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ABDOMINAL FATIGUE IMPAIRS ANAEROBIC, BUT NOT AEROBIC, CYCLING PERFORMANCE IN UNTRAINED ADULTS

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Abstracts

Relevance. Coaches and athletes across a variety of sports commonly perform abdominal exercises to promote core strength and endurance. However, the precise influence of abdominal strength and endurance on cycling performance remains elusive. ***Purpose.*** Determine whether abdominal fatigue affects anaerobic sprint and aerobic time-trial (TT) cycling performance. ***Methods.*** Twenty-three untrained young adults (age: 19,2 ± 1,0 years, height: 170,4 ± 7,5 cm, and weight: 74,5 ± 14,1 kg) participated in this study. Twelve of the participants completed two Wingate anaerobic power tests on a Monark 834 E ergometer set at 7,5 % of body mass and the remaining 11 participants completed two 3,2 km cycling TTs on an Expresso S3U virtual reality bike; tests were separated by 96 hours. All participants performed abdominal crunches to fatigue prior to the second test. Dependent t-tests were used to assess differences between the cycling trials for the two groups. ***Results.*** Abdominal muscle fatigue decreased mean anaerobic power (Pre: 486,75 vs. Post: 408,83 Watts (W, p < 0,001), increased the rate of fatigue (Pre: 42,01 vs. Post: 50,32 %, p = 0,004), and tended to decrease peak anaerobic power (Pre: 643,17 vs. Post: 607,27 W, p = 0,088). However, abdominal muscle fatigue did not affect TT mean power (Pre: 228,18 vs. Post: 220,09 W, p = 0,127) or TT performance (Pre: 382,7 vs. Post: 388,0 seconds, p = 0,222). ***Conclusion.*** Abdominal fatigue negatively affects anaerobic cycling performance in untrained young adults. Future studies should evaluate the impact of abdominal fatigue on cycling performance in trained cyclists.

Key words: Core strength, core exercise, cycling time trial, Wingate test, cyclists.

Стен О. Стрей-Гундерсен, Алекса Дж. Чандлер, Тамара Меувіссен, Джанна Ф. Мастрофіні, Блейн С. Лінтс, Шон М. Арент, Томас С. Свенсен. Вплив абдомінальної втоми на погіршення анаеробної фізичної активності нетренованих дорослих людей під час виконання велосипедних заїздів. ***Актуальність теми дослідження.*** Тренери та спортсмени з різних видів спорту зазвичай виконують абдомінальні вправи для розвитку силової витривалості. Однак не визначено рівень впливу абдомінальних вправ на покращення техніки їзди на велосипеді. ***Метою*** дослідження є оцінка впливу абдомінальної втоми на анаеробний біг та аеробний велосипедний заїзд. ***Методи.*** У дослідженні взяли участь 23 нетреновані дорослі (вік: 19,2 ± 1,0 рік, зріст: 170,4 ± 7,5 см; вага: 74,5 ± 14,1 кг). Дванадцять учасників на велоергометрі Monark 834 E, налаштованому на 7,5 % маси тіла, виконали два тести Вінгейта на анаеробну активність, а решта 11 учасників здійснили два 3,2-кілометрові велопробіги на велосипеді віртуальної реальності Expresso S3U. Загальний час тестування – 96 годин. Усі учасники відчували абдомінальну втому перед проходженням другого тесту. Для аналізу відмінностей між циклічними тестами для двох груп були використані t-тести. ***Результати дослідження*.** Абдомінальна м'язова втома зменшила показник середньої анаеробної потужності (до: 486,75, після: 408,83 Вт (Вт, p < 0,001), збільшила показник втоми (до: 42,01, після: 50,32 %, p = 0,004) й зменшила анаеробну фізичну активність (до: 643,17, після: 607,27 Вт, p = 0,088). Однак абдомінальна втома не вплинула на середню потужність аеробного велозаїзду (до: 228,18, після: 220,09 Вт, p = 0,127) або анаеробного бігу (до: 382,7, після: 388,0 секунд, p = 0,222). ***Висновки.*** Абдомінальна втома негативно впливає на продуктивність анаеробного циклу в нетренованих молодих людей. Подальші дослідження спрямовані на оцінку впливу абдомінальної втоми на майстерність тренованих велосипедистів.

Ключові слова: сила ядра, штовхання ядра, велосипедний заїзд, тест Вінгейта, велосипедисти.

Introduction. While the beneficial impact of strength and endurance training of sport-specific muscle groups is widely recognized, the precise influence of abdominal strength and endurance on sport performance remains somewhat equivocal. Some investigations point to a direct connection between the abdominal musculature and sport-specific movements while others do not [1; 3; 4; 9; 11–15; 18]. In practice,

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fitness professionals often prescribe abdominal muscle exercises to improve abdominal muscle function to enhance performance across a range of sports and activities [3; 4; 9; 13; 18].

Cycling is characterized by the use of multiple energy systems and relies heavily on lower body force production. Indeed, increased force production from the gluteal, quadriceps, hamstring, and calf muscles contribute directly to cycling performance [7]. As such, cycling coaches and athletes have focused training on the primary muscles used to generate force during cycling [5]. However, the abdominal muscles are also substantially active during a cycling effort and abdominal fatigue can alter cycling kinematics [1]. Given that the abdominal musculature stabilizes the body and enables the extremities to produce force, abdominal muscle strength and endurance may impact cycling performance, particularly at higher exercise intensities during which greater force production and core stabilization is required [1; 10]. However, to our knowledge, no study has specifically examined the effect of abdominal fatigue on cycling sprint and time trial (TT) performance. Therefore, the aim of this study was to determine the effects of abdominal muscle fatigue on anaerobic sprint and aerobic TT cycling performance. We hypothesized that abdominal muscle fatigue would impair both anaerobic sprint and aerobic TT cycling performance.

Research Material and Methods.

Members.

A convenience sample of 23 (female: n=14; male: n=9) volunteers between 18 and 22 years old participated in this study. Participants were not required to have any experience in sport, cycling, or exercise but were required to be healthy enough to complete the study requirements. Participants self-selected into two groups, Anaerobic (ANA; n=12) and Aerobic (AER; n=11) but were blinded to the group at the time of self-selection. Participant characteristics are displayed in table 1.

Table 1

Participant Characteristics

Measure	All (N=23)	ANA (n=12)	AER (n=11)
Age (Y)	19.2 ± 1.0	19.1 ± 1.2	19.3 ± 1.0
Height (cm)	170.4 ± 7.6	167.6 ± 8.7	173.4 ± 4.8
Weight (kg)	74.5 ± 14.1	69.0 ± 13.6	80.4 ± 12.6

All descriptive data are shown at mean ± standard deviation.

All participants gave informed consent and completed the Physical Activity Readiness Questionnaire (PAR-Q) prior to the first testing session. Additionally, a 24-hour health history questionnaire was completed prior to each session to ensure participants were physically healthy enough to complete strenuous exercise. All procedures were approved by Ithaca College's Human Subjects Research Committee and conducted in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standard.

Organization of the Research.

The experimental protocol consisted of three testing sessions: 1) familiarization, 2) cycling baseline, and 3) abdominal fatigue plus cycling test. The first two testing days were separated by 48 hours while sessions 2 and 3 were separated by 96 hours. Participants were rescheduled if they experienced any type of severe change in their daily routine or had partaken in any activity that may have influenced performance. *Day 1: Familiarization*

Participants arrived at the laboratory and completed the 24-hour health history questionnaire. Height and weight were measured using a calibrated stadiometer and scale. Participants then completed a standardized five-minute warm-up on a cycle ergometer (Model 834 E, Monark Exercise AB, Vansbro, Sweden) with a pedal rate of 80 revolutions per minute (RPM) against no resistance. This warm-up was used before all testing sessions, which were followed by a five-minute cool down that consisted of the same protocol at 80 RPM. After the warm-up, participants were familiarized with their assigned cycling test. The ANA group (females: n=11; males:

n=1) completed the Wingate Anaerobic Test (WAnT) while the AER group (females: n=3; males: n=8) completed the aerobic time trial cycling test.

Day 2: Baseline Testing

Participants returned to the laboratory approximately 48 hours after the familiarization session for baseline cycling tests. Participants then performed the standardized warm-up described above followed by either the WAnT or TT depending on their assigned group (ANA or AER).

Day 3: Performance Testing

Participants returned to the laboratory approximately 96 hours after the baseline testing session. Following the five-minute cycling warm-up, participants performed crunches to volitional exhaustion to elicit abdominal fatigue. Participants then performed their respective cycling test immediately after completion of the abdominal-fatiguing exercise bout.

Measurements and Instrumentation.

Wingate Anaerobic Test (WAnT)

The Wingate Anaerobic Test was conducted using the 834 E Monark cycle (Monark Exercise AB, Vansbro, Sweden). The cycle ergometer seat height was adjusted to elicit a 10 to 15-degree bend in the knee when pedaling; this seat height was recorded and used for subsequent tests. Participants completed the 5-minute warm-up previously described, but with WAnT-specific modifications. Participants pedaled against a resistance of 1,0 kp for males and 0,5 kp for females (Bar-Or, 1987) and completed three “spin-ups” at the first, second, and third minutes of the warm-up. During these “spin-ups,” participants pedaled as fast as possible to reach a maximal RPM to simulate the start the WAnT. After the third “spin-up”, the participant completed the remaining two minutes of the warm-up at 80 RPM. After the warm-up, participants were given a 10-second countdown during which they pedaled as fast as possible. At the end of the countdown, when participants reached maximal pedaling speed, a resistance of 7,5 % of body mass was applied to the ergometer for 30 seconds. Throughout the test, participants pedaled as fast as they could while remaining seated on the ergometer. The researchers provided verbal encouragement and updates of how much time was left in the test. Absolute peak power output, mean power output, and rate of fatigue were recorded using the OptoSensor 2000 system with SMI power software version 5.2.8 (St Cloud, MN). Specifically, absolute peak power output was recorded as the highest power output over two seconds during the test; this typically occurred at the beginning of test when the load was initially applied.

Time Trial

The 3,2 km TT test was performed using the Expresso S3U Virtual Reality Bike (Interactive Fitness, Santa Clara, CA). The seat was adjusted so there was a 10–15-degree bend in the participant’s knee while pedaling. During the familiarization session, the researcher explained how to steer the Expresso Bike and adjust the gears. Participants were instructed to decrease the gear ratio when traveling up hills and increase the gear ratio when traveling down hills to mimic outdoor cycling behaviors. After the standardized warm-up, the researcher selected the “Campus Loop” course programmed into the Expresso Bike. This course was classified as “easy” by the Expresso manufacturer. Researchers provided verbal encouragement throughout the test and participants were instructed to cross the finish line completely before terminating their efforts. Peak power output, mean power output, and time to completion were recorded.

Abdominal Fatiguing Exercise

The abdominal fatiguing exercise preceded the participants’ respective cycling performance on their third testing day. The abdominal fatiguing exercise followed a strict protocol to ensure maximal usage of the abdominal musculature. During this exercise, participants were instructed to lie on an exercise mat in a supine position with their arms shoulder width apart outstretched in the air. A wooden dowel was extended across their outstretched arms six inches above their fingertips. Participants were instructed to crunch up and touch the dowel until volitional exhaustion while keeping the abdomen flexed by not returning their shoulders to the mat between crunches. In a pilot study ($n = 10$), this protocol reduced abdominal power by 36 % ($p<0,0001$) as assessed with the front abdominal power throw using the procedures and protocols described in Cowley & Swensen (2008).

Statistical Analysis.

Data were analyzed using IBM SPSS 22,0 software. Baseline FAPT and ACSM curl-up scores were used to assess differences between ANA and AER groups at baseline. A dependent t-test was used to determine changes in cycling performance after the fatiguing abdominal exercise bout (Day 3) compared to baseline (Day 2) within the ANA and AER groups. An alpha level of 0,05 was used to determine statistical significance.

Research Results.

Abdominal fatigue significantly decreased anaerobic performance, as WAnT mean power output decreased by 16,0 % (487 vs 409 W; $p<0,001$) and the rate of fatigue increased by 19,8 % (42,0 vs 50,3 %; $p<0,01$) compared to baseline. Additionally, peak power output decreased by 6.2% after abdominal fatigue, although this decline did not reach statistical significance (643 vs 603 W; $p = 0,088$). Interestingly, of the 12 participants, seven decreased peak power by an average of 91,1 W, whereas the remaining five participants had a modest average peak power gain of 31,4 W. Fig. 1 shows the respective peak power, mean power, and rate of fatigue differences across days for ANA participants. In contrast to the anaerobic power scores, there were no significant changes in TT performance after abdominal fatigue when compared to baseline.

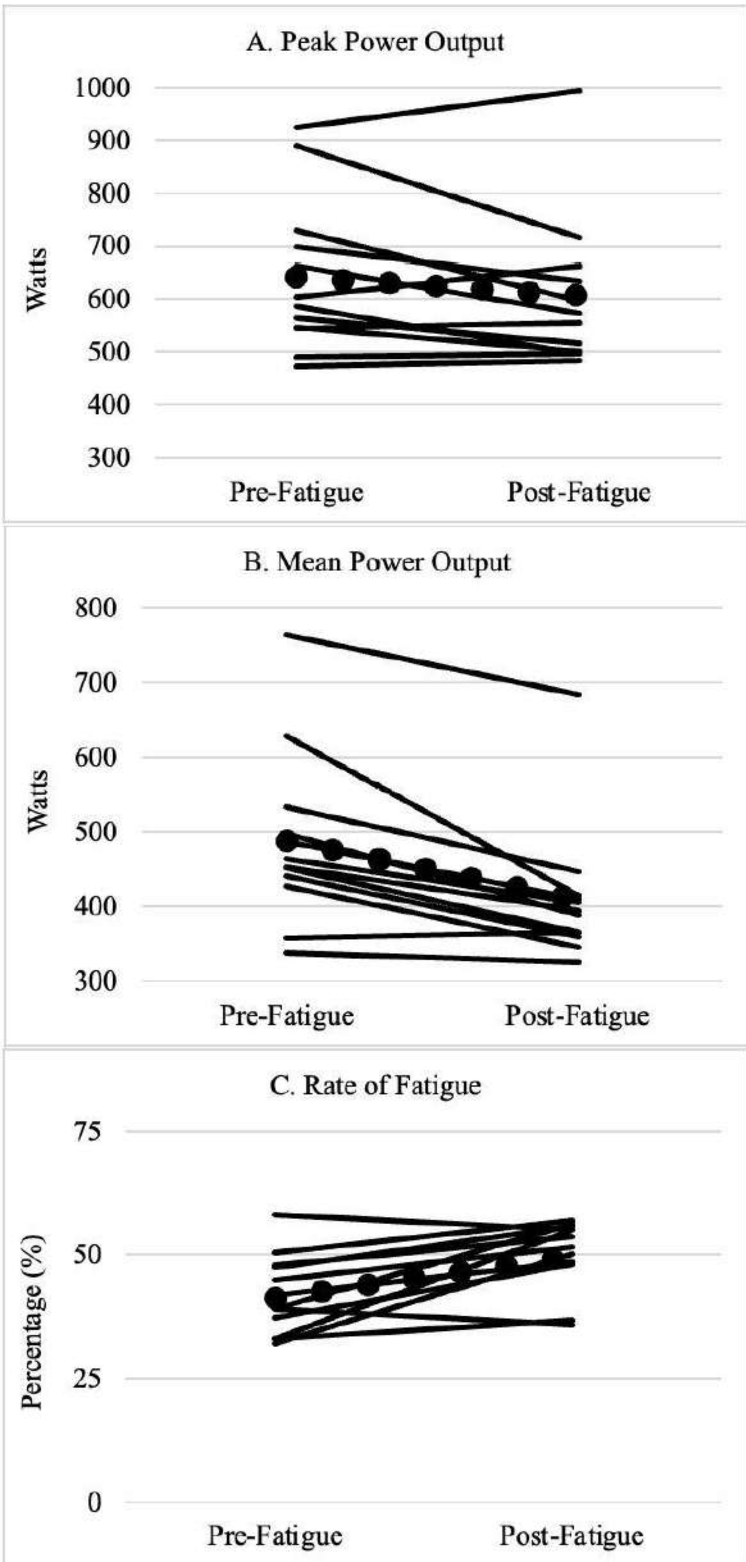

Fig. 1. *Results for WAnT A) Peak Power, B) Mean Power, and C) Rate of Fatigue. Solid lines represent Individual Results Pre- and Post-Abdominal Fatigue While Dotted Line Represents the Group Average*

These results are depicted in Table 2 and individual data are displayed in fig. 2.

Table 2

Pre- and Post-Abdominal Fatigue Cycling Measures

	Pre-Fatigue	Post-Fatigue	%Δ	*p-value*
ANA				
PP (W)	643 ± 145	607 ± 144	-6,2	0,088
MP (W)	487 ± 115	409 ± 93	**-16,0***	0,00040
RoF (%Δ)	42,0 ± 8,0	50,3 ± 7,2	**19,8***	0,0040
AER				
PP (W)	418 ± 10	442 ± 103	5,7	0,14
MP (W)	228 ± 33	220 ± 37	-3,6	0,13
Time (s)	383 ± 24	388 ± 31	.3	0,22

Pre-Fatigue = performance before abdominal fatigue; Post-Fatigue = performance after abdominal fatigue; PP = Peak Power; MP = Mean Power; RoF = Rate of Fatigue; Time = time to complete the time trial; * indicates statistical significance. Data are presented as mean ± standard deviation.

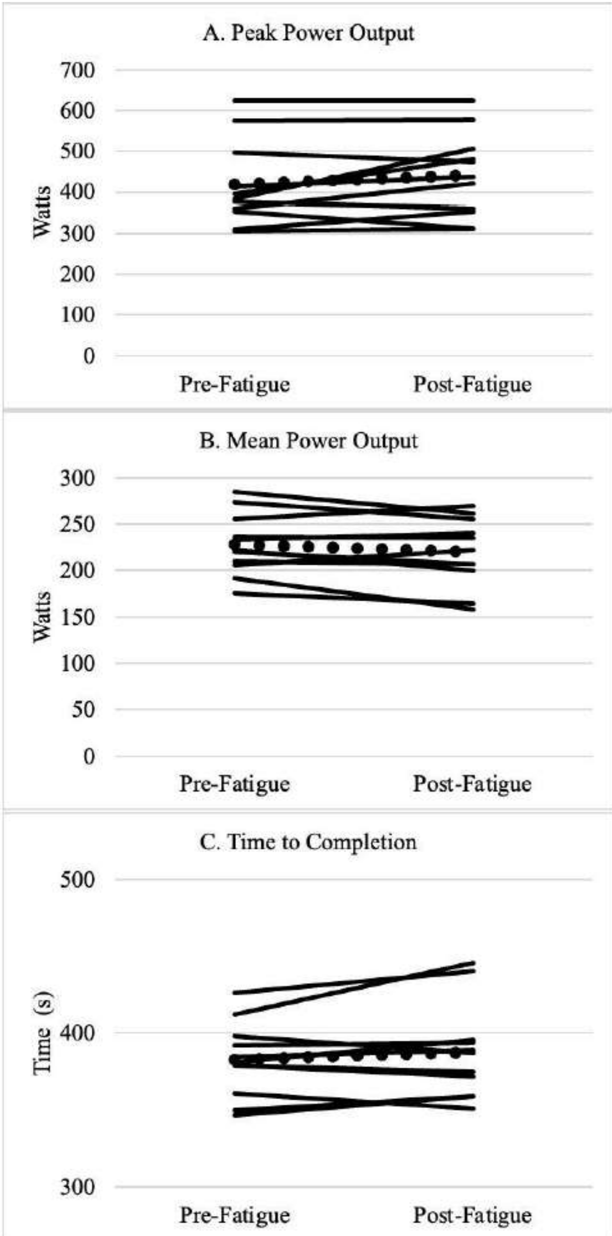

Fig. 2. *Results for Time-Trial A) Peak Power, B) Mean Power, and C) Time to Completion. Solid Lines Represent Individual Results Pre- and Post-Abdominal Fatigue While Dotted Line Represents the Group Average*

Discussion.

The purpose of the present study was to determine the impacts of abdominal fatigue on anaerobic and aerobic cycling performance. It was hypothesized that abdominal muscle fatigue would reduce both aerobic and anaerobic cycling performance due to the role the abdominals play in force production and stabilization during cycling. While abdominal muscle fatigue significantly decreased mean anaerobic power and increased rate of fatigue during anaerobic cycling performance, there were no significant effects on aerobic cycling performance. These results likely reflect the nature of the tests used as the WAnT requires substantial activation and stabilization of the trunk to generate as much power as possible, often reported to be 175 % of peak aerobic power (Bar-Or, 1987). In contrast, the TT was completed at a much lower intensity, as reflected by the average wattage produced during the test, thereby lessening reliance on abdominal muscles for force production when compared to sprinting.

The TT results in the present study are consistent with previously reported findings that abdominal muscle fatigue does not alter cycling endurance performance when measured with a maximum graded exercise test [1]. Additionally, a previous investigation found no improvements in multiple performance tests, including a 2000-meter maximal rowing ergometer test following an 8-week core endurance training program in trained rowers [17]. In contrast, results from the WAnT in the present study suggest abdominal muscle fatigue does reduce sprint performance. Therefore, the present findings suggest anaerobic power athletes may be affected by abdominal fatiguing exercise performed prior to an event.

However, a primary limitation of the present study emerges from the use of untrained non-cyclists, suggesting limited application to trained cyclists. While TTs are well-correlated to markers of aerobic ability, such as VO_{2max} and lactate threshold [16], and better simulate cycling performance than VO_{2max} tests in trained cyclists [6], performance can be highly impacted by pacing strategies [8]. Therefore, TT data observed in untrained cyclists may differ substantially from those in trained cyclists due to a lack of experience with pacing strategies. Additionally, the stationary cycle ergometer used for the TT may not require the same degree of core stabilization as would be needed when cycling outdoors thereby limiting the influence of abdominal fatigue on performance. Future studies should evaluate the impact of abdominal muscle fatigue on cycling performance in trained cyclists as well as in more realistic simulated racing conditions.

Despite its aforementioned limitations, the present study is the first to establish that abdominal fatigue significantly reduces anaerobic sprint cycling performance. Cyclists and coaches can use this information to better inform training programs. First, and most obvious, coaches should discourage their athletes from performing fatiguing exercises prior to competition. Second, sprint cyclists may benefit from integrating abdominal muscle exercises into their training programs to mitigate negative effects of abdominal fatigue on performance.

Conclusions.

The present study revealed a significant impact of abdominal fatigue on anaerobic sprint cycling performance, as evidenced by decreased mean anaerobic power and increased rate of fatigue during anaerobic cycling. While aerobic cycling performance remained unaffected, the results highlight the substantial impact abdominal muscle fatigue can have on sprint performance. Despite limitations related to the use of untrained non-cyclists, the present findings highlight the potential benefits of incorporating abdominal muscle exercises into training programs for sprint cyclists and advise against fatiguing exercises prior to competition to optimize performance. Future investigations regarding the impact of abdominal fatigue and abdominal-focused training in trained cyclists on both aerobic and anaerobic performance in outdoor conditions are warranted.

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