1 **Development of an app for lung cancer survivors (iEXHALE) to increase**
2 **exercise activity and improve symptoms of fatigue, breathlessness and**
3 **depression**
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6 **Running title: Development of an exercise app for lung cancer survivors**
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50 ## **Abstract**

51 **Objective**

52 Exercise-based self-management interventions are recommended for lung cancer survivors

53 and can provide physical, psychosocial and emotional relief. Mobile health technologies can

54 encourage self-management; however, currently no cancer-related apps address exercise

55 specific needs of lung cancer *survivors.* This paper details the design, development and

56 testing of an exercise app for lung cancer survivors (iEXHALE) which aims to increase

57 exercise activity and improve symptoms.

58 **Methods**

59 The research had two stages: 1) focus groups with healthcare professionals, patients and

60 family members (n=21) 2) app development and usability study with lung cancer survivors

61 (n=6). The Capability, Opportunity, Motivation-Behaviour model was used as a theoretical

62 framework; data were thematically analysed.

63 **Results**

64 Focus group findings identified many helpful exercises for managing lung cancer survivors'

65 symptoms. These findings, alongside relevant literature, informed iEXHALE's content and

66 design. The usability study found that lung cancer survivors valued iEXHALE's self-

67 management capabilities, but identified potential modifications, including improved self-

68 monitoring diaries and navigation.

69 **Conclusions**

70 iEXHALE's development has been theoretically and empirically informed, showing value as a

71 self-management tool. Next, we will test its effectiveness, acceptability and cost-

72 effectiveness.

73 **Keywords: Cancer, Depression, Exercise, Fatigue, Lung Cancer, Mobile Health, Oncology,**

74 **Qualitative Research, Self-Management, Survivorship**

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77 **Background**

78 Lung cancer is the most prevalent cancer globally, contributing to around 13% of cancer

79 cases [1]. Europe and North America have the highest incidence [1], with 36,761 new cases

80 in England in 2016 [2]. Over a third of lung cancer patients in England and Wales survive for

81 one year or more and 10% survive five years or more [2-3].

82 Despite advances in survival rates many lung cancer survivors (LCS) have unmet mental,

83 physical and psychosocial needs following treatment [4], which includes surgery,

84 immunotherapy, chemotherapy and radiotherapy [5]. Treatment can exacerbate

85 breathlessness, fatigue and depression due to enforced lifestyle changes and the struggle to

86 accept a 'new normality' [5-7]. Lung cancer's 'stigma' [8] and feelings of isolation following

87 treatment can result in reduced activities of daily living, increased social isolation, decreased

88 health and fitness and ability to return to work [9-10]. Most LCS feel they lack support from

89 health or social care services once treatment finishes [4].

90 A systematic review examining the effectiveness of exercise interventions in improving

91 breathlessness, fatigue and depression in LCS [11] highlighted the need for tailored self-

92 management support to optimise treatment outcomes and symptom control. Key findings

93 suggested many exercise interventions are beneficial and generally acceptable to LCS, can

94 be adopted daily and that different treatment pathways can impact on their effectiveness

95 [11]. Exercise can relieve physical, psychosocial and emotional burdens from cancer [4],

96 increasing empowerment, self-efficacy, quality of life, coping mechanisms, health

97 behaviours and outcomes and decreasing fatigue and depression [12-17]. However, less

98 than one third of LCS meet recommended exercise guidelines to reduce time spent

99 sedentary, increase strength and balance building activities and undertake 150 minutes

100 aerobic activity per week [18, 19].

101 Mobile health technologies can encourage patients to self-manage their health behaviours

102 and are feasible, acceptable and effective approaches to providing supportive care [20-24].

103 However, mobile health interventions to enhance exercise for cancer survivors remain

104 uncommon [25] and of the cancer-related apps available [26, 27], none are aimed at, or

105 address, the specific exercise needs of lung cancer *survivors* [28].

106   This paper reports on a programme of research consisting of focus groups, app
107   development and a usability study which aimed to design, develop and test an exercise app
108   for LCS (iEXHALE) to help increase exercise activity and improve symptoms of
109   breathlessness, fatigue and depression.

110   We provide an overview of the steps undertaken to create a tailored, evidence-based e-
111   health resource for LCS, divided into two studies: 1) qualitative focus groups 2) prototype
112   app development and usability study (Figure 1). STROBE reporting guidelines [29] enhanced
113   transparency of the research process.

114   **Study 1: Focus groups**

115   **Methods**

116   Focus groups explored how exercise can improve breathlessness, fatigue and depression in
117   LCS. Key objectives were to identify:

118   •   exercise interventions that improve symptoms

119   •   facilitators and barriers to exercise

120   •   behavioural change techniques to inform iEXHALE's development

121   Separate focus groups were organised for primary and secondary care professionals, LCS
122   and their families. A combined focus group was conducted for LCS and family members, due
123   to the different perspectives gathered through shared experiences of illness. In addition,
124   some LCS relied on family to accompany them. Separate primary and secondary care focus
125   groups were held due to differing time commitments.

126   The focus groups took place at an NHS Foundation Trust and a primary care centre in South
127   West England. The trust is a tertiary centre and large teaching hospital, with an established
128   cancer centre, whilst the primary care centre comprised a large multi-disciplinary team.

129   NHS HRA Ethics approvals were obtained (17/LO/1576; IRAS ID 231738).

130   Convenience sampling was used; lung cancer nurse specialists screened clinic lists to identify
131   eligible LCS treated at the cancer centre. Eligible participants were over 18 years old, had

132   completed curative intent treatment within six months of study entry, had stable disease

133   and were able to provide written informed consent. Eligible patients were provided with

134   participant information leaflets (PILs) and, if interested, were put in touch with the

135   researchers (CH/ZD).

136   Primary and secondary care staff were accessed by contacting a local general practitioner

137   and lung cancer nurse specialist, respectively, who distributed PILs to colleagues.

138   Participants were selected using convenience sampling: any healthcare professionals who

139   worked with cancer patients were invited to participate.

140   Focus groups for patients/families were held at a Maggie's centre on the hospital premises;

141   participants were offered travel reimbursements. The secondary care focus group was held

142   in a hospital meeting room and the primary care focus group at the primary care centre.

143   Refreshments were provided. Prior to commencing, participants provided written informed

144   consent. Focus group discussions were moderated and facilitated by the researchers

145   (CH/ZD) and were guided by a semi-structured topic guide (supplementary file). This was

146   informed by systematic review findings examining the effectiveness of exercise

147   interventions in improving symptom control in LCS [11]. Focus groups lasted one hour, were

148   digitally recorded and were transcribed by a local transcription company.

149   Data analysis was two-fold. During stage one, data were analysed thematically using the

150   Framework Method [30]. Focus group transcripts were coded (ZD); two were double-coded

151   (ZD, CH). Emerging themes were critiqued during study meetings to ensure transparency

152   and consistency in data analysis and interpretation.

153   During stage two, data were mapped against and theoretically underpinned by the COM-B

154   Framework for Behaviour Change and the Theoretical Domains Framework [31], using a

155   deductive framework for analysis. This is an integrative theoretical framework for

156   understanding target behaviours and designing interventions, including e-health and m-health

157   interventions, instead of looking to single theoretical models. The framework splits influences on

158   behaviour change into three components: 'C'apability, 'O'pportunity and 'M'otivation.

159   These components are matched with 'intervention functions' such as 'incentivisation' and

160   'training', which link to appropriate behaviour change techniques such as 'rewards' and

161 'goal-setting'. This approach has been used by healthcare researchers to develop and

162 implement tailored interventions [32, 33].

163 ## Findings

164 **Participant characteristics**

165 Twenty-one participants were recruited (Table 1). Four focus groups were undertaken, one

166 with secondary care professionals (n=5), one with primary care professionals (n=6) and two

167 with patients/family members (n=8). The size of the focus groups is in line with the

168 literature on focus group methodology and allowed data saturation to be achieved [34].

169 Face-to-face interviews (n=2) were undertaken with patients who could not attend focus

170 groups. All patient participants had a performance status of 0-1.

171 **Main findings**

172 Participants identified many exercises that they felt helped LCS to manage symptoms,

173 including activities of daily living, yoga, tai chi, walking, cycling, exercise classes, running,

174 resistance and strength training, golf, pilates, light stretching, breathing techniques,

175 mindfulness and swimming. Supervised and unsupervised, group and individual, and low

176 (e.g. walking) and high (e.g. running) intensity exercise activities were considered useful.

177 Themes relating to COM-B emerged from the dataset which were relevant for developing

178 iEXHALE:

179 **Capability**

180 *Physical skills*

181 All patient participants reported being affected by at least one debilitating symptom of

182 breathlessness, fatigue or depression. All participants recognised that differences in

183 performance status and symptom experience could affect which exercises LCS might want,

184 or be able to, participate in.

185   "It's a very broad group of patients that we're talking about, from someone that's a

186   performance status zero to four, so it's very dependent on the person" (Healthcare

187   professional FG2)

188   *Knowledge*

189   Most participants felt that LCS usually knew of the importance of exercise in recovery;

190   however, they emphasised the relevance of timely, structured, tailored and professional

191   advice for managing symptoms and accessing exercise interventions. Patients valued

192   information from healthcare professionals and noted that knowledge provision via an app

193   could be a convenient information provider.

194   "If you can go on[line] and find out your bits and pieces and whatever you need to,

195   then it's got to be a good thing…We are living in an age now, aren't we, that

196   everything is done online really." (Patient/family FG3)

197   *Behavioural regulation (self-monitoring, action-planning, habit formation, breaking habit)*

198   Health professionals stated that exercise guidance that facilitated patients' decision-making

199   might be helpful, whilst patients noted benefits of following exercise programmes.

200   "She'd give me a program every week...She used to put me on the bike and then I

201   did some weights...Then she put me on the treadmill…Actually I didn't want to come

202   off it." (Patient/family FG1)

203   All participants felt that patients who engaged in exercise prior to diagnosis would find it

204   easier to exercise post-treatment than those needing to initiate new exercise habits.

205   "Someone down the road may not attend because it's their history of poor

206   exercising" (Healthcare professional FG2)

207   **Opportunity**

208   *Environmental context/resources*

209   Healthcare professionals felt that location and access to transport were key to exercise

210   engagement. Similarly, patients/family members commented that, although willing to travel

211   to exercise, distance, time, transport links, assistance with transportation and parking

212   influenced this decision. Cost was not considered a factor. However, patients reported

213   varying preferences around exercising at home, in group, or individual settings and many

214   were frustrated at the lack of hospital-based exercise provision.

215   "[The hospital exercise class] ended…I wanted to [continue], but I couldn't."

216   (Patient/family FG1)

217   *Social influences*

218   All participants commented that patients' levels of social engagement, with family, carers,

219   colleagues or pets, could influence exercise uptake. Patients identified the role of healthcare

220   professionals and other role models (e.g., personal trainers) in continued exercise

221   engagement, by setting and redefining targets, reducing anxiety and providing an element

222   of accountability.

223   "Having the accountability helps. It's the same if you compare it to a Weight

224   Watcher's group…The people that attend the groups every week tend to do the

225   best." (Healthcare professional FG2)

226   **Motivation**

227   *Professional/social and role identity*

228   Gender, age, role obligations, lung cancer's stigma and disrupted feelings of normality were

229   considered potential barriers to exercise engagement, often impacting on mood and

230   motivation.

231   "The people that engage at the higher levels of intervention have been female and

232   within an age thing…People do think, well, I've had a good innings anyway."

233   (Healthcare professional FG2)

234   *Beliefs about capabilities and optimism*

235   Patients reported various beliefs about their capability and optimism for exercise which

236   fluctuated throughout recovery according to changes in fitness, health status or prognosis.

237   "I don't go too far. I'll stop and take a couple of deep breaths and then move on. Or

238   I'll slow up." (Patient/family FG1)

239   *Beliefs about consequences*

240 Patients/family members displayed positive beliefs about and experiences of the impact of

241 exercise on symptom control, as well as wider benefits to overall health and wellbeing, and

242 were generally willing to explore new exercises.

243   "If there is anything there that can assist you, then why not use it…If it makes you

244   feel better" (Patient/family FG3)

245 However, caution and fear of causing damage was apparent.

246   "Because of the surgical emphysema I had… Of course, I don't want that to come

247   back. And I'm conscious of that when I'm thinking about exercise. " (Patient/family

248   FG1)

249 *Intentions and Goals*

250 Most participants commented that exercise intent was influenced by changing health status,

251 symptom experience and progress in survivorship. They felt exercise goals should focus on

252 improving fitness, symptom management, avoiding illness, or improving quality of life and

253 these goals should be realistic, self-set, specific and clear.

254   "Feeling better…whether that's physically or psychologically…For some patients it

255   might be that they're leaving the house and meeting people, and for others it might

256   be that they're doing something that's hopefully going to improve their symptoms."

257   (Healthcare professional FG2)

258 *Reinforcement*

259 Remote monitoring and feedback were recognised as potential incentives to exercise by

260 healthcare professionals.

261   "A lot of people have smart phones…[Or] come with in-built health pedometers...I

262   think there definitely is the utilisation of that piece of equipment." (Healthcare

263   professional FG2)

264 *Emotions*

265 All participants perceived negative emotional reactions to symptom experience and

266 exercise, including fear and pain, as exercise deterrents.

267   "They would think this is horrible because it reminds of what lung cancer is like, and

268   this is why I'm short of breath. It makes me anxious and I'm going to die. So they

269   don't want to do it. It's that sort of cognitive cycle rather than I'm going to be push

270   and be strong." (Healthcare professional FG1)

271

Study 2: Prototype development and usability study

273

Methods

274   Findings of study 1 and the systematic review [11], enabled iEXHALE prototype 1 to be

275   developed with an app development company (Phase 0), adopting a user-centred approach

276   focusing on user-flow through the app. Design features and content were theoretically

277   grounded (using COM-B) and targeted at the needs and preferences of LCS. Prototype 1

278   included four core sections: an introduction containing information about lung cancer; a

279   section for generating recommended exercises by rating symptoms and inputting

280   preferences; a section containing information about recommended exercises; a self-

281   monitoring diary for recording activity (Table 2). The evidence-based algorithm

282   underpinning the self-rating symptom section was designed specifically for the app, and

283   used information inputted by users to generate three exercises that are known to benefit

284   the symptoms experienced, as well as responding to user preferences for exercise location,

285   intensity, and individual/group type.   Google analytics software was embedded within the

286   app to examine participants' interactions with the different sections.

287   A usability study was designed to test the app's effectiveness, efficiency and simplicity. The

288   usability study protocol has been detailed elsewhere [35]. The study consisted of three

289   consecutive phases, each interspersed with elements of data analysis and app prototype

290   redevelopment. NHS HRA Research Ethics Committee approvals were obtained (IRAS

291   number: 239116).

292   Patients/family members from Study 1 were invited to participate, provided they had access

293   to a smartphone or electronic device. Eligible participants were posted or emailed a PIL and

294   were contacted one week later by a researcher to confirm their participation.

295   The study took place at Oxford Brookes University; all participants provided written

296   informed consent. During phase 1 (figure 1), participants completed a pre-test Mobile

297   Device Proficiency (MDPQ-16) survey [36] to assess smartphone usage. Participants then

298   completed tasks in a university setting using prototype 1, which were quantitatively and

299   qualitatively evaluated. Metrics, including task completion, completion attempts,

300   completion time, clicks/touches to complete, error rate, type and severity, were used to

301   assess technical usability of the app. The 'think aloud' technique was used to assess the

302   user's experience of the app. 'Think aloud' behaviours and video recordings of participants

303   hands on the device were recorded for analysis. Participants also completed a post-test

304   Systems Usability Scale (SUS) [37], a reliable questionnaire using a 5-point likert scale

305   (strongly agree-strongly disagree) that measures user perceptions of web-based

306   applications ease of use. Findings informed the app's redevelopment (prototype 2), before

307   phase 2 commenced, replicating phase 1's activities. During phase 3, participants used

308   prototype 2 for two weeks before attending individual, semi-structured interviews to

309   describe their user-experiences.

310   Qualitative data from the 'think aloud' tasks and interviews were analysed thematically

311   using the Framework Method [30]. Descriptive statistics were produced for quantitative

312   metrics and examined against literature on thresholds for acceptability (usability),

313   effectiveness (completion and error rates) and efficiency (task-times) [38].

314   **Findings**

315   **Participant characteristics**

316   Six participants were recruited, enough for maximising the expected level of problem

317   discovery within technical application development [39]. Table 3 presents participant

318   demographics, pre- and post-task survey data. One participant (UX3) was a family member.

319   **Main findings**

320   One participant (UX1) was excluded from the analysis due to incomplete data. MDPQ-16

321   scores indicated low to moderate mobile device proficiency. SUS scores increased or

322   remained consistent between phases 1 and 2 in four participants, with most phase 2 scores

323   achieving okay (50 > SUS > 70) or good (SUS > 70) levels of acceptability. Phase 1&2 tasks

324 highlighted issues with participants' accuracy, completion of logins and self-monitoring

325 diaries. However, the overall task completion rate was high for tasks completed in under 10

326 minutes, with changes observed between phase 1 (83%) and phase 2 (87%). Most

327 participants completed tasks after one attempt (85%). Overall relative efficiency changed

328 from 95% in phase 1 to 96% in phase 2. The app appeared simple to use, with errors per

329 task ranging from 0.4 – 2.6; these consisted predominantly of participants selecting the

330 wrong icon, making incorrect gestures, or making navigation errors (70%). User frustration

331 per task was rated by researchers as 'zero to little frustration' for 67% of participants in

332 phase 1 and 77% in phase 2, with the remainder rated as 'medium/high frustration' or 'point

333 of failure'. 'Think aloud' commentary from participants was minimal and primarily consisted

334 of comments about app navigation.

335 During phase 3, participants identified app strengths and weaknesses across four themes:

336 Access, format, and presentation; self-rating symptoms and exercise recommendations;

337 self-monitoring diaries; future use.

338 *Access, format and presentation*

339 Participants liked the app's aesthetics and incorporating it into daily life. Most participants

340 used the app regularly and those who accessed the app least were not accessing it via a

341 mobile device.

342   "It's nice and friendly…I like the logo on it" (UX1)

343 Individual preferences for content presentation emerged. However, participants were

344 positive about text and audio-visual content that established links with healthcare

345 professionals.

346   "It gives you that sense of safety because of course they know what they're talking

347   about." (UX5)

348 The app pathway was not always clear to participants who felt that better sign-posting

349 would have improved navigation and facilitated better use of app sections.

350   "I'm having to sort of go into the menu… and you're scrolling away and reading, and

351   you go, hang on, I've done this" (UX4)

352   *Self-rating symptoms and exercise generation*

353   Participants liked customising their exercise preferences and ranking their symptom severity

354   to produce bespoke exercise recommendations, finding this useful and motivating.

355   "You can put in pretty much every day how you're feeling... I think it's brilliant. I

356   think it does give you a little push to actually think perhaps I ought to go for a walk"

357   (UX5)

358   *Self-monitoring diaries*

359   Whilst the diaries worked well for some, most participants felt they lacked complexity,

360   interactivity, and flexibility and were not being utilised fully.

361   "It's not reacting to information that I'm putting in, it's not an interactive app." (UX4)

362   *Future use*

363   Participants believed the app could help LCS during follow-up and those with other cancers

364   or chronic respiratory conditions and highlighted its benefit as a motivating self-

365   management tool. Some participants said they would use the app frequently, although they

366   believed the length of time this would continue was limited.

367   "If I was a physician or surgeon...This would be definitely something I would say well,

368   there are one or two things we can do. The NHS can't cope...But here is something

369   you could do for yourself, which would be incredibly valuable if it suits you." (UX6)

370   **<u>Conclusions</u>**

371   We have developed an empirically and theoretically informed exercise app to help LCS

372   increase their exercise activity and improve symptom control. Using COM-B [30], relevant

373   capabilities, opportunities and motivations associated with exercise engagement were

374   identified [30], which enabled relevant app features to be identified during iEXHALE's

375   development. iEXHALE's development is timely, as whilst numerous apps have aimed to

376   enhance physical activity in people with chronic illnesses such as diabetes and heart failure

377   [25], few apps are available to cancer survivors. Where these apps do exist [26, 27] they fail

378 to focus specifically on the exercise needs of lung cancer *survivors*, something iEXHALE has

379 achieved.

380 The usability study enabled iEXHALE's features to be assessed by LCS, allowing the

381 researchers to identify which features are favoured and which need improvement.

382 Specifically, the self-monitoring diaries, although identified as useful, were deemed

383 ineffective in their current form, highlighting a need for prototype redevelopment.

384 Participants' shared consensus of iEXHALE as a useful self-management tool for LCS,

385 providing flexible, customised exercise information that can be utilised and adapted to meet

386 individual needs and preferences, is encouraging, and demonstrates its value to this

387 population group. However, all patient participants had a performance status of 0-1 and

388 were relatively active. Further research into iEXHALE's usefulness for patients with

389 performance statuses of ≥2, would confirm its generalisability to the wider LCS population.

390 iEXHALE has been developed for use in the NHS and aligns with recent National Institute for

391 Health and Care Excellence (NICE) evidence standards for digital health technologies (40),

392 which emphasise a dynamic, value driven approach to their development and

393 commissioning to ensure relevance to patients (40). NICE also state that rehabilitation from

394 cancer should promote patients' ability to function, independence and adaptation to their

395 condition (41) and that this can be enabled through active self-management (41), something

396 that is central to iEXHALE.

397 **Study Limitations**

398 The lack of ethnic diversity and the older age of participants provide study limitations, as the

399 population sampled was not representative of the general population; however, it was

400 representative of a large demographic of LCS. Social desirability bias during the usability

401 study interviews was possible, if participants perceived a favourable response about the app

402 to be more acceptable. However, the quantitative usability findings suggested regular use of

403 the app in general, indicating that it was helpful to participants. Finally, no secondary care

404 consultants or primary care nurses participated in the focus groups; their perspectives may

405 have added insights to the findings.

406

Clinical implications

408 Findings have widespread implications on an international level, by demonstrating the

409 potential for an interactive, tailored digital resource to provide symptom management

410 support to LCS. We have detailed a methodology for developing technologies targeted at

411 older people with chronic conditions. Our approach can be applied to other disease groups

412 and older people who are not traditionally engaged with e-health interventions; this is

413 especially pertinent at a time when the ageing population is increasing globally.

414 iEXHALE has been designed with patients, for patients, has utilised the wider literature [11]

415 and the views of those central to LCS' follow-up pathways. The app can benefit both LCS

416 entering follow-up and healthcare professionals looking to provide a supportive, self-

417 management resource to patients. We intend to make modifications to iEXHALE based on

418 the usability findings, before testing its effectiveness, acceptability and cost-effectiveness in

419 a multi-centre study, to enhance generalisability. This will determine whether the app

420 should be made widely available to LCS entering follow-up. Future work will explore the

421 potential for iEXHALE to be adapted for patients with other cancer types and respiratory

422 diseases.

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Conflicts of Interest

427 The authors declare no conflicts of interest.

Data Availability Statement

429 Data are available on reasonable request from the corresponding author (CH)
430 (chenshall@brookes.ac.uk) and is comprised of deidentified focus group data and usability
431 study data from participants.

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570 **Tables**

571 **Table 1: Focus group participant demographics**

Participant characteristics		Patients (n=7)	Family members (n=3)	Primary care health professionals (n=6)	Secondary care health professionals (n=5)	Total participants (n=21)
Age (years)	18-39	0	0	1	2	3
	40-59	0	0	2	2	4
	60-79	5	2	-	-	7
	80+	2	1	0	0	3
Ethnicity	White	7	3	5	5	20
	Asian	0	0	1	0	1
Sex	Male	3	2	3	1	9
	Female	4	1	3	4	12
Cancer type	Non-small cell	2				
	Not known	5				
Treatment type	Chemo and radiotherapy	1				
	Chemo and surgery	2				
	Surgery	4				
Clinical role	General practitioner			5	0	5
	Practice Manager			1	0	1
	Lung cancer nurse specialist			0	4	4
	Physiotherapist			0	1	1
Years in healthcare profession	1-5			1	-	0
	6-10			1	2	3
	11-15			-	-	0
	>15			1	2	3

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582   **Table 2: Core sections of iEXHALE (prototype 1)**

Section	Content	Screenshot
Introduction	Information about lung cancer and its treatment, common symptoms of fatigue, breathlessness and depression, and benefits of exercise for improving symptoms.	
Self-rating symptoms	Users rate symptom severity, preferred activity level, and preferences for group/individual exercise activities. This information is used to generate three recommended exercises.	
Exercise information	Users are provided with further information about three recommended exercises. Including information about how to access these exercise and, where necessary, video demonstrations on how to complete these.	
Self-monitoring diaries	Participants rate their current symptoms and indicate how often they have undertaken recommended exercise activities each week (type, duration, subjective rating). Email reminders sent to participants.	

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590 **Table 3: Participant demographics and usability metrics**

Demographics	UX1	UX2	UX3	UX4	UX5	UX6
Age	61-70	>70	>70	>70	51-60	>70
Gender	Female	Female	Female	Male	Female	Male
Skill level	Intermediate	Intermediate	Intermediate	Novice	Novice	Novice
Use frequency	Daily	Hardly ever	Daily	Daily	Daily	Hardly ever
Home Device	N.K.	Computer	Apple iPhone	Apple iPhone	Sony Xperia	Computer
MDPQ	N.K.	15.5	21.5	39	23.5	11.5
SUS Phase 1	87.5	37.5	57.5	80	100	57.5
SUS Phase 2	NK	57.5	75	80	100	45

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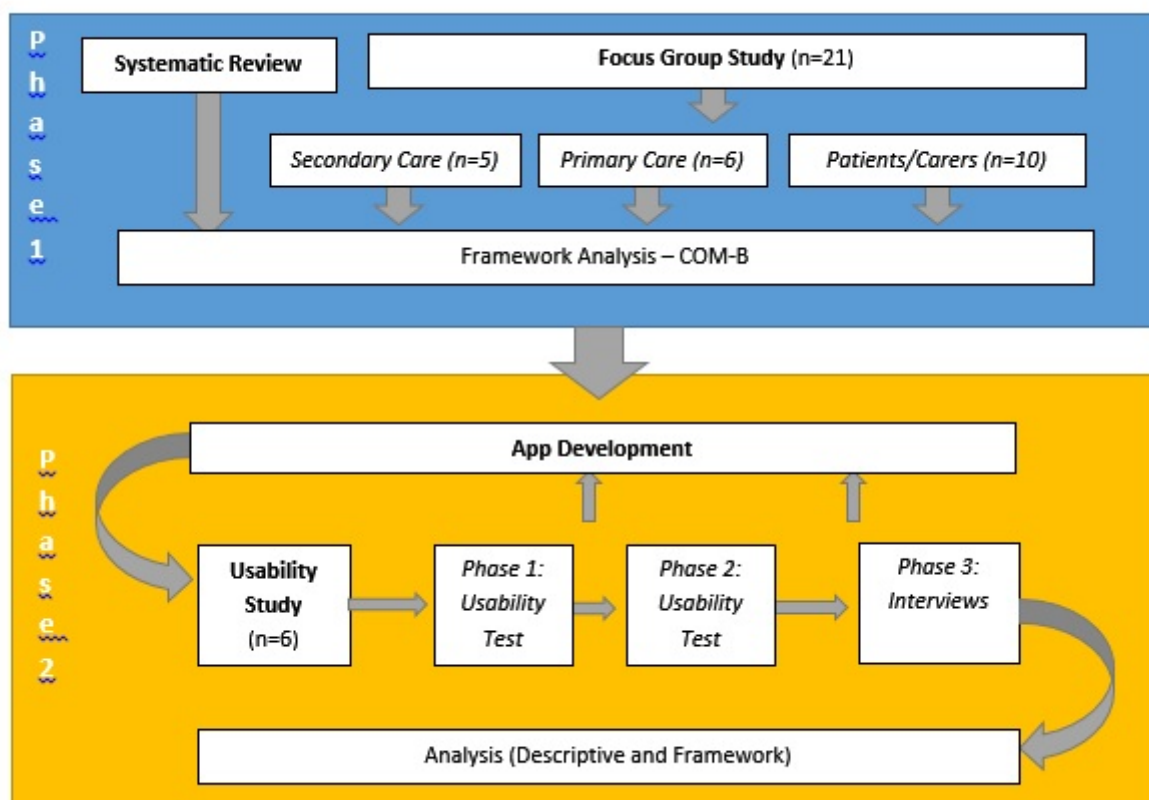
593 # Figure Legends

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595 **Figure 1:** Study flow diagram depicting the sequential phases of development of the iEXHALE app

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Figure 1: Study flow diagram

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