https://nbn-resolving.org/urn:nbn:de:bsz:ch1-qucosa2-806704

Practical studies on bike fitting – A biomechanical and physiological analysis under the influence of fatigue

Jonas Dully[1], Eva Bartaguiz[1], Carlo Dindorf[1], Stephan Becker[1] and Michael Fröhlich[1]

[1]Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Abstract

Bike fitting can have a major impact on the performance of cyclists (Bateman, 2014) and can reduce the risk of non-traumatic injuries (Bini et al., 2011). This study shows significant changes in lower body biomechanics of road cyclists during and after fatigue and therefore expands the research from a more practical view. These findings support the expansion of future research using sensor-based analyses of road cycling (e.g., IMUs, oxygen saturation).

Keywords: bike fitting; cycling; movement analysis; fatigue; lower body biomechanics

Introduction

In road cycling it is important to ride as economically as possible because over the course of a cycling stage, any energy saved due to an improved position might help to improve one's overall competition performance (Bateman, 2014) and reduce the risk of non-traumatic injuries (Bini et al., 2011). Regarding the practical application of bike fitting there seem to be no consistent standards on how to perform this (Bini et al., 2014). Occasionally, dynamic bike fitting is performed using submaximal loads perceived as habitual using stationary optical 2D or 3D-systems. Most research has focused on evaluating the efficiency of a seating position at a submaximal load perceived as habitually comfortable (Bini et al. 2014). However, if the relevant angles of the lower body are dependent on different riding intensity levels and the fatigue status, the determination of a position at a fixed submaximal load would underrepresent the real complexity. Cockcroft (2011) proposes that inertial measurement units (IMUs) may have the potential to track the rider's movement in training and competition and may therefore be more realistic than optical 2D/3D methods.

According to the abovementioned aspects, there is a lack of research regarding the influence of a realistic setting in the biomechanics of road cycling. Therefore, this study aimed to determine if different riding intensity levels relative to the individual anaerobic threshold (IAT) result in changes in the biomechanics of the lower body.

Methods

Six well-trained male road cyclists (age: M = 27.17, SD = 3.89 years; height: M = 180.41, SD = 5.31 cm; weight: M = 75.23, SD = 4.91 kg) with M = 8.33 and SD = 4.85 years of (professional) experience in road cycling underwent a dynamic 2D analysis on the bike. Videos were recorded for both sides in the sagittal plane during the test with two iPads (seventh generation, Apple, Cupertino, USA/CA) at 120fps as suggested by Bini et al. (2014). For all the subjects, a knee angle in a 90° position crank position, as well as the knee position in relation to the pedal axis, met the selected reference values (knee angle: 110°-115° in a 90° position; axis of the knee vertically above the pedal axis (Bini et al., 2014). The 90° position was selected for (pre-) evaluation as the forces present in the patellofemoral area are greater than those in the 180° position. The 180° position was additionally used for the following analysis, as it is the most commonly used in bike fitting practices and in other studies (Bini et al., 2011). After the pre-evaluation of the position on the bike, the subjects performed a lactate stepwise incremental test, starting with 100W and an increment of 20W for each time 3min until total exhaustion (Wahl et al., 2017). After reaching exhaustion, the cyclists had a short period of 5min of active regeneration, with low resistance selected as habitually comfortable. After this regeneration the subjects rode an increment of 50W every 3min, starting again with 100W and ending with 250W.

Fig. 1 Measuring procedure and angle definition (metatarsophalangeal joint, the lateral malleolus, the lateral part of the articulatio genus and the trochanter mayor)

For the lower body biomechanics, we focused on the knee and ankle angles, as shown in Fig. 1, because these were observed in most of the previous studies and are of high practical relevance (Swart et al., 2019). The calculations of the joint angles were based on those of Bini et al. (2014). Lactate was measured using a lactate-scout (EKF Diagnostics, Barleben, Germany) and the heart rate with a Polar V800 (Polar Electro, Kempele, Finland) with the matching pulse sensor. The angles were determined using Dartfish ProSuite 8.0 (Dartfish, Freiburg, Switzerland). Three images were selected for each position for each measurement point. The mean values of the three images separately for 90° and 180° positions were used for further calculations. To allow a comparison of the subjects, (a) the power output relative to the individual anaerobic threshold (IAT) was determined. Furthermore, (b) standardized angles were calculated by dividing each angle by the mean angle for the measurements under the IAT (assuming that the angles below the IAT were likely to be relatively similar due to lower fatigue). To answer the research question, the lower body biomechanics of the standardized angles depending on of the relative power output were modelled using linear regression. Outliers were removed if the values reached three times the interquartile range. Calculations were performed using Python (Python Software Foundation, Wilmington, DE, USA) and SPSS Statistics (version 16, SPSS Inc., Chicago, USA).

Results

The test was terminated after total subjective exhaustion (power output: M = 373.30, SD = 37.70 W; lactate: M = 11.58, SD = 2.82 mmol/l; heart rate: M = 186, SD = 16 1/min). The results showed that side asymmetries for the knee and foot relative to the IAT were present. When riding at 80% of the IAT the lowest mean absolute differences for the knee in the 180° position (*M* = 2.98, *SD* = 1.31°) were found. The highest mean absolute side differences were found for the foot in the 90° position (*M* = 5.89, *SD* = 4.85°). Exemplary results for the regression models and visualizations of the changes in knee and foot angles during the progressive intensity increase are presented in Fig 2.

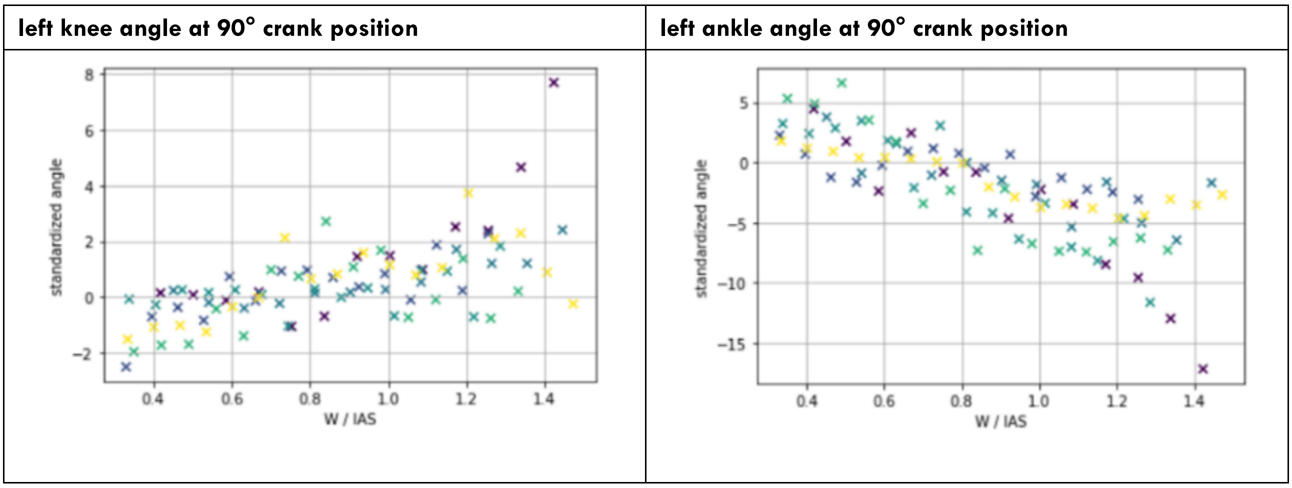

Fig. 2 Changes in the standardized angle (y-axis) relative to each subject's power output in relation to the IAT (x-axis). A value of 0 represents the mean angle of all the measurements (individually per subject) under the IAT. The colour code encodes the individual athletes.

Table 1 Regression models for each angle (L=left; R=right; K=knee; a= ankle)

	90°	180°
LK	$F(1, 85)=55.47$, $p<.001$; $R^2=.40$; $y=1.719+2.497*x$	$F(1, 83)=64.70$, $p<.001$; $R^2=.44$; $y=-2.903+4.383*x$
LA	$F(1, 85)=124.74$, $p<.001$; $R^2=.59$; $y=6.277-9.504*x$	$F(1, 85)=27.64$, $p<.001$; $R^2 = .25$; $y=4.078-6.243*x$
RK	$F(1, 84)=74.79$, $p<.001$; $R^2=.47$; $y=-2.039+3.057*x$	$F(1, 84)=14.85$, $p<.001$; $R^2=.15$; $y=-2.061+3.059*x$
RA	$F(1, 86)=49.78$, $p<.001$; $R^2=.37$; $y=6.306-9.135*x$	$F(1, 83)=9.00$, $p=.004$; $R^2=.0.10$; $y=2.487-3.769*x$

The regression models for the respective knee and ankle angles in the different positions showed similar results (Table 1). All the regression models were significant ($p \leq .04$). However, the quality of the fit (R^2) showed that the right knee and left ankle in the 180° position had a noticeably low R^2 ($R^2 < .25$) as compared to the other models ($R^2 \geq .37$), which can all be classified as a strong effect.

Discussion

The current study results showed that with a higher power output relative to the IAT, the joint angles changed significantly. Overall, the knee angles increased while the foot angles decreased. These findings are in accordance with the findings of Swart et al. (2019). Under the IAT, the differences between the respective angles appeared to be almost linear, while with higher levels of fatigue, the differences changed drastically and seemed to be non-linear. This may have been caused by different muscle exhaustion and compensation mechanisms, which seem to be highly individual in the subjects due to their individual physical capacities or additional factors (e.g., pain, limited flexibility, or the presence of side asymmetries). Nevertheless, the individuality of these changes underlines the recommendation for bike fitting conditions to be more realistic.

Taking sensor-based measurements into account could greatly change the field of bike fitting. Optical analysis has significant when measuring the biomechanics of road cycling as the settings in laboratories are not comparable to practical training and competition. Therefore, the use of IMUs to monitor the movement during cycling should be considered as these sensors promise to be valid and to be able to reliably track movements in the field (Teufl et al., 2019). In summary, there is a large quantity of data due to the different technologies available that can be used to describe the biomechanical and physiological states of a cyclist and can therefore help improve bike fitting as well as road cycling practice. Additional research should be carried out combining the different technologies, e.g., power output, pedal forces, near infrared spectroscopy, or sweat measurements, with the suggested use of IMUs to give direct feedback, reduce the risk of non-traumatic injuries, and further optimize the road cycling performance.

Conflict of interest We declare no conflicts of interest.

Funding This work was funded by Offene Digitalisierungsallianz Pfalz, BMBF [03IHS075B].

References

Bateman, J. (2014). Influence of positional biomechanics on gross efficieny within cycling. *Journal of Science & Cycling Book of Abstracts, 3*(2), 4.

Bini, R. R., & Carpes, F. (2014). Joint Kinematics. In R. R. Bini, & F. P. Carpes, *Biomechanics of Cycling* (S. 33-42). Heidelberg: Springer. doi:10.1007/978-3-319-05539-8_3

Bini, R., Hume, P. A., & Croft, J. L. (2011). Effects of bicycle saddle height on knee injury risk and cycling performance. *Spoorts Medicine, 41*(6), 463-476. doi:10.2165/11588740-000000000-00000

Cockcroft, S. J. (2011). An evaluation of inertial motion capture technology for use in the analysis and optimization of road cycling kinematics. Stellenbosch: Stellenbosch University: Faculty of Engineering. doi: 10.1055/a-1738-0252

Swart, J., & Holliday, W. (2019). Cycling Biomechanics Optimization—the (R) Evolution of Bicycle Fitting. *Current Sports Medicine Reports, 18*(12), 490-496. doi:10.1249/JSR.0000000000000665

Teufl, W., Taetz, B., Miezal, M., Lorenz, M., Pietschmann, J., Jöllenbeck, T., Fröhlich, M., & Bleser, G. (2019). Towards an Inertial Sensor-Based Wearable Feedback System for Patients after Total Hip Arthroplasty: Validity and Applicability for Gait Classification with Gait Kinematics-Based Features. *Sensors, 19*(22), 1-20. doi:10.3390/s19225006

Wahl, P., Manunzio, C., Vogt, F., Strütt, S., Volmary, P., Bloch, W., & Mester, J. (2017). Accuracy of a modified lactate minimum test and reverse lactate thershold test to determine maximal lactate steady state. *The Journal of Strength & Conditioning Research, 31*(12), 3489-3496. doi:10.1519/JSC.0000000000001770