The effect on gait kinematics with prefabricated Jalas® insoles compared to standard insoles

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# Abstract

**Purpose:** The purpose of this study was to evaluate a method for applying prefabricated insoles based on static foot assessments within the Jalas® system. The Foot Posture Index (FPI) which is considered the golden standard in terms of determining foot type was used to verify FootStopService (FSS) by Jalas®. Dynamic measurements of the distribution of plantar pressure during walking for participants with supinated, neutral or pronated feet were compared wearing the recommended Jalas® insoles (high-, neutral or low-arch) and the insoles included with Nike Air Pegasus and Nike Air Contrail.

**Methods:** 27 subjects were divided into three groups (high-, medium- and low-arch). Testing included, FootStopService by Jalas®, Foot Posture Index, and plantar pressure measurements (novel pedar-x). Plantar pressure was measured with Jalas® insoles and standard insoles in running shoes. Five recordings of 20 steps where the first and last five steps were excluded was used.

**Results:** FSS and FPI showed different results (p=0,0005), and FSS could not be validated. When using FSS division of groups neither SI or JI showed any differences between groups, when testing TST (p=570)(p=0,406), TPP (p=0,336)(p=0,281), X\_contact (p=0,242)(p=0,274) or X\_propulsion (p=724) (p=0,431). Using FPI division of groups showed no difference when testing SI, TST (p=336), TPP (p=0,321), X\_contact (p=0,314) or X\_propulsion (p=0,642).

**Discussion:** The results sheds light that it can be difficult to use static testing, to identify if a person either have low, normal or high arch. Furthermore, it is interesting to note, that prefabricated insoles doesn’t have any effect on either planter pressure or the kinematics in gait. A validated static technique on how to shape insoles are undiscovered.

**Conclusion:** No statistical significant differences on total stance time, CoP-distribution and total plantar pressure between standard and Jalas® insoles were measured. FSS couldn’t be validated due to different results compared to FPI.

**Key words:** Foot, prefabricated insoles, foot testing, gait kinematics, pronation, supination

# Introduction

The human ankle and foot form a complex mechanical unit with properties that have been proven difficult to analyze, mainly because of lack of reliable in vivo investigation methods (1). The foot has two main functions. Being unstable, to allow adaptation to surfaces, and being stable to achieve an efficient propulsion (2). Malalignment in foot biomechanics, especially low and high arch, have been connected to an increase in risk of plantar faschiitis and tibial stress syndrome etc. (3) (4).

Externally restrictive footwear may alter foot and ankle biomechanics. Footwear may also increase the risk of certain pathological conditions (5). A study have showed a difference in center of pressure (CoP) during barefoot walking, and walking while wearing shoes supported this hypothesis (6). A study showed that in a random community sample 10% overall, and 24% of 65 year-olds or older reported foot problems (7). Foot and ankle problems have been associated with age, female gender, high impact activities, faulty foot mechanics, obesity, occupations with prolonged standing, and improper shoes (8). Worldwide more than 60% of older adults are have been estimated to have some kind of foot disorder, which underlines the importance of improving knowledge in the area (9). A study showed that using custom-molded insoles to alleviate pressure under painful areas, was possible (7). A different study showed a significant decrease in plantar pressure area when wearing shoes and rigid-, semi-rigid- and soft insoles compared with barefoot walking, in female subjects with inverted and everted feet (10). Furthermore, custom-molded insoles have been proved to have a pain relieving effect for patients with rheumatoid arthritis of the foot (11). Both prefabricated and custom molded insoles have been found to reduce plantar pressure beneath the first and second metatarsal head (12). Biomechanical foot orthoses may lead to a kinematic symmetry in the pelvis, this symmetry result in pain reduction an decreases muscular tension (13). Foot experts, who make custom molded insoles, use a general insole on which they make adjustments according to the patients’ needs (7).

The purpose of this study was to evaluate a method for applying prefabricated insoles based on static foot assessments within the Jalas® system. The Foot Posture Index (FPI) which is considered the golden standard in terms of determining foot type (14) was used to verify FootStopService (FSS) by Jalas®. Dynamic measurements of the distribution of plantar pressure during walking for participants with supinated, neutral or pronated feet were compared wearing the recommended Jalas® insoles (high-, neutral or low-arch) and the insoles included with Nike Air Pegasus and Nike Air Contrail. It was hypothesized that the effect of the specific chosen insole would reduce total plantar pressure during walking, lengthen the total stance time, result in a more lateral center of pressure distribution (CoP) on the heel and more medial CoP on the forefoot.

# Methods

## Subjects

Subjects were rejected in case of foot deformities (15), other than everted and inverted feet, surgeries with influence on the subjects’ ability to walk or their feet’s functionality within the last 12 months or any other factors which inhibited the ability to walk properly. Forty-one people volunteered for the study after a brief introduction of the purpose. Ten persons were excluded due to not showing up for the second part of the trial and two persons and were excluded due to errors in the recorded data. The final sample included 27 subjects. Descriptive information on these subjects is shown in Table 1.

## Apparatus

FootStopService by Jalas® (FSS) consists of a pressure plate and a computer running the iStep software from Jalas®. The Foot Posture Index (FPI), a visual diagnostic clinical tool that consists of six items that, in combination tells in which degree a foot can be considered supinated, neutral or pronated. The examiner did 20 training FPI measurements beforehand in accordance with recommendations (14). FPI was used to validate the results of FSS. The FSS was used to divide the subjects into groups based on which Jalas® insole (JI) they were recommended (Jalas® 8710m medium arch support (medium), Jalas® 8711l low arch support (low), and Jalas® 8709h high arch support (high)). The recommended insole was then used in the measurement of plantar pressure during gait along with a standard insole (SI). Both insoles were tested in a control shoe (Nike Air Pegasus or Nike Air Contrail). A novel pedar-X in shoe dynamic pressure distribution measuring system was used to measure plantar pressure distribution during gait. The insoles consisted of 99 sensors each which were sampled at a rate of 100 Hz. Five differently sized insoles were used to cover the foot sizes of the sample. Calibration of the insoles was performed prior to testing according to the manufacturers’ manual. (16)

## Procedures

Each subject was tested on the FSS system, which is done by standing barefoot on the pressure plate for fifteen seconds. The recommended insole is then shown on the computer, next to a graphic representation of the static pressure distribution of the feet. The subjects were divided into three groups, one for each type of insole. This test was conducted one month prior to the remaining tests to make it possible to obtain the needed insoles.

FPI was tested when the subjects showed up for the second part of the trial. The experimenter prepared the subjects and conducted the test according to (14). A score from –2 to 2 was given in six categories. A total score from 0 to +5 was considered normal, +6 to +9 was considered pronated, +10 was considered highly pronated, -1 to –4 was considered supinated and –5 to –12 was considered highly supinated.

The plantar pressure during gait was tested in two conditions, SI and JI. The order in which the conditions were tested for each subject, was randomized using a random integer set generator (17). The pedar-X system was mounted on the subject.



Figure 1: Novel pedar-X mounted on a subject.

The subject then had two minutes to find a comfortable, self-selected walking velocity on a treadmill. Five sets of twenty steps were recorded, with a ten second gap between each set. This process was repeated for each condition.

## Data analysis

Analysis of variance (ANOVA) were performed to compare the three test groups anthropometrical data. P-values are shown in Table 1. After excluding the first and last five steps, for the left and right foot, for each trial, total stance time, total plantar pressure and x-coordinates of the CoP from the remaining 25[[1]](#footnote-1) steps were used to calculate averages for each condition and subject. The averages were calculated to eliminate faulty data. Each subject’s dataset consisted of four sets, SI left, and right, and JI left, and right, containing four measurements each; total stance time (TST), total plantar pressure (TPP) and Xcontact and Xpropulsion for CoP throughout the sample at a rate of 100 Hz. The hypotheses were, JI\_TST>SI\_TST, JI\_TPP<SI\_TPP, JI\_Xcontact>SI\_Xcontact and JI\_Xpropulsion<SI\_Xpropulsion. A multivariate analysis of covariance (MANCOVA), left or right foot being the covariate was executed. FSSs consistency with FPI was evaluated with a binomial test of a null hypothesis that FSS were consistent with FPI at a 95% confidence interval.

# Results

Valid data from 27 subjects in three groups were collected. Analysis of variance between the groups anthropometrical data were performed and p-values is shown in Table 1. The binomial test showed contradicting results for FSS and FPI. With a p-value of 0,000 it is possible to deny the null-hypothesis that FSS and FPI have matching results. One-way ANOVAs to test differences between groups and conditions were performed for the FSS distribution, and to test differences between groups for the FPI distribution. P-values are shown in Table 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Low arch | Medium arch | High arch | ANOVA |
|  |  |  |  |  |
|  | Average ± standard deviation | Average ± standard deviation | Average ± standard deviation | p-value |
| Age | 37,3±15,2 | 36,1±19 | 30±14,7 | 0,69 |
| Weight | 62,7±14,1 | 76,7±18,3 | 72,15,1 | 0,27 |
| Height | 160,3±11 | 172±12,5 | 173,9±11,6 | 0,12 |

Table 1: Anthropometrical data for the subjects including age, weight and height. No statistical differences were observed in an ANOVA.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | SI\_TST | SI\_TPP | SI\_X\_contact | SI\_X\_propulsion | JI\_TST | JI\_TPP | JI\_X\_contact | JI\_X\_propulsion |
| FSS | 0,570 | 0,336 | 0,242 | 0,724 | 0,406 | 0,281 | 0,274 | 0,431 |
| FPI | 0,336 | 0,321 | 0,314 | 0,642 |  |  |  |  |

Table 2: P-values for one-way ANOVAs testing differences between groups. No significant differences were observed.

# Discussion

The aim of this study have been to examine differences in CoP distribution, stance time and total plantar pressure using prefabricated insoles from Jalas® compared with standard insoles in running shoes. Further the aim of the study have been to validate FootStopService by Jalas®, which is designed to calculate the foot type of a person and from that recommend one of three insoles. The main findings have shown no significant differences between using insoles from Jalas® or standard insoles, on CoP distribution, stance time or total plantar pressure. However, a significant difference between FSS and FPI were outlined observed. Because of this observation, tests for differences according to the FPI distribution have been performed as well. No significant differences have been observed in either sample.

## FPI & FSS

To validate the FSS results FPI measurements have been obtained alongside the FSS measurements, since FPI is considered the golden standard in terms of determining foot types (14). With 45% of the subjects getting a faulty diagnosis by FSS, the tests have shown significantly different results (p-value = 0,000). The difference between FSS and FPI is the number of parameters tested. While FPI have six parameters FSS only has one. Overweight or thick tissue structure in the feet can affect the height of the longitudinal arch (18) (19). The FSS results are probably skewed because of this. There was not seen any indications in the anthropometrical data, but since overweight isn’t the only explaining factor, this explanation cannot be denied. Furthermore, the difference between the static and dynamic functionality of feet is considerable which further clarify the shortcomings in FSS (18) (20) (21). Dynamic testing is not feasible now and even orthopedic shoemakers use static tests to develop custom-made insoles (22), which means an accurate static test should be possible to develop (23).

## Total plantar pressure

One of the aims in this study have been, to identify whether Jalas® insoles had better cushioning than standard insoles. This was relevant due to the relation between cushioning and overuse injuries. This effect is shown for sedentary individuals in the early stages of a physical training program (24), (25), and for new recruits in the military, which includes large amounts of walking (26), (27). Anatomical factors, shoes and surfaces have been described as etiologic factors for common overuse injuries (28), (29). Studies have shown that lowering heel impact prevents chronic injuries, as low back pain and osteoarthritic changes in cartilage and surrounding bone of weight bearing joints (30), (31). With no significant changes in total plantar pressure between Jalas® insoles and standard insoles, there is no prove of differences in prevention of overuse injuries.

## Foot kinematics

Foot kinematics were exhibited by TST and CoP on the heel and forefoot in accordance to Soames et al. (6). It is unclear whether a redistribution of plantar pressure has a positive effect on foot complaints (7), but malalignment in the rear foot causes forefoot restrictions (32). A correct foot alignment enhances the ability to absorb impact in the heel and the flexibility in the forefoot (2). No significant difference in CoP or TST between JI and SI have been observed. This was evident in all three test groups, even though it was only expected in the medium group.

It has been argued, that static testing may not be adequate, and a complete dynamic analysis of the kinematic chain is required to fully understand how the foot works (33) (34). The Jalas® insoles are based on a static test, which might explain why no significant results were obtained. The prefabricated insoles could, if designed more radically, cause significant changes in both CoP and TST. Even though a lot of different types of insoles is produced, and the most optimal design is debatable (35), but full length insoles have been shown to be preferable to 2/3 length insoles for high arch patients (36). Molding have been proven more effective than posting in custom-made insoles, but the difference in terms of effect on overuse injuries is yet to be determined in running (37).

Table 3: Shows CoP-distribution for the right feet of randomly selected low and medium arch subjects. The low end of the x-axis represents the medial side of the foot, and the high end the lateral side of the foot.

Table 3 shows differences in CoP-distribution for a medium and low arch foot. The low arch CoP is medial compared to the medium arch. This is in accordance with previous studies (38) (39). High- or low arch foot types will result in a faster execution of the stance phase, because these foot types have a functional deformity relative to a neutral foot type. Insoles from Jalas® were hypothesized to result in a more neutral foot alignment resulting in a slower execution of the stride. (40) The Jalas® insoles have not resulted in any significant changes in stance time.

## Future research

Since FSS did not match the FPI results, which is a clinically validated method; any further studies should not use FSS scores, but solely focus on FPI as the method of deciding foot types. Another option is to change FSS and validate the updated version.

Introducing an adaptation period of eight weeks could show changes according to (39) (41), since muscular activity neutralizes the acute effect of insoles. The acute effect when introducing insoles cannot be measured on plantar pressure, instead, EMG measurements is recommended to measure differences in muscular activity (34). A cross-over design is recommended to examine whether any changes is persistent when removing insoles after the adaptation period. A more homogenous group is preferable, since there is a specific target group for safety shoes insoles.

# Conclusion

The results have shown no significant differences in CoP-distribution in either the contact- or the propulsion phase, total stance time, and total plantar pressure when wearing standard and Jalas® insoles or between low, medium and high arch groups.

The FSS could not be validated since these results were significantly different from the FPI results. The faulty FSS measurements resulted in a large removal of subjects, which lowered the validity of the kinematics tests as well.

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1. In two cases 10 steps was used instead of 25, due to incomplete data collection. It was assessed that 10 steps were sufficient in these cases. [↑](#footnote-ref-1)