

## COMFORT AND PLANTAR PRESSURE PATTERN DURING RUNNING WITH PREFABRICATED INSOLES

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The aim of this study was to investigate the relationship between plantar pressure pattern and wearing comfort of five different prefabricated insoles. Therefore wearing comfort was assessed by a questionnaire and the use of a visual analogue scale (VAS) and plantar pressure was measured by a Pedar-X system. For statistical analysis single factor ANOVA for repeated measurements, Bonferroni and Pearson correlation test were performed. Significant differences in comfort ratings and average maximum plantar pressure were found. A relationship between average plantar pressure and comfort could not be detected. Nevertheless prefabricated insoles are able to improve wearing comfort of running shoes. Additional parameters like insole hardness and/or flexibility might also influence wearing comfort and seems to modulate the plantar pressure pattern during running.

**KEY WORDS:** plantar pressure, wearing comfort, insoles, running, footwear, plantar loading

**INTRODUCTION:** Comfort plays an important role in the selection process of the best fitting running shoe (Piller, 2002). To improve wearing comfort of running shoes, the approaches of footwear accessory industry range from individually customized via “semi” customized to “one size fits all” prefabricated insoles. Yet in most studies about wearing comfort the used insoles were custom-made or specifically modified for the specific aim of the study, means there is only the fully customized approach covered in those investigations. Lucas-Cuevas et al. (2014) have shown that prefabricated insoles can reach the same comfort level as fully custom made insoles. Nevertheless consensus seems to be that softer insoles are more comfortable than hard insoles (Hennig et al., 1995; Mills et al., 2011; Mündermann et al., 2002). Also factors, like flexibility and contouring (Chen, et al., 1994) play an important role. However the relationship between wearing comfort and plantar pressure pattern is still unclear. Reduced plantar pressure has been correlated with comfort by Chen, et al. (1994) and Hennig et al. (1993) which is in contrast to findings of Jordan et al. (1995) and Wegener et al. (2008). Therefore the aim of the study was to investigate the effect of different prefabricated insoles on wearing comfort and plantar pressure pattern. To evaluate perceived comfort a reliable method has been established by Mündermann et al. (2002) and was also used by Lucas-Cuevas et al. (2014) and Wegener et al. (2008).

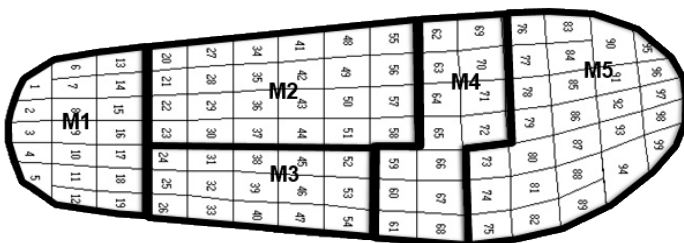
**METHODS:** Plantar pressure distribution of 31 physically active volunteers (15 male runners, age: 22±2 years, height: 178±2 cm, mass: 75±3 kg and 16 female runners, age: 22±3 years, height: 169±4 cm, mass: 62±3 kg), were measured with an insole pressure measuring system (Pedar-X by Novel, Germany). The measuring insoles (models: VW, WW, XW and YW, 99 sensors, sampling rate: 50 Hz) were calibrated with the recommended standard calibration device (Trublu, Novel, Germany) and the recommended dynamic range of 0-600 kPa. The Pedar-X device, attached to the subjects' waist, was used to collect and transfer data via Bluetooth to a Personal Computer. The recorded data were exported from Novel Pedar-X software (Novel 12.1) to a self-coded software application (MATLAB, Mathworks, USA) to analyse average maximum pressure (AMP) under the left foot. Measuring insoles

were divided (Fig. 1) into the five areas: heel area (M1), medial mid foot area (M2), lateral mid foot area (M3), metatarsal phalangeal joint area (M4) and toe area (M5), based on the human foot anatomy and the “functional” components of the prefabricated insoles. All prefabricated insoles (Runpro med, Currex, Germany; Pinnacle, Powerstep, USA; Green Superfeet, USA; Softec response, Sole, Canada; 3Feet mid arch, Sidas, France) were tested in a neutral running shoe (Kinvara 5, Saucony, USA; US shoe size: male 9.5 to 11.5, female 8.0 to 10.0).

To assess wearing comfort of five different insoles a 100 mm visual analogue scale (VAS), ranging from “most comfortable condition imaginable” (value of 100) to “least comfortable condition imaginable” (value of 0), was used to answer a comfort questionnaire in German based on Mündermann et al. (2002). The items of the questionnaire are listed in table 1.

Testing procedure started with a brief introduction of every subject followed by a visual inspection for excluding criteria, like abnormal leg alignment (e.g. varus, valgus) or abnormal plantar morphology (e.g. flat feet, high arch) by the use of a Footdisc<sup>®</sup>. The familiarization and plantar pressure measurement described in the following was equal for every insole condition. Familiarizing (approx. 3-5 min.) in the standard shoe condition (subjects’ preferred shoe size, sockliner) was realized by running ( $3.5 \text{ ms}^{-1} \pm 10\%$ ) on a firm laboratory surface while the subjects running speed was controlled by light beams 3 m apart in the middle of the runway. After familiarization, subjects assessed wearing comfort of the sockliner condition by answering the questionnaire, followed by the plantar pressure pattern measurement (15-20 valid steps). Familiarization and measurement of the plantar pressure pattern was the same for every insole condition. In the second part of the testing procedure the subjects first had to familiarize with the sockliner, to recalibrate themselves to the comfort feeling of the sockliner, before familiarizing with one of the five insoles conditions. The chronological order of insole conditions was chosen randomly. The subjects assessed the comfort of the insole in comparison to the sockliner and the measurement of plantar pressure pattern of that random insole.

For statistical analysis a single factor ANOVA for repeated measurements ( $p \leq 0.05$ ), a Bonferroni post-hoc test and a Pearson correlation were processed.



**Figure 1: Measuring insole (Novel) divided into five areas: heel area (M1), medial mid foot area (M2), lateral mid foot area (M3), metatarsal phalangeal joint area (M4) and toe area (M5).**

**RESULTS:** Results of 29 valid comfort assessments shown as average values and standard deviation of the comfort ratings for all 8 parameters of the questionnaire for the five insoles are listed in Table 1. ANOVA and Bonferroni tests revealed significant higher overall comfort ratings for the Currex insole compared to Superfeet and Powerstep insoles ( $p < 0.05$ ). The heel cushioning comfort ratings are significant higher for the Sidas insole in comparison to the Superfeet insole ( $p < 0.05$ ).

Table 1: Wearing comfort ratings for the five insole conditions in direct comparison to the sockliner condition. Values are given as mean  $\pm$  standard deviation (<sup>c</sup>: lower than Currex  $p < 0.05$ , <sup>s</sup>: lower than Sidas  $p < 0.05$ ). A value of '50' represents the comfort of the sockliner condition. A value of 0 would represent the "most uncomfortable condition imaginable" and a value of 100 would represent the "most comfortable condition imaginable".

	Currex	Powerstep	Superfeet	Sole	Sidas
Overall comfort	64 $\pm$ 18	51 $\pm$ 23 <sup>c</sup>	45 $\pm$ 17 <sup>c</sup>	56 $\pm$ 19	53 $\pm$ 20
Heel cushioning	61 $\pm$ 18	59 $\pm$ 17	50 $\pm$ 17 <sup>s</sup>	59 $\pm$ 17	62 $\pm$ 14
Fore foot cushioning	55 $\pm$ 15	57 $\pm$ 13	53 $\pm$ 14	55 $\pm$ 13	58 $\pm$ 15
Medio-lateral control	59 $\pm$ 19	60 $\pm$ 16	58 $\pm$ 14	61 $\pm$ 15	60 $\pm$ 13
Arch height	57 $\pm$ 20	41 $\pm$ 28	44 $\pm$ 25	45 $\pm$ 23	49 $\pm$ 23
Heel fit	60 $\pm$ 16	53 $\pm$ 19	55 $\pm$ 20	54 $\pm$ 22	57 $\pm$ 14
Heel width	60 $\pm$ 14	52 $\pm$ 15	54 $\pm$ 11	55 $\pm$ 16	55 $\pm$ 13
Fore foot width	58 $\pm$ 13	55 $\pm$ 13	57 $\pm$ 12	59 $\pm$ 12	58 $\pm$ 12

The average maximum plantar pressures (AMP) processed as a mean of all subjects of two areas (M2 and M3) are shown in figure 2. Significant higher AMP in area M2 can be found for the three insoles Superfeet, Sole and Powerstep compared to the sockliner, also when compared to Currex. The Superfeet insole showed significant higher AMP than Sidas. In area M3 the Superfeet insole has a significant higher AMP than the sockliner, the Currex and the Sidas insole. While the Sole condition also shows a significant higher AMP than the Sockliner and the Currex insole. All comparisons show a significance of  $p < 0.01$  except in area M3 Sockliner to Sole and Sidas to Superfeet only showed a  $p$ -value less than 0.05. In area M1 the Sockliner showed significant higher AMP than Superfeet insole and in M4 and M5 Superfeet insoles showed significant higher AMP than the Sockliner.

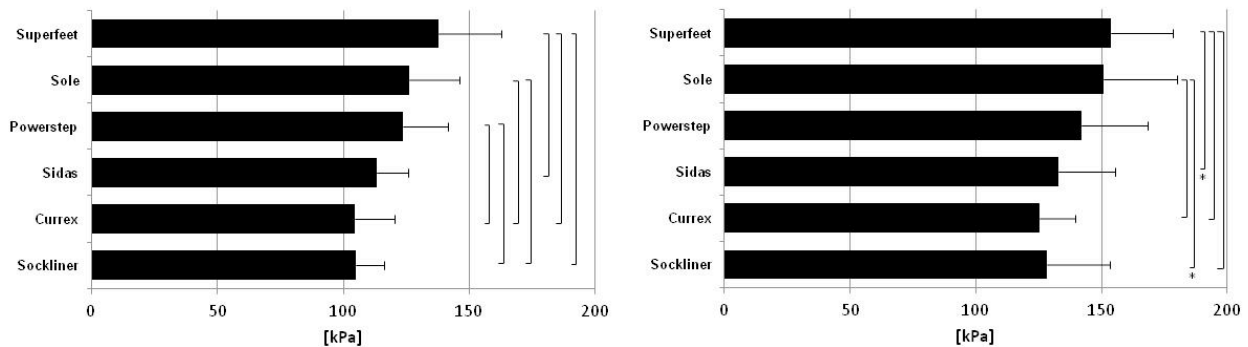


Figure 2: Mean average maximum pressure of M2 (left figure) and M3 (right figure) and standard deviation of the sockliner and the five insoles. The brackets are indicating significant differences ( $p < 0.01$ ; \*  $p < 0.05$ ).

No significant correlations were found neither between the average maximum plantar pressure of any area and the overall comfort nor between average maximum plantar pressure in the areas M2 and M3 to the comfort ratings of the arch height.

**DISCUSSION:** The aim of the study was investigate the relationship between wearing comfort and plantar pressure pattern while wearing different types of prefabricated insoles. Results show no correlation between comfort rating and average plantar pressure, this is in common with findings of Jordan et al. (1995) and Wegener et al. (2008) but in contrast to findings of Hennig et al. (1993). Also Chen et al. (1994) related comfort with plantar pressure pattern of walking but suggested that better pressure measuring systems will lead to the

same relation in running. A reason for the results might be, that not all subjects are able to identify smaller differences in the pressure pattern between the different insoles. Subjects could base their comfort decision on other factors like hardness or flexibility. Hardness has been brought in relation with perceived comfort by Hennig et al. (1995), Mills et al. (2011) and Mündermann et al. (2002). Chen et al. (1994) listed flexibility as a factor for comfort. These aspects of the five tested insoles differ, the Currex insole is the softest and most flexible of the five insoles. On the other hand the insole Superfeet seems to be the most rigid and hardest of the five insoles followed by Powerstep and Sole. Being harder and stiffer might also explain the differences in the average maximum pressure results.

**CONCLUSION:** Prefabricated insoles are able to increase wearing comfort of running shoes. However this study did not find any direct correlations between wearing comfort and the plantar pressure pattern. Nevertheless plantar pressure pattern might be an influential parameter on perceived wearing comfort, but it seems that runners also prioritize other factors like hardness or flexibility for their comfort rating.

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