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Demands of Simulated Commuting Using an Electrically Assisted Bicycle

D. TAYLOR LA SALLE†, ROBERT SHUTE†, MATTHEW HEESCH‡, and DUSTIN SLIVKA‡

School of Health, Physical Education, and Recreation, University of Nebraska at Omaha, Omaha, NE, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 10(3): 454-464, 2017. The American College of Sports Medicine (ACSM) recommends adults participate in weekly aerobic activity for a minimum of 30 minutes moderate intensity exercise 5 days per week or 20 minutes of vigorous activity 3 days per week. The electrically assisted bicycle may help individuals achieve the ACSM's aerobic recommendations and introduce inactive individuals to physical activity. To compare the physiological requirements of riding a bicycle with electric pedal assist versus non-assist among healthy active young adults. 6 males and 6 females completed two randomized cycling trials using electric pedal assist (PAB) and non-assist (NON). Cycling trials were completed over a 3.54 km course with varying terrain. Time to completion was faster in the PAB (12.5 ± 0.3 min) than the NON (13.8 ± 0.3 min, $p=0.01$). Rating of Perceived Exertion (RPE) was lower in the PAB (12.0 ± 0.4) than the NON (14.8 ± 0.5, $p < 0.001$). There was no difference in mean VO_2 between PAB (2.3 ± 0.1 $L \cdot min^{-1}$) and NON (2.5 ± 0.1 $L \cdot min^{-1}$, $p=0.45$). There was no difference in mean power output when comparing PAB (115 ± 11 Watts) to NON (128 ± 11 Watts, $p=0.38$). There was no difference in heart rate between PAB (147 ± 5 bpm) and NON (149 ± 5 bpm, $p=0.77$). Recreationally active younger (college age) individuals may self-select a similar physiological intensity of physical activity regardless of mechanical assistance, resulting in quicker completion of a commuting task with PAB. Both the PAB and NON exercise bouts met ACSM criteria for vigorous exercise.

KEY WORDS: Cycling, exercise intensity, energy expenditure, eBike, Garmin Vecto

INTRODUCTION

The American College of Sports Medicine (ACSM) recommends that adults participate in a minimum amount of aerobic exercise consisting of at least 20-30 min of moderate to vigorous intensity a minimum of 3 days per week (4). The goals behind these recommendations are to decrease physical inactivity and increase the health benefits associated with being physically active. The ACSM defines moderate intensity as any activity that requires 3-6 METs, and vigorous activity as any activity that requires more than 6 METs, with 1 MET equal to 3.5 $ml \cdot kg \cdot min^{-1}$ of oxygen uptake. The outlined guidelines suggest a minimum of 30 minutes of moderate intensity ≥ 5 days per week or 20 minutes of vigorous activity ≥ 3 days per week (7). A combination of moderate and vigorous intensity exercise may be utilized to achieve the daily goals, and daily physical activity must be accomplished in bouts of ≥ 10 min to achieve the daily goal (4). With the health risks linked to being physically inactive, it is important to provide opportunities to assist the population with reaching the guidelines for aerobic fitness established by the ACSM.

Commuting by bicycle is one possible way to achieve moderate intensity exercise in order to meet the ACSM recommended guidelines for aerobic physical activity (2). A 2009 study within the United States found that almost half of all trips within metropolitan areas are three miles or less. Twenty eight percent of those trips were one mile or less. For trips less than one mile, 60 percent were taken in an automobile (15). For individuals living within metropolitan areas, commuting by bicycle may be a viable option for many trips. Health assessment studies have suggested that the physical activity from commuting could increase life expectancy by 3 - 14 months (3), or decrease all-cause mortality rates by 12.28 to 39.87 deaths per year (14).

For many individuals within a metropolitan area, riding a bicycle may be a daunting task due to obstacles such as wind, hills, and traffic, in addition to the required physical exertion. An electric bicycle is a viable alternative to riding a regular bicycle that may help to overcome some of the obstacles and encourage the transition from being physically inactive to becoming physically active. Inactive individuals have experienced an easier time operating an electric bicycle compared to a standard bicycle (6), therefore, riding an electric bicycle may encourage an increase in physical activity. Use of an electric bicycle may allow individuals with a wide range of fitness levels to further increase participation in weekly physical activity. Further research in an applied urban commuting setting would provide greater insight into the varying intensity levels recreationally active individuals may achieve while using an electrically assisted bicycle. Previous studies indicate that the electric assist bicycle could elicit moderate to vigorous intensity physical activity in sedentary populations (16, 18). No studies have been performed using outdoor trials among daily traffic with healthy recreationally active young adults. Targeting this population may promote maintenance of physical active throughout adulthood. Therefore the purpose of this study is to investigate the physiological differences between commuting on an electrically assisted bicycle versus a non-assisted bicycle under real world conditions in an urban environment using healthy recreationally active young adults. It is hypothesized that participants will spend more time cycling at a vigorous intensity level in the non-assisted bicycle trial compared to the electrically assisted bicycle and that both the non-assisted and assisted cycling will demand at least moderate intensity physical activity. This research will further determine how riding an electrically assisted bicycle may help college-aged individuals achieve recommended weekly physical activity.

METHODS

Participants

Twelve recreationally active young adults (6 males and 6 females) completed two randomized cycling trials: 1) electric pedal assist (PAB) and 2) no assist (NON). All participants were healthy and classified as "low risk" according to the American College of Sports Medicine risk stratification criteria. Participants were screened to ensure they had cycling experience within the last 6 months and were able to ride an upright bicycle unassisted for distances greater than 7.1 kilometers (km) over varied terrain. All procedures were approved by the University of Nebraska Medical Center Institutional Review Board. All participants were informed of all procedures and risks before informed consent was obtained.

Protocol

The IZIP E3 Path electric bicycle (Currie Technolgies, Simi Valley, CA) was used for all trials. The IZIP E3 Path weighs 24kg and has a motor that can produce a total output of 250 watts or can be used independent of the electric assistance. The E3 Path has two electric modes; a pedal assist mode and an electric power mode. The pedal assist mode was used for the PAB trials. The pedal assist mode produces an electric assist to the rear wheel as long as the bicycle is being pedaled. The IZIP E3 Path is outfitted with a sensor that monitors cadence. When the sensor picks up movement from the crank of the bicycle it engages the motor and generates power to the rear wheel. The motor is only engaged while the bicycle is being pedaled. The pedal assist utilizes 50% of the 250 watt motor, therefore only producing an assistance of 125 watts to the rear wheel during the PAB trials. The same bicycle was used for the NON trials but with no electric assist.

During an initial visit at least five days before the experimental trials, descriptive data were collected. Body composition was measured by hydrostatic weighing using an electronic load cell based system (Exertech, Dresbach, MN). Corrections were made for estimations of residual lung volume (13) and body density was converted to percent body fat utilizing the equation set forth by Siri (17). After hydrostatic weighing, participants performed a graded maximal aerobic capacity (VO_{2peak}) test to volitional fatigue on a Computrainer (Racer Mate, Seattle, WA) indoor stationary cycling trainer. The IZIP E3 Path bicycle was used for the VO_{2peak} test as well as the outdoor experimental trials. The bicycle seat height and handlebar position was adjusted to fit the participant. The graded cycling test protocol had all participants start at 95 watts and increase by 35 watts every 3 minutes (11). Maximum workload was determined by summing the highest completed stage (in watts) and the proportion of time in the last stage multiplied by the 35 watt per stage increment. The highest VO_2 obtained during the graded cycling test was defined as VO_{2peak}. During the graded cycling test and subsequent outdoor experimental trials expired gases were measured using a calibrated portable metabolic measuring system, Medical Graphics VO2000 Metabolic measuring system (Medical Graphics, United Kingdom). Expired gases were recorded in ten second averages. After the VO_{2peak} test, participants were further familiarized to the IZIP E3

Path electric assist bicycle and the 3.54 km cycling route to be used during the experimental trials on the subsequent visit.

For the experimental trials, participants performed two randomized cycling trials outside. Trials were counter-balanced and were scheduled during daylight hours and both trials for a given subject were performed on the same day. PAB and NON trials were separated by as much time as was needed for heart rate to return to within 10 bpm of resting heart rate. Trials took place on the same 3.54 km route along normal bike paths and roads with stops and hills. This route was chosen due to light automobile traffic and marked crosswalks. The 3.54 km course was included 7 crosswalks and one significant hill. The hill was 0.64 km in length with a maximum gradient of 11%. Participants were instructed to dismount and walk across all crosswalks as required by local law. Trials were randomized into Electric Bicycle with Pedal Assist (PAB) and Electrical Bicycle with No Assistance (NON). Participants were instructed to cycle during the two trials at a self-selected pace consistent with their normal commuting cycling intensity as if they were to use this course and bicycle during a commute. Oxygen uptake (VO_2) measurements were taken using the portable Medical Graphics VO2000 Metabolic measuring system (Medical Graphics). Heart rate was measured with a chest strap using a Garmin 810 GPS based cycling computer (Garmin, Olathe, KS). Power output (*Watts*) was measured throughout the cycling trials using Garmin Vector Power Meter pedals (Garmin, Olathe, KS). To account for the variable terrain the course was divided into four equal segments (0.885 km/segment) for analysis purposes. Immediately following the trial, the participants dismounted from the bicycle and were asked to rate their overall perceived effort using Borg's 6-20 rating of perceived exertion scale (1). All trials were held during dry conditions to ensure the safety of the participants. No food was allowed 3 hours prior to the trials and the metabolic measurements precluded food or water intake during the trial. To ensure safety and provide assistance in case of any problems such as a flat tire, mechanical problems or accidents; participants were followed by an observing investigator during every trial. There was no communication between the observer and the participant and no problems occurred during any trial. All participants were required to wear a Consumer Product Safety Commission (CPSC) certified helmet.

Participants were given a five question survey upon completion of trials. The survey was used to determine previous experience, ease of use, and enjoyment. The first question was used to measure recent bicycle experience: "During the last 2 months, how many days per week on average do you ride a bicycle?" The following statements were presented using a 7 point Likert scale with 1 being "strongly disagree" and 7 being "strongly agree":

1. I am experienced with an electrically assisted bicycle.
2. I would be more likely to commute using an electrically assisted bicycle.
3. The electrically assisted bicycle is easy to use.
The electrically assisted bicycle is fun to use.

Statistical Analysis

METs, power output, HR, VO_2, were all analyzed with a repeated measures two-way (trial × time) ANOVA. When a significant F ratio was detected, Fishers protected least significant difference analysis was used to determine where differences occurred. Time to completion and RPE were analyzed using a paired *t-test*. All values are reported as Mean ± SE.

RESULTS

Six male and six female (n=12) participants completed the protocols required for this study (See Table 1).

Table 1. Participant Descriptive Data

	Male	Female
Age (yr)	25 ± 1	22 ± 1
Height (cm)	177 ± 2	171 ± 2
Weight (kg)	87.9 ± 6.0	71.2 ± 5.5
Body Fat (%)	16.8 ± 1.9	23.4 ± 3.3
VO_{2peak} (L · min^{-1})	3.74 ± 0.25	3.21 ± 0.23
VO_{2peak} (mL · kg^{-1} · min^{-1})	42.6 ± 2.9	45.6 ± 2.8

Data are mean ± SE; n = 12.

The average time between trials was 12 ± 2 minutes. This allowed for heart rate to return to within 10 beats per minute of pre-trial values. Average temperature of the trials was 13.2 ± 6.5° Celsius.

The 3.54 km course was completed faster in the PAB (12.5 ± 0.3 min) than the NON (13.8 ± 0.3 min, p = 0.01). There was no difference in average power output produced by the participant at the crank when comparing PAB (115 ± 11 Watts) to NON (128 ± 11 Watts, p = 0.19). When trials were separated in quarter segments (0.875 km), each segment had a different power output than all others regardless of condition ($p < 0.05$; Figure 1).

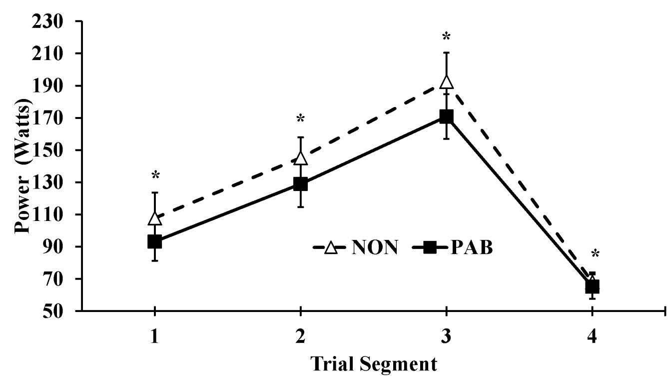

Figure 1. 3.54 km randomized trials showing mean Power Output (Watts) during each quarter (0.875 km) segment. Values are mean ± SE.

There were no differences for mean VO_2 between PAB and NON trials (p = 0.662). However, VO_2 was different during each quarter segment from all other segments, regardless of trial ($p < 0.05$; Figure 2.). Additionally, there was no difference in mean METs between PAB and NON trials (p = 0.648). Mean METs were different during each quarter segment from all other segments, regardless of trial ($p < 0.05$, Figure 3).

Heart rate was not different between trials. There was no difference in heart rate during segment 1 or 2 ($p > 0.05$) between PAB and NON trials. There was a trend toward heart rate being lower in the PAB trial compared to the NON trial for segment 3 (p=0.064). Heart rate was lower during segment 4 in the PAB compared to NON trial (p = 0.044f; Figure 4).

Additionally, rating of Perceived Exertion was lower in the PAB (12.0 ± 0.4) than the NON (14.8 ± 0.5, $p < 0.001$).

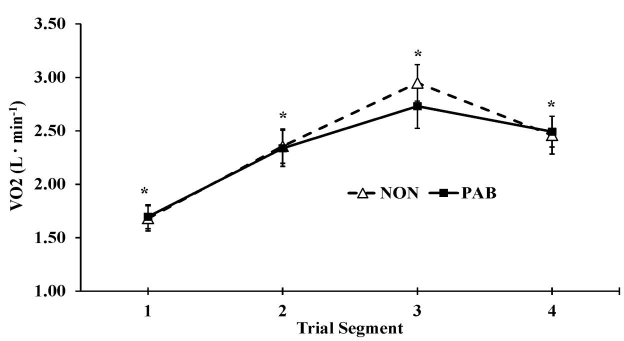

Figure 2. 3.54 km randomized trials showing mean VO_2 ($L \cdot min^{-1}$) during each quarter (0.875 km) stage. Values are mean ± SE. (*$p < 0.05$ compared to all other segments).

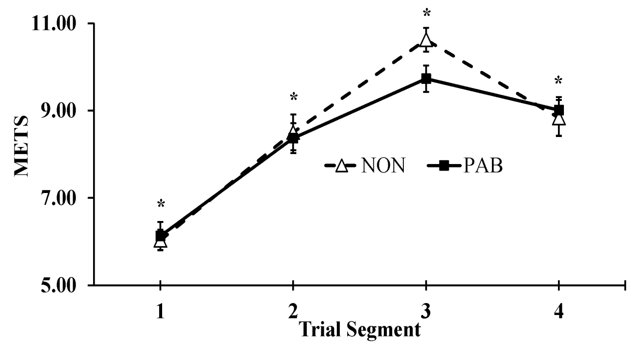

Figure 3. 3.54 km randomized trials showing mean METs during each quarter (0.875 km) segment. (*$p < 0.05$ compared to all other segments, values are mean ± SE).

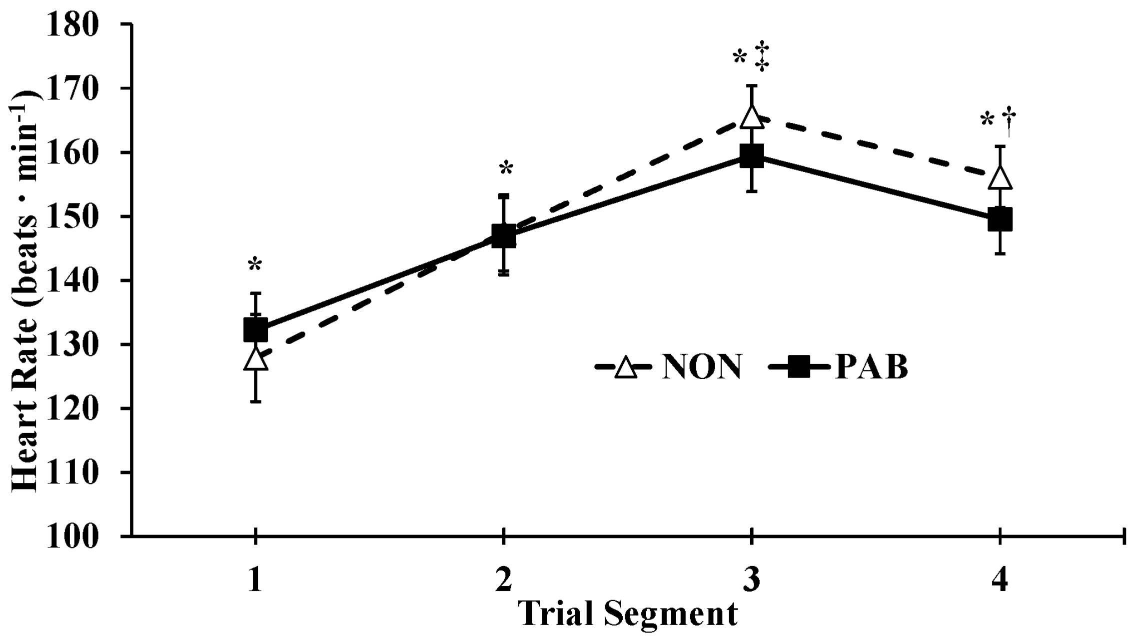

Figure 4. 3.54 km randomized trials showing mean Heart Rate during each quarter (0.875 km) segment. Values are mean ± SE. (*$p < 0.05$ compared to all other segments, values are mean ± SE). (†$p \leq 0.05$ between trials during the last quarter). (‡$p = 0.064$ trend toward heart rate being higher during segment 3).

The PAB trial met ACSM recommendations for vigorous physical activity intensity based on % VO_{2max}, % HR_{max}, and METs, while the RPE was classified as moderate. The NON trial met

ACSM recommendations for vigorous physical activity based on % VO_{2max}, % HR_{max}, METs, and RPE. See Table 2.

Table 2. Intensity of PAB and NON Trials based on ACSM criteria for moderate and vigorous activity.

	PAB Trial	NON Trial
% VO_{2max}	66.4 ± 2.6	68.0 ± 2.8
ACSM Intensity	Vigorous	Vigorous
% HRmax	79.1 ± 2.4	80.4 ± 2.6
ACSM Intensity	Vigorous	Vigorous
METs	8.3 ± 0.5	8.5 ± 0.6
ACSM Intensity	Vigorous	Vigorous
RPE	12.0 ± 0.4	14.8 ± 0.5
ACSM Intensity	Moderate	Vigorous

Data are mean ± SE.

Only one of the 12 participants had previous experience with an electric assist bicycle. Three of the participants had ridden a bicycle at least once a week in the last 2 months. After the trials, the one participant with previous electric assist bicycle experience felt they were moderately experienced with using the electric assist bicycle. The rest of the participants did not consider themselves experienced. Four of the 12 participants strongly agreed with the statement: "I would be more likely to commute using an electric assist bicycle". One of the participants moderately agreed with the previous statement, five participants said they would not be more likely to commute, and two were neutral in being more likely to commute if they used an electric assist bicycle. Ten participants agreed or strongly agreed with the statement: "The electric assist bicycle was easy to use" while two participants moderately agreed. Nine participants strongly agreed that "The electric bicycle was fun to use", while three participants moderately agreed that the electric assist bicycle was fun to use (See Table 3).

Table 3. Participant survey results.

	Number of Responses Selected						
Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	5	5	1		1		
2		3	2	2	1		4
3					2	2	8
4					3		9

DISCUSSION

The current study investigated the physiological differences of riding an electric assist bicycle in the electric pedal assist mode (PAB) and the non-assist mode (NON). Electric assist bicycles can be bought at a starting price point of $650 and range up to thousands of dollars with the MSRP of E3 Path used in this study being $1699. Twelve (6 male and 6 female) healthy, recreationally active participants completed two trials in a real world urban cycling environment that navigated a course among daily traffic with multiple stops and varying terrain. The main finding of this applied study was that when using both the PAB mode and the NON mode, vigorous intensity physical activity was elicited in this group of healthy young volunteers when self-selecting a commuting intensity. The current study found that markers of intensity (METs, VO_2, power output, and heart rate) were not different between the PAB trials and the NON trials; despite the PAB trials being completed significantly faster, with a significantly lower rating of perceived exertion.

The current protocol produced both moderate and vigorous exercise intensities during the trials, while the mean exercise intensity of both trials elicited vigorous intensity. According to the ACSM, a relative intensity of 64% to < 91% of VO_{2max} or an absolute intensity of 6.0 to < 8.5 METS qualify as vigorous intensity physical activity. The intensity of the PAB trial was only marginally lower (not significant) than the NON trial (66.4% of VO_{2peak} vs 68.0% VO_{2peak} respectively, and 8.3 METs vs 8.5 METs, respectively). These intensities are similar to previously reported intensities of commuting by traditional bicycle (2, 8, 12) and similar in relative intensities (%VO_{2peak}) reported using an electrically assisted bicycle (6, 16, 18). However, the absolute intensity (METs) achieved in the current study was higher than previously reported when using electrically assisted bicycles (6, 16, 18). Furthermore, the three previous studies utilizing electrically assisted bicycles reported lower exercise intensity when using an electrically assisted bike compared to a non-assisted bike (6, 16, 18). The current study did not find significant difference between the two cycling trials, as both PAB and NON trials elicited vigorous intensity physical activity. Differences between our study and the previous studies may be due to the unique characteristics of the completed routes, subject demographics, and the specific electric bicycle used in the studies. The previous study that incorporated a hilly terrain had max gradients ranging from 5.8% to 6% (6) while the current study included a hill with a max gradient of 11%. The hill in the current study, 0.64 km in length, was only one aspect of the 3.54 km variable terrain course. It should be noted that vigorous intensity standards were met even on the flatter sections that occurred before and after the hill of the current course. The data reported here are from healthy, recreationally active, young adults in contrast to the sedentary individuals used in previous investigations (6, 16). The active adults used for participants by Simons et al. (16) did not achieve the same level of absolute intensity (regardless of trial) as the participants in the current study (~5.7 METs compared to ~8.4 METs). However, the relative intensities appear to be similar indicating that the current participants had a higher maximum aerobic capacity. Therefore, participant fitness may be a factor that influences differences between assisted and non-assisted cycling as well as intensity achieved while riding an electrically assisted bike. It appears that the younger active individuals studied in the current investigation may self-select to spend more time in vigorous activity compared to older or less active individuals due to their enhanced aerobic capacity. Future studies designed to specifically address the impact of participant fitness are needed to further substantiate this observation.

The function of the specific electrically assisted bike used must also be considered when comparing electrically assisted bike studies or when determining the physiological demands. The IZIP E3 Path electric bicycle, which was used in the current study, has a motor that can produce 250 watts. The Pedal Assist System used on the IZIP E3 Path during the PAB trials was designed to utilize 50% of the 250 watt motor, producing an assistance of 125 watts.

Previous studies used assist modes which produce 250 watts and thus have more assistance than the IZIP E3 Path used in the current study. The 125 watt power output difference between assist modes, the specific course, and the fitness level of participants may all contribute to the differences between the current and previous electrically assisted bicycle studies. Furthermore, these variables may also provide rationale for the vigorous exercise intensities produced during both the PAB and NON trials in the current study. When the current findings are considered along with previous work, we conclude that when individuals cycle at a self-selected pace, the use of electric assist bicycles allows participants to reach at least moderate intensity physical activity.

While both trials in the current study elicited vigorous intensity activity, participants completed the 3.54 km course significantly faster in the PAB trial (12.5 ± 0.3 min) compared to the NON trial (13.8 ± 0.3 min, $p = 0.01$). The participants also perceived the effort to be lower in the PAB (12.0 ± 0.4,) than the NON trials (14.8 ± 0.5, $p < 0.001$). These findings suggest that if individuals used the electric assist bicycle they could reach their destination quicker and with less perceived effort, while still exercising at a vigorous intensity.

It is interesting to note that based on the survey results after the experimental trials, participants thought the electric assisted bicycle was fun, easy to use, and five of the participants indicated that they were more likely to commute by bicycle despite not having previous experience whereas five were not more likely and two were neutral towards being more likely (See Table 3). The electric assist bicycle may encourage more use as a means of transportation while also promoting the health benefits of aerobic physical activity.

The current study utilized a real world cycling protocol in an urban setting that allowed participants to navigate a course among daily traffic with multiple stops, cross walks and a hill. The 3.54 km course was chosen due to the expected time of completion being at least 10 minutes; accomplishing the ACSM minimum recommended aerobic exercise duration guidelines (5, 7). The current results suggest that the electric assist bicycle may be utilized as a means of commuting transportation while accomplishing recommendations for aerobic exercise. Although some individuals may be deterred from commuting due to hills, long distances of travel, sweating, and other obstacles; the IZIP E3 Path may allow for individuals to arrive at their destination sooner compared to a traditional non-assist bicycle, while also allowing commuters to perceive their exertion level lower than their physiological intensity. If individuals commute 10 minutes each way for a total of 20 minutes ≥ 3 days per week then an electrically assisted bicycle is a viable option to achieve the ACSM recommended 20 minutes of vigorous activity 3 days per week. The current study, combined with previous studies, also suggests that younger (college age) individuals may self-select vigorous intensity physical activity whereas older or more sedentary adults may self-select moderate intensity physical activity.

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