

Older E-bike Users: Demographic, Health, Mobility Characteristics, and Cycling Levels

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ABSTRACT

VAN CAUWENBERG, J., I. DE BOURDEAUDHUIJ, P. CLARYS, B. DE GEUS, and B. DEFORCHE. Older E-bike Users: Demographic, Health, Mobility Characteristics, and Cycling Levels. *Med. Sci. Sports Exerc.*, Vol. 50, No. 9, pp. 1780–1789, 2018. **Purpose:** Electric bicycles (e-bikes) may offer an opportunity to stimulate physical activity among older adults. The current study compared Flemish (Belgian) older e-bike users with those not using an e-bike on sociodemographics, health characteristics, and access to motorized transport. In addition, it examined the association between e-bike use and levels of cycling and the moderating effects of sex, body mass index (BMI), and cycling limitations. **Methods:** An online or interview version of the same questionnaire was completed by 1146 participants. Data were analyzed using logistic regression and hurdle models. **Results:** Women, those with a higher BMI, and those with one (compared with no) motorized vehicle in the household had higher odds of being an e-bike user. E-bike use was related to higher odds of having cycled for transport in the past week, and this relationship was stronger among those with a higher BMI (low BMI: odds ratio, 1.89; 95% confidence interval (CI), 1.24–2.91; high BMI: odds ratio, 3.34; 95% CI, 2.26–5.00). Among those who cycled for transport in the last week, e-bike use was associated with 35% more minutes of cycling for transport (95% CI, 17%–56%). E-bike use was related to 183% higher odds of having biked for recreation (95% CI, 115%–274%). Among women and those with cycling limitations who cycled for recreation in the last week, e-bike use was also related to 57% (95% CI, 18%–109%) and 180% (95% CI, 63%–381%) more minutes of cycling for recreation, respectively. **Conclusion:** E-bikes may provide an opportunity to promote cycling among older adults, particularly among subgroups at risk for physical inactivity. **Key Words:** PEDELECS, MOBILITY, SENIORS, ACTIVE AGEING

Despite the various physical, mental, and social health benefits of engagement in 30 min of moderate- to vigorous-intensity physical activity (PA) at least five times a week (1), 60% to 70% of the growing population of European older adults (≥ 65 yr) does not comply with this recommendation (2). Although walking has been described as an ideal PA for older adults (3), cycling enables to cover greater distances than walking and carries the possibility to substantially increase older adults' mobility (4). However, cycling requires greater physical effort than walking which may

render it unfeasible for older adults with decreased physical fitness. This may be addressed by electric bicycles (also called pedelecs or e-bikes), which are battery assisted and equipped with a torque or velocity sensor that triggers supporting power only when the cyclist exerts power onto the pedals. The use of e-bikes has strongly increased during the last years (5). In Europe, annual e-bike sales increased from 588,000 in 2010 to 1,357,000 in 2015, and the sale share of e-bikes (e-bikes/all bike sold) ranges from 1.1% in Great Britain to 23.4% in Belgium (6). The lower physical effort compared with conventional cycling makes e-bikes especially attractive for older adults. In the Netherlands, 65% of all e-bike owners have been reported to be 65 yr or older (7). In Flanders (the Northern part of Belgium), 25% of all bike trips by older adults were performed by e-bike, whereas this was only 7% in the general Flemish population (8).

E-bikes offer an alternative for "conventional" bicycles enabling to cycle similar or greater distances with less physical effort and reduce typical cycling barriers such as lack of fitness, hilliness, and windy conditions (5,9). Despite the lower physical effort required, average intensity levels during e-biking are sufficiently strenuous to be classified as moderately intensive and health enhancing (9–11). Furthermore, e-bike use may

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increase older adults' life space area and opportunities to engage in social activities (12). Hence, e-bikes may offer a solution to stimulate PA and mobility among older adults. To optimally tailor e-bike promotion campaigns, information on the characteristics of older e-bike users is needed. This information is required to identify whether or not e-bikes are used predominantly by segments of the older population who are already physically active or by segments known to be at risk for physical inactivity and low levels of mobility (i.e., the oldest old, women, those with decreased physical capacity, low socioeconomic background, and no access to private motorized transport) (13,14). In their literature review, Fishman and Cherry (5) identified a handful of studies examining e-bike user characteristics, but these did not focus explicitly on older adults and yielded inconsistent findings. For example, a US study reported their sample of e-bikes users (50% being older than 54 yr) to be higher educated than the general population (15), whereas an Austrian sample of e-bike users (62% being older than 60 yr) was found to be lower educated than the general population (16). In addition to examining the characteristics of older e-bike users, research is needed on how e-bike use relates to levels of cycling. To justify the promotion of e-bike use for PA promotion, e-bike use has to 1) initiate cycling among noncyclists, 2) increase cycling levels among older adults who were riding a conventional bike, or 3) promote maintenance of cycling among older adults who have difficulties riding a conventional bike (e.g., because of health issues) and contemplate about stopping to cycle. There is some evidence indicating that e-bike use leads to more frequent cycling and to trips of greater distance in the general adult population (5,17). Given that e-bikes enable cycling with lower physical effort, it could be hypothesized that e-bike use may particularly lead to higher levels of cycling among subgroups with lower levels of physical fitness (e.g., older adults, women, and those with overweight or difficulties cycling). To our knowledge, only one study previously examined e-bike use specifically among older adults. In a study among 69 older Australian e-bike users, Johnson and Rose (18) reported e-bike frequency to be high (34% rode their e-bike daily) and e-bikes predominantly replaced trips that were previously made by car. This suggests that e-bike use may lead to higher levels of cycling among older adults. It should be acknowledged that despite the potential benefits of e-bikes, there is also some concern that their heavier weights (approximately 25 kg) and speeds in combination with the increased physical vulnerability of older adults increase the risk for crashes and injuries (5,19).

In summary, despite the strong growth of e-bike use, research about e-bike user characteristics and the relationship between e-bike use and cycling levels is limited, particularly among older adults (5). Research conducted in younger populations may not be generalizable to older populations given that older adults are more likely to suffer from functional limitations, to be retired (and therefore do not have to commute), and to have less access to private motorized transport compared with the general adult population (20,21). The current

study aimed to compare Flemish older adults using an e-bike with those not using an e-bike on sociodemographics, health characteristics, and access to motorized transport. In addition, it examined the association between e-bike use and levels of cycling for transport, recreation and total cycling among older adults, and whether this association was moderated by sex, body mass index (BMI), and cycling limitations (i.e., health issues impeding cycling).

METHODS

Setting

The study was conducted in Flanders (northern Dutch speaking part of Belgium), a Western European region with 6,411,000 inhabitants (19.1% being 65 yr or older), an average population of 474 inhabitants per square kilometer, and residential density of 227 residences per square kilometer. More than one quarter of the Flemish surface (27%) is built up (22). In addition to the flat topography, a high degree of urbanization implies that distances to most daily destinations (i.e., shops and services) can be considered feasible to bike (23,24). In Flanders, 69.4% of all trips are made by car, 12.1% by (e-)bike, 11.4% by foot, 4.5% by public transport, and 2.6% by other modes (e.g., motorbike) (8).

Protocol and Participants

Data were collected by means of an online structured questionnaire developed using Lighthouse Studio version 9.3.1. Because 37% of the Flemish 65- to 74-yr-olds do not use the Internet regularly (25), the online data collection was complemented with interviews of the same questionnaire. For the online recruitment, a variety of organizations were contacted and asked to share the information about our study and the link to the survey among their members. These organizations included member organizations of the Flemish Senior Council (including political, sociocultural, and leisure organizations), city and municipal governments, social services and senior councils of cities and municipalities, organizations providing courses for older adults, and websites specifically targeting older adults. The participating organizations posted the information and link on their websites, newsletters, or Facebook account or sent it around by e-mail. Snowball sampling was also used by asking participants to send the questionnaire link to their relatives. For the interview administration of the questionnaire, participants were recruited in 15 local service centers spread over the five Flemish provinces. Local service centers target people in a novice care situation, are located within the neighborhood, and offer informative and recreational activities to stimulate self-reliance. Flyers and posters were used to announce a researcher's visit to the local service center. During the visit, the researcher interview-administered the computerized questionnaire in a communal area.

The following inclusion criteria were applied: being 65 yr or older, community dwelling, not severely limited by health conditions to ride a (conventional or e-)bike, and completing

all questions relevant to this study. Before data collection, the protocol and questionnaires were pilot-tested among six older adults and ambiguous questions were adapted. Actual data collection was performed between March and November 2016. Completing the questionnaire took approximately 30 min. Informed consent was automatically obtained when participants completed the questionnaire. The study protocol was approved by the ethical committee of the Ghent University hospital.

Measures

The questionnaire assessed sociodemographics, health characteristics, access to motorized transport, e-bike use, and cycling levels.

Sociodemographics. The following sociodemographics were assessed: age, sex, former main occupation, educational level, marital status, and area of residence. Former main occupation was recoded into household, blue collar (including independent and worker), and white collar (including clerk, teacher, executive, and professional). To assess educational level, 11 response categories were provided ranging from no diploma to postuniversity. These were recoded into lower secondary or less, higher secondary, and tertiary, which would correspond to maximum 9, 12, and more than 12 yr of education, respectively. Marital status was recoded into living with and without partner. To assess area of residence, participants were asked to indicate in which type of area they lived: in the center of a city (coded urban center), at the border of a city (coded urban periphery), in the center of a village (coded village center), and at the border of a village (coded rural).

Health characteristics. Limitations to cycle were assessed using one item similar to the items of the physical functioning scale of the validated RAND Short Form Health Survey (SF-36) questionnaire (26). Participants indicated to which degree their health limited them to ride a conventional or e-bike using three response options: 1) not limited at all, 2) slightly limited (I am able to ride a bike but my health makes it difficult), and 3) severely limited (my health makes it (almost) impossible to ride a bike). Participants reporting to be severely limited were excluded from this study. To calculate BMI (weight in kg/(height in m)²), participants self-reported their height and weight (27).

Access to motorized transport. Participants self-reported the number of motorized vehicles present in their household (recoded into none, one, and two or more), whether or not they possessed a driving license, and whether or not they were currently driving a motorized vehicle (excluding e-bikes).

E-bike use. Participants were asked to indicate whether or not they used an e-bike. E-bike users were asked to indicate how long they have been using an e-bike (recoded into <1, 1–2, and >2 yr) and whether or not they were still riding a conventional bike. Those using only an e-bike and those using an e-bike as well as a conventional bike were categorized as e-bike users, all others were categorized as nonusers (this includes those riding a conventional bike and noncyclists).

Cycling levels. Questions derived from the validated International Physical Activity Questionnaire (long form, last 7 d) were used to measure levels of cycling for transport and recreation (28). Participants reported the frequency of cycling for transport during the last 7 d and the average duration of cycling for transport on one of those days. Participants not using an e-bike reported frequency and duration of cycling for transport using a conventional bike. Participants only using an e-bike reported frequency and duration of cycling for transport using an e-bike. Participants using an e-bike and conventional bike reported frequency and duration of cycling for transport using an e-bike and conventional bike, separately. Weekly minutes of cycling for transport was calculated by multiplying the reported number of days by the duration of cycling for transport on one of those days (standard scoring procedures available on <http://www.ipaq.ki.se/>). For participants using an e-bike and conventional bike, levels of cycling for transport using an e-bike and conventional bike were summed. Weekly minutes of cycling for recreation was assessed and calculated similarly. Weekly minutes of cycling for transport and recreation was summed to obtain a measure of total cycling.

Statistical Analyses

In total, 1407 older adults accessed the questionnaire, but 102 reported to be severely limited to ride a bike and 159 older adults did not complete all questions relevant to the current study. This resulted in an analytic sample of 1146 participants.

Analyses were performed in R version 3.3.1. Descriptive statistics were calculated for the total sample, as well as for e-bike users and those not using an e-bike separately. To compare older adults using an e-bike with those not using an e-bike on sociodemographics, health characteristics, and access to motorized transport, logistic regression analyses were performed. First, a simple logistic regression model was fitted for each sociodemographic, health, or access to motorized transport variable separately. Second, a multiple logistic regression model was fitted including all sociodemographic, health, or access to motorized transport variables simultaneously. Because of multicollinearity with number of motorized vehicles in the household, current driving status was excluded from this model. This model was also adjusted for administration mode (online vs interview).

To examine the associations between e-bike use and levels of cycling for transport, recreation, and total cycling, hurdle models were used. Hurdle models were used because 41.8%, 56.9%, and 35.1% of the sample reported zero minutes of cycling for transport, cycling for recreation, and total cycling, respectively. A hurdle model consists of two separate analyses. First, a logistic regression model was fitted to estimate the relationship between e-bike use and the odds of having cycled in the past week. Second, a negative binomial regression model with log link function estimated the relationship between e-bike use and the volume of cycling among those participants who reported any cycling in the last 7 d. The exponent of a negative binomial regression coefficient represents

the proportional difference in cycling volume among those who did cycle in the past week between e-bike users and those not using an e-bike. To estimate the relationships between e-bike use and cycling levels and the moderating effects of sex, BMI, and cycling limitations, the same stepwise procedure was used for logistic and negative binomial regression models. The analyses were performed separately for cycling for transport, cycling for recreation, and total cycling. First, a main effect model was fitted including the main effects of e-bike use and all sociodemographic, health, and access to motorized transport variables (except for driving status because of multicollinearity) and administration mode. The results of this model are referred to as the results in the total sample in Table 3 and the corresponding text. Second, for each outcome and each logistic as well as negative binomial model, three separate models were fitted in which the interaction effect between e-bike use and one of the three potential moderators was added to the main effect model (resulting in 18 different models). Significant interaction effects were probed as described by Aiken and West (29). This implies that in case of significant interaction effects between e-bike use and BMI, which was a continuous moderator, associations of e-bike use with cycling levels were

estimated at mean BMI, mean BMI plus 1 SD, and mean BMI minus 1 SD. We refer to these as mean, high, and low levels of BMI, respectively.

Significance was determined based on alpha values of 0.05 and 0.10 for main and interaction effects, respectively. To assess models' goodness of fit, likelihood ratio tests were performed and Nagelkerke R^2 values were calculated.

Because higher educated older adults were overrepresented in our sample, we performed a sensitivity analysis using probability weights based on educational level. These weighted analyses were performed using the survey package in R (30).

RESULTS

Descriptive Statistics

Our sample had a mean age of 71.9 yr, 47.4% were women, and 40.9% had obtained tertiary education (see Table 1). This implies an overrepresentation of tertiary educated older adults because only 22.5% of the population of Flemish older adults is tertiary educated (31). Almost 20% (19.6%) reported to be slightly limited by their health to ride a (conventional or

TABLE 1. Characteristics of the total sample, those not using an e-bike, and e-bike users.

	Total Sample (n = 1146)	Not Using E-bike (n = 789)	E-bike Users (n = 357)
Age, M $\pm$ SD, yr	71.9 $\pm$ 5.5	72.0 $\pm$ 5.6	71.8 $\pm$ 5.2
Sex, % women	47.4	44.5	53.8
Occupation, %			
Household	9.2	8.0	11.8
Blue collar ^a	21.2	18.6	26.9
White collar ^b	69.6	73.4	61.3
Education, %			
Lower secondary or less ^c	30.9	28.0	37.3
Higher secondary ^d	28.2	29.5	25.2
Tertiary ^e	40.9	42.5	37.5
Marital status, % no partner	30.1	30.3	29.7
Area of residence, % ^f			
Urban center	15.4	15.5	15.1
Urban periphery	31.8	34.2	26.3
Village center	22.6	22.9	21.8
Rural	30.3	27.4	36.7
Limitations to cycle, % slightly limited	19.6	20.2	18.5
BMI, M $\pm$ SD, kg·m ⁻²	26.4 $\pm$ 3.9	26.2 $\pm$ 3.9	26.9 $\pm$ 3.8
No. motorized vehicles, %			
None	11.3	13.1	7.3
1	71.6	69.1	77.3
≥ 2	17.1	17.9	15.4
Driving license, % yes	93.8	93.2	95.2
Currently driving, % yes	83.5	81.5	88.0
Cycling for transport			
% having cycled for transport	58.2	52.6	70.6
Volume among transport cyclists ^g , Med (Q1–Q3)	120 (50–210)	100 (45–200)	135 (60–240)
Cycling for recreation			
% having cycled for recreation	43.1	35.9	59.1
Volume among recreation cyclists ^g , Med (Q1–Q3)	145 (60–360)	120 (45–300)	175 (80–360)
Total cycling			
% having cycled	64.9	57.4	78.2
Volume among cyclists ^g , Med (Q1–Q3)	200 (80–420)	160 (60–360)	260 (110–500)
Administration mode (% interview)	15.8	15.0	17.6

^aIncluding independent and worker.

^bIncluding clerk, teacher, executive, and professional.

^cCorresponds to maximum 9 yr of education.

^dcorresponds to 12 yr of education.

^eCorresponds to more than 12 yr of education.

^fTo assess area of residence, participants were asked to indicate in which type of area they lived: in the center of a city (coded urban center), at the border of a city (coded urban periphery), in the center of a village (coded village center), and at the border of a city (coded rural).

^gExpressed in minutes per week.

M = mean; Med, median; Q1, quartile 1; Q3, quartile 3.

e-bike, and 83.5% were currently driving a motorized vehicle. Almost one third (31.2%) of our sample was using an e-bike. Among the e-bike users, 21.3% was using an e-bike for less than 1 yr, 25.8% for 1 to 2 yr, and 52.9% for more than 2 yr. More than one third of all e-bike users were also riding a conventional bike (38.4%).

Comparison of E-bike Users against Those not Using an E-bike on Sociodemographics, Health Characteristics, and Access to Motorized Transport

Results of the multiple logistic regression model indicated that three variables were significantly related to the odds of being an e-bike user: sex, BMI, and number of motorized vehicles in the household (see Table 2). Women had a 75% higher odds of being an e-bike user compared with men (95% confidence interval (CI), 30%–137%). Those with a higher BMI were more likely to be an e-bike-user, with a 1-unit increase in BMI being associated with a 5% higher odds of being an e-bike user (95% CI, 2%–9%). Participants with one motorized vehicle in the household had a 125% higher odds of being an e-bike user compared with those having no car (95% CI, 34%–289%).

Associations between E-bike Use and Cycling Levels

Cycling for transport. E-bike use was significantly positively related to the odds of having cycled for transport in the past week and to the volume of cycling for transport

among those who had cycled for transport (see Table 3). Furthermore, a significant interaction effect between e-bike use and BMI was observed in the logistic regression model. Across all levels of BMI, e-bike users had significantly higher odds of having cycled for transport in the past week compared with those not using an e-bike, but this relationship was stronger among those with higher levels of BMI. Among those with a low BMI, e-bike users had 89% higher odds of having cycled for transport compared with those not using an e-bike (95% CI, 24%–191%). Among those with a mean BMI, e-bike users had 151% higher odds of having cycled for transport compared with those not using an e-bike (95% CI, 88%–238%). Among those with a high BMI, e-bike users had 234% higher odds of having cycled for transport compared with those not using an e-bike (95% CI, 126%–400%). No significant interaction effects were observed in the negative binomial model. This implies that e-bike use was associated with 35% more minutes of cycling for transport among those who did cycle for transport in the past week, independent of sex, BMI, and cycling limitations (95% CI, 17%–56%).

Cycling for recreation. In the logistic regression model for cycling for recreation, a significant positive association with e-bike use in the total sample and no significant interaction effects were found. E-bike users had 183% higher odds of having biked for recreation in the past week compared with those not using an e-bike independent of sex, BMI, and cycling limitations (95% CI, 115%–274%). In the negative binomial model, a significant positive association was also found in the total sample, but e-bike use significantly interacted with

TABLE 2. Relationships of sociodemographics, health characteristics and access to motorized transport with the odds of e-bike use.

	Simple Logistic Regression Analyses ^a		Multiple Logistic Regression Analysis ^b	
	OR (95% CI)	P	OR (95% CI)	P
Age	0.99 (0.97–1.0)	0.56	1.00 (0.98–1.03)	0.79
Sex (ref: men)				
Women	1.45 (1.13–1.87)	0.004	1.75 (1.30–2.37)	<0.001
Occupation (ref: household)				
Blue collar	0.98 (0.62–1.57)	0.93	1.28 (0.77–2.17)	0.34
White collar	0.57 (0.37–0.87)	0.008	0.75 (0.46–1.22)	0.24
Education (ref: lower secondary or less)				
Higher secondary	0.64 (0.46–0.89)	0.007	0.77 (0.54–1.10)	0.16
Tertiary	0.66 (0.50–0.89)	0.006	0.89 (0.62–1.27)	0.51
Marital status (ref: partner)				
No partner	0.97 (0.74–1.27)	0.84	0.90 (0.65–1.24)	0.53
Area of residence (ref: urban center)				
Urban periphery	0.79 (0.53–1.17)	0.24	0.72 (0.48–1.10)	0.13
Village center	0.97 (0.64–1.48)	0.90	0.86 (0.55–1.33)	0.49
Rural	1.37 (0.93–2.03)	0.11	1.16 (0.77–1.77)	0.47
Limitations to cycle (ref: not limited)				
Slightly limited	0.90 (0.65–1.23)	0.51	0.86 (0.61–1.21)	0.40
BMI	1.05 (1.02–1.08)	0.003	1.05 (1.02–1.09)	0.003
No. motorized vehicles (ref: none)				
1	2.01 (1.29–3.22)	0.003	2.25 (1.34–3.89)	0.003
≥2	1.55 (0.92–2.66)	0.11	1.77 (0.95–3.38)	0.08
Driving license (ref: yes)				
No driving license	0.68 (0.38–1.17)	0.18	0.69 (0.36–1.31)	0.27
Currently driving (ref: yes)				
Not driving	0.60 (0.41–0.86)	0.007	—	—

P < 0.05 was considered statistically significant.

^aAll simple logistic regression analyses included data from 1146 participants, except for the model with BMI, which included data from 1137 participants.

^bIncluded all variables concerning sociodemographics, health, and access to motorized transport, except for driving status because of multicollinearity. This model was also adjusted for administration mode (online vs interview). The model included data from 1137 participants. Likelihood ratio test (compared with model only including an intercept): $\chi^2 = 63.49$ ($df = 16$), $P < 0.001$; Nagelkerke $R^2 = 0.08$.

OR, odds ratio; Ref, reference category.

TABLE 3. Relationships of e-bike use with cycling for transport, recreation, and total cycling in the total sample and according to sex, BMI, and cycling limitations.

	Cycling for Transport			Cycling for Recreation			Total Cycling		
	Logistic Regression Model (n = 1137)		P	Logistic Regression Model (n = 1137)		P	Logistic Regression Model (n = 1137)		P
	OR (95% CI)	ExpB (95% CI)		OR (95% CI)	ExpB (95% CI)		OR (95% CI)	ExpB (95% CI)	
Total sample	2.58 (1.94–3.47)	1.35 (1.17–1.56)	<0.001	2.83 (2.15–3.74)	1.30 (1.07–1.58)	0.007	3.17 (2.33–4.36)	1.45 (1.24–1.69)	<0.001
IE with sex ^a	0.83 (0.46–1.47)	0.86 (0.65–1.14)	0.29	1.39 (0.81–2.40)	1.41 (0.96–2.05)	0.07	0.95 (0.51–1.76)	1.17 (0.87–1.58)	0.30
Men									
Women									
IE with BMI ^b	1.08 (1.00–1.16)	0.98 (0.95–1.02)	0.35	1.03 (0.96–1.10)	1.57 (1.18–2.09)	0.002	1.09 (1.00–1.18)	1.00 (0.96–1.04)	0.89
Low BMI	1.89 (1.24–2.91)		0.003		1.02 (0.97–1.08)	0.39	2.22 (1.42–3.52)		0.001
Mean BMI	2.51 (1.88–3.38)		<0.001				3.07 (2.26–4.22)		<0.001
High BMI	3.34 (2.26–5.00)		<0.001				4.26 (2.79–6.64)		<0.001
IE with cycling limitations	1.38 (0.68–2.80)	0.74 (0.48–1.15)	0.17	1.19 (0.58–2.46)	2.37 (1.34–4.19)	0.002	1.82 (0.88–3.84)	1.19 (0.76–1.87)	0.43
Not limited									
Slightly limited									
Goodness of fit ^c									
χ^2 and P^d	108.36	49.44	<0.001	72.03	2.37 (1.34–4.19)	0.02	101.19	54.16	<0.001
Nagelkerke R^2	0.16	0.11		0.14	1.18 (0.97–1.45)	0.10	0.17	0.10	

$P < 0.05$ and $P < 0.10$ were considered statistically significant for main and interaction effects, respectively.

All models were adjusted for age, sex, occupation, education, marital status, area of residence, cycling limitations, BMI, number of motorized vehicles in the household, driving license ownership, and administration mode.

^aThe exponent of a negative binomial regression coefficient represents the proportional difference in cycling volume among those who did cycle in the past week between e-bike users and those not using an e-bike.

^bReference category: men. Low BMI = mean BMI – 1 SD; high BMI = mean BMI + 1 SD.

^cFit indices were calculated for the main effect models (total sample) and compared with a null model (only including an intercept).

^dDegrees of freedom = 16 and 17 for all logistic and negative binomial models, respectively.

ExpB, exponent of regression coefficient B; IE, interaction effect; OR, odds ratio.

sex and cycling limitations. For women, e-bike use was related to 57% more minutes of cycling for recreation among those who have cycled in the past week (95% CI, 18%–109%). For men, no significant relationship between e-bike use and volume of cycling for recreation among those who did cycle for recreation was observed. For those reporting to be slightly limited by their health to ride a bike, e-bike use was related to 180% more minutes of cycling for recreation among those who did cycle for recreation (95% CI, 63%–381%). For those being not limited to ride a bike, no significant relationship between e-bike use and volume of recreational cycling was observed.

Total cycling. Similar to the results for cycling for transport, significant positive relationships with total cycling were observed for the total sample in the logistic regression and negative binomial models, and a significant interaction effect with BMI was observed in the logistic regression model. E-bike use was significantly positively associated with the odds of having cycled in the past week, and this was stronger among those with higher levels of BMI. Among those with a low BMI, e-bike use was related to a 122% higher odds of having cycled (95% CI, 42%–252%), whereas this was a 207% (95% CI, 126%–322%) and 326% (95% CI, 179%–564%) higher odds among those with a mean and high BMI, respectively. The negative binomial showed that e-bike use was related to 45% more minutes of cycling among those who have cycled in the past week (95% CI, 24%–69%), independent of sex, BMI, and cycling limitations.

Sensitivity Analyses Using Probability Weights Based on Educational Level

Overall, no substantial differences were observed between the unweighted (presented above) and weighted analyses (see Tables, Supplemental Digital Content 1, Relationships of sociodemographics, health characteristics, and access motorized transport with the odds of e-bike use weighted based on educational level, <http://links.lww.com/MSS/B267>, and Supplemental Digital Content 2, Relationships of e-bike use with cycling for transport, recreation and total cycling in the total sample and according to sex, BMI, and cycling limitations weighted based on educational level, <http://links.lww.com/MSS/B268>). However, in the weighted results, a significant interaction effect between e-bike use and cycling limitations in the negative binomial for cycling for transport was observed. For those not being limited to cycle, e-bike use was related to 44% higher volumes of cycling for transport (95% CI, 20%–73%) among those who have cycled in the past week. No such relationship was observed among those being slightly limited to cycle.

DISCUSSION

The current study aimed to examine e-bike user characteristics and relationships between e-bike use and cycling levels among Flemish older adults. We observed e-bike use to be higher among women, those with a higher BMI, and

those with access to motorized vehicles. E-bike use was related to higher probabilities and higher volumes of transport, recreation, and total cycling, with some of these relationships being stronger for women, those with a higher BMI, and those experiencing limitations to cycle.

Our finding that women were more likely to be e-bike users than men is promising because women are at increased risk for physical inactivity (32) and Flemish older women are less likely to cycle compared with men (33). The electric assistance of e-bikes may be especially appealing to women because they have lower muscular strength compared with men (34). It has been reported that women use their e-bike to be able to maintain cycling and keep up with their fitter husband who rides a conventional bike (15). E-bikes may also offer an alternative for trips by car especially for women because driving license ownership is lower among older women compared with men (8). However, the relationship between sex and e-bike use persisted in our multiple logistic regression model adjusting for driving license ownership. Furthermore, driving license ownership was not related to e-bike use, probably because 94% of our sample owned a driving license. Lastly, misconceptions such as e-biking being cheating (and not real cycling) and being too proud to give up conventional cycling may possibly deter men from using an e-bike (15).

A higher BMI was related to a higher probability of e-bike use. Overweight is a barrier for PA among older adults (14), and our findings suggest that the reduced intensity of e-biking compared with conventional biking may appeal in particular to older adults with a higher BMI. E-biking in turn may contribute to weight management among those with overweight. The previously described findings that e-bikes seem to be especially attractive for older adults at risk for physical inactivity is in line with recent findings in a sample of 1953 Norwegian adults (mean age, 45 yr) showing those with lower levels of cycling for transport and exercise being particularly interested in purchasing an e-bike (35). In addition, e-bike use was higher among those with one or more motorized vehicles compared with those having no motorized vehicles in the household. The number of motorized vehicles may be regarded as an indicator of socioeconomic status, which would imply that e-bike use is more prevalent among those with a higher socioeconomic background. However, the multiple logistic regression model was adjusted for educational level and former occupation, and in the simple logistic regression analyses, e-bike use was shown to be lower among those with a higher educational level and among white collars compared with those responsible for the household. In an Austrian sample of adult e-bike users, it was also found that the sample had higher levels of car ownership compared with the Austrian population (16). These findings indicate that e-bikes are not purchased to replace cars (i.e., buy an e-bike and sell a car), but rather to serve as an additional transport option. This confirms findings from a study among 427 Danish adult e-bike users showing that replacement of a car was the least important reason for e-bike purchase (36). However, this does not

imply that e-bikes may not be used to replace (some) car trips. Previous studies have shown that e-bikes could reduce the number of car trips (17,18). Such substitution effects may also depend on local context, culture, and available transport modes. Since only 11.3% of our sample did not possess a motorized vehicle, future research including larger subgroups that do not have access to motorized transport should confirm the observed relationships of motorized vehicle ownership and e-bike use. We found no relationships of age and cycling limitations with the probability of being an e-bike user. This suggests that e-bikes appeal to older adults independent of age and functional capacity. However, future studies should use more detailed measures of functional capacity to draw firm conclusions. Given that e-bikes are rather expensive compared with a conventional bike (an e-bike easily costs 2000 euro), it was also reassuring that e-bikes did not seem to be a privilege for older adults from higher education and occupation backgrounds.

In our sample, 31.2% was using an e-bike. According to the Flemish travel survey, 17.5% of all older households (i.e., those with a householder of 65 yr or older) possess an e-bike (8). This indicates that the prevalence in our sample is an overestimation of e-bike use in the Flemish older adult population. Our sample was also higher educated than the Flemish population of older adults (31). However, in the simple logistic regression model, a higher educational level was associated with a lower odds of being an e-bike user (so this does not explain the high prevalence of e-bike use in our sample). Although the instructions for participants at the beginning of our questionnaire did not explicitly mention that our study focused on bicycle and e-bike use, our invitation e-mails to participating organizations did mention this focus. This may have caused organizations to contact members who used an e-bike to participate in the study resulting in an overrepresentation of e-bike users in our sample. Among e-bike users, the prevalence of cycling for transport was somewhat higher than that of cycling for recreation (71% vs 59%). However, the median volumes among those who did cycle were higher for recreational than for transport cycling (175 vs 135 min·wk⁻¹). In a US study (13% being older than 65 yr), e-bikes were used predominantly for transport purposes (37), whereas in an Austrian study (62% being older than 60 yr), recreation was the main purpose of e-bike use (16). In the current study, e-bike use was related to higher odds and volumes of cycling for transport and recreation. These relationships were similar in magnitude for cycling for transport and recreation implying that e-bike use may contribute equally to stimulating cycling for transport and recreation. However, in a randomized controlled trial conducted among Norwegian adults (mean age, 49 yr), the effects of providing the intervention group with an e-bike were stronger on levels of cycling for transport compared with cycling for recreation (17). These inconsistencies between previous and current findings may reflect the samples' age differences (e.g., our participants were older and did not have to commute) or cultural and topographical differences between countries.

E-bike use was related to a higher odds of engagement in cycling for transport and recreation and total cycling. Considering those who reported no cycling in the past week, some of these may actually never cycle, whereas others may just cycle irregularly (and therefore reported no cycling in the past week). Our findings suggest that e-bike use may actually stimulate noncyclists to start cycling or irregular cyclists to cycle more regularly by reducing typical cycling barriers such as too much effort, long distances, and windy or hilly conditions (37). Future studies should examine whether e-bike use can actually stimulate uptake of cycling among older adults who stopped riding a conventional bike a long time ago. Previous studies on the (re-)uptake of conventional or e-biking in Australia (38) and the UK (39) have already indicated that dedicated cycling courses for older adults are necessary to successfully and safely promote cycling (re-)uptake among older adults.

Because e-bike use was also related to greater volumes of cycling for transport and recreation and total cycling among those who did engage in cycling, it does seem to not only stimulate engagement in any cycling but, when engaged in cycling, also stimulate to cycle more. Our cycling outcome measures were expressed in minutes per week. Given the higher average speeds of e-bikes (11), the higher volumes observed among e-bike users imply that e-bike users ride more frequently and/or ride longer distances than older adults not using an e-bike. A study among Danish e-bike users showed that cycling frequencies and distances increased after e-bike purchase among those older than 65 yr and that e-bike purchase eliminated the difference with younger age groups in cycling frequency but not distance (36). Consequently, e-bike use may not only entail health benefits but also increase older adults' life space area (i.e., the extent and frequency of movement outside one's home) and social participation (12). The reduced effort during e-biking apparently enables older adults to cycle more frequently and/or for a longer period of time. This is supported by our finding that the relationship between e-bike use and volume of recreational cycling was stronger among subgroups with lower physical fitness levels, that is, women and those with slight limitations to cycle. This is in line with findings from a randomized controlled trial among Norwegian adults (mean age, 49 yr) during which the effects of e-bike provision were tested (17). E-bike provision increased cycling frequency and overall distance cycled, and these effects on frequency (but not distance) were stronger among women compared with men. However, contrary to our findings for recreational cycling, our sensitivity analysis showed that e-bike use was only related to higher volumes of cycling for transport among those not being limited to cycle and not among those being slightly limited to cycle. Possibly, e-bike use may not stimulate cycling for transport among those with cycling limitations because cycling for transport often implies carrying things while cycling (e.g., a shopping bag). Carriage of such items on an already heavy e-bike, which may cause balance problems, may prevent older adults with cycling limitations from increasing

their cycling for transport with an e-bike. Our findings that e-bike use relates to higher volumes of recreational cycling are promising and suggest that e-bikes may promote PA and health among those currently not cycling and those who would quit cycling without access to an e-bike. However, among older conventional cyclists who are still fit enough to ride a conventional bike but want to switch to e-biking, the higher cycling volumes related to e-bike use need to be balanced against the reduced intensity of e-biking. The higher intensity of conventional cycling (e.g., when riding uphill) may provide more benefits for older adults' cardiovascular fitness and lower limb muscular strength, and, consequently, their physical functioning and overall health (1,34). Lastly, to accurately assess the potential health effects of e-biking, a more comprehensive approach is needed because e-bike use may affect not only cycling levels but also levels of car and public transport use and walking. For example, in a UK trial among 80 working adults, it was shown that the increase in cycling caused by providing participants with an e-bike for 6 to 8 wk was offset by a decrease in time spent walking (40). However, the increase in cycling after e-bike purchase was not compensated for by reductions in other PA in a study among Norwegian adults (35).

Our findings suggest that policies aiming to stimulate e-bike use among older adults (e.g., the provision of e-bike charging stations, subsidies for e-bike purchasing, investments in cycling infrastructure, and introductory e-bike courses) may increase cycling levels, especially among subgroups at risk for physical inactivity (women and those with overweight and functional limitations). However, more research is needed to examine the relationships of older adults' e-bike use with levels of cycling, overall PA, and health outcomes preferably using longitudinal and/or experimental designs. Furthermore, e-bikes' higher speeds and weights in combination with older adults' particular physical vulnerability have raised concerns regarding e-bike crashes and injuries (5). In a Dutch study, e-bike users were observed to have a higher risk for a crash requiring treatment at an emergency department in comparison to conventional bike users (19). Furthermore, older adults were more likely to be (severely) injured from an e-bike crash in comparison to younger age groups. To be able to assess the balance between the potential risks against the benefits of e-bike use, more research is needed about older e-bikers' crash risk in comparison to conventional bikers. When promoting e-bike use among older adults, it seems appropriate to offer e-bike courses to teach older adults how to safely ride an e-bike. Research into the circumstances of e-bike crashes may yield important information for the development of e-bike courses for older adults and the provision of safe e-biking infrastructure.

The current study provided us with first insights into e-bike user characteristics and relationships with levels of cycling specifically among older adults in Flanders. In addition, examination of the moderating effects of sex, BMI, and cycling limitations allowed us to focus on subgroups known to be at risk for physical inactivity. Besides these strengths, several limitations should be acknowledged. First, we examined

cross-sectional differences between older e-bike users and nonusers. To establish causal relationships between e-bike use and cycling levels, longitudinal and/or experimental research is necessary. Second, all our data were self-reported and cycling limitations were assessed with only one item. Future studies could include a more comprehensive (and objective) assessment of older adults' cycling abilities. Third, although our sample was large and included older participants from varying socioeconomic backgrounds and areas of residence and with varying levels of cycling, our sample was not representative for the Flemish population of older adults. For example, tertiary educated older adults were overrepresented, which may be explained by most of our participants being recruited online. However, we performed sensitivity analyses using probability weights based on educational level, which yielded similar results and conclusions. The online recruitment and lack of information on the interview's rejection rate prevent us from calculating an overall response rate. Fourth, we did not assess participants' household income, which may be a more direct predictor of e-bike use than other measures of socioeconomic status (such as education and occupation). Fifth, the current study was conducted in Flanders and our

findings may not be generalizable to regions with a different cycling culture, topography, and climate.

The current study was one of the first studying e-bike use specifically among older adults. It showed that e-bike use especially appeals to those at risk for physical inactivity (i.e., women and those with a higher BMI) and that it relates to higher probabilities as well as volumes of cycling for transport and recreation. If our results are confirmed by longitudinal and experimental studies, policies should be implemented to promote e-bike use among older adults. This may be an effective approach to increase PA levels among the growing population of older adults, and particularly so among subgroups at risk for physical inactivity (i.e., women and older adults with a higher BMI and limitations to cycle).

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REFERENCES

- Chodzko-Zajko WJ, Proctor DN, Singh MA, et al. Exercise and physical activity for older adults. *Med Sci Sports Exerc.* 2009;41(7):1510–30.
- European Commission. *Special Eurobarometer 412: Sport and Physical Activity*. Brussels: European Commission, Directorate-General for Communication; 2013. p. 21.
- Morris JN, Hardman AE. Walking to health. *Sports Med.* 1997;23(5):306–32.
- Mandl B, Millonig A, Klettner S, et al. Growing older, staying mobile: transport needs for an ageing society. Deliverable D4.2 Older People. Available from: http://www.goal-project.eu/images/reports/d4-2_goal_final_20130701.pdf.
- Fishman E, Cherry C. E-bikes in the mainstream: reviewing a decade of research. *Transport Rev.* 2015;36(1):1–20.
- CONEBI. *European Bicycle Market 2016 edition—Industry & Market Profile (2015 Statistics)*. Brussels (Belgium): Confederation of the European Bicycle Industry; 2016. pp. 24.
- Hendriksen I, Engbers L, Schrijver J, Van Gijlswijk R, Weltevreden J, Wilting J. *Elektrisch Fietsen. Marktonderzoek en verkenning toekomstmogelijkheden [E-bikes. Market Research and Exploration of Future Possibilities]*. Leiden: TNO Kwaliteit van Leven; 2008.
- Declercq K, Reumers S, Polders E, Janssens D, Wets G. Onderzoek Verplaatsingsgedrag Vlaanderen 5.1 (2015–2016): Tabellenrapport. Instituut voor Mobiliteit (Universiteit Hasselt) in opdracht van de Vlaamse Overheid [Report of Tables. Hasselt (Belgium): Institute for Mobility (University of Hasselt) commissioned by the Flemish Government]; 2016.
- Sperlich B, Zinner C, Hebert-Losier K, Born DP, Holmberg HC. Biomechanical, cardiorespiratory, metabolic and perceived responses to electrically assisted cycling. *Eur J Appl Physiol.* 2012;112(12):4015–25.
- Gojanovic B, Welker J, Iglesias K, Daucourt C, Gremion G. Electric bicycles as a new active transportation modality to promote health. *Med Sci Sports Exerc.* 2011;43(11):2204–10.
- Berntsen S, Malnes L, Langaker A, Bere E. Physical activity when riding an electric assisted bicycle. *Int J Behav Nutr Phys Act.* 2017;14(1):–55.
- Tsunoda K, Kitano N, Kai Y, et al. Transportation mode usage and physical, mental and social functions in older Japanese adults. *J Transp Health.* 2015;2(1):44–9.
- Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet.* 2012;380(9839):258–71.
- Baert V, Gorus E, Mets T, Geerts C, Bautmans I. Motivators and barriers for physical activity in the oldest old: a systematic review. *Ageing Res Rev.* 2011;10(4):464–74.
- Popovich N, Gordon E, Shao Z, Xing Y, Wang Y, Handy S. Experiences of electric bicycle users in the Sacramento, California area. *Travel Behav Soc.* 2014;1:37–44.
- Wolf A, Seebauer S. Technology adoption of electric bicycles: a survey among early adopters. *Transp Res Part A Policy Pract.* 2014;69:196–211.
- Fyhri A, Fearnley N. Effects of e-bikes on bicycle use and mode share. *Transp Res Part D Transp Environ.* 2015;36:45–52.
- Johnson M, Rose G. Extending life on the bike: electric bike use by older Australians. *J Transp Health.* 2015;2(2):276–83.
- Schepers JP, Fishman E, den Hertog P, Wolt KK, Schwab AL. The safety of electrically assisted bicycles compared to classic bicycles. *Accid Anal Prev.* 2014;73:174–80.
- UK Department for Transport. *National Travel Survey: England 2016*. London: Dandy Booksellers; 2017. p. 9.
- Lynott J, Figueiredo C. *How the Travel Patterns of Older Adults Are Changing: Highlights From the 2009 National Household Travel Survey*. Washington (DC): AARP Public Policy Institute; 2011. p. 4.
- SVR [Internet]. Vlaanderen in cijfers 2015. Brussels, Belgium: Studiedienst Vlaamse Regering, Vlaamse Overheid. SVR. Flanders in numbers 2015. Brussels (Belgium): Study service Flemish Government. 2015. Available from: <https://www.vlaanderen.be/nl/publicaties/detail/vlaanderen-in-cijfers-2015>.
- Vandenbulcke G, Thomas I, de Geus B, et al. Mapping bicycle use and the risk of accidents for commuters who cycle to work in Belgium. *Transp Policy.* 2009;16(2):77–87.
- de Geus B, Degraeuwe B, Vandenbulcke G, et al. Utilitarian cycling in Belgium: a cross-sectional study in a sample of regular cyclists. *J Phys Act Health.* 2014;11(5):884–94.

25. FOD Economie KMO, Middenstand en Energie Web Site [Internet]. Enquête ICT-gebruik bij de gezinnen [FPS Economy, S.M.E.s, Self-employed and Energy. Survey ICT-use among households]. 2016. Available from: http://statbel.fgov.be/nl/statistieken/cijfers/arbeid_leven/ict/.
26. Ware J, Kosinski M, Keller S. *SF-36 Physical and Mental Health Summary Scales: A User Manual and Interpretation Guide*. Boston: The Health Institute, New England Medical Center; 1994.
27. World Health Organization. Global Data Base on Body Mass Index. 2018 [cited 2018 January 17]. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.
28. Van Holle V, De Bourdeaudhuij I, Deforche B, Van Cauwenberg J, Van Dyck D. Assessment of physical activity in older Belgian adults: validity and reliability of an adapted interview version of the long International Physical Activity Questionnaire (IPAQ-L). *BMC Public Health*. 2015;15:433.
29. Aiken LS, West SG. *Multiple Regression: Testing and Interpreting Interactions*. Newbury Park (CA): Sage; 1991.
30. Lumley T. Package 'survey': analysis of complex survey samples. 2018 [cited 2018 February 14]. Available from: <http://r-survey.r-forge.r-project.org/survey/>.
31. Belgian Federal Government Web Site [Internet]. Enquête naar de arbeidskrachten (EAK). Algemene Directie Statistiek—België [Employment Survey. General Direction of Statistics—Belgium]; 2013. Available from: <http://statbel.fgov.be/nl/statistieken/gegevensinzameling/enquetes/eak/>.
32. Althoff T, Sosic R, Hicks JL, King AC, Delp SL, Leskovec J. Large-scale physical activity data reveal worldwide activity inequality. *Nature*. 2017;547(7663):336.
33. Van Cauwenberg J, Clarys P, De Bourdeaudhuij I, et al. Physical environmental factors related to walking and cycling in older adults: the Belgian aging studies. *BMC Public Health*. 2012;12(142).
34. Brady AO, Straight CR, Evans EM. Body composition, muscle capacity, and physical function in older adults: an integrated conceptual model. *J Aging Phys Act*. 2014;22(3):441–52.
35. Sundfor HB, Fyhri A. A push for public health: the effect of e-bikes on physical activity levels. *BMC Public Health*. 2017;17(1):809.
36. Haustein S, Moller M. Age and attitude: changes in cycling patterns of different e-bike user segments. *Int J Sustain Transp*. 2016;10(9):836–46.
37. MacArthur J, Dill J, Person M. E-bikes in the North America: results from an online survey. *Transp Res Rec*. 2014(2468):123–30.
38. Rissel C, Passmore E, Mason C, Merom D. Two pilot studies of the effect of bicycling on balance and leg strength among older adults. *J Environ Public Health*. 2013;2013:1–6.
39. Jones T, Chatterjee K, Spinney J, et al *Cycle BOOM Design for Lifelong Health and Wellbeing—Summary of Key Findings and Recommendations*. Oxford (UK): Oxford Brookes University; 2016. pp. 1–56.
40. Cairns S, Behrendt F, Raffo D, Beaumont C, Kiefer C. Electrically-assisted bikes: potential impacts on travel behaviour. *Transp Res Part A Policy Pract*. 2017;103:327–42.