Advances in Physical Education, 2022, 12, 255-270
https://www.scirp.org/journal/ape
ISSN Online: 2164-0408
ISSN Print: 2164-0386

Competitive Cyclists' Freely Chosen Cadence Is History Dependent

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How to cite this paper: Stilling, E. J. J., Kristiansen, M., & Hansen, E. A. (2022). Competitive Cyclists' Freely Chosen Cadence Is History Dependent. *Advances in Physical Education, 12,* 255-270.
https://doi.org/10.4236/ape.2022.123020

Received: July 6, 2022
Accepted: August 1, 2022
Published: August 4, 2022

Abstract

Background: Not much is known about history dependence of freely chosen cadence in competitive cyclists. **Objective:** It was investigated whether initial cycling at relatively low and high preset target cadences affected a subsequent freely chosen cadence at the end of the same bout of submaximal ergometer cycling. **Methods:** Nineteen male competitive cyclists performed a single test session consisting of three separate bouts at 180 W. In one bout, cycling at 60 rpm was followed by cycling at freely chosen cadence. In another bout, cycling at 110 rpm was followed by cycling at freely chosen cadence. In yet another bout (considered reference), the cadence was freely chosen, throughout. Motor rhythm output (cadence), biomechanical (including tangential pedal force), and physiological (heart rate) responses were measured. **Results:** Increased cadence resulted in increased internal power and decreased maximal tangential pedal force, and *vice versa*. This was in accordance with existing knowledge. Initial cycling at 60 and 110 rpm caused the subsequent freely chosen cadence to be about 6 rpm lower and higher ($p < 0.01$), respectively, than the freely chosen cadence (91.2 ± 9.9 rpm) at the end of the reference bout. These differences in cadence were accompanied by differences in heart rate and pedal force ($p < 0.05$). **Conclusions:** For competitive cyclists, the freely chosen cadence at the end of a submaximal bout of cycling depends on the preset target cadence applied initially.

Keywords

Bicycling, Exercise, Pedal Rate, Preferred Pedalling Frequency, Rhythmic Movement, Sports

1. Introduction

The cadence during cycling can obviously be consciously controlled by a cyclist.

However, unless it constitutes an explicit task to pedal at a certain cadence, a highly conscious control of the cadence has been suggested to be unlikely to occur when prolonged cycling is performed (Hansen & Smith, 2009). More likely, the motor control of the freely chosen cadence during submaximal cycling is highly automated. Thus, it appears likely that the cognitive awareness is directed towards other aspects than the cadence when prolonged cycling is performed unrestricted, at a self-selected, or freely chosen cadence. In support of the largely automated control of the freely chosen cadence, the intra-individual freely chosen cadence during ergometer cycling has been reported to be consistent across months, for individuals who were blinded to the cadence during the cycling (Hansen & Ohnstad, 2008). Further, it should be mentioned for completeness that the inter-individual difference in freely chosen cadence is considerable. As an example, the intra-group standard deviation of freely chosen cadence was reported to be 7 rpm (reflecting a range from 89 to 106 rpm) in trained cyclists, during cycling at 180 W (Hansen et al., 2006). As another example, the intra-group standard deviation was reported to be 9 rpm for a group of highly fit experienced cyclists, during cycling at 200 W (Marsh & Martin, 1993).

Biomechanical and physiological responses during cycling are affected by the applied cadence. This has previously been reviewed thoroughly (Abbiss et al., 2009). In short, if cadence is increased, it decreases values of maximal and average tangential pedal force (Patterson & Moreno, 1990). An increased cadence also increases internal power (Hansen et al., 2004). Internal power has been defined as the power output that represents the energy changes of the moving body segments (Hansen & Sjøgaard, 2007). Regarding physiological responses, which during submaximal cycling is reflected by, for example, energy turnover, oxygen uptake, and heart rate, there is an approximately U-shaped relationship with cadence (Coast & Welch, 1985). The bottom of the U-shape is commonly considered an optimum. A consistent observation during submaximal cycling is that the freely chosen cadence is higher than the optimal cadence, as it has previously been pointed out in a summary of several studies (Nielsen et al., 2004). In fact, the oxygen uptake at the freely chosen cadence amounts to about 5% higher values than at the optimal cadence (Hansen et al., 2006; Hansen & Ohnstad, 2008). It follows that the cadence during submaximal cycling has potential importance for test results, as well as energy depletion, and ultimately performance, during prolonged cycling.

History dependence can refer to the phenomenon that a recent activity affects a subsequent motor output, or performance. An example of history dependence is that steady-state isometric force at a preset muscle length is lower and higher after active shortening and active stretching of the muscle, respectively (Abbott & Aubert, 1952). Another example is that freely chosen tapping rate in a bout of index finger tapping is increased after a preceding tapping bout and a rest period, which has been termed repeated bout rate enhancement (Hansen et al., 2015). A final example is that performance (for example, in jumping) is enhanced after a conditioning exercise (for example, in the form of squats), which has been termed post activation potentiation (Young et al., 1998). Not much is known about history dependence of freely chosen cadence in competitive cyclists, which can be defined as the effect that a prior cadence condition has on the subsequent freely chosen cadence during pedalling. It is of note that this definition is inspired by the definition of history dependence of muscle force production (Herzog, 2004). A recent study showed that initial cycling at relatively low (50 rpm) and high (90 rpm) preset target cadences during 7-min submaximal ergometer cycling bouts, performed by recreationally active individuals, caused the freely chosen cadence at the end of the bouts (the last 3 min) to be about 5% lower and higher, respectively, than a reference freely chosen (Hansen et al., 2021). In the case that history dependence of freely chosen cadence exists in competitive cyclists, it has the potential to cause a cascade of effects from physiological and biomechanical responses to performance, as described above.

Therefore, the purpose of the present study was to investigate whether initial cycling at relatively low and high preset target cadences (performed in two separate bouts) would affect a subsequent freely chosen cadence at the end of the same bouts of submaximal ergometer cycling. For the investigation, the freely chosen cadences were compared to a reference cadence at the end of a third bout, which was performed at freely chosen cadence throughout. Tests in the present study were deliberately performed on competitive cyclists who, to a large extent, are highly accustomed to cycling through their regular cycling. A high degree of habituation to cycling suggests that pedalling is controlled in a highly automated way. In the case that initial preset target cadences affect the subsequent freely chosen cadence in competitive cyclists, it might be interpreted to support the working hypothesis that the motor rhythm output of freely chosen cadence is history dependent. Conversely, no effect of the initial cycling cadence might obviously be interpreted to support that the motor rhythm output of freely chosen cadence is not history dependent.

2. Methods

2.1. Participants

Nineteen male individuals (1.82 ± 0.05 m, 73.9 ± 7.5 kg, 33 ± 11 years) participated in the study. The participants were competitive (ranging from junior to elite level) cyclists with 10 ± 7 years of cycling training history. During the year prior to the study, the participants had performed cycling 4.1 ± 1.5 times per week, which resulted in 9.4 ± 3.1 h of cycling per week. The participants had been asked to refrain from intensive cycling 24 h before testing as well as to abstain from intake of alcohol, caffeine, and nicotine 12 h before testing. The participants were carefully informed about the procedures of the study and the overall aim ("to enlarge our knowledge about control of rhythmic leg movement"). In addition, they were kept naïve to the specific purpose of the study. The reason for this was to avoid conscious control of the cadence when this was freely chosen. Written informed consent was obtained from the participants.

The study conformed to the standards set by the Declaration of Helsinki and the procedures by The North Denmark Region Committee on Health Research Ethics.

2.2. Overall Design

Each participant reported to the laboratory on a single day, for a test session of about 1 h duration. During the test session, the participant performed three separate bouts of submaximal ergometer cycling at preset target cadences and freely chosen cadence. The order of the bouts was counterbalanced. During the cycling, biomechanical and physiological responses were recorded.

2.3. The Test Session

First, the participant's age was noted. Further, height and body mass were measured. Next, the participant was asked about his cycling experience. Then, the seat height and handlebar position of the electromagnetically braked SRM cycle ergometer (Schoberer Rad Messtechnik, Jülich, Germany) was adjusted by the participant according to his own preference. Further, the ergometer's power measuring unit as well as the Powerforce system for tangential pedal force measurements (Radlabor GmbH, Freiburg, Germany) were reset according to the manual of the manufacturers.

Thereafter, 6 min of familiarization was performed. For this, the cycle ergometer was pre-programmed to maintain a power output of 180 W. Gear 8 and "constant watt" operating mode of the SRM cycle ergometer were used. This entails a pre-programmed power output, regardless of cycling cadence. The participant was instructed to cycle at varying cadences between 60 and 110 rpm to get familiar with the cycle ergometer. The familiarization bout was followed by 5 min rest.

After the rest, three separate 7-min bouts of ergometer cycling were performed at a pre-programmed power output of 180 W. The order of the bouts was counterbalanced and bouts were referred to as bout A, B, and C. All bouts were separated by 5 min rest. Bout A consisted of 2 min of ergometer cycling at a preset target cadence of 60 rpm followed by 5 min at freely chosen cadence. Bout B consisted of 2 min of ergometer cycling at a preset target cadence of 110 rpm followed by 5 min at freely chosen cadence. Bout C consisted of 7 min of ergometer cycling at freely chosen cadence. Bout C was considered a reference bout. Based on the literature, it was predicted that the cadence in bout C would be about 85 rpm, as an average value across participants (Hansen et al., 2002; Marsh & Martin, 1993). Sixty and 110 rpm in bout A and B were deliberately chosen to represent considerably lower and higher cadences, respectively, compared to the expected freely chosen cadence. The participants had visual feedback on cadence during pedalling at the preset target cadences. It was a goal that the low and high preset target cadences would be equally different from the reference freely chosen cadence in bout C. It applied to all bouts that when cadence was at a preset target, visual cadence feedback was given to the participant. On the other hand, when cadence was freely chosen, the participant was blinded to the cadence by covering the display on power control unit of the ergometer. For the cycling at freely chosen cadence, the following instruction was given: "You must now pedal at a freely chosen cadence. You could try to imagine that you are bicycling outside on a road. There is no correct or incorrect cadence. Simply, pedal as you find it natural". Participants wore their own cycling shoes and cycling clothing during the ergometer cycling. Further, the cycle ergometer was mounted with the participant's own pedals. For an illustration of a bout and the recorded data, the reader is referred to Figure 1.

2.4. Data Recording and Analysis

Cadence was recorded every 30th s. For further analysis, a single value of freely chosen cadence was calculated as an average across the last 3 min of each bout.

Tangential pedal forces (forces directed perpendicular to the crank arm, with positive values in the rotation direction) from the left and the right pedal were recorded during each bout for a duration of 30 s from 1:15 (min: s) to 1:45 and again from 6:15 to 6:45. For an illustration of the tangential pedal force and a data example, the reader is referred to Figure 2. The forces were recorded at 2000 Hz using a 16-bit A/D converter, and the data acquisition LabVIEW-based software IMAGO Record (part of the Powerforce system). For each 30-s recording, the Powerforce system calculated a single average tangential pedal force profile for one revolution, for each of the two pedals. From these profiles, maximal and minimal values of the tangential pedal force, as well as the crank angles at which these values occurred, were found. Average values of the values from the left and the right pedal were calculated, for further analysis.

Internal power (in W) was estimated by the following equation:

$$\text{Internal power} = q \times m \times f^3 \tag{1}$$

In the equation above, q is a constant of 0.153 J·s²·kg⁻¹, m is body mass in kg, and f is cadence in Hz, according to a previous publication (Minetti et al., 2001). The cadences, which were included in the calculation of the internal power estimates were taken at the time point 1:30 in bout A and B as well as from the final

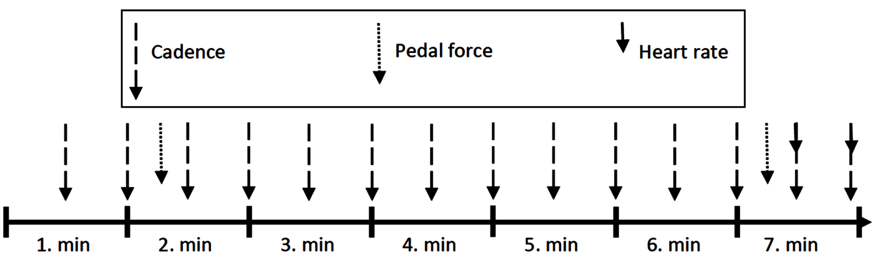

Figure 1. An overview of data collection during a single bout of ergometer cycling. In bout A and B, the first 2 min were performed at a preset target cadence of 60 rpm and 110 rpm, respectively. The rest of the bout was performed at freely chosen cadence. In bout C, the cadence was freely chosen throughout.

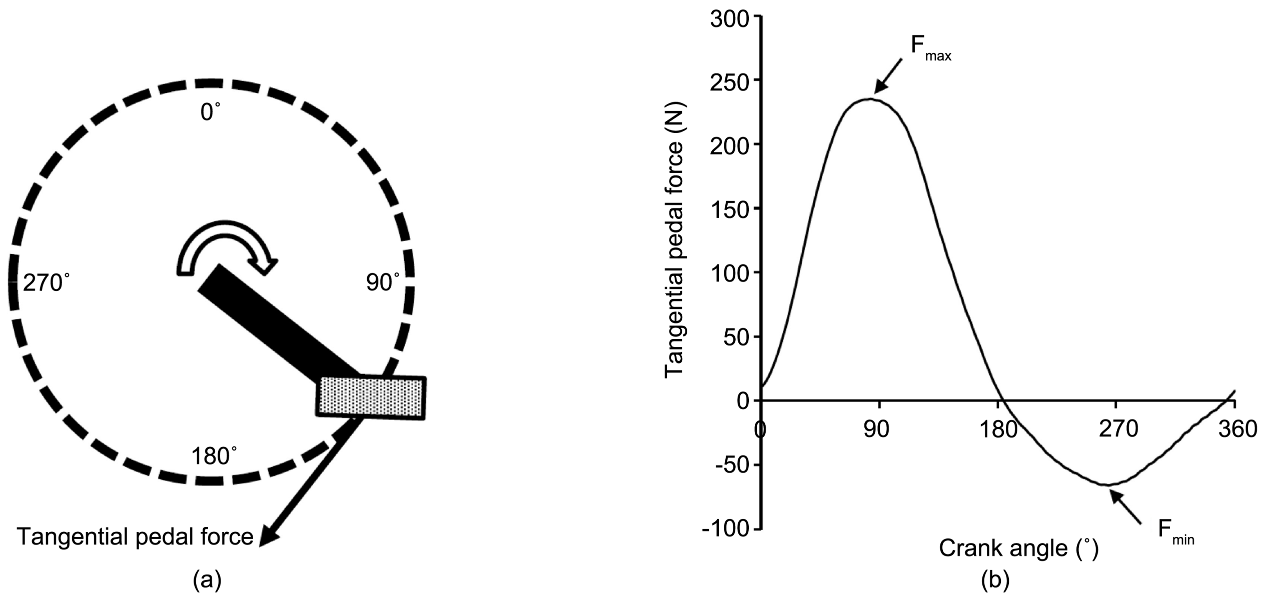

Figure 2. Panel (a) contains an illustration of the direction of the tangential pedal force (perpendicular to the crank arm) for the right pedal. An illustration for the left pedal would have been mirrored. The crank cycle can be divided into three main phases. A pushing phase (from 350˚ to 10˚), a downstroke phase (from 10˚ to 180˚), and an upstroke phase (from 170˚ to 350˚). Panel (b) contains a data example of a tangential pedal force profile. $n = 1$. This typical example represents an average of the data recorded for the left pedal, across 30 s. The following selected key characteristics are indicated on the profile: F_{max}, maximum tangential pedal force; F_{min}, minimum tangential pedal force.

part (average across the last 3 min) of all the bouts. Of note is that an evaluation of the equation has been performed previously (Hansen et al., 2004). Of further note is that there is a debate about methods and criteria for estimation of internal power (Sjøgaard et al., 2002) including arguments about whether internal power is lost or recaptured during cycling (Kautz & Neptune, 2002; McDaniel et al., 2002). So far, it appears that a physiological approach suggests that muscles do perform internal power independently of external power (Hansen et al., 2004), which contrasts with what is suggested based on a strictly mechanistic approach (Kautz & Neptune 2002).

Heart rate was recorded twice by an Ambit3 (Suunto, Vantaa, Finland) at the end of each bout (at 6:30 and 6:55). An average of the two values was calculated, for further analysis.

2.5. Statistical Analysis

A sample size estimation performed (http://www.biomath.info/power/prt.htm) (Faul et al., 2007) in the design phase of the study resulted in 19 participants. This estimation was based on paired *t*-tests to be performed with an alpha value of 0.01 (set conservatively due to correction for multiple tests), an expected difference of 7 ± 8 rpm, and a power of 0.80. Differences were tested for statistically significance by a two-tailed paired students *t*-test performed in Excel 2016 (Microsoft Corporation, Bellevue, WA, USA). Due to the design of the study, where data from two bouts (A and B) were systematically compared with data from bout C (considered a reference bout), $p < 0.025$ (i.e., 0.050 divided by 2, according to Bonferroni correction) was considered statistically significant.

3. Results

3.1. Cadence

Cadence, as a function of time during the three bouts of submaximal ergometer cycling, is depicted for two individuals in **Figure 3** (to provide a couple of data examples) and for the entire group of participants in **Figure 4**. The freely chosen

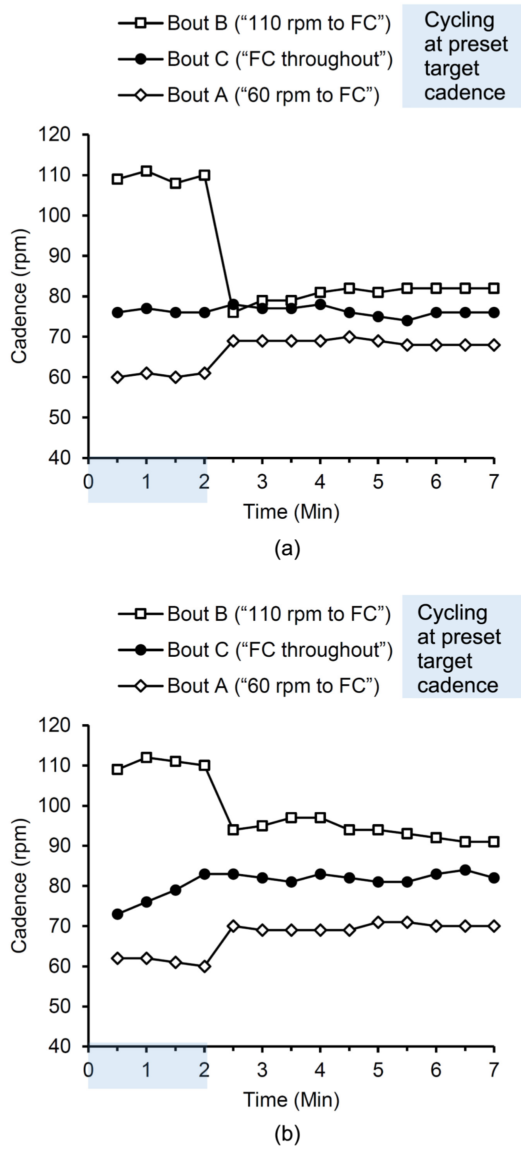

Figure 3. An illustration of two data examples ($n = 1$, for each of Panel (a) and (b)) of cadence as a function of time during bout A, B, and C. The tendency for these two participants was that their freely chosen cadence during bout A and B, i.e., subsequent to cycling at the preset target cadences, approached the reference freely chosen cadence. Although, without fully merging with the reference freely chosen cadence. This tendency represented the overall finding across all participants. FC, freely chosen cadence.

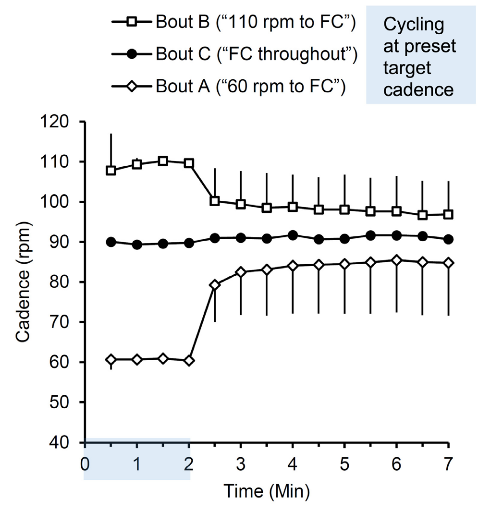

Figure 4. Cadence as a function of time during bout A, B, and C, for all participants. $n = 19$. Data represent average values. For the sake of clarity, SD-bars are only shown in one direction for bout A and B, and not at all for bout C. For statistical evaluation, the reader is referred to the results section and Table 1. FC, freely chosen cadence.

cadence during the last 3 min of bout A was 6.3 ± 8.1 rpm lower than during bout C. For comparison, the freely chosen cadence during the last 3 min of bout B was 6.4 ± 5.7 rpm higher than during bout C. For absolute values of cadence as well as *p*-values, the reader is referred to Table 1.

3.2. Tangential Pedal Force Profile

Key characteristics of tangential pedal force profiles are presented in Table 1. In the following, merely statistically significant differences between key characteristics at the end of bout C and at the end of bout A and B, respectively, are mentioned. Thus, F_{max} was 13 ± 19 N lower for bout B (as compared to bout C). F_{min} (which is a negative value) was 3 ± 6 N less negative for bout A (as compared to bout C). F_{min} was 3 ± 3 N more negative for bout B (as compared to bout C). For absolute values as well as *p*-values, the reader is referred to Table 1. For relative values of F_{max} throughout the 7 min of cycling in bout A and B, based on reference values from bout C, the reader is referred to Figure 5.

3.3. Internal Power

Values of estimated internal power are included in Table 1. The value during cycling at freely chosen cadence in bout A was 7 ± 8 W lower than in bout C. The value during cycling at freely chosen cadence in bout B was 7 ± 8 W higher than in bout C. For absolute values as well as *p*-values, the reader is referred to Table 1. For relative values throughout the 7 min of cycling in bout A and B, based on reference values in bout C, the reader is referred to Figure 5.

3.4. Heart Rate

The heart rate at the end of bout A was 128 ± 22 beats min^{-1}. This was not

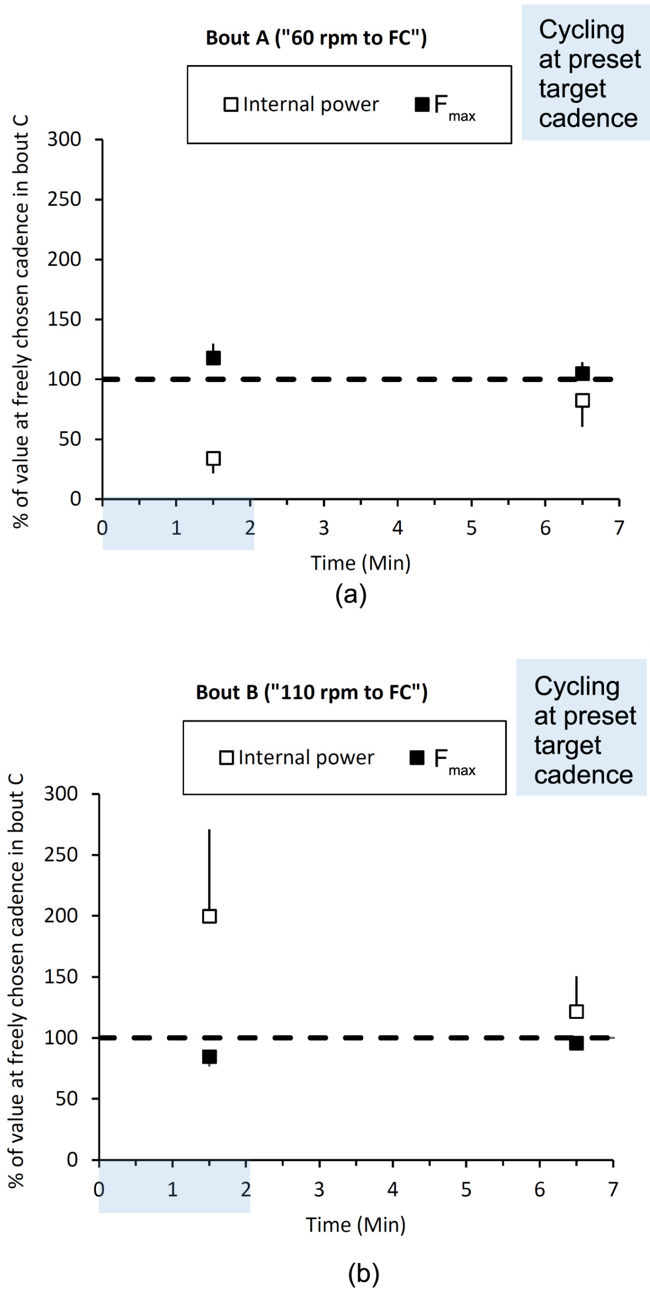

Figure 5. Relative values of internal power and maximal tangential pedal force as a function of time during bout A (Panel (a)) and bout B (Panel (b)). $n = 19$ for internal power. $n = 18$ for pedal force, due to one lost data set. The data are presented as relative to the values from bout C (100%, the broken line), which was performed with freely chosen cadence throughout. Data represent average values. For the sake of clarity, SD-bars are only shown in one direction. For absolute values and statistical evaluation, the reader is referred to the results section and Table 1. FC, freely chosen cadence.

significantly different ($p = 0.092$) from the heart rate at the end of bout C, which amounted to 129 ± 22 beats min^{-1}. The heart rate at the end of bout B was 132 ± 22 beats min^{-1}, which was significantly different from the heart rate at the end of bout C ($p < 0.001$).

Table 1. Selected key characteristics of tangential pedal force profiles as well as estimates of internal power during submaximal cycling at a pre-programmed power output of 180 W. Values of freely chosen cadence at the end of the bouts (averages across the last 3 min) are also included.

	Cadence (rpm)	F_{max} (N)	Crank angle at F_{max} (˚)	F_{min} (N)	Crank angle at F_{min} (˚)	Internal power (W)
Bout A (“*60 rpm to FC*”)						
Initially	60.9 ± 1.2	340 ± 28	101 ± 4	−36 ± 17	286 ± 79	12 ± 1
Finally	84.8 ± 12.8[a]	309 ± 34[c]	105 ± 5[e]	−48 ± 18[g]	293 ± 14[i]	34 ± 15[k]
Bout B (“*110 rpm to FC*”)						
Initially	110.2 ± 1.0	245 ± 20	110 ± 6	−58 ± 14	288 ± 7	70 ± 7
Finally	97.5 ± 8.3[b]	283 ± 31[d]	108 ± 6[f]	−54 ± 15[h]	287 ± 8[j]	48 ± 13[l]
Bout C (“*FC throughout*”)						
Finally	91.2 ± 9.9	296 ± 35	107 ± 5	−51 ± 16	290 ± 11	42 ± 13

FC, freely chosen cadence. The initial cadence values in bout A and B are from time point 1:30 (min: s). [a]Different from the cadence in bout C ($p = 0.003$). [b]Different from the cadence in bout C ($p < 0.001$). [c]Not different from bout C ($p = 0.052$). [d]Different from bout C ($p = 0.008$). [e]Not different from bout C ($p = 0.127$). [f]Not different from bout C ($p = 0.689$). [g]Different from bout C ($p = 0.019$). [h]Different from bout C ($p < 0.001$). [i]Not different from bout C ($p = 0.124$). [j]Not different from bout C ($p = 0.176$). [k]Different from bout C ($p = 0.002$). [l]Different from bout C ($p = 0.002$). $n = 19$ (except for pedal force and crank angle data for which $n = 18$, due to one lost data set).

4. Discussion

The freely chosen cadence causes a compromise of a relatively low pedal force in each pedal thrust and a relatively low physiological response, such as oxygen uptake or heart rate. Yet, each of these variables can easily be reduced further by increasing or decreasing the cadence. However, it is a trade-off condition in which a reduction of one part inevitably will be accompanied by an increase of the other part.

The magnitude of both pedal force and physiological response can be perceived by the cyclist during cycling. It may therefore appear conspicuously that previous research showed freely chosen cadence to be unaffected by changes in mechanical and cardiopulmonary loading during ergometer cycling (Hansen & Ohnstad, 2008). However, in line with that, it has been suggested that freely chosen cadence is largely automated and thus to merely a limited extent subject to volitional control, based on, for example, sensory feedback (Hansen, 2015; Hansen & Smith, 2009; Sakamoto et al., 2014). Future studies should investigate further, to which extent the freely chosen cadence is a volitionally generated motor rhythm output. It has been reported that the freely chosen cadence during ergometer cycling, with the cadence being blinded, was consistent for individuals across months (Hansen & Ohnstad, 2008), which supports the consideration of the freely chosen cadence to be an inherent automated motor rhythm output.

The novel finding of the present study suggests that history dependence should be added as a non-volitional aspect to the overall way that the motor rhythm output of freely chosen cadence is controlled in competitive cyclists. From **Fig-**

ure 5 (and Table 1), it is clear that internal power and maximal tangential pedal force at the end of bout A and B approach the values at the reference bout C. Interestingly though, the values do not fully merge, which is a result of the fact that the freely chosen cadences at the end of bout A and B do not fully merge with the freely chosen cadence in bout C. In total, that encapsulates the present phenomenon of history dependence and a part of the cascade of consequences of the phenomenon. Future studies must elucidate whether more than 7 min of cycling would have caused the freely chosen cadence in bout A and B to merge with the reference freely chosen cadence in bout C. From Figure 4, it appears possible. The relatively short duration of the bouts was chosen since it reflects a widely applied practice during cycle ergometer testing.

There is nothing in the present study, which indicates that the history dependence of the freely chosen cadence should be the result of a volitional motor control. Rather, the phenomenon is suggested to occur unconsciously. In line with that, it may be presumed that the freely chosen cadence is a result of a process involving the tripartite system of spinal CPGs, sensory feedback, and supraspinal input (Grillner, 2009; Hansen & Smith, 2009). Further, that the freely chosen cadence reflects a motor rhythm output, which is produced in a largely non-volitional, or automated, way. Importantly, this is not the same as presuming that sensory feedback caused by biomechanical and physiological responses does not at all affect the freely chosen cadence through conscious control. However, the generation of the freely chosen cadence is presumed to mainly occur unconsciously. In the present study, the history of the cadence was altered purposely. The applied intervention clearly revealed that the freely chosen cadence is history dependent. A question that remains to be answered is, what could have caused this phenomenon to occur. It is not possible to exhaustively answer the question based on the present study. However, this does not prevent a theoretical consideration based on, for example, results from animal experiments, which allow more invasive techniques to be applied. In a review, focusing on results from animal studies, it was suggested that supraspinal input, as well as sensory feedback, have the potential to alter a CPG's net state of excitability (For additional details, the reader is referred to Figure 1 and the associated figure text in (Frigon, 2017)). In line with that, others have suggested that spinal neural networks can be considered to be balanced as a result of simultaneous increases in excitation and inhibition (Berg et al., 2019). The present results of lower and higher freely chosen cadences, as compared to the reference cadence, following initial cycling at relatively low and high preset target cadences might reflect slightly tipped balances of the networks. A neuromodulation like that may be due to effects of inhibition (Miller, 2019) and excitation (Majczynski et al., 2020) caused by neurotransmitters. Perhaps an altered CPG-mediated freely chosen cadence in that way is a result of an altered condition of the CPGs, which are being involved in the generation of the rhythmic motor output. Alternatively, the changed motor rhythm output may be a result of a modulated supraspinal descending tonic drive to the CPGs (De Luca & Erim, 1994). It is also possible that a combination of the two mentioned possibilities occurred. In fact, data has been published that, according to the authors, indicated that the corticospinal excitability of the biceps brachii during arm cycling showed an overall increase with increased arm cycling cadence (Forman et al., 2015).

With respect to previous investigations on a possible effect of a prior cadence on subsequent freely chosen cadence, we are aware of only a couple of comparable studies. Thus, it was recently reported that initial cycling at relatively low (50 rpm) and high (90 rpm) preset target cadences during 7-min submaximal ergometer cycling bouts, performed by recreationally active individuals, caused the freely chosen cadence at the end of the bouts (last 3 min) to be about 5% lower and higher, respectively, than a reference freely chosen cadence (Hansen et al., 2021). In other words, a finding that is comparable to the present results. In another study, also performed on recreationally active individuals, it was shown that 5-min rest applied between initial pedalling at a low preset target (50 rpm) cadence and subsequent pedalling at freely chosen cadence caused the history dependence phenomenon to be averted. This was interpreted as a weakening of the history dependence phenomenon (Sheikulislami et al., 2022). In these previous studies, participants were healthy and recreationally active individuals and, thus, not competitive cyclists who are accustomed to a considerable amount of cycling, as in the present study. In summary, it appears that the documented phenomenon of the freely chosen cadence to be history dependent may be independent of cycling experience.

5. Practical Applications

The observed history dependence in the preset study may be of practical relevance, as illustrated by the following example. Submaximal ergometer cycling at a preset submaximal power output is applied frequently by some competitive cyclists, as a test to monitor training status (Åstrand & Rodahl, 1986: p. 369). Rate of perceived exertion and blood lactate concentration are examples of variables, or responses, which can be measured during the ergometer cycling. Besides, heart rate and oxygen uptake can be measured during the exercise, and these particular variables are closely related (Berggren & Hohwü Christensen, 1950). Improved training status can be accompanied by reduced heart rate, due to increased pumping capacity of the heart (including larger stroke volume), as well as reduced oxygen uptake, due to increased efficiency. In a case where the cadence is about 6 rpm higher, due to history dependence, the internal power will be about 7 W higher, which will cause the oxygen uptake to be about 100 mL (approximately 14 $mL \cdot W^{-1}$), or 4%, higher (Åstrand & Rodahl, 1986: p. 366). Heart rate, as well as other responses, may also be affected. Consequently, the test result can be markedly influenced by history dependence, which furthermore can conceal a change of the training status.

6. Conclusion

The present study showed that, in competitive cyclists, freely chosen cadence depended on the cadence applied at the beginning of the submaximal ergometer cycling bout. Thus, an initial relatively low target cadence (60 rpm) caused the subsequent freely chosen cadence to be about 6 rpm lower than a reference freely chosen cadence of on average 91 rpm. Besides, an initial relatively high target cadence (110 rpm) caused the subsequent freely chosen cadence to be about 6 rpm higher than the reference freely chosen cadence. The results were collected from competitive cyclists who, to a large extent, are highly accustomed to cycling through their regular cycling. The present observation was interpreted to support the working hypothesis that the motor rhythm output of freely chosen cadence in competitive cyclists is history dependent.

Authors Contributions

EAH and EJJS have given substantial contributions to the conception or the design of the manuscript. EJJS, EAH, and MVK have given substantial contributions to acquisition, analysis, and interpretation of the data. All authors have participated in drafting the manuscript. All authors read and approved the final version of the manuscript.

Ethical Approval

The present study was performed in line with the principles of the Declaration of Helsinki. The study conformed to the standards set by the North Denmark Region Committee on Health Research Ethics.

Consent to Participate

Written informed consent was obtained from the participants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

F_{max}	Maximum tangential pedal force
F_{min}	Minimum tangential pedal force
Rpm	Rounds per minute
SRM	Schoberer Rad Messtechnik