“Kleist”: Ideas for new parameter to measure running style

Many people prefer running to keep in shape. In recent years many self-tracking and self-optimization gadgets has become popular especially for running. We are interested in the quality of running because individual running style has an impact on the running performance as well as on the running injury risk. Hence, in order to increase the performance and lower the injury risk, runners should be educated towards a healthy running technique. Before making an advice, it is crucial to distinguish between different running styles.

“Kleist”: Ideas for new parameter to measure running style

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Background

Many people prefer running to keep in shape. In recent years many self-tracking and self-optimization gadgets has become popular especially for running. We are interested in the quality of running because individual running style has an impact on the running performance as well as on the running injury risk. Hence, in order to increase the performance and lower the injury risk, runners should be educated towards a healthy running technique. Before making an advice, it is crucial to distinguish between different running styles.

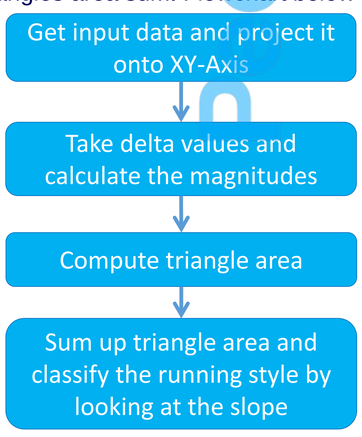
Aim

The goal is to evaluate the possibility for a running style app using accelerometer data, which is able to track and display the user’s current running style by using accelerometer data, based on which advice can be given for a healthy and efficient running style. Another field of application is purchase advise for running shoes. The feature “Kleist” could be used to find shoes with optimal damping for a runner.

Methods

Characterization of the running quality can be done by measuring the acceleration data of body center of mass (COM). In this study, we investigated a new measure called “Kleist” for qualitative classification of running styles. The measure is named after the writer Heinrich von Kleist who praised smooth body motion. In our study, we explored high quality accelerometer data for different running styles at the same velocity and same step frequency. The accelerometer data is gathered from the actibelt, an accelerometer included in a belt buckle. This sensor collects data close to the body COM in all three directions. The main focus of this work are detection and grading the different running style features, which are able to clearly distinguish different running styles. 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 discriminant feature we propose a new measure “Kleist”. The basic idea is, that perfect runner in equilibrium has acceleration zero – moving forward at constant speed. In order to classify the running style, first project the up-down movement on the y-axis and the forward-backward movement on the x-axis of a coordinate system. Take the zero-g point as the reference point such that series of measurement points will correspond to a series of triangles. After calculating and summing up areas of these triangles the running quality can be classified by looking at slope of the triangles area sum. Flowchart below show procedure of the algorithm.



$$x_i \in R^3, i = 1,2,\dots,L$$
$$x_i: row\ data;\ L: total\ nr.samples$$

$$d_{j_i} = j_{i+1} - j_i\ , j = \{x, y\}$$
$$r_i = \sqrt{x_i^2 + y_i^2};\ d_{r_i} = \sqrt{d_{x_i}^2 + d_{y_i}^2}$$

$$A_i = \frac{r_i * r_{i+1} * \sin(\alpha_i)}{2}\ , with\ \alpha_i = arccos\left(\frac{d_{r_i}^2 - r_i^2 - r_{i+1}^2}{2 * r_i * r_{i+1}}\right)$$

$$A_{sum_i} = A_{sum_{i-1}} + A_i\ , with\ A_{sum_{i-1}} = 0\ for\ i = 0$$

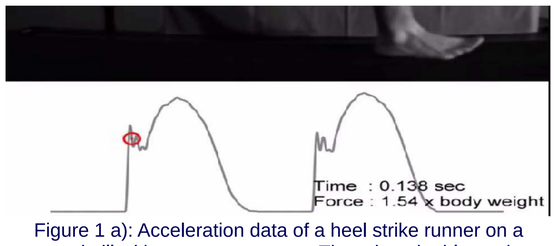


Figure 1 a): Acceleration data of a heel strike runner on a treadmill with pressure sensors. There is a double peak. Picture and graphics from [1]

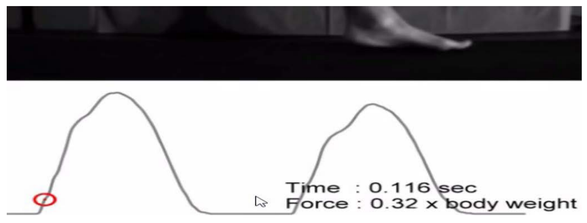


Figure 1 b): Acceleration data of a forefoot runner on a treadmill with pressure sensors. There Is no double peak. Picture and graphics from [1]

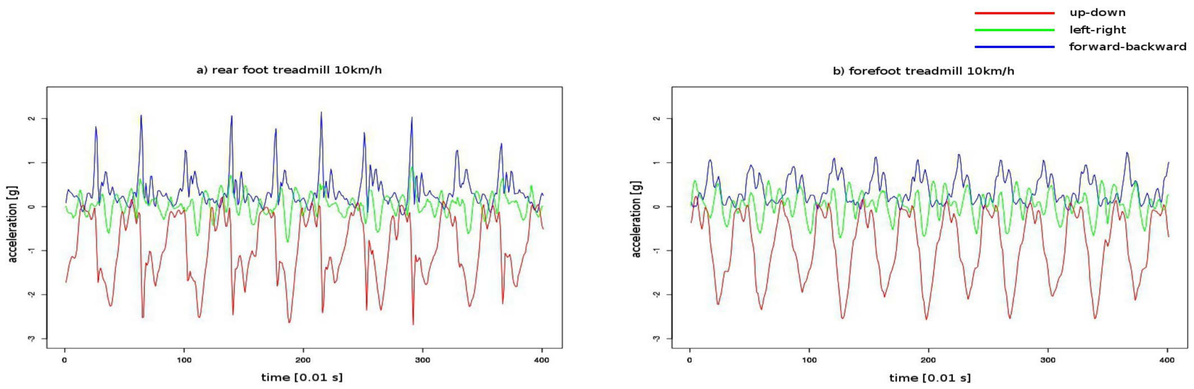


Figure 2: Accelerations as measured by a 3D-accelerometer mounted in a belt buckle. On the treadmill (a,b), the patterns in the up-down axis (red) are compatible with the ground reaction forces from Lieberman [1.

Results

We explored the discriminant power of different features and could show that Kleist provides a good separation of the different running techniques. “Kleist” separates data better by factor 1.7 compare to only using the magnitude of the acceleration. We also investigate the energy of the signal, which coincide the results came out by using “Kleist”. The steepness of “Kleist” is a valid measure for the running quality and can be used for offline and online feedback about the running quality.

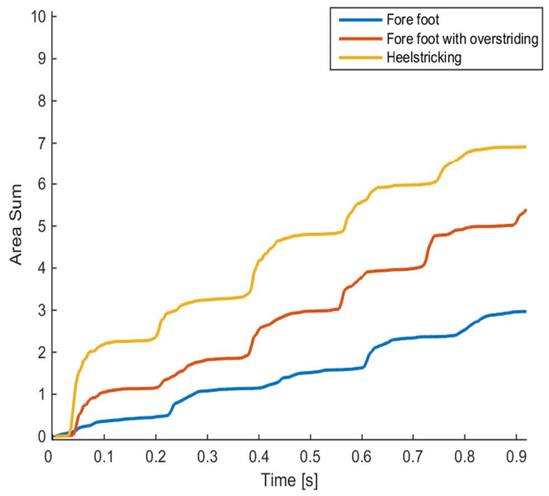


Figure 3: Detailed slope information of three different running styles.

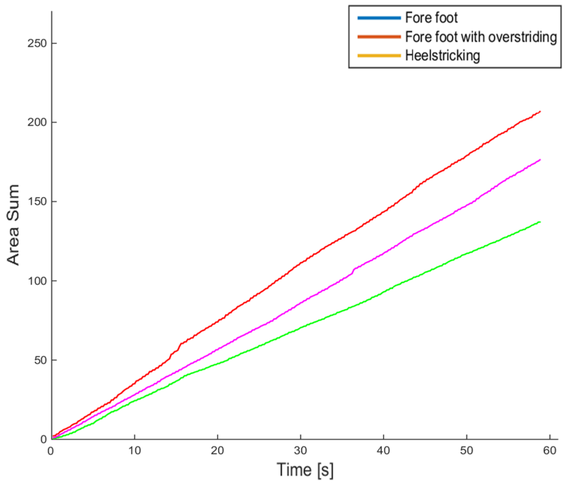


Figure 4: Clear distinction between fore foot, fore foot with over striding and heel striking

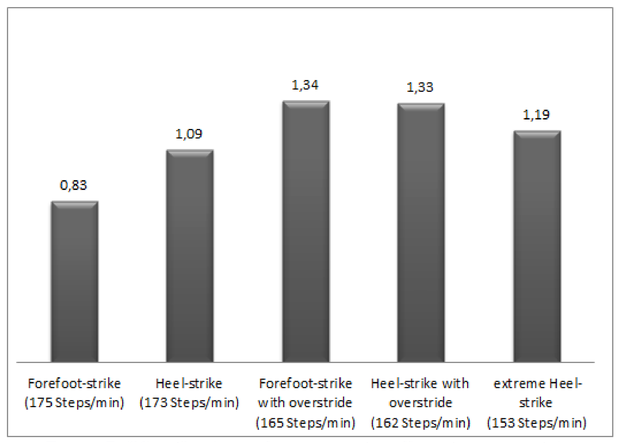


Figure 5: “Kleist” values of runners with different running style

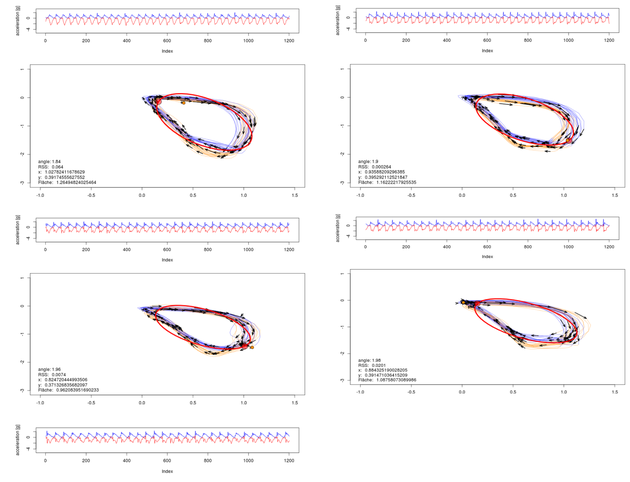


Figure 6: 2D-acceleration projection
a) Fore-foot strike
b) Heel strike
c) Fore-foot strike with over-stride
d) Heel strike with over-stride
e) Extreme heel strike

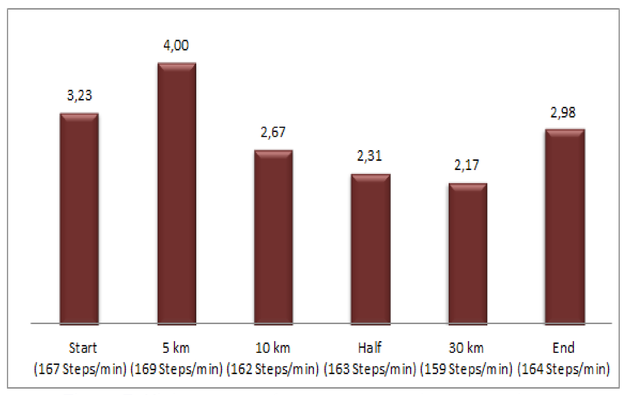


Figure 7: Kleist per step for a person running a marathon with variable speed in each split

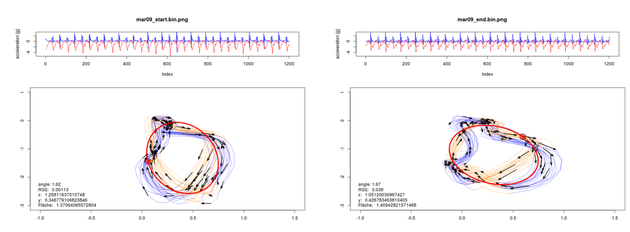


Figure 8: 2D-acceleration projection: start and end of the marathon

CONCLUSIONS

In our study, we showed promising results for classification of running quality by using the measure “Kleist”. Further research in outdoor environments is necessary to build a “big data” base of annotated accelerometer data, possibly complemented by other sensors (e.g. place in the socks) to distinguish different running styles outdoors.

References

[1] http://www.barefootrunning.fas.harvard.edu/4BiomechanicsofFootStrike.html
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[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
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[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

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