BAREFOOT, INSOLE AND GROUND PRESSURE MEASUREMENT COMPARISONS DURING 5m/s RUNNING

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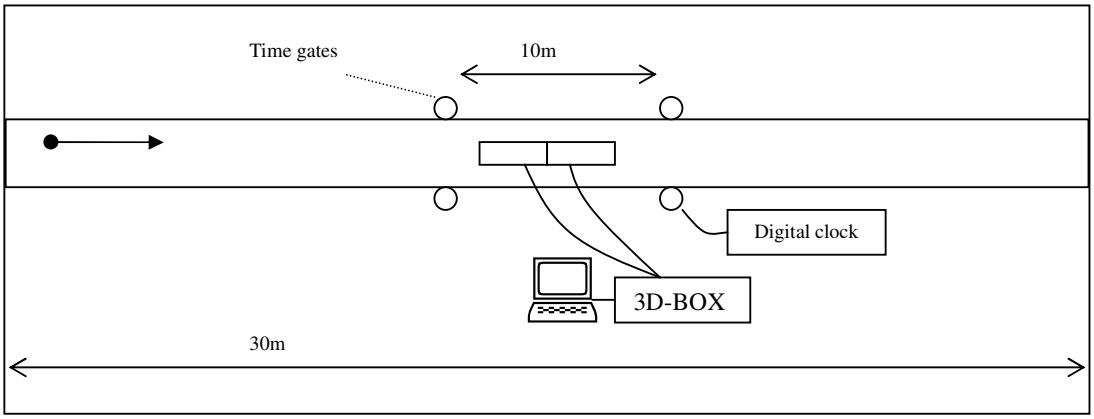
INTRODUCTION

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. Which information is given by a pressure platform and which 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, lineair 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 bij electronic time gates interfaced with a digital scoreboard (Timetronics, 0.01 s resolution). The gates were located 10meters apart, with the pressure platform in the center.



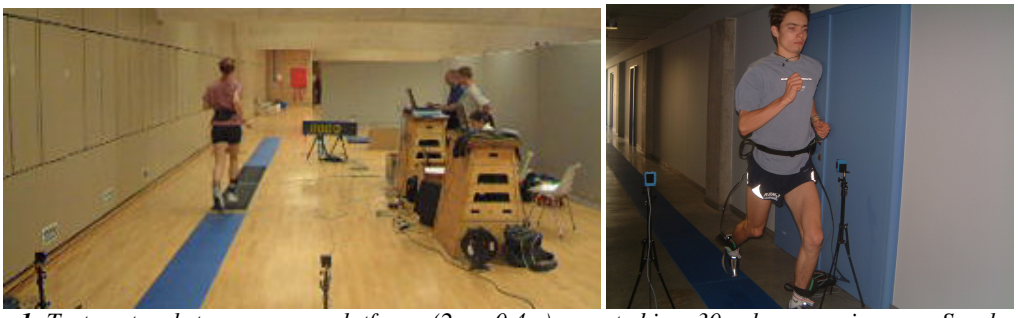


***Figure 1**: Test protocol: two pressure platforms (2m x 0.4m) mounted in a 30 m long running way. Synchronised insole and ground pressure measurements at a running speed of 5.07m/s (+/- 0.39m/s).*

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 (RSscan 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 was analysed in the footscan scientific softwareversion 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 detecs the foot print as a left or a right foot, and places a mask on top of the footprint that devides it in nine regions: hallux, heads M_1, M_2, M_3, M_4, M_5, midfoot, medial heel and lateral heel. The dynamic region system is used in both sytems, pressure platform and the insoles. For the insoles and for shod running the same mask as for barefoot prints was used.

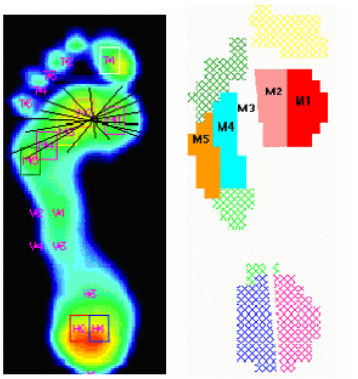


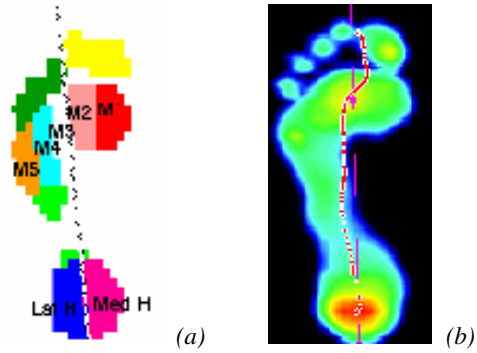
Figure 2: *Dynamical Region Analysis*

After dynamical region analysis, the software calculated Balance Line (BL) and $M_{1,2}$ for each foot print 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) *(b)*

Figure 3*: (a) The balance Line: medio-lateral distribution of plantar pressure. (b) Pattern of the Center Of Pressure (COP) during roll-over of the foot.*

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 footaxis 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 be 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 2, 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 . 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.

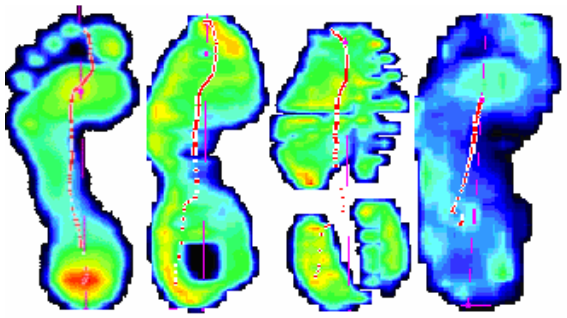
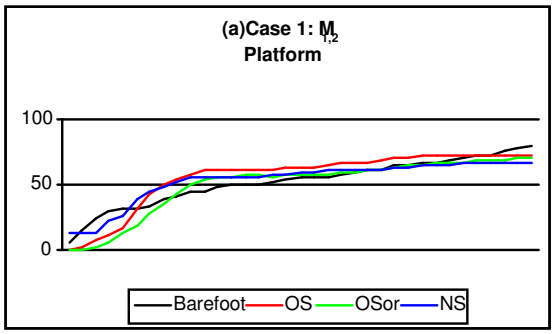


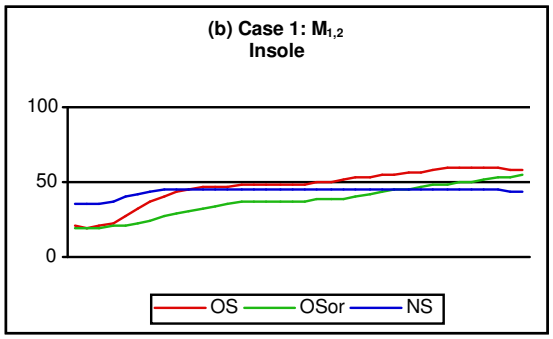
Figure 2*:1 footscan platform barefoot, 2 footscan platform flat-soled running shoe, 3 footscan platform own shoe,4 Insoles footscan own shoe*

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

Figure 4 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 M1,2 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.





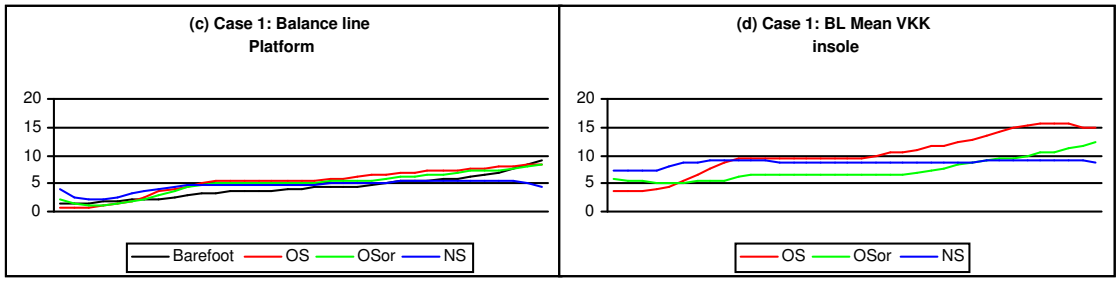


***Figure 4**: Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves of 4 trails (between 10% and 80% of foot contact) are given for the four running conditions: barefoot running (barefoot), own shoes (OS), own shoes with orthotics (OSor) and neutral flat-soled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

For this runner, orthotics were placed to solve a problem of exceeded pronation. 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 graph 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 5 shows the graphs for $M_{1,2}$ and BL for a steeple 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).
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 graph 5(a) showed almost no differences between the three shod running conditions for $M_{1,2}$, in graph 5(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, graph 5(d) showed an earlier medial shift of the balance line compared to running without orthotics.
Running with or whithout orthotics do not much influence the curves of M1,2 and BL in this case. Therefore the the orthotics is neutral (left), no compensation.

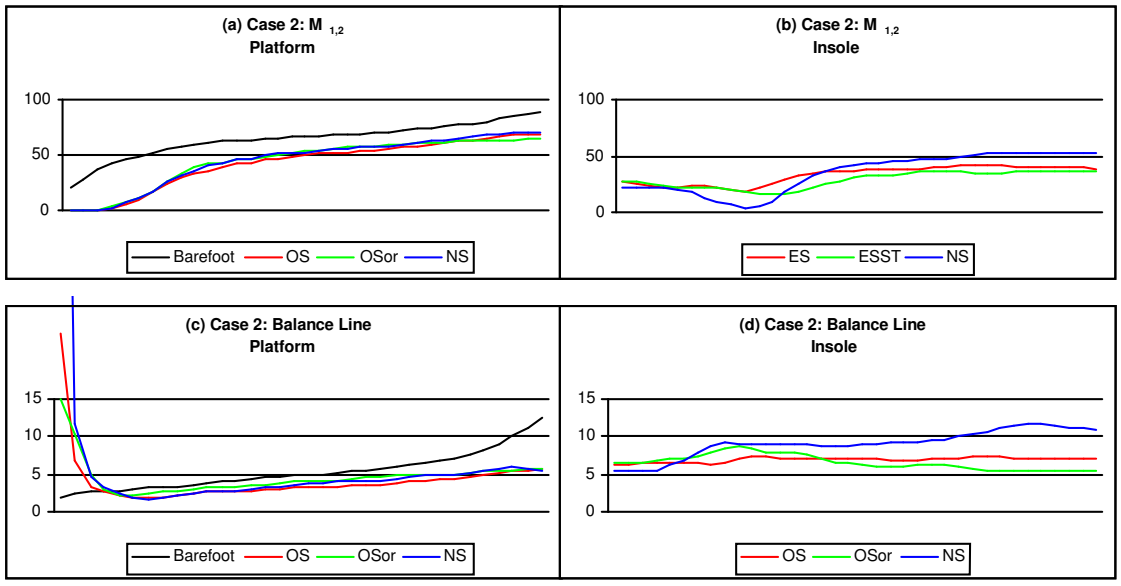


Figure 5: *Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves curves of 4 trails (between 10% and 80% of foot contact) are given for the four running conditions: barefoot running (barefoot), own shoes (OS), own shoes with orthotics (OSor) and neutral flat-soled shoes (NS).*

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

Figure 6 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 fast 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 difference between the shod running conditions are minimal.

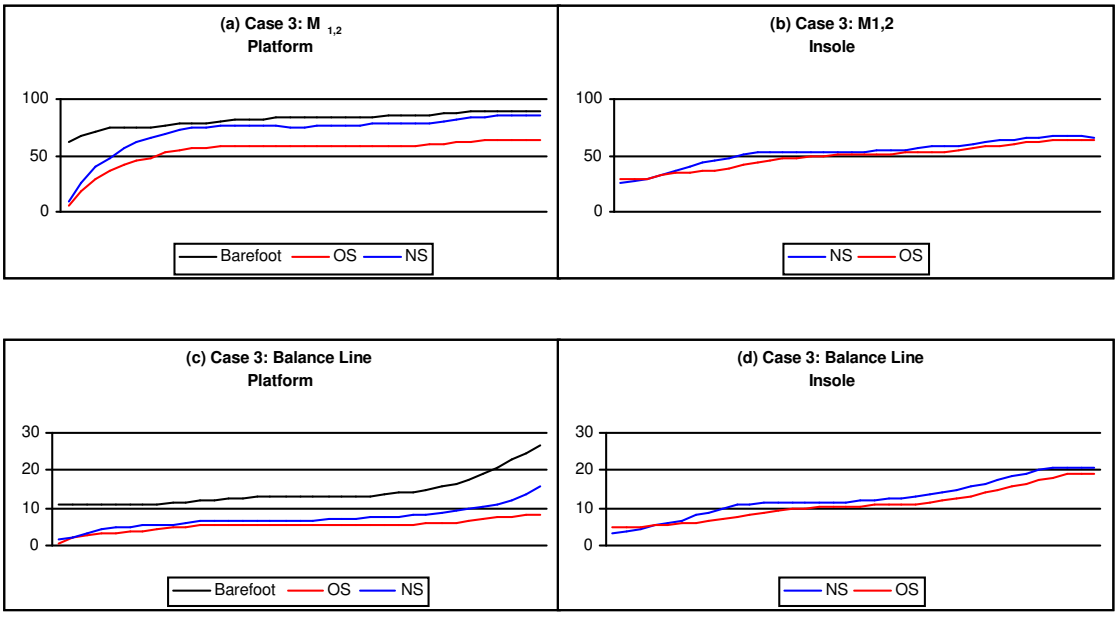


Figure 6: *Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves curves of 4 trails (between 10% and 80% of foot contact) are given for the four running conditions: barefoot running (barefoot), own shoes (OS), own shoes with orthotics (OSor) and neutral flat-soled shoes (NS).*

Compare

To compare the foot unroll of different athletes, it is nescessary to start from similar test protocol. It would be unlikely to compare data from different athletes in the own shoe condition, cause 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 comparisson could be usefull. Figure 7 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 becomes clearly. 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 steeple 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 unroll. She also had the highest $M_{1,2}$ values, but it was the long disctance runner of case 1 who runs with orthotics to solve exceeded pronation, althought the graphs (insole) do not show exceeded values for $M_{1,2}$.

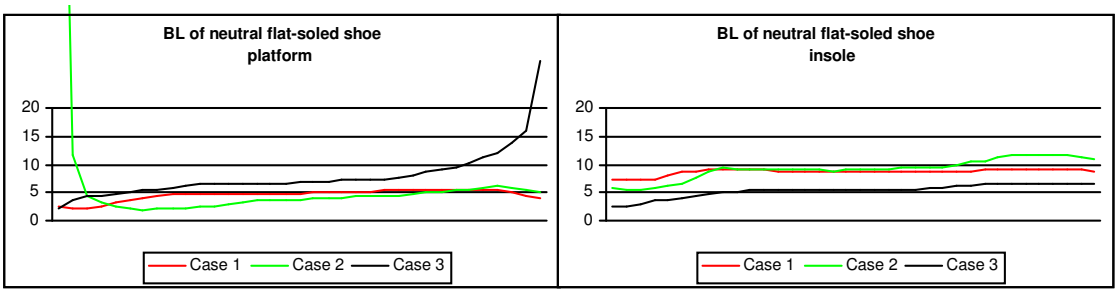


Figure 7: *Graphs of $M_{1,2}$ and Balance Line for insole and ground pressure measurements. Mean curves (between 10% and 80% of foot contact) for running with neutral flat-soled running shoes.*

SUMMARY

The two different pressure measurement systems produce different results for the three discussed parameters. One of the reasons for this differences is that the insoles translocate and bend with the shoes. An other aspect is that the pressure platform measure the shoe-to-ground interaction, where an insole measure a foot-to-shoe interaction.

Not only differences between the two systems were found in the results, also differences between the four running conditions occured.

And at least, to compare athletes or patient, it is nescesarry to start from the same test protocol with the same testing shoes. All running shoes had reliefs in there soles which influence foot-to-ground contact for measurements with pressure platform. In most of the running shoes, some intern adaptations were done which influence the foot-to-shoe interaction measured by insoles.

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 had to be carefull when evaluating plantar pressure data of different systems, different conditions and different patients.

REFERENCES

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