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Exploring the factors influencing the use of electrically assisted bikes (e-bikes) by stroke survivors: A mixed methods multiple case study

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1 **Exploring the factors influencing the use of electrically assisted bikes (e-bikes) by**
2 **stroke survivors: A mixed methods multiple case study**

3

4 **Abstract**

5 **Purpose:** E-bikes have the potential to overcome some of the barriers that stroke
6 survivors face with regards to physical activity. This study aims to explore the factors
7 that affect e-bike usage by stroke survivors.

8 **Methods:** A mixed methods multiple case studies design, using semi-structured
9 interviews and GPS data. Subject to GP approval, participants loaned an e-bike or e-trike
10 for up to three months. Interviews were undertaken pre and post intervention. The COM-
11 B behaviour change model acted as a framework for analysis. GPS data relating to
12 journey duration and distance travelled was collected fortnightly.

13 **Results:** Six participants were recruited; only three loaned an e-bike/e-trike (with
14 adaptations as required). Storage, being unable to get GP approval, and safety were
15 withdrawal reasons. Level of impairment was a factor influencing the type of e-bike used,
16 level of support required and the motivation of the participants.

17 **Conclusion:** Stroke survivors can use e-bikes although barriers exist. Electrical
18 assistance was a positive factor in enabling some of the participants to cycle outdoors.
19 Due to the small sample size and the number of participants who were able to loan an e-
20 bike, further research is required to determine whether e-bikes are a feasible and effective
21 intervention to increase physical activity for stroke survivors.

22

23 Keywords: Stroke; E-bikes; electrically assisted bikes; factors, physical activity,
24 barriers, active transportation, active travel

25 **Introduction**

26

27 The effects of stroke can have a major impact on mobility, affecting many
28 activities of daily living (1), with over half of stroke survivors reporting restrictions to
29 physical and outdoor activities one year after stroke (2). Systematic reviews have
30 identified a mix of physical, environmental, social and motivational barriers to physical
31 activity after stroke (3, 4). Barriers include: physical concerns around balance, fear of
32 falling, and the effects of fatigue (4); environmental factors include a lack of
33 transportation and other resources, such as the cost of participation (4); lack of social
34 support from friends and family (3). Physical inactivity can reduce physical fitness, which
35 can contribute to a sedentary lifestyle, thereby increasing the risk of a recurrent stroke
36 and cardiovascular diseases (5). There is currently limited evidence regarding the
37 effectiveness of interventions aimed at increasing physical activity in stroke survivors (6)
38 which has led to calls for new, innovative approaches to the development of interventions
39 (7, 8).

40

41 Cycling has the potential to be an outdoor form of physical activity for stroke
42 survivors (9). Cycling is a popular method of aerobic exercise for stroke survivors with
43 studies indicating that it can improve walking ability (10) aerobic fitness (11) and muscle
44 strength in sub-acute and post-acute stroke survivors (12). Cycling is also a repetitive
45 low weight-bearing exercise that incorporates the use of the affected side of the body (13,
46 14) and is seen as a solution for individuals who may have weak lower limbs and struggle
47 with rehabilitation exercises aimed at developing walking ability e.g. treadmill exercise

48 (10-12, 15). However, research into cycling within stroke rehabilitation has been
49 confined to indoor cycling using ergometer devices (10-12, 15), and outdoor cycling for
50 stroke survivors has only recently begun to be explored (9).

51

52 Recent exploratory research has shown that stroke survivors value outdoor
53 cycling as it improves their mood, increases independence and to feel part of a community
54 (9). However, road safety, balance, adaptations, social support and not having the energy
55 or strength to pedal are also challenges for stroke survivors (9). Electrically assisted
56 bikes could provide a possible solution to some of these issues. Fitted with a battery and
57 a motor, electrically assisted bikes (commonly referred to as e-bikes), provide electrical
58 assistance when the user is pedalling, allowing the user to cover greater distances with
59 minimal effort (16). There is growing evidence that e-bikes are an alternative form of
60 physical activity for individuals with physical limitations or for those that live sedentary
61 lifestyles (17-19). E-bikes can also have a positive impact on mental health and cognitive
62 function (20) and are an enjoyable form of physical activity that provides autonomy and
63 an opportunity to socialise (21, 22). E-bikes can be fitted with adaptations to help
64 overcome the effects of a disability and are available as a tricycle version (e-trike) to
65 overcome issues around balance (23). Recent studies have explored e-bike usage in
66 relation to diabetes (22), and coronary artery disease (24) and are a popular mode of
67 cycling for people with disabilities (25). Although some studies have included stroke
68 survivors as participants (9, 22, 26), e-bike usage within the context of stroke has yet to
69 be fully explored.

70

71 To understand whether e-bikes can be used as a method of physical and outdoor
72 activity for stroke survivors, it is important to first understand the factors that affect their

73 use (27). In studies that have investigated factors affecting physical activity in the stroke
74 population there is an increased emphasis on using behaviour change theory as a
75 framework for analysis (5, 28-30). This analysis can then form the basis of intervention
76 design (31). The COM-B model is a behaviour change model which has been used within
77 a variety of health contexts, including stroke rehabilitation (28) and most recently within
78 the development of an intervention to reduce sedentary behaviours in stroke survivors
79 (32). Devised by Michie et al (31), the COM-B model is part of a broader framework (the
80 Behaviour Change Wheel) and it proposes that for a behaviour to occur the individual
81 must have both the psychological and physical capability (C), the physical and social
82 opportunity (O), and finally they must be motivated (M; automatic and reflective).
83 Despite criticism that some components of the BCW are not well defined (28), the COM-
84 B model and the BCW have generally been regarded as a useful framework within
85 intervention development (28, 32, 33).

86

87 The aims of this study were: 1) to qualitatively explore the factors that influence
88 the use of e-bikes for stroke survivors, and 2) to quantitatively measure the utilisation of
89 the e-bike by stroke survivors. To the best of the authors' knowledge this will also be
90 the first study to explore both stroke survivors' perceptions of e-bikes and their actual
91 experiences of using e-bikes.

92

93 **Methods**

94 *Study Design*

95 The study used a mixed methods multiple case studies design (34) consisting of
96 semi-structured interviews and global positioning system (GPS) data collected from e-

97 bikes.

98 ***Participants***

99 A volunteer sample were recruited from local stroke support groups and through
100 contacts within the University of Central Lancashire's dedicated Stroke Research team.
101 Participants were eligible to take part in the study if they had previously had a stroke,
102 were able to walk (with or without assistance) and able to meet the visual function
103 requirements relating to mobility scooters/powerful wheelchairs, which states individuals
104 should be able to read a car's registration number from a distance of 12.3 metres (40 feet)
105 (35). Participants needed sufficient command of spoken English language to allow them
106 to participate in an interview, be over 18 years of age and, due to the limitations of the e-
107 bike, they needed to weigh less than 127 kg. Participants were required to obtain written
108 permission from their GP to loan the e-bike/e-trike, confirming that they did not have any
109 visual, physical or cognitive impairments that would prevent them from its safe use. If
110 they were unable to obtain this approval they were excluded from the practical element
111 of the study.

112 ***Ethical Approval and Consent***

113 Ethical approval was received from the University of Central Lancashire (UCLan)
114 STEMH Research Ethics Committee, and all participants provided written informed
115 consent.

116 ***Data Collection***

117 Data were collected over three phases: pre-, during- and post-intervention,
118 which included the loan of an e-bike or e-trike for up to three months.

119 *Interviews*

120 Semi-structured interviews were carried out pre- and post-intervention. An
121 interview schedule was developed pre-intervention using the COM-B model for guidance
122 (31). For interviews conducted post-intervention a different interview schedule was
123 shaped using both the COM-B model (31) and from responses from fortnightly
124 conversations that took place with the participants during the intervention. These
125 conversations identified if the participants required any additional support, what they
126 were using the bike for, e.g. leisure activities, shopping etc, and to explore if any new
127 factors had emerged. These conversations were recorded on a structured interview sheet,
128 and later used to inform the structure and content of the post-intervention interviews for
129 each participant. All interviews took place in the homes of the participants and were
130 conducted by the same researcher (PB). Interviews were audio recorded and transcribed
131 by PB. Any participants that withdrew from the study prior to the intervention but took
132 part in the pre-intervention interviews gave consent to use their data in the analysis.

133 *GPS Data*

134 GPS data were collected to assess e-bike use, support the interview data provided during-
135 and post-intervention, and to overcome recall and social desirability bias. Each e-bike/e-
136 trike was fitted with a LK209C GPS tracker made by LK-GPS which recorded movement
137 in two-minute intervals. Data were accessed by one researcher (PB) and downloaded to
138 an Excel spreadsheet every two weeks and the number and duration of journeys made
139 during the intervention were calculated. A journey was deemed as a round-trip (from
140 home-to-home), and only the time spent moving was recorded. Any breaks in the data
141 during a journey, possibly as a result of resting, were not included in the overall journey
142 time. ArcGIS Online (36) was then used to calculate approximate distance covered per

143 journey. The longitudinal and latitudinal coordinates for each journey were plotted on a
144 map. From there the distance between each location was measured and the approximate
145 distance was calculated, and visualized paths of each journey were captured. During the
146 intervention, two participants (Jim and Rob) experienced technical difficulties with the
147 GPS trackers and the first two weeks of their loan period were not recorded. There also
148 were instances where the trackers failed to record portions of the journey being made
149 meaning these journeys were not included in the final analysis.

150

151 *Intervention*

152

153 Following the pre-intervention interview and upon receiving GP approval,
154 participants were provided with either an e-bike or e-trike (Figure 1). Over the course of
155 two visits, participants were fitted and trained on the safe use of the e-bike/e-trike. Fitting
156 was carried out by staff from a company that specialised in e-bikes, with two members of
157 the research team present to provide support, should it be required. During the fitting
158 stage, participants were assessed for whether they should use an e-bike or e-trike, and for
159 any alterations that may be required to the brakes and pedals (Figure 2). The selected e-
160 bike/e-trike was then built to the participant's specification and a second visit was
161 arranged where the participant was trained on its use. Training was carried out by the
162 same individuals from the e-bike company, with at least one member of the research team
163 present. Participants were provided with a helmet and a bike lock, and each bike was
164 fitted with a GPS tracker. Additional visits were arranged on an ad hoc basis.

165

166 ***Data Analysis***

167 Audio recordings from the semi-structured interviews were anonymised,
168 transcribed and imported into NVivo 11 for thematic analysis (37). Coding for the first
169 pre-intervention interview was carried out by two members of the research team (PB and
170 JJ) to ensure consistency. All remaining interviews were coded by one researcher (PB).
171 The COM-B model was used as a framework for the analysis (38).

172 The GPS data were analysed in Excel and ArcGIS by PB. For each participant,
173 number of journeys, time of journey and approximate distance were analysed
174 descriptively, and Arc-GIS provided a visualised path for each journey.

175 **Results**

176 *Case Descriptions*

177 Six male participants were recruited, but only three loaned an e-bike/e-trike during
178 the study. All participants were given pseudonyms and a summary of each case study can
179 be found in Table 1. Nine interviews were carried out in total, six pre-intervention, and
180 three post-intervention. Analysis of the interviews identified a number of factors
181 influencing the use of the e-bike by the stroke survivors.

182

183 *Cross-case Analysis*

184 The following are the results of a cross-case analysis from the GPS data, and the
185 thematic analysis using the COM-B model as a framework.

187 The GPS data, post-intervention interviews, and telephone conversations during
188 the intervention, revealed that the participants used the e-bike/e-trike to make a variety of
189 short and long journeys (Table 2). Brian loaned an e-trike for 11 weeks, making seven
190 journeys. Brian cycled predominantly when his son came to visit, when they would both
191 cycle around the estate where he lived for an average time of 16 minutes, and an average
192 distance of approximately 2.45km. Figure 3 provides a visualised path of the type of
193 journey Brian was making.

194 Jim loaned an e-bike for eight weeks, the GPS tracker recorded 13 complete
195 journeys. He used the bike for short journeys to make errands to local shops, but also
196 longer journeys of up to 168 minutes covering approximately 45.9km. Figure 4 is an
197 example of the type of journey Jim was able to make on the e-bike. Jim reported that he
198 cycled as a leisure activity, shopping and for physical fitness. During the post-
199 intervention interview Jim reported that he used his car to transport the e-bike to some
200 locations and therefore his averages should be treated with caution.

201 Rob loaned an e-trike for eight weeks. The GPS trackers recorded three complete
202 journeys in that time. Rob cycled primarily as a means of physical fitness. Journeys were
203 short, with the longest distance being less than 2km. See Figure 5 for a visualised path
204 of the sort of journey Rob was making. According to the post-intervention interview and
205 from telephone conversations, Rob preferred to cycle on a disused car park away from
206 busy roads. It should also be noted that Rob's wife cycled on the e-trike to and from this
207 location, and therefore this data should be treated with caution.

208

209 *Interview Analysis*

210 The following is a summary of the factors identified by all the participants from
211 the interviews carried out pre- and post-intervention, set within the framework of the
212 COM-B model. Quotes are provided, and whether the participant was able to loan an e-
213 bike/e-trike is highlighted in parenthesis.

214 *1.0 Physical Capability*

215 Factors relating to Physical Capability referred to the effects of stroke and how physical
216 impairment impacted the participants ability to use the e-bike/e-trike as well as how it
217 could help overcome fatigue.

218 *1.1 Level of impairment*

219 Impairment to arms and legs was a factor in the type of e-bike the participants could use,
220 with the most severely impaired participants (Rob and Brian) opting to use the e-trike due
221 to issues around balance. Level of impairment was also a significant factor in the
222 participants ability to cycle. Ismail, who had successfully been fitted for an e-trike had
223 to withdraw from the study at the training stage because he was tensing up on his effected
224 side whilst cycling. This meant he was constantly dragging the e-trike into the curb and
225 because of this he not did feel safe cycling. Similarly, Rob’s impairment meant he had
226 to cycle one-handed:

227 “I feel totally 100% safe using the bike. It's just me, myself. It's me, really
228 having one hand to steer and one to pull to the right all the time.” – Rob (e-trike)

229

230 During the loan period, Rob also experienced pain in his calf, as a result of the
231 increased tone in Rob’s foot muscles on his affected side which also prevented him from
232 cycling for a period during the intervention.

233

234 1.2 Effect on fatigue

235 Before the intervention participants perceived that the e-bike could help

236 overcome post-stroke fatigue, a residual effect of stroke:

237 “...I don't have the same energy levels as normal. The thing about a stroke is

238 you soon get tired... The assistance from the electric will be good.” – Brian (e-

239 trike)

240 2.0 Psychological Capability

241 Psychological Capability refers to whether participants had the necessary knowledge

242 or awareness to carry out the behaviour (31). For the participants this was primarily

243 in relation to participants having misconceptions about how the e-bike works.

244 2.1 Misconceptions about the e-bike

245 In the post-intervention interviews, both Brian and Jim (experienced cyclists

246 before their strokes) described how they thought that the e-bike would operate in a similar

247 way to a mobility scooter and that it would not require constant pedalling to operate.

248 “I thought it would have been motorized but I realized now with having it a while

249 that you've got to put a certain amount of effort in to in to have it moving.” – Brian

250 (e-trike)

251

252 3.0 Physical Opportunity

253 Physical Opportunity related to factors concerning the e-bike itself, the

254 adaptations required, in addition to environmental factors that effected the participants

255 use of the e-bike.

256 3.1 The e-bike/e-trike

257 Battery life and the additional weight of the e-bike were mentioned as an area for
258 concern by one of the participants who reported that the battery ran out whilst out on a
259 long journey:

260 “[The battery running out] didn't cause me any problems other than the bike is
261 quite heavy to cycle compared with an ordinary bike without any electrical assist...
262 It cuts out pretty acutely.” – Jim (e-bike)

263

264 3.2 The electrical assistance

265 The electrical assistance provided by the e-bike/e-trike was mostly seen as a
266 benefit, giving the participants the confidence to cycle further for longer without feeling
267 tired, and manage different gradients, safe in the knowledge that they could get home
268 again.

269 “I think what the electric cycle does, it gives you the confidence to go further and
270 stay out for longer.” – Jim (e-bike)

271

272 However, it should also be noted, due to the increased speed of the e-bike/e-trike,
273 participants were only comfortable using a certain level of assistance, and because one of
274 the participants (Rob) was cycling one-handed, he preferred to not use the electrical
275 assistance at all as he deemed it too fast for him.

276 “I just feel that the assistance could be a bit too fast, especially when I hit a hill
277 [or] slope. I just get nervous then.” – Rob (e-trike)

278

279 3.3 Adaptations

280 Adaptations to the e-trike enabled participants with impairments to their arms and
281 legs to cycle although there were advantages and disadvantages to the adaptations used.

282 The adaptations to the brakes allowed both brakes to be used simultaneously by the
283 participant's least effected side and were seen as a benefit. However, the adaptations to
284 the pedals required assistance from a member of the family to get on and off the bike
285 which was a challenge for Rob.

286 "I couldn't see that foot because [my wife] was saying "you're on my hands!" but
287 I just couldn't see it to get into the strap." – Rob (e-trike)

288

289 Brian, who uses an adapted cycle as part of his leisure and fitness activities at a
290 local running track, which requires him to be strapped in, was able to adapt himself whilst
291 using the e-trike without using adapted pedals which he felt was important to him as he
292 did not like being strapped into a bike:

293 "It's probably a good thing I didn't use an adapter because I've adapted myself to
294 do it, so it's been good... When I arrived at the [running track], [the instructor]
295 straps my foot on, but I don't like that, I don't like being strapped on. At least with
296 this bike on my own I can manage, I can get on and get off, no problem. But
297 you're strapped, you know, you need somebody to undo the strap although I do
298 undo it myself...Subconsciously you think about it, you think if anything would
299 happen." – Brian (e-trike)

300

301 3.4 Environmental factors

302 Pre-intervention, all the participants had expectations of using the e-bike to access
303 amenities such parks, shops, and places of physical activity. However, the two
304 participants who were most severely impaired preferred to cycle more locally, either
305 around the estate where he lived progressing slowly, accompanied by a family member
306 (Brian) or cycling around a disused car park away from busy roads (Rob). Additionally,

307 when Rob visited his local park, he felt that the uneven paths were unsafe to cycle on.
308 Storage of the e-bike was also a determining environmental factor for Ken. Ken felt that
309 his outdoor shed was not a secure place to store an e-trike and due to the size of the e-
310 trike and his small living space it would not have been feasible for Ken to able to store
311 one in his home and therefore withdrew from the study.

312 *3.0 Social Opportunity*

313 Social support from family members, and the prospect of using the e-bike to
314 socialise were important factors relating to Social Opportunity. Despite, mostly
315 positive reactions from family members, not everyone was encouraging, and one
316 participant felt there was a stigma attached to using an e-bike.

317 *4.1 Social Support*

318 Social support from family members played an integral role in the participants in
319 enabling participants to use an e-bike/e-trike. Pre-intervention, family members provided
320 encouragement to cycle and during the intervention, one participant (Rob) was reliant on
321 his wife to help him mount and dismount the e-trike and cycle to a safe location.

322 “Well yeah, my son was encouraging me to get a bike.” – Brian (e-trike)

323

324 However, not all family members provided encouragement and Ken’s family
325 members did not feel he was physically capable.

326 “I’ve told my sons and my granddaughter, my grandsons. One of them didn’t think
327 it won’t be a good idea [laughs] to be honest... He said, ‘I just don’t think you’ll
328 be able to manage it.’” – Ken (no loan)

329

330 During the pre-intervention stage, the opportunity to socialise was seen as an
331 important factor for wanting to use the e-bike by many of the participants.

332 “And also, I shall probably use it in social situations such as visiting the coffee
333 shop and all the rest of it.” – Tim (no loan)

334 Although it should be noted here that Tim had to withdraw from the study because
335 his GP would not give the written approval, he needed to loan the e-bike. The reason for
336 this was not given to the participant.

337 4.2 Stigma

338 None of the participants who loaned an e-bike/e-trike cycled as part of a group.
339 When asked about this, one of the participants felt there was a social stigma attached to
340 using e-bikes by other cyclists:

341 “Think compared with those people who are avid cyclists on road bikes they’re
342 seen as something outside of their circle...I think they probably don't see it as
343 serious cycling...I think there's a lot of ignorance, in fact you do have to pedal it's
344 not like a mobility scooter that you can just twist and go, you know?” - Jim (e-
345 bike)

346

347 5.0 Reflective Motivation

348 Reflective motivation related to motivational factors for wanting to use the e-bike,
349 these focused on belief in capability, a belief that the e-bike was a good form of exercise,
350 it allowed them to return to a previous activity, was a goal to achieve and a way of gaining
351 increasing independence.

352 5.1 Belief in capability

353 Belief in capability often refers to the participants' feelings regarding their own
354 abilities and the control they have over their physical activity, which can be influenced
355 by people around them, usually family members (29). Within this study there were
356 examples of family members doubting the participants' capabilities, but also there was
357 an example of a participant (Brian) having great belief in his own ability, while family
358 members were concerned about him cycling on his own. As a compromise, Brian cycled
359 primarily when his son came to visit, which eased the fears that his family had and also
360 provided Brian with a companion to cycle with.

361 "My son comes with me. He's a keen cyclist. So, he's really been a godsend
362 because I would have gone on my own, but you know people don't seem to think
363 I'm safe [laughs]" – Brian (e-trike)

364

365 5.2 The e-bike is a form of physical activity

366 All the participants identified that the e-bike was a form of physical activity which
367 could improve their fitness and mobility.

368 "It's a brilliant idea because you're getting the exercise as well. Which is what
369 you want it for isn't it really?" – Brian (e-trike)

370 5.3 Increase independence

371 The participants recognised that using the e-bike was an outdoor activity that
372 would allow them to "get out and about" and gain some independence and possibly
373 relieve the burden placed on friends and family to provide a form of transport.

374 "The freedom. The freedom to go wherever I want to go and do what I want." –
375 Ken (no loan)

376 “[The e-bike] will actually help me because to ask my friend to come and collect
377 me here it’s... I wouldn’t say he doesn’t mind but it’s a bit inconvenient for him.
378 So, if I can make my own way, the better yeah.” – Tim (no loan)

379

380 5.4 Return to a previous activity

381 Pre-intervention, participants saw using the e-bike as an opportunity to return to
382 a previous activity that they had enjoyed prior to their stroke.

383 “It wouldn't bother me at all, it would be like being normal. Bikes and cars, I'm
384 just normal.” – Brian (e-trike)

385

386 5.5 A goal to achieve

387 For the participants, the use of an e-bike was identified as a possible continuation
388 of their rehabilitation and as a goal to achieve:

389 “And it’s a goal, you know, all these things are goals, the bike’s been a good one
390 though from day one getting back to that.” – Brian (e-trike)

392

393

394 6.0 Automatic Motivation

395 Factors identified as being linked to Automatic Motivation were regarding
396 emotional reactions to using the e-bike with participants experiencing contrasting feelings
397 at various stages of the study.

398 6.1 Cycling as an enjoyable activity

399 Prior to the intervention, most of the participants perceived that they would find
400 using the e-bike an enjoyable activity, which was an outcome expressed by those that

401 were able to use the e-bike/e-trike. One participant (Jim) was also encouraged to purchase
402 an e-bike as a result his experience.

403 “I’ve just gone out to enjoy riding and I’ve done that. You know, I’ve just enjoyed
404 it. We’ve come back, and we’ve put it back in the garage and I’m not tired and
405 I’m not out of breath and I don’t want to lie down.” – Brian (e-trike)

406

407 “I think now having used one I think yeah, you know, I like this. And I think I’d
408 use it enough to justify the expense or spend on an e-bike. It’s not exactly a
409 fortune, you know but it is something I would enjoy doing.’ – Jim (e-bike)

410

411 6.2 Fear

412 Fear of bumping into things and feeling unsafe were experienced by some of the
413 participants. As mentioned above, Ismail withdrew from the study because he did not
414 feel safe using the e-bike due to how his impairment effected his ability to cycle. In
415 addition to feeling nervous using the electrical assistance, Rob also remarked about how
416 he did not feel confident cycling on the street due to a fear of bumping into things:

417

418 “I tend to stay off the street because my confidence isn't brilliant on the street. It's
419 down to my own confidence, yeah being out on the street cos I don't want to bump
420 into cars...” – Rob (e-trike)

421 **Summary**

422 The participants identified several interconnected factors that influenced their use
423 of an e-bike/e-trike as illustrated by Figure 6. Level of impairment, social support,
424 motivation, environmental factors and the e-bike itself were all independent or connected

425 factors for the participants. For example, level of impairment affected the choice of e-
426 bike, the level of support required, confidence and where participants could travel.

427

428 **Discussion**

429 This study explored the factors that influenced the use of e-bikes by stroke
430 survivors. The aims were: 1) to qualitatively explore the factors that influence the use of
431 e-bikes for stroke survivors, and 2) to quantitatively measure the utilisation of the e-bike
432 by stroke survivors. At the time of writing it was the first study to investigate both the
433 perceptions and actual experiences of loaning an e-bike or e-trike by stroke survivors. Of
434 the six participants that took part in the pre-intervention stage, only three went on to loan
435 an e-bike/e-trike. Despite the small sample, the participants identified a variety of factors
436 that both influenced e-bike usage and enabled us to explore the barriers to participation
437 experienced by those who withdrew.

438

439 The three participants who loaned an e-bike/e-trike were able to cycle outdoors,
440 although only two participants cycled using the electrical assistance. For these
441 individuals, they reported they felt it gave them the confidence to cycle further for longer
442 which is a significant benefit of using e-bikes (21, 39, 40). Although, it should be noted
443 that the longest journeys were made by the least impaired participant, who required no
444 adaptations and support. Despite being able to use the e-trike to cycle outdoors, the fact
445 that one participant preferred to cycle without the use of the electrical assistance does
446 raise concerns about whether e-bikes/e-trikes are suitable for everyone.

447

448 Level of impairment was a significant factor affecting the choice of e-bike, with
449 the most severely impaired participants having to use the e-trike, which concurs with

450 previous studies where balance is an issue (9, 23). However, the increased size and weight
451 of the e-trike proved a significant barrier for one of the participants, who withdrew from
452 the study because he was unable to store the e-trike in his home. The added weight of the
453 e-bike in general is a commonly cited barrier for e-bike users, along with battery life (21,
454 39, 40), which was also a concern for one of the participants.

455

456 Adaptations aided the two participants with the most severe impairments to use
457 the e-trike. However, the use of pedal adaptations proved to be problematic, requiring
458 assistance by a family member to mount and dismount the e-trike, while another
459 participant spoke of wariness about being strapped in. These findings match those of
460 Greenhalgh et al (9) who also reported that adaptations designed to overcome disability
461 were a cause of anxiety or risk of falls for stroke survivors using adapted cycles.
462 Currently, research into adaptations to e-bikes is limited to one study involving young
463 people with cerebral palsy (41). Stroke survivors experience a diverse range of
464 impairments, requiring an individually tailored approach. This could be an avenue for
465 e-bike manufacturers to explore in future research, not only be in terms of how to adapt
466 an e-bike for the stroke population, but also with regards to the specifics of the e-bike e.g.
467 a lighter frame and longer battery life.

468

469 Social support played an important role in enabling the most severely impaired
470 participants to cycle and was a motivating factor. Family members encouraged use of the
471 e-bike, assisted in mounting and dismounting the e-trike, and acted as a companion to
472 cycle with. In addition, during the pre-intervention stage participants also saw the e-bike
473 as an opportunity to socialise and relieve the pressure on relatives to provide a mode of
474 transport. This finding adds to the evidence that social support is important in influencing

475 physical activity in stroke survivors (3, 4) but also that e-bikes can facilitate social
476 interactions and a sense of belonging for those with mobility restrictions (9, 23).

477

478 This study also highlighted the common impression that there is a stigma attached
479 to using e-bikes (18, 21, 23, 26, 39). It was perceived by one of the participants that using
480 the e-bike may not be seen as real cycling by other cycle enthusiasts. In this case it did
481 not discourage them from cycling but has been identified as an area for concern in
482 research focusing on older cyclists (23). Similarly, there was also a misconception about
483 how the e-bike works and the need to constantly pedal, making it distinct from mobility
484 aids. Other research has also reported misconceptions around how e-bikes operate which
485 has been attributed to a lack of knowledge (21, 23, 26, 38), which could also explain
486 social stigma. It should also be noted that a reason for one of the participants withdrawing
487 from the study was due to being unable to gain GP approval. Reason for this was not
488 provided, although it may have been due these misconceptions or a lack of knowledge.
489 Given that the endorsement from healthcare providers is an important factor in increasing
490 physical activity participation in stroke patients (42) future research may investigate the
491 perceptions of healthcare professionals, whether they understand that e-bikes can provide
492 both cognitive and physical benefits (20) and could possibly act as a tool to aid
493 rehabilitation.

494

495 Several motivating factors encouraged the use of the e-bike/e-trike. Achieving a
496 goal, returning to a previous activity that was enjoyed prior to stroke and increased
497 independence were all positive factors, which have been attributed to greater engagement
498 in physical activity within the stroke population (3, 9, 43). However, there were also
499 concerns around fear of bumping into things and a belief among family members that the

500 participants were not safe cycling despite having confidence in their own ability. These
501 factors have been associated with reduced self-efficacy and an inability to take control of
502 one's behaviour, affecting levels of physical activity post-stroke (44).

503

504 *Strengths and Limitation*

505

506 To the best of the authors' knowledge this was the first study to explore the factors
507 affecting the use of e-bikes by stroke survivors, utilising a method that allowed for the
508 collection of data both on their perceptions and actual experiences. The unique properties
509 of the study and its participants meant we encountered issues around public liability
510 insurance and ethics which necessitated the requirement for GP approval. This in turn had
511 an unexpected impact on participation.

512

513 The small sample of volunteers was self-selected, consisting of stroke survivors
514 who were motivated to use an e-bike, and therefore these findings are not generalisable
515 to the general stroke population. However, due to the exploratory nature of the study, a
516 large sample was unnecessary. Despite the small sample size, the inclusion of six
517 participants from the outset meant that unlike many studies, we were able to explore real
518 barriers.

519

520 During the intervention, which took place between May 2018 – Aug 2018, the
521 UK experienced unusually high temperatures which affected how often the participants
522 wanted to cycle. There were also other periods when they were not cycling, such as during
523 holidays. Other limitations concerned the GPS trackers. Technical issues meant that data
524 for the first two weeks of the intervention was not collected for two of the three

525 participants, also data for some trips was not recorded and therefore not included in the
526 analysis. Several e-bike studies have also experienced problems using GPS trackers (45-
527 47) and a possible alternative could be via the use of video observation and biographical
528 interviews as methods of data collection as used by Jones and colleagues for the
529 *cycleBoom* project which also included a participant who had previously had a stroke
530 (26). Finally, this study did not explore all the different types of e-bikes and adaptations
531 that are available, and some participants may have benefitted from these.

532 **Conclusion**

533

534 In conclusion, although a limited sample, this study shows that stroke survivors
535 can use e-bikes and e-trikes, however it highlighted a number of barriers they may
536 encounter with regards to cycling outdoors. The assistance provided by the e-bike was a
537 positive factor in enabling the participants to cycle. However, level of impairment, social
538 support and motivation were all significant factors and e-bikes may not be accessible or
539 suitable for everyone.

540

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548

549 **Declaration of Interest**

550 No potential conflict of interest was reported by the authors.

551

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695

696 Figure Captions

697 Figure 1: The e-trike used by the participants

698 Figure 2: The adaptations available to the stroke survivors. From left to right -

699 repositioned breaks that could be operated simultaneously by the least effected side, a

700 self-levelling pedal with ankle support, and a pedal with a strap attached

701 Figure 3: A visualised path of the type of journey Brian was making using the e-trike.

702 Figure 4: A visualised path of the type of journey Jim was making using the e-bike.

703 Figure 5: A visualised path of the type of journey Rob was able to make using the e-trike.

704 Figure 6: Interconnecting factors identified by the stroke survivors

705 Table 1: Demographic information by case

Participants	Age (yrs)	First Stroke	Time since stroke occurred (months)	Current methods of physical activity	Living alone or with a partner	Able to loan an e-bike (Y/N)	E-bike or e-trike	Adaptations	Reason for withdrawal
Brian	72	Yes	30	Walking, going to the gym and cycling using an adapted cycle	Partner	Y	e-trike	Brakes	-
Ken	64	No	72	Fishing	Alone	N	-	-	Lack of storage space
Jim	63	Yes	1	Walking his dog	Partner	Y	e-bike	None	-
Rob	56	Yes	40	Walking and attending exercise classes twice a week	Partner	Y	e-trike	Brakes and pedals	-
Ismail	65	Yes	36	Walking	Alone	N	-	-	Did not feel safe using the e-trike
Tim	55	Yes	5	Walking	Alone	N	-	-	Could not get GP approval

706

707

708

709

710 Table 2: Journey details for the participants who loaned an e-bike/e-trike.

Participants	Brian	Jim	Rob
Number of weeks loan	11	8	8
Number of completed journeys recorded	7	13	3
Mean average Journey Length (min)	16	48	27
Min Journey Length (min)	10	6	22
Max Journey Length (min)	22	168	32
Average distance (km)	2.45	13.97	1.68
Min journey distance (km)	1.68	1.43	1.36
Max journey distance (km)	3.33	45.9	1.89

711