ORIGINAL ARTICLE
SPORTS Orthopaedics and Traumatology
Sports Orthop. Traumatol. xx, xx–xx (2016)

www.SOTjournal.com
http://dx.doi.org/10.1016/j.orthtr.2016.10.007

Summary

Background: Pedobarography systems have been used in numerous studies and have become an important tool for the evaluation of foot loads during sports activities. The aim of this study was to provide a valid comparison of plantar force patterns obtained with insole based and platform based systems.

Material and methods: 14 healthy participants were recruited from the medical faculty. A total of two trials were performed. Firstly the participants walked on the platform under barefoot conditions (emed®-n50 platform, novel Inc., Munich, Germany). The second trial used a ''neutral-shoe'' with an in-shoe measurement system (Pedar® X system, novel Inc.). Peak force values were analysed from four foot regions.

Results: For all foot portions, forces on the platform were significantly lower than the corresponding in-shoe values, excepting the toes ($p = 0.11$) and metatarsal heads ($p = 0.067$) of the non-preferred foot. The biggest difference was observed for the midfoot (preferred foot: 24%, non-preferred foot: 33%). Forces under the metatarsal heads displayed the smallest difference between the systems (preferred foot: 10% ($p < 0.05$), non-preferred foot: 6% ($p = 0.067$)).

Conclusion: Absolute maximum force values from platforms cannot be equated to those from sensor-loaded insoles. Interpretation and comparison of pedobarographic data should be performed cautiously if different systems are chosen.

Level of Evidence: IV, Case series.

Keywords
Pedobarography– plantar forces– insoles– platform

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Abweichungen plantarer Kraftverhältnisse in der dynamischen Pedobarographie – Die Rolle von Innenschuhmesssystemen und ortsbasierter Messplattformen als beeinflussende Faktoren

ORIGINAL ARTICLE

Plantar force deviations in dynamic pedobarography – The role of insole and platform based systems as influencing factors

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Eingegangen/submitted: 08.06.2016; überarbeitet/revised: 17.09.2016; akzeptiert/accepted: 10.10.2016
Online verfügbar seit/Available online: xxx

Introduction

Pedobarography systems have been used in numerous studies for recognition of the foot pressure conditions. In general, foot loads can be monitored with two different approaches, the platform based assessments and insole based systems. Recent investigations that have used sensor-loaded insoles include outcome studies following surgical treatments of the rheumatic and diabetic foot, plantar pressure changes in orthotic devices and sport shoes [5,6,13,14,22,25]. Due to the ability to record consecutive steps in one measurement the insole based pedobarography has become an important tool for the evaluation of foot loads during activities particularly sports activities such as tennis, sprint, badminton and basketball [9–11,24]. It is also frequently applied in biomechanics studies [2,17].

The application of platforms includes the assessment of foot loadings in sports activities such as soccer and ballet [26,27] also. Likewise, pedobarography has been utilized inter alia for evaluation of surgical treatments, plantar pressure distribution in young adults with chronic ankle instability and in cases of diabetic peripheral neuropathy [12,16,21].

The insole based system has been described as an accurate, valid and reliable method for measuring local loads between the foot sole and the shoe or orthotic devices [7,18]. The question whether or not insole based and platform based force values are interchangeable has been addressed in only three studies so far with inconsistent results. In addition to several methodological weaknesses that are noticeable in all of these studies, a bias of in-shoe systems that may come from the dorsum of conventional shoe wear is highlighted in all of these studies [2,8,19]. As such, the aim of the present study was to perform a valid comparison of plantar forces assessed by the means of an in-shoe device and a platform. The

Zusammenfassung

Hintergrund: Die dynamische Pedobarographie wurde in einer Vielzahl sportorthopädischer und biomechanischer Fragestellungen angewandt und hat als kinetisches Messverfahren einen hohen Stellenwert erlangt. Grundsätzlich können plantare kinetische Parameter mithilfe einer ortsbasierten Messplatte oder mit flexiblen Messsohlen im Innenschuhverfahren ermittelt werden. Das Ziel unserer Studie war es, in systematischer Vorgehensweise die beiden oben genannten Messverfahren gegenüberzustellen.

Material und Methoden: Mithilfe des Innenschuhmesssystems pedar®-X (novel GmbH, München) sowie der emed®-n50 Plattform wurde die Größe ,,Maximalkraft'' bei 14 gesunden Probanden (12 rechte und linke Schritte) unter 4 anatomischen Regionen gemessen. Die Datenerhebung erfolgte auf der Messplattform unter Barfußbedingungen, zur Fixierung der Messsohlen im Innenschuhverfahren wurde ein Neutralschuh (Breidbach, Fulda) verwendet.

Ergebnisse: Für alle definierten plantaren Regionen zeigte sich bis auf die Zehen ($p = 0.11$) und Metatarsalköpfchen ($p = 0.067$) des nicht bevorzugten Fußes eine statistisch signifikante Abnahme der Maximalkraft auf der Messplattform im Vergleich zum Innenschuhmessverfahren. Der größte Unterschied zeigte sich im Mittelfußbereich (bevorzugter Fuß: 24%, nicht bevorzugter Fuß: 33%). Im Bereich der Mittelfußköpfchen (bevorzugter Fuß: 10% ($p < 0.05$), nicht bevorzugter Fuß: 6% ($p = 0.067$)) zeigte sich die geringste Kraftänderung.

Schlussfolgerung: Die von uns angewandten Messverfahren unterscheiden sich in Bezug auf die plantare Maximalkraft statistisch signifikant. Pedobarographische Messwerte müssen daher vor dem Hintergrund des verwendeten Messverfahrens beurteilt werden und Messwerte unterschiedlicher Messsysteme sind per se nicht vergleichbar.

Evidenzebene: IV, klinisch experimentelle Studie.

Schlüsselwörter
Pedobarogaphie – Plantare Maximalkraft – Messsohlen – Messplattform

underlying hypothesis was that plantar force assessments from insoles and platform based pedobarography are statistically not significantly different.

Materials and methods

Participants

14 healthy students (5 men and 9 women, mean age 25 ± 3.5 years, mean BMI 22 ± 2.7 kg/m^2) with no current acute or overuse injuries of the lower limb or foot complaints in history were recruited from the medical faculty and asked to participate. All participants had the right foot as their preferred foot. There was no leg length discrepancy in any participant (determined with a pelvic scale by senior author). Motion of lower limb joints was also unrestricted.

Data collection

One-time data collection has taken place in the biomechanic laboratory of the orthopedic department. The measurement values were obtained by first and senior author (orthopedic surgeon). A total of two trials were performed. During the first trial the participants were asked to walk on the platform barefooted. These measurements were obtained on the emed®-n50 platform (Novel Inc., Munich, Germany). The measuring surface was 700 × 403 mm and included 6080 installed sensors leading to a sensor area of 475 × 320 mm at a resolution of 4 sensors/cm^2. After an initial adjustment period the subjects walked over the platform 8 times in order to ensure a sufficient level of reliability [15]. The second trial was performed walking normally across on an even floor using the Pedar® X system (Novel Inc., Munich, Germany), consisting of insoles holding 99 capacitive sensors that monitor local loads from the foot-sole interface at a frequency of 50 Hz. The size of the soles was adjusted individually based on each participants' foot size. A so-called "neutral shoe" (Fuss und Schuh Breidbach® Inc., Fulda, Germany) (Figure 2) was utilized, which has recently been described as reference shoe for insole-based pedobarography [20]. This shoe is made of Aerolastic® (Nora Systems GmbH, Weinheim, Germany). Its major component is ethylenvinylacetate-polymer, with a material thickness of 4 mm. At a density of 0.38 g/cm^3, the shore hardness is up to 50 Shore. The base material is shaped and pressed in its foot-enclosing form by thermoforming. Two Velcro buckles facilitate the adaption and fixation around the foot. These shoes have a heel pitch of 0 mm. Maximum force values (N, highest values during trial under foot) were obtained from 12 steps per foot (preferred and non-preferred), following a previously published protocol [1]. Walking speeds were kept constant (±5% tolerance) for each volunteer between the trials, controlled by photoelectric barrier, inter-individual deviations were accepted. The manufacturer calibrated both systems immediately before data collection. The following foot portions were defined for data analysis (Figure 1): hindfoot (0–30% length 0–100% width); midfoot (31–58% length, 0–100% width); MH 1-5 (59–80% length, 0–100% width) big and lesser toe (81–100% length, 0–100% width) and finally the entire foot.

Statistical analysis

Absolute values of peak force were transferred to GraphPad Prism® 5 software (GraphPad Software Inc., San Diego, USA). Values were checked for normality with the D'Agostino-Pearson test. In cases of normality, the paired t-test was