18th Congress of the Italian Society of Clinical Movement Analysis (SIAMOC)

Politecnico di Torino, Torino, Italy, 4th-7th October 2017

XVIII CONGRESSO SIAMOC TORINO 2017

siamoc Società Italiana di Analisi del Movimento in Clinica

Abstracts presented within:

Oral Session 3 – Posture and balance

O15 - Effect of age and gender on the main baropodometric parameters: normative data for pressure plates

P. Caravaggi, G. Garibizzo, A. Giangrande, S. Tamarri, L. Berti, G. Lullini, C. Belvedere, M. Ortolani, A. Leardini
Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy

INTRODUCTION

Foot morphology and biomechanics are affected by age and gender. As far as the age is concerned, this is consequence of biological alterations of joints and soft tissues which can also be detected by modifications in plantar pressure measurements. While the relationship between some pedobarographic-based parameters and different foot types has been reported in a study involving a large population [1], our current understanding of how ageing affects plantar pressure during walking is still limited. Aim of the study was to characterize plantar pressure data during walking according to gender and age in a population of healthy subjects. The pedobarographic-based foot parameters are expected to provide useful information for gender- and age-specific populations.

METHODS

From January to July 2016 more than three hundred subjects were visited by an experienced podiatrist at the Movement Analysis Laboratory of Istituto Ortopedico Rizzoli, and also in other locations: a primary school; a gymnastic training center; a volleyball training center, and a swimming pool. 133 subjects (70 M, 63 F) with BMI < 29 presenting asymptomatic feet with normal heel alignment (heel varus < 5 deg) and medial longitudinal arch, and with no previous history of lower limb trauma or surgery, were acquired using a 2304-sensor pressure plate (P-walk, BTS, Italy). Five left and five right steps were recorded for each subject while walking at comfortable speed. A custom software was developed and used to determine pedobarographic-based parameters from plantar pressure data [2]: arch-index (AI, %); centre of pressure excursion index (CPEI, %); peak pressure (PP, kPa); pressure-time integral (PTI, kPa*s); foot progression angle (FPA, deg); foot length and foot width (mm). Subjects' data were pooled according to gender, and in four age groups: 6-12; 13-20; 21-40; and 41-60 years. For each gender, differences in pedobarographic parameters between age groups were determined via Kruskall-Wallis test with significance at 0.05. Mann-Whitney test was used to determine differences in each parameter between age-matched gender groups.

RESULTS

Differences were found in all parameters across age groups, with the exception of AI and CPEI. The 5-12 years group showed the smallest PP, PTI and foot dimensions for both genders. In general, FPA increased with age: the oldest group showed larger FPA than the youngest group (Figure 1). With exception of the youngest group, foot dimensions were always larger in males. Differences between males and females in several parameters were found in the 13-20 years group. For example, median PTI in the left foot was 111 kPa*s [94 - 132] in the female group and 142 kPa*s [119 - 171] in the male group (p=0.009).

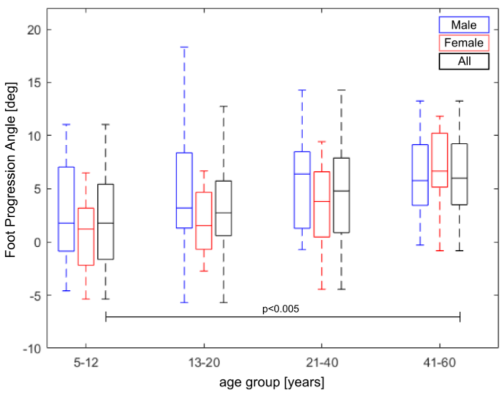

Figure 1 Distribution of the FPA [deg] for the left foot of males, females, and of the whole population in each of the four age groups.

DISCUSSION

Pressure plates are useful and reasonably priced instrumentation for the analysis of plantar pressure. While this instrumentation is increasingly used by podiatrists, plantar pressure data are often assessed on a qualitative basis only. According to this study, several pedobarographic-based parameters characterizing foot biomechanics during walking are age- and gender-dependent. Gender- and age-specific normative data are thus recommended when assessing foot biomechanics and in the diagnosis of foot ailments. This data may help assist with the diagnosis of foot pathologies and morphological alterations, and with the interpretation of foot biomechanics in healthy subjects.

REFERENCES

[1] Menz HB, et al., *Rheumatology* 2013; 52: 2275-82.
[2] Caravaggi P, et al., Bone & Joint Journal Orthopaedic Proceedings Supplement 2017; 2:19.

O16 - The instrumented Fukuda Stepping Test: quantifying balance impairment in patients with sub-acute stroke.

V. Belluscio [1], E. Bergamini [1], M. Iosa [2], G. Morone [2], M. Tramontano [2], G. Vannozzi [1]
[1] *BOHNES, University of Rome "Foro Italico", Rome, Italy,* [2] *S. Lucia Foundation IRCCS, Rome, Italy*

INTRODUCTION

Balance impairment is one of the most common consequences after a stroke event [1]. To assess the effects of this deficit, the Fukuda Stepping Test (FST), in which the subject has to step on the spot blindfolded, can be used. However, the relevant parameters traditionally considered in the clinical environment, i.e. body rotation and displacement measured from final foot position, are not fully representative of the patient's motor ability [2]. The purpose of this study is to devise an instrumented version of the FST (iFST) that embodies inertial measurement units (IMUs). A set of parameters based on segmental accelerations and angular velocities will be analyzed to describe subject-specific motor strategies and to complement and integrate the outcomes of traditional clinical scales.

METHODS

Twenty-seven sub-acute stroke patients (SP; 66±16 years; 45±30 days from the stroke event; 22 ischemic and 5 hemorrhagic) and 18 healthy adults (CG) (57±5 years) were included in the study. The Barthel Index, Tinetti Balance and Gait, Berg Balance, and Functional Ambulation Classification (FAC) scales were administered to each patient, and the SP group was split in two groups according to their FAC score: FAC3 (nr=11) and FAC4 (nr=16). Participants performed the Fukuda Stepping Test, wearing 5 IMUs: 2 positioned on the tibiae and used for step segmentation, and 3 located at the pelvis (P), sternum (S), and head (H) levels. From final foot position, body rotation and lateral and longitudinal displacements were measured. From accelerometer data, the attenuation coefficients between each level pair (C_{ij}) [3] and a stepping symmetry index (iHR) [4] were obtained. Finally, the angular velocity (ω) about the cranio-caudal (CC) axis was plotted for each upper body level pair and the regression line of each scatterplot was computed. The coefficient of determination (R^2) of this line, providing information about the repeatability of the step-by-step ω profiles, was then obtained (Fig. 1). To investigate if significant differences existed between SP (FAC3 and FAC4) and CG, the Kruskal-Wallis test was performed for all the aforementioned parameters (α=0.05).

RESULTS

No significant difference was found between both SP groups and CG for the amount of body rotation and lateral and longitudinal displacements. Conversely, significant differences were found for all C_{ij} (antero-posterior, AP) and iHR (AP, CC) between the SP groups and CG, with smallest values displayed by SP. Significant differences were also found between FAC3 and FAC4 groups for R^2 (PS, PH, SH), with smallest values displayed by FAC3 patients (Fig. 1).

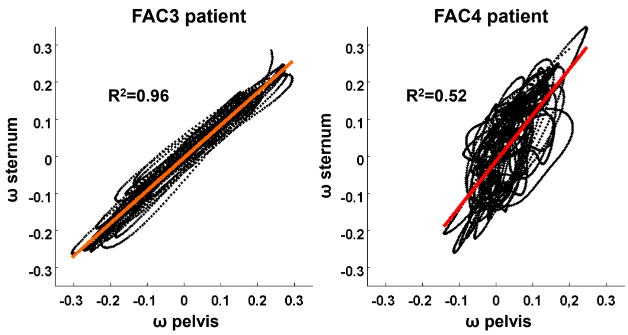

Fig.1 ω (P, S) and R^2 for FAC3 and FAC4 patients

DISCUSSION

Body rotation and lateral and longitudinal displacements do not provide enough useful information about the motor strategies implemented by SP and CG. Conversely, the iFST parameters are able to discriminate not only between SP and CG (C_{ij} and iHR), but also between FAC3 and FAC4 patients (R^2). Specifically, C_{ij} shows that SP lack the ability of attenuating accelerations from lower to upper body levels, and thus of stabilizing the head, especially in the AP direction. In addition, FAC3 patients display a less repeatable step-by-step pattern in terms of angular velocity with respect to FAC4: this result suggests that the R^2 could provide useful information about SP motor strategies, discriminating among patients characterized by different deficit. The iFST could be included in the clinical routine assessment of balance impairment, supporting the design of personalized rehabilitation protocols.

REFERENCES

[1] Langhorne P et al. *Lancet Neurol* 2009;8(8):741–754.
[2] Honaker JA et al. *J Am Acad Audiol* 2009;20(5):311–314.
[3] Mazzà C et al. *J Neuroeng Rehabil* 2008;5:30.
[4] Pasciuto I et al. *J Biomech* 2017;53:84–89.

O17 - Motor unit plasticity in stroke survivors: altered distribution of gastrocnemius' action potentials

T Vieira[1], T Lemos[2], LAS Oliveira[2], CHR Horsczaruk[2], F Tovar-Moll[3], EC Rodrigues[2,3]
[1] LISiN - *Politecnico di Torino, Italy,* [2] *UNISUAM, Rio de Janeiro, Brazil*, [3] *IDOR, Rio de Janeiro, Brazil*

INTRODUCTION

Stroke leads to severe motor deficits, affecting balance control, lower limb function and gait. Motor impairments may persist even months after stroke [1,2] and are possibly associated with motor unit plasticity. Considering stroke leads to the death of motor neurons and the consequent reinnervation of orphan fibres by surviving motor neurons [1], it is possible that the territory of motor units increases after stroke. Here we investigate this issue with intramuscular and surface electromyograms (EMGs).

METHODS

While eight stroke survivors (56 ± 6 years) stood upright over a force-plate, 15 differential surface EMGs were recorded proximo-distally from their healthy and paretic medial gastrocnemius (MG; 1 cm inter-electrode distance). Surface EMGs were triggered with the firing instants of individual motor units, identified by decomposing intramuscular EMGs; wire electrodes inserted at 40% of the distance between the popliteal crease and the distal extremity of MG superficial aponeurosis (Figure, *A*). The RMS amplitude of surface potentials was computed separately for each channel. The number of channels detecting RMS values greater than 70% of the maximal RMS amplitude, normalised with respect to the total number of channels, was then considered to assess the size of the skin region where action potentials of single MG units were detected in both limbs. This methodology provides an indirect estimation of the territory size of MG motor units [3]. Ultrasound images were acquired to control for the effect of differences in subcutaneous thickness between limbs. Since action potentials were not observed in EMGs collected from the paretic limb when some participants stood at ease, additional trials were applied. Specifically, these subjects were asked to load their limbs as equally as possible while provided with centre of pressure visual feedback (Figure, *B*).

RESULTS

Thirty-four MG motor units were identified, of which 13 in the paretic limb. When compared to motor units in the healthy MG, action potentials of motor units in the paretic MG were represented at a 33% wider skin region (Mann-Whitney test; $P<0.001$). Side differences in the representation of motor unit were not associated with differences in subcutaneous thickness (Spearman *rho*=-0.45; $P=0.32$).

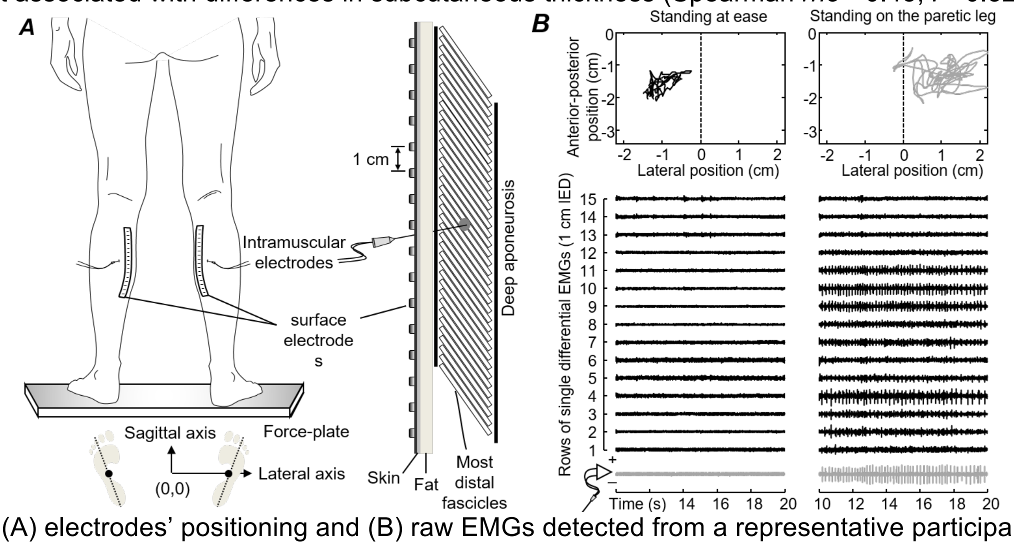

Figure. (A) electrodes' positioning and (B) raw EMGs detected from a representative participant.

DISCUSSION

The spatial distribution of the amplitude of action potentials of postural motor units in the MG muscle is significantly larger in the paretic than in the healthy limb. These results suggest that, at least for MG motor units recruited during standing, stroke leads the enlargement of motor units territory.

REFERENCES

[1] Lukács M. *Clinical Neurophysiology* 2005;116:1566-70.
[2] Geurts ACH, de Haart M, van Nes IJW, Duysens J. *Gait and Posture* 2005;22:267-81.
[3] Vieira TM, Loram ID, Muceli S, Merletti R, Farina D. *Journal of Physiology* 2011;589:431-43.

O18 - Biomechanical and functional alterations in the diabetic foot: differences between type I and type II Diabetes

P. Caravaggi[1], L. Berti[1] , A. Leardini[1], G. Lullini[1], G. Marchesini[3], L. Baccolini[3], C. Giacomozzi[2]
[1] Movement Analysis Laboratory, Istituto Ortopedico Rizzoli, Bologna, Italy [2] Department of Cardiovascular, dysmetabolic and aging-associated diseases, Italian National Institute of Health, Rome, Italy [3] Policlinico Sant'Orsola-Malpighi, Bologna, Italy

INTRODUCTION

Biomechanical alterations in the diabetic foot have been studied for decades, and are still under discussion [1]. In particular, an agreement is far to be reached in terms of a comprehensive, clinically relevant biomechanical model of foot segments loading during locomotion [2]. In order to get a better insight into this topic, a wide study has been designed and conducted which relies on an integrated pressure - kinematic methodology [3]. Main aim of the study is to detect and quantify the impact of Diabetes-associated modifications of foot function by isolating the role of each possible confounding factor. In this preliminary study we investigated the role of type I and type II Diabetes, while strictly controlling the remaining relevant biological and clinical variables.

METHODS

From January 2016, a wide sample of diabetic patients and healthy volunteers was examined through an integrated pressure-kinematic technique based on the Rizzoli Foot Model and five foot regions of interest [3,4]. At present, 140 participants have been enrolled and acquired under controlled, self-selected cadence. Five consistent trials have been collected for each foot. Patients were clinically stratified based on type I or type II Diabetes and, within each type, grouped according to: presence/absence of neuropathy; presence/absence of deformities or functional limitations; BMI; age; walking cadence. This preliminary combined study on pressure and kinematics was conducted on a sample of 30 feet, equally distributed among three subgroups: diabetics type I (T1), diabetics type II (T2), and age-matched healthy controls (C). For all subjects, walking cadence was in the range 50-55spm, BMI was < 30kg/m^2, deformity or functional limitation and Neuropathy were absent. Based on previous correlation studies [4], the range of motion (RoM, degrees) of the ankle joint in the frontal plane was selected as the relevant kinematic variable. Pressure-time integral (PTI, kPa*s) was used to investigate loading under the total foot and the five regions of interest. 1-way ANOVA ($p<0.05$) with Bonferroni-Holm correction was applied to all parameters and groups.

RESULTS

T1 (who only differed from C for the presence of long-term Diabetes), with respect to C, showed a significant shift of loading from midfoot and forefoot to toes (T1, respectively: 19.2 ± 7.4, 104.3 ± 38.3, 47.0 ± 29.3; C: 24.1 ± 10.1, 118.9 ± 26.3, 34.1 ± 20.8), associated with a moderate – albeit not statistically significant - RoM reduction (T1: 6.9 ± 2.4; C: 7.6 ± 2.4). T2, with respect to C, showed significant changes in forefoot and toes loading (T2: 150.4 ± 63.3, 28.4 ± 15.6) and a significant ankle RoM reduction (6.0 ± 1.2) likely due to Diabetes but also in possible association with older age. Further, T2 (61.0 ± 14.2) significantly differed from T1 (69.6 ± 17.2) for the lower loading at hindfoot. Lower loading was observed also at the toes, and higher loading at the forefoot.

DISCUSSION

The present results show that the Diabetes type alone, i.e. without neuropathy or deformity complications, is responsible for major biomechanical changes of foot function in the stance phase of walking.

REFERENCES

[1] Van Netten JJ, et al, *Diab Metab Res Rev* 2016, 32(Suppl. 1): 84–98.
[2] Bus SA, *Diab Metab Res Rev* 2012 28(Suppl 1): 54–59.
[3] Giacomozzi C, et al., In *Handbook of Human Motion*. 2017 Springer, Integration of foot pressure and foot kinematics measurements for medical applications in-press.
[4] Caravaggi P, et al., *J Biomech* 2016 49(14):3485-3491

O19 - Automatically recognize postural transitions in TUG test using machine learning methods

L. Pinna[1], A. Mannini[1], A. M. Sabatini[1], C. Dolciotti[2], P. Bongioanni[3], M. C. Carboncini[3] and G. De Petris[4]

[1] Scuola Superiore Sant'Anna, Pisa, Italy; [2] Clinical physiology CNR, Pisa, Italy; [3] Department of Neuroscience, Azienda Ospedaliera Universitaria, Pisa, Italy; [4]Tim, Pisa, Italy

INTRODUCTION

Patients with Parkinson disease (PD) report that balance disorders are the most important cause of reduced quality of life [1]. For this reason monitoring motor signs in PD, such as gait and balance, has a primary relevance. Several approaches in the clinical assessment practice, involving either clinical rating scales or the use of wearable, inertial sensor technology [2]. Wearable sensors fulfill the need of an objective, observer-independent measure of PD motor impairment. One of the most commonly used functional measurement in PD is the Timed Up & Go Test (TUG). The aim of this work is to automatically recognize postural transition during TUG test, i.e. sit to stand and stand to sit, building on previous results in the field, [3-4]. In particular, different machine learning methods were compared in solving the problem of automatic recognition of postural transitions from inertial sensors data.

METHODS

Data were collected from 18 healthy adult subjects, with no history of gait issues (69.2 ± 7.5 years old), and from 25 people with Parkinson's disease, from stage 1 to 3 of H&Y scale (69.7 ± 8.5 years old). The experimental protocol involved the TUG test: the participants were asked to rise from a chair, walk three meters at their normal comfortable speed, turn around, walk back to the chair, and sit down.Three wearable inertial measurement units were placed at trunk and shanks, however, trunk sensor data only were retained for processing in this work. Sensors were connected via Bluetooth to a smartphone that managed data synchronization and storage. Building on the work by Salarian et al, postural transitions were identified in two steps. First postural transition candidates were identified by applying a low-specificity threshold on trunk tilt estimates and then, the obtained candidates were classified by extracting a set of features from inertial data in correspondence of the candidate transition, [3]. Feature vectors were classified by means of machine learning methods to automatically recognize if candidate events were actually transitions or not. In particular, six classification strategies were compared (random forests RF, support vector machines SVM, decision tree J48, logistic regression LogReg, naive Bayes NB and k-nearest neighbour kNN). Differently from previous works, the leave-one subject-out cross validation was applied to evaluate the methodology.

RESULTS

Cross-validation results are summarized in figure 1. All methods successfully identified the postural transitions in the TUG test, showing above 90% accuracy, sensitivity, specificity and positive predictive value (PPV). It can be noticed that all classifiers show accuracy higher than 90%, ranging from the 94.8% of J48 decision tree to 97.7% of SVM classifier.

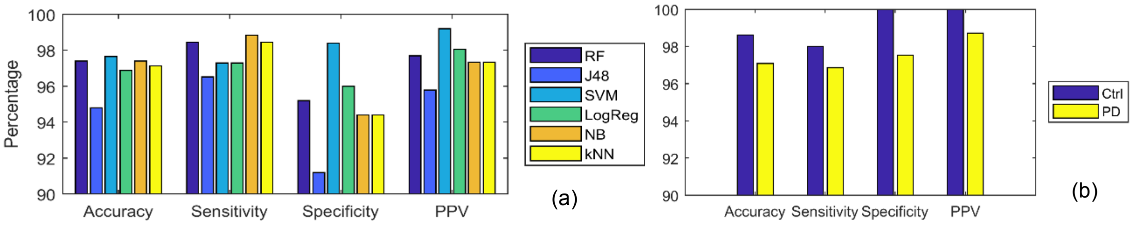

Figure 1. Leave-one-subject-out cross validation results of the automatic postural transition detector for the tested set of classifiers (a). SVM results across the two groups of subjects (b).

DISCUSSION

Albeit a direct comparison with previous methods is not completely fair, due to differences in the dataset, our approach results reach higher sensitivity and PPV in relation to previous work (see figure 1 in relation to [3]). In conclusion, the proposed method can successfully identify postural transitions during a TUG test and could find a straightforward application in the processing of data acquired during such clinical test.

REFERENCES

[1] Tuchman M. *Park Alliance Balanc,* 2009; vol 20, pp.1-15.
[2] Hobert M, et al. *Acta Neurol* 2014; vol. 130, no 3: pp. 139-147
[3] Salarian A, et al. *IEEE Trans Biomed Eng* 2007; vol.54, no.12: pp. 2296–2299,

[4] Najafi B, *IEEE Trans Biomed Eng* 2003; vol. 50, no. 6 pp. 711–723.

O20 - Real time detection of sit-to-stand phases: an early study

A. Di Marco [1], M. Testa [1]
[1] *Università degli Studi di Genova, Genova, Italy*

INTRODUCTION

The Sit to Stand (STS), defined as the transition from the sitting to the standing position, is a basic ability performed many times every day [1]. It is commonly adopted in clinical practice because musculoskeletal or neurologic degenerative pathologies, as well as the natural process of ageing, determine an increasing difficulty in rising up from a seated position [2]. Recently, MEMS (Micro Electro-Mechanical Systems) have been used for assessing functional test, included STS. The majority of the analysis are computed offline, instead it would be interesting to analyse the exercise in real time in order to provide a properly feedback. The biggest difficulty associated with the real time STS analysis is to distinguish the different phases of STS. Previous works limited to detect the seat-off and seat-on [3]. The aim of this study is to develop an advantageous real time classifier able to differentiate the STS phases.

METHODS

Experimantal Design. The study involved 16 subjects, 7 females (23.4$\pm$3.0 years). The subjects wore 8 inertial sensors (Xsens MTw, Xsens Technologies BV, Enschede, The Netherlands) placed on sternum, back (L4-L5), femur, tibia and ankle. The apparatus included also a height-adjustable chair, a seat switch (for detecting seat off and seat on). The participants sit on the chair with the arm crossed at the chest, without back resting and the feet placed in order that knee angle was 90°. Previously, the experimenter explained the properly way to execute the exercise. Each subject performed the exercise ten times at self-selected speed. An acoustic alarm indicated the start of each trial.

Data Analysis. Inertial sensors recorded acceleration, angular velocity in three dimensions (sampling frequency 50 Hz).The data from the inertial sensors were synchronized with the signal from the seat switch. In particular, the acceleration of each axes and the Euler angles were analyzed. MatLab 2016a performed the data analysis (**The MathWorks, Inc., Natick, Massachusetts, United States.).** Initially, the STS phases were individuated: Trunk Leaning (TL), Standing (SDG), Balance (BL) and Sitting (STG). Each phase was segmented in epoch of 0.1 s and 0.2 s. For each epoch were calculated: mean, standard deviation, root mean square (RMS), maximum normalized to RMS, minimum normalized to RMS, covariance factor and first derivative. From each one of these datasets were extrapolated one dataset relative only to sensors placed on sternum, right femur, left. We compared the performance of three different classifiers, Complex Tree, K-Nearest Neighbors (KNN) and Support Vector Machine (SVM) for each dataset.

RESULTS

The classifiers accuracy has been evaluated by F1 score, reported in the table 1.

Table 1. Summary of F1 score for each classifier and dataset

DATASET	TREE [%]	KNN [%]	SVM [%]
Epoch 0.1, 8 sensors	98	98	99
Epoch 0.1, 3 sensors	85	95	96
Epoch 0.2 ,3 sensors	74	96	99
Epoch 0.2 ,8 sensors	97	97	98

DISCUSSION

Although the more accurate classifier was the SVM, it had longer computational time. So, it's not suitable for real time application. The Tree classifier had shortest computational time, but it needed the features from all sensors for having a better accuracy. A good compromise, should be the KNN classifier that had good accuracy also with less features. The duration of the epochs did not affect the accuracy of the KNN classifier, so it's preferable choice an epoch of 0.2 s. The next step is the evaluation, during the different phases, of the kinetic parameters in order to evaluate their accuracy.

REFERENCES

[1] Nuzik S., Lamb R., Vansant A., and Hirt S., *Physical Therapy* 1986; vol. 66(11) pp. 1708–1713,
[2] Mak M.K.Y., Levin O., Mizrahi O., and Hui-Chan C. W. Y., *Clinical Biomechanics* 2003; 18 (3): 197–206

[3] van Lummel R.C., Ainsworth E., Hausdorff J.M., Lindemann U., Beek P.J. and van Die J. H., *Physiological Measurement* 2012 ; 33 1855-1867

O21 - A new protocol for the biomechanical evaluation of sport shoes and insoles: comparison between in-shoe prefabricated and off-the-shelf insoles with metatarsal bar

A. Giangrande, A. Leardini, M. Ortolani, G. Lullini, L. Berti, C. Belvedere, P. Caravaggi
Istituto Ortopedico Rizzoli, Bologna, Italia

INTRODUCTION

Practicing sport is a good habit to control body weight and to maintain a healthy cardiovascular system. However, the importance of wearing the correct sport shoes is underestimated and the choice of footwear is often merely dictated by fashion. However, only few studies have thus far reported the baropodometric effects of different foot types in sport shoes [1], and the influence of different insoles and shoes in running [2]. In this study, an ad-hoc "sport trial" was designed in order to reproduce in laboratory motor tasks common to different sports. Native insoles, i.e. provided with the shoes, were compared to an off-the-shelf sport insole and to a featureless flat insole.

METHODS

20 young physically active subjects (10 M, 10 F; age 32 ± 9 years; BMI 22.3 ± 2.8 kg/m^2) were asked to perform a series of tasks in an ad-hoc "sport-trial", in the following sequence: normal walking; fast walking; running; sprints with change of direction; stair ascending; jump off a 0.5 m high platform; jump on the spot, and side-to-side shuttle run. Three insoles were tested: the prefabricated insoles within the sport shoes (NATIVE); a flat insole in latex (FLAT), and off-the-shelf sport insole (OTS-sport) in EVA featuring a latex heel insert and a metatarsal pad. The testing order of the insoles was randomized for each subject and the test was blind. A capacitive 99-sensor insole system (Pedar, Novel) was used to measure plantar pressure in a number of foot regions. Analysis of the pedobarographic parameters, e.g. peak pressure (PP, kPa) and pressure-time integral (PTI, kPa*s), and statistical analysis were performed using a proprietary software written in Matlab (MathWorks, Inc.). A VAS questionnaire was filled after each test to score the comfort of each insole [3]. Non-parametric paired Friedman test with Bonferroni correction was used to assess statistical differences in pedobarographic parameters and comfort between the three insoles (α=0.05).

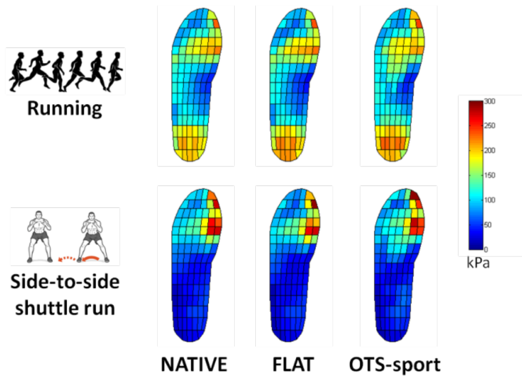

Figure 2 Color-map of the intersubject mean peak pressure (kPa) in each sensor during running and side-to-side shuttle run, for the three insoles.

RESULTS

Statistically significant differences in comfort were found between OTS-sport and the other two insoles (NATIVE = 7.0 ± 2.3; FLAT = 7.5 ± 2.3; OTS = 4.2 ± 2.6; $p < 0.05$). Significant differences in pedobarographic parameters at the same plantar region were observed between tasks, and between the three insoles for the same task. Side-to-side run showed plantar loading mainly at the forefoot (Figure 1). In fast walking, the OTS-sport showed larger PP and PTI at the rearfoot than NATIVE (PP (kPa): NATIVE = 280 ± 90; FLAT = 302 ± 81, OTS = 328 ± 78; $p < 0.05$) but no significant differences at forefoot. In running, the OTS-sport showed the largest PTI and PP at forefoot (PTI (kPa*s): NATIVE = 50 ± 19; FLAT = 47 ± 13; OTS = 53 ± 11; $p < 0.05$).

DISCUSSION

In this study, an ad-hoc sport-trial was designed and proposed to allow the acquisition of in-shoe plantar pressure during motor tasks common to several sports. The presence of a metatarsal pad in the OTS-sport insole appeared to affect negatively the insole performance. This study has allowed to get an insight into the effects of foot orthotics on plantar pressure magnitude and distribution in sport shoes, and to measure the forces acting on the foot in different motor tasks in order to help with the selection of the most appropriate combination of footwear and orthotics for each sport.

REFERENCES

[1] Robin MQ, et al., *Gait & Posture* 2009; 29: 582-586.
[2] Lucas-Cuevas AG, et al., *Journal of Sports Sciences* 2014; 32: 1712-1721.
[3] Mundermann A, et al., *Gait & Posture* 2002; 16: 38-45.