TITLE

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Abstract

Nowadays, fixed gear competitions on outdoor circuits such as criteriums are regularly organized worldwide. To date, no study has investigated this alternative form of cycling. The purpose of the present study was to examine fixed gear performance indexes, and to characterize physiological determinants of fixed gear cyclists. This study was carried out in two parts. Part1 (n = 36) examined correlations between performance indexes obtained during a real fixed gear criterium (time trial, fastest laps, averaged lap time during races, fatigue indexes) and during a sprint track time trial. Part2 (n = 9) examined correlations between the recorded performance indexes and some aerobic and anaerobic performance outputs (VO_{2max}, maximal aerobic power, knee extensor and knee flexor maximal voluntary torque, vertical jump height, and performance during a modified Wingate test). Results from Part1 indicated significant correlations between fixed gear final performance (i.e. average lap time during the finals) and single lap time (time trial, fastest lap during races and sprint track time trial). In addition, results from Part2 revealed significant correlations between fixed gear performance and aerobic indicators (VO_{2max} and maximal aerobic power). However, no significant relationship was obtained between fixed gear cycling and anaerobic qualities such as strength. Similarly to traditional cycling disciplines, we concluded that fixed gear cycling is mainly limited by aerobic capacity, particularly criteriums final performance. However, specific skills including technical competency should be considered.

Keywords: Strength; aerobic fitness; competition

Introduction

Fixed gear is a relatively new cycling discipline consisting of riding track bicycles outdoors on roads, streets or circuits. Bicycles are brakeless, without freewheel, relying on one speed only. Without any official instances, numerous competitions are organized worldwide. One competition format is the criterium, which takes place in short closed circuits (< 2 km) with several turns, accelerations, and decelerations. Usually, competitions are composed of different steps such as qualifications (one lap), heats (< 20 minutes) and finals (> 40 minutes).

According to the competition format, the aerobic system should play a major role in fixed gear performance (Craig & Norton, 2001). Indeed, cycling performance < 90 minutes was shown to be strongly correlated to the maximum power output, and power at lactate threshold (Bentley, McNaughton, Thompson, Vleck, & Batterham, 2001). Anaerobic power was also found to be an important factor in cycling performance (Baron, 2001; Inoue, Sá Filho, Mello, & Santos, 2012). As a consequence, it could be speculated that the energy used during fixed gear criteriums would be mainly derived from both aerobic and lactic anaerobic systems.

However, fixed gear cycling specificity and the competition format require: (i) pedalling constantly, (ii) regularly braking bicycles via isometric or eccentric muscle actions, while blocking or slowing down the rear wheel, respectively and (iii) regularly re-accelerating that requires other specific physical attributes such as muscle strength. Sprint cycling, for instance, was shown to be strongly associated to maximum and explosive strength (Stone et al., 2004). More specifically, high eccentric strength levels may characterise fixed gear riders who frequently need to brake the bicycle. These frequent actions could influence muscle fatigue (Garrandes, Colson, Pensini, & Legros, 2007). Finally, one should acknowledge that cyclists require excellent technical and tactical skills to control and stabilize the bicycle during frequent direction changes.

However, to date no study investigated fixed gear cycling. Consequently, the aim of this study was to examine fixed gear performance indexes and to describe the physiological determinants of fixed gear cyclists. According to the multifactorial nature of fixed gear cycling, we hypothesized that performance requires both strength (to decelerate and accelerate bicycle for direction changes) and anaerobic and aerobic attributes (for long-duration cycling). For that purpose, we tested potential relationships between performance indexes obtained during a real fixed gear criterium, measurements of maximal and explosive strength, anaerobic power, and aerobic capacity.

Methods

Study overview

This study was divided into two distinct parts. Part1 consisted in analysing results from a fixed gear competition, namely ‘the National Moutarde Crit #5’. Part2 consisted in analysing results from the same fixed gear criterium followed by aerobic and anaerobic physical performance measurements. Riders were compared as a function of their results during the main race day, and correlations were made to establish performance determinants. This study was conducted according to the declaration of Helsinki, and approval for the project was obtained from the local Institutional Review Board.

Participants

Part1 involved the analysis of publicly available results of a fixed gear criterium. Accordingly no consent was required. Data were retrieved from the online competition datasheet and from direct contact with the race director. Based on the competition results, values were extracted from the 39 riders that competed during the two events (see below). Twenty-two were in the superfinal, 14 in final A, and three in final B. Due to huge differences between riders, values from the riders in final B were excluded from analysis. A total of 36 riders were considered.

Part2 included nine-male fixed gear riders. Fixed gear experience was depicted using a short survey to determine history (i.e. years of practice), fixed gear bicycles use (i.e. exclusive, recurrent or occasional with practice > 75% of all cycling types, ranging from 50 to 75% or < 50%, respectively), and estimated kilometres per week. Participants were all free of injury within the three months preceding the experiment. All read and signed a written informed consent document outlining the procedures of the experiment. This experiment was conducted during three different sessions. The first session consisted in the fixed gear competition. After at least one-week recovery and during the following month, individuals were tested in two separate occasions. One session was dedicated to a maximal aerobic power test. The other session was used to evaluate power during maximal vertical jumps, strength of the leg extensor and flexor muscles, and a modified anaerobic cycling power test in that order. The two tests sessions were randomized with at least one week in-between. Participants were requested to abstain from any fatiguing exercise, and to have similar food/drink intake during the 24h before each testing session.

Fixed gear competition (Part1 and Part2)

The main fixed gear competition, ‘the National Moutarde Crit #5’ took place in Dijon on September the 9th 2017. This competition included ~180 males from 15 different countries (women races were also performed but not considered here) involving top-class cyclists. The track was flat, 980 m long with eight turns (Figure 1). The competition included three different stages: 1. time trial, 2. heats and, 3. finals. All stages were performed after a free warm-up generally including cycling on a roller (lasting various durations), and cycling on the competition track during 10 to 15 min. Time trial was performed individually. Riders had to perform one lap as fast as possible starting from a stationary position with feet set on the pedals. Cyclists were held by one of the competition organizers. Heats consisted in five laps performed by groups of 40 riders. The position on the starting grid was dependent on the time trial performance. Finals and starting positions during finals were dependent on the performance during heats. Lap numbers were different according to the finals considered (28, 22 and 18 laps for the superfinal, final A and final B, respectively). During such a competition, riders were stopped when the leader of the race was close to them (i.e. no late lap was allowed). At least 90 minutes rest was allowed between each stage of this competition. Riders used their own bicycles (track bikes) with no brakes. They were free to choose their own development ratio (generally 48 x 14). From this competition, the time trial, the time of the fastest lap for each stage, the average lap time (total time divided by lap numbers) during heats and finals, and lap numbers during finals were extracted. Average lap time was used for analysis due to the fact that riders had different lap numbers. Also, to provide a fatigue index (i.e. decline in cycling velocity over a race) the percentage difference between the fastest lap and average lap time was calculated during heats and finals.

The day after this main event, some riders participated in a second competition on an outdoor bike track (250 m). It consisted in a 1000 m time trial. Riders first performed a free warm-up generally including cycling on the track and then on a roller (with various durations). Time trial was performed individually and riders had to perform four laps as fast as possible starting still with feet set on the pedals. Cyclists were held by one of the competition organizers. This event was used for Part1 study. From this time trial, the fastest lap (250 m), the total time to achieve the four laps (1000 m) and the fatigue index were retained.

During both events, time was measured electronically (Chronelec Protime, Norges-la-ville, France) using sensors placed on the starting/finishing line and on the bike. Time was measured at a 1,000 Hz sampling frequency.

Physical performance measurements for Part2

At least one week after the competition, participants came to the laboratory for two different sessions randomly assigned. One session was designed to test maximal aerobic power. During this visit, anthropometric data were first measured. Body fat was estimated using a bioelectrical impedance analysis system (TBF 410GS, Tokyo, Japan). Then, participants were equipped with a heart rate monitor (Polar Electro Oy, Finland) and with a gas exchange measurement system (Cosmed K5, Roma, Italy). Afterwards, the maximal aerobic power test was performed on an indoor ergocycle (CyclOps 400 Pro equipped with PowerTap, Madison, USA) with saddle and handlebar settings individually adjusted. The incremental maximal aerobic test started at a power of 100 W during two minutes and increased with 25 W increments every two minutes. Tests were interrupted when participants were unable to maintain the requested cycling rate. The pedalling rate ranged between 80 and 90. Maximal aerobic power was calculated according to the duration of the last step. The maximal heart rate value was recorded during the test, and the maximal VO_2 value (VO_{2max}) was calculated as the average over the last 30 seconds of the test.

During the second test session, vertical jump height, maximal knee extension and flexion torque and anaerobic power using a modified Wingate test were measured. A short warm-up was first performed. It consisted in submaximal cycling during 10 minutes at a 150 W, submaximal vertical jumps and submaximal knee flexion and extension performed on an isokinetic dynamometer (submaximal concentric and eccentric knee extension, knee flexion with increasing intensity). After five minutes rest, vertical jump height was measured during a counter movement jump using the Optojump system (Optojump, Microgate, Bolzano, Italy). The counter movement jump was performed starting from a standing position, then squatting down to a 90° knee flexion angle and then extending the knees in one continuous movement. Arms were free to move. Subjects were asked to jump as high as they could for three times, and the best performance was retained. After five minutes rest, participants were tested for the right knee extension and knee flexion torque, on an isokinetic dynamometer (Biodex 4 Quickset, Biodex Corporation, Shirley, NY, USA). Participants were seated with the hip at 100°. Straps were applied tightly across the chest, pelvis and midthigh to minimize hip and thigh motions during contractions. The leg was secured to the dynamometer apparatus and the dynamometer rotation axis was aligned to the knee joint rotation axis. Arms were always positioned across the chest with each hand clasping the opposite shoulder. Measurements consisted in a series of five consecutive concentric knee extensions and flexions from 90° of flexion to full extension (0°). After one-minute rest, a series of five eccentric knee extensions and flexions was achieved. Contractions were performed at a 60 $°.s^{-1}$ angular velocity. The peak torque (gravity corrected) was measured directly from the Biodex software. The best trial was retained for analysis. After 5 minutes rest, participants performed a modified anaerobic test according to the ergocycle possibilities (CyclOps 400 Pro equipped with PowerTap, Madison, USA). It consisted in pedalling as fast as participants could during 30 seconds. A constant 750 W power was used for all participants. Performance was quantified according to pedalling frequency decreasing that corresponded to the percentage decrement between the first five seconds and last five seconds.

Statistical analyses

Data are presented as mean values ± standard deviation (SD). For Part1, cycling performance outcomes were compared between riders from the different finals using a Student t-test. Standard parametric regressions were achieved to compare the degree of association between all outcomes. It involved all riders together, then riders from superfinal or final A, separately. For Part2, cycling performance during the race was analysed using parametric statistics: a repeated analysis of variances (ANOVA) for the fastest lap performance and a Student t-test for average lap time and fatigue index. Standard parametric regressions were also achieved to compare the degree of association between all outcomes. For correlations analyses from Part1 and Part2, time trial performance and average lap time during finals were considered as the most important performance indicators. Statistical analyses were conducted using Statistica v8.0 (StatSoft Inc., Tulsa, USA). $P < 0.05$ was set as the level of statistical significance for all tests.

Results

Part1

Significant differences ($P < 0.05$) were obtained between cyclists from the superfinal ($n = 22$) and final A ($n = 14$) for the 250m and 1000m track, race time trial, fastest lap and average lap time during heats and finals (Table 1). Correlations analyses indicated significant associations (Table 2) between time trial and track performance (250m and 1000m) as well as race performance (fastest lap and average lap during heats and finals). The average lap time during finals was significantly correlated with track performance (250m and 1000m) as well as race time trial, fastest lap and average lap during heats.

When considering riders from the superfinal, correlations were only obtained between race time trial and the final's fastest lap ($r = 0.559$, $P = 0.007$) and average performance ($r = 0.584$, $P = 0.004$). The average lap time during the final was associated with race time trial (r =

0.584, P = 0.004), the fastest lap (r = 0.891, P < 0.001) and average lap time during heats (r = 0.801, P < 0.001). When considering riders from final A, correlations were obtained between time trial and average lap time during heats (r = 0.553, P = 0.04) and between average lap time during the final with average lap time during heats, heats and final fatigue indexes (r = 0.639, P = 0.02; r = 0.556, P = 0.039; r = 0.715, P = 0.004; respectively).

Part2

All cyclists included in the study performed all stages of the criterium. From the nine riders, five were in the superfinal, two in final A and two in final B. Anthropometric characteristics, cycling performance during the criterium race and physical performance are presented in Table 3. The fastest lap was significantly slower during the time trial than during heats and finals (P < 0.001). The average lap time was significantly slower during heats as compared to finals (P < 0.05). Finally, we observed a slightly greater fatigue index during heats as compared to finals that did not reach significance (P = 0.071).

Correlation analyses only revealed few associations between variables (Table 2). Time trial performance was associated with the fastest lap during finals, maximal aerobic power and VO_{2max}. The average lap time during finals was associated with the fastest lap during heats and fatigue index during finals.

Discussion

The present study was conducted to describe fixed gear performance during criteriums performed on outdoor closed circuits, and to depict physiological determinants of fixed gear cyclists. Results did not confirm our initial hypothesis because competition performance was mainly related to aerobic attributes but not to strength parameters. Fixed gear cycling, therefore, presents numerous similarities to common cycling disciplines but with specificities that should be considered during training.

The first part of our study aimed at analysing results from a fixed gear criterium in combination with a track time trial. Our main findings revealed that fixed gear performance (i.e. average lap time during finals) was related to time trial performance and fastest lap time. In other words, the final performance (> 40 min total duration) is highly correlated with cycling efforts shorter than 2 min. The second part, which attempted to determine physiological characteristics (including anaerobic and aerobic attributes) of fixed gear riders, confirmed Part1 results. Indeed, significant correlations were obtained between circuit time trial and aerobic attributes (maximal aerobic power and VO_{2max}) and the averaged performance during finals was correlated with fatigue index during finals.

At first these findings are surprising but are in general agreement with previous data (Black, Durant, Jones, & Vanhatalo, 2014; Craig & Norton, 2001; Dantas, Pereira, & Nakamura, 2015; Støren, Ulevåg, Larsen, Støa, & Helgerud, 2013). Firstly, while considering the contribution of the different energy systems, short distance track events have been shown to predominantly involve the aerobic system. For example, the aerobic system was estimated to contribute to half of the power production during a 1000 m track time trial (Craig & Norton, 2001). Certainly, increasing the competition duration increases the contribution of the aerobic system until > 95% for an hour time trial (Craig & Norton, 2001). Similarly, the aerobic system was shown to be predominantly involved in BMX performance (multiple very short races) (Louis et al., 2012). Secondly, other authors concluded that short duration events could predict endurance performance distance (Black et al., 2014; Dantas et al., 2015). For instance, a 3-min all-out test has been validated to anticipate cycling performance longer than 20 minutes (Black et al., 2014).

When considering groups (i.e. cyclists involved in superfinal or final A), conclusions were slightly different. Performance for cyclists from the superfinal was related to time trial and fastest lap. In contrast, correlations for cyclists from final A were mainly obtained with heats performance and some fatigue indexes. Taken together, these results would indicate that fatigue limits the performance more with the decreasing level of the cyclists. The correlation between the average lap time during finals and fatigue index during Part2 confirmed this assumption. The greater the lap time (i.e. slower lap) the greater the fatigue. Different hypotheses related to cyclists' level could explain such finding.

A first explanation could be related to pacing (Skorski & Abbiss, 2017). Authors previously concluded that pacing during track cycling was dependent on athletes' performance level (Wilberg & Pratt, 1988). Slow athletes usually started too fast relative to their performance level and, as a consequence, developed greater fatigue. In contrast, others concluded on top-level track athletes (world championship level) that pacing was similar between slow and fast cyclists (Corbett, 2009). For these top-level athletes, the final performance was mainly related to the first lap of a 1000 m. During longer events, the influence of training status on pacing is unclear. For example, some authors obtained similar pacing strategies between different levels of trained mountain bike cyclists (Viana, Pires, Inoue, & Santos, 2018). However, this conclusion was obtained using a simulated laboratory design, i.e. excluding any packed race. Another recent study, considering cyclo-cross world championships, demonstrated different pacing strategies during races as a function of cyclists position (top-placed vs. bottom-placed cyclists) (Bossi, O’Grady, Ebreo, Passfield, & Hopker, 2017). Authors showed that top-athletes could slightly decrease intensity in the middle of the race as compared to others. As a consequence, the fatigue effect on performance is reduced. Although not quantified here, pacing strategy could have been different during the fixed gear criterium finals according to cyclists' level. However, one should bear in mind that during such an event, tactics also account for these pacing strategies. Moreover, other factors such as aerodynamic draft should be considered (Peterman, Lim, Ignatz, Edwards, & Byrnes, 2015; Spence, Thurman, Maher, & Wilson, 2012). The lower lap time during heats or finals as compared to the initial time trial partly confirmed this phenomenon.

Interestingly, when considering groups separately, no significant correlation was obtained between track time trial and time trial on the race circuit. This lack of dependency could be attributed to technical skills. Indeed, high-technical and tactical skills as well as high-risk tolerance are required (Figure 1), similarly to other cycling disciplines such as off-road biking (Impellizzeri & Marcora, 2007; Mastroianni, Zupan, Chuba, Berger, & Wile, 2000; Miller, Macdermid, Fink, & Stannard, 2017). Moreover, fixed gear cycling requires specific skills to ride packed in a closed circuit minimising the loss of time during direction changes. Finally, a lower cyclists level promotes mental fatigue (Martin et al., 2016). Obviously technical skills or decision-makings, and therefore performance, are impaired over time.

In contrast with our initial hypothesis, fixed gear performance was not related to strength or lactic anaerobic power. Such result is surprising because fixed gear cycling requires numerous eccentric contractions to slow down bicycles as well as concentric force for re-acceleration but it confirmed previous data obtained on road cyclists (Støren et al., 2013). Considering the methodology used, our data are obtained using a small sample size meaning that additional measurements are required. A control group, for example including road cyclists, would have been of interest for comparison. Moreover, maximal strength was measured here in fresh conditions. Because fixed gear performance during criteriums is long lasting, considering strength measurements under fatigue state could be more interesting to understand this cycling discipline. Also, eccentric strength was evaluated on an ergometer but eccentric strength is produced using a specific action for braking bicycles on the bike. A more specific assessment should be more accurate.

The specificity of fixed gear cycling is related to the repeated eccentric contractions. It is well known that eccentric solicitation necessitates lower muscle activation levels than concentric contractions (Babault, Pousson, Ballay, & Van Hoecke, 2001). It has also been shown that eccentric pedalling requires reduced neuromuscular activation than concentric and could lower metabolic cost (Peñailillo, Blazevich, & Nosaka, 2017). Despite a different cycling pattern between the preceding study and fixed gear cycling, one can speculate that repeating eccentric contractions during fixed gear cycling would produce different neuromuscular and cardiovascular behaviours. The direct consequence is related to fatigue origins. Indeed, it was previously demonstrated that specific fatigue as a result of eccentric conditions is reduced in eccentric trained athletes (Michaut, Babault, & Pousson, 2004). Also, some authors observed that road cyclists show greater fatigue in eccentric conditions as compared to triathletes (Garrandes, Colson, Pensini, & Legros, 2007). Triathletes are indeed used to such contraction mode. Moreover, while investigating power and endurance-trained athletes, the same authors (Garrandes, Colson, Pensini, Seynnes, & Legros, 2007) suggested that the neuromuscular fatigue profile is dependent on training background. Specific training (and more particularly in eccentric conditions) could diminish eccentric-induced fatigue and also favour the repeated bout effect that could protect the neuromuscular system from fatigue and muscle damage. To investigate the different neuromuscular behaviour and fatigue during cycling, it could be interesting to determine differences between the physiological demand while cycling fixed gear bikes and road bikes, for example using electromyography. The only electromyographic studies considering some fixed gear bicycles were performed during sprint track cycling (Watanabe et al., 2016). However, none has considered fixed gear cycling on closed circuits with repeated deceleration and acceleration phases.

The potential specific fatigue associated with fixed gear cycling is not only related to the repeated eccentric contractions. It could also be related to cycling cadences. Fixed gear bicycles have a unique gear (adapted to cyclists and to race circuits). As a consequence, cycling on a closed circuit with numerous direction changes requires varying pedalling rates (cadences). During road cycling, it is well known that cyclists use a preferred cadence that is usually different from the cadence that minimize the pedalling energy cost (the so-called optimal cadence) (Gregor, Broker, & Ryan, 1991). The preferred cadence has been shown to be related with endurance training status of cyclists while the optimal cadence was related to strength capacities (Bieuzen, Vercruyssen, Hausswirth, & Brisswalter, 2007). The different cadences used during fixed gear cycling, in association with the different resistances would alter the neuromuscular activation pattern (Katona, Pilissy, Tihanyi, & Laczkó, 2014) or cardiovascular drift (Kounalakis & Geladas, 2012) and consequently neuromuscular fatigue. Specific training with different cadences are therefore needed because cycling training adaptations seem to be cadence specific (Paton, Hopkins, & Cook, 2009; Whitty, Murphy, Coutts, & Watsford, 2016). Previous authors concluded that the optimal cadence was related to strength capacities (Bieuzen et al., 2007), therefore, we can speculate that fixed gear development ratio could be related to fatigue resistance strength capacities.

Taken together, the results of the present study indicate that fixed gear cycling is similar to other cycling disciplines. Cycling performance during fixed gear criteriums (which are performed on closed circuits with numerous direction changes) is predominantly dependent on the aerobic system. Albeit this type of cycling involved several decelerations and accelerations using eccentric and concentric muscle actions, strength, as measured in this study, is not a key factor. More particularly, one can argue that fixed gear cycling resemble cyclo-cross or mountain-bike cycling due to some technical skills similarities. However, some specific fixed gear cycling actions that require specific training should be considered.

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Figure 1: A. Satellite view of the National Moutarde Crit #5 circuit. B. Picture illustrating two consecutive direction changes during the Criterium (© 2017 Michel Udny, with permission).