ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

PLANTAR PRESSURE DISTRIBUTION DURING STAIR DESCENT IN SUBJECTS WITH AND WITHOUT FOREFOOT VARUS: A PILOT STUDY

[1]Rodrigo Scattone da Silva, [1]Ana Luisa Granado Ferreira and [1]Fábio Viadanna Serrão
[1]Department of Physical Therapy, Federal University of São Carlos (UFSCar), São Carlos, São Paulo, Brazil
Email: fserrao@ufscar.br

SUMMARY
Forefoot varus (FV) is a foot misalignment where the forefoot is supinated in relation to the rearfoot when the subtalar joint is in neutral position. It has been suggested that FV could alter the foot mechanics and modify the plantar pressure distribution, however this has not yet been demonstrated. Therefore, the purpose of this study was to compare the peak plantar pressure during stair descent between healthy subjects with and without FV. Ten subjects were divided into 2 groups: subjects with FV (GV, n=4) and subjects with neutral forefoot alignment (GA, n=6). Insoles from the *Pedar X-System* were used to quantify peak plantar pressure in the subjects while they performed stair descent. Group differences were assessed using independent t-tests, with a significance level of 5%. Results showed that the GV presented greater peak pressure at the medial forefoot and smaller peak pressure in the midfoot when compared to the GA. These results indicate that FV alters plantar pressure distribution in young adults. Considering that higher values of peak pressure have been associated with foot overuse injuries, these results bring further enlightenment in the relationship between FV and foot injuries.

INTRODUCTION
Forefoot varus is a foot misalignment where the forefoot is supinated in relation to the rearfoot when the subtalar joint is fixed in non-weight-bearing neutral position [6]. As a consequence, the first metatarsal is raised in relation to the other metatarsals. It is believed that forefoot varus could result in increased pronation of the subtalar and mid-tarsal joints during weight-bearing stance, in order to allow the medial metatarsals to contact the floor [2]. Therefore, it has been suggested that this forefoot misalignment could alter the foot mechanics and modify the plantar pressure distribution [6].

A previous study has demonstrated that there is a significant relationship between forefoot varus and the presence of ulcers in the metatarsal heads [5]. Also, previous studies have shown that greater regional plantar pressure values are associated with diabetic ulceration [7] and osteoarthritis in the medial aspect of the foot [4]. However, to our knowledge, no study has attempted to verify if subjects with forefoot varus present altered plantar pressure distribution while performing functional tasks in comparison to subjects with aligned forefoot. Therefore, the purpose of the present study was to compare the plantar pressure distribution during the stair descent task between healthy subjects with and without forefoot varus. We hypothesized that subjects presenting forefoot varus would exhibit greater values of plantar pressure in the medial forefoot when compared to subjects with aligned forefoot.

METHODS
Ten healthy subjects (18-30 years) were recruited for this study and were divided into two groups: Group of subjects presenting forefoot varus (GV; n=4, 23.50±5.80 years, 63.50 ±10.41 kg, 1.68±0.09 m) and group of subjects presenting aligned forefoot (GA; n=6, 26.67±2.66 years, 77.67±5.96 kg, 1.75±0.08 m). The exclusion criteria for this study were the following: 1) History of congenital deformity, surgery, or traumatic injury to either lower extremity [3]; 2) Presence of forefoot valgus; and 3) Obesity, defined as a body mass index greater than 30kg/m^2. Each participant signed an informed consent form, as required by the University's Ethics Committee, which approved the study.

Forefoot alignment evaluation was performed without weight-bearing, with the subjects in prone lying [3]. Subjects were positioned with the hip of the evaluated limb in neutral position, with the knee extended and the foot outside of the examining table. The other hip was positioned in abduction and external rotation, with 90° of knee flexion. A line was drawn bisecting the calcaneus of the evaluated foot. The forefoot alignment was measured with the subtalar joint held in neutral position. Subtalar joint neutral was determined using a palpation method previously described [3]. With the subtalar joint held in neutral, the ankle was dorsiflexed until firm resistance was felt. The angle of forefoot varus was measured with a universal goniometer. While one hand held the subject's subtalar joint in its neutral position, the other hand was used to align the goniometer in such a way that the fixed arm was positioned perpendicular to the bisection of the calcaneus, and the moveable arm was aligned to an imaginary line drawn through the metatarsal heads [3]. Measurements were taken 3 times and an average was calculated for greater reliability.

Subjects were considered to have excessive forefoot varus if they presented an angle of forefoot varus $\geq 8°$. Subjects presenting an angle of forefoot varus between 0° and 7° were considered to have an aligned forefoot [3]. In subjects

with bilateral forefoot varus, the lower limb presenting greater forefoot varus was considered for evaluation. Subjects from the GA were matched to the subjects from the GV regarding anthropometric variables and regarding the lower limb that would be submitted to the plantar pressure distribution evaluation.

Evaluation of plantar pressure distribution was performed using the *Pedar-X System* (Novel, GER) at a sampling rate of 100 Hz. All subjects were evaluated using the same sport shoes (Asics, IDN) and the *Pedar* insoles of the appropriate size to the subject's foot. A three-step wooden staircase (step height=20.5cm, tread=27.5cm) was used in the biomechanical evaluations. Subjects were instructed to descend the steps without using a handrail for support, placing a single foot on each step. They were instructed to initiate stair descent with the non-evaluated lower limb. Data from the contact of the evaluated foot with the last step were utilized for analysis. Cadence during stair descent was controlled by a metronome at 96 steps/min in order to minimize cadence interference in the pressure variables [1].

Data processing was performed with the *Novel Multiprojects Software* (Novel, GER). The variable used for analysis was peak pressure (kPa), defined as the highest pressure experienced by all sensors in a specific plantar area. This variable was evaluated in six plantar areas: medial forefoot, lateral forefoot, midfoot, medial rearfoot, central rearfoot and lateral rearfoot [1]. Plantar pressure data were normalized by each subject's body mass. Statistical analysis was performed with the software *Statistica 7.0* (StatSoft Inc, USA). For group comparisons, independent t-tests were carried out, with a significance level of 5%.

RESULTS AND DISCUSSION

Results of peak plantar pressure of both groups during stair descent are presented in **Table 1**. Subjects of the GV presented higher values of peak plantar pressure in the medial forefoot in comparison to the subjects of the GA (P=0.05). Conversely, the GV presented smaller values of peak plantar pressure in the midfoot in comparison to the GA (P=0.01). **Figure 1** illustrates the typical behavior of plantar pressure distribution in a subject with forefoot varus and a subject with aligned forefoot.

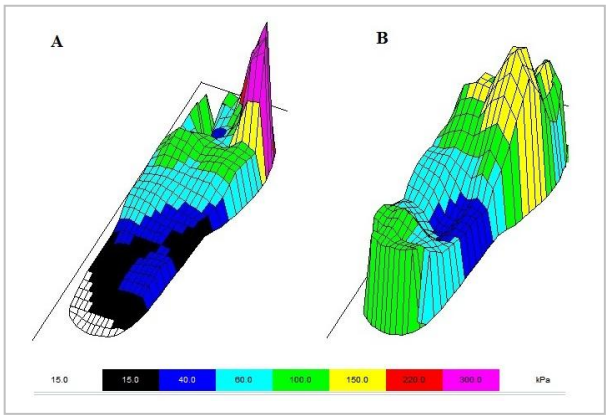

Figure 1: Left foot peak plantar pressure in a subject with forefoot varus (A) and a subject with aligned forefoot (B).

Our results have confirmed the hypothesis that forefoot varus is associated with greater values of peak pressure in the medial forefoot. Although forefoot varus had been previously related to overuse foot injuries [5], no study had performed an evaluation of plantar pressure distribution in subjects presenting this forefoot misalignment. These results are relevant since they contribute for a better understanding of the effects of forefoot varus on foot biomechanics.

This study also showed that the GV presented smaller values of peak pressure in the midfoot when compared to the GA. This result is not surprising, since forefoot varus has been linked to excessive mid-tarsal pronation, and, therefore, to a collapse of the foot's medial longitudinal arch [6]. A collapse of this arch would likely increase the contact area at the midfoot, which would reduce plantar pressure at this location. Future studies should include evaluations of the plantar contact area, in order to confirm this hypothesis.

CONCLUSIONS

Healthy subjects with forefoot varus presented greater peak pressure in the medial forefoot when compared to subjects with aligned forefoot during stair descent. These findings might contribute to greater enlightenment in the relationship between forefoot varus and overuse injuries at the foot.

ACKNOWLEDGEMENTS

We would like to acknowledge that the *Fundação de Amparo a Pesquisa do Estado de São Paulo* (FAPESP) provided financial support for this research.

Table 1: Peak plantar pressure (kPa) in the different foot areas during stair descent

	Forefoot Varus Group (n=4)	Control Group (n=6)	*P* value
Medial Forefoot	272.78 ± 61.49*	188.83 ± 35.64	0.05
Lateral Forefoot	135.56 ± 19.80	152.50 ± 29.15	0.41
Midfoot	98.61 ± 17.51	147.17 ± 19.13*	0.01
Medial Rearfoot	56.94 ± 22.52	89.17 ± 30.25	0.16
Central Rearfoot	60.28 ± 15.64	95.00 ± 23.44	0.07
Lateral Rearfoot	56.11 ± 8.35	90.33 ± 26.51	0.08

* Significantly greater in comparison to the other group ($P \leq 0.05$)

REFERENCES

1. Aliberti S, et al. *Phys Ther Sport*. **11**:30-34, 2010.
2. Alonso-Vázquez A, et al. *Gait Posture*. **29**:214-9, 2009.
3. Buchanan KR, Davis J. *J Orthop Sport Phys Ther*. **35**:559-566, 2005.
4. Menz H, et al. *Osteoarthr Cartilage*. **18**, 317-322, 2010.
5. Mueller MJ, et al. *Phys Ther*. **70**:356-362, 1990.
6. Tiberio D. *Phys Ther*. **68**:1840-1849, 1988.
7. Veves A. *Diabetologia*. **35**, 660-663, 1992.