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**Easy to use accurate measuring system
for cycling pedaling motion using a small LED and a smartphone.**

Masahiro Fukuda[1,2], Tomoki Kitawaki[1].
[1] Department of Mathematics, Kansai Medical University, Osaka, Japan,
[2] Hamster Spin, Tokyo, Japan.
Contact e-mail: info@hamsterspin.com

Introduction:

In recent years pedaling torque can easily be measured along with pedaling power using a pedaling monitor system (i.e. Pioneer Pedaling Monitor System). Measuring pedaling torque with such system has made it clear that each zone in a pedaling revolution has several different torque patterns even in the same cadence.

Last year we reported that heel motion affects torque patterns, by measuring the foot angle between pedal axle and heel position using a simple marker. (Fukuda et al., 2018).

However, the simple, non-light-emitting marker we used in the previous study often made obtaining accurate pedaling parameters challenging.

Other measuring methods can overcome the problem we encountered with our marker, however with their limitations. Motion capturing systems including 3D cameras and LED systems (i.e. Retul) can measure pedaling motions with high accuracy. However, the system is expensive and also requires a large space, therefore not suitable for the use in the training context. More simplified (however more complex than our previous marker) systems are also available (e. g. Bike Fast Fit), however the accuracy is low.

In this study, we aim to solve these issues and develop a more easy-to-use system that can measure motion with high accuracy. We demonstrated that a system equipped with a cheap LED and a built-in slow-motion camera of a generic smartphone could track pedal and heel position accurately.

Methods:

Subjects: Three riders took part in the experiment as the subject. They are asked to pedal for one minute, each in 200W and 300W of pedaling power.

Measurements: We recorded 720p HD/120 fps movie with iPhone SE of Apple Inc. The smartphone was set horizontally on a tripod.

Development of analysis software: We developed our analysis software upon OpenCV (Open source computer vision) and Python language.

Fig 1. LED and position.

Measurement Equipment: In order to track foot movement, we need "feature points" in an image. In this study, we used a green LED as a feature point (fig.1). For feature points we can use several types of markers; however, non-light-emitting markers change colors in a movie depending on the lighting. Therefore we used LED instead as a light-emitting marker. When we used the LED marker, just by making the room darker, we can easily detect the position of "feature points" more precisely. During the measurement, we placed the foot close to the top dead point so that we could easily identify BB, pedal and heel markers.

Analyze: Each marker was detected frame by frame in the movie, and was compared against the marker in the previous frame image to calculate the movement. After calculating the movement of each marker, we calculated the crank angle by the pedal position of BB center and calculated angle displacement by pedal and heel position. Based on this method, the crank angle was deemed an absolute value while the heel angle was a relative value. The software enabled us to generate and store a stationary image where all the marker positions from all frames are overlapped. What it achieves is a visualization of foot orbit, which allows us to grasp the movement more intuitively.

Result & Discussion:
The analysis of the pedaling of three subjects showed that their movement patterns are all different. Also, as Fig 2. Shows, within the same rider, pedaling has fluctuated with every rotation, in a short measuring period of 1 minute. Also, their pedaling patterns differ depending on the power output they were asked to realize (200W, 300W).

The system we developed in the current study has achieved sufficient accuracy; however, because this is a 2D imaging, the angle of a rider and the camera and lens aberration can cause distortion. Our future study needs to consider algorithms to correct these distortions.
Also, increased pedaling power causes bicycles to vibrate. This issue also needs to be addressed.

Fig 2. Pedal axle and heel movement (1min, 200W)

Conclusion:
In this study, We improved the system that measures pedaling skills and increased the accuracy of detecting movement pattern using LED markers. Although we already know that heel motions affect pedaling torque and power, the easy and accurate measurement of foot orbit we achieved in this study will shed more like on the correlations between heel motion and torque in a crank revolution Lastly, it is also our scope to develop and publish a smartphone application of this motion measurement system.

References:
Fukuda et al.(2018), Connection between Heel Motion and Torque in crank revolution. J Science & Cycling, Vol7 No2(2018)