COMPARISON OF BIOMECHANICAL DATA OF A SPRINT CYCLIST IN THE VELODROME AND IN THE LABORATORY

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The aim of this study was to develop a reliable testing method to measure biomechanical variables that describe sprint cycling performance on a velodrome track, compared to on an ergometer in a laboratory. Seven elite track sprint cyclists performed sprints on an isokinetic ergometer in a laboratory and over half lap distances in a velodrome. Key biomechanical variables characterising sprint cycling were measured. Relatively small differences in the variables were found between the ergometer and track sprints. However, the static task constraints of ergometer cycling led the cyclists to adopt a different position which seemed to allow them to increase overall power output and rate of force development. Future research is needed to assess whether the differences in joint angles and crank powers were due to the different environmental and task constraints between the ergometer and the track bicycle sprints.

KEYWORDS: track sprint cycling, ergometer cycling, representative experimental design, maximal power.

INTRODUCTION: In biomechanics research the measurement of key variables in sport performance are typically undertaken in laboratory settings, although some previous studies have revealed differences with measures recorded in a performance environment: in diving and running (Barris, Davids, & Farrow, 2013; Button, Moyle, & Davids, 2010). Brunswick (1956) proposed the concept of *representative experimental design*, referring to the design of experimental task constraints so that they represent the behavioural setting to which the results of an investigation are intended to be generalised (Brunswick, 1956; Pinder, Davids, Renshaw, & Araujo, 2011). These differences raise questions of specificity of movement coordination measures recorded under certain laboratory task constraints (e.g., when using ergometers or treadmills), compared to the performance environment.

To exemplify, in biomechanical analyses of cycling performance, most studies have investigated movement behaviours on an ergometer fixed in a laboratory, which is not representative of cycling on a track. The theory of ecological dynamics proposes the importance of studying athlete behaviours under specific environmental and task constraints that faithfully simulate competitive performance, because differences in task constraints between laboratory ergometers and a velodrome track may impact cycling performance. In previous work, Gardiner and colleagues compared maximal torque- and power-pedalling rate relationships between sprints on an inertia ergometer and when cyclists performed a standing start 65m on a velodrome track. They found similar relationships between laboratory and field data, concluding that ergometer data can be used to model sprint cycling performance (Gardner, Martin, Martin, Barras, & Jenkins, 2007). However, they did not record detailed biomechanics variables such as joint angles, angular velocities and powers that characterise intermuscular coordination in sprint cycling.

The purpose of this study was to develop a reliable testing method to measure biomechanical variables that describe elite sprint cycling in a velodrome, and compare results to performance on an ergometer in a laboratory.

METHODS: Participants were seven elite track sprint cyclists: 2 males (age: 18yr, body mass: 81.3 ± 12.8 kg; height: 1.84 ± 0.02 m, flying 200m PB: 10.6 ± 0.3 s), and 5 females (age: 18 ± 0.7yr, body mass: 68.9 ± 6.9 kg, height: 1.63 ± 0.07 m, flying 200m PB: 11.6 ±

0.4 s). Participants were provided with study details and gave informed consent. The study was approved a university ethics committee.

An isokinetic ergometer was set up to replicate each participant's track bicycle position, with a crank length of 165mm. Riders undertook their typical warm-up on the ergometer for at least 10 mins, before performing 3 x 4 s seated sprints at a pedalling rate of 135rpm on the isokinetic ergometer (SRM Ergometer, Julich, Germany) with 4 minutes recovery between efforts. All participants had previously undertaken sprints on the isokinetic ergometer, so were familiar with the protocol. On the track, riders undertook their typical warm-up on their track bicycle on rollers for 10 mins, before performing 3 seated half lap sprints, motor paced up to a speed of 62.5km/h before starting the half lap effort. Participants typically had 4 minutes recovery between efforts, and laboratory and track sessions were conducted either on the same day or a day apart.

The isokinetic ergometer had been modified so the flywheel was braked by a motor to control pedalling rate effort. Participants commenced their bouts at the target pedalling rate, rather than expending energy in accelerating the flywheel. The ergometer was fitted with Sensix force pedals and a crank encoder, sampling data at 200Hz (Model ICS4, Sensix, Poitiers, France). Normal and tangential pedal forces were resolved using the crank and pedal angle into the effective (propulsive) and ineffective (applied along the crank) crank forces.

In the laboratory two-dimensional kinematics of the participants' left side were recorded using high speed cameras with infra-red ring lights at 100Hz (Quintic, Coldfield, UK). Reflective markers were placed on the pedal spindle, lateral malleolus, lateral femoral condyle, greater trochanter and acromion. Kinematics and kinetics on the ergometer were recorded by CrankCam software (CSER, SHU, Sheffield, UK) which synchronised the camera and pedal force data and was used for data processing to carry out inverse dynamics analysis.

On the track the two-dimensional kinematics of participants' left side were captured using 8 Qualisys Opus 7+ cameras, recording at 200Hz (Qualisys, Gothenburg, Sweden). Cameras were located in the track centre and covered a capture volume of 14m along the black line from pursuit line to start of the bend. The same marker set as used in the laboratory was supplemented with five markers to the left side of the bicycle frame to define the bicycle reference frame (rear wheel axle, seat stay, seat tube, downtube, front wheel axle). A left force pedal (Sensix) with a pedal strap was fitted to the riders' track bicycle. A cable ran from the pedal to a backpack containing a junction box and Wi-Fi NIDAQ to transmit data from the force pedal to a laptop. The cable was attached to the riders’ leg using Velcro straps.

All kinetic and kinematic data were filtered using a Butterworth 4th order low pass filter with a cut of frequency of 14Hz. Crank power was calculated from the product of the left effective crank force and the crank angular velocity. To calculate average crank power per revolution the left crank power was multiplied by two assuming both sides produced equal power. Using pedal forces and limb kinematics, joint-specific moments were calculated via inverse dynamics. Segmental mass, moments of inertia and location of centre of mass were estimated using the regression equations of De Leva (De Leva, 1996). Joint powers at the ankle, knee and hip were determined by taking the product of the net joint moment and joint angular velocity. The pedal power was calculated from the sum of the joint powers.

Data were analysed using a custom Matlab script. Each laboratory sprint lasted for 4 s providing six complete crank revolutions which were resampled to 100 data points around the crank cycle. The joint angles, angular velocities and powers were averaged over these revolutions to obtain representative values for each trial on the ergometer.

Track kinematics and kinetics were processed using a similar method used for the analysis of laboratory sprints. However, as the bicycle moved through the capture volume, marker trajectories were converted to a local coordinate system relative to the bicycle to match the laboratory coordinate system. The track force pedal data were synchronised with kinematic data using a Pearson’s correlation to find the best match of the pedal angle measured by the force pedal encoder during the 3 heel raises, with pedal to ankle angle measured by the motion capture system. It was not possible to fit a crank encoder to a track bicycle due to the type of bottom bracket; therefore, the crank angle was calculated from the pedal marker trajectory.

Due to the small capture volume of the cameras, only 1 revolution (7.93 m distance) for each trial was captured. Therefore, the mean values of the joint angles, angular velocities and powers for the track session were calculated from 3 revolutions, compared to the sprints on the ergometer which were calculated from 18 revolutions.
Differences between pedalling rate and mean crank powers for the ergometer and track sprints were assessed using a paired t-test. Differences between joint angles, angular velocities and powers for laboratory and track conditions were assessed using Statistical Nonparametric Mapping paired t-tests (Pataky, 2010). Level of statistical significance was set at p=0.05.

RESULTS: The mean pedalling rate for the sprints in the laboratory was 135.4 (1.2) rpm and for track 138.0 (1.4) rpm ($t_{(6)}$=-3.27, p=0.017). The mean crank power for the sprints in the laboratory was 1038 (155) W and for track 878 (110) W ($t_{(6)}$=5.20, p=0.002).

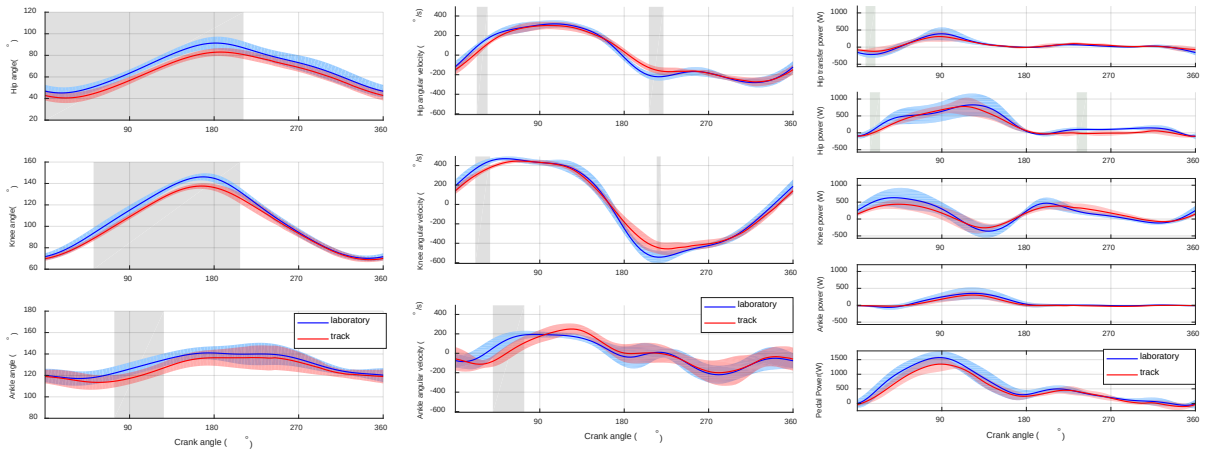

Figure 1: Comparison of mean joint angles, angular velocities and powers for the ergometer and the track sprints. Areas of the graph shaded grey where the non-parametric SPM is significant.

The joint angles were significantly different (p<0.05) between the ergometer and track sprints for parts of the crank cycle (ankle 74° to 126°, knee 51° to 208°, and hip 0° to 211°). The joint angular velocities were significantly different (p<0.05) between the ergometer and track sprints for small proportions of the crank (ankle 40° to 73°, knee 21° to 37° and 215° to 219°, and hip 23° to 34° and 206° to 222°). Only the hip joint power and hip transfer power were significantly different (p<0.05) between the ergometer and track sprints for small proportions of the crank (hip 13° to 24° and 234° to 245°, hip transfer 9° to 19°).

DISCUSSION: Cyclists produced higher crank power on an isokinetic ergometer than in the flying half lap efforts on the track. There was a higher peak pedal power and rate of force development for the ergometer sprints. When sprinting on the ergometer, the riders only have to focus on producing maximum power, whereas on the track they also have to control the bicycle direction and stability whilst trying to produce maximal power (Gardner et al., 2007), which may be a limiting factor in producing maximum power on track.
For the ergometer sprints the cyclist's hip, knee and ankle angles were larger during the downstroke, signifying they were pedalling with a straighter leg. On the ergometer participants displayed a tendency to hover over the saddle possibly because they did not have to control stability and direction of a moving bicycle. This altered riding position potentially allows them to produce more crank power on the ergometer. The altered environment and task constraints for the track sprints (for example: the control of a moving bicycle, the banking of the track, environment the velodrome) may have influenced the joint angles and rider position, however further research is required to investigate how these constraints cause the changes in rider position. There are some differences in joint angular velocities and powers between the ergometer and track sprints, however only statistically

significant for small proportions of the crank cycle in part due to between participant variability and the small sample size.
The differences between the mean pedalling rate for the ergometer and track sprints were statistically significant. However, a change of pedalling rate of 2.6 rpm is small enough not to influence the joint angles, angular velocities and powers (Dorel et al., 2005; McDaniel, Behjani, Elmer, Brown, & Martin, 2014).
The finding that cyclists produced higher crank power on an ergometer than on the track is incongruent with data reported by Gardiner and colleagues who found similar peak power values between ergometer and track sprints, with considerable individual variability (Gardner et al., 2007). However, their experimental protocol was different to the current study. They used an inertial load ergometer in the laboratory, and laboratory and track efforts were both from a standing start, so the power was measured during the acceleration phase. They also recorded power data using an SRM power meter which only samples at 5Hz (Gardner et al., 2007), whereas the Sensix force pedals used in the current study sampled at 200Hz.
The isokinetic ergometer was set up to match the riders' track bicycle using the same force measurement system. The type of track effort was chosen as it was most similar to the sprint on the ergometer.
Further research is needed to investigate differences between cycling on an ergometer and a track bicycle using a larger sample of participants and observing a greater number of crank revolutions of track data.

CONCLUSION: There are relatively small differences in movement organisation between sprinting on a velodrome track and on an ergometer. However, the riders adopted a different pedalling position on the fixed ergometer compared to the track where they needed to also control the stability and direction of the bicycle. The on-track data collection method has the potential to be a useful tool to help coaches assess pedalling on a track. The findings imply it is important to undertake biomechanical analyses of movement organisation in elite sports practice in a representative environment.

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