Diagnostic Plantar Impact Analysis in Runners

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Abstract

Over the course of a year, studies estimate that roughly 60% of runners will sustain some form of injury. One of the largest factors in injury, and thus injury prevention is technique. While no single consensus opinion exists amongst experts, one factor that seems to be fairly universal is impact. In response to this, we created a novel system of impact-based gait analysis that is technique-independent, low-energy, and simple to implement compared to other systems currently on the market. By significantly lowering the cost and complexity of providing useful biofeedback, this system has the potential to substantially raise the availability of advanced electronic monitoring among runners, thereby reducing injury.

Overview

Based on some of the leading biophysics literature available on differential running gaits, we determined that a chief characterization of a dangerous foot impact would be the presence of an impact transient, or short high-frequency spike in amplitude which occurs at the onset of a sharp impact and then rapidly dissipates.

The method we devised centred around the identification of this spike. Simplicity was maintained by using a frequency-based approach. The overall system comprises:

1. *Pressure Sensor* - Plantar mounted ink-resistive film

2. *Data Conditioning* - Sallen-Key implemented filter and segmentation algorithm

3. *Frequency Analysis Algorithm*

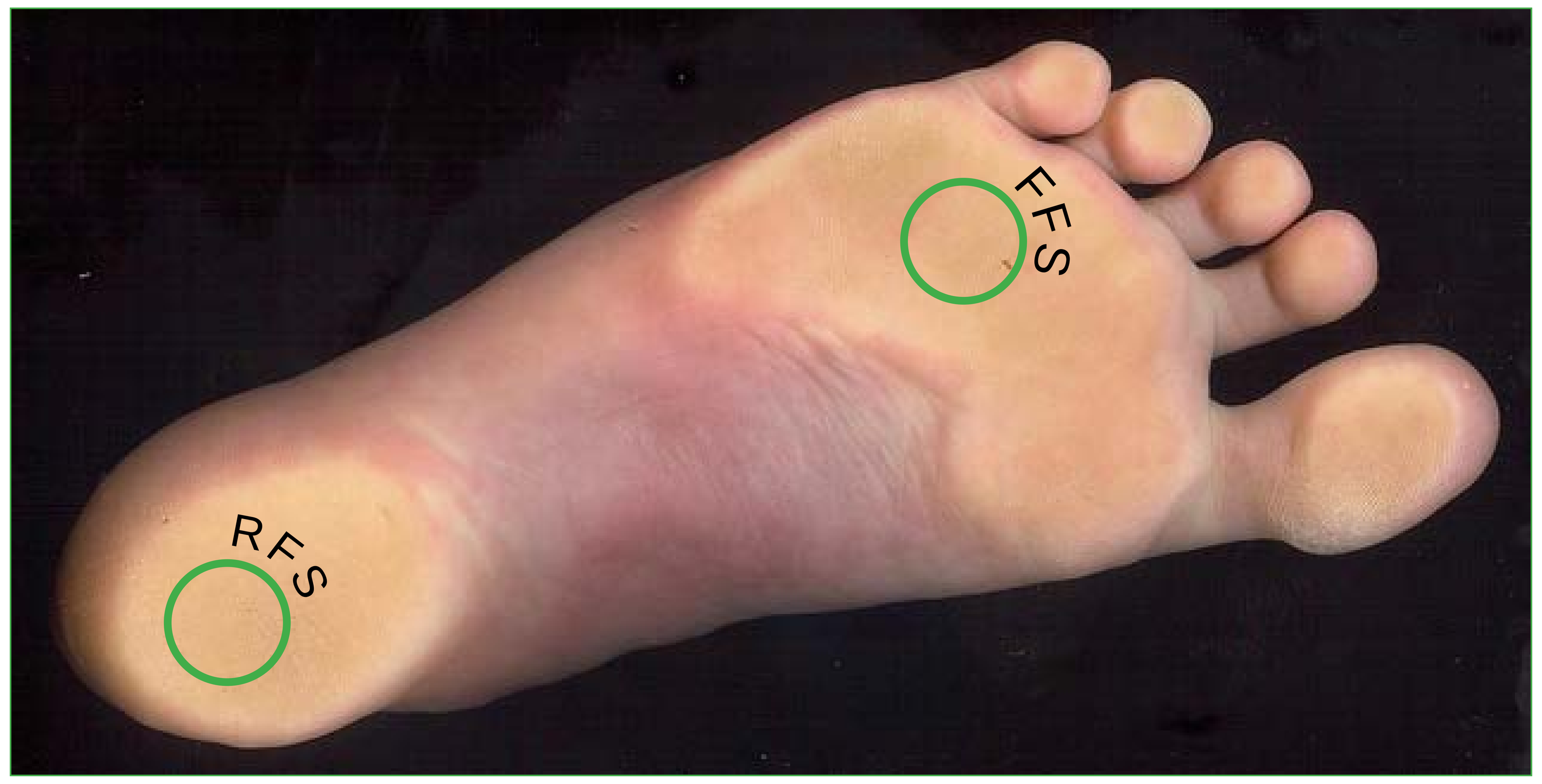
4. Statistical feedback from running average of past samples.

Acknowledgements

I would like to thank Dr. Morley for his consistent wise support throughout the project and Dr. Mueller for helping us sort through the best possible sensor design.

Data Capture

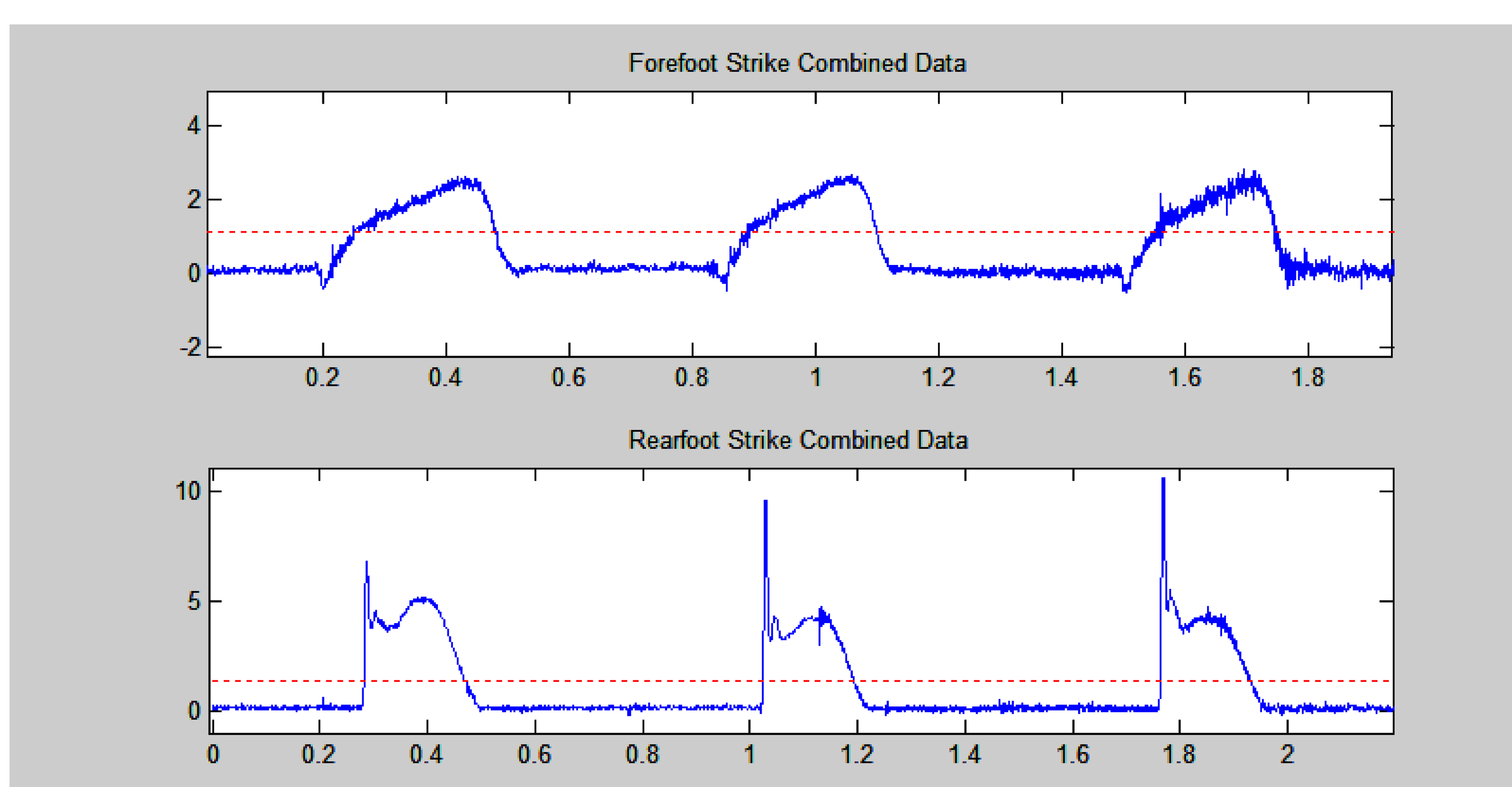
Because most running styles impact on either the rear-foot (RFS) or the front-foot (FFS), we simplified or data capture to two sensors, mounted on the heel and ball of the foot respectively:



Shown above are the ideal locations for sensor placement. The forefoot sensor is placed underneath the fourth metatarsal head. By summing the data from the two sensors, we were able to capture and accurate proportional picture of impact force.

Data Conditioning

Based on some preliminary data, we determined that impact transients generally fell in a frequency band between 20-80 Hz. Once this was established, we constructed and implemented a filter to avoid any aliasing when data was sampled from the sensor. After data was captured, we designed and utilized a segmenting algorithms to parse individual impacts out of the data. Shown below are samples of FFS versus RFS impacts. Note the strong impact transient on the RFS impact.

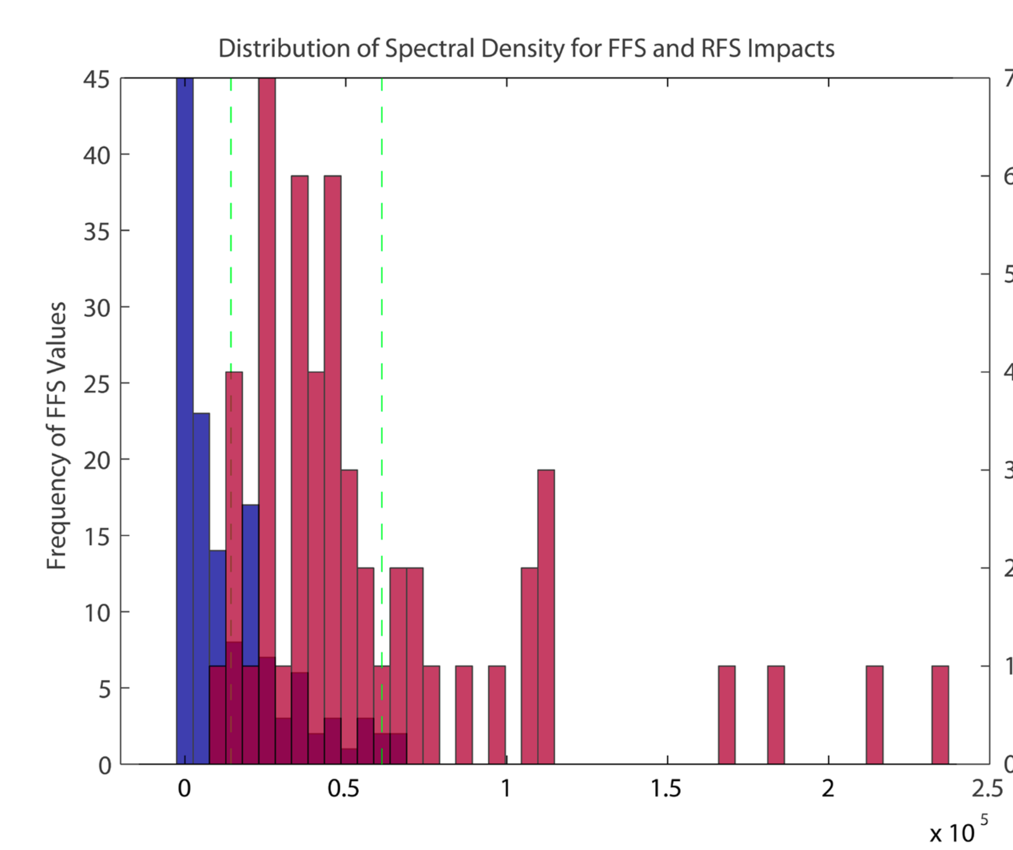


Signal Processing

The basis for the analysis is a spectral density sample for each impact, on the frequency band 20-80 Hz. If impact transients are present, there is a quantifiably higher density in that band. This was tested by performing trials of ideal (low impact FFS) and typical (high impact RFS) running, and then evaluating both the separability of the populations and the ROC behavior of the system.

Statistical Analysis

Based on sample pools of n = 50 RFS impacts and n = 130 FFS impacts, we found that the populations were separable based on a 2-population unpooled t-test, which yielded p = 4.7E-9. The distribution of the two populations is shown below, with FFS in blue and RFS in red.



And shown below is the ROC for the overall system, emphasizing peak operating point (cut-off point).