INTRODUCTION

In many clinical or scientific applications, such as gait analysis, pressure measurements, either from a pressure platform or an insole-system, are used. Rarely both systems are used synchronised. The question is what information is given by a pressure platform and what by an insole system?

The purpose of this study is therefore to compare insole and ground pressure measurements for some specific parameters.

METHODS

Plantar pressure data was collected from 20 athletes (6 sprinters, 5 middle distance runners and 9 long distance runners), 12 males (age: 23.7, +/- 3.4 years) and 8 females (age: 25.5, +/- 2.8 years). Two Footscan® pressure platforms (RSscan International, 2m x 0.4m, 16 384 conductive polymer sensors of size 7mm to 5mm, 500 Hz, linear calibration) were mounted in the middle of a 30m long EVA running track.

The subjects ran at a speed of 5.07m/s (+/- 0.39 m/s). Running speed was controlled by electronic time gates interfaced with a digital scoreboard (Timetronics, 0.01 s resolution). The gates were located 10 meters apart, with the pressure platform in the center (Figure 1).

The athletes performed 4 trials of each of the following conditions: barefoot running (barefoot), shod running with custom made flat-soled running shoes (NS), shod running with their own running shoes, with orthotics (OSor) and without orthotics (OS). During shod running, in-shoe measurements were performed with a Footscan® insole system (RScan International, size 7mm to 5mm conductive polymer sensors, 500 Hz), ranging dependent on the shoe size, wired to a battery powered data logger strapped on the lumbar region. The pressure platforms and insole system were synchronised during the measurements.

Data were analysed in the Footscan® scientific software Version 6.3.45. Markers were set by dynamic region analysis, based on a screening of the foot from different directions and adapted to the foot type (Figure 2). The software automatically detects the foot print as a left or a right foot, and places a mask on top of the footprint that divides it in nine regions: hallux, heads M1, M2, M3, M4, M5, midfoot, medial heel and lateral heel. The dynamic region system is used in both systems, pressure platform and the insoles. For the insoles and for shod running the same mask as for barefoot prints was used.

Figure 1: Test protocol: two pressure platforms (2m x 0.4m) mounted in a 30 m long running way. Synchronised insole and ground pressure measurements at a running speed of 5.07m/s (+/- 0.39 m/s).
After dynamical region analysis, the software calculated Balance Line (BL) and $M_{1,2}$ for each footprint in all running conditions:

$$BL = \frac{M_1 + M_2 + \text{medial heel}}{M_3 + M_4 + M_5 + \text{lateral heel}}$$

$$M_{1,2} = \frac{M_1 + M_2}{M_1 + M_2 + M_3 + M_4 + M_5}$$

The BL showed a medial/lateral distribution of pressure underneath the total footprint during running. $M_{1,2}$ shows medialisation of pressure underneath metatarsals I → V.

A third parameter, used for comparison of the two systems, is the pattern of the center of pressure (COP) during roll-over of the foot. For each time instant, the software detected the place of the center of pressure, related to the foot axis of the foot. In this study, BL, $M_{1,2}$ and COP pattern are the parameters used to compare and evaluate insole and ground pressure measurements.

**RESULTS**

Only a few results are given, because not all the data have been analysed on this time point. In the next paragraph, the results of the COP pattern are given and discussed. The results of $M_{1,2}$ and BL are given and discussed in three specific cases.

The COP pattern showed large differences between the measurements of the pressure platform and measurements of the insole system. As can be seen in Figure 3, the COP pattern showed a typical S-curve for the measurements of the pressure platform. On the other hand, the insole measurements showed more a straight line for the COP pattern.

Within the measurement of the Footscan platform there is also a difference between the running conditions barefoot, NS, OS, Osor (Figure 4). In barefoot running, the COP pattern starts almost in the middle of the rearfoot, where in shod running the COP pattern starts at the lateral side of the heel and this for both conditions (own shoes en flat-soled shoes). COP is dependent on the contact surface of the foot with the pressure plate or with the insole. So a pes cavus or pes valgus gives a different pattern.

**Case 1: Long distance runner (male, 21 years old, orthotics for exceeded pronation)**

Figure 5 shows the graphs with the mean curves of $M_{1,2}$ and balance line of the four running conditions (barefoot, own shoe, own shoe with orthotics and neutral flat-soled shoe) measured by the two systems, platform and insole, from 10% to 80% of foot contact. Little differences were found between insole and ground pressure measurements for $M_{1,2}$ and BL.

In graph 4(a), the influence of the shoes on pressure distribution can be seen. In barefoot running an almost linear increase of $M_{1,2}$ occurs. The $M_{1,2}$ curve for the shod running conditions increases faster compared to barefoot running. Also a kind of stabilization occurs for the shod running. Differences between shod running curves are almost not visible. On the other hand graph 4(b), shows some differences between the three shod running conditions. The $M_{1,2}$ curve for the neutral shoe has a flat course. The curves of the own shoe running conditions almost have an equal shape, but for the OSor condition, the curve still increases at the end.
Figure 5: Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves of 4 trails (between 10% and 80% of foot contact) are given for the four running conditions: barefoot running (barefoot), own shoes (OS), own shoes with orthotics (OSor) and neutral flat-soled shoes (NS).

For this runner, orthotics were placed to solve a problem of exceeded pronation. Figure 4 (b) showed a lower $M_{1,2}$ curve for OSor condition what may be due to the placement of the orthotics. On the other hand, a longer increase occurs compared to the curve of OS. This may be an indication of longer pronation. The same effect is found in Figure 4(d), what means that for the condition with orthotics a longer medial shift occurs compared to running with own shoes (without orthotics).

Case 2: (3000steeple and 5000m) runner (male, 21 years old, orthotics for Iliotibial Band Syndrome - right):

Figure 6 shows the graphs for $M_{1,2}$ and BL for a steeple-chase runner. The mean curves for the four running conditions (barefoot, OS, OSor and NS) are given for both system, platform (a,c) and insole (b,d).

Figure 6: Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves of 4 trails (between 10% and 80% of foot contact) are given for the four running conditions: barefoot running (barefoot), own shoes (OS), own shoes with orthotics (OSor) and neutral flat-soled shoes (NS).
In this case larger differences in the curves between the two systems were found. In contrast with Case 1, for barefoot running $M_{1,2}$ and BL are increased compared to shod running. However Figure 6(a) showed almost no differences between the three shod running conditions for $M_{1,2}$, in Figure 6(b) some difference between the three conditions were found. A more pronounced decrease occurs in the curve of the neutral shoe condition compared to the own shoe condition, followed by a more pronounced increase in $M_{1,2}$ for the neutral shoe condition. Orthotics do not have much effect here, and they provided a delayed shift in the increase of $M_{1,2}$. In contrast to this finding, Figure 6(d) showed an earlier medial shift of the balance line compared to running without orthotics.

Running with or without orthotics do not much influence the curves of $M_{1,2}$ and BL in this case. Therefore the effect of the orthotics is neutral (left), producing no compensation.

### Case 3: Sprinter (female, 24 years old, no orthotics):

Figure 7 shows the graphs of $M_{1,2}$ and BL for a sprinter. The mean curves are given for three running conditions (barefoot, OS and NS). Also in this case, some differences in the curves are seen between insole and ground pressure measurements. For $M_{1,2}$, a rapid increase occurs in the measurements of the platform, where this increase in the insole measurements is not so fast.

Similar to Case 2, $M_{1,2}$ and BL for barefoot running showed higher values compared to shod running, but the difference is larger for the balance line. The differences between the shod running conditions are minimal.

Figure 8 shows the graphs of $M_{1,2}$ and BL of the three cases. The ground pressure measurements shows for the three athletes, almost the same curves for $M_{1,2}$ and BL. In the insole measurements, differences between the three runners become clear. The long distance runner (Case 1) showed a flat course of the $M_{1,2}$ curve after a short increase. The pressure underneath metatarsal 1 and metatarsal 2 decreases almost to zero for the steeplechase runner, but on the other hand, no lateral shift of the balance line can be found. The sprinter showed an increase over the total foot unrolling. She also had the highest $M_{1,2}$ values, but it was the long distance runner (Case 1) who runs with orthotics to correct excessive pronation, although the graphs (insole) do not show excessive values for $M_{1,2}$.

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### Figure 7: Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves curves of 4 trails (between 10% and 80% of foot contact) are given for the four running conditions: barefoot running (barefoot), own shoes (OS), own shoes with orthotics (OSor) and neutral flat-soled shoes (NS).

### Comparison

In comparing the foot unrolling of different athletes, it is necessary to start from similar test protocol. It would be unlikely to compare data from different athletes in the own shoe condition because of the different shape and construction of the shoes. In this study, all the athletes had performed running trials with the same neutral flat-soled running shoes, so a comparison could be useful.
SUMMARY

The two different pressure measurement systems produced different results for the three discussed parameters. One of the reasons for these differences is that the insoles move and bend with the shoes. Another aspect is that the pressure platform measures the shoe-to-ground interaction, whereas an insole measures a foot-to-shoe interaction.

Not only were differences between the two systems found in the results, but also differences between the four running conditions occurred. Therefore, to compare athletes or patients, it is necessary to start from the same test protocol with the same testing shoes. All running shoes had cushioning in the soles which influences foot-to-ground contact when measurements are taken with the pressure platform. In most of the running shoes, some internal adaptations occurred which influence the foot-to-shoe interaction measured by insoles.

The variables M1,2 and the balance line could be good parameters to evaluate the influence of orthotics or shoes on the medial/lateral distribution of plantar pressure by the human foot.

In conclusion, clinicians should be careful when evaluating plantar pressure data from different systems, under different conditions and from different patients.

REFERENCES

De Cock A., De Clercq D. et al. (2002). Gait & Posture, 16, suppl. 1, September