On the measurement of running style

Martin Daumer, Michael Trost, Paul Subkowski, Andreas Schneider, Damian Mrowca, Rui Ding, Han Gao, Markus Walther, Christian Lederer

The measurement of running style must be ecologically valid. The individual running style has an impact on the running performance as well as the running injury risk. In order to increase the performance and lower the injury risk, runners should be educated towards a healthy running style. But before advice can be made it is crucial to distinguish running styles from each other. Thus, it is interesting to detect and optimize the running style of individuals. The goal is to evaluate the possibility for a running style app using accelerometry data, which is able to track and display the user's current running style by using accelerometry data, based on which advice can be given for a healthy and efficient running style with the help of gaming tools (meta product). To validate the approach, a gold standard with outdoor running acceleration data has to be created.

PeerJ PrePrints

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.496v1 | CC-BY 4.0 Open Access | rec: 11 Sep 2014, publ: 11 Sep 2014

On the measurement of running style

M. Daumer[123], M. Trost[3], P. Subkowski[13], A. Schneider[3], D. Mrowca[3], R. Ding[3], H. Gao[3], M. Walther[4], C. Lederer[1]

[1] SLCMSR e.V. - The Human Motion Institute - Munich; [2] Trium Analysis Online – Munich; [3] TU Munich - Fakultät für Elektrotechnik und Informationstechnik – Munich; [4] Schön Klinik München Harlaching - Munich

Background

The measurement of running style must be ecologically valid. The individual running style has an impact on the running performance as well as the running injury risk. In order to increase the performance and lower the injury risk, runners should be educated towards a healthy running style. But before advice can be made it is crucial to distinguish running styles from each other. Thus, it is interesting to detect and optimize the running style of individuals.

Aim

The goal is to evaluate the possibility for a running style app using accelerometry data, which is able to track and display the user's current running style by using accelerometry data, based on which advice can be given for a healthy and efficient running style with the help of gaming tools (meta product). To validate the approach, a gold standard with outdoor running acceleration data has to be created.

Methods

The accelerometry data used by the smartphone app is gathered from the "actibelt", an accelerometer included in a belt buckle. This sensor collects data close to the body COM in all three dimensions which is transferred to a smartphone via Bluetooth in real-time. The main focus of this work is the validation of an acceleration based detection of different running styles, namely heel strikes, midfoot strikes and forefoot strikes. Features, which are able to clearly distinguish different running styles, have to be extracted out of the accelerometry data. Therefore, laboratory experiments have been conducted to analyze the actibelt data of three test persons performing heel, midfoot and forefoot strikes on a pressure sensitive treadmill with video control. As running apps are mainly used outdoors, the results had to be reproduced with outdoor running data. In an extreme ends approach four test persons with different running experience ranging from professional to occasional runners were asked to successively run on their heels, midfoot and forefoot, while accelerometry data was recorded and synchronized with mobile high speed video. The different running styles were performed on different substrates, with different shoes and speeds. Moreover, 29 actibelts were distributed at the "B2RUN" event in Munich (6.4 km, 22:59 min - 57:45 min, 21-53 y, 12 m and 17 f, 50-95 kg).
The data (weight, height, training level etc.) of the carriers of the actibelts was documented and can be used for further research. The accelerometry data was analyzed with two different approaches.
1) The "traditional" approach just renders the 1-dimensional accelerometry data (backward-forward and up-down) over time and is trying to characterize the running style with different peak patterns.
2) The new approach creates a 2-dimensional trajectory consisting of a rotating vector of the acceleration data. The form of the trajectory could give useful information about the running style.
You can see these approaches in the following figures.

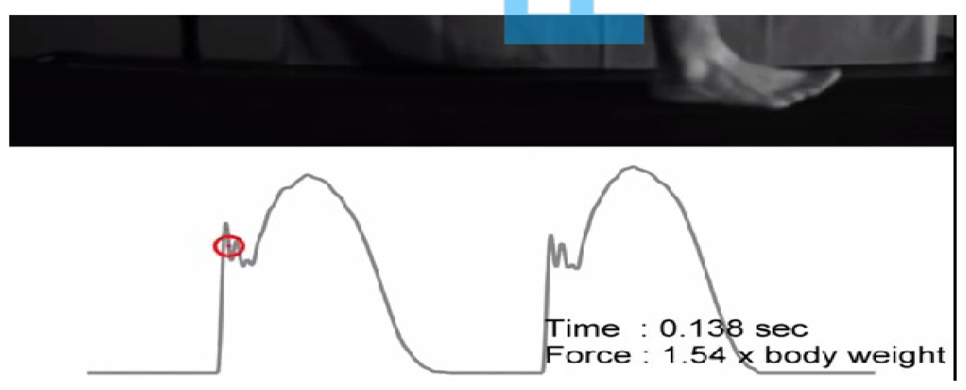

Figure 1 a): Acceleration data of a heel strike runner on a treadmill with pressure sensors. There is a double peak. Picture and graphics from [1]

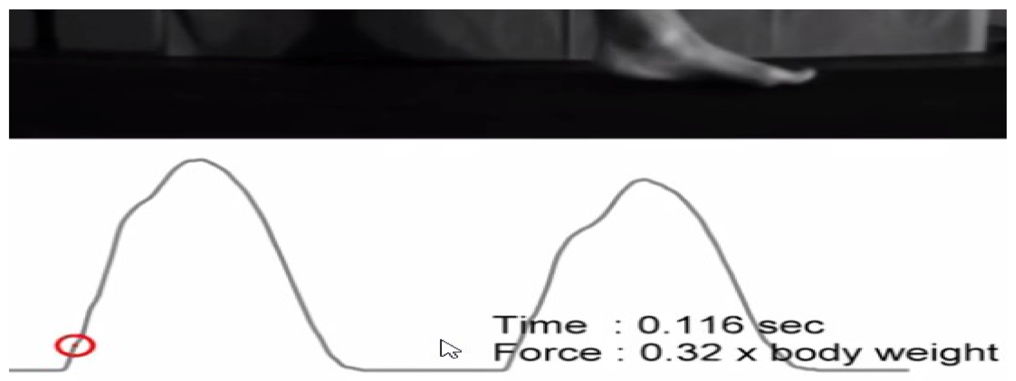

Figure 1 b): Acceleration data of a forefoot runner on a treadmill with pressure sensors. There Is no double peak. Picture and graphics from [1]

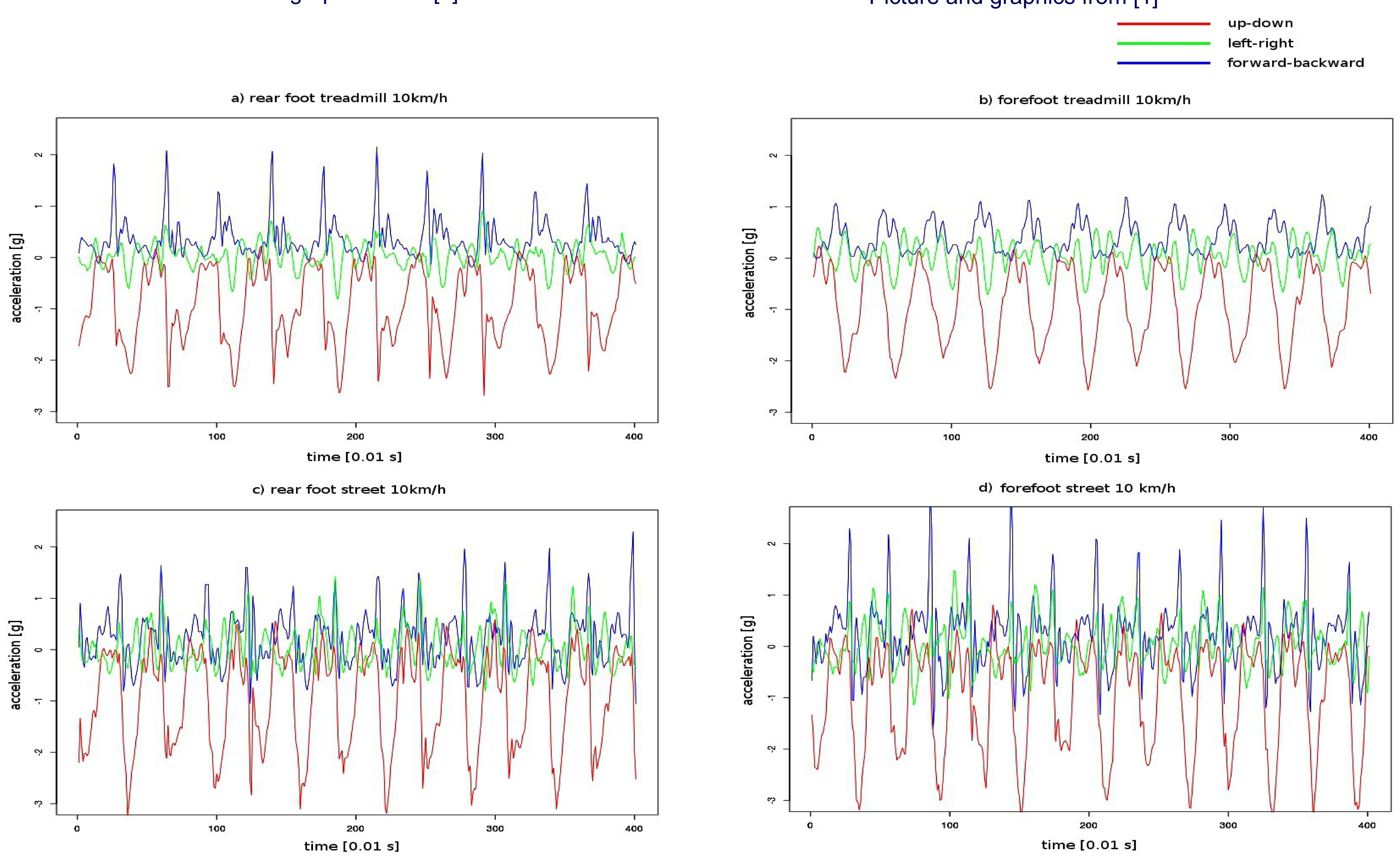

Figure 2: Accelerations as measured by a 3D-accelerometer mounted in a belt buckle. On the treadmill (a,b), the patterns in the up-down axis (red) are compatible with the ground reaction forces from Lieberman [1] and heel strike running is clearly distinguishable from forefoot running. This is no longer the case for outdoor running (c, d) [4].

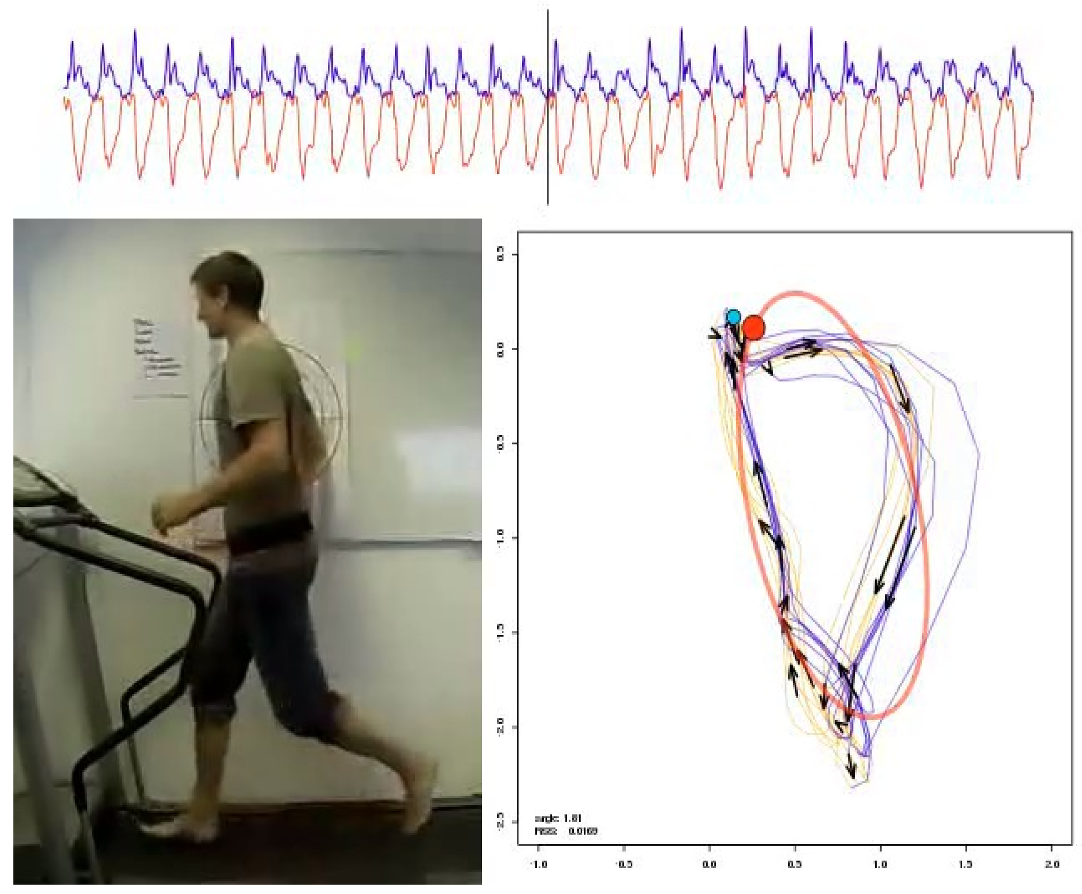

Figure 4 a): Flying phase – no contact to the bottom.

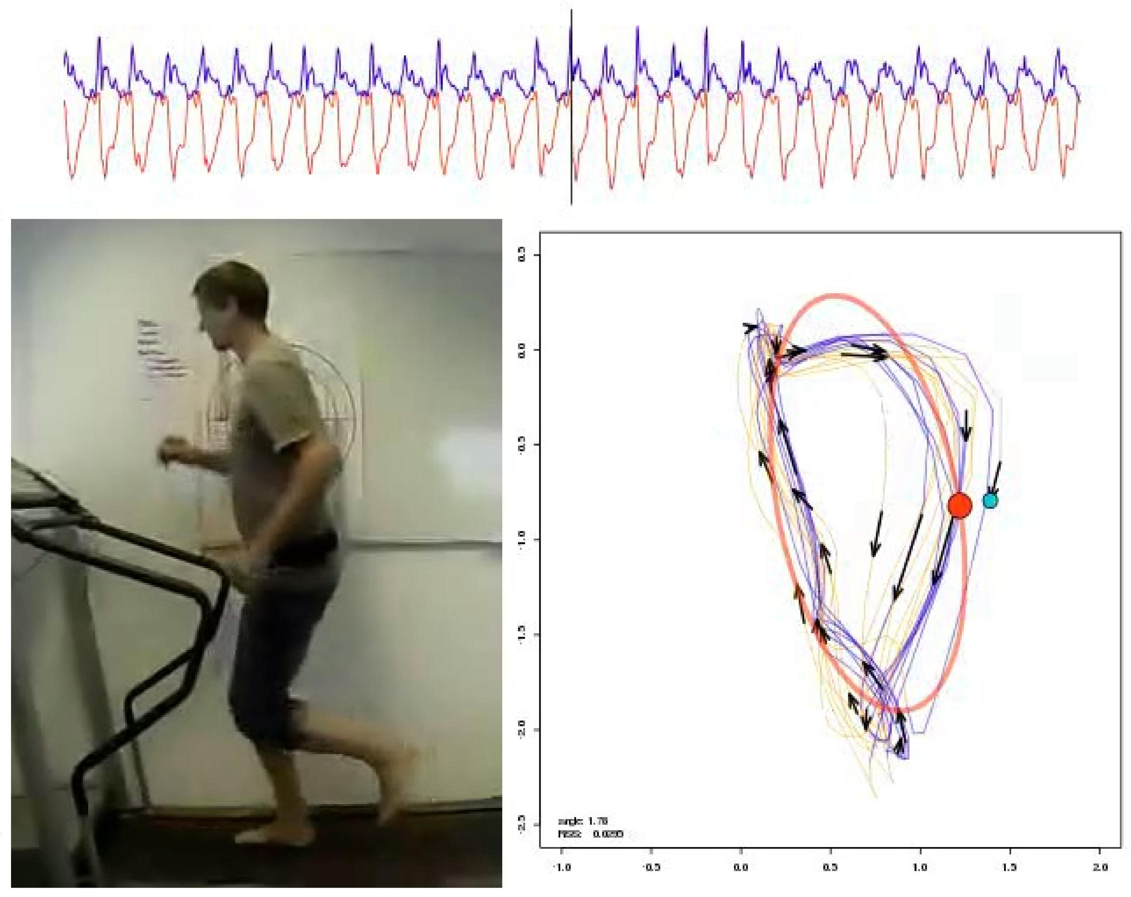

Figure 4 b): Maximum x-Acceleration – Brake effect

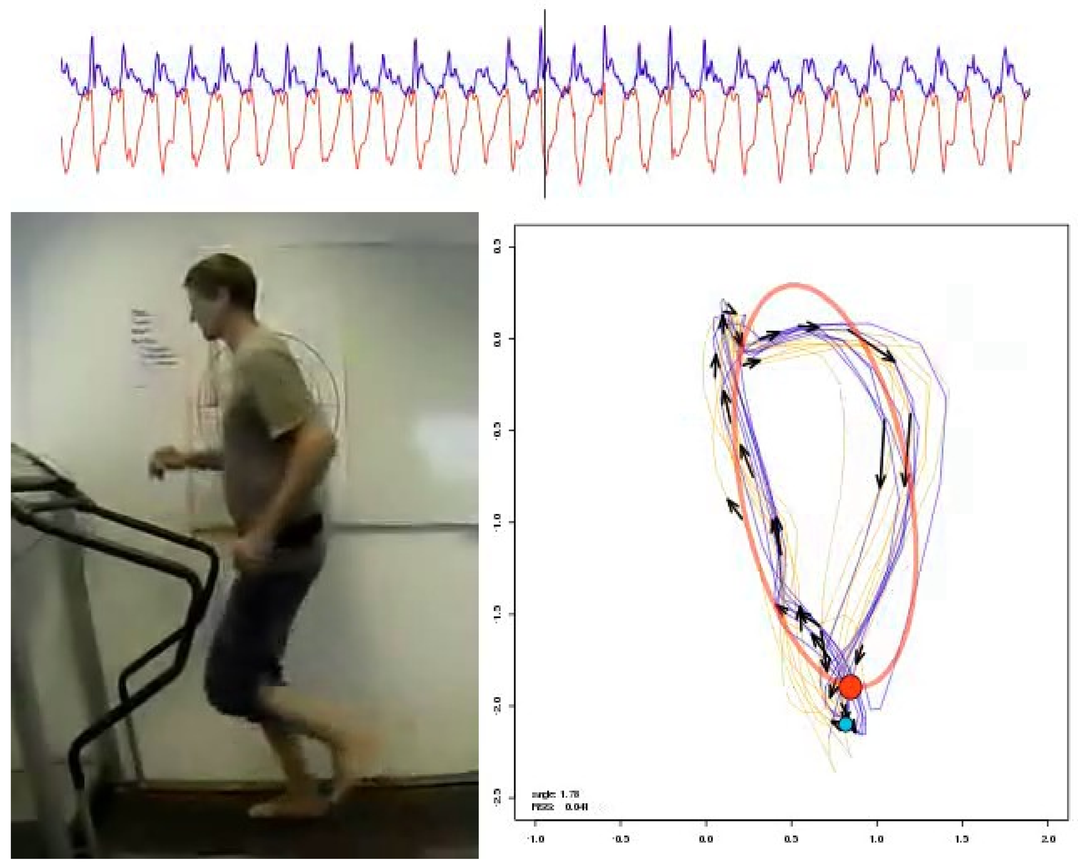

Figure 4 c) : Begin of the positive acceleration.

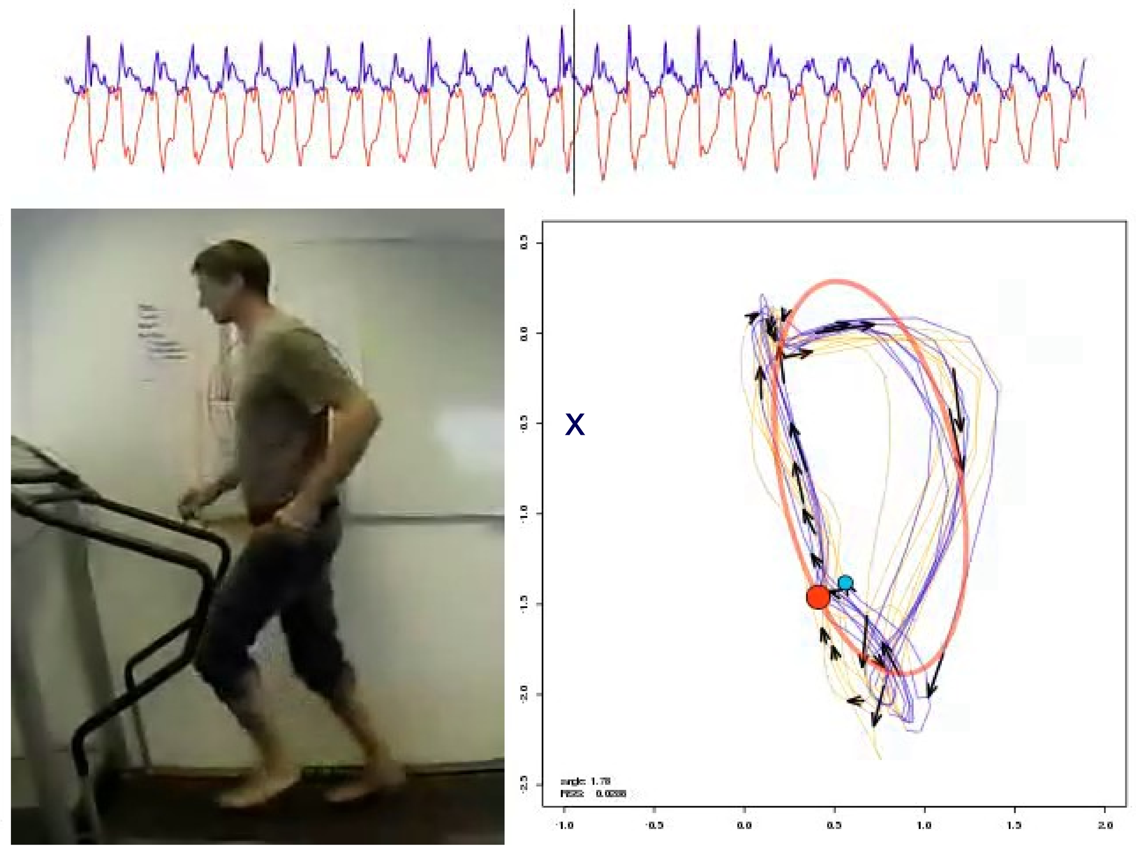

Figure 4 d): Almost in the flying phase

Figure 4 a) - d): The four different phases of running and the associated trajectory.
For different runners and running styles, different trajectories of the accelerometry data will be created.

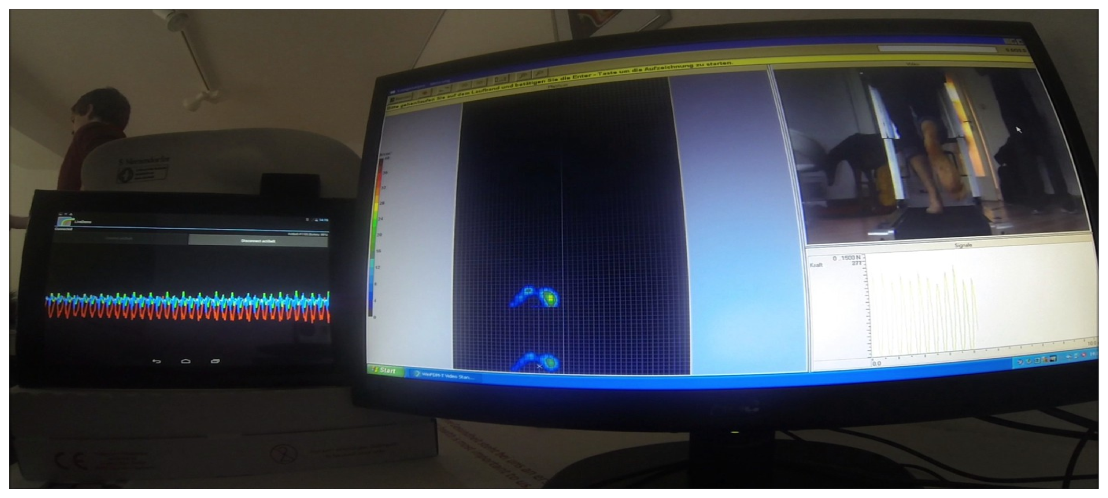

Figure 3: Heelstrikes on a pressure sensitive treadmill [6]

Results

"Traditional" approach: While significant differences in the accelerometry data of the running styles have been observed in the laboratory, those differences couldn't be reproduced in outdoor environments. Characteristic peak patterns (Lieberman, nature 463, 531-535) could be reproduced in the laboratory but disappeared in outdoor running. The most distorting aspects are the harder and less comfortable surface and an irregular speed compared to treadmill running: there is no direct link between the recorded outdoor data and the running style. The ecologic validity of laboratory experiments is not given.
New approach: With help of the "gestalt" of the trajectory we can distinguish between different runners and running styles. To measure the quality of a running style the area and inclination of the ellipse and the symmetry of the yellow and blue lines might be useful parameters.

CONCLUSIONS

Consequently it is not obvious, if Lieberman's finding concerning the relation between running style, load distribution in the joints and injury rate are valid for general outdoor running. Further research in outdoor environments is necessary to build a "big data" base of annotated accelerometry data, possibly complemented by other sensors (e.g. place in the socks) to distinguish different running styles outdoors. A promising idea to influence the running style may be to optimize the flight time as estimated by accelerometry data by increasing stride frequency, avoiding overstriding and changing to a mid/forefoot stride.

References

[1] http://www.barefootrunning.fas.harvard.edu/4BiomechanicsofFootStrike.html
[2] www.runningpad.de.
[3] http://www.thehumanmotioninstitute.org/
[4] **M. Daumer, C. Kleinmond, C. Stolle, C. Lederer, M. Hilgers, M. Walther,** Risks and benefits in transitioning to barefoot/minimal footwear running, PeerJ submitted 2014
[5] **Lieberman D et al.,** Foot strike patterns and collision forces in habitually barefoot versus shod runners, Nature 463, 531-535 (28 January 2010).
[6] **Martin Daumer, Andreas N. Schneider, Damian Mrowca, Rui Ding, Han Gao, Christian Lederer,** Meta Products towards a "gait/running style app", PeerJ preprint 2014

PeerJ PrePrints | http://dx.doi.org/10.7287/peerj.preprints.496v1 | CC-BY 4.0 Open Access | rec: 11 Sep 2014, publ: 11 Sep 2014

info@thehumanmotioninstitute.org
Contact: Dr. Martin Daumer