INFLUENCE OF CRANK LENGTH ON PEDALLING ECONOMY IN THE ACCELERATION PHASE IN TRACKCYCLING – A SINGLE CASE STUDY

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The purpose of this study was to identify different effects of crank-length on cycling performance in track cycling. Two different crank lengths (162,5mm and 170mm) were used in a single-blind and balanced order at a wooden indoor cycling track. Saddle height and the position of the handlebar were kept constant during all trials. The subject was asked to complete 100m with maximum load with every crank length in each test session. To avoid test effects and effects from fatigue, the order of crank length was changed throughout all test sessions. Measured variables were torque (Nm), power output (W), Force (F), Cadence (rpm) and time (s). Results showed that force output stayed constant, while the 170mm condition had advantages in time, torque and power output due to the longer lever arm. Longer distances than 100m were not analysed.

KEY WORDS: cycling, track cycling, crank length, cycling performance.

INTRODUCTION: Extensive research was conducted regarding the influence of crank length on cycling performance. However, previous research presented distinctive differences regarding this topic. Some examples should be depicted here: Inbar et al. (1983) tested five crank lengths from 125mm to 225mm. Based on wingate anaerobic tests, they calculated the optimal crank length for mean power output to be 164mm and for maximal power output to be 166mm. They calculated a difference of power output of 0.77% and 1.24% for an interval of ±5cm of crank length. But they mentioned that this difference is so low, that they recommended a standard length of 175mm for a homogeneous sample.

For athletes who prefer a higher cadence and athletes with shorter leg length also shorter crank length were recommended (Martin & Spirduso, 2001; Hull & Gonzalez, 1988), while Morris and Londeree (1997) mentioned that it is not reasonable to deduce the optimal crank length from the leg length. Martin, Malina & Spirduso (2002) found out that the crank length had an influence on the cadence for maximal power output in 8-11 year old boys, but they did not examine elite athletes, while Macdermit and Edwards (2010) presented a performance advantage of 27.8% for 170mm compared with 175mm in seven female athletes. But in track cycling commonly used crank length differ from 165mm to 175mm, depending on the discipline, therefore, a smaller range of crank lengths should be considered for examination as well. Also, the examined crank length should be shorter than the lengths considered by Macdermit and Edwards (2010), trying to gain more information regarding shorter crank lengths. For this reason crank lengths of 162.5mm and 170mm were considered for this study, which are shorter (162.5mm) than commonly used lengths respectively in the normal range of commonly used crank lengths (170mm).

In track cycling, the acceleration phase is a key aspect for performance. The faster an athlete is able to accelerate, the earlier the highest velocity can be reached. Hence, a longer distance can be cycled with a high velocity which leads to a shorter competition time. Therefore, in this study the focus was set on the acceleration phase. The aim of this study was to determine the influence of different crank length on torque, power output, cadence and force production during the acceleration time using shorter crank length than used by Macdermit and Edwards (2010) due to the different requirements in track cycling.

METHODS: The study took part at a wooden indoor cycling track, with a constant air temperature of 22°C. One female elite track cyclist participated in this study. Two different crank lengths (162.5mm and 170mm) were used in balanced order and single blinded. Gear ratio was kept constant through all trials.

The subject was asked to perform a distance of 100m with maximum power output, three times with each crank length. The subject started each trial out of a starting machine with a 10-second-countdown similar to the international competition rules. Between each trial a 30-minute break was inserted to ensure that the subject was able to recover completely. At each day 3 trials with each crank length were performed. Within two test days the subject completed 6 trials with each crank length. Saddle height was kept constant during all trials. Due to the maximum acceleration, the subject used a standing position in all trials. Hence, saddle height did not affect the results.

Measurement equipment based on strain gauges was inserted into the crank. Strain gauges were calibrated from 0N to1800N in steps of 100N. The accuracy of the measurement equipment was determined with an measurement error of 0.06%. Force was measured in tangential direction. Lateral and shearing forces were not considered, since these forces do not contribute to acceleration.

All 100m-trials were separated into 13 intervals. Each interval represented one full pedal revolution. For each revolution the data were calculated and displayed separately. Measured variables were mean force output in N (F_{mean}), peak force output in N (F_{peak}), mean power output in W (P_{mean}), peak power output in W (P_{peak}), mean torque in Nm (M_{mean}), maximum torque in Nm (M_{max}), maximum cadence in rpm (Cad_{max}) and time (s). For the maximum cadence, only the highest value of all 13 revolutions was taken into account, because trials were started with a speed of v=0. Because of the fixed gear ratio, the cadence was rising from revolution to revolution. Hence, mean values from 13 revolutions with different speed are not reasonable to present maximum cadence.

Statistical analysis was made using pared t-Tests. Test for normal distribution was done using Kolmogorov-Smirnov-Test. For all tests the level of significance was set to 5%. The tests were computed using the statistic software package RStudio (Version: 0.98.1102).

RESULTS: The athlete completed the 100m trials in 10.4±0.06s in the 162.5mm condition and in 10.2±0.04s in the 170mm condition. For the analysed parameters the mean values and standard deviation are presented in table 1.

Table 1: Means and SD of analysed variables

Crank length	P_{mean}	P_{Peak}	Cad_{max}	F_{mean}	F_{Peak}	M_{mean}	M_{max}
162,5mm	521.6±34.7	1663.9±84.2	119.0±1.1	363.8±9.0	1139.0±33.8	59.1±1.5	185.1±5.5
170mm	554.4±40.6	1685.8±108.9	120.5±1.0	363.9±16.3	1091.7±26.4	61.9±2.8	185.6±4.5

For the variables time, P_{mean}, F_{Peak}, M_{mean} and Cad_{max} significant differences were found between the different crank lengths ($p<0.05$). Higher values were found in the 170mm condition except of the time. The 100m-time was significantly lower in the 170mm condition than in the 162.5mm condition ($p<0.05$). No significant differences were found for the other variables.

DISCUSSION: In this study, it was the aim to identify effects of different crank lengths on cycling performance, especially in the acceleration phase at the first 100m on a cycling track. It was shown that the 100m time was significantly lower in the 170mm condition than in the 162.5mm condition, while the parameters P_{mean}, F_{Peak}, M_{mean} and Cad_{max} showed higher values in the 170mm condition, while the mean force did not differ significantly. The athlete was able to produce constant forces in all trials. This showed that the athlete really performed maximum sprints with maximum acceleration during all trials. Differences in time and other parameters are not dependent on differences in the force output but must be explained by other experimental conditions.

The only condition that was changed was the crank length. Although the force output was kept constant, torque and power output differed, due to a different lever arm. A longer lever arm leads to higher values of torque and power output, when force is kept constant. On the other hand a higher torque and power output leads to a higher acceleration and therefore, to higher final speed. Due to the fixed gear ratio a higher final speed causes directly in a higher maximum cadence.

Data showed an advantage of the 170mm condition over the 162.5mm condition in the first 100m acceleration phase in this subject. This is in line with the results of Macdermit and Edwards (2010), who compared 170mm with 175mm crank length. They showed an advantage of 170mm over the 175mm condition.

As mentioned before, the optimal crank length might be affected by anthropometrical data (Martin & Spirduso, 2001; Hull & Gonzalez, 1988). So these results might of course not be valid for all track cyclists. Individual conditions might differ and results might change for other athletes.

In this study only the first 100m were examined. One lap of a cycling track has commonly a length between 250m and 333m. The acceleration phase is not completed after 100m. Cadence and speed will still rise after the examined distance. Effects of different crank length on longer distances were not examined here. It is possible, that shorter crank length might have more advantages in longer distances and higher speed and cadences. Due to the smaller circumference of the pedal circle the pedal has a lower velocity in shorter cranks than in longer cranks. Lower pedal velocity at the same cadence might lead to advantages regarding motoric skills in higher cadences. Hence, it might be possible that athletes are not able to perform similar cadences with longer cranks as they are able to produce with short cranks. For this reason the shown advantage in the start phase might be compensated with higher cadences in the later phase of the race.

The saddle height was kept constant during the whole study. Because of technical conditions of the race bike it was not possible to change the saddle height. In a seating position, this will lead to different joint angles and different muscle length at the bottom dead centre as well as in the top dead centre. This could also have an influence on the results in the later phase of a lap. During the first 100m athletes use a standing position for maximum acceleration in the competition as well as in this test. Hence, the saddle height is not important considering the first 100m. In later studies, considering longer distances, the saddle height should be changed simultaneously with a change of the crank length, to compare different conditions of the crank length using nearly the same seating position.

CONCLUSION: This study identified advantages of a 170mm crank compared with a 162.5mm crank in a single case study. In this study the acceleration phase of the first 100m at a cycling track was considered, only. Although the force production was constant during all trials, torque and power output as well as maximum cadence were significantly higher and 100m time was significantly lower in the 170mm condition compared to the 162.5mm condition. These results showed an advantage of the 170mm crank length during the start phase in this athlete due to the longer lever arm. It is not clear, whether these effects will remain for a longer distance with a longer acceleration phase and therefore, with a higher cadence, or not.

Because of the different circumference of the pedal circle, the pedal speed differs at the same cadence. With higher cadences athletes might be limited with their motoric skills using longer cranks. Hence, shorter cranks might have an advantage in higher cadences which might compensate the shown disadvantage during the starting phase of a race. However, anthropometrical data of the athletes might have an influence on the optimal crank length, too. Further research with a higher amount of athletes should be conducted in the future to consider these mentioned topics and to clarify the optimal crank length for longer distances.

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