room that was covered in either ice or wooden planks. Subjects wore T&T Medilogic foot pressure insoles (Schonefeld, Germany) inside their shoes which recorded plantar pressure data at 60Hz.

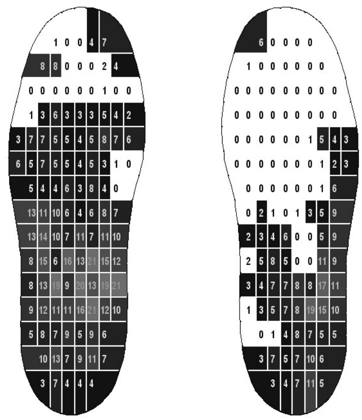

Fig. 1 Pressure sensor layout

RESULTS

The number of sensor elements detecting non-zero pressure was used to determine the contact area between the foot and the surface. The number of sensors detecting non-zero pressure (proportional to the contact area) was calculated for each sampling period and averaged over all samples for each of the two conditions (shown in Table 1). Figure 1 shows a typical layout of sensor elements in the insoles. The exact number of sensors changes with the size of the insole.

Table 1: Average number of insole sensor elements detecting non-zero pressure

	Subject 1		Subject 2		Subject 3		Subject 4	
Surface Type	Left	Right	Left	Right	Left	Right	Left	Right
Wood	111.0	86.6	54.8	50.9	73.7	62.9	51.9	49.7
Ice	112.5	87.1	57.4	53.4	75.1	61.9	61.4	54.9

DISCUSSION

In all but one case (Subject 3 – right foot) contact area of the foot was less for the wood surface than for the ice surface. This result is consistent with our hypothesis that subjects walk more *flat-footed* on ice than on the wooden surface. However, it should be noted that the differences between average contact area for wood and ice surfaces were small. On average this difference was 2.8 sensors. The large differences in contact area between left and right feet for all subjects are likely due to the limitation of the short (4m) walkway. Artifacts likely contaminate our data at the start and finish of each traversal due to acceleration and deceleration as well as effects of subjects favouring their dominant feet. In fact, it may be that larger differences in contact area may be found in subjects walking uninterrupted for a longer distance.

CONCLUSIONS

This pilot study finds that differences in contact area are not a good indicator of difficulty of walking over short distances because the magnitude of the differences observed is relatively small. Future work will consider using a comparison of the paths of the centre of pressure to see if differences in walking surface can be detected.

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P-5-3

WEARABLE INERTIAL SENSORS DETECT ANTICIPATORY POSTURAL ADJUSTMENTS PRIOR TO STEP INITIATION IN EARLY PARKINSON'S DISEASE

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INTRODUCTION

Anticipatory postural adjustments (APA) prior to step have been detected using forceplates and EMG activity. APAs are impaired in advanced Parkinson's disease (PD) [1] and could be an important parameter to monitor motor preparation. However, only one study has evaluated APAs in subjects with early PD [2]. We recently demonstrated the ability to detect APAs in healthy subjects using accelerometric sensors [3]. We hypothesized that inertial devices could provide sensitive measures of gait initiation deficits in early PD.

METHODS

We examined 10 PD and 10 healthy, age-matched control subjects. PD subjects were newly diagnosed and were not taking any medications. Subjects wore 3 MTX Xsens (49A33G15) sensors, mounted with Velcro belts laterally on the thigh and on the posterior trunk, at the level of L5 and C7. Subjects took 2 voluntary steps starting from a force plate (AMTI). Three repetitions at a comfortable pace were performed. The onset of the first measurable change in center of pressure (COP) and lateral acceleration measured by the sensor positioned at L5 level are compared in the present study.

RESULTS

Prior to step initiation, the lateral peak COP and the lateral peak acceleration at L5 level were reduced in early PD, compared to control, subjects. The similar information extracted from peaks of COP and acceleration was supported by a strong linear correlation between the two parameters ($r=0.79$, $p=0.005$).

DISCUSSIONS / CONCLUSION

Anticipatory postural adjustments are affected in early PD, and wearable inertial sensors can detect this impairment. This preliminary result suggests promising applications of portable sensors in monitoring patients' progression in the home environment and for giving biofeedback for gait initiation training.

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P-5-4

WIRELESS ACCELEROMETRY FOR MOTOR CONTROL QUANTIFICATION

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INTRODUCTION

Ambulatory motor monitoring has been mainly focused in obtaining quantitative aspects about subjects' activities, but it has been seldom employed [1] in describing the quality of functional movements and its evolution with time and interventions. As a part of an ongoing effort to quantify motor control as it is qualitatively measured today (with scales and operator-evaluated tests), we describe a wireless system and its ability to reliably grasp relevant objective information during the Berg Balance Scale (BBS) test.

METHODS

2 triaxial wireless accelerometers (MicroStrain G-Link) were placed on the trunk and upper dominant leg of 5 healthy subjects while they performed a series of tasks as required by the BBS ("stand to sit", "tandem stance", "functional reach"). On the subjects were also placed reflective markers in order to quantify angular excursions of the trunk and leg body segments using a VICON stereometric system. Accelometric data was processed (FIR LP filter) in order to obtain an estimate of the inclination in the sagittal and longitudinal subjects' planes and the results compared to the ones produced by the stereometric system.

RESULTS

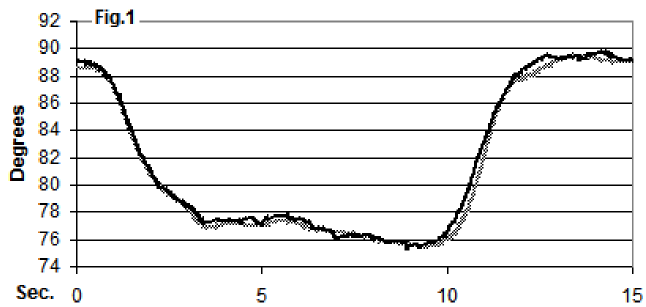
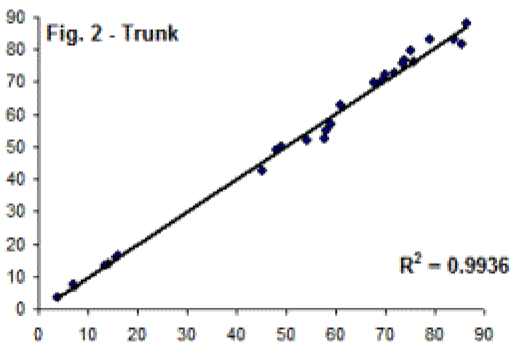
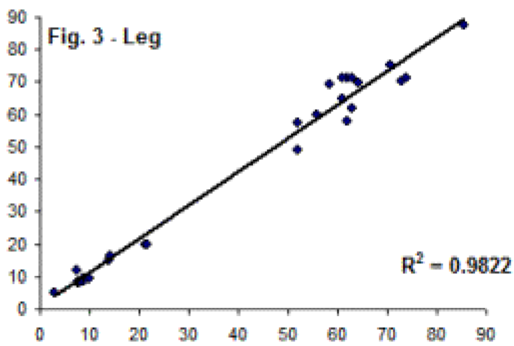


Fig 1 shows the trunk inclinations in the sagittal plane obtained by accelerometric data (greyed line) and by the stereometric data during the leaning forward phase of a "functional reach" task. Figs 2 and 3 show the correlation between inclination ranges in the sagittal plane of the trunk and leg as measured by accelerometric data (X axis) and stereometric data (Y Axis) in all subject and tasks.





DISCUSSION

The quasi-static conditions of the BBS tasks are responsible for the good concordance between the data computed with the two methods. Also, due to the standardized conditions imposed by the BBS, durations (of the entire task and of the transitions) along with the speed can be easily computed from the accelerometric data.

CONCLUSIONS

The described method seems useful in adding quantitative 'operator independent' information to the BBS. Once validated in pathology, it is also suitable for home monitoring of postural motor control.

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P-5-5

BALANCE SKILL STATUS OF FOUR TO SIX YEAR OLD PRE-SCHOOL CHILDREN

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INTRODUCTION

Pre-school age is recognized as the most appropriate period for the development of Fundamental Movement Skills (FMS) [1]. This motor developmental phase is essential because basic foundations are laid for proper daily functioning and lifelong physical activity participation. Currently, there is evidence that a large number of young children do not meet daily recommended amounts of physical activity (PA) [2]. Consequently this reduced time spent in physically activities has an impact on the development of FMS. Therefore, the aim of this study was to chart balance skill development among four to six year-old pre-school children in Flanders.

METHODS

A clustered sample of Flemish pre-school children (N= 1208, n_{boys}= 654, n_{girls}=554) was assessed on their FMS development with the Motoriktest für Vier- bis Sechsjärige Kinder [MOT 4-6] [3]. The test features 18 test items including fine and gross motor movement skill items. Informed consent was obtained from the school team, parents and children. The pre-school children were between four and six years of age (M=5.18 years, ± 0.61). Due to the scope of this study twenty two test administrators were involved in data collection. Prior to the test administrations they received a standardized training. Data were used to describe the developmental status of balance skills among Flemish pre-school children on item level.

RESULTS

In table 1 the % of children that reached advanced balance skill levels is presented. The results show that the mastery of balance skills increases with age and that difference between girls and boys is present.

	4 - 4 ½		**4 ½ -5**		**5 - 5 ½**		**5 ½ - 6**		**6 - 6 ½**	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Forward balance	29,2	41,5	37,7	47,9	42,1	60,0	55,3	75,0	58,3	80,0
Reverse balance	0,0	9,6	2,0	2,9	2,6	5,2	5,3	8,6	8,3	20,0
Jumping in a hoop on 1 foot, standing on 1 leg	2,7	8,5	6,0	12,1	25,0	31,0	36,5	50,0	26,7	45,7
Stand up holding a ball on the head	9,7	21,3	9,3	17,9	21,7	25,2	29,4	35,9	38,3	51,4
Jump and turn in a hoop	34,5	27,7	40,4	32,9	44,7	50,3	58,2	61,7	56,7	77,1

Table 1: % of pre-school children that master the movement skill task

DISCUSSION

Balance skills are mastered well in static situations and at the age of six most pre-school children have reached an advanced level of balance skills. However, there is a large number of pre-school children that has not reached full mastery level of the skills at the age of six. When the task becomes more dynamic, there is a sudden decrease in ability to maintain balance (e.g. losing visual control in backward balance skill and regaining stability on one leg after jumping forward).

CONCLUSIONS

Already a large number of pre-school children in Flanders have several shortcomings in mastering balance skill tasks appropriate for their age. When planning and implementing interventions which focus on lifelong PA and health, it is strongly recommended taking into consideration the creation of opportunities to develop FMS.

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P-5-7

FOOT-WEAR DEPENDED ACCELERATION MEASUREMENTS OF A FALL PREVENTION SYSTEM BASED ON A WEARABLE SENSOR

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INTRODUCTION

Populations are aging around the world [1]. Thus, maintaining the health of the individual in daily life through exercise is very important. The exercise that individuals can do most easily is walking. However, the risk of falling while walking is high for the elderly. Moreover, even a simple fall can result in a broken bone which can lead to severe complications in the elderly. Our solution, using a wearable sensor, is detailed in this paper along with the design of a system that can reduce the risk of falling. We focus here, as a first step, on the changes in walking patterns of different subjects occasioned by changes in footwear and time.

METHODS

We used a 3 axis acceleration sensor to acquire acceleration data while the subject walked. The sensor was attached to the ankle of the right leg. The sampling rate was set to 100Hz. The walking speed was the speed that the subject felt comfortable with. Each subject was asked to walk a straight line for about 60m.During the walk, we confirmed that the subject's movements were rhythmic. Each subject repeated the walk over several days.

RESULTS

Figure 1 shows a part of the acquired acceleration data. No significant difference was seen in the acceleration data when the footwear was changed. For some subjects, the correlation in acceleration patterns with shoes and sandals was very strong at 0.98 or more. Moreover, we obtained a strong correlation in the patterns of the same subject's data separated by several days.

DISCUSSION

Figure 1 clearly shows that acceleration values have almost the same pattern for both shoes and sandals especially at the time frames indicated by each circles. This implies a subject walks with the fixed pattern (walking speed, step, etc) regardless of footwear.

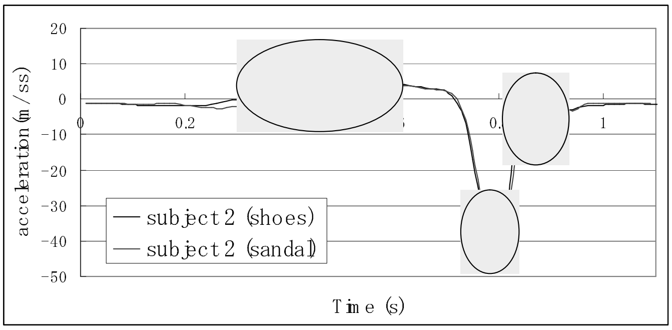

Fig.1 Acceleration data (Two foot-wears used with the same subject)

CONCLUSIONS

The basic experiment showed that the subject walked by the fixed pattern regardless of footwear. So, recognizing the change of walking pattern from the ordinal will make the system that can prevent the fall beforehand by warning. We are conducting to obtain the walking pattern (timing and size etc. of the output of the acceleration) that doesn't depend on the subjects and footwear in detail.

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P-5-8

CLINICAL EVALUATION OF THE VIBROTACTILE LABYRINTHINE SUBSTITUTION SYSTEM (VLS) FOR PATIENTS WITH SEVERE VESTIBULAR FUNCTION LOSS

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INTRODUCTION

An ambulant balance prosthesis could be a potent aid for patients with bilateral vestibular dysfunction to reduce body sway. We developed for clinical application a light weight ambulant Vibrotactile Labyrinthine Substitution system (VLS) to improve postural stability in patients with bilateral vestibular dysfunction by use of tactile feed back. The aim of this study is to investigate the impact and a possible cognitive or placebo effect of the VLS upon postural stability.

METHODS

The VLS consists of 1) a DynaPortMiniMod (McRoberts) sensor, containing 3 orthogonal linear piezo-capacitive accelerometers, which can be mounted on the patients head or trunk, 2) a belt with 12 actuators (Nokia 3210 vibra-motors) around the waist, 3) an ATmega128 (Atmel) processor to translate sensor output into vibrations and 4) a LiPo battery pack to supply power to all components. The VLS is a able to code body tilt in the horizontal plane under both static and dynamic conditions and equipped with 2 operational modes. In normal mode the VLS codes body tilt angle and direction into the activation of specific actuators. In random mode the activation of vibrators is semi-random, used to assess a possible cognitive effect of the VLS. The VLS was tested on 17 adult patients with partial or complete bilateral areflexia. Static body sway was assessed by stabilometry (force platform), balance during gait was evaluated from video-recordings (frontal, sagital and back) and both were combined with accelerometer data. The static experiment consists of a maximum of 8 different tasks with increasing level of difficulty. The dynamic experiment consists of a maximum of 6 tasks with increasing level of difficulty. In both experiments the VLS was tested using 3 settings – off, normal, random – and 2 sensor locations – head, trunk.

RESULTS

The VLS decreased body sway in 11 of our patients, of whom a cognitive or placebo effect could be shown in 5 patients. The predictive value for a true VLS effect or no VLS effect of the simple task and the difficult task is 82% and 71% respectively. The predictive value for a VLS cognitive or placebo effect of the simple task and the difficult task is 37% and 75% respectively.

DISCUSSION

The VLS improved postural stability in 65% of our patients, which is in 45% of the cases based on a cognitive or placebo effect. Moreover, some of our patients reported they felt more stable using the VLS, although a decrease in body sway could not be shown, clearly indicating the need to do more VLS training with our patients.

CONCLUSIONS

Our set of balance tests enables us to tune the level of difficulty to every individual, which is good tool to investigate the effect of the VLS and training.

P-5-9

THE DISCRIMINATING POWER OF SWAY PARAMETERS IN STANCE TASKS

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INTRODUCTION

The aim of this study is to determine which sway parameter can discriminate best between different stance tasks. Both a triaxial accelerometer and a force platform are used to measure sway, the calculated parameters are those which are typically used in literature [1, 2, 3].

METHODS

Eleven healthy subjects (age 22-29, 4 male, 7 female) performed 8 different stance tasks twice with increasing level of difficulty; standing with eyes closed and bare feet for 45 seconds on a 1) firm surface, feet at hip width, 2) firm surface, feet closed, 3) foam surface (Airex Balance-Pad 6 cm), feet at hip width, 4) foam surface, feet closed, 5) firm surface, semi tandem, 6) firm surface, tandem, 7) foam surface, semi-tandem and 8) foam surface, tandem. The tasks were all performed on a force platform (Maastricht Instruments BV) and a triaxial accelerometer (McRoberts, Dynaport MiniMod) was attached to the subject's back at the location positioned over the L3 region. From each measurement swaypath, swayarea and mean sway were calculated from both the platform and MiniMod displacement data. Within subject analysis was performed using Wilcoxon's signed ranked test with Bonferroni correction ($p<0.007$).

RESULTS

Based on the calculated parameters, the difficulty level of the stance tasks was 1-2-5-3-4-6-7-8, with 1 (firm surface, feet at hip width) the easiest task and 8 (tandem stance on foam) the most difficult task. The differences between tasks 4 & 6 were not significant for any parameter. Between tasks 6 & 7 only the MiniMod swaypath showed a significant increase ($p=0.005$). Between tasks 1 & 2, 3 & 4, and 7 & 8 MiniMod swaypath, swayarea and mean sway and platform swaypath showed significant increases. Differences between tasks 2 & 5 were not significant for the MiniMod parameters, but platform swaypath significantly increased. Between tasks 5 & 3 MiniMod swaypath, swayarea and mean sway significantly increased, but platform parameters were not significantly different.

DISCUSSION

The calculated parameters from both the force platform and the MiniMod triaxial accelerometer result in 1) a consistent level of difficulty for and 2) a consistent discrimination between the performed stance tasks. The force platform parameters mean sway and swayarea are not able to show an increase in sway, whereas the MiniMod displacement parameters mean sway and swayarea are. Swaypath increases significantly in at least 4 difficulty steps, although not consistent for MiniMod and force platform. MiniMod swaypath is the only parameter to show a significant increase in sway between a tandem stance on a firm surface and a semi-tandem stance on a foam surface.

CONCLUSIONS

Swaypath appears to be the most useful parameter to discriminate different stance tasks.

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P-6-1

MOUSE AND KEYBOARD INTERACTIONS IN COMPUTER BEHAVIOR

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INTRODUCTION

Variability in exposures is generally believed to be important to the risk of contracting musculo-skeletal disorders at the work place [1]. This is especially true for extensive computer use, which is characterized by prolonged periods of low loads with little variation. During computer use mouse and keyboard are however intermittently used. Switching from one input device to another could therefore be regarded as a source of exposure variation. However, no studies have quantified the precise temporal pattern of mouse and keyboard use. That is, how often are the mouse and the keyboard used during a working day? Is there a preference for either using the mouse or the keyboard and how much time does it take to switch from one device to another? In order to quantify exposure variation in computer users we developed registration software [2] which could precisely monitor keyboard and mouse use over extensive periods of time. The recorded data was used to precisely characterize the episodic nature of mouse and keyboard use.

METHODS

For the current study we collected user data for more than 70.000 workdays, from over 500 individuals working with the computer regularly. We developed algorithms that identified three types of behavior in the recorded time traces: 1) mouse use (moving the mouse, clicking and scrolling), 2) keyboard use, and 3) non-computer work (pause). In order to identify these episodes, we implemented a temporal criterion (threshold) that specifies the maximum amount of time two subsequent data points (events) can be separated in time, while the time in between is still classified as continuous work [2]. Besides this temporal criterion, activity of the other input device could mark the end of an episode of input device activity (mouse use stops a keyboard episode and visa versa). On the basis of these two criteria, the durations of the episodes and the time it took to switch from one input device to another were calculated. Switch times larger than the temporal threshold were omitted from further analysis.

RESULTS

Compared to the duration of the working day, the keyboard was used in 9% and the mouse 21% of the time. The average working day consisted of 249 (Inter Quartile Range: 253) keyboard, 318 (IQR: 324) mouse and 146 (IQR: 149) non-work episodes, with average durations of 10 (IQR: 11), 18 (IQR: 21) and 134 (IQR: 174) seconds respectively. The distributions of the episode durations were highly skewed to the right (many short, and only a few long durations). Switching from keyboard to mouse occurred more often (81% of all keyboard episodes) than vice versa (62%). The number of switches towards mouse use was 14% larger than would be expected on the basis of higher number of mouse episodes during the work day. Switching time from keyboard to mouse was shorter (median: 0.79s) than from mouse to keyboard (0.96s).

DISCUSSION

Although computer use is commonly regarded as work with low exposure variability, we found large variability in the duration of mouse, keyboard and non-computer work episodes across the work day. Working with the mouse was generally preferred. This was reflected in both a larger number of mouse episodes as well as longer episode durations. Switching behavior between input devices is asymmetrical: keyboard to mouse use switches occur more often and are faster. The preference for mouse use puts the computer user at a higher risk for contracting musculoskeletal disorders, since the duration of mouse use is more closely related to the development of these complaints than keyboard use [3].

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P-6-2

PIMEX, AN APPLICATION WHICH MAKES PHYSICAL LOAD VISIBLE

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INTRODUCTION

Physical overload is a major cause of absenteeism due to illness. Many work related muscoskeletal disorders and diseases are related to behavior components of methods of working. In order to prevent too much physical overload it is important to motivate employees to change their behavior. This presentation shows an application to do so, which is already used for chemical risk communication in occupational health.

METHODS

To influence behaviour, it's necessary to improve the knowledge of workers and management of physical load related to their work. Communication tools have been searched to improve this knowledge of preventing physical overload. PIMEX (Picture Mix Exposure), is a widely used instrument in the Netherlands for risk communication in the field of chemical exposure and it has been proven to be a very strong communication tool. The PIMEX system combines video recordings of a person at work with graphics of variation in exposure to a certain "exposure" (e.g. a chemical substance, noise or a physical load parameter) on a real time basis. Arbo Unie investigated whether PIMEX was also applicable to physical strain situations. What emerged was that it can show the extent of the physical strain with a manual push/pull force gauge as one of the useable monitoring instruments. For instance when pulling a mobile patients hoist.

RESULTS

In this presentation one of the PIMEX videos will be shown. The video was made for employees in health services as an application for risk communication. The employees are working with a mobile patients hoist. Mobile patients' hoists are used to reduce physical overload (lifting patients). But according to how it is used, exposure (pushing or pulling forces) will be lower or higher. In a video you can see someone pulling the lift. At the same time a red bar appears indicating the force used. When the wheels are crossways, the bar will shoot up. A much lower peak appears when the wheels are in the proper position. So the video shows the difference in exposure between moving the lift in the wrong and proper way.

DISCUSSION

PIMEX as an application for risk communication is used to improve the knowledge of workers and management of physical load related to their work. By watching recorded material, the personnel involved will get a better understanding of the relation between the situation at the workplace and their exposure. The instrument was tried out in The Wietel, a care centre in Limburg. Evaluation found out that the images were very clear and convincing the effect of a proper method of working. It's also powerful educational material. Using PIMEX with pulling as an aspect of physical load is relative easy because suitable guidelines are available, and the results of measurements can be interpreted easily. But the development of work related musculosketal disorders is multifactorial, with the risks related to lifting, carrying, pushing/pulling, postures and repetitive work. Another monitoring instruments which was compatible with the PIMEX system, is an EMG biofeedback instrument (Analyses of myoelectrical activity). Especially for EMG the selection of the right muscle is very important. Extended literature search needs to be done to proof if the EMG signal is a good marker for the risk.

CONCLUSIONS

PIMEX is a promising application as a risk communication tool for physical load. After all, one image says more than a thousand words. However more research and try outs have to be done to enlarge the possibilities of this instrument for the visualization of physical load.

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P-7-1

A MODEL-BASED APPROACH FOR AMBULATORY MEASUREMENT OF MOTOR SYMPTOMS IN PARKINSON'S DISEASE

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INTRODUCTION

Continuous ambulatory monitoring is a promising technique for the assessment of real-life motor dysfunction in movement disorders. In Parkinson's disease (PD), it could provide a better knowledge in circadian fluctuations of motor behaviour. This may lead to an optimization of therapeutics and to a significant reduction of health costs, in a disease affecting two millions people in Europe. However, despite technological feasibility, long term on-line classification of the 4 main motor symptoms observed in PD (bradykinesia-rigidity, tremor and dyskinesia) remains difficult [1]. Studies approaching this objective more closely [2] use multiple sensors and sophisticated classification methods which make daily living applications difficult. Thus, most of existing ambulatory platforms remain experimental and are confined to laboratory settings. To overcome such shortcomings, we developed an original, model-based approach, referring directly to the structure of abnormal movement.

METHODS

We built up a 2 channels wrist-worn device able to acquire raw accelerometric signals up to 5 consecutive days. For the need of the study, data were locally stored, then transferred to a PC station for off-line processing. Concurrently, we developed a (neuro)biomechanical model of reaching movement at the upper limb, derived from a model of parkinsonian rigidity, we published previously [3]. Additionally, real accelerometric recordings were performed in (short term) laboratory conditions (pointing task at the upper limb, walking on a treadmill) in PD patients and healthy controls. Real data and simulations obtained from the computer model were compared, to select valid measurements of motor symptoms in PD. Finally, these measurements were used to process long term (48 h) recordings performed in ambulatory, real-life conditions, using an algorithm we developed to automatically classify and quantify motor symptoms in PD. These measurements were finally compared to a self –assessment of motor symptoms fulfilled by the patient during the period of recording.

RESULTS

This preliminary study enrolled five PD patients, at various stages and suffering from various clinical features of the disease (akinetic-rigid, dyskinetic and tremor features) and 5 age-matched controls. During short-term and long-term recordings in real subjects, conventional data processing (as low pass or high pass filtering) was unable to differentiate voluntary motor activity from dyskinesia, especially during walking, because of confounding frequency characteristics. Varying control parameters of the computer model allowed to modify the structure of movement and to simulate accelerometric data in various motor symptoms observed in PD (akinetic-rigid behaviour, dyskinesia, tremor). From these simulations, we derived a "complexity index" allowing to successfully classify dyskinesia, as well as to differentiate them from walking activity. This index was further adapted to classify dyskinesia in long-term recordings. It allowed to separate dyskinetic recordings from other ones, according to patients self assessments.

DISCUSSION / CONCLUSION

The main interest of ambulatory monitoring in PD is to separate voluntary motor activity (i.e. what the patient is functionally able to do) from involuntary motor activities (i.e. unexpected movements or motor complications). Conventional signal processing methods, as frequency analysis, fail to identify dyskinesia, precluding their use in real life conditions. In this context, computer simulations may be useful, to select valid measurements adapted for on-line processing of movement disorders. For example, the complexity index we propose for the identification of dyskinesia could be implemented in a portable device. After some refinements and adaptations of the model, this approach may be adapted to other motor diseases with high health costs (stroke, multiple sclerosis, cerebellar disorders, fall in the elderly, epilepsy …). It may arouse the interest of public health organizations, pharmaceutical industry and patients associations.

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P-7-2

A METHOD FOR PERSONAL POSITIONING AND ACTIVITY MONITORING IN 3D INDOOR UTILIZING WEARABLE SENSORS AND MAP KNOWLEDGE

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INTRODUCTION

Personal positioning is one of the essential factors strongly required in various ambulatory monitoring applications such as safety monitoring, in-store customer tracking, and enhanced activity assessment in relation to ones location in daily living. However, due to particularities of indoor situations, conventional use of infrastructure-based measurement systems would not be applicable by reasons of their limited availabilities as its installation efforts or costs to get proper measures. The method in demand must be autonomous needs of neither external measurement references nor cumbersome installations to the environment, and also be robust to uncertainty of human movement within free ambulatory. This study was intended to present a practical method for tracking personal activities, especially focusing on ones positioning in a multi-story indoor environment, by means of the wearable ambulatory monitoring.

METHODS

The method employed small body-mounted instrument consisted of a three-axis accelerometer, combined three-axis angular rate sensors (gyro), and a piezo-resistive barometer specially designed to catch features of vertical movements such as stair climbing or elevator use. Considering usability and low restrictiveness, the device was attached to the center of lower back. The walking trajectory was basically estimated by Dead Reckoning where the position from a known reference is determined by an accumulation of the walking displacements and heading rotations over time. Each walking step was detected as a maximum peak of differential acceleration, and step length variation was modeled as a function of acceleration amplitude. Additionally, an appropriate discriminate function was designed to classify typical ambulatory patterns as level walking, stair walking and elevator use. The heading direction was calculated by the numerical integration of angular velocities as measured. Amount of atmospheric pressure differential was corresponded to a direction and velocity of vertical movements. These estimated factors involve errors due to uncertainty of human movements and signal noise accumulations. To avoid inherent problems of error accumulation in the Dead Reckoning, we applied nonlinear filtering method to Map Matching algorithm that fuses the estimated location and the map knowledge. As an implementation of the method, Particle filter featuring recursive Bayesian estimations and Monte Carlo based processing was employed [1].

RESULTS

The experiment was performed to confirm utility for free pedestrian tracking in general multi-story office building. Healthy male subjects were participated in our study. The result showed that we had a feasible success in reasonable tracking of continuous walking trajectory including stair walking and elevator use. The result suggested that use of the probabilistic Map Matching contributed to overcoming uncertainness of human walking, providing reliable positioning according to the likelihood basing on spatial arrangements of floors. Improved accuracy for activity monitoring was also demonstrated in the experiment.

CONCLUSIONS

A practical method for three-dimensional indoor personal positioning was presented. Only the body-mounted inertial sensors and the map knowledge on the place were utilized due to being autonomous and having high reliability in the pedestrian activity monitoring. A probabilistic Map Matching algorithm including Bayesian estimation with Particle filter was applied to clear Dead Reckoning problems due to uncertainty of human walking, thereby get reasonable location on the basis of maximum likelihood. The experimental results demonstrated that the proposed method provided successful estimation of personal positioning while continuous ambulatory in the multi-story building.

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P-7-3

AUTOMATIC ACTIVITY RECOGNITION FOR TECHNOLOGY-SUPPORTED STROKE REHABILITATION

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INTRODUCTION

Philips Research is developing and clinically testing solutions to increase the efficiency and effectiveness of rehabilitation. As part of the Stroke Rehabilitation Exerciser a wireless inertial sensor system records the patient's movements [1,2]. The data is used to foster motor learning through feedback on the patient's performance. A key element in feedback generation is the automatic recognition of activities from a continuous stream of motion data. Previously, automatic recognition algorithms have been successfully applied to problems such as gesture recognition [3]. However, these investigations were usually performed with healthy subjects. In this paper, we investigate the performance of such algorithms based on motion data of stroke patients recorded during a clinical trial.

METHODS

The clinical data was gathered during a pilot study at Roessingh Research and Development in Enschede, The Netherlands. The patient group consisted of 11 male and 4 female first-time post-stroke patients of age 29 through 72 years (mean age: 43.6 years) without severe spasticity, neglect or aphasia. They had a central paresis of the arm/hand and strength MRC grade from 2 through 4 at entry. Each patient was asked to repeatedly perform activities such as 'drinking from a cup' and 'raising the arm'. The motion data from three inertial sensors worn on trunk and upper and lower affected arm was continuously recorded during the execution of the activities. After discarding unusable recordings, 11 data sets were chosen for each activity. To evaluate the performance of algorithms for automatic recognition based on features such as joint angles, position, duration and derivatives, a two-step approach was used. In the first step the continuous stream was coarsely segmented into non-overlapping segments by three different methods (motion/rest, peak detection, piecewise linear approximation). In the second stage activity candidates were generated by combining segment sequences. These activity candidates were then analyzed and classified with four different classifiers (naïve Bayes classifier, Bayes network classifier, multilayer perceptron, tree classifier). The performance of each combination of the segmentation approaches and the classifiers was evaluated by a ten-fold stratified cross validation.

RESULTS

For 'raising the arm' the most successful classification schemas are all based on the segmentation by peak detection. A simple tree classifier yielded 100% correctly classified candidates by as few as two features. For 'drinking from a cup' the relative absolute error is over 50% with all classification schemas, which is worse than results for healthy subjects.

DISCUSSION

The reduced recognition rate with more complex tasks is due to a larger variability in the execution of the tasks since it is more defined by the result (e.g. drinking from cup) rather than by the movement (e.g. raising the arm). Impaired subjects show even greater variability in their movements than healthy subjects due to compensation or jerkiness, which further decreases the recognition rate.

CONCLUSIONS

While simple activities such as 'raising the arm' can be recognized reliably, for more complex activities such as 'drinking from cup' the recognition accuracy with impaired subjects is not sufficient to enable effective feedback on motor performance. This suggests that automatic activity recognition utilizing inertial sensors for rehab purposes (such as recently reported the Nintendo Wii) is only applicable to simple movements and less so for task oriented training.

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P-8-1

ACCELEROMETER BASED DETECTION OF PHYSICAL ACTIVITY IN CHILDREN AND ADULTS

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INTRODUCTION

Accelerometers are gaining popularity quickly because they are easy and unobtrusive to wear. They can continuously measure the intensity, frequency, and duration of body movements and activities for extended periods of time. The aims of this study were: a) to calibrate a piezocapacitive accelerometer (DynaPort MiniMod) for the classification of light, moderate and vigorous activity in children and adults; and b) to asses reproducibility of accelerometer output (movement intensity) during walking.

METHODS

579 volunteers, age 4-96 years, walked a known distance at their custom walking speed and at a self-selected high walking speed. In a subgroup of 153 children, teenagers and elderly repeated measurements were taken to assess reproduciblity of movement intensity. A regression equation was derived to estimate walking speed from movement intensity. Using equations from the literature that describe the relationship between walking speed and energy expenditure, we predicted energy expenditure in METs from movement intensity and defined cutoff points on movement intensity for light, moderate en vigorous activity.

RESULTS

Reproducibility of movement intensity was high. ICC's for inter-rater reliability were 0.82, 0.91 and 0.95 in children, teenagers and elderly, respectively. The relationship between movement intensity and walking speed depended on body length and shoe type (R^2=0.84). Cutoff points on movement intensity were determined for the classification of activities as light, moderare, of vigorous, for different categories of age and body length.

DISCUSSION

The piezocapacitive accelerometer can accurately classify walking activities of short and long periods of time into light, moderate and vigorous. This can be used to classify people according to current physical activity recommendations.

CONCLUSION

The accelerometer may be suitable for use in programmes for coaching people towards a more active lifestyle. Further validation in other activities than walking is necessary.

P-8-2

DOES ACCELEROMETER PLACEMENT AFFECT METABOLIC ENERGY EXPENDITURE ESTIMATION IN NORMAL WEIGHT AND OBESE SUBJECTS?

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INTRODUCTION

A linear model can be used to estimate energy expenditure from a body-mounted accelerometer. However, the accuracy of this model may vary depending on the body segment to which the sensor is attached. The aim of this study was to investigate the relationship between energy expenditure and accelerometer counts for three different attachment sites, in both normal-weight and obese subjects.

METHODS

10 normal-weight (mean BMI=23) and 9 obese (mean BMI=33) subjects took part in the experiment. Each subject walked for 5 minutes at three separate speeds, their self selected pace and this pace ± 1Km/h. Energy expenditure was quantified by measuring VO2 (Ferraris Medical, UK) over the final minute of each condition, adjusted for the resting measurement. Triaxial accelerometers (ETB, UK) were placed on the sacrum, thigh & ankle and accelerometer counts obtained for 1 minute epochs after band pass filtering (0.2 - 40Hz). Pearson's correlations coefficients were then used to quantify the accuracy of the relationship between accelerometer counts and energy expenditure (normalized for body mass). Separate correlation coefficients were derived for each attachment site for both the normal weight subjects (3 speeds x 10 subjects: n=30 data points) and the obese subjects (3 speeds x 9 subjects: n=27 data points).

RESULTS

In the normal weight cohort, almost identical correlation coefficients were obtained across the different attachment sites (Sacrum: r=0.89, Thigh: r=0.9 and Ankle r=0.89, all tests $p<0.001$). Similarly, in the obese cohort, the correlation coefficients showed similar, albeit lower, values across the different sites. (Sacrum: r=0.78, Thigh: r=0.81 and Ankle r=0.76, all tests $p<0.001$).

DISCUSSION

The pelvis, thigh and shank have different motions during walking. However, our results demonstrated minimal variation in the r values between different attachment sites. This most likely reflects the strong coupling between the different segments during walking. Strong correlations were found for the normal-weight group. However, in the obese group the r values were lower. This suggests that additional information may be required to accurately predict energy expenditure for these subjects.

CONCLUSIONS

The results of this study suggest that the accuracy of energy expenditure estimation from accelerometer data may not be affected by attachment location. However, this estimate may be subject to more uncertainty in obese compared to normal weight individuals.

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P-8-3

COMPARISON OF COMBINED PHYSICAL ACTIVITY MEASUREMENT DEVICES: A BRIEF REVIEW

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INTRODUCTION

The purpose of this review is to compare features and validity of three multi-channel, pattern recognition monitors for estimating physical activity energy expenditure (PAEE). Data channels from the Actiheart (i.e., accelerometer and heart rate), SenseWear Pro Armband (i.e., accelerometer, heat/temperature and galvanic skin response) and the Intelligent Device for Energy Expenditure and Activity (IDEEA; multipoint accelerometer-based neural network) provide opportunity for more precise algorithm development for estimation of PAEE.

METHODS

A systematic review was conducted on MEDLINE for validation studies of the three monitors. The search was limited to studies published between 2000-2007 that included a criterion measure of either doubly labeled water or indirect calorimetry.

RESULTS

A total of 15 articles were identified that used the Actiheart (5), SenseWear Pro Armband (8) and the IDEEA monitors (2). The Actiheart utilizes branched equation modeling to decide conditions which may be most accurately estimated by heart rate, accelerometer or the combination of the two. Results generally supported the improved accuracy of the branched chain model [1]. The SenseWear Pro Armband integrates movement data with a variety of heat-related sensors to improve the accuracy of energy expenditure estimations. Results from several studies show that the SenseWear Pro Armband yielded more accurate estimates than accelerometry-based monitors [2]. The IDEEA uses a complex array of sensors to detect performed activities and then applies prediction algorithms for each. Results from several studies support accuracy of IDEEA's algorithms for detection of specific activities and resulting PAEE estimates [3].

CONCLUSIONS

The reviewed literature supports the validity of these sensors for PAEE estimates specific to the sample populations and physical activities used to validate the respective instruments. Further validation involving a wider range of free-living activities and including special populations (e.g., children, older adults, obese, etc.) are needed. Research is also needed to compare the different instruments with each other.

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P-8-4

PHYSIOLOGIC RELEVANCE OF OPTIMIZED BRANCHED ALGORITHM ANALYSES IN ESTIMATING ENERGY EXPENDITURE

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INTRODUCTION

Branched algorithm (BA) analyses improve the accuracy with which heart-rate (HR) and accelerometry (ACC) can monitor physical activity energy expenditure (PAEE) [1]. Importantly, it is only in optimizing the parameters (coefficients) of the BA that it can be used to achieve such accurate results. Using a previously published BA [1], and novel optimization by simulated annealing, we describe the stability and physiological relevance of BA parameter optimization.

METHODS

The BA was used to predict PAEE from ACC and HR data collected during a protocol involving a variety of daily-living activities. Error in this prediction was measured by the root mean square error (RMS) between BA-predicted PAEE, and criterion PAEE measured by indirect calorimetry. To optimize the 9 BA parameters we used simulated annealing [2] to search for an optimal configuration within a search space of 7.5×10^{20} possibilities. Practical implementations of simulated annealing rarely arrive at the absolute optimum, but at a solution that very closely approximates it [3]. We used this characteristic to assess the stability of the BA parameters by repeating the optimization 50 times to determine the distribution of parameter solutions.

RESULTS

The 50 iterations of simulated annealing resulted in BA parameters that gave very similar estimates of daily-living PAEE, the greatest difference in RMS for any two iterations was 1.35027 vs. 1.35181 (0.114%). Optimal values for the various BA parameters were more varied. Values for parameters determining FLEX-HR were very tightly constrained (varied little with repeated optimization), while optimal values for the remaining parameters varied significantly. This suggests that the three stable parameters are most important in determining algorithm accuracy.

DISCUSSION

Iterative optimization suggests that branched algorithm parameters affecting the FLEX-HR value and weighting of HR and ACC regressions at high exercise intensities are the most important determinants of BA accuracy.

CONCLUSIONS

Refinement of methods to designate and weight FLEX-HR is likely to improve accuracy of PAEE prediction in the field, and specifically in the context of BA analyses.

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P-8-5

ALTERNATIVE APPROACH FOR PRESENTING DATA OF ENERGY COST OF WALKING

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INTRODUCTION

Both in medical research and clinical practice the ambulatory assessment of energy cost (*EC*) of walking is increasingly used to evaluate the effect of interventions that aim to improve gait. This assessment method is attractive because of its practical feasibility, and also it provides an objective means for quantifying overall gait pathology. Moreover, ambulatory EC measures are proven to be reproducible and sufficiently sensitive to detect clinical relevant changes in a patient's condition [1]. This makes EC useful as a support for clinical decision-making, and also as a valid evaluative measure (pre-/post treatment) in gait studies. The validity of EC, however, as a measure for evaluation, is also dependent on the way data is processed and presented. Recently, several advances for processing EC data have been proposed [2,3]. The goal of this study is to introduce an alternative approach for presenting EC data that may be more clinically valuable than the traditional approaches.

METHODS

A retrospective analysis was performed on EC data (pre-/post orthotic treatment) that was collected in the Center for Gait and Motion Analysis at Gillette Children's Hospital in St Paul, USA. In total, data of 172 children with cerebral palsy was processed and analyzed.

The following steps in processing EC data were made: An objective method (Kendall's tau-b) was used for determining steady state of EC data [3]. Steady state EC data was then normalized according the net-nondimensional (NN) normalization scheme [2]. Subsequently, NN-EC data was related to speed-matched control data (that was drawn from an able-bodied reference population previously measured in Gillette). Finally, relative NN-EC data was separated into different change possibilities: changes due to differences in speed and changes due to a shift of the gait pattern toward a more efficient gait.

RESULT

Differences in relative NN-EC are presented in Figure 1. Results are clearly mixed, with a large number of positive changes (quadrant 4), but also a significant number of mixed (quadrants 2 & 3) and poor (quadrant 1).

DISCUSSION

Using relative cost as an outcome measure enables to separate changes in NN-EC in two distinct areas. That is, improvements that are solely due to increases in speed (which would occur at a constant relative NN-EC) can be distinguished from those that are due to a shift of the gait pattern toward a more efficient gait (which would occur at a decreased relative NN-EC). It may be helpful to think of different "movements" on the speed vs. cost plot (Figure 1). Improvements due to speed increases are represented by a movement *along* a direction tangent to that of the average control subject, and improvements due to a shift in the gait pattern are represented by a movement straight down. Any change in the relative NN-EC can be thought of as a sum of these two components, and can provide indications to evaluate the gait more profoundly; giving further insight into what changes in the gait pattern did occur to cause an efficiency shift. This alternative approach for presenting EC data leads to an improved insight in treatment outcomes, and may therefore be more clinically valuable than the traditionalapproaches.

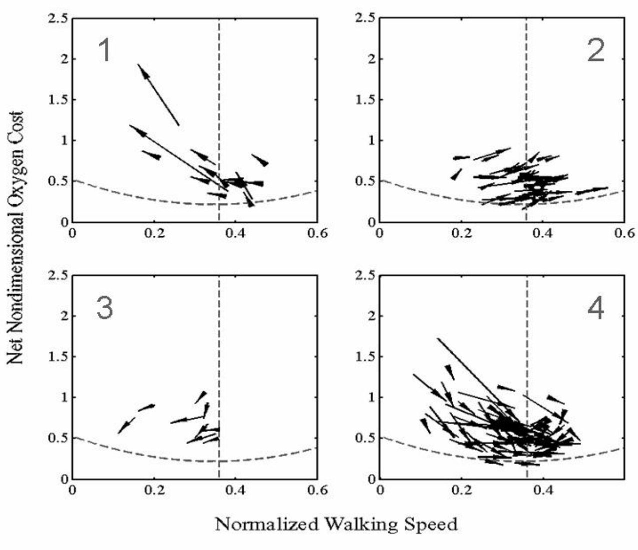

Figure 1. Differences in NN-EC between pre- (beginning of arrow) and post (end of arrow) treatment conditions.

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P-9-1

COMPARISON OF SENSOR CONFIGURATION IN TELE-HEALTH APPLICATIONS ON CLASSIFICATION OF BEHAVIOR

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INTRODUCTION

The effectiveness and success of tele-health services crucially depend on the ease with which clients can use and access the service. In the case of tele-monitoring applications in which clients must wear sensors, ease and comfort of use are compromised if the sensors must be tightly fixed to the body at precise points. Several studies (e.g. [1]) have shown that it is possible to reliably monitor physical behaviors of ambulant clients by means of accelerometers that are tightly attached to the lower part of the body. In this study we investigate to what extent reliable information about the behaviors can be obtained from accelerometers that are attached to the client's clothes, instead of to the body.

METHODS

We carried out experiments with five healthy subjects. Six Minimod 3-D acceleration sensors (Mcrobberts) were used to capture information about the behavior of the subjects. These sensors were split up into two sets; one set was tightly fixed to three body segments (both upper legs and the torso). The other set was attached to the clothing of the subject on corresponding sites (sensors were put in both pockets of the subjects' trouser and one was attached to the belt). The subjects performed a set of controlled movements and postures, viz. sitting, laying, standing, walking at four different speeds, walking up and down the stairs, and bicycling on a home trainer at four different speeds. In addition, a set of semi-natural activities were recorded, viz. sitting at a desk and working on a computer, reading in a chair without a table, playing a game of pictonary (while standing), bicycling outside, walking up stairs to fetch some item and a housekeeping task. The signals were exported to Matlab for further processing. We will use a two stage Hidden Markov Model (HMM) for the classification of posture and movement. In the first stage the posture of the body is predicted and in the second stage the movement of the body is predicted based on prior knowledge of the prediction in the first stage. Initial training and validation experiments with the first stage of the model are currently evaluated. The model is trained per subject. Future steps include training and validation of the whole model on both the body and clothes worn sensor sets.

RESULTS

The Initial training and validation experiments of the first stage of the model showed excellent results for both the body worn sensors and the sensors attached to the clothes. We observed no significant difference in performance between these sensor sets. In case of both sensor sets the test set is correctly classified for at least 95%.

DISCUSSION

The first stage of the model can be trained excellent on both sets of accelerometers. Hence, both sensor sets contain the necessary information for the classification of sitting, lying, and standing. The next step is to train and validate the full classification model on both sensor sets. We hypothesize that both sets will have comparable good classification results in this second step.

CONCLUSIONS

The acceleration signals from sensors worn in clothing are sufficient reliable for detection of postures in ambulant behavior monitoring applications.

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P-10-1

WRIST-ACTIGRAPHY TO ASSESS DISTURBED REST-ACTIVITY PATTERNS IN DELIRIUM AFTER CARDIAC SURGERY

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INTRODUCTION

Patients with a delirium after cardiac surgery frequently show a disturbed 24-hour motor activity pattern [1,2]. However, objective data of rest-activity patterns of patients following cardiac surgery is lacking. Wrist-actigraphy can be used as an objective method to assess spontaneous motor activity. The aim of this study was to explore the usefulness of wrist-actigraphy to quantify characteristics of 24-hour motor activity patterns during a 5-day post-operative period after cardiac surgery in patients who did or did not develop a delirium.

METHODS

We studied 85 patients of 65 years and older who underwent elective cardiac surgery at the department of Cardiothoracic Surgery. Presence of the delirium was assessed daily by means of the Confusion Assessment Method - Intensive Care Unit (CAM-ICU). Subjects were excluded from analyses if they were comatose. Three groups were defined: 1) non-clinically relevant delirium (absent or ≤1 day; n=46), 2) post-operative delirium of short duration (≤3days; n=16), and 3) sustained post-operative delirium (≥4 days; n=17). The patients wore an Actiwatch^R (Cambridge Neurotechnology Ltd) for a post-operative period of 5 days. We focused on the Amplitude (difference in activity between rest and activity, per 24 hour period) as indicator of recovery of circadian rest-activity pattern.

RESULTS

The activity Amplitude was found to be significantly higher for patients without delirium or with short delirium episodes (≤3days), and to increase significantly more during the subsequent days in these groups as compared to patients with sustained delirium episodes (≥4 days). There was a significant time-dependent increase in Amplitude in non-clinically relevant delirium, reflecting a gradual normalization of rest-activity patterns. In sustained delirium episodes the disturbance of circadian rest-activity patterns continued.

DISCUSSION / CONCLUSIONS

Dependent upon the duration of the delirious episode, recovery of circadian rest-activity patterns was found to be severely diminished in delirium after cardiac surgery. Wrist-actigraphy proves to be an elegant tool to objectively quantify characteristics of circadian motor activity patterns in post-operative recovery. Future research should focus on relationships between clinical subtypes of delirium and motor activity assessments by means of actigraphy.

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Time Table

	Wednesday	Thursday	Friday	Saturday
7:30 – 8:30		**8:15: Conference Opening**		
8:30 – 10:20		**S-1: Physical activity: measurement & general issues**	**S-5: Balance & Falls**	**S-9: Remote monitoring (8:30-10:10)**
10:20 – 11:00		**Coffee break & Poster Presentations (Part I)**	**Coffee break & Poster Presentations (Part II)**	**Coffee break (10:10-10:40)**
11:00 – 12:25		**S-2: Medical & Public Health Applications I**	**S-6: Ergonomics & Occupational Health**	**S-10: Psychology & Miscellaneous (10:40-11:45)** **S-11: "What's next" & Conference Closing (11:45-13:00)**
12:25 – 14:00		**Lunch** **W-2: Work shops**	**Lunch** **W-3: Work shops**	**Lunch (13:00-14:00)**
14:00 – 15:25		**S-3: Gait and 3D kinematic analysis outside the lab**	**S-7: Signal Processing & Analysis**	
15:35 – 16:05	**W-1: Workshops (15:00-17:30)**	**Coffee break & Poster Presentations (Part I)**	**Coffee break & Poster Presentations (Part II)**	
16:05 – 17:30		**S-4: Medical & Public Health Applications II**	**S-8: Energy Expenditure**	
	18:00-19:30: Welcome Reception at City Hall Rotterdam	17:15: Social Program "Historic tour through Rotterdam"	19:00 Social Program: Boat tour & Conference Dinner	

Registration is possible Wednesday in WTC (14:00-17:30) and in the City Hall (18:00-19:30), and during the conference from Thursday 7:30.