FootStriker: An EMS-based Foot Strike Assistant for Running

Figure 1: The FootStriker lab prototype on a running treadmill.

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Abstract
In this demo, we present our FootStriker prototype in companion to the full paper. FootStriker detects heel striking while running with a pressure-sensitive insole and corrects the striking in real-time to mid-/forefoot running by applying electrical muscle stimulation (EMS) on one of the calf muscles. The device will be worn and demonstrated by the presenter but if possible, it can also be tested directly by the conference attendees. We provide them with visual real-time feedback for demonstration purposes.

Author Keywords
Electrical Muscle Stimulation; Wearables; Real-time Feedback; Motor Learning; Sports Training; Running; In-situ Feedback; Real-time Assistance; Mobile Interface

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
Running watches, wearable fitness trackers and other training tools are ubiquitous today [1, 11]. Many wearable devices exist today that can be used to track and analyze running activities. However, most of them only provide assistance and feedback on running performance (for example distance, elevation, pace), not running technique [3].

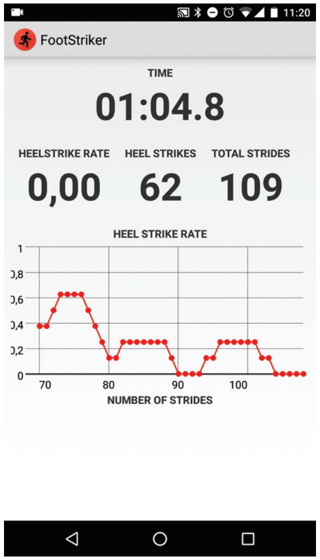

Figure 2: The mobile interface connected via Bluetooth LE to the wearable: it displays total time, total strides, number of heel strikes, and the heel strike rate as percentage in a real-time graph.

Nylander et al. [8] surveyed how technology can help athletes in rehabilitation and how to use them to avoid injuries. Jensen and Mueller [3] reviewed current technologies that are used in training for running, and based on that, present a design space and initial guidelines for research and development of future run training interfaces. Our work complements the blind spot in their design space with a run-training technology that focuses on running technique and assistive feedback. It addresses the problem of knee-related injuries that are common and mostly appear in conjunction with high impact forces when striking the ground with the heel first (heel strike).

Changing the running style to mid- or forefoot running reduces the risk of injury, since the leg muscles then act as a spring and better absorb the impacts. Once a heel strike gets detected, the EMS signal is triggered and tilts the foot forward in the flight phase of the stride before landing. In the accompanying full paper, we evaluated the prototype in lab conditions on a treadmill [2]. For this demo, we additionally visualize the sensor data and the actuation events on a mobile interface to the user. The mobile interface is depicted in Figure 2.

Some research on EMS as an interface exists in HCI. Lopez and Baudisch [4] proposed an EMS interface for video games. In their approach a mobile game is controlled by tilting the device, and the EMS signal is sent to the player's arm to add a level of difficulty into the game. In [5], the physical impact of a virtual reality (VR) boxing game is simulated by actuating the arm in a similar movement to what actually happens in a physical boxing match. VR research has also shown that users could experience the feeling of the softness and hardness of virtual 3D objects with EMS [7, 10]. Affordance++ by Lopes et al. [6] is an extension to the physical affordance of everyday objects. Objects can communicate with users and tell them how they are supposed to be used. For example, a can of paint can direct the user to shake it before using it.

An approach that is closely related to our work is using EMS for pedestrian navigation [9]. Typical GPS navigation systems rely mostly on visual and audio feedback. The EMS-based actuated navigation is a new kind of pedestrian navigation where the system could steer participants and change their walking direction by applying an EMS signal to the sartorius muscles in the upper legs.

Existing approaches using wearables to improve running technique mostly provide post-analysis only. In contrast, our work provides real-time feedback on running technique using EMS. To the best of our knowledge, FootStriker is the first application of EMS actuation to correct running technique.

The FootStriker Wearable

The FootStriker wearable consists of a medically approved EMS device (SANITAS SEM 42), an insole with three force sensing resistors (FSR), a Bluetooth LE capable control board (RFDuino), two electrodes for the calf muscle, a battery, and the newly contributed mobile application (see Figure 3 and 1). The latter is solely designed and implemented for the visualization of the data but is not used for data processing or actuation of the EMS signal. It is easily portable and can be used to collect and display data of the

Demo Procedure

Based on the results of the EMS condition in the main study [2], we hypothesize that we can generate similar results with a short indoor run. More specifically, most of the participants of the lab study decreased their heel strike rate in less than five minutes (see Figure 4). For the demo, we

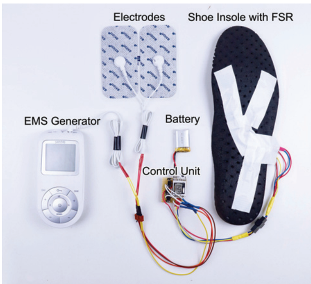

Figure 3: The system components of the FootStriker wearable.

will provide two fully functional wearable devices. We would wear one unit ourselves for short demonstration and illustration purposes. Thereby, the attendee can look at the interface of the mobile application (see Figure 2) during or after a short run to see the recognized heel strikes and an in- or decrease of the heel strike rate over time in a graph.

Optionally, if an attendee is interested in an actual in-depth experience of the EMS actuation, she can wear our second prototype and take it for a short run for which we expect a similar effect as in our lab study [2]. After the run, we will explain the difference of the running styles, in which phase of the stride the device triggered the EMS signal, and individually analyze the attendee's results. Of course, we will carefully consider any medical requirements and possible risks in a written consent/disclaimer before any self-application of EMS. In terms of insoles, we will provide several sizes with already attached FSR sensors that can quickly be exchanged with a connector and worn in the shoes of the attendees.

Conclusion

With FootStriker we demonstrated the potential of using EMS-based assistance to trigger an unconscious motor learning process at the time of physical exercise. FootStriker detects the user's running stride pattern and provides real-time feedback via EMS to intuitively assist the runner in adapting to mid- or forefoot running.

With a significant improvement over the traditional coaching technique, showing technical feasibility and effectiveness in terms of motor skill learning, we laid the foundation for novel assistive wearable devices for sports. Still, running professionals and coaches cannot be replaced by our system as their expert knowledge is required for the externalization of domain knowledge at the time of building or reprogramming the system. We envision that athletes who do not have constant access to professional coaches can in future use the proposed class of wearable devices as an inner feedback loop to communicate with experts to receive qualitative feedback about their personal technique advancements.

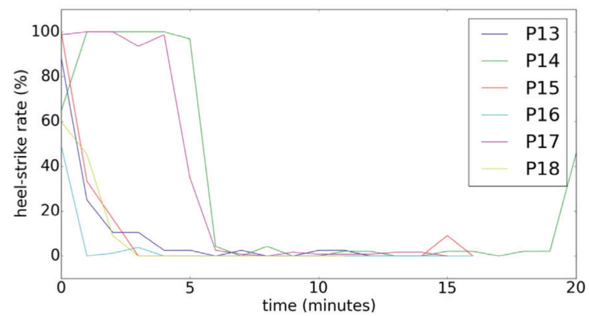

Figure 4: Heel strike rate over time during EMS actuation.

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