Effect of fatigue and incline on cycling cadence and efficiency

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Abstract

We attempted to determine how factors associated with cycling (cadence or rate of pedaling, incline, and fatigue) affect efficiency, or heart rate/power output. Training and optimal cycling form should result in greater usage of more efficient aerobic muscle fibers and groups producing more ATP/glucose. Paradoxically, using weaker, slow-twitch aerobic fibers should result in higher cadences with less force needed per pedal stroke (opposite for stronger, fast-twitch glycolytic fibers). Fatigue would also result in slower cadences, as more fast-twitch fibers are recruited to maintain power. Inclines and declines would result in similar changes, as less-trained muscle groups, with lower aerobic capacity, would be recruited to maintain body position. We hypothesize higher efficiency for higher cadences, lower fatigue, and 0% incline. As expected, fatigue resulted in slower cadence. Surprisingly, variable spontaneous cadence and a negative incline (on a stationary bike) were most efficient.

Introduction

Previous studies in our lab suggest that increasing cadence (higher RPM) allows you to cycle at the same power with less effort. This was tested physiologically by measuring heart rate, oxygen consumption, and lactate. It was found that lactate threshold increased from 60 to 80 RPMs. However, it was noticed that subjects had trouble maintaining assigned cadences as fatigued increased. No literature on cycling cadence addresses this fatigue issue. Almost collectively, all studies addressing optimal cadence suggest that natural cadences are too slow and that higher cadences were more efficient and prolonged time-to-fatigue (1). Therefore, the purpose of this study is to determine if cycling cadence and efficiency are affected by fatigue and other factors that might alter muscle recruitment, like changes in body position associated with incline. To test this systemically, FTP (functional threshold power), or baseline power, of each subject was determined to tailor the testing protocol to their aptitude. Using 85% of their FTP, subjects performed several treatments for 3 minutes each (to achieve steady state) at different cadences and inclines. Information gained in this study, could aid individuals in future training, competition and exercise in general.

Methods/Procedure

- Due to the vigorous exercise involved in this study, subjects had to fill out a PAR-Q (Physical Activity Questionnaire) prior to participation to determine if subjects had indications that would exclude them from this study.
- Subjects also read and signed a consent form to ensure they understood various aspects of participation including it being voluntary and anonymous and that they could withdraw at any time.
- A Wahoo Kickr and Climb were used to generate and measure the desired power and incline (Figure 1).
- Subjects donned a chest strap heart rate transmitter that was disinfected after each use.
- Heart rate was used as a measure of efficiency, a lower HR indicates less effort to maintain the same power.
- An estimate of maximum heart rate, MaxHR = 207 – 0.7(age) (2) was calculated prior to participation as a safety measure to prevent overexertion.
- The iWorx Labscribe program was used to record data from the heart rate sensor as well as power and cadence from the smart trainer. Additionally, power was controlled by the Wahoo Fitness app.
- Random.org was used to randomized the treatments, in order to remove the effects of fatigue, unless this was being tested for.
- Subjects performed the following procedure:
  1. 5-10min warm up where constant, preferred start cadence was determined.
  2. Ramp test for FTP determination: subjects began at a power between 140-160 watts followed by an increase of 20 watts every minute until power could no longer be maintained. FTP was determined by calculating 75% of the highest power achieved.
  3. Maintaining 85% of FTP, subjects performed a total of 10 treatments for 3 minutes each (to achieve steady state). 1) at different cadences (constant preferred from start, 10% above, and 10% below), 2) different inclines (-10%, 0%, 10%, and 20%), and lastly 3) the effect of fatigue on the efficiency of variable spontaneous cadenced vs a constant preferred cadence (based on the preferred cadence from the warmup) for comparison. The 10 treatments are shown below.

Treatments

Randomized first two treatments
- Constant, preferred start cadence, 0% incline
- Variable, spontaneous cadence, 0% incline

Randomized middle six treatments
- 10 RPM faster, 0% incline
- 10 RPM slower, 0% incline
- Variable, spontaneous cadence, 10% decline
- Variable, spontaneous cadence, 0% incline
- Variable, spontaneous cadence, 10% incline
- Variable, spontaneous cadence, 20% incline

Randomized last two treatments
- Variable, spontaneous cadence, 0% incline
- Constant, preferred start cadence, 0% incline

Results

Figure 1: Wahoo Kickr and Climb

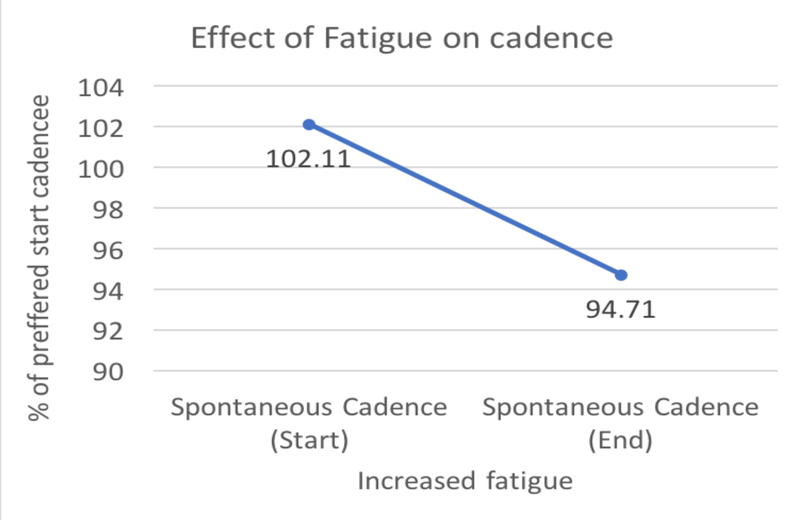

Figure 2: Spontaneous cadence at start vs spontaneous cadence at end

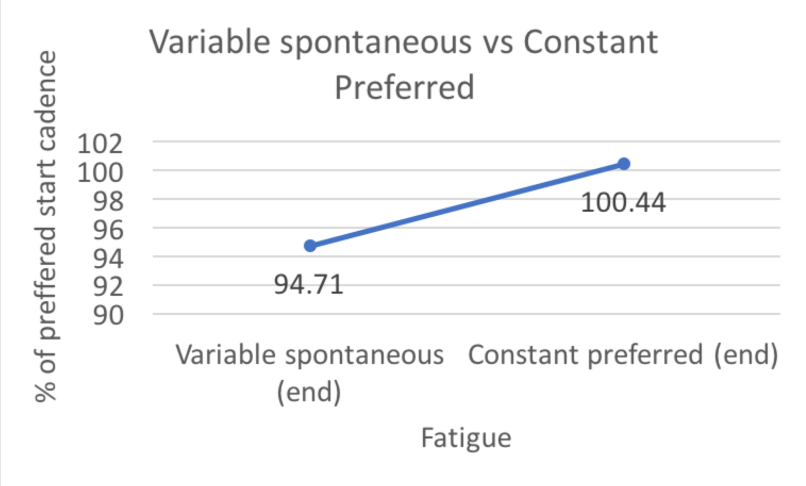

Figure 3: Variable spontaneous cadence at the end compared to the Constant preferred cadence (based from warm up cadence)

- Three subjects completed the study (N=3), so results are preliminary
- Fatigue resulted in a decrease of cadence (**Figures 2 and 3**)
- When fatigued, a variable, spontaneous cadence was more efficient (a lower % max heart rate indicates higher efficiency) than a forced constant, preferred cadence (from warm up) (**Figure 4**)
- Variable, spontaneous and forced preferred cadences were more efficient than both forced above or below preferred cadence, with the highest cadence being the least efficient (**Figure 5**)
- A negative incline was the most efficient compared to both no incline and positive inclines. Flat (0% incline) was the least efficient (**Figure 6**)

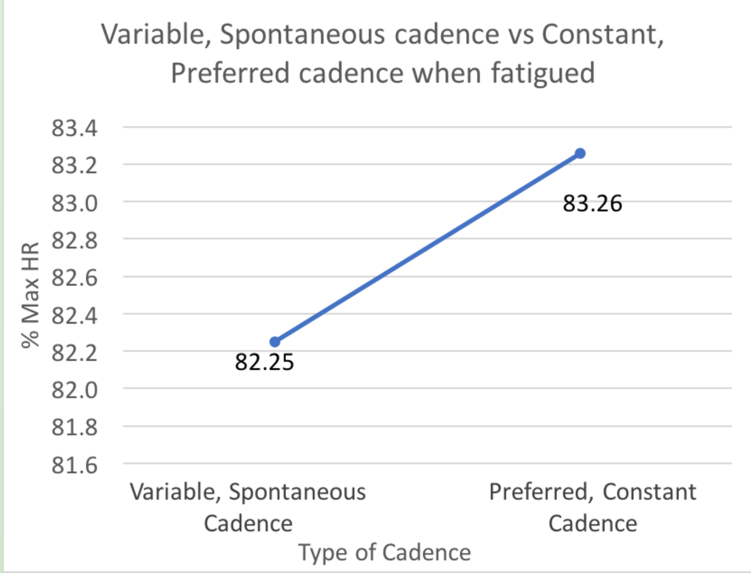

Figure 4: Efficiency compared between variable spontaneous and constant preferred cadence when fatigued. A lower % of Max HR indicates higher efficiency.

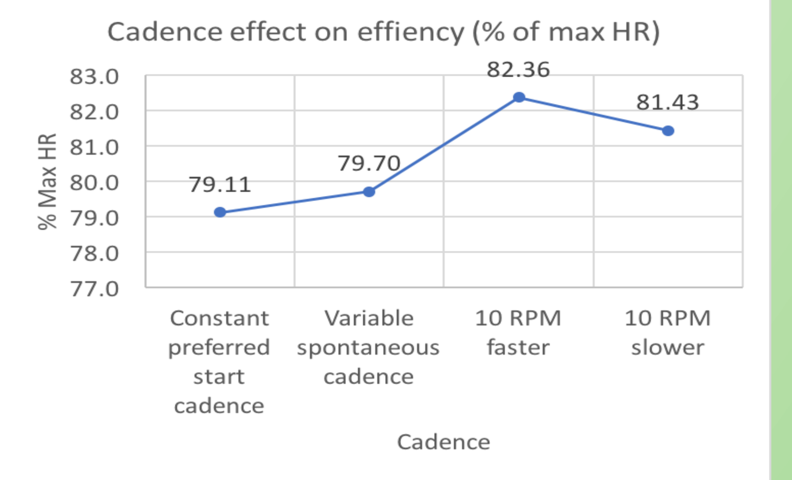

Figure 5: Efficiency at different cadences. A lower % of Max HR indicates higher efficiency.

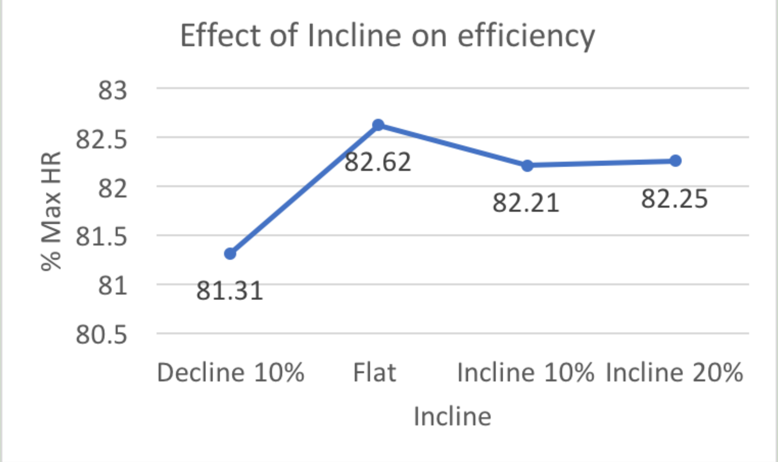

Figure 6: Efficiency at different inclines. A lower % of Max HR indicates higher efficiency.

Discussion

- The expected decrease in cadence with fatigue is likely due to recruitment of more powerful, fast-twitch muscles as stated in the introduction (more force allows the same power to be maintained with fewer pedal strokes).
- The rest of the results went against our expectations as well as findings from previous studies (1).
- When fatigued, a slower spontaneous cadence was more efficient than a forced, faster preferred cadence determined at the start of the trial (pre-fatigue). This indicates that muscle recruitment has been optimized for the level of fatigue and forcing an alternation from this is counterproductive. In this study, all subjects were experienced cyclists that have likely optimized their cycling form for various conditions, including fatigue. Perhaps less trained subjects would benefit from forced alternations to spontaneous cadences.
- This conclusion, regarding experienced cyclists, was further supported by a decrease in efficiency for forced cadences 10 rpm above and below preferred cadence.
- Another surprise was that a declined body position was the most efficient compared to no incline and various inclines. It is possible that the perception of effort through the mind-body connection literally alters the physiological responses, specifically a lower HR at similar power output. When cycling down a hill, the mind is conditioned to expect less effort to be required to maintain or even increase speed. Gravity does the work for you. This makes one wonder about the benefits of visualization. Could you literally reduce your effort for similar power outputs by imagining yourself going down a hill or being refreshed and unfatigued.
- Perhaps these and other questions will be explored in future studies in our lab.

References

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