# The feasibility and acceptability of an app-based intervention with brief behavioural support (APPROACH) to promote brisk walking in people diagnosed with breast, prostate, and colorectal cancer in the UK

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### Acknowledgements

This work was funded by Yorkshire Cancer Research (Award reference number: RA/2018/R1/005).

Thank you to the participants for giving their time to take part and complete assessments. Thank you to Charlotte Edwardson for her guidance with the activPAL processing and to Yingying Shen for assisting with the economic analyses.

### Ethical approval statement

This study was approved by the Yorkshire & The Humber-South Yorkshire Research Ethics Committee (21/YH/0029) and the Health Research Authority.

### Clinical trial registration number

ISRCTN registry, ISRCT N1806 3498. Registered 16 April 2021.

### Data availability statement

The data sets generated during and/or analysed during this study are available from the corresponding author on reasonable request.

### Conflicts of interest

HWWP has paid consultancy roles for two digital health companies, Thrive Therapeutic Software Limited and Flo Health UK Limited. He has a PhD student who works at and has fees paid by AstraZeneca, and another who works at and has fees paid by Patients Know Best.

## Abstract

**Introduction:** Increased moderate to vigorous physical activity (MVPA) can improve clinical and psychosocial outcomes for people living with and beyond cancer (LWBC). This study aimed to assess the feasibility and acceptability of trial procedures in a pilot randomised controlled trial (RCT) of a theory-driven app-based intervention with behavioural support focused on promoting brisk walking (a form of MVPA) in people LWBC (APPROACH).

**Methods:** Participants diagnosed with breast, prostate, or colorectal cancer were recruited from a single UK hospital site. Assessments at baseline and 3-months included online questionnaires, device-measured brisk walking (activPAL accelerometer) and self-reported weight and height. Participants were randomised to intervention or control (care as usual). The intervention comprised a non-cancer-specific app to promote brisk walking (National Health Service ‘Active 10’) augmented with print information about habit formation, a walking planner, and two behavioural support telephone calls. Feasibility and acceptability of trial procedures were explored. Initial estimates for physical activity informed a power calculation for a phase III RCT. A preliminary health economics analysis was conducted.

**Results:** Of those medically eligible, 369/577 (64%) were willing to answer further eligibility questions and 90/148 (61%) of those eligible were enrolled. Feasibility outcomes, including retention (97%), assessment completion rates (>86%) and app download rates in the intervention group (96%), suggest that the trial procedures are acceptable, and that the intervention is feasible. The phase III RCT will require 472 participants to be randomised. As expected, the preliminary health economic analyses indicate a high level of uncertainty around the cost-effectiveness of the intervention.

**Conclusions:** This pilot study demonstrates that a large trial of the brisk walking intervention with behavioural support is both feasible and acceptable to people LWBC.The results support progression onto a confirmatory phase III trial to determine the efficacy and cost-effectiveness of the intervention.

**Keywords:** Cancer survivors; physical activity; brisk walking; pilot study; mobile apps; habits

## Introduction

Cancer is a leading cause of death worldwide and accounts for over 167,000 deaths in the UK every year [1]. However, advances in the detection and treatment of cancer have led to increased survival rates in recent years, with a rising population of people living with the immediate and long-term effects of a cancer diagnosis and its treatments [2]. It is estimated that there are presently over 375,000 new cases of cancer in the UK each year, and this is predicted to rise to over 500,000 by 2040 [3]. Long term effects include fatigue, low mood, persistent emotional distress and anxiety states, trauma-related responses, reductions in physical capabilities, being at increased risk for development of other cancers and other chronic conditions and experiencing lower quality of life [4-9]. Supportive interventions that can mitigate some of these effects are urgently required and need to be cost effective, easily accessible, and scalable to large, diverse populations.

### Physical activity and cancer

A large body of evidence demonstrates that physical activity can improve many outcomes for people living with and beyond a cancer diagnosis (LWBC) [10-14]. Exercise (one domain of physical activity) is safe and recommended for people who are still undergoing cancer treatment and improves multiple physical and psychosocial outcomes [15]. While breast, prostate, and colorectal cancer comprise three of the four most commonly diagnosed cancers in the UK, these cancer types also demonstrate the strongest evidence supporting a positive role of physical activity on health and psychosocial outcomes after a cancer diagnosis [16, 17]. This includes several systematic reviews and meta-analyses presenting evidence of an inverse association between physical activity and the risk of all-cause and cancer-specific mortality in these cancer populations [12, 13, 18-20]. The importance of physical activity after diagnosis is highlighted by Schmid and Leitzmann’s systematic review reporting that an increase in physical activity by *any* amount was associated with reduced total mortality risk in people diagnosed with breast or colorectal cancer [21]. Furthermore, meta-analyses of hundreds of interventional trials find that higher levels of physical activity in people LWBC are associated with reduced sleep disturbance and pain, and improved emotional well-being and quality of life [22-24]. Reflecting this evidence, as well as the more recent recognition of the benefits of jointly increasing physical activity while reducing time spent sedentary (i.e. sitting time), the World Cancer Research Fund recommends that adults LWBC should aim to engage in >150 minutes of at least moderate intensity physical activity per week if possible, or aim to ‘move more and sit less’ [25-27]. To support people LWBC in engaging with these recommendations, the Independent Cancer Taskforce recommend that every person diagnosed with cancer should receive physical activity guidance as part of their care [28].

Despite these recommendations, people LWBC are rarely provided with physical activity advice from their care team [29-32]. Qualitative exploration with healthcare professionals (HCP) including general practitioners, oncology nurses, and specialised physicians has identified barriers such as lack of time in appointments, lack of knowledge of resources to direct patients to, and not self-identifying as the right person to provide this advice to people LWBC [33-35]. These findings highlight the need to develop low-cost, widely accessible resources for people LWBC that are feasible to implement into the cancer care pathway with a low burden to the HCP.

### Physical activity interventions in people LWBC

Digital interventions offer the possibility of remotely delivering large-scale physical activity interventions to people LWBC [36]. In a recent scoping review of 231 trials using digital health interventions for people LWBC, Lee and colleagues reported that web-based digital health technology was the most commonly used type of digital intervention (50%) and this was followed by mobile apps (13%). The UK Office of Communications reported that over 90% of the population own a smartphone in 2022, with 68% of people aged over 65 reporting that they personally use them [37, p.203]. As smartphone apps can offer scalable behaviour change intervention to a wider population at a relatively low cost once developed, this presents a promising opportunity to target older age-groups who are also at higher risk of a cancer diagnosis [38]. Furthermore, Khoo and colleagues reported that personal contact complementary to a smartphone intervention may improve intervention efficacy, with Wallbank and colleagues suggesting that this contact may help address any lack of personalisation that is inherently associated with using technology-based supports [39, 40].

Our group conducted a meta-analysis of 15 studies of digital interventions and identified that digital behaviour change interventions may successfully increase physical activity rates among people LWBC by up to 49 minutes per week [41]. However, only two studies tested apps, most follow-up periods were only three months, and studies were generally of low quality, highlighting the need for investigation with larger randomised controlled trials (RCTs), using device-based, rather than self-reported physical activity, and with longer follow-up than three months. In a more recent review of 18 studies investigating digital physical activity interventions for people diagnosed with breast cancer, Kang and colleagues reported that half of these used apps to deliver the intervention [42]. Similar to our findings, their meta-analysis of five studies revealed that digital physical activity interventions significantly improved physical activity duration with a medium effect size in people diagnosed with breast cancer. These results were also supported by qualitative findings [42].

In their study of 627 Canadian adults diagnosed with cancer, Ester and colleagues reported widespread ownership of smartphones (88%) along with considerable use of physical activity/health-related apps in this sample (32%) [43]. Additionally, over 80% of respondents rated physical activity/health apps as useful or very useful for supporting physical activity engagement, suggesting that incorporating such apps would be an effective strategy with this population. While there are many health and fitness apps available to download, few studies have investigated whether these are suitable for promoting physical activity among people LWBC [44-46]. In preparation for the current study, along with the aforementioned meta-analysis, we conducted qualitative user experience research in 32 people diagnosed with breast, prostate, and colorectal cancer. Participants were given apps that promote physical activity that are designed for the general public rather than specifically for those LWBC and we sought to assess the acceptability of this approach. In line with previous research, participants reported that they found the idea of an app-based intervention appealing for physical activity promotion and should focus on walking [45, 47]. This preference for walking was also reported in two recent reviews of over 100 studies of physical activity participation across all cancer types and treatment stages [48, 49]. Previous research conducted by our group and others suggests that people LWBC find that walking is the most achievable form of physical activity both during and after treatment [45, 48]. While after treatment has been identified by people LWBC as the preferred time to start physical activity programmes [48], evidence suggests that limited awareness about the benefits of physical activity engagement during treatment may also play a role in these findings [48, 50]. In their recommendations for cancer survivorship, the American Cancer Society reported that engaging in exercise during treatment is associated with a positive impact on quality of life in this population [51]. Moreover, there is preliminary evidence to support that physical activity during cancer treatment may improve treatment response and tolerance [51-53]. In a study of 279 women diagnosed with breast cancer, Phillips and colleagues reported that a technology-supported exercise intervention was rated as somewhat/very helpful at all stages of the cancer care pathway, with high interest during (83%) and after treatment (90-93%) [47]. Physical activity research with people LWBC has primarily been conducted in people diagnosed with early-stage cancers. However, advancements in treatment have led to improved survival in patients with diagnosed metastatic disease [54] and the available physical activity guidelines are applicable to all people LWBC across the continuum of care inclusive of those with metastatic disease, albeit with more supervision and support [55]. However, due to experience of higher burden of symptoms among this group, compliance and adherence to physical activity can be challenging, with high drop-out rates reported in some studies [56-58]. Despite this challenge, Wilk and colleagues noted the importance of including patients with metastatic disease in studies as evidence supports a beneficial role for physical activity in supporting improvements in health and psychosocial outcomes in this population [59]. Collectively, this evidence highlights the importance of conducting research to explore the acceptability of implementing physical activity interventions at all stages of the cancer care continuum and recognises the need for designing interventions that can be applied in practical contexts and delivered as part of routine contact and care.

The importance of physical activity guidance coming from a trusted source is well documented within the literature [48, 60, 61]. In our qualitative research study, participants expressed a preference for the intervention being recommended by direct members of their care team (ideally their cancer nurse), badged under a recognised organisation (such as the United Kingdom [UK] National Health Service [NHS]) [45, 47]. This preference was also demonstrated in a qualitative study of 14 patients with breast cancer, where participants indicated that their belief in the credibility of the app would increase if it was recommended or validated by their healthcare professional [62]. We conducted qualitative interviews with 19 cancer nurses and found willingness to embed app-based referral programmes into care so long as there was evidence of efficacy [63].

### Objectives

Informed by habit theory [64], we developed an intervention that implements a multitude of behavioural change techniques that have shown promise in promoting physical activity [65-67]. This complex intervention includes a publicly available app with additional brief behavioural support to promote brisk walking (as a form of MVPA) after a cancer diagnosis [APPROACH; 68]. The Medical Research Council published seminal guidance on the development and evaluation of complex interventions, and continuously emphasise the importance of assessing the feasibility and acceptability of interventions with pilot studies before progressing to larger scale evaluations of interventions [69, 70]. The feasibility study should assess the criteria that will be necessary for the evaluation design (e.g., trial procedures) as well as the intervention itself [70]. The guidance also asserted the importance of including economic considerations surrounding intervention effectiveness and recommended including an assessment of the likelihood of cost-effectiveness at the feasibility stage of intervention development [70]. Preliminary economic modelling is important to determine if the anticipated benefits of the intervention justify the costs involved, including the costs of additional research and this is essential for guiding the decision to proceed with larger scale evaluations [71]. In addition to preliminary economic modelling, this feasibility study will allow for planning of a larger scale trial and inform on any necessary refinements to the intervention to improve engagement [70]. Following this guidance, this paper describes a pilot study assessing the feasibility and acceptability of the outcome measures and trial procedures to assist in the planning of a confirmatory phase III RCT. This larger trial will determine the efficacy and cost-effectiveness of the intervention. This pilot study also aimed to inform the larger RCT by obtaining estimates for the parameters required in the sample size calculation for the intended future primary outcome (such as estimates of the variability in each arm and dropout rate), and by implementing a preliminary health economic analysis.

## Methods

### Design

The full protocol for the current pilot has been previously published [68]. This was a single-centre, two arm pilot RCT comparing an app-based brisk walking intervention with behavioural support against a control (usual care) arm in people diagnosed with localised or metastatic breast, prostate, or colorectal cancer. After completion of baseline assessments, participants were randomised using minimisation (1:1 allocation), stratified by cancer type and disease status (local vs metastatic disease), to either the control or intervention arm.

### Participants

Participants were individuals living with localised or metastatic breast, prostate or colorectal cancer recruited from a single hospital site in Yorkshire (UK). All participants were smartphone owners, able to provide informed consent, willing to answer online questionnaires and had access to a computer and email address. Patients who met any of the following criteria were excluded: had localised disease and it had been more than 6 months since completion of radical treatment (i.e. surgery to remove cancer, radiotherapy, systemic therapy with curative intent), were unable to understand spoken/written English, had an Eastern Cooperative Oncology Group (ECOG) performance status ≥ 3, a diagnosed cognitive impairment (e.g. dementia), a cognitive and/or physical impairment that prevents participation in brisk walking, a clinician-estimated life expectancy of < 6 months, or were receiving end of life care, due to have surgery to remove cancer in the next 5 months, were < 6 weeks after surgery to remove cancer, reported already achieving 150 minutes of at least moderate-intensity physical activity weekly, reported previous/current use of the intervention app (Active 10), or reported current or recent (< 6 months) participation in a health behaviour change study. Hormone therapy was not considered a radical treatment as it is not a treatment with curative intent. A timeframe of within six months was selected based on previous research reporting a preference for receiving information from their clinical care team [48, 60, 61]. This timeframe aligns with the assumption that people would still be receiving support within the NHS at this stage, rather than having transitioned into long-term survivorship.

### Procedure

Medical records (lists of patients seen at multidisciplinary team meetings) were screened for potential participants against a set of initial eligibility criteria. This included having a diagnosis of breast, prostate, or colorectal cancer, being more than 6 weeks post-surgery, being less than 6 months after finishing treatment (localised disease), not due surgery in the next 5 months, being able to provide consent, understanding English, having no diagnosis of cognitive impairment, not having an ECOG ≥ 3, and having clinician-estimated life expectancy of over 6 months and/or not receiving end of life care. Identified patients were then sent a brief information letter about the study and could indicate their interest via telephone or email.

Further eligibility was assessed by telephone where potential participants were asked if they were able to understand and complete the assessments in English, if they had any health conditions that would prevent them from walking, what treatment they had completed and plans for future treatment. Their ECOG status was confirmed (based on hospital records). Their physical activity levels were assessed using the screening question "As a rule, do you do at least half an hour of moderate or vigorous exercise (that makes you breathe faster and feel warmer) on five or more days of the week?” (ineligible if yes) [72, 73]. They were asked if they had taken part in a health behaviour study in the past 6 months (ineligible if yes), whether they owned a smartphone (ineligible if no), have access to a computer (ineligible if no), and if they have ever used an app for tracking activity before (ineligible if they named Active 10). If eligible, participants were sent an email with a link to the online participant information sheet and consent form. This was hosted on the electronic data capture tool REDCap [74, 75].

At baseline, participants were sent a weighing scale (Seca 803 if they weighed less than 150kg and Seca 813 if they weighed over 150kg) and tape measure (Seca 201) with instructions on how to complete assessments. Participants were also sent an activPAL accelerometer (PAL Technologies Ltd., Glasgow, UK) to wear for 7 days and a log sheet to track their waking/sleeping times. Two links were sent to participants. One was to complete the main online baseline questionnaire and the other was to input their measurements in the anthropometrics questionnaire, both of which were hosted on REDCap [75]. If participants found this challenging, they could contact the research team to enter their data over the phone. Table 1 presents the schedule of assessments and the measures included in the online questionnaire.

**<Table 1 here>**

Participants in the intervention group were mailed an intervention pack containing a leaflet, walking planner, and a letter from their clinical care team. The leaflet provided information on the benefits of physical activity after a cancer diagnosis with a focus on brisk walking. Information on forming walking habits was also provided in the leaflet, along with instructions to download the freely available NHS Active 10 app. The Active 10 app encourages users to do 10 minutes of brisk walking (known as one ‘Active 10’) and at the time of the pilot study, allowed users the flexibility to set their own goal of completing between one and three Active 10s each day. This was to support users to reach 30 minutes of at least moderate intensity physical activity each day. The app tracks activity and distinguishes between total walking and brisk walking. Users could see how many minutes per day they spent in each walking type. Brisk walking was captured by Active 10 when participants walked at a cadence of approximately 100 steps per minute or more [76]. The weekly walking planner was designed to allow participants to engage in action-planning and monitor their walking. The letter from their care team endorsed physical activity participation and provided an appointment time for their first intervention behavioural support video/telephone call. The first intervention call involved the facilitator discussing the physical activity guidelines for people LWBC, talking through the benefits of physical activity, using the intervention materials, setting goals, and forming habits. Intervention participants were subsequently invited to a second call approximately 4 weeks after the first call to check if they are using the Active 10 app and if they are increasing their brisk walking, as well as talking through their goals and recapping the information provided in the first call. A detailed description of the behavioural change techniques employed across the intervention components is described in the published protocol [68]. Participants in the control group were informed of their group allocation by telephone and continued with their standard care without any additional support. Three months after their randomisation date (T1), all participants were asked to complete the assessments and online questionnaires again.

### Measures

#### Sociodemographic and medical information

Participants’ cancer diagnosis (date and type) and stage, treatment, prior cancer diagnoses, and other health conditions (osteoporosis; osteoarthritis/degenerative arthritis; rheumatoid arthritis; type 1 diabetes; type 2 diabetes; asthma; a mental health condition; Parkinsons disease; dementia; heart disease; high blood pressure; lung disease; back pain; irregular heart rhythm) were collected from hospital records. Participants also self-reported any comorbid health conditions from the same predefined list of conditions. Data from both sources were combined and where a comorbid condition was identified in either the medical records or by self-report, this was coded as having this health condition. Similarly, participants were asked to self-report any prior cancer diagnoses to their most recent diagnosis of breast, prostate, or colorectal cancer (date and type) and where a prior cancer diagnosis was identified in either the medical records or by self-report, this was coded as having had a prior cancer diagnosis. The type (surgery; radiotherapy; chemotherapy; hormone therapy; biological therapy) and stage of treatment (due to start; undergoing; completed; not had/having) was collected from the medical records. This was recorded at the time the participant was sent the baseline assessment pack, although this was difficult for researchers to confirm from records due to the possibility of attending other hospital sites for treatment(s). Participants self-reported their age (years), gender (male; female), employment status (employed full-time; employed part-time; full-time education; unemployed; retired; unable or too ill to work), education level (7 levels ranging from ‘no formal qualifications’ to ‘Masters/PhD/PGCE or equivalent’), marital status (married/in a relationship; single/divorced/separated; widowed), living arrangements (alone; with partner only; with family; with friends; in a residential care/nursing home), and ethnicity (White; Asian/Asian British; Black/African/Caribbean/Black British; Mixed/Multiple ethnic groups; other ethnic group). Socioeconomic position was determined from participants’ postcodes and the English Index of Multiple Deprivation (IMD) [77].

#### Feasibility outcomes

The feasibility and acceptability outcomes (listed in Table 2) were used to investigate the potential for this study design to be used in a phase III trial and to further inform the final sample size calculation. We pre-specified that a study enrolment rate <30% or a 3-month retention rate <65% would require a reconsideration of trial procedures to make them more acceptable to participants [68].

**<Table 2 here>**  
Intervention feasibility

During their first behavioural support call, the researcher recorded if participants in the intervention group had downloaded the Active 10 app (before the call, during the call) or had not downloaded it. Intervention participants were also asked how long they had used the app for (once; 1 week; 2 weeks; 1 month; 2 months; 3 months) in the follow-up online questionnaire. Participants were asked to rate how useful they found the intervention using a Likert scale (not at all useful; slightly useful; somewhat useful; very useful; extremely useful).

##### Linking to UK cancer registries

The consent form included an optional additional consent to access Hospital Episode Statistics (HES) and National Cancer Registration and Analysis Service (NCRAS) data about participants. This was to assess *willingness* to give this consent, as we may wish to explore the impact of the intervention on longer-term cancer outcomes in the RCT, but this data was not accessed in the pilot.

##### Potential sociodemographic biases

We intended to collect anonymous sociodemographic data on patients who were potentially eligible to participate who did not participate. This was not possible due to data protection concerns. The hospital site was however able to provide aggregate anonymous data on cancer type, sex, ethnicity, age and IMD scores for all patients who were diagnosed with breast, prostate or colorectal cancer[[1]](#footnote-2) between August 2021 and August 2022, regardless of participation, to allow identification of any recruitment bias.

##### Fidelity of intervention calls

The content of the intervention calls is outlined in our published protocol [68]. Intervention calls were designed to include 25 behaviour change techniques (BCTs) from the Behaviour Change Technique Taxonomy v1 [67]. A 25-item checklist was created by the researchers based on these BCTs. Each BCT was coded as either delivered or not delivered by examining the intervention call transcripts. One researcher (SW) carried out the coding of the intervention calls with a second researcher (SS) coding a subset of calls (n=5). It was agreed that an 80% level of agreement would be acceptable. Any discrepancies that exceeded 20% were discussed amongst the researchers until consensus was reached. This occurred for 20% of the transcripts that were double coded (n=1/5).

##### Contamination

At T1, all participants were asked if they used any physical activity app to help them do physical activity during the study period (yes; no) and if they answered yes, they were asked to name the app.

#### App engagement

It was not possible to retrieve actual app use data from NHS Digital as the data were not stored in a way that could link with our trial data. In the T1 questionnaire, intervention participants were asked if they ever used the Active 10 app to track their walking (Yes and I’m still using it; Yes but I’m not using it any more; No). Participants who reported still using it were asked how often they used the app (Less than monthly; monthly; fortnightly; weekly; 3-4 times per week; almost every day or every day). Participants who had ceased using the app were asked how long they had used it for (Once; Less than a week; 1 week; 2 weeks; 1 month; 2 months; 3 months). The Digital Behaviour Change Intervention Scale was used to assess engagement with the app [78]. Participants were asked questions exploring their first use and their most recent use of the app for tracking their walking. Participants were asked how strongly they remembered experiencing feelings from a specified list (interest, fatigue, focus, inattention, distraction, enjoyment, annoyance, pleasure) while using the app (7-point scale from not at all to extremely), how much time they spent on the app (minutes per day), and what components in the app they remembered using from a specified list (e.g., viewing today’s walks). The full set of questions is presented in the supporting information.

#### Physical activity

Physical activity was measured using an activPAL4 micro accelerometer worn on the midline of the thigh. The activPAL was waterproofed in specialist nitrile sleeves and waterproof dressing and was supplied with adhesive for attaching to the thigh. The sampling frequency was programmed at the default setting of 20 Hz. Participants were asked to wear the activPAL continuously for 7 days and to complete log-sheets to record when they got up and went to bed across these seven days and if they removed the device at all. Wearing the activPAL monitor was implemented to assess the feasibility and acceptability of using this outcome measure but this was not a mandatory requirement for participation in the study.

A valid day of wear was defined where the activPAL was worn for the full 24 hours and 3 days of valid wear were necessary to be included in the analysis [79]. The collected data were processed using the Processing PAL software V1.3 [80]. The previously validated default settings were applied [81], apart from setting the minimum number of steps to delineate waking wear time to 200 steps as this was more suited to our patient population. ‘Sleep’ encompassed all time spent in bed and was not subclassified into time spent asleep by biological definitions and/or other time spent in bed [81, 82]. This broad definition included brief periods out of bed inclusive of trips to the bathroom during the night. Heat maps were created to visualise periods of ‘sleep’ versus waking wear time for each participant, at each time-point. These were compared to participant log-sheets to identify possible scenarios where the algorithm may have incorrectly coded ‘sleep’ and waking time [79]. Where discrepancies were identified (e.g., approximately one hour of data was inaccurately coded) corrections were made to reclassify periods of time as ‘sleep’ or wake time as appropriate. Brisk walking was defined as >100 steps per minute as this is the threshold identified to elicit the sufficient walking intensity for MVPA in adults [83, 84]. Total minutes of brisk walking per day was derived from the data as this is the intended primary outcome for the definitive trial. Total minutes walking at any pace was also derived to compare groups at baseline.

#### Trial experience interviews

Semi-structured interviews were conducted with participants in both arms by two researchers (FK and SS) to explore experiences of all aspects of trial participation. Engagement with the app and intervention materials were explored with intervention arm participants and are reported briefly here with more detail reported in a separate process evaluation paper (in preparation for publication).

### Statistical analysis

The target sample size was based on a minimum of 30 participants per arm required for estimating parameters in a feasibility study [85, 86] and a conservative drop-out rate of up to 33%. Analyses of all data, including feasibility outcomes and physical activity are descriptive in nature. The sample size calculation for the phase III confirmatory trial was carried out in PASS 2023 Power Analysis and Sample Size Software (2023).

### Qualitative analysis

Coding of the interviews was completed by a single researcher (SS) due to time constraints, which impacted the availability for resources for data analysis. However, any uncertainties surrounding participant responses were resolved with a second researcher (FK). Content analysis was used to systematically explore participants’ experience of taking part in the study and to quantify responses related to the feasibility and acceptability of study procedures [87].

### Cost effectiveness analysis

An exploratory health economic analysis was carried out to provide preliminary cost-effectiveness estimates and to inform the design of the larger trial and economic analyses. A Markov-style health economic model was developed that linked increases in physical activity to reductions in cancer and other cause mortality over a lifetime horizon. The model baseline population was a cohort of individuals with characteristics taken from the APPROACH pilot participant data. Intervention effectiveness data from the trial was converted into metabolic equivalent tasks (METs) to enable stepping at different rates to be represented within a single metric [88, 89]. The model took an NHS perspective for costs and health benefits. Intervention costs were calculated at £62.52 per person based on resources used in the trial. This included printing and posting materials which were costed directly, and nurse time for training and to deliver the intervention, which were costed using PSSRU unit costs [90]. It was assumed that a mid-Band 7 hospital nurse would deliver the intervention on an individual basis to 200 patients per year, taking 55 minutes per patient; whilst a Band 8a hospital nurse would deliver a day of training to ten Band 7 nurses, which would be valid for three years. As the Active 10 app is a publicly available app developed by the NHS that exists outside of this intervention, the cost of the app per person was not included as an intervention cost. Quality-adjusted life years (QALYs) were estimated based on patient-reported EQ5D scores at baseline, projected over the patient lifetime. Full details of the model methodology are reported in the supplementary materials.

Probabilistic sensitivity analysis (PSA) was used to estimate mean lifetime costs, QALYs and cost-effectiveness, with a discount rate of 3.5% applied for costs and QALYs in line with National Institute for Health and Care Excellence (NICE) guidelines [91]. Expected value of perfect information (EVPI) and perfect parameter information (EVPPI) were estimated [92]. Structural uncertainties were investigated through scenario analyses.

### Ethical considerations

This pilot study was approved by the Yorkshire & The Humber-South Yorkshire Research Ethics Committee (21/YH/0029) and the Health Research Authority.

## ­­Results

### Overview

Figure 1 presents the flow of participants from initial screening to enrolment and participation. Of the 1037 patients diagnosed with breast, prostate, or colorectal cancer that were assessed for eligibility, 460 (44%) were excluded at the medical records stage. A further 577 patients were sent the initial letter about the study and 429 (74%) were excluded either due to not being interested in participating or based on follow-up eligibility screening, as outlined below. The Study Information Sheet was sent to 148 patients, with 93 (63%) consenting to participate and 90 (61%) being randomised. Reasons given for declining to participate are presented in the supporting information but included finding that the study would be ‘too much’ currently (n=7), that they had too much already going on with treatment (n=6), and that they were too busy (n=4).

**<Figure 1 here>**

### Sample Characteristics

Table 3 presents sociodemographic and clinical factors, as well as physical activity outcomes at baseline in the sample. Participants were mainly breast (n=36, 40%) and prostate (n=36, 40%) cancer patients, with fewer colorectal cancer patients (n=18, 20%). The mean age of participants was 63 (*SD*=11, range=40-85), with a similar number of males (n=47, 52%) to females.

**<Table 3 here>**

### Feasibility outcomes

Table 4 presents the results of the feasibility outcomes. The trial procedures were acceptable to participants with no participants giving randomisation as their reason for declining (0%) or withdrawing (0%), high completion rates (>86%), and a 96% participant retention rate. Delivery of the intervention was feasible with 98% of the intervention group receiving the behavioural support call and 96% downloading the app.

**<Table 4 here>**

#### Potential sociodemographic biases

Table 5 presents a descriptive comparison of enrolled participants to the aggregate data of the population of people diagnosed with breast, prostate, and colorectal cancer at the recruiting NHS Trust. Accounting for the small sample size, enrolled participants were similar in terms of gender, age, ethnicity and IMD quintile. There was a more equal ratio of men to women in this study, but a lower proportion of colorectal cancer patients and a greater proportion of prostate cancer patients were recruited than what would be representative of the population at the site.

**<Table 5 here>**

### App engagement

Two participants withdrew several weeks after randomisation, and one did not complete this intervention feedback section of the questionnaire. Two participants reported not downloading the app and weren’t shown any further questions on app use. Out of 39 participants asked if they ever used Active 10 to track their walking, 85% reported using and still using the app (n=33). Out of these participants, 82% reported using it almost every day or every day (n=27) and 18% reported using it 3-4 times per week (n=6). Fewer participants reported using the app but were no longer using it (n=5, 13%). Of those who said that they had stopped using the app, they reported using the app for the following time periods: 1 week (n=1), 2 weeks (n=1), 1 month (n=1), 2 months (n=1), 3 months (n=1). One participant reported not using the app at all.

Results from the DBCI assessing engagement with the app are presented in Table 6. The mean reported time spent using the app on their first day of use was 19.6 minutes (range 2-60, SD=16.0). On their most recent day of use, the mean reported time spent using the was 17.1 minutes (range 1-60, SD=16.7). The proportion of app components used was relatively high with participants reporting a mean use of 67.5% of the six key components on their first use of the app and a mean use of 46.3% of the components on their most recent use. The most frequently reported components used by participants at first use of the app were ‘Setting or reviewing targets’ (n=35), ‘Viewing today’s walks’ (n=34), and ‘Viewing my walks’ (n=33). On their most recent use of the app, the most frequently reported components used by participants were ‘Viewing today’s walks (n=34), ‘Viewing my walks’ (n=30) and ‘Viewing rewards’ (n=19). Results of use of all the available components are presented in supplementary table 4.

**<Table 6 here>**

### Intended primary outcome: Physical activity

Table 7 presents the time spent brisk walking derived from the ActivPAL data for the 82 participants (91%) who provided data at both timepoints (Intervention n=40; Control n=42). Due to the small sample size, the data are reported for descriptive purposes only, with median and interquartile ranges presented due to the skewness of the data.

**<Table 7 here>**

### Main trial power calculation

A total of N=472 participants are required in the larger RCT to detect an effect size of 0.10 hours per day of activity at 100 steps per minute, with 90% power and two-sided 5% significance level, after allowing for up to 10% dropout. This is equivalent to a difference of 6 minutes per day (42 minutes per week) between the experimental and control arms. This calculation assumes a standard deviation of 0.20 hours per day in the control group with a variance ratio of 1:4 (control:intervention) and is supported by the data observed at both timepoints.

### Trial experience interviews

All participants who remained in the study at T1 were approached about taking part in the end of study interviews (n=87; n=2 withdrawn, n=1 deceased). In total, 72 participants completed trial experience interviews. Seven participants provided no reason for declining to participate. Other reasons for not taking part included: not responding to the invitation to interview (n=3); not feeling up to it due to illness-related side effects (n=2); not feeling confident speaking on the phone (n=1); not feeling like they had much to offer (n=1); being too busy (n=1). Overall participants were generally happy with the trial procedures and a more detailed presentation of the feedback from the qualitative interviews is presented in the supporting information. Participants reported mixed feelings about randomisation, with some indicating indifference, and others sharing views that related to their experimental group allocation (Supplementary Table 5). Participants generally found the completion of study assessments at both timepoints to be acceptable, including wearing the activPAL, completing their body measurements, and completing the online questionnaires (Supplementary Table 6). Most participants expressed that the timing of being approached to take part was reasonable, despite being at different points of their cancer care plan (Supplementary Table 7). All participants reported a willingness to consent linkage to HES/NCRAS registries for long term follow up, describing an understanding of why this data would be important and a willingness for the data to be used to help others (Supplementary Table 8).

### Preliminary cost-effectiveness analysis

As expected, there was high uncertainty around the results of the preliminary cost-effectiveness analysis, given that the feasibility study had not been designed to produce statistically significant effectiveness data. The base-case health economic analysis suggests that based on the study results, APPROACH would cost £69 (95% credible intervals: £34; £102) and produce 0.0019 (-0.0078; 0.111) QALYs over the lifetime of the average participant compared with no intervention, resulting in an incremental cost-effectiveness ratio (ICER) of £36,475 and a net monetary benefit of -£31 (-£195; £124) at a willingness to pay threshold of £20,000 per QALY. Whether or not the intervention is cost-effective is highly uncertain, with a 37% probability that the intervention is cost-effective at this threshold, and a 63% probability that it is not (Figure 2). EVPI analysis suggests that it could be worth spending up to £18.83 per person likely to be affected by the decision (that is, whether to make the intervention available in the NHS) to remove parameter uncertainty and ensure that the correct decision is made. This is equivalent to a value of approximately £2.8m across all patients diagnosed with breast, prostate, and colorectal cancer in the UK each year. 95% of this value comes from uncertainty around the physical activity intervention effectiveness parameters, particularly changes in stepping at a rate lower than 100 steps per minute.

Given the small sample size in this pilot study, no definitive inferences could be drawn about the effect of the intervention and the durability of the effect. However, scenario analysis indicates that the intervention would have a strong likelihood of being cost-effective if one or more of the following were true: a) intervention effectiveness is higher than observed in this small pilot study; b) duration of intervention effect is longer than 7 years; c) intervention costs are reduced; d) NHS resource use is reduced by a small % in the intervention arm; e) the selected population have a higher baseline mortality risk (e.g. older, more advanced cancer stage or lower baseline physical activity) (see Supplementary Table 6). A definitive trial should help to inform these parameters more accurately.

**<Figure 2 here>**

## Discussion

The results of this pilot study suggest that an app-based intervention with brief behavioural support is a feasible and acceptable way to promote brisk walking in people LWBC. The data provided in this study informed the design of a larger, funded, efficacy trial that is powered to determine the impact of the intervention in terms of brisk walking and the cost-effectiveness of this intervention.

### Interest in and acceptability of the study

Previous research reports that people LWBC have a strong desire to receive physical activity advice but are often not provided with it as part of their care [29, 30]. This reported desire is supported by the high interest in taking part in this study (64%) and supports the need to develop physical activity interventions that can be delivered and are accessible to people LWBC. Although many of these interested patients were not enrolled due to exclusion criteria, this was expected and does not undermine the feasibility of the recruitment strategy going forward. Furthermore, participants in this study were similar to the population of people diagnosed with breast, prostate, and colorectal cancer at the hospital site. Although there was a higher percentage of white participants than that observed in the aggregate population data, this can be attributed to the small sample size and the location of the pilot site. Additionally, the final sample included proportionally fewer colorectal cancer patients and more prostate cancer patients than the aggregate data. This is likely due to differences in engagement from the clinical staff involved in the care of these patient populations at the single hospital site where the pilot was undertaken. This should be overcome by involving more sites in the confirmatory RCT, as well as monitoring recruitment closely and adapting strategies if needed to increase engagement with clinical staff.

The relatively high enrolment rate (61%) and very high retention rate (97%) show that the trial is feasible. Despite previous research suggesting that randomisation may be unacceptable to some participants, no participants in the present study withdrew directly after randomisation and no potential participants gave randomisation as their reason for declining to take part [93, 94]. Despite some reported disappointment related to control group allocation, the qualitative interviews indicated that participants found randomisation acceptable and being disappointed did not lead to any withdrawals. The outcome assessments were acceptable to participants and there were high completion rates (over 86%) for all assessments at baseline and at follow up. This is in line with high retention and assessment completion rates reported in other studies in similar samples with similar follow-up times and provides a good premise for the potential of sufficient retention rates in a larger trial with more participants and longer follow-up [95, 96]. These results informed the power calculation for such a trial and suggests that 472 participants would be required for the larger trial to allow for similar retention rates.

This study recruited participants across the cancer care continuum and included patients with localised and metastatic disease, as well as those still receiving treatment and those within six months of radical treatment completion. This inclusive approach was a key consideration at this pilot stage, considering previous research highlighting varying preferences in the timing of the delivery of physical activity interventions [47, 48]. In their qualitative research, Ijsbrandy and colleagues reported how some participants felt that during treatment felt too soon to begin rehabilitation, while others felt that it should have been offered earlier [97]. Similarly, some participants felt that they would prefer to avoid the hospital after appointments, while others felt it should be integrated within hospital care. Most participants in the current study felt that the timing of being approached was suitable and this aligns with the proposed integration of the intervention into standard NHS care while patients still have contact with their clinical care team. By including a diverse range of participants, we aimed to capture the complexities and challenges associated with delivering a physical activity intervention across different disease contexts and aimed to replicate the implementation of this type of intervention in a realistic setting as closely as possible. This allows for a more inclusive approach that aims to maximise the reach of the intervention to patients at different stages of the cancer care pathway, while the randomisation strategy helps mitigate the potential confounding effects resulting from heterogeneity across treatment and disease stages. When participants are randomly allocated to the intervention and control group, it is assumed that the distribution of patients across these factors is balanced, reducing the risk of confounding bias [98].

### Cost-effectiveness uncertainty

As expected, preliminary investigations into the cost-effectiveness of the intervention indicate a high level of uncertainty driven by the physical activity intervention effectiveness parameters. While this is partly due to the small study size, it is compounded by the outcome measures used in the study which are relatively crude (weekly minutes spent walking >100 steps per minute vs weekly minutes spent walking at any pace). The economic analysis converted this measure to METs and used this single metric, as this enabled changes in physical activity to be linked to mortality. However, this required some assumptions about how many METs are represented by each of the primary outcome measures, introducing further uncertainty. Furthermore, there was uncertainty in the physical activity parameters, where the studies used for linking physical activity and mortality in people LWBC included both self-report and objective measures of physical activity. Previous research suggests that self-report may significantly underestimate the effect of physical activity on risk reduction, compared to objective measures [99]. Future research in the planned main trial should adopt a more comprehensive approach to estimating METs with more precision from the accelerometer data, as well as reducing uncertainty by accounting for the potential differences in the measurement of physical activity across studies. Taking these steps will not only improve accuracy in the estimates of physical activity change but will also reduce uncertainties surrounding the cost-effectiveness of the intervention. Scenario analyses demonstrate the need for the larger RCT, not only to reduce uncertainty around intervention effectiveness, but also to capture potential differences in NHS resource use between arms, which could make a large impact on model results. A larger trial would also enable more comprehensive subgroup data to be collected. In the economic modelling, a uniform effect was assumed across all population subgroups due to the small sample size prohibiting the analysis of subgroups. However, data exploration suggested that the intervention may be more cost-effective in people who are older, with increased morbidities, or less active at baseline. Our EVPI analyses suggest that the value of conducting the larger RCT is likely to be high.

### Potential of the intervention

The results suggest that intervention delivery in a future larger-scale trial can continue as per the pilot study with some refinement and optimisation [68]. A second paper reports the process evaluation of the intervention as per the Medical Research Council guidance to improve the implementation of complex interventions [70]. This has allowed for refinement of the intervention for the larger trial, based on both qualitative interview feedback and questionnaire feedback from pilot participants. Adherence to physical activity interventions is a key challenge in healthy populations and this challenge is heightened in people LWBC due to several factors including treatment effects, fatigue, and comorbid conditions [100]. However, adherence can be improved with well-designed physical activity interventions that employ behaviour change techniques and encourage habit formation [101]. Supporting the intervention design, participant engagement with the app was very high with most of the intervention participants reporting that they were still using Active 10 after one month (95%). This may be attributed to the promotion of habit formation in the intervention, inviting an exploration of the habit scores in a larger scale trial with a longer follow-up. The results of the DBCI also demonstrated good engagement with the app and participants reported a high proportion of use of the app’s key features and demonstrated continuing to use these during their most recent use of the app (e.g., viewing today’s walks).

While the intervention demonstrates potential for improving MVPA, it is important to note that device-based measures of physical activity suggest that participants in this study were already relatively active. Participants were screened before taking part, and this already higher level of MVPA could be attributed to discrepancies in device-based versus self-reported recall of physical activity [102-104]. While people typically perceive their participation in physical activity in relation to a total duration of purposeful physical activity (e.g., 30 minutes of walking), accelerometers can fragment the movement behaviours further (e.g., five minutes brisk walking during a 30-minute duration walk) [103, 105, 106]. However, the screening tool employed was validated and appropriate for our clinical population, given that it would not be feasible to objectively measure physical activity at this early stage of recruitment and the eligibility questions mirrored the physical activity recommendations, which are based on self-report [72, 73, 103]. In any case, the intervention group demonstrated a larger increase in the primary outcome than the control group when using the device-based measure of physical activity. This supports the appropriate use of the activPAL to accurately capture our primary outcome in the phase III trial physical activity measurement.

### Strengths and limitations

Strengths of this study included that the sample was similar in terms of gender, ethnicity, age and IMD quintile to the population diagnosed with the relevant cancers at the participating hospital site. This intervention was designed and developed based on data collected from people LWBC and drew on behavioural change theory and habit theory to promote brisk walking [45, 64, 67]. The concept development considered the practical implementation of the intervention beyond the trial and therefore is a low-cost, scalable, time-effective intervention that could be incorporated into routine care in people LWBC and potentially delivered by cancer specialist nurses [63]. The use of accelerometers to measure physical activity is favourable to self-report and the activPAL has shown strong reliability and validity in the measurement of walking at different paces [107].

Limitations of this study include that participants were recruited from a single site, thus may not be demographically and ethnically representative of the larger population of people LWBC. The larger, confirmatory trial will recruit from multiple sites. This study also required participants to have a smartphone which may have excluded participants of older age and lower socioeconomic position [108]. Despite this being a reported exclusion reason for 81 individuals (although non-eligibility reasons could be >1 and therefore some individuals may have been ineligible on other criteria as well), smartphone ownership is still increasing [37]. Particularly given the lasting effects of the COVID-19 pandemic on remote delivery of cancer care, an app-based behavioural intervention such as APPROACH may be preferable as it can support a wide population while still incorporating the proposed benefit of personal contact in effectively changing behaviour [39, 109]. It is however important to note that app usage was collected via self-report which may be impacted by recall errors and recency biases [110]. However, it was not possible to access direct app use analytics. Another limitation of the present study was the limited availability of resources which prevented the involvement of additional coders in the qualitative interview analysis. Despite this constraint, it is widely acknowledged that including qualitative data in pilot studies provides important insights that would have been otherwise overlooked if the data had been excluded completely due to this limitation [111]. Lastly, as expected, the health economic analysis was limited by the uncertainty surrounding the economic modelling, due to the small study size and crude effectiveness data collected.

### Conclusion

This pilot study demonstrates that the APPROACH intervention is feasible and acceptable to people living with and beyond a diagnosis of breast, prostate, or colorectal cancer. This supports the progression onto a confirmatory phase III trial with a larger sample to determine the clinical effectiveness of the intervention and to evaluate its cost-effectiveness.

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## Tables

|  |  |  |
| --- | --- | --- |
| **Table 1.** Schedule of study assessments. | | |
| **Assessment** | **Baseline (T0)** | **12-16 weeks from T0 (T1)** |
| Demographics | X |  |
| Medical Information | X |  |
| Physical activity (GLTEQ) | X | X |
| Anthropometrics (height, weight, waist circumference) | X | X |
| Health-related quality of life (EQ-5D-5L) | X | X |
| Cancer-specific quality of life (FACT-G) | X | X |
| Fatigue (FACIT-F) | X | X |
| Sleep Quality (PSQI) | X | X |
| Anxiety (GAD-7) | X | X |
| Depression (PHQ-9) | X | X |
| Physical activity self-efficacy (PAAI) | X | X |
| Self-efficacy to manage cancer (CS-SES) | X | X |
| Habit strength for walking (“Going for a walk” and “Walking briskly”) (SRBAI) | X | X |
| Health and social care service usage (CSRI) | X | X |
| Question about usage of any physical activity app |  | X |
| Question about usage of Active 10 app |  | X |
| Intervention engagement (DBCI Engagement Scale) |  | X |
| Chronotype (MEQ) |  | X |
| Abbreviations : GLTEQ=Godin Leisure-Time Exercise Questionnaire [112]; EQ-5D-5L=Five-level EuroQol-5D [113]; FACT-G=Functional Assessment of Cancer-General [114]; FACIT-F=Functional Assessment of Chronic Illness Therapy-Fatigue [115]; PSQI=Pittsburgh Sleep Quality Index [116]; GAD-7=General Anxiety Disorder Assessment [117]; PHQ-9=Patient Health Questionnaire-9 [118] ; PAAI=Physical Activity Appraisal Inventory [119]; CS-SES=Cancer Survivors Self-Efficacy Scale [120]; SRBAI=Self-Report Behavioural Automaticity Index [121]; CSRI=Client Service Receipt Inventory [122]; DBCI Engagement Scale=digital behaviour change intervention Engagement Scale [78]; MEQ=Morning-Eveningness Questionnaire [123]. | | |
|  | | |

|  |  |  |
| --- | --- | --- |
| **Table 2** Feasibility outcomes | | |
| **Feasibility outcomes** | **Detail of specific outcome** |
| Interest | * % of medically eligible interested/willing to answer eligibility questions. |
| Enrolment | * % fully eligible patients enrolled. |
| Acceptability of randomisation | * % of participants who withdraw post-randomisation (within 1 week of being informed). |
| * % potential participants who state that randomisation is their reason for declining. |
| Feasibility of administering intervention | * % of intervention group who received a behavioural support call. |
| * % of intervention group who self-reported downloading the app. |
| Acceptability of intervention | * % of participants who reported that no aspect of the intervention was useful. |
| * % of participants in the intervention group who report using the app for less than a month. |
| * % of withdrawals from the intervention group compared to control group. |
| * % of reasons for withdrawal relating to the intervention. |
| Retention rate | * % of participants, in each group, who complete any of the T1 follow-up assessment. |
| Acceptability of outcome assessments | * % of participants who consent who complete any baseline assessments. |
| * Completion rates, in each group, for each of the assessments at baseline and follow-up. |
| Willingness to consent to linkage with HES/NCRAS registries for long-term follow-up | * % of participants who consent for this aspect of the study. |
| Acceptability of online assessments | * % of participants who required help to complete the questionnaires * % of potential participants who give this method of data collection as a reason for declining to participate. |
| Acceptability of providing informed consent online | * % of participants who give online informed consent as a reason for declining. |
| Proportion of screened participants ineligible and reasons for ineligibility | * Number of participants screened and deemed ineligible for each inclusion/exclusion criteria. |
| Potential sociodemographic biases in recruitment | * Comparison of sample demographics with hospital level data on patients with breast, prostate, and colorectal cancer. |
| Fidelity of intervention delivery in telephone/video calls | * Average % of required behaviour change techniques covered in intervention calls. |
| Contamination of the control group | * % of participants who report using the Active 10 app or that a health professional recommended it to them, during the study period. |
| Abbreviations: HES=Hospital Episode Statistics; NCRAS=National Cancer Registration and Analysis Service | |

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 3.** Descriptive statistics for sociodemographic and clinical factors, and physical activity outcomes at baseline | | | |
|  | **Total (N=90)** | **Intervention (n=44)** | **Control (n=46)** |
| **Age (years): mean(range)** | 63 (40-85) | 63 (40-85) | 62 (41-78) |
| **Sex n(%)** |  |  |  |
| Male | 47 (52) | 22 (50) | 25 (54) |
| Female | 43 (48) | 22 (50) | 21 (46) |
| **Ethnicity n(%)** |  |  |  |
| White | 87 (97) | 42 (96) | 45 (98) |
| Asian/Asian British | 2 (2) | 1 (2) | 1 (2) |
| Other† | 1 (1) | 1 (2) | 0 |
| **Education level n(%)** |  |  |  |
| No formal qualifications | 11 (12) | 5 (11) | 6 (13) |
| High school/secondary school | 31 (34) | 15 (34) | 16 (35) |
| AS & A levels or equivalent | 13 (14) | 8 (18) | 5 (11) |
| Level 4-5 vocational qualifications | 12 (13) | 2 (5) | 10 (22) |
| Bachelor’s degree or equivalent | 14 (16) | 11 (25) | 3 (7) |
| Master’s degree, PGCE, PhD or equivalent | 9 (10) | 3 (7) | 6 (13) |
| **Employment n(%)** |  |  |  |
| Employed full-time | 19 (21) | 8 (18) | 11 (24) |
| Employed part-time | 15 (17) | 9 (21) | 6 (13) |
| Unemployed | 2 (2) | 2 (5) | 0 |
| Retired | 47 (52) | 22 (50) | 25 (54) |
| Unable/too ill to work | 7 (8) | 3 (7) | 4 (9) |
| **Marital status n(%)** |  |  |  |
| Married/in a relationship | 75 (83) | 37 (84) | 38 (83) |
| Single/divorced/separated | 8 (9) | 3 (7) | 5 (11) |
| Widowed | 7 (8) | 4 (9) | 3 (7) |
| **Living arrangements n(%)** |  |  |  |
| Alone | 12 (13) | 5 (11) | 7 (15) |
| With partner only | 53 (59) | 25 (57) | 28 (61) |
| With family | 25 (28) | 14 (32) | 11 (24) |
| **Index of Multiple Deprivation Quintile n(%)** |  |  |  |
| 1 (most deprived) | 18 (20) | 8 (18) | 10 (22) |
| 2 | 15 (17) | 6 (14) | 9 (20) |
| 3 | 17 (19) | 9 (21) | 8 (17) |
| 4 | 27 (30) | 16 (36) | 11 (24) |
| 5 (least deprived) | 13 (14) | 5 (11) | 8 (17) |
| **Cancer type n(%)** |  |  |  |
| Breast | 36 (40) | 18 (41) | 18 (39) |
| Prostate | 36 (40) | 18 (41) | 18 (39) |
| Colorectal | 18 (20) | 8 (18) | 10 (22) |
| **Cancer stage n(%)** |  |  |  |
| 1 | 29 (32) | 15 (34) | 14 (30) |
| 2 | 30 (33) | 14 (32) | 16 (35) |
| 3 | 24 (27) | 12 (27) | 12 (26) |
| 4 | 7 (8) | 3 (7) | 4 (9) |
| **Treatment type and stage**‡ **n(%)** |  |  |  |
| **Surgery n(%)** |  |  |  |
| Underwent surgery | 55 (61) | 25 (57) | 30 (65) |
| Not had/having surgery | 35 (39) | 19 (43) | 16 (35) |
| **Radiotherapy n(%)** |  |  |  |
| Due to start radiotherapy | 26 (29) | 13 (30) | 13 (28) |
| Currently undergoing radiotherapy | 2 (2) | 0 (0) | 2 (4) |
| Completed radiotherapy | 19 (21) | 9 (21) | 10 (22) |
| Not had/having radiotherapy | 43 (48) | 22 (50) | 21 (46) |
| **Chemotherapy n(%)** |  |  |  |
| Due to start chemotherapy | 0 (0) | 0 (0) | 0 (0) |
| Currently undergoing chemotherapy | 10 (11) | 3 (7) | 7 (15) |
| Completed chemotherapy | 14 (16) | 8 (18) | 6 (13) |
| Not had/having chemotherapy | 66 (73) | 33 (75) | 33 (72) |
| **Hormone therapy n(%)** |  |  |  |
| Due to start hormone therapy | 4 (4) | 2 (5) | 2 (4) |
| Currently undergoing hormone therapy | 39 (43) | 20 (46) | 19 (41) |
| Completed hormone therapy | 6 (7) | 2 (5) | 4 (9) |
| Not had/having hormone therapy | 41 (46) | 20 (46) | 21 (46) |
| **Biological therapy n(%)** |  |  |  |
| Due to start biological therapy | 0 (0) | 0 (0) | 0 (0) |
| Currently undergoing biological therapy | 7 (8) | 3 (7) | 4 (9) |
| Completed biological therapy | 2 (2) | 2 (5) | 0 (0) |
| Not had/having biological therapy | 81 (90) | 39 (89) | 42 (91) |
| **Months since diagnosis§: median (IQR)** | 5 (4-8) | 6 (4-8) | 5 (4-7) |
| **Previous cancer diagnoses n(%)** |  |  |  |
| Previously diagnosed with one other cancer¶ | 12 (13) | 8 (18) | 4 (9) |
| No previous diagnosis of cancer | 78 (87) | 36 (82) | 42 (91) |
| **Comorbid health conditions n(%)** |  |  |  |
| None | 28 (31) | 13 (30) | 15 (33) |
| 1 condition | 34 (38) | 16 (36) | 18 (39) |
| 2+ conditions | 28 (31) | 15 (34) | 13 (28) |
| **Body Mass Index††: median(IQR)** | 28 (25-33)**††** | 27 (24-31)**††** | 28 (25-34) |
| **Minutes spent brisk walking per week§§: median (IQR)** | 181 (116-363) | 211 (126-374) | 171 (105-255) |
| **Minutes spent walking at any pace per week§§: median (IQR)** | 607 (433-784) | 626 (493-912) | 557 (396-751) |
| **Hours spent sitting per day§§: median (IQR)** | 10 (9-11) | 10 (9-11) | 10 (9-11) |
| **Hours spent standing per day§§: median (IQR)** | 3 (3-4) | 4 (3-4) | 3 (2-4) |
| Abbreviations:PGCE=postgraduate certificate of education; PhD=Doctor of Philosophy; IQR=interquartile range.  †Participants could specify their ethnicity in the textbox. ‡At the date when the baseline assessment pack was sent to the participant. §At the date of randomisation. ¶No participants had received a diagnosis of more than one other cancer. ††Whencleaning the data, the BMI of one participant was removed from the analysis due to an outlier weight value that was deemed implausible. §§88 participants consented to wearing and received the activPAL and 85 participants’ activPAL data are reported as three participants did not provide data for the specified sufficient number of days to be included (3 days [36, 55]). | | | |

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| **Table 4.** Results of the pre-specified feasibility outcomes | | |
| **Feasibility outcomes** | **Detail of specific outcome** | **Result** |
| Interest | * % of eligible interested/willing to answer eligibility questions | * 64% (369/577) |
| Enrolment | * % eligible patients enrolled | * 61% (90/148) |
| Acceptability of randomisation | * % of participants who withdraw post-randomisation (within 1 week of being informed) | * None |
| * % potential participants who state that randomisation is their reason for declining | * None |
| Feasibility of administering intervention | * % of intervention group who received a behavioural support call | * 98% (43/44)† |
| * % of intervention group who self-reported downloading the app | * 96% (42/44) |
| Acceptability of intervention | * % of participants who reported that no aspect of the intervention was useful | * None |
| * % of participants in the intervention group who report using the app for less than a month | * 5% (2/39‡) |
| * % of withdrawals from the intervention group compared to control group. | * 5% (2/44) in intervention group. None in control group. |
| * % of reasons for withdrawal relating to the intervention | * None |
| Retention rate | * % of participants, in each group, who complete any of the T1 follow-up assessment | * 97% (87/90) completed any follow-up assessments, and there were similar rates between study groups§. |
| Acceptability of outcome assessments | * % of participants who consented completed any baseline assessments | * 100% (91/91¶) |
| * Completion rates, in each group, for each of the assessments at baseline and follow-up | * Completion rates were high for all assessments (>86%), and similar between study groups§. |
| Willingness to consent to linkage with HES/NCRAS registries for long-term follow-up | * % of participants who consent for this aspect of the study | * 100% (90/90) |
| Acceptability of online assessments | * % of participants who required help to complete the questionnaires online | * 4% (4/90) participants required partial help completing questionnaires. |
| * % of potential participants who give this method of data collection as a reason for declining to participate | * None |
| Acceptability of providing informed consent online | * % of participants who give online informed consent as a reason for declining | * None |
| Potential sociodemographic biases in recruitment | * Comparison of sample demographics with hospital level data on patients with breast, prostate, and colorectal cancer | * The sample was similar in terms of age, gender, ethnicity, IMD and cancer type to potentially eligible participants at the recruiting NHS site††. |
| Fidelity of intervention delivery in telephone/video calls | * Average % of required behaviour change techniques (BCT) covered in intervention calls | * 96% of the 25 BCTs‡‡. |
| Contamination of the control group­ | * % of participants who report using the Active10 app or that a health professional recommended it to them | * None§§ |
| †97.7% received the first support call (43/44); 88.6% received the second support call (39/44). ‡Five intervention participants did not provide data for this outcome. Two participants withdrew several weeks after randomisation, and one did not complete this intervention feedback section of the questionnaire. The further two participants who stated they did not download the app were not shown this question.  §See Supplementary Table 2. ¶Of the 93 participants who consented, two of these were not sent the questionnaire link due to (1) choosing not to take part due to family crisis and (2) as the study had met its recruitment target and did not have sufficient resources to recruit this participant. The other participant completed the baseline questionnaires but withdrew to focus on their treatment, prior to wearing the activPAL. ††See Table 5. ‡‡Most intervention participant calls were coded (42/43), except where there was a recording error (n=1). One participant did not receive any call (n=1). In total, 81 intervention calls (42 first calls and 39 second calls) from 42 participants were included. §§Eight participants from the control group reported using an app to help them with physical activity since beginning their participation in the study and the named apps are presented in Supplementary Table 3. | | |

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| **Table 5.** Comparison of recruited participants in the pilot study and anonymised aggregate data at hospital site to examine potential recruitment bias | | | |
|  | **Pilot study participants (N=90)** | **Aggregate site data (N=1072)** |
| **Age (years): mean** | 63 | 66 |
| **Sex n(%)** |  |  |
| Male | 47 (52) | 435 (41) |
| Female | 43 (48) | 637 (59) |
| **Cancer type n(%)** |  |  |
| Breast | 36 (40) | 405 (38) |
| Prostate | 36 (40) | 71 (7) |
| Colorectal | 18 (20) | 596 (56) |
| **Ethnicity n(%)** |  |  |
| White | 87 (97) | 977 (91) |
| other | 3 (3) | 95 (9) |
| **Index of Multiple Deprivation quintile n(%)** |  |  |
| 1 | 18 (20) | 271 (25) |
| 2 | 15 (17) | 225 (21) |
| 3 | 17 (19) | 203 (19) |
| 4 | 27 (30) | 270 (25) |
| 5 | 13 (14) | 103 (10) |

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| **Table 6.** Results of the Digital Behaviour Change Intervention Scale assessing engagement with the app (N=38†) | | |
|  | **First use ratings**  *Mean (standard deviation)* | **Last use ratings**  *Mean (standard deviation)* |
| Interest‡ | 5.9 (1.0) | 5.5 (1.3) |
| Intrigue‡ | 5.3 (1.3) | 4.1 (1.9) |
| Focus‡ | 5.7 (1.1) | 5.0 (1.7) |
| Inattention‡§ | 6.2 (1.1) | 6.2 (1.2) |
| Distraction†§ | 6.1 (1.1) | 6.2 (1.2) |
| Enjoyment‡ | 5.3 (1.3) | 5.2 (1.5) |
| Annoyance‡§ | 6.70 (0.65) | 6.5 (0.9) |
| Pleasure‡ | 5.1 (1.5) | 4.8 (1.8) |
| How long (in minutes) do you roughly think that you spent on the app that day? | 19.6 (16.0) | 17.1 (16.7) |
| Which of the app’s components do you remember visiting (tick all that apply)?¶ | 67.5% (28.1) | 46.3% (26.7) |
| †Two participants withdrew several weeks after randomisation, and one did not complete this intervention feedback section of the questionnaire. Two participants reported not downloading the app and weren’t shown any further questions on app use. ‡Possible range 1-7, with 7 being more engagement. §Reverse scored. ¶Presented as the proportion (%) of components that participants reported using (out of a possible 6 components). | | |

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| **Table 7** Minutes spent brisk walking per week at T0 and T1 (N=82) | | |
| **Experimental group** | **T0** | **T1** |
| Intervention (n=40): median (IQR) | 211 (124-378) | 276 (179-427) |
| Control (n=42): median (IQR) | 167 (103-269) | 192 (91-310) |
| Abbreviations: IQR=interquartile range. | | |

## Author contributions:

**Phillippa Lally:** conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, writing -review & editing. **Fiona Kennedy**: conceptualisation, data curation, formal analysis, investigation, methodology, writing – review &editing. **Susan Smith:** data curation, investigation, methodology, writing – original draft, writing – review & editing. **Rebecca Beeken:** conceptualisation, funding acquisition, writing – review & editing. **Caroline Buck:** investigation, writing - review & editing. **Chloe Thomas:** conceptualisation, formal analysis, funding acquisition, methodology, writing – review & editing. **Nicholas Counsell:** conceptualisation, formal analysis, methodology, writing – review & editing. **Lynda Wyld:** review & editing. **Charlene Martin:** data curation, investigation, methodology, writing – review & editing. **Sarah Williams:** data curation, methodology, writing - review & editing. **Anna Roberts:** conceptualisation, funding acquisition, writing - review & editing. **Diana Greenfield:** conceptualisation, funding acquisition, writing - review & editing. **Jacqui Gath:** funding acquisition, writing – review & editing. **Henry Potts:** conceptualisation, funding acquisition, writing – review & editing. **Nicholas Latimer:** conceptualisation, funding acquisition, writing – review & editing. **Lee Smith:** conceptualisation, writing – review & editing. **Abi Fisher (corresponding author):** conceptualisation, funding acquisition, writing – review & editing.

**Supporting information**

The Digital Behaviour Change Intervention Scale used to assess intervention engagement

**When you first used the app to track your walking how strongly do you remember experiencing (response scale 1-7, end and middle points anchored as not at all, moderately and extremely)**

Interest

Intrigue

Focus

Inattention

Distraction

Enjoyment

Annoyance

Pleasure

**When you first used the app to track your walking how long (in minutes) do you roughly think that you spent on the app that day?**

**When you first used the app to track your walking which of the app’s components do you remember visiting (tick all that apply)?**

* Setting or reviewing targets for how many daily minutes of brisk walking you’ll aim for (1, 2 or 3 Active 10s)
* Setting or reviewing your goals/reasons for why you’re doing Active 10
* Setting a daily activity reminder within the app
* Viewing your “Rewards” for achieving walking targets
* Viewing “today’s walks” (today’s feedback about the amount of walking/brisk walking you’ve done)
* Viewing “my walk’s” (reviewing the amount of walking/brisk walking you have done over the past days, weeks and months)
* Reading the help section (e.g. tips and FAQs)
* Using the links to
* Government advice
* Weight management advice
* Mental health support
* The Health Unlocked Active10 Community
* Physical Activity guidelines
* The Couch to 5K App

**We are also interested in the last (most recent) time you used the app.**

**When you last used the app how strongly do you remember experiencing (response scale 1-7, end and middle points anchored as not at all, moderately and extremely)**

Interest

Intrigue

Focus

Inattention

Distraction

Enjoyment

Annoyance

Pleasure

**When you last used the app how long (in minutes) do you roughly think that you spent on the app that day?**

**When you last used the app to track your walking which of the app’s components do you remember visiting (tick all that apply)?**

* Setting or reviewing targets for how many daily minutes of brisk walking you’ll aim for (1, 2 or 3 Active 10s)
* Setting or reviewing your goals/reasons for why you’re doing Active 10
* Setting a daily activity reminder within the app
* Viewing your “Rewards” for achieving walking targets
* Viewing “today’s walks” (today’s feedback about the amount of walking/brisk walking you’ve done)
* Viewing “my walk’s” (reviewing the amount of walking/brisk walking you have done over the past days, weeks and months)
* Reading the help section (e.g. tips and FAQs)
* Using the links to

o Government advice

o Weight management advice

o Mental health support

o The Health Unlocked Active10 Community

o Physical Activity guidelines

o The Couch to 5K App

Reasons for declining to participate

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| Supplementary Table 1. Reasons given for declining to participate in the study (N=42)† | | | | |
|  | ***N*** | ***Breast***  ***(n=15)*** | ***Colorectal***  ***(n=13)*** | ***Prostate***  ***(n=14)*** |
| No reason given | 12 | 5 | 3 | 4 |
| Felt that the study would be ‘too much’ currently | 7 (1 metastatic‡) | 2 | 4 | 1‡ |
| Too much on – treatment specifically | 6 (2 metastatic‡) | 4‡ | 0 | 2 |
| Too busy currently | 4 (1 metastatic‡) | 1 | 2‡ | 1 |
| Struggling with health/side effects | 4 (1 metastatic‡) | 2‡ | 1 | 1 |
| Too much on with treatment & had issue with giving online consent | 1 |  |  | 1 |
| Too much on currently; struggling with breathlessness & put off by website aspect | 1 |  | 1 |  |
| Too busy & doesn’t want to keep thinking about experience | 1 |  | 1 |  |
| Doesn’t want to keep thinking about experience | 1 | 1 |  |  |
| Not in good place mental health wise | 1 |  | 1 |  |
| Put off by activPAL & recent bad weather | 1 |  |  | 1 |
| Computer issues – has one but on way out | 1 |  |  | 1 |
| Doesn’t carry phone on person & doesn’t feel right person for the study | 1 |  |  | 1 |
| Wants to maintain own health & fitness activities | 1 |  |  | 1 |
| †Nine eligible individuals did not respond to the PIS (6.1%) and 4 (2.7%) were not chased further as we had met our target. | | | | |

Completion rates table

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| Supplementary Table 2. Assessment completion rates at baseline and follow up | | | |
| **Assessment** | **Total n(%)** | **Intervention group n(%)** | **Control group n(%)** |
| Baseline questionnaire | 90/90 (100) | 44/44 (100) | 46/46 (100) |
| Baseline anthropometrics | 90/90 (100) | 44/44 (100) | 46/46 (100) |
| Baseline activPAL | 85/90 (94) | 42/44 (98) | 43/46 (98) |
| Follow-up questionnaire | 85/90 (94)† | 41/44 (93) †‡ | 44/46 (96)§ |
| Follow-up anthropometrics | 80/90 (89) | 38/44 (86)‡ | 42/46 (91)§ |
| Follow up activPAL | 84/90 (93) | 41/44 (93)‡ | 43/46 (93)§ |
| †One follow-up questionnaire was only partially completed. ‡Two participants withdrew from the intervention group and therefore no follow up data were available. §One participant in the control group was lost to follow up (deceased) and therefore no follow up data were available. One participant in the control group withdrew due to frustration with wearing the activPAL and therefore no follow up data were available. | | | | |

Use of other apps to support physical activity

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| Supplementary Table 3.Names of the apps reported by participants to support their physical activity during the study† | |
| **App name** | **N** |
| **Control group** |  |
| Fitbit | 3 |
| Zwift | 1 |
| Kinomap | 1 |
| Pedometer | 1 |
| Samsung Health | 1 |
| Walk tracker‡ | 1 |
| Apple watch and health | 1 |
| **Intervention Group§** |  |
| Heroband 111 | 1 |
| Map my walk | 1 |
| Youtube | 1 |
| Google fit | 1 |
| Fitbit | 1 |
| Strava | 1 |
| Slimming world | 1 |
| Huawei Health | 1 |
| Samsung Health | 1 |
| †Participants could report use of >1 app so numbers will not add up. ‡This participant specified ‘My walk tracker’ without further explanation but is assumed that it may part of their phone health app, e.g., Apple Health, Samsung Health.§Excluding reporting of Active 10 use. | |

Detailed results of the Digital Behaviour Change Intervention Scale

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| Supplementary Table 4. Intervention participant use of the different key components of the Active 10 app | | | | | |
|  | | **Number of participants who ticked using each component at first use and last use of the app (%)†** | | | |
| **App component** | | **First use** | | **Last use** | |
| Setting or reviewing targets | | 35 (85.4) | | 18 (43.9) | |
| Setting or reviewing goals for why doing Active 10 | | 21 (51.2) | | 9 (22.0) | |
| Setting reminder within app | | 12 (29.3) | | 4 (9.8) | |
| Viewing rewards | | 31 (75.6) | | 19 (46.3) | |
| Viewing Today’s walks | | 34 (82.9) | | 34 (82.9) | |
| Viewing My walks | | 33 (80.5) | | 30 (73.2) | |
| †% calculated out of the 41 participants who completed the intervention feedback section of the T1 questionnaire. Two participants withdrew several weeks after randomisation, and one did not complete this intervention feedback section of the questionnaire. Two participants reported not downloading the app and weren’t shown any further questions on app use. | | | | | |

Trial experience interviews

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| Supplementary Table 5. Illustrative quotes and frequency counts about acceptability of randomisation† | | |
| **Feedback** | **n** | **Supporting quotes *(sex, age [in years], experimental group)*** | |
| Gratitude in the intervention group | 27 | “I guess I felt pleased to be part of it and felt it would be beneficial to me and I think it was” *(Female, 60, intervention)*  “I was glad because I don’t know that I would have done it myself” *(Female, 40, intervention)* |
| Indifference about randomisation | 23 | “I’m just one cog in this whole thing and it didn’t matter to me which way or the other way I was going” *(Female, 47, control)*  “I was okay with it, as I say I had no issues with it at all” *(Male, 73, intervention)* |
| Disappointment but understanding in the role of the control group | 14 | “Well I think disappointed, yes, because I was looking forward to seeing what was going to be on the app and how it was going to work” *(Female, 61, control)*  “I was disappointed to start with…But that was like five seconds…And then I understood. It’s like, you know, both are required for the study” *(Male, 64, control)* | |
| Not understanding or knowing about randomisation | 6 | “I didn’t really understand between the groups was, so I just stayed with you know what I call the standard army issue one…Well was the other one going into meetings or sitting down with people in a circle and all saying “I’ve got cancer” and blah de blah de blah” *(Male, 69, intervention)*  “Well I didn’t know what group I was in. I haven’t been told what group I’m in. I still don’t know what group I’m in.” *(Female, 66, control)* |
| †Two participants were not asked about the acceptability of randomisation. | | |

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| Supplementary Table 6. Illustrative quotes and frequency counts about the acceptability of study assessments | | |
| **Feedback** | **n** | **Supporting quotes *(sex, age [in years], experimental group)*** |
| **Wearing the ActivPAL†** |  |  |
| Satisfaction with wearing the activPAL | 53 | “Once you’ve got it on you do tend to forget about it” *(Female, 61, control)*  “Didn’t bother me at all, not one bit. Just put it in and forgot about it really” *(Female, 62, intervention)*  “Fine, yes. Absolutely fine, yes, no problems at all” *(Female, 47, control)* |
| Discomfort wearing the activPAL | 14 | “A little bit of discomfort on a certain time because it kept pulling hairs on my legs”*(Male, 60, intervention)*  “It was itching me sometimes, so that was bothering me a little bit” *(Female, 56, intervention)*  “a little bit of red and soreness”*(Male, 41, control)* |
| ActivPAL fell off during the wear-period | 4 | “so on a couple of occasions it fell off”*(Male, 41, control)*  “the little guy bailed out three and a half days into the seven day period”*(Male, 73, control)* |
| More instructions about the activPAL are needed | 3 | “It was the peeling back those bits – don’t understand how that fitted with what I was doing” “Seeing it done in action to replicate it, then it’s easier to do**”** *(Female, 48, control)*  “I wouldn’t have known how to put it on you see if I didn’t have this other sticky tape” *(Female, 67, intervention)*  “I wondered whether I was a bit confused by what comes away and what doesn’t” *(Male, 76, intervention)* |
| **Completing body measurements‡** |  |  |
| Satisfaction with completion of body measurements | 58 | “Yes, yes, it was no problem doing them at home” *(Female, 59, control)*  “That was fine, yeah, didn’t bother me at all” *(Male, 69, intervention)* |
| Issues with completion of body measurements | 3 | “You know, I’m looking at it and thinking, and then you tighten it up a bit and then you slacken off a bit and you wonder what is the exact measurement”*(Male, 76 intervention)*  “It wouldn’t take the numbers and that for the weight” *(Male, 58, intervention)*  “Yes I didn’t understand why I was doing that” *(Male, 57, control)* |
| **Completion of study questionnaires§** |  |  |
| Satisfaction with the length of the questionnaires | 55 | “So, yes I didn’t find it a problem at all anyway doing that” *(Female, 58, control)*  “I did have to find like twenty minutes to be able to do it but no that was fine” *(Female, 41, intervention)*  “That was okay, I had no problem, 10 minutes is not a big issue” *(Male, 73, intervention)* |
| Dissatisfaction with the length/relevance of the questionnaires | 15 | “The answers you were looking for I think you could’ve achieved in less questions” *(Female, 62, control)*  “Yes it was quite draining that, wasn’t it” *(Male, 74, intervention)*  “Yeah a lot of them were like over and over, sort of saying the same question in a different way, but it just wasn’t relevant to me” *(Female, 62, intervention)* |
| Emotions induced by the questionnaires | 1 | “We’ve just got to get on with it and I felt like it started making me think about it all again” *(Female, 67, intervention)* |
| †Two participants did not wear the activPAL. ‡11 participants were not asked about completing the body measurements. §One participant reported not remembering the questionnaire completion. | | |

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| Supplementary Table 7. Illustrative quotes and frequency counts about the timing of being approached to take part in the study† | | |
| **Feedback** | **N** | **Supporting quotes *(sex, age [in years], experimental group)*** |
| Satisfied with timing of being approached | 60 | “Yes it was fine for me. If I could have helped earlier, I would have” *(Female, 66, control)*  “I don’t think it matters, it’s down to a person, how a person reacts to it” *(Male, 69, intervention)*  “For me it was good because it was a distraction. It was something to do, something I had control over” *(Female, 62, control)* |
| Being approached after treatment is preferable | 6 | “Well it was a bit awkward because I was still undergoing radiotherapy, so initially I couldn’t do much at all because I was sort of all day at the hospital *(Male, 74 intervention)*  “Yes I would probably say maybe a few weeks after, two or three weeks afterwards to try and build your fitness levels up and that again” *(Male, 59, intervention)* |
| Mixed feelings about the timing of being approached | 3 | “Yes and no…I thought if I had given a choice of which week to wear or something it might have been better because then next week I could’ve worn it whole week so that is another thing” *(Female, 49, control)*  “Well yes and no…I wanted to take part but it was, because of the hormone treatment…I couldn’t process or play golf regular, like go for walks or anything like that” *(Male, 75, control)*  “Yes and no, I think I was still a bit depressed…at the same time I thought, well if it’s going to help me get going and as I say get out of this hole, start doing things I thought it was fine, a bit of both” *(Female, 67, intervention)* |
| †Three participants were not asked about how they felt about the timing of being approached. | | |

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| Supplementary Table 8. Illustrative quotes and frequency counts about participant willingness to link data with Hospital Episode Statistics and the National Cancer Registration and Analysis Service† | | |
| **Feedback** | **n** | **Supporting quotes *(sex, age [in years], experimental group)*** |
| Willingness to consent to linking their data | 71 | “I’d rather give the information, if it helps somebody else and helps you along the way long term no, fine do it” *(Female, 58, control)*  “yeah, and that don’t worry me at all. I’m hoping it might help people in the future so” *(Male, 69, intervention)*  “No I can’t remember but it would certainly have been okay, I would have agreed to that” *(Male, 68, control)* |
| †One participant did not remember giving consent for this and did not explain further. | | |

Cost effectiveness model

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| Supplementary Table 9. Summary of incremental per person scenario analysis results† | | | | | |
| **Scenario** | **Costs** | **QALYs** | **INMB** | **ICER** | **Prob. CE** |
| Basecase | £69.02 | 0.0019 | -£31.17 | £36,475 | 0.37 |
| No extreme values PA effectiveness | £72.18 | 0.0028 | -£15.35 | £25,403 | 0.45 |
| Upper bound PA effectiveness | £102.01 | 0.0120 | £138.05 | £8,499 | 1.00 |
| Lower bound PA effectiveness | £28.95 | -0.0098 | -£225.45 | -£2,947 | 0.00 |
| No treatment costs | £62.74 | 0.0019 | -£24.89 | £33,156 | 0.42 |
| Treatment costs 99% in intervention | -£72.62 | 0.0019 | £110.47 | -£38,380 | 0.92 |
| 1 year duration of effect | £64.49 | 0.0004 | -£56.58 | £163,026 | 0.00 |
| 5 year duration of effect | £70.81 | 0.0029 | -£13.72 | £24,805 | 0.46 |
| 7 year duration of effect | £71.54 | 0.0034 | -£3.56 | £21,048 | 0.49 |
| 10 year duration of effect | £71.89 | 0.0041 | £11.03 | £17,339 | 0.53 |
| Discount rate 1.5% | £69.38 | 0.0023 | -£23.95 | £30,541 | 0.42 |
| Discount rate 5% | £68.77 | 0.0017 | -£35.20 | £40,974 | 0.32 |
| Population baseline PA halved | £71.53 | 0.0027 | -£16.87 | £26,175 | 0.47 |
| Population baseline PA doubled | £65.56 | 0.0009 | -£48.08 | £74,994 | 0.11 |
| Population age <65 | £66.60 | 0.0014 | -£38.50 | £47,397 | 0.30 |
| Population age ≥65 | £73.85 | 0.0027 | -£19.95 | £27,400 | 0.44 |
| Population all colorectal cancer | £76.94 | 0.0031 | -£14.64 | £24,699 | 0.46 |
| Population all breast cancer (female) | £69.26 | 0.0021 | -£27.01 | £32,790 | 0.40 |
| Population all prostate cancer (male) | £64.50 | 0.0008 | -£49.41 | £85,457 | 0.12 |
| Population all cancer stage 4 | £87.66 | 0.0047 | £7.02 | £18,518 | 0.52 |
| Population all cancer stage 1 or 2 | £65.53 | 0.0011 | -£42.96 | £58,063 | 0.19 |
| Abbreviations: QALY=quality-adjusted life year; INMB=incremental net monetary benefit; ICER=incremental cost-effectiveness ratio; prob.CE=probability cost effective; PA=physical activity.  †Net monetary benefit and probability cost-effective represent the £20,000 per QALY threshold. | | | | | |

Promoting physical activity via a smartphone application in people living with cancer (APPROACH): Pilot Study

Supplementary Information

Health Economic Modelling Methods

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[Appendix D: Model Parameters and their Distributions 31](#_Toc130547221)

Model Structure

The APPROACH model was developed as an adaptation of the health economic model used for the U@Uni study [1, 2]. This is an individual patient Markov-style model written in the R programming language, which links health behaviours directly to mortality outcomes. There are effectively only two health states in the U@Uni model: Alive and Dead, with transition from the Alive to the Dead state being dependent upon patient characteristics, health behaviours and interventions. However, in the APPROACH model, the Dead stage is split into either cancer death or other cause death as shown in Figure 1. The model has annual cycles and a lifetime horizon.

*Figure 1: Diagram showing the structure of the APPROACH health economic model*

A diagram of cancer

Description automatically generated

Model Baseline Population

The model baseline population is selected at random (with replacement) from the 87 individuals who were enrolled in the APPROACH pilot (intervention and control arms combined) and who had complete baseline physical activity data. Only a small subset of the population characteristics gathered in the APPROACH pilot were used in the model to inform the baseline population. These include age, sex, cancer type (either breast cancer, prostate cancer or colorectal cancer), cancer stage (from 1 at the least severe to 4/metastatic at the most severe), baseline physical activity data, and responses to the Euroqol 5-dimensions (EQ-5D) 5 level questionnaire which enables health-related quality of life to be assessed [3]. Summary information for the baseline population from the APPROACH pilot is presented in Table 1.

*Table 1: Summary information for the individuals enrolled in the APPROACH pilot (n=87 with full physical activity data)*

|  |  |  |
| --- | --- | --- |
| CHARACTERISTICS | MEAN | STANDARD DEVIATION |
| Age | 62.5 | 10.4 |
| EQ-5D | 0.858 | 0.160 |
| Daily Total Stepping Minutes | 90.3 | 35.4 |
| Daily Stepping Minutes Above 100 Steps/Minute | 31.9 | 20.7 |
| Calculated METS (hours per week) | 30.39 | 12.39 |
|  | Percentage |  |
| Male | 51.7% |  |
| Breast Cancer | 40.2% |  |
| Prostate Cancer | 39.1% |  |
| Colorectal Cancer | 20.7% |  |
| Stage 1 Cancer | 32.2% |  |
| Stage 2 Cancer | 33.3% |  |
| Stage 3 Cancer | 26.4% |  |
| Stage 4/Metastatic Cancer | 8.0% |  |

Physical Activity Trajectories

Whilst the U@Uni model included four different health behaviours (smoking, alcohol consumption, physical activity and fruit & vegetable consumption) [1, 2], the APPROACH model includes only physical activity. The APPROACH study collected physical activity information using two metrics – total time spent stepping and time spent stepping at a pace that is above or equal to 100 steps per minute (both in hours per day), with the primary outcome for the APPROACH study being the second of these. From this, time spent stepping at a lower rate could be calculated by subtracting the time spent stepping over 100 steps/minute from the total time spent stepping. Note that the accelerometers used in the study were able to pick up data on types of physical activity other than walking, but these would all be conceptualised in terms of steps, so more vigorous activity (e.g. running) would likely fall into the over 100 steps/minute category.

We converted these measurements into Metabolic Equivalents (known as METS), which are defined as a ratio of energy expenditure for a given task compared with energy expenditure when resting [1, 2]. There were several reasons for using METS. Firstly, the data linking physical activity to risk of mortality (see below section) primarily uses METS to define different levels of physical activity; secondly, it enables changes in both the total amount and level of physical activity to be included in the modelling, as both will have mortality benefits. Evidence suggests that a stepping rate of 100 steps per minute is roughly equivalent to 3 METS which represents the boundary between moderate and light physical activity [4], although this varies by physical activity type and personal characteristics. In the APPROACH trial, the average stepping rate ≥100 steps per minute was approximately 110 steps per minute, whilst the average rate <100 steps per minute was not collected. In the basecase analysis, it was assumed that stepping at a rate <100 steps per minute was equivalent to 2.55 METs, the midpoint between male and female confidence intervals for light activity from a 1990 paper which calculated MET values for a large range of different activities [5], whilst stepping at ≥100 steps per minute (mean 110 steps per minute) was assumed to be approximately equivalent to 3.5 METs. Note that these were parameterised as non-overlapping distributions to ensure METS ≥100 steps per minute would always be greater than METS <100 steps per minute. Total METs (in minutes per week) were calculated for each baseline individual using these values and distributions.

Physical activity varies over the life course, with the total amount declining as people age. Individual trajectories of physical activity over time in METs were estimated based on the percentile method. This assigns each individual at baseline to an activity percentile compared to the distribution in activity in a representative group of the same age. For example, someone who is very active might be on the 95th percentile, meaning that 95% of individuals of their age do less physical activity and only 5% do more physical activity. Individuals are then assumed to stay on the same percentile as they age, unless intervention moves them to a different percentile. This means that their weekly METs will vary over their life course in a realistic way.

Health Survey for England (HSE) 2014 individual level data was used to obtain physical activity distributions for each age [6]. HSE was chosen as it is fairly large and representative sample of the English population. Data from three variables was selected: TotmVigWk (time spent on vigorous physical activity in the last week in minutes), TotmModWk (time spent on moderate physical activity in the last week in minutes) and TotmWalWk (time spent walking in the last week in minutes). HSE individuals not eligible for exercise data to be collected were removed from the sample (mainly those aged under 16), and missing data was recoded (assumed to be zero). Total METs (hours per week) were then calculated for each remaining person in the population, using the method described above and assuming that time spent walking corresponded to light activity as previously defined. For light, moderate and vigorous activity, MET values of 2.55 (95% CI: 1.2 - 3.9), 4.35 (95% CI: 2.8 - 5.9) and 6.15 (95% CI: 4.4 – 7.9) were chosen as the midpoint between male and female confidence intervals for light, moderate and heavy activity respectively, from a 1990 paper which calculated MET values for a large range of different activities [5].

Figure 2 shows a graph plotting change in METs over time by decile of the HSE 2014 population.

*Figure 2: Calculated mean physical activity (MET hours per week) for each decile of the HSE 2014 population.*

A graph of age and age

Description automatically generated with medium confidence

Physical Activity Risk Functions

Literature Review

A rapid review was carried out to identify published literature sources that linked post-diagnosis physical activity in people with breast, prostate or colorectal cancer to mortality outcomes. Searches were carried out in a single database (PubMed). Search terms included terms for cancer, physical activity (“exercise” or “physical activit\*” or “sport” or “walking” or “steps”) and mortality (“mortality” or “survival” or “death” or “fatality”). In total 623 citations were identified through searches. An additional 20 citations were identified through citation searching of a systematic review produced by the 2018 Physical Activity Guidelines Advisory Committee Scientific Report [7]. After duplicates were removed this resulted in a total of 630 citations.

Inclusion and exclusion criteria were specified as given in Table 2. Using these criteria, 603 citations were excluded and the remaining 27 titles were evaluated at full text level. Three full texts were excluded because they combined survivors of different types of cancer into a mixed population for analysis and four were excluded because they didn’t include mortality outcomes. The remaining 20 studies included 11 that considered breast cancer only [8-18], five that considered prostate cancer only [19-23], two that considered colorectal cancer only [24, 25], one study that looked at breast and colorectal cancer separately [26], and one study that looked at all three cancer types separately [27] (see Appendix A for a summary). All studies indicated a significant impact of physical activity on both all-cause mortality and cancer-specific mortality (Appendix A). Most studies used weekly METS as the measure of physical activity and considered multiple MET cut-off points.

*Table 2: Inclusion and exclusion criteria for a review of literature linking post-diagnosis physical activity in people with cancer to mortality outcomes.*

|  |  |  |
| --- | --- | --- |
| Selection Criteria | Inclusion | Exclusion |
| Population | Adults (aged 16 years or over) with breast, prostate, or colorectal cancer at any stage | Children (aged under 16)  Adults without breast, prostate, or colorectal cancer |
| Intervention | Post-diagnosis physical activity | Pre-diagnosis physical activity |
| Comparators | No or less physical activity than intervention. | None |
| Outcomes | All-cause mortality.  Cancer specific mortality. | Outcomes for primary prevention of cancer.  Pooled mortality estimates for unspecified cancer subtypes. |
| Study type | Any type of study | None |
| Language | Studies published in English | Studies published in other languages |

Separate studies were identified for each of the three cancer types [17, 23, 26], based on a series of criteria including study type (meta-analysis preferred, followed by clinical trials and then observational studies), population (representative of all cancer stages preferred), study sample size, study location (UK or Europe preferred), study date, and reporting of outcomes (outcomes from multiple, clearly defined physical activity categories preferred). Data from the three chosen studies is shown in Table 2.

*Table 3: Data used to construct continuous risk functions linking physical activity and mortality*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Continuous Risk Functions Data | | | | | | Ref |
| Breast Cancer Mortality | MET hrs per week | <3 | 2.5-8.9 | ≥7.5 | ≥14.9 | [17] |
| Hazard Ratio | 1 | 0.68 | 0.59 | 0.62 |
| Breast Cancer: Other Cause Mortality | MET hrs per week | <3 | 2.5-8.9 | ≥7.5 | ≥14.9 |
| Hazard Ratio | 1 | 0.69 | 0.59 | 0.52 |
| Prostate Cancer Mortality | MET hrs per week | <3.5 | 3.5-8.75 | 8.75-17.5 | ≥17.5 | [23] |
| Hazard Ratio | 1.13 | 1 | 0.81 | 0.69 |
| Colorectal Cancer Mortality | MET hrs per week | <3 | +5 | +10 | +15 | [26] |
| Hazard Ratio | 1 | 0.86 | 0.75 | 0.65 |
| Colorectal Cancer: Other Cause Mortality | MET hrs per week | <3 | +5 | +10 | +15 |
| Hazard Ratio | 1 | 0.85 | 0.72 | 0.62 |

In general, the studies indicated that impacts on cancer-specific and all-cause mortality were fairly similar; so whilst the chosen prostate cancer study only reported impacts on cancer-specific mortality [23], it was assumed that there would be the same impact on all-cause mortality, and for all three cancer types it was assumed that the impact on other (non-cancer) causes of mortality would be similar to that for all-cause mortality. There was a further limitation with the prostate cancer study only recruiting patients with non-metastatic cancer [23]; however it was assumed that similar benefits would also accrue to patients with metastatic cancer.

Constructing continuous risk functions

The data suggests that the relationship between physical activity and reduced mortality risk is continuous, meaning that even small changes in physical activity are likely to have some impact on mortality risk. Continuous risk functions were constructed to enable the relationship between mortality hazard ratios and physical activity to be represented. Most of the mortality hazard ratios given by the studies use the category with lowest physical activity as the reference, with higher physical activity categories having hazard ratios of below one. It was therefore necessary to adjust the hazard ratios so that a value of one corresponded to the population mean level of physical activity, enabling individuals with lower physical activity levels to have greater mortality than average, and those with higher physical activity levels to have lower mortality than average. Ideally, data from individuals with cancer would be used to adjust hazard ratios; however, the APPROACH pilot does not include sufficient individuals to do this, so HSE 2014 METs data (calculated as described above) [6], from individuals aged 40 and over (no-one enrolled in APPROACH was aged under 40), was used instead. This is a minor limitation because individuals with cancer have lower levels of physical activity than people in the general population on average, which means that more than half are likely to end up with hazard ratios over one, and this might lead to a slight overestimate of total cancer and other cause mortality in the population.

For each continuous risk function, adjusted hazard ratios for each MET category were estimated in reference to all other MET categories using the following equation:

Adj\_HRcatA = (HRcatA \* HSEcount catA + ... HRcatX \* HSEcount catX)/( HSEcount catA + ... HSEcount catX)

Where Adj\_HR = adjusted hazard ratio; HR = published hazard ratio; HSEcount = number of individuals in that MET category; catA/catX = MET categories given in published data.

For each MET category, mean METS was calculated using HSE data, and then linear regression of log mean METS against adjusted HRs was carried out to obtain a slope and intercept parameter for each continuous risk function. In general the curves fitted reasonably well with an R2 for each one of around 0.9-0.93. A graphical representation of the continuous risk function for prostate cancer mortality is shown in Figure 3, whilst the slope and intercept parameters for each continuous risk function are shown in Table 3.

*Figure 3: A graph showing the continuous risk function for prostate cancer mortality. Average METS are plotted against adjusted hazard ratios for each physical activity category (red diamonds) and the logarithmic curve fitted to the data (black line), together with its equation and R2 (top right).*

A graph of cancer

Description automatically generated

*Table 4: Parameter values for continuous risk functions linking physical activity with mortality*

|  |  |  |  |
| --- | --- | --- | --- |
| Continuous Risk Function | Slope | Intercept | R2 |
| Breast Cancer Mortality | -0.0958 | 1.2914 | 0.9108 |
| Breast Cancer: Other Cause Mortality | -0.1076 | 1.3198 | 0.9289 |
| Prostate Cancer Mortality | -0.1077 | 1.3368 | 0.9317 |
| Prostate Cancer: Other Cause Mortality | -0.1077 | 1.3368 | 0.9317 |
| Colorectal Cancer Mortality | -0.1087 | 1.3117 | 0.9047 |
| Colorectal Cancer: Other Cause Mortality | -0.1214 | 1.3451 | 0.8991 |

Note that the continuous risk function gives a value of infinity for anyone with 0 METS of physical activity (which is the case for many individuals particularly at older ages). To avoid this causing an error in the model all values of 0 METS were replaced with 0.1 METS. This meant that the greatest adjusted hazard ratios for people doing the least physical activity ranged between 1.51 and 1.62.

Cancer Mortality

Cancer mortality was informed using Office for National Statistics (ONS) publicly available net survival data, based on adults diagnosed with cancer between 2013 and 2017, and followed up until 2018 [28]. Net survival data by cancer type, stage, sex and age group for one and five years after diagnosis, was extracted from the pivot table. Year one mortality was calculated directly from the year one survival data. Probability of mortality in each of years’ two to five was assumed to be constant and was calculated by converting the mortality difference between year five and year one into an annual rate and back into an annual probability. Unfortunately 10-year survival data was not available by stage and age, although there is some further cancer-specific mortality expected in this time period. The mortality rate was assumed to be half of that in years 2-5. It was assumed that there would be no further death from cancer ten years or more after diagnosis. Full cancer mortality parameters can be found in Appendix B.

Each modelled patient was assigned a risk of cancer mortality depending upon their cancer type, stage, sex and age group and time since diagnosis. It was assumed that year one mortality would correspond to the first modelled year, given that patients enrolled in APPROACH had recently finished their acute treatment. Physical activity hazard ratios obtained using the continuous risk functions described above were then applied to modify risk of cancer mortality by physical activity level for each patient.

Other Cause Mortality

ONS life tables for the United Kingdom (2018-2020) were used to inform all-cause mortality rates by age and sex (based on the qx variable) [29]. Given that cancer mortality was estimated separately, it was necessary to subtract this from the all-cause mortality rates to get other cause mortality. This was done separately for each of the three included cancer types. To do this, publicly available ONS death certificate data for 2019 by underlying cause, age and sex was used [30]. For colorectal cancer C18 Malignant neoplasm of colon and C19 Malignant neoplasm of rectum were combined to represent colorectal cancer death. For breast cancer C50 Malignant neoplasm of breast was selected, and for prostate cancer C61 Malignant neoplasm of prostate was selected. Total deaths from all causes was also extracted. The proportion of death due to each of the three cancers by age was calculated and these values were subtracted from the all-cause mortality rate to get the other cause mortality rate. It was assumed that anyone aged beyond 100 would have 100% mortality from other causes. Each modelled patient was assigned a risk of other cause mortality for each year of their life depending upon their cancer type, sex and age. Physical activity hazard ratios obtained using the continuous risk functions described above were then applied to modify risk of other cause mortality by physical activity level for each patient. Full other cause mortality parameters can be found in Appendix C.

Utilities

Each modelled individual has an EQ-5D score at baseline which represents their health-related quality of life. Given that patients enrolled in APPROACH are living with cancer and within 6 months of radical treatment, it is likely that many of them are still suffering symptoms or recovering from treatment. Baseline EQ-5D is therefore likely to be considerably lower than a general population of the same age. There are various studies available that assess health-related quality of life in people with cancer. These tend to indicate that quality of life is poorer in people with higher stage cancer, and often is worse in the first year after diagnosis than in subsequent years, due to the impact of treatments [31-33]. It is therefore important in the modelling to reflect any improvements in utility that are likely to occur in subsequent years compared to the first year.

For the modelling, three different sources were chosen for cancer utilities through rapid Google search and review, each one representing one of the cancer types included. For breast cancer, a 2007 Swedish study of 361 patients was chosen as this was one of the few breast cancer utility studies that provided a general estimate for first year and subsequent years, with a separate estimate given for metastatic disease [33]. For prostate cancer, utility estimates were taken from a 2014 modelling study for prostate-specific antigen screening, which combined utilities from various sources to get values to inform model health states [32]. For year one utility (all stages), an average of utility at 2-12 months after radiation therapy or prostatectomy was used; for subsequent year utility for stage 1-3, utility in the post-recovery period was taken; and for subsequent year utility for metastatic disease, utility of patients in palliative care was taken. For colorectal cancer, a 2014 review and meta-analysis of CRC utilities was used [31], which provided a linear fixed effects model for utility based on various characteristics. Utilities chosen for the APPROACH model all included the intercept and the EQ-5D coefficient, with year one utilities also including the ‘3 months after surgery’ coefficient and stage 4 utilities including the ‘stage 4’ coefficient.

It was assumed in the modelling that the baseline EQ-5D values represented the health-related quality of life in the first year after diagnosis. Utility multipliers were calculated to represent the change in health-related quality of life in subsequent years by cancer type and stage. An age decrement of 0.00432 was also applied for each subsequent year of the patients’ lives, to represent the gradual decline in quality of life due to other causes as people age [34].

Model utilities were discounted by 3.5% in line with National Institute of Health and Care Excellence (NICE) guidelines [35].

*Table 5: Utilities taken from the selected studies*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Health State Informed by Utility | Mean | Lower 95% CI | Upper 95% CI | Source |
| Breast Cancer Year 1, Stage 1-3 | 0.696 | 0.634 | 0.747 | [33] |
| Breast Cancer Year 1, Stage 4 | 0.685 | 0.62 | 0.735 |
| Breast Cancer Year 2+, Stage 1-3 | 0.779 | 0.7 | 0.849 |
| Breast Cancer Year 2+, Stage 4 | 0.685 | 0.62 | 0.735 |
| Prostate Cancer Year 1, Stage 1-3 | 0.775 | 0.655 | 0.895 | [32] |
| Prostate Cancer Year 1, Stage 4 | 0.775 | 0.655 | 0.895 |
| Prostate Cancer Year 2+, Stage 1-3 | 0.95 | 0.93 | 1 |
| Prostate Cancer Year 2+, Stage 4 | 0.6 | 0.24 | 0.86 |
| Colorectal Cancer Year 1, Stage 1-3 | 0.87 | 0.74 | 0.99 | [31] |
| Colorectal Cancer Year 1, Stage 4 | 0.68 | 0.54 | 0.81 |
| Colorectal Cancer Year 2+, Stage 1-3 | 0.92 | 0.8 | 1.04 |
| Colorectal Cancer Year 2+, Stage 4 | 0.73 | 0.61 | 0.86 |
| Age (additional year) | -0.00432 | -0.00460 | -0.00404 | [34] |

Disease Costs

The model takes an NHS perspective. Some information about utilisation of NHS resources (including appointments and medications) was obtained from patients in the APPROACH pilot using the CSRI questionnaire. However, with such a small number of patients enrolled in the pilot, costs were likely to be highly variable and any differences between arms would be unlikely to be statistically significant but could be highly skewed due to chance events. We therefore chose not to use the CSRI data for this pilot analysis and instead decided to parameterise disease costs in the model using literature-based costs for cancer patients.

A single UK costing study from 2016 was identified (through previous review of cost sources during our other cancer modelling work), which covered all three cancer types [36]. This study reports NHS costs for people from up to three years prior to cancer diagnosis, to nine years after diagnosis. Costs are reported for two age groups (<65 and ≥65) and for breast and colorectal cancer are also split into early stage (1-2) and late stage (3-4). It was assumed in the modelling that individuals would incur the year one cost in the first modelled year, and subsequently incur the year 2-9 costs over the following eight years. From year 10 onwards, no disease costs were assumed to be incurred. Costs for all years were assigned in the model based on the age at diagnosis. Disease costs were inflated to 2021 costs using the NHS Cost Inflation Indices [37]. Model costs were discounted by 3.5% in line with NICE guidelines [35]. Full details of costs used in the modelling can be found in the parameters table in Appendix D.

Intervention

Effectiveness

Intervention effectiveness was taken from the APPROACH pilot. The pilot ran for three months, after which average total time spent stepping and time spent stepping at a rate greater or equal to 100 steps per minute was re-measured. The average difference in stepping time for each of these two measurements at 3 months compared to the baseline measurements was taken for each arm, and then the intervention effects were calculated by the trial statistician as the difference between arms (Table 5). For the >100 steps per minute variable, a separate calculation of intervention effect was performed excluding two individuals with extreme stepping values, which resulted in a much higher intervention effect. This was used in a sensitivity analysis. Note that with the larger sample of the main trial it will be possible to include individual level variation to enable intervention effectiveness to vary by cancer type, stage and other personal characteristics if there are significant differences by subgroup. However, the pilot study sample was too small to make this worthwhile for the preliminary health economic model. All individuals in the intervention arm were therefore assumed to have the mean intervention effect. As the model runs on annual cycles, the three-month intervention effect was implemented at baseline rather than with a delay.

*Table 6: Effectiveness data from the APPROACH pilot study*

|  |  |  |
| --- | --- | --- |
| Parameter | Mean | 95% CI |
| Change in total stepping time, intervention vs control | 0.01 | -0.2; 0.22 |
| Change in stepping time >100 steps per minute, intervention vs control | 0.09 | -0.04; 0.23 |
| Change in stepping time >100 steps per minute, intervention vs control excluding extreme values | 0.15 | 0.02; 0.27 |

Duration of effect

No information is yet available from the APPROACH study to inform duration of intervention effect. However, a UK study of walking interventions in a general population did report data at one and three or four years of follow-up for three slightly different interventions [38]. Data for the nurse-based PACE-UP intervention, which recruited people aged 45-75, was thought to be most relevant to APPROACH. The data showed that the intervention effect almost halved at 12 months compared to 3 months; however the 12 month effect was then maintained until the end of the follow-up period at three years. Based on this, an equivalent reduction in intervention effectiveness at 12 months was implemented in our model, followed by a constant hold until a user-defined duration of effect time period had elapsed, after which no further effect was assumed to apply. This user-defined duration of effect was set to three years in the basecase analysis to reflect the follow-up time from the PACE-UP data, but was varied in sensitivity analysis to investigate the impact of the considerable uncertainty around this parameter (see below).

Lag time

The U@Uni model included a lag time to mortality impact, which was derived from expert elicitation [1, 2]. This was required in the U@Uni model because individuals were very young at baseline, and a lack of physical activity would not affect health and mortality until they reached older ages. Evidence from the studies linking physical activity to mortality in cancer patients however, indicate that the benefits of physical activity for preventing mortality occur within a reasonably short time period (most have been measured over a small number of years), and therefore it was appropriate to assume that there would be no lag in implementation of the mortality benefits. Equally it was assumed that there would be no lag in the reduction or removal of mortality benefits once the intervention duration of effect had passed.

Intervention cost

The intervention was costed directly from resources used in the APPROACH pilot. This included printing and posting materials which were costed directly, and nurse time for training and to deliver the intervention, which were costed using PSSRU unit costs [37]. It was assumed that a mid-Band 7 hospital nurse would deliver the intervention on an individual basis to 200 patients per year, taking 55 minutes per patient; whilst a Band 8a hospital nurse would deliver a day of training to ten Band 7 nurses, which would be valid for three years. This resulted in a total cost of £62.52 to deliver the intervention to each patient. Cost breakdowns are shown in Table 6.

*Table 7: Intervention resource use and costs*

|  |  |  |  |
| --- | --- | --- | --- |
| Item | Unit Cost | N Patients | Cost per Patient |
| Printing Materials | £127.00 | 45 | £2.82 |
| Posting Materials | £2.00 | 1 | £2.00 |
| Band 7 Nurse to deliver intervention (55 minutes) | £56.83 | 1 | £56.83 |
| Band 7 Nurse training (7.5 hours) | £465.00 | 600 | £0.78 |
| Band 8a Nurse to deliver training (7.5 hours) | £525.00 | 6000 | £0.09 |
| TOTAL | | | £62.52 |

Model Running and Sensitivity Analysis

Cost-effectiveness modelling was carried out using probabilistic sensitivity analysis (PSA), which produces a joint distribution of costs and QALYs for intervention and comparator arms. PSA involves running the model multiple times, each time using different parameter values randomly drawn from their probability distributions. A full table of all parameter values and their distributions for PSA can be found in Appendix C. PSA enables a true estimate of the mean output values to be obtained, taking into account model non-linearity and also enables the impact of parameter uncertainty to be assessed. For each modelling analysis, 5000 PSA runs were carried out for the cohort of 87 individuals, each with a different set of sampled parameter values.

In addition, a set of scenario analyses were carried out (each using PSA) to investigate structural uncertainties in the modelling.

1. **Intervention Effectiveness:** Different scenarios around effectiveness were implemented in sensitivity analysis. Firstly, the alternative estimate produced by excluding the two individuals with extreme values was used. Secondly, the pilot study is not sufficiently powered to detect significant impacts on physical activity, meaning that uncertainty around the mean result could be higher than that implied by the distribution implemented in the PSA. To investigate this uncertainty further, sensitivity analysis was carried out using alternative mean effectiveness values corresponding to the 95% confidence intervals for both the >100 steps per minute and the total steps per minute measures (note that in these two sensitivity analyses the mean physical activity was kept at the same value in all PSA runs, but all other parameters, including METS conversion parameters varied as normal).
2. **Intervention Costs:** An analysis was carried out to determine what level of intervention costs would change the decision based on a willingness to pay threshold of £20,000 per QALY.
3. **Duration of effect:** Sensitivity analyses were carried out to investigate uncertainty around duration of effect. Alternate values were utilised assuming either immediate return to baseline after the first year (the most pessimistic scenario), or longer return to baseline of up to ten years representing an optimistic scenario. Additional analyses were carried out to find at which point the decision changed based on a willingness to pay threshold of £20,000 per QALY.
4. **Disease costs:** Healthcare costs for people with cancer have been included in the model from external sources as there is insufficient data gathered as part of the APPROACH pilot to inform these costs. However, whilst in practice increasing physical activity is likely to reduce healthcare costs, this cannot be informed from the pilot, so the only impact the intervention has on these costs is to increase them indirectly through people living for longer as a result of doing more physical activity. This may lead to the intervention appearing less cost-effective than it actually is. Alternative scenarios were modelled where; a) disease costs were not included in the model at all; b) disease costs were assumed to be reduced by 1% in all individuals due to intervention.
5. **Population:** Sensitivity analysis was carried out around the level of baseline physical activity in the population, age, and cancer type and stage to see whether the intervention is more cost-effective in more active versus less active individuals, or in individuals of different cancer types and stages. Alternative scenarios were modelled where baseline physical activity measurements were either halved or doubled, where all patients were assumed to be stage 4 (metastatic) or early stages (stage 1 or 2), where all patients were assumed to represent only one of the cancer types (with relevant sex also selected where necessary) and where patients were aged either under 65 or over 65. This approach was taken rather than modelling each population subgroup separately, as the sensitivity analyses aimed to assess the impact of each characteristic being examined in turn, and not other characteristics that may have been correlated in the sample. For each of these analyses the intervention effect was kept at the basecase level, although it is likely that at least some of them would impact on effectiveness, even though the pilot is insufficiently powered to detect this.
6. **Discounting:** Alternative discount rates for costs and QALYs of either 1.5% or 5% were used to investigate uncertainty around discounting.

Value of Information Analysis

Value of information analysis was carried out by applying the Sheffield Accelerated Value of Information (SAVI) tool [39] to the basecase results. This is an online tool which takes PSA parameter samples and modelled costs and QALYs corresponding to each sample as inputs, and calculates expected value of parameter information (EVPI), which enables an estimate of the expected monetary value of removing all parameter uncertainty from the decision. In addition, SAVI can perform expected value of perfect parameter information (EVPPI) analysis, providing estimates of the expected value of removing uncertainty from single or groups of parameters, and thereby enabling identification of key parameters that contribute to decision uncertainty. Note that EVPI does not estimate the value of other model uncertainties (such as structural uncertainty).

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Appendix A: Review of Studies Linking Physical Activity & Mortality

*Table 8: A summary of included citations identified in a review of studies linking post-diagnosis physical activity in people with cancer to mortality.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Study Design** | **Setting** | **Population (N)** | **Type of physical activity** | **Follow-up** | **Survival Outcomes** | | | |
| **Outcome** | **Reference Group** | **Intervention Group** | **Hazard Ratio /Relative Risk**  **(95% CI)** |
| **Breast Cancer** | | | | | | | | | |
| Salam 2022 [17] | SR and meta-analysis of RCTs | Multiple | Breast cancer patients (18,214) | Various including walking and recreational activities | 1-11 years median | Cancer-specific mortality | <3 MET-h/wk | 2.5-<8.9 MET-h/wk  ≥7.5 MET-h/wk  ≥14.9 MET-h/wk | 0.68 (0.56-0.80)  0.59 (0.48-0.71)  0.62 (0.41-0.82) |
| All-cause mortality | <3 MET-h/wk | 2.5-<8.9 MET-h/wk  ≥7.5 MET-h/wk  ≥14.9 MET-h/wk | 0.69 (0.59-0.79)  0.59 (0.50-0.68)  0.53 (0.42-0.64) |
| Kehm 2021 [15] | Prospective cohort | Australia, Canada, USA, NZ | Patients having first invasive breast cancer (4,610) | Recreational physical activity | 11 years median | All-cause mortality | No recreational  physical activity (RPA) | Any RPA  Moderate RPA: 150-300 mins/wk  Strenuous RPA: 75-150 mins/wk | 0.84 (0.72-0.98)  0.82 (0.70-0.97)  0.86 (0.73-1.02) |
| Delrieu 2020 [10] | Non randomised, prospective cohort | France | Metastatic breast cancer patients within 1 year of diagnosis (833) | All activity (including walking, recreation, transport & work) | 3 years | All-cause mortality | <10 MET-h/wk | 10-50 MET-h/wk  >50 MET-h/wk | 0.95 (0.70-1.29)  0.76 (0.53-1.10) |
| Johnsson 2019 [12] | Prospective cohort | Sweden | Breast cancer patients (847) | Various including walking and recreational activities | 4-24 years | Cancer-specific mortality | PA score = 0 (no PA) | PA score = 1  PA score = 2  PA score = 3  PA score = 4  PA score = 5  PA score = 6 | 0.32 (0.05-1.95)  0.71 (0.20-2.52)  0.56 (0.16-2.04)  0.59 (0.19-1.84)  0.48 (0.15-1.55)  0.25 (0.03-2.29) |
| All-cause mortality | PA score = 0 (no PA) | PA score = 1  PA score = 2  PA score = 3  PA score = 4  PA score = 5  PA score = 6 | 0.71 (0.30-1.63)  0.47 (0.22-0.99)  0.45 (0.22-0.93)  0.43 (0.22-0.82)  0.35 (0.18-0.67)  0.29 (0.09-0.90) |
| Jung 2019 [14] | Prospective cohort | Germany | Patients with invasive breast cancer aged 50-74 (3,813) | Walking & cycling | 5.8 years median | Cancer-specific mortality | 0 MET-h/wk | >0 -<7.5 MET-h/wk  ≥7.5 MET-h/wk | 0.65 (0.37-1.16)  0.48 (0.25-0.91) |
| All-cause mortality | 0 MET-h/wk | >0 -<7.5 MET-h/wk  ≥7.5 MET-h/wk | 0.71 (0.48-1.06)  0.43 (0.26-0.72) |
| Spei 2019 [18] | SR and meta-analysis of observational studies | Multiple | Breast cancer patients (23,041) | Various including walking | 3.5-12.7 years median | Cancer-specific mortality | The lowest category in each study | The overall effect of PA | 0.87 (0.48-1.58) |
| All-cause mortality | The lowest category in each study | The overall effect of PA | 0.76 (0.48-1.20) |
| Friedenreich 2016a [27] | SR and meta-analysis of prospective cohort studies | Multiple | Breast cancer patients (17,666) | Various | 4.3-22 years median | Cancer-specific mortality | The least active participants | The most active participants | 0.62 (0.48-0.80) |
| Jones 2016 [13] | Prospective cohort | USA | Patients with early breast cancer (6,211) | Recreational physical activity | 7.2 years median | Cancer-specific mortality | <2 MET-h/wk | 2-10 MET-h/wk  >10-25 MET-h/wk  >25 MET-h/wk | 0.90 (0.68-1.19)  0.82 (0.62-1.10)  1.00 (0.74-1.34) |
| Ammitzbøll 2016 [8] | Prospective cohort | Denmark | Breast cancer patients (959) | Various including household, walking and recreational activities | 11-17 years | All-cause mortality | 0-41 MET-h/wk | >41-63 MET-h/wk  >63-97 MET-h/wk  >97 MET-h/wk  >41 MET-h/wk  Continuous (per 10 MET-h/wk) | 0.98 (0.61-1.58)  0.80 (0.48-1.31)  0.74 (0.42-1.28)  0.85 (0.57-1.29)  0.98 (0.94-1.02) |
| Lahart 2015 [16] | SR and meta-analysis of prospective cohort studies | Multiple | Breast cancer patients (123,574) | Recreational physical activity meeting guidelines | 4.3-12.7 years median | Cancer-specific mortality | <8 MET-h/wk Lowest PA | ≥8 MET-h/wk Highest PA | 0.67 (0.50-0.90)  0.59 (0.45-0.78) |
| All-cause mortality | <8 MET-h/wk Lowest PA | ≥8 MET-h/wk Highest PA | 0.54 (0.38-0.76)  0.52 (0.43-0.64) |
| Schmid 2014 [26] | SR and meta-analysis of prospective cohort studies | Multiple | Breast cancer patients (21,975) | Various | 3.3-10 years median | Cancer-specific mortality | 0 MET-h/wk  Least active | Inc of 5 MET-h/wk  Inc of 10 MET-h/wk  Inc of 15 MET-h/wk  Most active | 0.94 (0.92-0.97)  0.89 (0.85-0.94)  0.84 (0.78-0.91)  0.72 (0.60-0.85) |
| All-cause mortality | 0 MET-h/wk  Least active | Inc of 5 MET-h/wk  Inc of 10 MET-h/wk  Inc of 15 MET-h/wk  Most active | 0.87 (0.80-0.94)  0.76 (0.64-0.89)  0.66 (0.52-0.84)  0.58 (0.48-0.70) |
| Beasley 2012 [9] | Prospective cohort | UK, China, USA | Breast cancer patients (13,302) | Recreational physical activity | 2-28 years | Cancer-specific mortality | Lowest quintile (Q1)  ≤10 MET-h/wk | Q2  Q3  Q4  Q5  >10 ΜΕΤ-h/wk | 1.00 (0.83-1.21)  0.87 (0.71-1.06)  0.74 (0.60-0.91)  0.73 (0.59-0.91)  0.75 (0.65-0.85) |
| All-cause mortality | Lowest quintile (Q1)  ≤10 MET-h/wk | Q2  Q3  Q4  Q5  >10 ΜΕΤ-h/wk | 0.90 (0.77-1.04)  0.77 (0.66-0.90)  0.71 (0.60-0.84)  0.60 (0.51-0.72)  0.73 (0.66-0.82) |
| Ibrahim 2011 [11] | SR and meta-analysis | Multiple | Breast cancer patients (12,108) | Various | Not stated | Cancer-specific mortality | <3 MET-h/wk | 2.8 -<8.9 MET-h/wk  ≥8 MET-h/wk  ≥15 MET-h/wk  Overall effect of PA | 0.76 (0.61-0.95)  0.54 (0.40-0.73)  0.61 (0.46-0.81)  0.66 (0.57-0.77) |
| All-cause mortality | <3 MET-h/wk | 2.8 -<8.9 MET-h/wk  ≥8 MET-h/wk  ≥15 MET-h/wk  Overall effect of PA | 0.65 (0.55-0.76)  0.54 (0.45-0.66)  0.54 (0.45-0.66)  0.59 (0.53-0.65) |
| **Prostate Cancer** | | | | | | | | | |
| Dickerman 2019 [20] | Prospective cohort model | USA | Patients with non-metastatic prostate cancer (2,299) | Not specified | 10 years median | All-cause mortality | No PA intervention | ≥1.25 h/wk vig. PA  ≥2.5 h/wk vig. PA  ≥3.75 h/wk vig. PA  ≥2.5 h/wk mod. PA  ≥5 h/wk mod. PA  ≥7.5 h/wk mod. PA | 0.84 (0.75-0.94)  0.72 (0.58-0.88)  0.68 (0.53-0.85)  0.90 (0.84-0.94)  0.81 (0.73-0.88)  0.79 (0.71-0.86) |
| Wang 2017 [23] | Prospective cohort | USA | Patients with non-metastatic prostate cancer (5,319) | Various including walking and recreational activities | 1-20 years | Cancer-specific mortality | 3.5- <8.75 MET-h/wk | <3.5 MET-h/wk  8.75- <17.5 MET-h/wk  ≥17.5 MET-h/wk | 1.13 (0.77–1.66)  0.81 (0.58–1.15)  0.69 (0.49–0.95) |
| Friedenreich 2016a [27] | SR and meta-analysis of prospective cohort studies | Multiple | Patients with prostate cancer (8,158) | Various | 4.3-22 years median | Cancer-specific mortality | ≤42 MET-h/wk | >42-73 MET-h/wk  >73-119 MET-h/wk  >119 MET-h/wk | 0.66 (0.42-1.05)  1.02 (0.64-1.61)  0.65 (0.37-1.13) |
| All-cause mortality | ≤42 MET-h/wk | >42-73 MET-h/wk  >73-119 MET-h/wk  >119 MET-h/wk | 0.72 (0.56-0.93)  0.74 (0.57-0.97)  0.58 (0.42-0.79) |
| Friedenreich 2016b [21] | Prospective case control | Canada | Patients with stage II-IV invasive prostate cancer (988) | All activity (including walking, recreation, transport & work) | 14-17 years | Cancer-specific mortality | The least active participants | The most active participants | 0.62 (0.47-0.82) |
| Bonn 2015 [19] | Retrospective cohort | Sweden | Patients with localised prostate cancer (4,623) | Various including walking, recreational and household activities | 10-15 years | Cancer-specific mortality | <5 MET-h/d | >=5 MET-h/d | 0.78 (0.55-1.11) |
| All-cause mortality | <5 MET-h/d | >=5 MET-h/d | 0.63 (0.52-0.77) |
| Kenfield 2011 [22] | Prospective cohort | USA | Patients with non-metastatic prostate cancer (2,705) | Various including walking and recreational activities | 7.8-9.7 years median | Cancer-specific mortality | <3 MET-h/wk | 3- <9 MET-h/wk  9- <24 MET-h/wk  24- <48 MET-h/wk  >48 MET-h/wk | 0.91 (0.48-1.73)  0.6 (0.32-1.11)  0.83 (0.44-1.55)  0.42 (0.20-0.88) |
| All-cause mortality | <3 MET-h/wk | 3- <9 MET-h/wk  9- <24 MET-h/wk  24- <48 MET-h/wk  >48 MET-h/wk | 0.80 (0.61-1.06)  0.69 (0.53-0.90)  0.65 (0.49-0.86)  0.38 (0.27-0.53) |
| **Colorectal Cancer** | | | | | | | | | |
| Ratjen 2017 [24] | Prospective cohort | Germany | Patients with CRC (1,376) | Various including walking, recreational household activities | 7 years median | All-cause mortality | <64.5 MET-h/wk | >64.5-99.7 MET-h/wk  >99.7-144.9 MET-h/wk  >144.9 MET-h/wk | 0.65 (0.45-0.94)  0.52 (0.34-0.79)  0.53 (0.36-0.80) |
| Wu 2016 [25] | SR and meta-analysis of observational studies | Multiple | Patients with CRC (11,289) | Various | 3.8-11.9 years median | Cancer-specific mortality | No post-diagnosis PA | Post-diagnosis PA | 0.77 (0.63-0.94) |
| All-cause mortality | No post-diagnosis PA | Post-diagnosis PA | 0.71 (0.63-0.81) |
| Friedenreich 2016a [27] | SR and meta-analysis of prospective cohort studies | Multiple | Patients with CRC (9,698) | Various | 4.3-22 years median | Cancer-specific mortality | Least active participants | Most active participants | 0.62 (0.45-0.86) |
| Schmid 2014 [26] | SR and meta-analysis of prospective cohort studies | Multiple | Patients with CRC (6,862) | Various | 4.9-11.9 years median | Cancer-specific mortality | 0 MET-h/wk  Least active | Inc of 5 MET-h/wk  Inc of 10 MET-h/wk  Inc of 15 MET-h/wk  Most active | 0.86 (0.81-0.92)  0.75 (0.65-0.85)  0.65 (0.53-0.79)  0.61 (0.40-0.92) |
| All-cause mortality | 0 MET-h/wk  Least active | Inc of 5 MET-h/wk  Inc of 10 MET-h/wk  Inc of 15 MET-h/wk  Most active | 0.85 (0.81, 0.90)  0.72 (0.65, 0.80)  0.62 (0.53, 0.72)  0.58 (0.48-0.70) |

Appendix B: Cancer-specific Mortality Parameters

*Table 9: Breast cancer annual probabilities of mortality by age group, stage and time since diagnosis based on English breast cancer survival data from 2013-2017[28]. Note that no breast cancer survival data is available for men with breast cancer.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stage | Sex | Age group | Mortality Rate (years post-diagnosis) | | |
| Year 1 | Year 2-5 | Year 6-10 |
| Stage 1 | Female | 15-44 | 0.001 | 0.006061 | 0.00303 |
| 45-54 | 0 | 0.003519 | 0.001759 |
| 55-64 | 0 | 0.002006 | 0.001003 |
| 65-74 | 0 | 0.000751 | 0.000375 |
| 75-99 | 0.004 | 0.011752 | 0.005876 |
| Stage 2 | Female | 15-44 | 0.004 | 0.023399 | 0.011699 |
| 45-54 | 0.003 | 0.014086 | 0.007043 |
| 55-64 | 0.003 | 0.015923 | 0.007961 |
| 65-74 | 0.006 | 0.017295 | 0.008647 |
| 75-99 | 0.029 | 0.042253 | 0.021127 |
| Stage 3 | Female | 15-44 | 0.026 | 0.051599 | 0.0258 |
| 45-54 | 0.016 | 0.04631 | 0.023155 |
| 55-64 | 0.02 | 0.048284 | 0.024142 |
| 65-74 | 0.032 | 0.062111 | 0.031055 |
| 75-99 | 0.093 | 0.102232 | 0.051116 |
| Stage 4 | Female | 15-44 | 0.165 | 0.152387 | 0.076193 |
| 45-54 | 0.201 | 0.141509 | 0.070755 |
| 55-64 | 0.268 | 0.179971 | 0.089985 |
| 65-74 | 0.337 | 0.213262 | 0.106631 |
| 75-99 | 0.473 | 0.255395 | 0.127697 |

*Table 10: Prostate cancer annual probabilities of mortality by age group, stage and time since diagnosis based on English prostate cancer survival data from 2013-2017 [28]*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stage | Sex | Age group | Mortality Rate (years post-diagnosis) | | |
| Year 1 | Year 2-5 | Year 6-10 |
| Stage 1 | Male | 15-54 | 0.004 | 0.001257 | 0.000629 |
| 55-64 | 0 | 0 | 0 |
| 65-74 | 0 | 0 | 0 |
| 75-84 | 0 | 0 | 0 |
| 85-99 | 0 | 0.021696 | 0.010848 |
| Stage 2 | Male | 15-54 | 0 | 0 | 0 |
| 55-64 | 0 | 0.0005 | 0.00025 |
| 65-74 | 0 | 0 | 0 |
| 75-84 | 0 | 0 | 0 |
| 85-99 | 0 | 0.026809 | 0.013404 |
| Stage 3 | Male | 15-54 | 0 | 0.007842 | 0.003921 |
| 55-64 | 0 | 0.003519 | 0.001759 |
| 65-74 | 0 | 0.004531 | 0.002265 |
| 75-84 | 0 | 0.01067 | 0.005335 |
| 85-99 | 0.006 | 0.080031 | 0.040015 |
| Stage 4 | Male | 15-54 | 0.072 | 0.126199 | 0.0631 |
| 55-64 | 0.068 | 0.121941 | 0.060971 |
| 65-74 | 0.093 | 0.120374 | 0.060187 |
| 75-84 | 0.168 | 0.157089 | 0.078545 |
| 85-99 | 0.321 | 0.222598 | 0.111299 |

*Table 11: Colorectal cancer annual probabilities of mortality by age group, sex, stage and time since diagnosis based on English colorectal cancer survival data from 2013-2017 [28]*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stage | Sex | Age group | Mortality Rate (years post-diagnosis) | | |
| Year 1 | Year 2-5 | Year 6-10 |
| Stage 1 | Male | 15-44 | 0.006 | 0.004813 | 0.002407 |
| 45-54 | 0.01 | 0.007405 | 0.003703 |
| 55-64 | 0.008 | 0.009458 | 0.004729 |
| 65-74 | 0.022 | 0.009332 | 0.004666 |
| 75-99 | 0.053 | 0.040397 | 0.020199 |
| Female | 15-44 | 0.003 | 0.00241 | 0.001205 |
| 45-54 | 0.004 | 0.003709 | 0.001855 |
| 55-64 | 0.009 | 0.008431 | 0.004215 |
| 65-74 | 0.012 | 0.0051 | 0.00255 |
| 75-99 | 0.041 | 0.030285 | 0.015142 |
| Stage 2 | Male | 15-44 | 0.019 | 0.032937 | 0.016469 |
| 45-54 | 0.013 | 0.026627 | 0.013314 |
| 55-64 | 0.029 | 0.024024 | 0.012012 |
| 65-74 | 0.049 | 0.027393 | 0.013697 |
| 75-99 | 0.115 | 0.037669 | 0.018834 |
| Female | 15-44 | 0.015 | 0.018261 | 0.00913 |
| 45-54 | 0.018 | 0.024567 | 0.012283 |
| 55-64 | 0.024 | 0.019519 | 0.00976 |
| 65-74 | 0.051 | 0.025171 | 0.012585 |
| 75-99 | 0.122 | 0.031654 | 0.015827 |
| Stage 3 | Male | 15-44 | 0.057 | 0.071789 | 0.035895 |
| 45-54 | 0.055 | 0.062176 | 0.031088 |
| 55-64 | 0.055 | 0.061855 | 0.030928 |
| 65-74 | 0.078 | 0.07159 | 0.035795 |
| 75-99 | 0.178 | 0.114671 | 0.057335 |
| Female | 15-44 | 0.033 | 0.049586 | 0.024793 |
| 45-54 | 0.044 | 0.051427 | 0.025713 |
| 55-64 | 0.045 | 0.0521 | 0.02605 |
| 65-74 | 0.09 | 0.064491 | 0.032246 |
| 75-99 | 0.241 | 0.101804 | 0.050902 |
| Stage 4 | Male | 15-44 | 0.403 | 0.251888 | 0.125944 |
| 45-54 | 0.4 | 0.290677 | 0.145339 |
| 55-64 | 0.434 | 0.294775 | 0.147387 |
| 65-74 | 0.52 | 0.281097 | 0.140548 |
| 75-99 | 0.689 | 0.373213 | 0.186606 |
| Female | 15-44 | 0.387 | 0.271136 | 0.135568 |
| 45-54 | 0.388 | 0.278329 | 0.139165 |
| 55-64 | 0.446 | 0.279856 | 0.139928 |
| 65-74 | 0.556 | 0.281999 | 0.141 |
| 75-99 | 0.765 | 0.324256 | 0.162128 |

Appendix C: Other-Cause Mortality Parameters

*Table 12: Annual probability of other cause mortality for people with breast, prostate or colorectal cancer calculated from UK life tables 2018-2020 [29] and death certificate data 2019 [30] (note that there are some men with breast cancer in death certificate data)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Age | Male:  Prostate Cancer | Male:  Colorectal Cancer | Female: Colorectal Cancer | Male:  Breast Cancer | Female: Breast Cancer |
| 1 | 0.000229 | 0.000229 | 0.000214 | 0.000229 | 0.000214 |
| 2 | 0.000127 | 0.000127 | 0.000114 | 0.000127 | 0.000114 |
| 3 | 0.000102 | 0.000102 | 0.000095 | 0.000102 | 0.000095 |
| 4 | 0.000086 | 0.000086 | 0.000064 | 0.000086 | 0.000064 |
| 5 | 0.000074 | 0.000074 | 0.000074 | 0.000074 | 0.000074 |
| 6 | 0.000085 | 0.000085 | 0.000071 | 0.000085 | 0.000071 |
| 7 | 0.000067 | 0.000067 | 0.000055 | 0.000067 | 0.000055 |
| 8 | 0.000069 | 0.000069 | 0.000058 | 0.000069 | 0.000058 |
| 9 | 0.00006 | 0.00006 | 0.000051 | 0.00006 | 0.000051 |
| 10 | 0.000078 | 0.000078 | 0.000066 | 0.000078 | 0.000066 |
| 11 | 0.000077 | 0.000077 | 0.000055 | 0.000077 | 0.000055 |
| 12 | 0.000102 | 0.000102 | 0.000057 | 0.000102 | 0.000057 |
| 13 | 0.000116 | 0.000116 | 0.000087 | 0.000116 | 0.000087 |
| 14 | 0.000129 | 0.000129 | 0.000096 | 0.000129 | 0.000096 |
| 15 | 0.000172 | 0.000171 | 0.000113 | 0.000172 | 0.000113 |
| 16 | 0.000205 | 0.000204 | 0.000131 | 0.000205 | 0.000131 |
| 17 | 0.000311 | 0.00031 | 0.000158 | 0.000311 | 0.000158 |
| 18 | 0.000402 | 0.0004 | 0.000218 | 0.000402 | 0.000218 |
| 19 | 0.000454 | 0.000452 | 0.000212 | 0.000454 | 0.000212 |
| 20 | 0.000525 | 0.000525 | 0.000187 | 0.000525 | 0.000186 |
| 21 | 0.000507 | 0.000507 | 0.00021 | 0.000507 | 0.00021 |
| 22 | 0.000497 | 0.000497 | 0.000244 | 0.000497 | 0.000244 |
| 23 | 0.000524 | 0.000524 | 0.000214 | 0.000524 | 0.000214 |
| 24 | 0.000556 | 0.000556 | 0.000222 | 0.000556 | 0.000222 |
| 25 | 0.000601 | 0.000594 | 0.000258 | 0.000601 | 0.000254 |
| 26 | 0.000607 | 0.0006 | 0.000255 | 0.000607 | 0.000251 |
| 27 | 0.000629 | 0.000622 | 0.000307 | 0.000629 | 0.000303 |
| 28 | 0.000681 | 0.000673 | 0.000311 | 0.000681 | 0.000307 |
| 29 | 0.000728 | 0.00072 | 0.000335 | 0.000728 | 0.000331 |
| 30 | 0.000771 | 0.000757 | 0.000373 | 0.000771 | 0.000355 |
| 31 | 0.000835 | 0.00082 | 0.00038 | 0.000835 | 0.000362 |
| 32 | 0.000858 | 0.000842 | 0.000451 | 0.000858 | 0.00043 |
| 33 | 0.000957 | 0.000939 | 0.000475 | 0.000957 | 0.000453 |
| 34 | 0.000989 | 0.000971 | 0.000564 | 0.000989 | 0.000537 |
| 35 | 0.0011 | 0.001062 | 0.000564 | 0.0011 | 0.000526 |
| 36 | 0.001155 | 0.001115 | 0.000646 | 0.001155 | 0.000602 |
| 37 | 0.001351 | 0.001304 | 0.000725 | 0.001351 | 0.000676 |
| 38 | 0.001317 | 0.001271 | 0.000754 | 0.001317 | 0.000704 |
| 39 | 0.001457 | 0.001406 | 0.000827 | 0.001457 | 0.000771 |
| 40 | 0.001605 | 0.001557 | 0.000885 | 0.001605 | 0.000814 |
| 41 | 0.001699 | 0.001648 | 0.000962 | 0.001699 | 0.000885 |
| 42 | 0.001847 | 0.001792 | 0.001056 | 0.001847 | 0.000971 |
| 43 | 0.002014 | 0.001954 | 0.001187 | 0.002014 | 0.001092 |
| 44 | 0.002208 | 0.002143 | 0.001288 | 0.002209 | 0.001185 |
| 45 | 0.002459 | 0.002403 | 0.001438 | 0.002467 | 0.001272 |
| 46 | 0.002637 | 0.002577 | 0.001574 | 0.002645 | 0.001393 |
| 47 | 0.002734 | 0.002672 | 0.00169 | 0.002742 | 0.001495 |
| 48 | 0.00295 | 0.002883 | 0.001905 | 0.002959 | 0.001686 |
| 49 | 0.003286 | 0.003212 | 0.001987 | 0.003296 | 0.001759 |
| 50 | 0.003555 | 0.003453 | 0.002143 | 0.003577 | 0.001936 |
| 51 | 0.003797 | 0.003689 | 0.002352 | 0.003821 | 0.002125 |
| 52 | 0.00405 | 0.003934 | 0.002476 | 0.004075 | 0.002237 |
| 53 | 0.004375 | 0.00425 | 0.002651 | 0.004402 | 0.002395 |
| 54 | 0.004691 | 0.004557 | 0.002843 | 0.00472 | 0.002569 |
| 55 | 0.004977 | 0.004856 | 0.003146 | 0.005044 | 0.002932 |
| 56 | 0.005516 | 0.005382 | 0.003485 | 0.00559 | 0.003248 |
| 57 | 0.005977 | 0.005832 | 0.003764 | 0.006057 | 0.003508 |
| 58 | 0.006603 | 0.006443 | 0.004185 | 0.006692 | 0.0039 |
| 59 | 0.00714 | 0.006967 | 0.004511 | 0.007236 | 0.004204 |
| 60 | 0.007732 | 0.007579 | 0.005035 | 0.00791 | 0.004825 |
| 61 | 0.008439 | 0.008272 | 0.005409 | 0.008634 | 0.005183 |
| 62 | 0.009382 | 0.009197 | 0.006191 | 0.009598 | 0.005932 |
| 63 | 0.010312 | 0.010107 | 0.006543 | 0.010549 | 0.00627 |
| 64 | 0.010917 | 0.0107 | 0.007081 | 0.011168 | 0.006786 |
| 65 | 0.012036 | 0.011948 | 0.007807 | 0.012455 | 0.007637 |
| 66 | 0.013381 | 0.013284 | 0.008439 | 0.013848 | 0.008255 |
| 67 | 0.014279 | 0.014175 | 0.009194 | 0.014776 | 0.008993 |
| 68 | 0.015791 | 0.015676 | 0.010202 | 0.016342 | 0.00998 |
| 69 | 0.017338 | 0.017212 | 0.011026 | 0.017942 | 0.010785 |
| 70 | 0.01838 | 0.018501 | 0.012448 | 0.01923 | 0.012186 |
| 71 | 0.019868 | 0.019998 | 0.013164 | 0.020786 | 0.012887 |
| 72 | 0.021766 | 0.021909 | 0.014962 | 0.022772 | 0.014647 |
| 73 | 0.024648 | 0.024811 | 0.01669 | 0.025788 | 0.016338 |
| 74 | 0.027493 | 0.027674 | 0.019006 | 0.028764 | 0.018606 |
| 75 | 0.030757 | 0.031188 | 0.021082 | 0.032291 | 0.02091 |
| 76 | 0.034023 | 0.0345 | 0.02363 | 0.03572 | 0.023437 |
| 77 | 0.038218 | 0.038754 | 0.027041 | 0.040125 | 0.02682 |
| 78 | 0.043029 | 0.043632 | 0.030433 | 0.045175 | 0.030184 |
| 79 | 0.047858 | 0.048528 | 0.034591 | 0.050245 | 0.034308 |
| 80 | 0.053245 | 0.054366 | 0.038499 | 0.056127 | 0.038341 |
| 81 | 0.058828 | 0.060066 | 0.04386 | 0.062012 | 0.04368 |
| 82 | 0.065625 | 0.067006 | 0.048788 | 0.069177 | 0.048587 |
| 83 | 0.073486 | 0.075033 | 0.055551 | 0.077463 | 0.055322 |
| 84 | 0.082789 | 0.084533 | 0.063314 | 0.087271 | 0.063053 |
| 85 | 0.092316 | 0.094986 | 0.072035 | 0.097463 | 0.072081 |
| 86 | 0.104386 | 0.107405 | 0.082557 | 0.110206 | 0.082609 |
| 87 | 0.116307 | 0.119671 | 0.09369 | 0.122791 | 0.093749 |
| 88 | 0.130367 | 0.134138 | 0.105294 | 0.137635 | 0.105361 |
| 89 | 0.146333 | 0.150566 | 0.118784 | 0.154492 | 0.118859 |
| 90 | 0.155648 | 0.16048 | 0.134685 | 0.163468 | 0.134244 |
| 91 | 0.174533 | 0.179951 | 0.151436 | 0.183302 | 0.15094 |
| 92 | 0.191235 | 0.197172 | 0.168794 | 0.200844 | 0.168241 |
| 93 | 0.212287 | 0.218877 | 0.187095 | 0.222953 | 0.186481 |
| 94 | 0.232875 | 0.240105 | 0.205158 | 0.244575 | 0.204485 |
| 95 | 0.256052 | 0.264001 | 0.227223 | 0.268917 | 0.226478 |
| 96 | 0.276562 | 0.285148 | 0.249868 | 0.290457 | 0.249049 |
| 97 | 0.298988 | 0.308271 | 0.274312 | 0.31401 | 0.273413 |
| 98 | 0.319416 | 0.329333 | 0.295739 | 0.335464 | 0.29477 |
| 99 | 0.3522 | 0.363134 | 0.315736 | 0.369895 | 0.314701 |
| 100 | 0.371778 | 0.38332 | 0.346166 | 0.390457 | 0.345031 |

Appendix D: Model Parameters and their Distributions

*Table 13: Model parameters, their mean values, 95% confidence intervals and distributions for PSA*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Mean | 95% CI Lower | 95% CI Upper | Distribution for PSA | Ref. |
| METS conversion vigorous PA | 6.15 | 4.4 | 7.9 | Normal | [5] |
| METS conversion moderate PA | 4.35 | 2.8 | 5.9 | Normal | [5] |
| METS conversion light PA | 2.55 | 2.1 | 3 | Uniform | [5] |
| METS conversion >100 steps per minute | 3.5 | 3 | 4 | Uniform | [4] |
| Mean change total stepping time | 0.01 | -0.2 | 0.22 | Normal | \* |
| Mean change 100spm time stepping | 0.09 | -0.04 | 0.23 | Normal | \* |
| Mean change 100spm time stepping EX | 0.15 | 0.02 | 0.27 | Normal | \* |
| PA change 3 month duration coefficient | 1173 | 844 | 1501 | Normal | [38] |
| PA change 12 month duration coefficient | 677 | 365 | 989 | Normal | [38] |
| HR BC mortality 2.5-8.9 METS | 0.68 | 0.56 | 0.8 | Lognormal | [17] |
| HR BC mortality ≥3 METS | 0.63 | 0.55 | 0.71 | Lognormal | [17] |
| HR BC mortality ≥7.5 METS | 0.59 | 0.48 | 0.71 | Lognormal | [17] |
| HR BC mortality ≥14.9 METS | 0.62 | 0.41 | 0.82 | Lognormal | [17] |
| HR OC mortality BC patients 2.5-8.9 METS | 0.69 | 0.59 | 0.79 | Lognormal | [17] |
| HR OC mortality BC patients ≥3 METS | 0.61 | 0.55 | 0.67 | Lognormal | [17] |
| HR OC mortality BC patients ≥7.5 METS | 0.59 | 0.5 | 0.68 | Lognormal | [17] |
| HR OC mortality BC patients ≥14.9 METS | 0.53 | 0.42 | 0.64 | Lognormal | [17] |
| HR PC mortality <3.5 METS | 1.13 | 0.77 | 1.66 | Lognormal | [23] |
| HR PC mortality 8.75-17.5 METS | 0.81 | 0.58 | 1.15 | Lognormal | [23] |
| HR PC mortality ≥17.5 METS | 0.69 | 0.49 | 0.95 | Lognormal | [23] |
| HR CRC mortality +5 METS | 0.86 | 0.81 | 0.92 | Lognormal | [26] |
| HR CRC mortality +10 METS | 0.75 | 0.65 | 0.85 | Lognormal | [26] |
| HR CRC mortality +15 METS | 0.65 | 0.53 | 0.79 | Lognormal | [26] |
| HR CRC mortality high METS | 0.61 | 0.4 | 0.92 | Lognormal | [26] |
| HR OC mortality CRC patients +5 METS | 0.85 | 0.81 | 0.9 | Lognormal | [26] |
| HR OC mortality CRC patients +10 METS | 0.72 | 0.65 | 0.8 | Lognormal | [26] |
| HR OC mortality CRC patients +15 METS | 0.62 | 0.53 | 0.72 | Lognormal | [26] |
| HR OC mortality CRC patients high METS | 0.58 | 0.48 | 0.7 | Lognormal | [26] |
| Utility age decrement | 0.00432 | 0.00404 | 0.0046 | Normal | [34] |
| Utility CRC Yr1 stage 1-3 | 0.87 | 0.74 | 0.99 | Normal | [31] |
| Utility CRC Yr1 stage 4 | 0.68 | 0.54 | 0.81 | Normal | [31] |
| Utility CRC Yr2+ stage 1-3 | 0.92 | 0.8 | 1.04 | Normal | [31] |
| Utility CRC Yr2+ stage 4 | 0.73 | 0.61 | 0.86 | Normal | [31] |
| Utility PC Yr1 all stages | 0.775 | 0.655 | 0.895 | Normal | [32] |
| Utility PC Yr2+ stage 1-3 | 0.95 | 0.93 | 1 | Normal | [32] |
| Utility PC Yr2+ stage 4 | 0.6 | 0.24 | 0.86 | Normal | [32] |
| Utility BC Yr1 stage 1-3 | 0.696 | 0.634 | 0.747 | Normal | [33] |
| Utility BC Yr1 stage 4 | 0.685 | 0.62 | 0.735 | Normal | [33] |
| Utility BC Yr2+ stage 1-3 | 0.779 | 0.7 | 0.849 | Normal | [33] |
| Utility BC Yr2+ stage 4 | 0.685 | 0.62 | 0.735 | Normal | [33] |
| APPROACH intervention cost | £62.52 | £51 | £75 | Gamma | \* [37] |
| Cost CRC treatment stage 1-2 Age <64 Yr1 | £18,178 | £14,791 | £21,910 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr2 | £4,457 | £3,626 | £5,372 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr3 | £3,742 | £3,044 | £4,510 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr4 | £2,947 | £2,397 | £3,552 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr5 | £2,676 | £2,177 | £3,225 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr6 | £1,909 | £1,553 | £2,301 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr7 | £1,975 | £1,607 | £2,380 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr8 | £1,831 | £1,490 | £2,207 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age <64 Yr9 | £1,613 | £1,312 | £1,944 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr1 | £17,307 | £14,081 | £20,860 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr2 | £4,412 | £3,590 | £5,318 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr3 | £3,699 | £3,010 | £4,458 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr4 | £3,170 | £2,579 | £3,820 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr5 | £3,209 | £2,611 | £3,867 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr6 | £3,237 | £2,634 | £3,901 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr7 | £2,992 | £2,434 | £3,606 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr8 | £3,256 | £2,649 | £3,925 | Gamma | [36] |
| Cost CRC treatment stage 1-2 Age 65+ Yr9 | £2,810 | £2,286 | £3,387 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr1 | £23,391 | £19,032 | £28,193 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr2 | £7,823 | £6,365 | £9,429 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr3 | £5,424 | £4,413 | £6,537 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr4 | £4,474 | £3,640 | £5,393 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr5 | £3,262 | £2,654 | £3,932 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr6 | £2,770 | £2,254 | £3,338 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr7 | £3,188 | £2,594 | £3,842 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr8 | £2,500 | £2,034 | £3,014 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age <64 Yr9 | £1,795 | £1,460 | £2,163 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr1 | £18,788 | £15,287 | £22,645 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr2 | £6,270 | £5,102 | £7,557 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr3 | £4,956 | £4,032 | £5,973 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr4 | £3,990 | £3,247 | £4,809 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr5 | £3,766 | £3,064 | £4,539 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr6 | £3,601 | £2,930 | £4,341 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr7 | £2,485 | £2,022 | £2,995 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr8 | £3,076 | £2,503 | £3,707 | Gamma | [36] |
| Cost CRC treatment stage 3-4 Age 65+ Yr9 | £2,504 | £2,037 | £3,018 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr1 | £13,101 | £10,659 | £15,790 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr2 | £4,093 | £3,330 | £4,933 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr3 | £2,381 | £1,937 | £2,870 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr4 | £1,984 | £1,614 | £2,391 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr5 | £1,971 | £1,604 | £2,376 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr6 | £1,886 | £1,535 | £2,273 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr7 | £1,699 | £1,383 | £2,048 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr8 | £1,678 | £1,365 | £2,022 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age <64 Yr9 | £1,559 | £1,269 | £1,879 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr1 | £9,262 | £7,536 | £11,163 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr2 | £3,083 | £2,509 | £3,716 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr3 | £2,628 | £2,139 | £3,168 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr4 | £2,719 | £2,212 | £3,277 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr5 | £2,532 | £2,060 | £3,052 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr6 | £2,650 | £2,156 | £3,194 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr7 | £2,515 | £2,046 | £3,031 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr8 | £2,602 | £2,117 | £3,136 | Gamma | [36] |
| Cost BC treatment stage 1-2 Age 65+ Yr9 | £2,687 | £2,186 | £3,239 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr1 | £16,233 | £13,208 | £19,565 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr2 | £7,053 | £5,738 | £8,500 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr3 | £4,611 | £3,751 | £5,557 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr4 | £3,574 | £2,908 | £4,308 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr5 | £3,464 | £2,818 | £4,175 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr6 | £3,225 | £2,624 | £3,887 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr7 | £3,192 | £2,597 | £3,847 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr8 | £3,120 | £2,538 | £3,760 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age <64 Yr9 | £2,253 | £1,833 | £2,715 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr1 | £10,733 | £8,733 | £12,937 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr2 | £4,450 | £3,621 | £5,363 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr3 | £3,865 | £3,144 | £4,658 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr4 | £3,565 | £2,900 | £4,297 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr5 | £3,605 | £2,933 | £4,345 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr6 | £3,393 | £2,761 | £4,089 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr7 | £3,539 | £2,880 | £4,266 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr8 | £2,992 | £2,434 | £3,606 | Gamma | [36] |
| Cost BC treatment stage 3-4 Age 65+ Yr9 | £3,574 | £2,908 | £4,308 | Gamma | [36] |
| Cost PC treatment Age <64 Yr1 | £6,304 | £5,129 | £7,598 | Gamma | [36] |
| Cost PC treatment Age <64 Yr2 | £2,396 | £1,949 | £2,887 | Gamma | [36] |
| Cost PC treatment Age <64 Yr3 | £2,349 | £1,911 | £2,832 | Gamma | [36] |
| Cost PC treatment Age <64 Yr4 | £1,809 | £1,472 | £2,181 | Gamma | [36] |
| Cost PC treatment Age <64 Yr5 | £1,901 | £1,546 | £2,291 | Gamma | [36] |
| Cost PC treatment Age <64 Yr6 | £1,931 | £1,571 | £2,328 | Gamma | [36] |
| Cost PC treatment Age <64 Yr7 | £1,724 | £1,403 | £2,078 | Gamma | [36] |
| Cost PC treatment Age <64 Yr8 | £1,830 | £1,489 | £2,206 | Gamma | [36] |
| Cost PC treatment Age <64 Yr9 | £1,769 | £1,439 | £2,132 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr1 | £5,729 | £4,661 | £6,905 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr2 | £3,298 | £2,683 | £3,975 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr3 | £3,167 | £2,577 | £3,818 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr4 | £3,083 | £2,509 | £3,716 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr5 | £3,161 | £2,572 | £3,810 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr6 | £3,092 | £2,516 | £3,726 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr7 | £4,596 | £3,740 | £5,540 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr8 | £3,392 | £2,760 | £4,088 | Gamma | [36] |
| Cost PC treatment Age 65+ Yr9 | £3,165 | £2,575 | £3,815 | Gamma | [36] |
| \* APPROACH pilot data; CI confidence interval; PSA probabilistic sensitivity analysis; METS metabolic equivalents; PA physical activity; EX 2 extreme values excluded; HR hazard ratio; BC breast cancer; PC prostate cancer; CRC colorectal cancer; OC other cause; Yr year | | | | | |

1. Due to how the data was stored this included those diagnosed with localised breast, prostate or colorectal cancer and those diagnosed with metastatic breast or colorectal cancer. [↑](#footnote-ref-2)