Electrically Assisted Cycling: A New Mode for Meeting Physical Activity Guidelines?

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ABSTRACT

SIMONS, M., E. VAN ES, and I. HENDRIKSEN. Electrically Assisted Cycling: A New Mode for Meeting Physical Activity Guidelines? *Med. Sci. Sports Exerc.*, Vol. 41, No. 11, pp. 2097–2102, 2009. **Purpose**: The purpose of this study was to assess the potential of the electrically assisted bicycle (EAB) as a novel tool for meeting the physical activity guidelines in terms of intensity. **Methods**: Twelve habitually active adult subjects were requested to cycle a track of 4.3 km at an intensity they would normally choose for commuter cycling, using three different support settings: no support (NO), eco support (ECO), and power support (POW). For estimating the intensity, the oxygen consumption was measured by using a portable gas-analyzing system, and HR was simultaneously measured. The bicycle was equipped with the SRM Training System to measure subjects' power output, pedaling rate, and the cycle velocity. **Results**: Mean intensity was 6.1 MET for NO, 5.7 MET for ECO, and 5.2 MET for POW. Intensity was significantly lower in POW compared with that in NO. No differences were found between NO and ECO and between ECO and POW. Mean HR was significantly higher in NO compared with that in ECO and POW. The cycling speed with electrical support settings was significantly higher than cycling in the NO condition. Mean power output during cycling was significantly different among all three conditions. Most power outputs were supplied in the NO condition, and the lowest power output was supplied in the POW condition. **Conclusions**: Intensity during cycling on an EAB, in all three measured conditions, is sufficiently high to contribute to the physical activity guidelines for moderate-intensity health-enhancing physical activity for adults (cutoff, 3 MET). Further study is needed to conclude whether these results still hold when using the EAB in regular daily life and in subjects with other fitness level. **Key Words:** HEALTH-ENHANCING PHYSICAL ACTIVITY, ENERGY EXPENDITURE, HEALTH PROMOTION, NONMOTORIZED TRANSPORT, EXERCISE INTENSITY

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Physical inactivity is a major health problem. Participation in moderate-intensity physical activity on a regular basis can provide important health benefits. Despite warnings about the potentially negative health consequences of a sedentary lifestyle, a large proportion of adults is physically inactive. To promote and maintain health the American College of Sports Medicine (ACSM) makes the following recommendation (8): all healthy adults aged 18–65 yr need moderate-intensity aerobic physical activity for a minimum of 30 min on 5 $d \cdot wk^{-1}$ or vigorous-intensity aerobic activity for a minimum of 20 min on 3 $d \cdot wk^{-1}$. Moderate-intensity physical activity is defined as activities performed at an intensity of 3–6 MET and vigorous-intensity physical activity is defined as >6 MET (8). This recently updated recommendation now specifies that moderate- and vigorous-intensity activities are complementary in the production of health benefits and that a variety of activities can be combined to meet the recommendation. This combining of activities is based on the amount of activity (intensity × duration) performed during the week. When combining moderate- and vigorous-intensity activities to meet the current recommendation, the minimum goal should be in the range of 450 to 750 $MET \cdot min \cdot wk^{-1}$ (8).

A potential novel device that could help people to meet the physical activity guideline is the electrically assisted bicycle (EAB). In the EAB, human pedaling is supplemented by electrical power from a storage battery. The EAB gives electrical support up to 25 $km \cdot h^{-1}$ and weights approximately 30 kg. The EAB can, for example, be used for commuting to and from work. Commuter cycling is an excellent way of exercise, which fits well in daily life routines and provides a promising manner to reach many people especially in those countries with a good cycling infrastructure. Earlier studies have shown that commuter cycling can improve physical

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performance (4,10) and health (3,16) and could have a positive effect on the prevention of overweight (11,17). The EAB can help to overcome the barriers toward commuter cycling and could possibly reduce dropouts among sedentary individuals caused by the sometimes vigorous intensity needed for cycling (e.g., when encountering strong contrary winds or uphill cycling). However, the question is whether cycling on an EAB, while using the electrical support, is intensive enough to make a contribution to meeting the physical activity guidelines.

The aim of the present study was to assess the potential of an EAB as a novel device for meeting the physical activity guidelines for intensity. The central question in the current study was whether the self-selected physiological load of electrically assisted cycling meets the recommended intensity standards for health-enhancing physical activity (3–6 MET for moderate-intensity activity or >6.0 MET for vigorous-intensity activity). A secondary purpose was to study the effect of electrical support on 1) intensity, 2) cycling speed, 3) power output (PO), 4) pedaling rate (PR), and 5) perceived exertion.

METHODS

Subjects. Twelve subjects (six males, six females) voluntarily participated in the study. All participants were habitually active and in good health as reported by a medical screening questionnaire. Seven (58%) of them met the current physical activity recommendation, which was measured using two questions on moderate-intensity and vigorous-intensity physical activity. This questionnaire is validated in the Netherlands (6). Eight subjects (67%) were experienced users of an EAB. They have used the EAB for 24 ± 22 months for 3.4 ± 2.3 times a week.

Subjects were informed on the nature of the experiment and signed an informed consent before participation. The protocol was approved by the local ethical committee of TNO Defence, Security and Safety. The characteristics of the subjects are shown in Table 1.

Experimental procedure. The experiment consisted of three tests, executed on the same day, with at least 1-h rest between each test. The tests were executed on a Sparta Ion M-Gear (Sparta, the Netherlands) with seven gears and three support modes: eco (light support), normal (moderate support), and power (high support). The tire pressure was set at 4 bar as advised by the manufacturer of the EAB and to ensure that the rolling resistance was equal for all subjects. The saddle and handlebars were repositioned to suit each subject. The three conditions used in this experiment were no support (NO), eco support (ECO), and power support (POW).

TABLE 1. Characteristics of the 12 subjects (mean, SD, and range).

	Mean	SD	Range
Age (yr)	52.2	8.7	32–60
Height (cm)	173.3	7.6	160–190
Body weight (kg)	73.6	9.7	56–88
Body mass index ($kg \cdot m^{-2}$)	24.5	2.6	20–28
30-min moderate exercise (times per week)	4.3	1.1	2–6
20-min intensive exercise (times per week)	3.5	2.7	0–9

All conditions were performed in a balanced order according to a Latin square to adjust for influence of the support condition on cycling speed. Subjects cycled on a public track over cycle paths. The track had a length of 4.3 km and was almost flat. At two points approximately halfway the track, a stop-and-go was built in the protocol to make the trip more realistic. Subjects had to stop, completely get off the bike, and start again.

Subjects cycled the track on a self-selected comfortable speed as if they used the bike for commuter cycling. They were free in choosing their gear and PR. During the trip, one of the research workers cycled behind the subject to control for any irregularity (e.g., flat tire, getting lost, accident, problems with bicycle chain, etc.). No feedback was given during or between the conditions.

Measurements. The parameters measured during the tests were oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), HR, cycling speed (v), PO, PR, comfort sensation (CS), and RPE.

The $\dot{V}O_2$ and $\dot{V}CO_2$ ($L \cdot min^{-1}$) were determined (mean for 15 s) by analysis of expired gases using K4b2 (Cosmed, Italy) (15). RER was calculated as the divider of $\dot{V}CO_2$ and $\dot{V}O_2$. Intensity was estimated by converting oxygen consumption into MET, that is, 1 MET was set as 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$, and by calculating the mean MET value. Total energy expenditure in kilocalories (kcal) was calculated as follows: energy expenditure ($kcal \cdot min^{-1}$) = $(3.815 + 1.232RER)\dot{V}O_2$ (7). The total energy expenditure was also expressed in MET-minutes by calculating the multiplication of the mean intensity (MET) and total cycling time (min).

HR was measured (5-s sample) with a Polar S810i (Polar Electro, Finland). Maximal HR was calculated with the formula: 220 − age (18). The bicycle was equipped with the SRM Training System (Schoberer Rad Messtechnik, Germany) to measure (60 Hz) the subjects' PO, PR, and the cycling speed.

The CS (from comfortable "1" to extremely uncomfortable "5") was recorded according to ISO 10551 (1993) (12) at the end of each condition. Also, the RPE was recorded at the end of each condition using Borg's scale (from no exertion at all "6" to maximal exertion "20") to determine the subjects' perception of exercise intensity (1).

Statistical analysis. Means and SD during the whole cycle track were reported for dependent variables. Using a commercially available software (Statistica 6.0; StatSoft, Tulsa, Oklahoma USA), repeated-measures ANOVA was used to determine whether there were significant differences for condition and cycling time. If significant effects among conditions were observed, Tukey's honestly significant difference *post hoc* analyses were performed to determine

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TABLE 2. Physiological variables measured during cycling tests in NO, ECO, and POW mode (mean and SD).

	NO		ECO		POW	
	Mean	SD	Mean	SD	Mean	SD
Intensity (MET)	6.1*	1.6	5.7	1.2	5.2*	1.4
Total energy consumption (kcal)	108.1*†	18.4	94.3†‡	14.9	77.5*‡	20.0
HR (bpm)	123.8*†	23.2	116.2†	22.4	112.4*	22.9
HR (% HR_{max})	73.9*†	14.5	69.3†	13.5	67.1*	14.1
Cycling speed ($km \cdot h^{-1}$)	19.6*†	2.4	21.1†‡	2.2	23.4*‡	1.7
Cycling time (min:s)	13:38*†	1:49	12:45†‡	1:26	11:33*‡	0:58
Power output (W)	118.2*†	30.9	101.8†‡	24.8	94.2*‡	29.2
PR (rpm)	55.0*†	5.6	51.5†	6.1	49.1*	7.2
RPE (range, 6–20)	13.1*†	1.6	10.8†‡	1.0	8.3*‡	1.8
CS (range, 1–5)	1.7*†	0.7	1.1†	0.3	1.0*	0.2

* Significant difference between NO and POW.
† Significant difference between NO and ECO.
‡ Significant difference between ECO and POW.

which conditions differed. Statistical significance was accepted at $P < 0.05$. All values are reported as mean ± SD.

RESULTS

All subjects completed all experimental conditions. Table 2 shows the mean and SD values for intensity (MET), total energy expenditure (kcal), HR, percentage of maximal HR, cycling speed, cycling time, PO, PR, RPE, and CS.

Intensity and energy expenditure. The intensity was only significantly different between the no support (NO) and power support (POW) conditions. In the NO and in the eco support (ECO) conditions, all the subjects cycled at an intensity of at least 3.0 MET; in the POW condition, this was 92%. In the NO condition, 50% of the subjects cycled at an intensity of at least 6.0 MET; in the ECO condition, 33%; and in the POW condition, 17%. The total energy expenditure during the whole cycle track in MET-minutes was significantly different among the three conditions. In the NO condition, energy expenditure was 81.4 ± 15.4 MET·min; in the ECO mode, it was 71.6 ± 12.2 MET·min; and in the POW mode, it was 60.3 ± 13.6 MET·min. Total energy expenditure in kilocalories was calculated for the whole cycle track. Significant differences were observed among all three conditions: most of the energy was consumed in the NO condition, and the lowest energy was consumed in the POW condition.

HR. Mean HR was significantly higher in the NO mode compared with the ECO and POW modes. No differences were found between the ECO and POW conditions. In Figure 1, a typical example of HR measured during the cycling test is shown. The mean percentage of (estimated) maximal HR at which subjects cycled during the tests did not differ between ECO and POW but was significantly higher in the NO mode. Maximum HR during the cycling test was 135.8 ± 23.6, 130.5 ± 23.3, and 125.5 ± 23.2 for NO, ECO, and POW, respectively. Only NO and POW differed significantly.

Cycling speed. Mean cycling speed differed significantly among the three conditions (Table 2). Cycling speed was highest in the POW condition, and therefore, the mean total cycling time in the POW mode was significantly shorter compared with both other conditions. A typical example of the cycling speed during the three conditions is shown in Figure 2.

Power output. Mean PO during cycling was significantly different among all three conditions. Most PO was supplied in the NO condition, and the lowest PO was supplied in the POW condition. Mean PO during minutes 1 to 4, in which subjects did not stop, was significantly higher in the NO condition (125 ± 35 W) compared with the ECO (100 ± 24 W) and POW (96 ± 36 W) conditions. The ECO and POW conditions did not differ from each other. Subjects supplied most PO directly after one of the two stops. Maximum power (during 1 s) did not differ among the three conditions: 259.1 ± 79.5, 266.6 ± 104.2, and 253.8 ± 92.4 W for the NO, ECO, and POW conditions, respectively.

PR. Mean PR was significantly higher during cycling in the NO condition compared with cycling in the ECO or the POW condition. No differences were found between the two conditions with support.

Subjective rating scales. Cycling in the NO mode was perceived as somewhat hard, with ECO as light and with POW as very light. Subjects rated cycling supporting the NO mode significantly less comfortable compared with

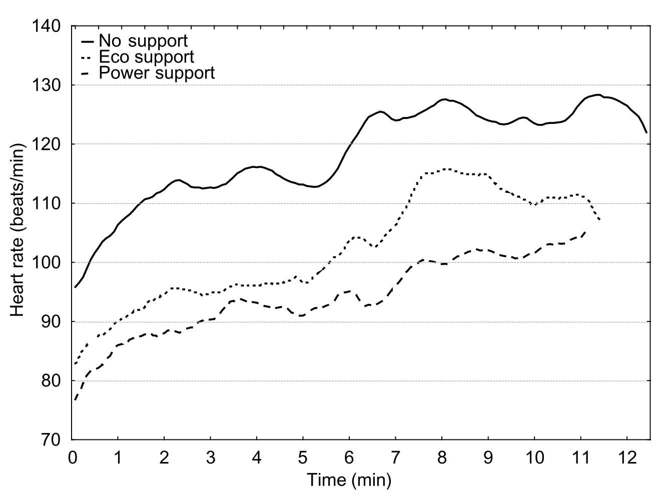

FIGURE 1—Typical example of the HR during the cycling test without support, in the eco, and in the power mode.

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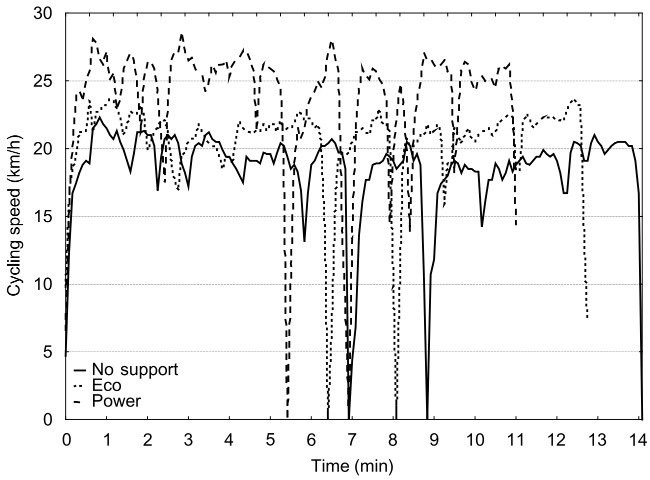

FIGURE 2—Typical example of the cycling speed during the cycling test without support, in the eco, and in the power mode.

cycling in the ECO or the POW mode. No differences were found between the two electrically assisted conditions. However, subjects cycled in all three conditions in the comfortable zone.

DISCUSSION AND CONCLUSION

The results showed that the intensity of cycling on an EAB, in all three measured conditions, was sufficiently high to contribute to the moderate-intensity standard (3–6 MET) of the physical activity guidelines for adults. The intensity of cycling with electrical support was not high enough to meet the vigorous-intensity standard (>6 MET). Only cycling on an EAB without support showed a mean intensity of at least 6.0 MET. In this condition, half of the subjects cycled at a mean intensity of at least 6.0 MET. In the ECO and POW conditions, 33% and 17%, respectively, met the vigorous-intensity standard. To meet the current public health recommendation, moderate- and vigorous-intensity activities can be combined. The minimum goal should be in the range of 450 to 750 MET·min·wk^{-1}. The least fit individuals will already benefit at the lower end of the range, but the more fit individuals will only benefit at the higher range. Electrical support reduces the intensity and exertion of cycling and could therefore take away barriers (hilly environment or strong contrary winds) for commuter cycling, which seems to discourage especially the least fit individuals.

In the current study, the energy expenditure during the whole cycle track was, on average, 81.4 MET·min in the NO mode, 71.6 MET·min in the ECO mode, and 60.3 MET·min in the POW mode. The cycling distance in the test situation was 4.3 km. If this would be the distance for a one-way cycle trip to work, which is in line with the mean commuter cycling distance in the Netherlands (4.3 km in 2007) (2), then subjects have to cycle at least four times a week per round trip when using the ECO (573 MET·min·wk^{-1}) or the POW (482 MET·min·wk^{-1}) mode to meet the combined recommendation for physical activity. Subjects could also choose to cycle their way to work using the ECO mode, which prevents them from arriving sweaty, and to cycle their way home without support, where they can have a shower. By implementing this three times a week, an energy expenditure of 459 MET·min·wk^{-1} is realized, and in this way, the public health recommendations for physical activity are met only by active commuting. The EAB could be an important tool for overcoming barriers for cycling, and by this means, promotion of the EAB could have a positive effect on the number of subjects meeting the physical activity guidelines.

The mean intensity for cycling without support was 74% HR_{max}, which is comparable to the 68%–79% HR_{max} mentioned by studies focused on the intensity of conventional cycling (5,10,16). Also, the mean intensity values of cycling with ECO (69% HR_{max}) and POW (67% HR_{max}) are at the lower end of the same range. The mean cycling speed while cycling without support was 19.6 km·h^{-1}. This is in accordance with the mean cycling speed for commuter cycling on a conventional bicycle reported by Oja et al. (16), Hendriksen et al. (10), and de Geus et al. (5), which ranges between 17.6 and 20.1 km·h^{-1}. The average cycling distances in these studies were longer (6.4–9.7 km) than the distance used in the current study (4.3 km). The shorter distance in the current study as well as the two built-in stop-and-go points, which is a very limited frequency compared with a usual commuter trip, could have positively influenced the mean cycling speed. On the other hand, an EAB weights approximately 13 kg more than a conventional bicycle does, which could result in a somewhat decreased cycling speed. In the current study, the cycling speed with electrical support was significantly higher than cycling without support. The more electrical support, the higher the cycling speed. The electrical support also had an influence on the PR. The PR during cycling with electrical support was lower than cycling with no support. HR and PO decreased with more support. The intensity (MET) differed only between NO and POW. The subjects also perceived less exertion when cycling with electrical support than cycling with no support. These results indicate that cycling with electrical support is less intensive than cycling without support. The subjects partly compensated the lower intensity of cycling with electrical support by cycling faster, but the physical load was still not comparable with cycling without support. It is not known if, in regular daily life, people would also compensate the lower intensity of cycling with electrical support with a higher cycling speed or if, in real life, the cycling speed will be lower and therefore also the intensity. Further study is needed to investigate which support mode is used in regular daily life and at what speed and intensity people cycle on the EAB in real life.

To decrease all-cause mortality, a minimum of 1050 kcal·wk^{-1} should be expended (9,14). In the current study, the subjects expended 108.1, 94.3, and 77.5 kcal during the one-way trip (4.3 km) for the NO, ECO, and POW modes, respectively. As a result, only cycling five times a week with no support would be enough to decrease all-cause mortality, assuming that 4.3 km is the one-way distance. Maybe when covering longer distances that the energy expenditure of cycling with electrical support is also sufficient to decrease all-cause mortality. In a questionnaire study by Lataire et al. (13), it was found that people changed their cycling behavior when they could use an EAB for several weeks. At least 36% said to ride more kilometers with the EAB than they would do with their conventional bicycle. So maybe the lower intensity of cycling on an EAB will result in using the EAB more often and for longer distances than a conventional bicycle. This should be verified in future studies.

In the E-Tour project in Brussels, the effects of physically active commuting to work using an EAB on health-related parameters and aerobic fitness in a sedentary population were studied. Twenty subjects (10 men and 10 women) were asked to use the EAB at least three times a week for commuter purposes. The minimal distance to work had to be 6 km (one way). After 6 wk of cycling, the maximum oxygen uptake ($\dot{V}O_{2max}$) did not differ from the baseline values, but the maximum PO increased significantly in both men and women (from 150 W at baseline to 169 W after 6 wk). Also, the relative PO (Watt per kilogram body weight) and the submaximal performance at a lactate concentration of 2 and 4 $mmol{\cdot}L^{-1}$ had significantly improved. These results show that the intensity of commuter cycling on an EAB for 6 wk was enough to significantly improve the mean fitness level (13).

A limitation of the current study was that the subjects were not observed during everyday commuter cycling. The route was outlined and standardized for this study, and they were instructed to cycle at a speed they would normally choose when cycling to work. This could have resulted in somewhat different outcomes than when observing the subjects in a natural setting. The outlined route in the current study had only two stops, and the people were not free to choose their own level of support. Future study should therefore focus on how people use the EAB in regular daily life, namely, frequency of cycling, covered cycling distances, and use of support modes. The small number of subjects and the fact that some of the subjects had no experience with cycling on an EAB could also have influenced the results. Therefore, future studies should focus on measuring intensity and energy expenditure during cycling on an EAB in real life, using a large study population with experienced EAB cyclists. It may also be beneficial to focus on insufficiently active or sedentary adults to see whether cycling on an EAB helps them meet the physical activity recommendation. More benefit to society is derived from getting inactive and insufficiently active individuals to be more active than from stimulating already active individuals to be more active. Attention should also be given to factors such as differences between age groups and sexes.

It can be concluded that, in this study, the self-selected physiological load of electrically assisted cycling was sufficiently high to meet the currently recommended public health intensity standards for health-enhancing physical activity. Active commuting using an EAB seems to be a promising mode for contributing to meeting the physical activity guideline, but further study is needed to conclude whether these results still hold when using the EAB in regular daily life and in subjects with other fitness levels.

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There are no conflicts of interest.

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