INTERNATIONAL JOURNAL OF -EXERCISE SCIENCE-

*Original Research*

# Physiological and Biomechanical Responses to Indoor Cycling with and without the Ability to Sway

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## Abstract

***International Journal of Exercise Science 18(7): 531-542, 2025.*** https://doi.org/10.70252/FQRW7720 The purpose of this study was to understand whether or not physiological and biomechanical measures were influenced by cycling sway and intensity. Participants (n=13; 24.9±6.5 years; 1.7±0.1 m; 64.7±11.2 kg) completed two submaximal-effort cycling conditions using a stationary smart bike placed on a rocker board: 1) cycling with the rocker board set to allow sway (unblocked); 2) cycling with blocks placed in the rocker board to prevent sway (blocked). The order conditions were counterbalanced, and each condition was 12-mins. For each condition, four intensity levels were completed. Prior to testing, target power was identified for each Rating of Perceived Exertion (RPE) level (11, 13, 16, 17). Rate of oxygen consumption ($\dot{V}O_2$; ml·kg$^{-1}$·min$^{-1}$) was measured using a metabolic cart (1 sample every 5 sec) along with RPE and heart rate (HR). Cadence, speed, and power were measured via the smart bike interface for each condition. Sway was measured using a custom rotary switch that measured (250 Hz) the angle of the rocker board while cycling. Each dependent variable was compared using a 2 (Condition: blocked, unblocked) x 4 (Intensity) repeated measures ANOVA. For sway, $\dot{V}O_2$, HR, speed, and cadence, there was no interaction between Condition and Intensity ($p>0.05$). Sway was influenced by the main effect of Condition ($p<0.001$). $\dot{V}O_2$, HR, and speed were each influenced by the main effect of Intensity ($p<0.001$). Overall, it was determined that participants did sway when there was the potential to sway; however, physiological or biomechanical measures were not influenced by the ability to sway.

Keywords: Endurance, sports, performance, lateral movement, perception

## Introduction

In 2017, approximately 47.5 million people in the United States participated in some sort of bicycling.[1] Each year more people cycle, whether it is for leisure, transportation, or sport. When it comes to cycling as a sport, in 2018 more than 160 million people attended a cycling event in the U.S.[1] Some types of sports cycling include cyclocross, track, mountain, and road cycling.

There is a strong body of literature for example, researchers have examined physiological and biomechanical measures to evaluate cyclists' performance. For example, there is a wealth of research on cycling power,[2-3] heart rate,[4-5] oxygen consumption,[2] and rate of perceived exertion[6-7] during cycling. Much of this research has been conducted in a laboratory on a fixed stationary cycle. However, it is well known that the skill of cycling involves balancing.[8] There is limited research on the influence of balancing a bike on physiological and/or biomechanical measures.

Maintaining balance on a bicycle is a dynamic task that involves coordinating steering inputs, body, and bike movements.[8] A measurable component of balance is the amount of lateral sway of the bike that occurs during cycling.[8] More specifically, when cycling, the bicycle can be maneuvered from side-to-side. For this paper, bicycle sway is analogous to the amount of bicycle lean[8] or lateral sways.[9] It is important to recognize that another approach is to quantify the lean of the bike as well as the lateral lean of the cyclist relative to the bike.[8] The term 'sway' represents the amount of bike deviation (lateral rotational movement) from a vertical reference line during cycling. Since balancing is a crucial component to propelling a bicycle (i.e., keeping the bike upright), understanding the effects sway may have on the physiological and biomechanical parameters while cycling is important to cycling performance.

Cycling is a sport that requires balance for optimal performance.[10] Cycling balance skills vary between the different skill levels of cyclists (i.e., novice vs experienced).[8] For novice riders, balancing is a skill that is acquired with practice. Anecdotally, when a novice cyclist begins to maneuver a bicycle, the bicycle will sway or move laterally as they attempt to propel the bicycle forward. This is due to the multiple demands required to ride a bicycle. For instance, some of these demands include balancing on the bicycle, keeping the handlebars horizontal, and simultaneously having to push on the pedals to rotate the tires to propel the bicycle forward. On the other hand, with experienced cyclists, bicycle lateral movement may be wanted for times when generating more power is necessary such as uphill cycling or sprinting.[8,11-12] Regardless of skill level, balancing a bicycle may affect other cycling parameters (e.g., power output) and in turn, affect overall performance.

Cycling power is a parameter that majority of athletes use to gauge their performance outcomes.[2, 13-15] This measurement is widely used due to the equipment readily available to athletes. The invention of the power meter allows cyclists to have continuous, real-time power data displayed while they cycle. From this data, athletes can target certain power output zones during specific portions of their ride. For example, different types of terrain may be navigated during a competition (e.g., flat, semi-mountainous, mountainous) which requires various power demands. Research has shown that with more mountainous terrains greater power demands are needed.[5,16] Therefore, the power measurement and the power meter are an integral part of cycling performance.

Oxygen consumption is the gold standard to measuring a person's cardiorespiratory fitness and endurance performance.[2,17] Heart rate and oxygen consumption have a linear relationship with both measurements indicating an individual's physiological capabilities to perform moderate-to-strenuous exercise.[4] Both types of measurements are used in cycling research because it can determine a person's ability to perform certain cycling protocols. This aids in researchers'

understanding of cycling performance and then interventions or changes can be made that can help cyclists in training or in competition. Limited research has examined these two measurements in conjunction with sway. There may be a link between a person's ability to maneuver a bicycle laterally and the effects it has on physiological parameters.

Therefore, the purpose of this study was to understand whether or not physiological and biomechanical measures were influenced by cycling sway and intensity. The overarching goal of this study was to understand why we cycle a certain way. The information derived from this study may have implications on whether sway is beneficial to the physiological demand and biomechanics while cycling. It is hypothesized that sway may be an important factor that influences heart rate and the amount of oxygen consumption required when cycling at a given intensity. Specifically, since sway is a natural component of cycling, it is hypothesized that restricting sway on a fixed cycle trainer coincidentally increases the intensity of cycling as it would interfere with the natural benefit of a sway component. It was hypothesized that heart rate (HR) and rate of oxygen consumption ($VO_2$) would be lower for a given cycling resistance when sway was allowed vs. prevented.

## Methods

*Participants*

Thirteen participants (age = 24.9 ± 6.5 years; height = 1.7 ± 0.1 m; body mass = 64.7 ± 11.2 kg; mean ± SD) volunteered to participate in the study. Twelve participants were inexperienced cyclists (cycling zero to 15 miles per week in the past year) and one subject was an experienced cyclists (cycling roughly 150 miles per week). This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science*.[18] This study was approved by the Institutional Review Board of the university (ID#UNLV-2023-357). All participants gave written informed consent. Participants were deemed apparently healthy as per ACSM Guidelines and following a brief health history questionnaire (Physical Activity Readiness Questionnaire for Everyone, PAR-Q+). Only participants who answered 'no' to the first seven screening questions were able to participate in the study. All participants reported they were comfortable riding a bicycle. Participants were not allowed to have any current medical restrictions for exercise or have any injury that would interfere with their ability to cycle, could they be pregnant or think they could pregnant, or have any electronic implanted devices (e.g., pacemaker) due to the use of bioelectric impedance to measure body composition.

A G*Power analysis conducted determined that a sample size of 24 subjects was recommended. Lack of data in this area did not allow for an accurate G*Power analysis. Therefore, thirteen participants were selected as a first look into this using the procedures in this experiment.

*Protocol*

Participants reported to the laboratory for a single day of testing. Anthropometric measures of height, weight, and body composition (InBody USA, Cerritos, CA) were recorded. The participant had a chest heart rate monitor (Wahoo Fitness, Atlanta, GA) placed on them.

All cycling conditions were completed using a smart trainer bike (Wahoo KICKR Bike, Wahoo Fitness). The smart bike measures cycling parameters such as power, cadence, speed, and distance. The resistance of the smart bike was controlled by the researcher. The smart bike was placed on a rocker board (KOM Cycling) (Figure 1). The rocker board allows for side-to-side rotation while using the stationary smart bike. The ability of the board to rock is controlled by two inflatable balls, one on each side of the rocker board. These balls were inflated to 20 psi. Due to the asymmetrical weight distribution of the bike due to the flywheel (left leaning), 2.7 kg was added to the right side of the board. A level was used to ensure the board was balanced prior to data collection. A custom rotary sensor (Pasco Scientific, Roseville, CA) was secured on the back of the rocker board where the axis of rotation of the board and rotary switch were aligned.




**Figure 1**: Bike-board system and rotary device setup.

The rotary sensor set-up was connected to a computer wirelessly via Bluetooth. Pilot work was completed to confirm the ability of the rotary sensor to measure sway. This work consisted of comparing rotary sensor output to digitizing and inclinometer methods while placing the rocker board in specific rotations.

Rotary sensor data were recorded using data acquisition software (Pasco Scientific) at a sample rate of 250 Hz. The smart bike and heart rate monitor measured and recorded at 1 Hz through specific data acquisition software (Wahoo Fitness). The metabolic system (Parvo Medics) and software were used to measure and record oxygen consumption (1 sample every 5 sec) data during each cycling condition.

Prior to data collection, the participants were asked to perform at least a 5-minute self-selected warm-up. Warm-up consisted of cycling until the participant felt comfortable with prior to

collection. After the warm-up, the bike was fitted properly for the participant. During all cycling conditions, participants were instructed to maintain the same posture (e.g., hand position, head position) and to stay seated (i.e., no standing). In addition, participants were not allowed to change gears. Participants were given time to cycle on the bike-board system until they were comfortable. Prior to the warm-up, participants were given instructions on using the 6-20 point RPE scale.[19]

All participants completed two cycling conditions: unblocked vs blocked. The unblocked condition allowed the participant to sway laterally freely as they cycled. The blocked condition had blocks placed within the rocker board to prevent sway.

Prior to testing, participants completed a self-selected preferred power output phase with the rocker board set to no-sway. During this phase, participants were instructed to cycle at an RPE of 11. The participant would tell the researcher to increase or decrease the resistance until he/she indicated that the RPE is 11. The participant would not be able to view their power during this process. Once the subject indicated he/she was at RPE 11, the researcher recorded the power that was produced, and the subject was asked to stop pedaling. This process was repeated two more times and the average of the three power measurements was used as the target power for RPE 11 during data collection. This process was repeated for RPE levels of 13, 15, and 17. The preferred power at each RPE level was used in the experiment as the target powers.

After determining the target powers, participants were fit with a face mask so that expired air could be recorded. Resting measurements of $VO_2$ and heart rate were recorded for six minutes while the participant rested in a seated position.

Following the resting measurement, the participant was informed of the order of the sway conditions (i.e., blocked, unblocked). The order of the conditions was counterbalanced between subjects. For each condition (i.e., sway, no sway), the participant completed a continuous graded test progressing from RPE 11, 13, 15 to 17. The resistance was set to the target power for each RPE level.

Each intensity level was three minutes for a total condition time of 12 mins. In between sway conditions, the participant was given rest as needed. Sway (radians), heart rate (bpm), $VO_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), cadence, speed, power were recorded during each condition.

Data were processed through a custom program (MathWorks MATLAB, Natick, MA) and spreadsheets (Excel, Microsoft Inc.). All raw data were graphically inspected through MATLAB. After visual inspection of the raw data files, specific data sets were excluded from the analysis due to quality of the data. For the right and left sway, 2 of the 104 data points (i.e., all subject-condition data points) were excluded. For heart rate data, cadence, and speed, 3 of the 104 data points (i.e., all subject-condition data points) were excluded from the analysis.

For heart rate and $VO_2$, the last one minute of the three-minute stage for each intensity level was averaged. Speed and cadence were each averaged for each 3-min intensity stage. Sway data were recorded for 30 seconds during the last minute of each intensity. To quantify sway, the local

maximum rotation in each direction (Right, Left) were identified. These local maximums were then averaged for each direction resulting in Right sway and Left sway data of each intensity level for unblocked (Figure 2) and blocked conditions.

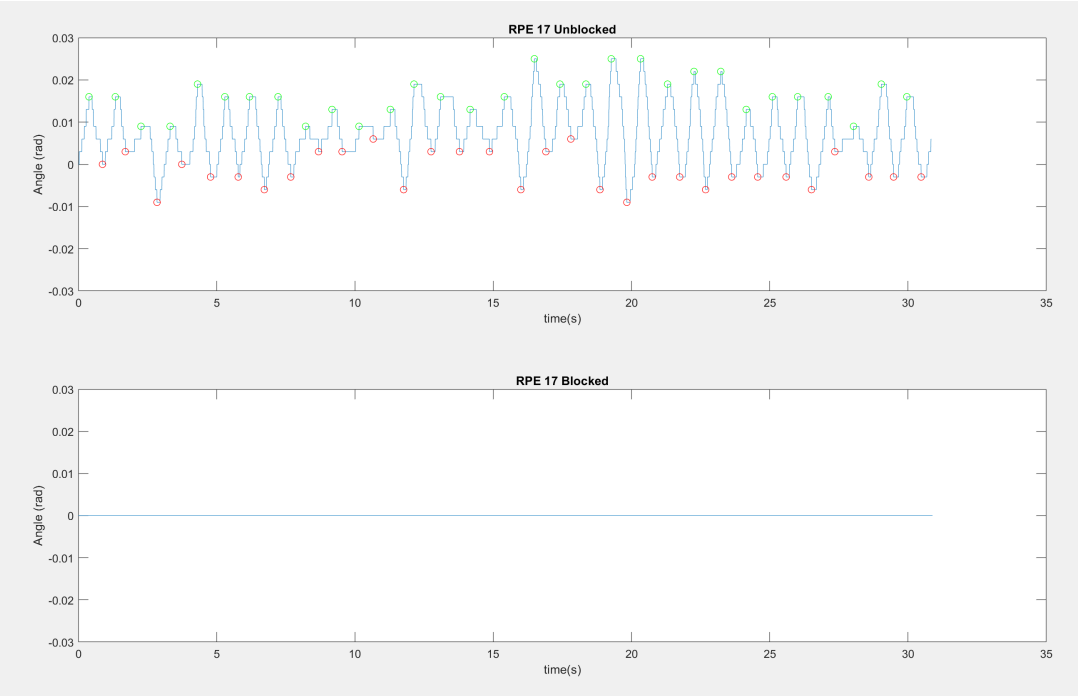


**Figure 2.** An example data set of sway data for an RPE of 17 for the unblocked and blocked conditions.

*Statistical Analysis*

The dependent variables were: right sway, left sway, cadence, power, speed, heart rate, and $VO_2$. The independent variables were Intensity (RPE 11, 13, 15, and 17) and Sway condition (blocked, unblocked).

Each dependent variable was analyzed using a 2 (Sway: blocked vs unblocked) x 4 Intensity: RPE 11, 13, 15, 17) repeated measures analysis of variance (ANOVA). All statistical analyses were conducted using IBM SPSS version 28 ($\alpha$=0.05). If Mauchly's Test of Sphericity was violated, then the degrees of freedom, F-ratio and p-value were adjusted using Greenhouse-Geisser. When the F-ratio was found to be significant, a planned pairwise comparison analysis was performed using a Bonferroni correction to analyze significant differences between conditions. Furthermore, effect size ($\eta$2) was reported and determined small at 0.01, medium at 0.06, and large at 0.14.

## Results

Physiological and biomechanics data for all conditions are presented in Table 2 (means ± standard deviations).

*Sway*

Right sway was not influenced by the interaction of sway and intensity ($F(3,33) = 2.209$, $p = 0.106$, partial $\eta^2 = 0.167$). Right sway was influenced by sway condition regardless of intensity ($F(1,11) = 9.066$, $p = 0.012$, partial $\eta^2 = 0.452$). Right sway was not influenced by intensity ($F(3,33) = 2.576$, $p = 0.070$, partial $\eta^2 = 0.190$).

Left sway was not influenced by the interaction of sway and intensity ($F(1.126,12.391) = 1.880$, $p = 0.196$, partial $\eta^2 = 0.146$). Mauchly's Test of Sphericity was violated ($p < 0.05$) and the F-ratio was adjusted using Greenhouse-Geisser. Left sway was influenced by sway condition regardless of intensity ($F(1,11) = 6.882$, $p = 0.024$, partial $\eta^2 = 0.385$). Left sway was not influenced by intensity ($F(1.113,12.245) = 1.586$, $p = 0.235$, partial $\eta^2 = 0.126$).

*$\dot{V}O_2$*

$\dot{V}O_2$ was not influenced by the interaction of sway and intensity ($F(1.750, 20.996) = .932$, $p = 0.398$, partial $\eta^2 = 0.072$). Mauchly's Test of Sphericity was violated ($p < 0.05$) and the F-ratio was adjusted using Greenhouse-Geisser. $\dot{V}O_2$ was not influenced by sway condition ($F(1, 12) = 0.248$, $p = 0.627$, partial $\eta^2 = 0.020$). $\dot{V}O_2$ was influenced by intensity ($F(1.144, 13.732) = 49.971$, $p < 0.001$, partial $\eta^2 = 0.806$).

*Heart Rate*

Heart rate was not influenced by the interaction of sway and intensity ($F(1.203, 12.026) = .929$, $p = 0.373$, partial $\eta^2 = 0.085$). Mauchly's Test of Sphericity was violated ($p < 0.05$) and the F-ratio was adjusted using Greenhouse-Geisser. Heart rate was not influenced by the main effect of sway condition ($F(1, 10) = 1.644$, $p = 0.229$, partial $\eta^2 = 0.141$) but was influenced by the main effect of intensity ($F(1.620, 16.203) = 104.621$, $p < 0.001$, partial $\eta^2 = 0.913$).

*Cadence*

Cadence was not influenced by the interaction of sway and intensity ($F(1.332, 13.316) = 0.319$, $p = 0.645$, partial $\eta^2 = 0.031$). Mauchly's Test of Sphericity was violated ($p < 0.05$) and the F-ratio was adjusted using Greenhouse-Geisser. Cadence was not influenced by the main effect of sway condition ($F(1, 10) = 0.923$, $p = 0.359$, partial $\eta^2 = 0.084$) or intensity ($F(1.767, 17.673) = .275$, $p = 0.736$, partial $\eta^2 = 0.027$).

*Speed*

Speed was not influenced by the interaction of sway and intensity ($F(1.005,10.045) = .556$, $p = 0.474$, partial $\eta^2 = 0.053$). Mauchly's Test of Sphericity was violated ($p < 0.05$) and the F-ratio was adjusted using Greenhouse-Geisser. Speed was not influenced by sway condition ($F(1, 10) = .401$, $p = 0.541$, partial $\eta^2 = 0.039$) but speed was influenced by intensity ($F(1.632, 16.324) = 92.148$, $p < 0.001$, partial $\eta^2 = 0.902$).

**Table 1.** Means and standard deviations of main dependent variables.

| | Unblocked Condition | | | | Blocked Condition | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variables | RPE 11 | RPE 13 | RPE 15 | RPE 17 | RPE 11 | RPE 13 | RPE 15 | RPE 17 |
| Right Sway (radians) | 0.01±0.01 | 0.02±0.02 | 0.02±0.02 | 0.02±0.02 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Left Sway (radians) | -0.01±0.01 | -0.01±0.01 | -0.01±0.01 | -0.03±0.07 | 0.00±0.00 | 0.00±0.01 | 0.00±0.00 | 0.00±0.00 |
| $VO_2$ (ml·kg$^{-1}$·min$^{-1}$) | 17.7±6.2 | 20.5±7.0 | 23.8±7.9 | 27.4±10.2 | 18.1±6.4 | 21.0±7.7 | 24.1±8.7 | 27.2±10.8 |
| Heart rate (bpm) | 111.2±16.3 | 122.3±17.1 | 134.6±18.4 | 145.2±20.5 | 116.5±18.6 | 129.1±22.6 | 137.0±22.6 | 147.0±23.7 |
| Cadence (rpm) | 74.4±14.2 | 71.2±15.8 | 72.3±15.2 | 72.5±17.9 | 73.8±15.0 | 73.7±16.0 | 73.4±16.6 | 71.9±16.4 |
| Speed (m·s$^{-1}$) | 13.4±5.1 | 17.7±5.6 | 21.0±5.5 | 23.5±5.1 | 13.1±5.2 | 17.60±5.8 | 21.0±5.6 | 23.5±5.1 |
| Power (Watts) | 56.5±32.6 | 76.7±37.9 | 92.9±42.8 | 110.7±51.7 | 56.5±32.6 | 76.7±37.9 | 92.9±42.8 | 110.7±51.7 |

## Discussion

The most important observation of this study was that physiological and biomechanical parameters were not influenced by sway at matched power. The hypothesis that the potential to sway the bike vs. not being able to sway would result in a heart rate and lower $\dot{V}O_2$ was refuted. As expected, $\dot{V}O_2$, heart rate, power, and speed increased with intensity whereas cadence did not. However, none of these parameters were different between sway conditions. Overall, the potential to sway did not influence physiological or biomechanical measurements.

This study sought to investigate whether the potential to sway a bike was influential to physiological demand while cycling. This experiment investigated the potential to sway during two conditions (unblocked, blocked). The findings discovered that sway was different when the participants were cycling on a rocker board that allowed sway vs. having the rocker board blocked to prevent sway. These results make sense due to the unblocked condition allowing participants the opportunity to sway and the blocked condition restricting a participant's ability to maneuver the bike. It should be noted that prior to this experiment, the unblocked condition as categorized as the "potential to sway". Due to the novelty of this study design, it was not certain if participants would sway the bike or not during the unblocked condition. Based upon the observations in this study, participants did employ sway when it was allowed. However, that sway did not influence $\dot{V}O_2$, heart rate, or cadence used during cycling at a target power.

Although this study is unique and there are no direct published results of sway measured during using a rocker board set up using a stationary cycle, there are some parallel studies that are in line with the results of the present study. For example, in a study by Cain et al.[8] it was reported that at higher speeds more experienced riders exhibited more rider lean while seated than their less experienced counterparts. It should be noted that Cain et al[8] classified rider lean as the participants torso lateral movement and bicycle roll angle as the bicycle's lateral movement. Cain et al[8] reported that rider lean and bicycle roll angle were negatively correlated. This indicates that as the bicycle moved laterally in one direction, for example to the right, the rider would lean the opposite direction, to the left. In the present study, we examined the bike-rider system magnitude of sway from side-to-side, not the lateral movement of the person vs. bike.

Although physiological and biomechanical parameters were not influenced by natural sway used by the participants, it is not clear if there is a limit that may exist for how much sway is optimal. For example, if there is too much sway, a cyclist may lose balance/control of the bicycle and/or be detrimental to generating power. It may be that there is an optimal sway magnitude for a given power or range of power. Interestingly, there is research comparing sway during seated vs standing positions[9] or just standing[20] during cycling. It may be that due to the changes in mechanics (e.g., change in center of mass, increased engagement of the upper body, additional weight due to lack of saddle support, increased sway of the bicycle and body) during standing allows cyclist to generate more lateral movement which may be beneficial for cycling performance especially during uphill cycling[21] or sprinting.[20]

Bouillod et al[9] reported that cycling at varying slopes and intensities while standing resulted in increased bicycle sway, increased mechanical cost, and increased heart rate vs seated. In their conclusion, they advised that since a relationship exists between bicycle sway and mechanical cost, cyclists should decrease their bicycle sway in order to reduce the mechanical cost of locomotion.[9] This study suggested that there may be optimal amounts of bicycle sway while standing at different intensities and slopes. This experiment sought to investigate whether or not sway while seated would be different at different intensity levels. However, sway did not differ between intensities. Nevertheless, further research is needed to see if sway differs at different magnitudes of slope. With the smart bike used in the present study, there is the capability to increase and decrease the slope. It would be interesting in future studies to examine sway while seated with no slope vs. with a slope.

Wilkinson and Kram[20] sought to understand the different magnitudes of sway and its effect on power while standing. Participants completed three 5-s maximal sprints while standing for three conditions (ad libitum, minimal lean, and no lean). The study reported a decrease in power (5%) when sway was minimized vs ad libitum and locked positions. It is important to note that in the present study, intensity was always submaximal with each condition lasting 3-mins. It may be that larger sway magnitudes for maximal effort 5 s sprints is more critical than sway during submaximal, sustained efforts.

A limiting factor that may have affected the study was the experience level of the cyclists. The majority of the participants (N=12) were inexperienced cyclists (cycling zero to 15 miles per week in the past year) and one subject was an experienced cyclists cycling roughly 150 miles per week. Since the majority of the participants were novice cyclists, it is not clear whether a group of only experienced cyclists would respond similarly. Future research is needed to determine if cycling experience is a factor that must be controlled. In the present study, the majority of the participants were novice and demonstrated sway during the unblocked condition. If the experiment was repeated with experienced cyclists, we hypothesize that they would exhibit less sway than inexperienced cyclists during the unblocked condition.

Furthermore, in this study a stationary bike was used. Even though the stationary bike was placed on a rocker board to simulate natural riding style outdoors, this setup was still not equivalent to riding an actual bicycle. A stationary bike is rigid creating more stability while cycling on a bicycle outdoors requires dynamic balance. This requires a complex interaction between the cyclist and bike in order to not only maintain the balance of the bike while riding on changes in surface, turning, riding uphill, etc. Given the results of this study, a follow up study of sway while riding outdoors would be helpful to better understand cycling balance dynamics.

This study is limited in the ability to generalize the results to cycling outdoors vs. indoors. Although the rocker board does allow for a degree of freedom of movement in one axis vs. using a stationary, fixed cycle ergometer, cycling outdoors may require control over additional degrees of freedom related to dynamic balance of cycling. However, this study does provide insight into what appears to be no relationship between $VO_2$ and sway when riding indoors.

This experiment examined the potential to sway and purposefully prevented sway whereas the vast majority of research examining sway has examined cyclists while have the ability to sway their bicycle. Further research should investigate the potential to sway as a means of balance and its possible influence on cycling performance. However, in the present study, allowing participants the opportunity to sway did increase sway but that sway had no influence on physiological or biomechanical parameters.

A potential confounding factor in this study was that the power for each intensity level was determined during the unblocked condition (i.e., sway was allowed). It is not known if subjects would have selected different target powers for the blocked (i.e., no sway) condition. However, the experiment was designed around the idea that power would be matched during blocked and unblocked conditions.

A confounding factor for this experiment may have been the understanding and appropriate feelings of exertion related to the Rate of Perceived Exertion Scale. Instructions were provided to participants prior to data collection explaining the protocol is designed to be a submaximal test. Since the majority of the participants were novice, it was challenging for participants to understand the feeling of resistance associated with the different intensity levels (fairly light, somewhat hard, hard, and very hard) while cycling. Nevertheless, since $VO_2$ was different between conditions, the procedures were adequate for determining unique intensity levels. That being said, future studies could be completed using experienced cyclists to determine if blocked or unblocked conditions elicit differences in sway, heart rate, $VO_2$, cadence and speed.

It is known that cycling requires balance to propel the bicycle forward. This balance may play into a person's ability to sway (i.e., move the bicycle from side-to-side) in an advantageous way. In this experiment, it was observed that sway did not influence $VO_2$, heart rate, cadence, or speed when cycling power was controlled. Understanding the concept of sway may lead to revealing ways to optimize sway and maximize cycling performance and better understand why we cycle a certain way.

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