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Evaluation of pressure insoles during running

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Abstract

Pressure insoles could be a useful tool for measuring vertical ground reaction forces during field tests. However, several studies have indicated problems that can affect the reliability of the output of the insoles. The aim of this study was to test the reliability, durability and repeatability of Tekscan F-scan pressure insoles with 2 running tests in combination with walks across and jumps on a force platform. During the both running tests in this paper the sensitivity of the pressure insoles deteriorated rapidly. A comparison of the force output of the pressure insoles and force platform during walks and jumps showed clear differences in both the shape and magnitude of the force curves. The rapid decrease in sensitivity and frequent need of calibration of the pressure insoles make the pressure insoles not reliable and practical enough for measuring vertical ground reaction forces during running.

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Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

To gain knowledge of the loading on the musculoskeletal system during various movements it is essential to collect biomechanical data. This provides information on the forces that act on specific parts of the body and can give insight on possible risk factors for injuries or how to improve performance.

One of the key problems when collecting biomechanical data is that tests performed in a laboratory environment are limited to the available space. Therefore performed movements are bound to several restrictions, which can make it difficult to perform the movements naturally. Consequently it is questionable how valid the outcomes will be for actual in-game scenarios.

On the other hand, field tests are also limited by several factors. Not all equipment is suitable for use outdoors or difficult to incorporate in a realistic environment, for example a grass soccer pitch. Pressure insoles could provide a practical outcome for collecting data on the experienced vertical ground reaction forces (vGRF). Since the insoles are put in the shoe they can be used in the laboratory or field. An other advantage is that the data collection unit is small, which means that it has easy transportability. However, while some previous studies have used these insoles

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during running and claimed accurate results[1], others have indicated some problems (e.g. durability, temperature sensitivity) that might affect the reliability of the pressure insoles [2,3,4,5]. Therefore the aim of this study was to evaluate the reliability, durability and repeatability during running and the accuracy of reproducing vGRF while walking across and jumping on a force platform of Tekscan pressure insoles.

2. Methods

To measure the reliability, durability and repeatability of the pressure insoles two different treadmill tests were performed by a 23 year old male subject (body mass 100 kg), who provided informed consent. Tekscan F-scan (#3000) pressure insoles were cut to the shoe size of the subject (UK 12) and used with the F-scan mobile system (Tekscan Inc., South Boston, MA). For both tests the insole was placed in the right running shoe (Nike Air Max) of the subject. The first test involved a 5 x 1.5 minute run on a treadmill at 9km/h. After each run the insole was removed from the shoe and put back in, which meant the subject had a rest period of approximately 1 minute between runs. The pressure data was collected 60s into each run and for a duration of 15s (200Hz). The second test consisted of a continuous 23 minute run on a treadmill at 9 km/h, with pressure data collected after 1, 5, 10 and 23 minutes. For each test a new insole was used which was equilibrated in an airbladder calibration system at 20 PSI. After this the pressure insole was placed in the right shoe of the subject followed by step calibration, where the subject had to shift the weight from his left foot onto his right foot. Followed by a walk around the lab to ‘break in’ the insoles. After each test the pressure insoles were put in the airbladder again to examine the output and wear of each cell when put under a uniform pressure.

Before and after each of the running tests the subject was asked to walk twice across a force platform (9821 CA, Kistler Instrument AG, Switzerland, 1000Hz) and to perform two vertical squat jumps on top of the force platform in order to compare the output of the insoles with that of the force platform. Both running tests were recorded with a high speed video camera to assess whether the subject fatigued during the test.

The pressure data from the insoles was analysed using F-scan mobile research 6.30. For the analysis the step calibration done before each run was used to determine the behaviour of the pressure insole output during each test. A frame calibration was used to calibrate one point of the force curve with the force platform data for comparison between the pressure insole and the force platform.

3. Results

3.1. 5 x 1.5 minute run

The force curve of the pressure insoles with the step calibration show that with each run the output decreased substantially, with a 41% drop of the peak force between the first and the last run (Fig. 1). Similar differences were found for specific regions across the foot (Fig 2). Nevertheless the shape of the force curve seemed consistent for all the trials.

When the insoles were put in the air bladder after the test it appeared that the forefoot region had degraded more than mid- and rear foot as the output of those cells was less than in other regions under the same pressure (Fig 3). There were also a few cells that failed to produce any output.

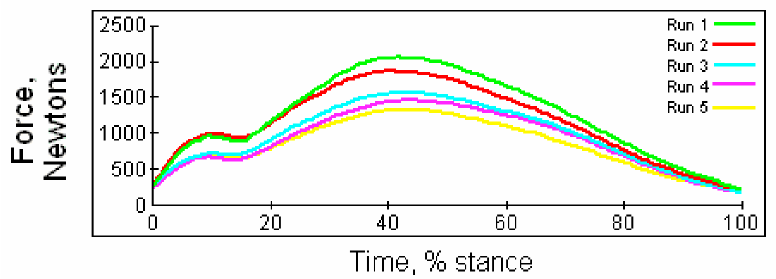
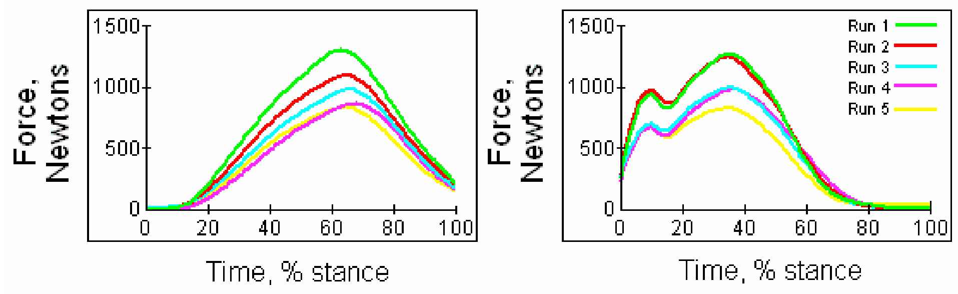


Fig. 1. With each run during the 5 x 1.5 minute test the output of the pressure insole decreased gradually



(a) (b)

Fig. 2. During the 5 x 1.5 minute runs the output of the insoles decreased both in the forefoot (a) as in the rear foot (b)

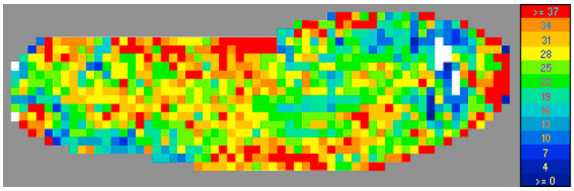


Fig. 3. Putting the insole in the airbladder at a constant pressure after the test showed that the cells did not degrade uniformly, there were also a couple of cells that failed to produce any output.

3.2. 23 minute run

The force curve of the pressure insoles with the step calibration show a similar decrease during the 23 minute run, with a maximal difference in peak force of 47% (Fig 4).

During the 23 minute run the insole sustained a significant amount of damage due to a backwards shift of the insole inside the shoe (Fig 5), resulting in deformation of the rear foot section of the insole and the lower part of the cuff which connects the insole to the data collection device. The airbladder test after the run showed that number of cells did no longer produce any output (Fig 6).

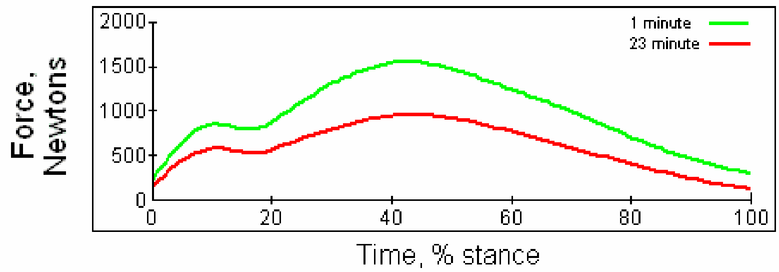


Fig. 4. A comparison of the output at 1 minute and at 23 minutes of the 23 minute shows a clear degradation of the pressure insole

Fig. 5. The insole was clearly deformed at the heel part and a part of the insole cuff during the 23 minute run

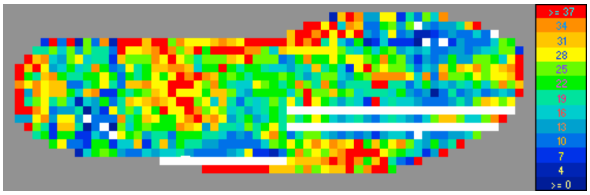
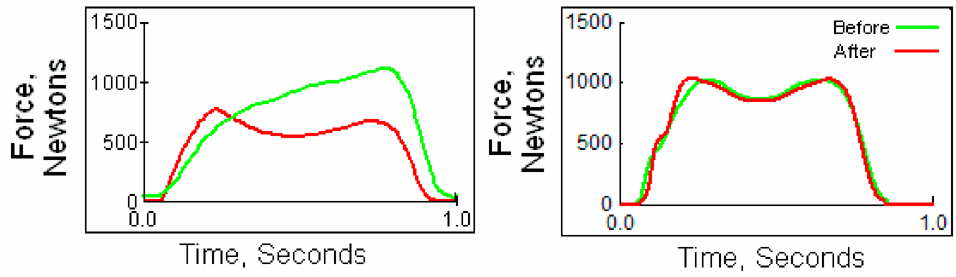


Fig. 6. The white lines in the pressure insole output show the damage that occurred during the 23 minute run

3.3. Walking across the force platform

A comparison between the walks across the force platforms before and after both tests, showed similar decreases in the output of the insoles as during both running tests (Fig 7a). The output of the force platform was similar before and after test (Fig 7b).

Another difference in the output of the pressure insoles was the ground reaction force profile. The walks before the running tests did not have the typical vGRF profile during walking with two peaks [6], whereas the walks after the runs did have this profile (Fig 7a). Though only the two walks after the 5 x 1.5 minute test were used because of the damage of the insole after the 23 minute test, the forces found in the vGRF curve were clearly different to the vGRF measured by the force platform (Table 1).



(a) (b)

Fig. 7. The output of the walking trials before and after the running tests show the same degradation of the pressure insoles (a), while the output of the force platform remained the same (b).

Table 1.Comparison of the second peak in the force curve of the walking trials before the running tests from the force platform and pressure insole with step calibration

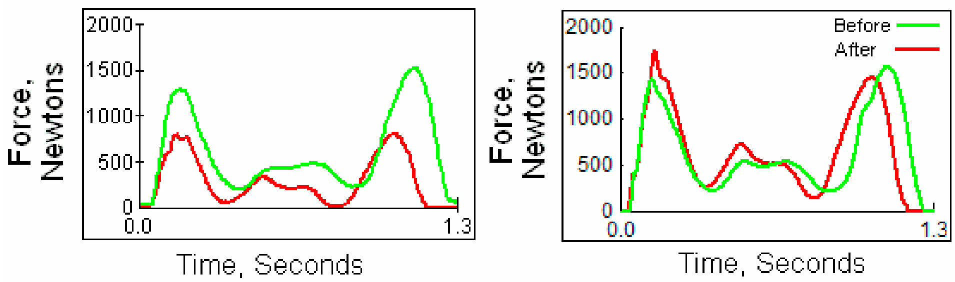
	5 x 1.5 minute test		23 minute test	
	1st trial	2nd trial	1st trial	2nd trial
Force platform	1007 N	992 N	986 N	1024 N
Pressure insole	1111 N	1093 N	806 N	805 N

The frame calibration was used to calibrate the second peak of the vGRF curve of the insole to the force of the second peak of the force platform data. While this made sure that the second peak had a similar force level other parts of the force curve still showed differences. The dip between the two peaks of the vGRF curve showed lower values for the pressure insoles than measured with the force platform. For the first walk after the test the insole and force platform respectively measured a minimum vGRF of 791 N and 880 N. For the second walk respectively 658N and 829N.

3.4. Jumps on force platform

Comparing the jumps on the force platforms before and after both tests, showed similar decreases in pressure insole output as during both running tests (Fig 8). The output of the force platform stayed in the same range 1436 N – 1742 N before and after each test. In contrast to the results of the walks the force profiles of the jumps are similar before and after the test. However, similar to the results of the walks the forces found were significantly different, though the vGRF of second peak in the first trial was close to that of the force platform, 1527 N vs.1568 N(Table 2).

With the second peak calibrated to the force platform data with the frame calibration it also got clear that again the forces were not similar across the force curves as insole data provided substantially lower forces for the first peak compared to that measured with the force platform (Table 3).



(a) (b)

Fig. 8. The output of the jump trials before and after the running tests show the same degradation of the pressure insoles (a), while the output of the force platform remained the same (b)

Table 2. Comparison of the first and second peak in the force curve of the jump trials before the running tests from the force platform and pressure insole with step calibration

	5 x 1.5 minute test				23 minute test			
	1st trial	1st trial	2nd trial	2nd trial	1st trial	1st trial	2nd trial	2nd trial
	1st peak	2nd peak	1st peak	2nd peak	1st peak	2nd peak	1st peak	2nd peak
Force platform	1426 N	1568 N	1611 N	1403 N	1742 N	1454 N	1649 N	1436 N
Pressure insole	1292 N	1527 N	1271 N	1251 N	1285 N	1141 N	1237 N	1151 N

Table 3. Comparison of the first peak in the force curve of the jump trials from the force platform and pressure insole with the second peak of the pressure insole curve calibrated to the force platform data

First peak	5 x 1.5 minute test				23 minute test	
	1st trial	2nd trial	3rd trial	4th trial	1st trial	2nd trial
Force platform	1436 N	1611 N	1735 N	1567 N	1742 N	1649 N
Pressure insole	1202 N	1272 N	1300 N	1170 N	1482 N	1447 N

4. Discussion

The decrease in pressure insole output during both tests shows that the sensitivity of the Tekscan F-scan pressure insoles degrades rapidly during running, which indicates a limited durability and reliability. Since the insoles were only calibrated once before each test the repeatability of the insoles also turned out to be limited. To some extent this can be solved by recalibrating them regularly. This however will put restrictions on the applicability of the pressure insoles. A comparison between the shapes of the vGRF curves from the pressure insole and force platform also showed clear differences.

As mentioned above the degradation of the pressure insoles can to some extent be solved with regular calibration. However during field tests or prolonged trials it will be complicated to do this reliably. Step calibration is the most practical means of calibrating the pressure insoles during field tests. The walking and jump trials clearly showed that this leads to vGRF curves which differ in shape and magnitude to the force platform data. Some of the differences of the vGRF curves might be caused by the worn shoes and its damping properties. However, the properties of the shoe will not have changed that drastically to explain the decreased output of the pressure insoles. Therefore the decreased output of the pressure insoles must be caused by a decreased sensitivity of the insoles.

The issue of calibration during prolonged trials can to some extent be solved by calibrating afterwards by using the frame calibration. Yet this puts restrictions to the testing environment, which negates one of the strengths of the pressure insoles. Furthermore this type of calibration also has a limited reliability as the vGRF curves again differed in shape and magnitude to the force platform data.

The calibration of the pressure insoles was one of the weaknesses of this study as both the step calibration and frame calibration the insoles are based on a single calibration point. Previous studies have shown that a calibration using multiple points and variable loads can be more reliable[7]. This however has no influence on the main results of this study, that the Tekscan F-scan pressure insoles show a rapid deterioration in sensitivity during running, which supports the findings of previous studies [4,5].

Another important issue with the pressure insoles is a lack of robustness as they were damaged easily due to a backwards shift inside the shoe during the 23 minute run. While this might be prevented to some extent by attaching the pressure insole to the sole of the shoe, during high impact movements which put a lot of strain on the insoles some movement and consequent damage appears inevitable.

The results of this study show that the Tekscan F-scan pressure insoles are not reliable enough to be used as a tool to measure vGRF during running with either the step calibration or the frame calibration. Apart from this the sensitivity of the insoles degraded rapidly during both running tests making frequent calibration necessary, which limits the use to short trials or makes the use of a force platform necessary.

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