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E-bikes among older adults: benefits, disadvantages, usage and crash characteristics

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Abstract
The promotion of sustainable and healthy mobility among older adults (≥65 years) is an important challenge. E-bikes may be part of the solution, but research about e-bike use among older adults is scarce. The current study aims to examine e-bikes' purchase reasons, benefits and disadvantages, purposes and amount of use, substitution effects and crash characteristics among older e-bike users. Additionally, it examines differences between men and women. In Flanders (Belgium), 357 older e-bike users completed an online- or interview-version of the same questionnaire. Among men and women, the most prevalent reason for e-bike purchase was to bike with less effort (24.1%). The most important benefit of e-bike use was to be able to bike longer distances (35.0%). E-bikes' heavy weight was the most frequently reported disadvantage (33.3%). Men more frequently reported battery issues, but also that they do not experience any disadvantage. Women more frequently reported fear of falling/injuries. Participants used their e-bikes for various purposes. Men more frequently reported to cycle for recreation alone while women used the e-bike more for social reasons. E-bikes predominantly replaced trips by conventional bike (72.0%) and car (50.7%). About one quarter (27.5%) had experienced an e-bike crash, most frequently caused by an uneven or slippery surface (26.5%). To promote active ageing, policy initiatives could include strategies aimed at stimulating e-bike use. These strategies should focus on emphasizing the identified benefits, reducing the disadvantages and increasing e-bike safety. Research in countries with less favorable cycling cultures is necessary to confirm current findings.

Keywords Pedelecs · Seniors · Sustainable mobility · Bicycling · Active ageing

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Introduction

Worldwide, the proportion of older adults (≥ 65 years) is projected to almost double from 8.9% in 2017 up to 16.6% in 2050 (U.S. Census Bureau 2017). Supporting the mobility of this growing population of older adults (≥ 65 years) is an important challenge for modern societies (United Nations 2015; Rosenbloom 2001). While the age difference is decreasing, older adults still have lower rates of driving license ownership and car access compared to younger adults (Minton and Clark 2018). For example, in Flanders (northern part of Belgium) 22.3% of all older adults do not own a driving license. In addition, rates of driving license ownership and car access are even lower among older women compared to men. In Flanders, 3.1% of older men versus 38.0% of older women does not own a driving license (Declercq et al. 2016). The possibility of driving a car has been linked to higher trip frequencies, engagement in out-of-home activities and well-being among older adults (Siren and Hakamies-Blomqvist 2004; Nordbakke and Schwanen 2015; Siren and Haustein 2015). However, a recent study showed driving cessation to be related to poorer mental health, but only among women with low levels and not among women with high levels of engagement in social activities (Pachana et al. 2016). This suggests that strategies helping to maintain mobility and support engagement in social activities may buffer driving cessation-related decreases in mental health.

While car driving may be necessary for older adults to reach destinations that are located further away, active transport modes (i.e. walking and cycling) should be encouraged to reach destinations located within shorter distances for sustainability and health reasons (Rosenbloom 2001; Mueller et al. 2015). Whereas walking requires less skills and equipment, cycling is faster and enables to travel greater distances than walking and may, therefore, provide greater benefits for older adults' mobility. A study among Japanese older adults residing in a rural area found higher frequencies of cycling for transport to be associated with stronger social networks and better mental health (Tsunoda et al. 2015). The authors explained their findings by stating that cycling increases older adults' activity spaces, which, in turn, resulted in more independence, the possibility to engage in social activities and maintain social relationships. Older adults' cycling mode shares (number of cycle trips/total number of trips) vary strongly across the world; 0.5% in the US, 1% in the UK, 9% in Germany, 12% in Flanders (Belgium), 15% in Denmark and 23% in the Netherlands (Buehler and Pucher 2012; Declercq et al. 2016). While cycling may not be a feasible alternative for long distances, many of older adults' car trips are within distances feasible for cycling. For example, Flemish older adults travel 50% of all their trips shorter than three kilometres and 30% of all their trips shorter than one kilometre by car (Janssens et al. 2011). In a study among 1402 Canadian adults, Winters et al. (2011) reported ease of cycling (e.g., flat routes, speed of travel, distance) to be the second most important influence on cycling (after safety issues). A review on the determinants of bicycle commuting confirms this importance of hilliness, distance, travel time and effort in the decision to bike to work (Heinen et al. 2010). Because of decreased physical fitness, ease of cycling may be an even more important barrier towards cycling among older adults. Indeed, lack of physical fitness has been reported to be a major barrier for older adults to engage in physical activities (Baert et al. 2011). A technological innovation that makes cycling "easier" is the electric bicycle (also called pedelec or e-bike). An e-bike is battery-assisted and equipped with a torque or velocity sensor that triggers supporting power only when the cyclist exerts power onto the pedals.

The current cross-sectional survey study aims to examine e-bikes' purchase reasons, benefits and disadvantages, purposes and amount of use, substitution effects and crash characteristics among Flemish older e-bike users. In addition, it examines differences between men and women. In the next section, we provide an overview of the available literature on e-bike use among (older) adults. Consecutively, we describe the methods of our cross-sectional survey study followed by the obtained empirical results, their discussion and an overall conclusion.

Literature review

E-bikes have gained popularity during the past years (Fishman and Cherry 2015) with European e-bike sales increasing from 58,800 to 135,700 per year between 2010 and 2015. However, strong differences in e-bikes' sale shares between countries have been noted. E-bike sale shares (number of e-bikes sold/number of all bikes sold) are markedly lower in Great-Britain (1.1%) and France (3.3%) compared to Germany (11.0%), the Netherlands (21.8%) and Belgium (23.4%) (CONEBI 2016). E-bikes are especially popular among older adults; in the Netherlands, 65% of all e-bike owners are aged 65 years or older (Hendriksen et al. 2008). In Flanders, 7% of all bike trips are performed by e-bike in the general population whereas this is 25% of all bike trips among older adults (Declercq et al. 2016). Among Dutch adults (Kroesen 2017) and Flemish older adults (Van Cauwenberg et al. 2018), e-bike use was higher among women than among men. Furthermore, studies among Norwegian adults (Fyhri and Fearnley 2015) and Flemish older adults (Van Cauwenberg et al. 2018) have shown that e-bike use more strongly relates to higher levels of cycling among women than among men.

In 2012, Rose (2012) proposed a conceptual model to frame e-bike research. The model postulates that mobility choices (e.g., e-bike purchase) influence travel choices (e.g., trip frequencies, mode choice, trip purposes) which in turn will determine the level of e-bike use with resulting impacts on mobility, health and safety. Since 2012, a few studies have examined the reasons for e-bike purchase in general adult populations. Health benefits, to be able to maintain cycling, to replace some car trips, overcoming hills and to ride with less effort were the most important reasons for e-bike purchase among adults in the US (MacArthur et al. 2014; Popovich et al. 2014), the UK and the Netherlands (Jones et al. 2016b). These studies also examined the perceived benefits of e-bike use, which were in line with reasons of purchase; the higher speed and acceleration of e-bikes, less physical exertion, easier to ride hills, fun and positive effects on health. On the other hand, participants also experienced the following disadvantages: e-bikes' heavy weight and high cost, risk of theft, traffic unsafety, limited battery range and social stigma ("e-biking is cheating"). To our knowledge, only one study previously focused on purchase reasons and purposes of e-bike use specifically among older adults. This study included 69 older Australian e-bike users and reported the following reasons for e-bike purchase: riding with less effort (53.6% of participants), to replace car trips (50.7%), maintain or increase health and fitness (42.0%), to overcome hills (40.6%), to ride with a medical condition (34.8%) and keeping up with family and friends (27.5%) (Johnson and Rose 2015a). Furthermore, they found e-bikes to be used predominantly for local trips (69.6% of participants), followed by visiting friends (31.9%), exercise (18.8%) and recreation (14.5%). A sample of 451 US adults (13% older than 65 years) used e-bikes primarily for transportation purposes (MacArthur et al. 2014). On the other hand, among 1398 Austrian adults (62% older than 60 years) recreation was the dominant purpose of e-biking (Wolf and Seebauer 2014). Such differences in purposes of e-bike use may be explained by studies being conducted in regions with different cycling cultures and topographies and in samples with different age compositions.

E-bikes reduce typical cycling barriers such as lack of fitness, hilliness and windy conditions and enable to cycle similar or greater distances with reduced physical effort (Fishman and Cherry 2015; Heinen et al. 2010). While e-biking requires less physical effort, intensity levels during e-biking have been shown to be sufficiently high to provide health benefits (Sperlich et al. 2012; Berntsen et al. 2017). One important aspect to determine whether e-bikes contribute to older adults' sustainable and active mobility are their substitution effects; which trips are substituted for trips by e-bike? Several studies in the general adult population in North-America, where car driving is the dominant travel mode, have shown that e-bike trips predominantly replace car trips (MacArthur et al. 2014; Popovich et al. 2014). On the other hand, several studies among adults in Europe, where cycling is more prevalent than in the US, showed that e-bikes replace trips by car as well as trips by conventional bike (Jones et al. 2016b; Cairns et al. 2017; Kroesen 2017). In the one study among older adults in Australia, e-bikes predominantly substituted car trips (Johnson and Rose 2015a). Starting to use an e-bike may provide health and mobility benefits when it stimulates more cycling or maintenance of cycling among those contemplating to quit cycling (e.g., because of health issues). On the other hand, starting to use an e-bike will not result in health benefits when the e-bikes merely replace conventional bikes since this will reduce cycling intensity and duration (because of e-bikes' higher speeds).

While e-bikes may have beneficial impacts on older adults' mobility and health, their heavy weights (approximately 25 kg) and higher speeds in combination with older adults' decreased motor competence and increased physical vulnerability cause concerns about crashes and injuries. In the Netherlands, Schepers et al. (2014) reported e-bikers to be more likely to be involved in a crash requiring treatment at an emergency department than conventional cyclists. Furthermore, they found older e-bikers to be at higher risk for (severe) injuries caused by an e-bike crash in comparison to younger e-bikers. In a field experimental study among Dutch older adults, it was shown that the relatively high speed and mental workload in complex traffic situations may increase the crash risk of older e-bikers (Vlakveld et al. 2015). In Switzerland, Papoutsi and colleagues showed that only 17.4% of the hospitalised e-bike users were injured after a collision with a vehicle, other injuries resulted from single bicycle accidents (Papoutsi et al. 2014). Another Swiss study using police crash reports showed single bicycle crashes to be more common among e-bikers than among conventional bikers (Weber et al. 2014). A Danish study among 685 adult e-bike users, reported that 29% had been involved in a safety-critical incident (i.e., a crash or a dangerous situation) that would probably not have happened on a conventional bike (Haustein and Moller 2016). The most common incidents were related to other road users underestimating the speed of the e-biker, regulation of e-bike speed (by the e-biker), a slippery surface and e-bike weight (balance problems). Participants aged 60 years and older reported problems related to e-bike weight and balance (i.e. during mounting and dismounting) more frequently than younger participants.

Previous studies on e-bike use have mainly focused on general adult populations. Older adults have a lower physical fitness, have different transportation needs (i.e. no need to commute) and are more physically vulnerable than younger adults. Therefore, the current study examines e-bikes' purchase reasons, benefits and disadvantages, purposes and amount of use, substitution effects and crash characteristics among Flemish older male and female e-bike users.

Methods

Study setting

Flanders is the northern Dutch speaking part of Belgium. It is situated in Western Europe and has 6.411.000 inhabitants from which 19.1% is aged 65 years or older. Flanders is a highly urbanized region; over one quarter of the Flemish surface (27%) is built up (SVR 2015), the mean residential density is 227 residences/km^2 and most daily destinations (i.e. shops and services) are feasible to reach by bike (Vandenbulcke et al. 2009; de Geus et al. 2014). Flanders is generally flat, but there are some hilly regions (highest point = 287 m). Average temperatures range from 2 to 17 °C and yearly precipitation is approximately 800 mm (Koninklijk Metereologisch Instituut 2018). 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) (Declercq et al. 2016).

Protocol and participants

Data collection occurred via an online structured questionnaire developed with Lighthouse Studio version 9.3.1. Given that 37% of the Flemish 65-to-74-year-olds are not regular Internet users (FOD Economie 2016), we also administered the questionnaire by means of interviews. For the online recruitment, we contacted different organizations including member organizations of the Flemish Senior Council (including political, socio-cultural 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. We asked these organizations to share the information about our study and the link to the questionnaires among their members. The participating organizations posted the information and link on their websites, newsletters or Facebook-account or sent it around by e-mail. After completing the questionnaire, participants were also asked to send the questionnaire link to their relatives. For administering the questionnaire by means of interview, we recruited participants in 15 local service centers across the five Flemish provinces. Local service centers are neighborhood-based and offer informative and recreational activities to stimulate self-reliance among people in a novice care situation. Flyers and posters announced a researcher's visit to the local service center. During the visit, the researcher interview-administered the computerized questionnaire.

Participants had to comply with the following criteria to be included in the current study: 65 years or older, community-dwelling, not severely limited by health conditions to ride a (conventional or e-)bike, using an e-bike and completing all questions relevant to this study. We assessed age, health limitations to ride a (conventional or e-)bike and e-bike use using a questionnaire (see Measures section below for more details). Participants not using an e-bike were excluded from the current study. Their data were used in another publication examining differences between older conventional cyclists and e-bikers (Van Cauwenberg et al. 2018). We conducted a pilot test prior to data collection; six older adults completed the questionnaires to identify and resolve ambiguity. Actual data collection was performed between March and November 2016 (meteorological spring, summer and autumn). Completing the questionnaire took approximately 30 min. Informed consent was automatically obtained when participants completed the questionnaire. The ethical committee of the Ghent University hospital approved the study protocol.

Measures

Socio-demographics, health characteristics and access to motorized transport

We assessed the following socio-demographics: age, gender, former main occupation (recoded into household, blue and white collar), educational level (recoded into lower secondary or less, higher secondary and tertiary), marital status (recoded into living with and without partner) and area of residence (urban center, urban periphery, village center and rural). We assessed limitations to cycle using one item similar to the items of the physical functioning scale of the validated RAND SF-36 questionnaire (Haywood et al. 2005; Ware et al. 1994). 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. To calculate body mass index [BMI = (weight in kg)/(height in m)^2], participants self-reported their height and weight. 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

We asked participants to indicate whether or not they used an e-bike. For the current study, those reporting not using an e-bike were excluded. For descriptive purposes, participants (i.e. those using an e-bike) indicated how long they had been using an e-bike (recoded into less than 1 year, 1–2 years, and more than 2 years) and whether or not they still rode a conventional bike.

Reasons of e-bike purchase and benefits and disadvantages

Participants indicated their most important reason to purchase an e-bike (eight response options), the most important benefit (eight response options) of and disadvantage (eleven response options) of using an e-bike (see Additional File 1). Each list of response options included the possibility to indicate "other" and to describe their most important purchase reason, benefit or disadvantage in text. These questions were based upon a questionnaire used by MacArthur and colleagues (MacArthur et al. 2014).

Purposes of e-bike use and substitution effects

Participants indicated all e-bike purposes (e.g., shopping, to visit someone, recreational alone or in group) using a list of seven potential purposes including the possibility "other" where they could specify any other purpose (see Additional File 1) (MacArthur et al. 2014; Declercq et al. 2016). To assess substitution effects, participants indicated which trips that they made before purchasing an e-bike (e.g., trips by car, conventional bike) were now replaced by e-bike trips. This also included the option ‘new trips’, for trips that were not made before e-bike purchase.

Levels of e-biking

To assess amount of e-biking for transport and recreation in the past week, questions derived from the validated International Physical Activity Questionnaire (IPAQ, long form, last 7 days) were used (Hurtig-Wennlof et al. 2010; Van Holle et al. 2015). Participants reported the frequency of e-biking for transport (e.g., to a shop, library or to visit someone) during the past week and the average duration of e-biking for transport on such a day. We calculated weekly minutes of e-biking for transport by multiplying the reported number of days by the duration of e-biking for transport on such a day (standard scoring procedures available on http://www.ipaq.ki.se/). Weekly minutes of e-biking for recreation (e.g. merely for pleasure, relaxation or exercise) was assessed and calculated similarly. Total e-biking was calculated by summing weekly minutes of e-biking for transport and recreation.

In addition to e-biking in the past week, we also assessed participants’ usual monthly e-biking frequencies in the different seasons. Participants reported how frequently they usually e-biked in summer, autumn, winter and spring. We provided six response categories; never (coded 0), about once a month (coded 1), several times per month (coded 2), weekly (coded 4), several times per week (coded 12) and (almost) daily (coded 24). “Several times per week” was coded 12 since we considered it to approximate 3 days per week and multiplied this by four to obtain a monthly frequency. Similarly, we considered almost daily to correspond to six times per week and again multiplied this by four.

Crash circumstances

Participants indicated whether or not they had experienced a crash with their e-bike. Participants who had experienced a crash with their e-bike reported in what circumstances the crash occurred. Participants could choose from eight potential circumstances (see Additional File 1), which were based on a previous study examining e-bike crashes in the Netherlands (Schepers et al. 2014). An “other” option was also provided where participants could describe their crash circumstance in their own words.

Statistical analyses

We performed all statistical analyses using IBM SPSS Statistics Version 23 with statistical significance determined at alpha = 0.05. Descriptive statistics (frequencies and means ± SD) of socio-demographics, health characteristics and access to motorized transport were calculated for the total sample and men and women separately. Men and women were compared on these characteristics using independent sample t tests for continuous and Pearson Chi square tests for categorical variables.

Frequencies for purchase reasons, benefits, disadvantages, purposes of e-bike use and substitution effects were calculated for the total sample and men and women separately. Differences between men and women were examined using Pearson Chi square tests. We presented medians and quartiles of minutes of e-biking in the past week and frequency of e-biking in different seasons since these variables were heavily skewed. Differences between men and women on these variables were calculated using Mann–Whitney U tests.

Prevalence of e-bike crashes was calculated and compared between men and women using a Pearson Chi square test. Among participants who had experienced an e-bike crash, frequencies for crash circumstances were calculated for men and women combined and separately. Given the small cell sizes (60% of cells had expected frequencies below 5), it was inappropriate to perform a statistical test to examine gender differences in crash circumstances (Field 2005).

Results

Sample characteristics

In total, 1407 older adults accessed the questionnaire, but 102 reported to be severely limited to ride a bike, 159 older adults did not complete all questions relevant to this study and 789 did not use an e-bike. This resulted in a sample of 357 older e-bikers. Our sample had a mean age of 71.8 ± 5.2 years, 53.8% were women, 61.3% had performed a white collar job, 37.5% had obtained tertiary education and 29.7% had no partner (see Table 1). Almost one-fifth (18.5%) reported to be slightly limited by their health to ride a conventional or e-bike. Only 7.3% did not have a motorized vehicle in the household and 88.0% was currently driving a car. About half of the participants (52.9%) was using their e-bike for longer than 2 years and 38.4% was also riding a conventional bike. The vast majority of participants (82.4%) completed the questionnaire online.

Compared to men, women were significantly younger, more likely to have been responsible for the household, to live without partner, to have no motorized vehicle in the household, to not possess a driving license and to be a non-driver. Women also tended to have a lower BMI.

Reasons of purchase

The two most important reasons why participants had purchased an e-bike were to bike with less effort (24.1%) and to be able to bike longer distances (23.5%) (see Table 2). The third most important reason of e-bike purchase were health issues making it difficult to ride a conventional bike (14.8%). This was followed by to ride in hilly/windy conditions (9.2%), to improve fitness/health (8.1%), to be able to keep up when cycling with family/friends (7.6%), to drive less (6.7%) and other reasons (5.9%). There were no significant gender differences in reasons to purchase an e-bike.

Benefits

By far the two most important benefits of e-bike use were to be able to bike longer distances than with a conventional bike (35.0%) and health issues making it difficult to ride a conventional bike but the e-bike enabled them to maintain biking (26.3%) (see Table 2). These were followed by it is better for the environment than going by car (9.0%), fun (7.8%), faster than a conventional bike (6.4%), healthy (5.6%), cheaper than going by car (5.6%) and other (4.2%). There were no significant gender differences in e-bikes' benefits.

Table 1 Characteristics of the total sample, men and women

	Total sample (n = 357)	Men (n = 165)	Women (n = 192)	Test statistic	p
Age (M ± SD)	71.8 ± 5.2	72.8 ± 5.6	71.0 ± 4.7	$t = -3.2^{a}$	0.001
Occupation (%)				$Chi^2 = 31.9$	< 0.001
Household	11.8	1.8	20.3		
Blue collar	26.9	33.9	20.8		
White collar	61.3	64.2	58.9		
Education (%)				$Chi^2 = 0.1$	0.94
Lower secondary or less	37.3	37.0	37.5		
Higher secondary	25.2	26.1	24.5		
Tertiary	37.5	37.0	38.0		
Marital status (% no partner)	29.7	11.5	45.3	$Chi^2 = 48.6$	< 0.001
Area of residence (%)				$Chi^2 = 1.2$	0.75
Urban center	15.1	17.0	13.5		
Urban periphery	26.3	27.3	25.5		
Village center	21.8	20.6	22.9		
Rural	36.7	35.2	38.0		
Limitations to cycle (% yes, slightly)	18.5	20.6	16.7	$Chi^2 = 0.9$	0.34
BMI (M ± SD)	26.9 ± 3.8	27.3 ± 3.3	26.6 ± 4.1	$t = 1.82^{a}$	0.07
Number of motorized vehicles (%)				$Chi^2 = 6.1$	0.05
No	7.3	3.6	10.4		
One	77.3	80.0	75.0		
Two or more	15.4	16.4	14.6		
Driving license (% yes)	95.2	99.4	91.7	$Chi^2 = 11.7$	0.001
Currently driving (% yes)	88.0	93.9	82.8	$Chi^2 = 10.4$	0.001
Time since e-bike purchase (%)				$Chi^2 = 4.0$	0.14
Less than 1 year	21.3	24.2	18.8		

Table 1 (continued)

	Total sample (n = 357)	Men (n = 165)	Women (n = 192)	Test statistic	p
1–2 years	25.8	28.5	23.4		
Longer than 2 years	52.9	47.3	57.8		
Also riding conventional bike (% yes)	38.4	40.0	37.0	$Chi^2 = 0.3$	0.56
Administration mode (% online)	82.4	81.2	83.3	$Chi^2 = 0.3$	0.60

[a]Derived from an independent samples t test. *M* mean, *SD* standard deviation

Table 2 Reasons of e-bike purchase and benefits and disadvantages of e-bike use

	Total sample (n = 357)	Men (n = 165)	Women (n = 192)	Chi^2	*p*
Most important reason to purchase e-bike (%)				6.6	0.47
To bike with less effort	24.1	25.5	22.9		
To be able to bike longer distances	23.5	20.6	26.0		
My health made it difficult to ride a conventional bike	14.8	13.3	16.1		
To ride in hilly/windy conditions	9.2	10.9	7.8		
To improve my fitness/health	8.1	9.7	6.8		
To be able to keep up when cycling with family/friends	7.6	5.5	9.4		
To drive less	6.7	7.3	6.3		
Other	5.9	7.3	4.7		
Most important benefit of e-bike use (%)				10.8	0.15
I can bike longer distances than with a conventional bike	35.0	33.3	36.5		
My health condition made it difficult to ride a conventional bike, because of the e-bike I am able to maintain biking	26.3	24.2	28.1		
It is better for the environment than going by car	9.0	9.1	8.9		
It is fun	7.8	7.9	7.8		
It is faster than a conventional bike	6.4	4.2	8.3		
It is healthy	5.6	6.7	4.7		
It is cheaper than going by car	5.6	8.5	3.1		
Other (e.g., easier in windy conditions)	4.2	6.1	2.6		
Most important disadvantage of e-bike use (%)				16.7	0.01
The weight of the e-bike	33.3	32.7	33.9		
No disadvantages at all	29.1	34.5	24.5		
Fear of theft or vandalism	11.8	10.9	12.5		
Expensive	8.4	9.7	7.3		
Fear of falling/injuries	7.0	3.0	10.4		
Battery issues (long charge time, limited action radius)	5.9	7.3	4.7		
Other disadvantages (e.g., conflicts with pedestrians or cyclists, e-biking is difficult and complex)[a]	4.5	1.8	6.8		

[a]16 participants reported other disadvantages: eight reported e-biking being difficult or complex and three participants reported conflicts with pedestrians and cyclists. The five remaining participants each reported a different disadvantage: technical failure of e-bike, poor cycling infrastructure, difficulties replacing batteries, knee problems and hard to ride without battery

Disadvantages

One-third of the participants (33.3%) reported e-bikes' heavy weight to be the most important disadvantage of e-bike use (see Table 2). However, 29.1% reported e-bikes to have no disadvantages at all. Fear of theft or vandalism was reported by 11.8%, e-bikes being expensive by 8.4%, fear of falling/injuries by 7.0%, battery issues by 5.9% and other disadvantages by 4.5% of all participants. There were significant gender differences in the reported disadvantages. Men were significantly more likely to report no disadvantages at all and battery issues being the most important disadvantage. On the other hand, women were significantly more likely to report fear of falling/injuries and other disadvantages (e.g., conflicts with pedestrians or cyclists, e-biking is difficult and complex).

Purposes of e-bike use

With 63.3%, cycling for recreation alone was the most prevalent purpose of e-bike use (see Table 3). This was followed by e-bike use for shopping (52.9%), for recreation in group (47.9%), for trips to services (47.3%) and to visit someone (46.2%). Finally, biking to social activities was the least prevalent purpose of e-bike use (38.9%). There were some significant gender differences in purposes of e-bike use. Cycling for recreation alone was significantly more prevalent among men while e-bike use to visit someone was significantly more prevalent among women. E-biking to social activities also tended to be more prevalent among women.

Substitution effects

For 72.0% of the participants, e-bikes substituted trips previously made by conventional bikes. For half of the participants (50.7%), e-bikes replaced trips previously made by cars. Using an e-bike generated new trips for 23.8% of the participants. E-bikes also replaced trips previously made by foot (22.1%) and by public transport (19.9%). No significant gender differences in substitution effects were observed.

Levels of e-biking

Participants reported a median of 60.0 min of transportation, 40.0 min of recreation and 135.0 min of total e-biking in the past week. The assessments occurred between March and November corresponding to European spring, summer and autumn. No significant gender differences in minutes of e-biking in the past week were observed.

Participants reported a median e-biking frequency of 12 trips/month in the summer, autumn and spring time. This frequency was lower in the winter with a median of 2 times/month. E-biking frequencies in the autumn, winter and spring were significantly higher among men compared to women, but there were no significant gender differences for e-biking frequencies in the summer.

Table 3 Purposes of e-bike use, substitution effects and amount of use

	Total sample (n = 357)	Men (n = 165)	Women (n = 192)	Chi^2	*p*
Purposes of e-bike use (%)					
To cycle for recreation alone	63.3	69.1	58.3	4.4	0.04
For shopping purposes	52.9	52.7	53.1	0.0	0.94
To cycle for recreation in group	47.9	43.6	51.6	2.2	0.14
For trips to services (e.g., post office)	47.3	47.3	47.4	0.0	0.98
To visit someone	46.2	39.4	52.1	5.7	0.02
To social activities (e.g. senior organization, sports club)	38.9	33.9	43.2	3.2	0.07
E-bike substitutes trips previously made by… (%)					
Conventional bike	72.0	72.1	71.9	0.0	0.96
Car, motorbike	50.7	50.9	50.5	0.0	0.94
New trips	23.8	21.2	26.0	1.1	0.29
By foot	22.1	21.8	22.4	0.0	0.90
Public transport	19.9	18.2	21.4	0.6	0.45
Minutes of e-biking in the past week (Med, Q1–Q3)				**Mann–Whitney U**	
For transportation	60.0 (0.0–150.0)	60.0 (0.0–180.0)	35.0 (0.0–140.0)	14,480	0.15
For recreation	40.0 (0.0–180.0)	50.0 (0.0–180.0)	32.5 (0.0–180.0)	15,297	0.56
Total cycling	135.0 (5.0–360.0)	125.0 (27.5–370.0)	137.5 (0.0, 347.5)	14,910	0.34
Frequency of e-biking in different seasons (Med, Q1–Q3)[a]					
Summer	12 (4–24)	12 (12–24)	12 (4–24)	14,455	0.13
Autumn	12 (2–12)	12 (4–12)	4 (2–12)	12,907	< 0.01
Winter	2 (0–4)	2 (1–12)	1 (0–4)	12,653	0.001
Spring	12 (4–12)	12 (4–24)	12 (2–12)	13,775	0.03

[a]Expressed in times cycled/month; *Med* median, *Q1* quartile 1, *Q2* quartile 2

Table 4 Prevalence of different crash circumstances

	Total sample (n = 98)	Men (n = 47)	Women (n = 51)
Uneven or slippery surface	26.5	38.3	15.7
During (dis)mounting the e-bike	22.4	23.4	21.6
Avoiding or hitting an obstacle (e.g., a bollard)	16.3	14.9	17.6
Avoiding or hitting an (e-)biker or pedestrian	11.2	6.4	15.7
Avoiding or hitting a car	5.1	6.4	3.9
E-biker not paying attention	5.1	4.3	5.9
Other	5.1	4.3	5.9
While turning	4.1	0.0	7.8
During a climb or descent	2.0	2.1	2.0
While decreasing speed/stopping	2.0	0.0	3.9

All values in the table are percentages. No statistical tests could be performed to compare prevalence of crash circumstances between men and women because of small cell sizes

Crash characteristics

In the total sample, 98 participants (27.5%) had experienced an e-bike crash. There was no significant difference in crash prevalence between men (28.5%) and women (26.6%, $chi^2 = 0.2$, $p = 0.69$). The most frequently reported crash circumstance was an uneven or slippery surface (26.5%), followed by during (dis)mounting the e-bike (22.4%), avoiding or hitting an obstacle (16.3%) and avoiding or hitting an (e-)biker or pedestrian (11.2%) (see Table 4). The other circumstances were less prevalent. While no statistical tests could be performed because of small cell sizes, some substantial differences in crash circumstances between men and women could be observed. Among men, a crash on an uneven or slippery surface was more prevalent than among women (38.3% vs. 15.7%). Among women, a crash while avoiding or hitting an (e-)biker or pedestrian (15.7% vs. 6.4%), while turning (7.8% vs. 0.0%) and while decreasing speed/stopping (3.9% vs. 0.0%) was more prevalent than among men.

Discussion

The current study aimed to examine e-bikes' purchase reasons, benefits and disadvantages, purposes and amount of use, substitution effects and crash characteristics among 357 Flemish older male and female e-bike users. The most frequently reported purchase reasons (i.e. to bike with less effort, bike longer distances, difficulties riding a conventional bike and bike in hilly/windy conditions) and perceived benefits (i.e. being able to maintain biking and to bike longer distances) support the idea that e-bikes may stimulate cycling and mobility by decreasing typical cycling barriers (Fishman and Cherry 2015). Furthermore, a substantial proportion of our sample (18.5%) reported to suffer from health issues that slightly limited their ability to ride a bike, 14.8% reported to have purchased an e-bike because health issues impeded riding a conventional bike and

26.3% stated that the e-bike enabled them to maintain cycling. These figures indicate that e-bikes have the potential to extend life on a bike.

Participants used their e-bikes for a variety of purposes. Cycling for recreation alone was the most prevalent purpose and it was more prevalent among men compared to women. However, median minutes of cycling for transport in the past week were higher than minutes of cycling for recreation (60 vs. 40 min/week). Findings from previous studies examining e-bike trip purposes among adults have yielded inconsistent results (MacArthur et al. 2014; Wolf and Seebauer 2014). In a study among 69 Australian older adults, only a minority of participants reported e-biking for exercise or recreation (Johnson and Rose 2015a). Differences in cycling cultures may explain the different findings across studies. A vast proportion of our sample used their e-bike for social purposes (i.e. to visit someone or to social activities) and these purposes were more prevalent among women compared to men. This suggests that e-bikes may help to maintain social relationships, which are crucial for healthy ageing, but may be lost when one stops driving a car (Pachana et al. 2016; World Health Organization 2015). This is particularly relevant for older women given their lower levels of car access (Declercq et al. 2016; Webber et al. 2010).

To determine e-bikes' contribution to sustainable mobility, knowledge about the trips that are substituted by e-bikes is crucial. In our study, substitution of trips by conventional bike was most prevalent, but about half of our sample also reported to substitute trips by car. This is in line with previous studies among European adults showing that e-bikes substitute trips by conventional bike as well as by car (Jones et al. 2016b; Cairns et al. 2017; Kroesen 2017). However, 72% of our participants reported to substitute trips by conventional bikes, which seems to be higher than the figures reported in studies among adult samples. For example, in an e-bike trial among UK employees, only 26% of participants reported to have decreased their conventional cycling in the 6–8 week period during which they were loaned an e-bike (Cairns et al. 2017). In a sample of Dutch and UK adults, 55% reported to have decreased their conventional cycling since purchasing an e-bike (Jones et al. 2016b). The higher prevalence of substituting conventional bike trips by e-bike trips in our sample of older adults may be explained by differences in e-bike purchase reasons. In comparison to younger age groups, older adults may be more likely to purchase an e-bike because of health issues impeding their ability to ride a conventional bike (MacArthur et al. 2014). Within our sample, 14.8% purchased an e-bike because health issues impeded riding a conventional bike and 26.3% indicated that the most important benefit of e-bike use was that it enabled them to maintain biking. Consequently, older adults will also be more likely than younger age groups to replace their conventional biking trips by e-bike trips. The general rationale is that e-bikes will confer environmental and health benefits if they replace trips made by motorized transport and not trips by conventional bike. However, for older adults, substitution of trips by conventional bike may still confer benefits when health problems are hampering conventional biking and an e-bike enables the older adult to maintain cycling. Furthermore, almost one-fifth of our participants stated to use their e-bike for trips that they did not make before.

In the present study we did not compare cycling levels of e-bikers versus those not using an e-bike, but previous studies have reported that e-bike use was related to increases in cycling trip frequency and duration among adults (Fyhri and Fearnley 2015; Sundfor and Fyhri 2017) and older adults (Van Cauwenberg et al. 2018). In our sample, the median level of total e-biking in the past week was 135 min/week. Since e-biking can be classified as a moderate-intensity physical activity (Sperlich et al. 2012; Berntsen et al. 2017), this implies that e-biking can be a good means for older adults to achieve the health-guidelines of 150 min moderate- to vigorous-intensity physical activity per week (Chodzko-Zajko et al. 2009). Furthermore, we observed no gender differences in minutes of e-biking in the past week and frequency of e-biking in summer. Women are at risk for low levels of physical activity (Althoff et al. 2017) and cycle less in comparison to men (Van Cauwenberg et al. 2012). Our findings suggest that e-bikes may enable older women to reach cycling levels similar to those of men.

In line with previous findings among adults (MacArthur et al. 2014; Popovich et al. 2014; Jones et al. 2016b), the heavy weight of the e-bike was also considered its most important disadvantage in our sample of older adults. Our findings also showed that e-bikes' heavy weight was especially a disadvantage for women. Furthermore, we found women to be more likely to be fearful of falling and to report other disadvantages (mainly dealing with conflicts with pedestrians/cyclists or the complexity of e-biking). This is in line with a previous study among 685 adult Danish e-bikers showing perceptions of e-bike safety to be lower among women compared to men (Haustein,Moller 2016). This may also explain why women e-biked less frequently in autumn, winter and spring; they may be more fearful from falling due to icy or wet conditions. Strategies aiming to promote e-bike use among older adults may first need to reduce older women's safety concerns by increasing their traffic and cycling skills and having them practicing these skills in a safe and controlled environment. The need for dedicated cycling courses when aiming to promote the (re-)uptake of conventional or e-biking among older adults has already been suggested by others (Rissel et al. 2013; Jones et al. 2016a). It should also be noted that 34.5% of the men and 24.5% of the participating women reported e-bikes to have no disadvantages at all. Furthermore, technological advancements will also enable to reduce the weight of e-bike batteries, the current main disadvantage of e-bikes.

In our sample of older e-bikers, 27.5% had ever experienced a crash. This is substantially higher than the 15.9% of older e-bikers who had experienced a crash in an Australian study (Johnson and Rose 2015a). This difference may be explained by the long duration of e-bike use in our sample; 52.9% used their e-bike for at least 2 years. However, this cannot be confirmed since duration of e-bike use was not available in the Australian study. In a sample of 685 Danish adult e-bike users (35% aged over 60 years, 49% used an e-bike for over 1 year), 29% reported to have been involved in a crash or dangerous situation that they thought would not have happened on a conventional bike and this prevalence was not related to age (Haustein and Moller 2016). Similar to this Danish study, we observed no gender difference in crash prevalence.

In our sample, the majority of crashes were caused by an uneven or slippery surface and men reported this type of crashes more frequently than women. In a study among 478 Australian e-bikers (42% aged over 60 years), surface issues was the third most prevalent contributor to unsafe events, after interactions with motor vehicles and rider errors (Johnson and Rose 2015b). It was also reported that 4.9% of the e-bike users avoided locations with poor surfacing and this was independent of participants' cycling experience. Problems related to road grip/surface were the third most frequently reported cause of a crash or dangerous situation that would not have happened on a conventional bike in the Danish study, after other road users underestimating e-bike's speed and own regulation of speed (Haustein and Moller 2016). In a qualitative study among 22 adult Dutch and UK e-bikers, participants also reported minor incidents caused by other road users not anticipating the speed of e-bikes (Jones et al. 2016b). However, crashes due to avoiding or hitting an (e-)biker or pedestrian (11.2%) and a car (5.1%) were only the fourth and fifth most frequently reported crash circumstances in our sample. This difference may be explained by different conceptualizations, i.e. a crash versus 'a crash/dangerous situation that would not have happened on a conventional bike' and 'a minor incident'. In addition, differences in crash circumstances between adults and older adults may be explained by both groups cycling during different time periods; adults may cycle more frequently during peak hours (i.e. during their commute) and may, therefore, experience more incidents involving other road users. Lastly, crashes caused by avoiding or hitting a car may result in more severe injuries, and hospitalization. Older adults who have experienced such a crash may be underrepresented in our sample. The higher prevalence of uneven or slippery surfaces causing a fall among men compared to women, may be explained by the higher frequencies of e-biking in autumn, winter and spring among men.

The second most prevalent e-bike crash (and the most prevalent among women) occurred during (dis)mounting the e-bike. In their study among adult Danish e-bikers, Haustein and Moller (2016) found e-bike weight and balance problems to be more frequent causes of crashes and dangerous situations among older compared to younger participants. For conventional biking, getting on and of the bicycle was, with 20% of all injuries, the most frequent cause of injury in a Swedish study based on hospitalization data of injured older bicyclists (Scheiman et al. 2010). Falls due to unevenness in the surface (13%), ice and snow (8%) and gravel or sand on the asphalt (5%) were also common causes of conventional cycling injuries. This suggests that the causes of crashes with conventional and e-bikes among older adults are similar and it confirms previous findings among adults showing that single bicycle accidents are the most prevalent form of e-bike crashes (Papoutsi et al. 2014; Weber et al. 2014). In this perspective, it is also interesting to note that avoiding or hitting an obstacle (e.g., a bollard) caused 16.3% of all crashes. More research including detailed exposure measures, information about rider characteristics (e.g., cycling experience/skills, speed) and descriptions of crash circumstances and consequences is needed to accurately determine e-bike crash risk in comparison to other transport modes and to develop strategies to reduce this crash risk. At this stage, e-bike courses targeting older adults who start using an e-bike, should include components focusing on safely (dis)mounting an e-bike and strategies to avoid/deal with uneven and slippery surfaces. Furthermore, the provision and adequate maintenance of even and obstacle-free cycling infrastructure may prevent a substantial proportion of e-bike crashes.

The current study is one of the first specifically focusing on e-bike use among older adults, an important and growing demographic subgroup with particular mobility needs. A second strength is the assessment of a comprehensive set of characteristics of e-bike use, including reasons of purchase, perceived benefits and disadvantages, purposes of use, substitution effects, amount of use in the past week, usual frequency in different seasons, crash prevalence and crash characteristics. Thirdly, we examined gender differences, which provides detailed information necessary to tailor future initiatives aiming to promote safe e-biking among older adults.

A first limitation of this study is its cross-sectional design, longitudinal studies are needed to examine how e-bike purchase causally influences older adults' mobility and health. This would enable insights into e-bikes' potential to reduce age-related decreases in physical activity, mobility and health. In addition, a longitudinal follow-up enables to collect detailed information about crashes (Vanparijs et al. 2015). Secondly, the current study only included older adults who already used an e-bike, future studies could assess perceived benefits and disadvantages of e-bike use among older men and women not (yet) using an e-bike. This would provide important information for developing interventions aiming to promote e-bike use. Thirdly, amount of e-bike use was measured by means of a questionnaire, future studies may use odometers or global positioning systems (GPS) to objectively assess e-bike use and mobility. This would help to overcome recall and social desirability bias inherent to self-report measures. Fourthly, our sample is likely to be not representative for the Flemish population of older e-bike users. For example, 37.5% of our sample did obtain tertiary education while this is only 16% in the overall Flemish older adult population (Belgian Federal Government 2013). We have no information on educational level of the population of Flemish older e-bike users. Lastly, Flanders has a strong cycling culture and favourable cycling conditions, i.e. a relatively well-developed cycling infrastructure, a flat topography and no extreme weather conditions, therefore, our findings may be generalizable to comparable West-European regions but not to other regions. While the acceptability of e-bikes may be an issue in regions with a weaker cycling culture, the potential benefits of e-bikes may be stronger in regions where distances to destinations are generally greater. Further research in different regions around the world is needed to confirm our results.

To conclude, our findings suggest that e-bikes may contribute to older adults' sustainable and active mobility. Initiatives aiming to promote e-bike use could highlight its advantages, i.e. the possibility to maintain biking and to bike longer distances. The provision of e-bike courses including components to build cycling confidence (especially among women), learn how to safely (dis)mount and avoid or deal with uneven and slippery surfaces may be necessary to promote safe e-biking. Cycling infrastructure should be well-maintained, even and obstacle-free to avoid crashes. Future research using longitudinal designs, objective measures of mobility and detailed assessments of crash circumstances are warranted to provide further insights into the contribution of e-bikes to older adults' sustainable and active mobility in a safe manner.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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