
Artificial intelligence enabled tele-health coaching impact on patient health outcomes: *A prospective cohort study*

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Abstract

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Background - In the last decade, the number of patients admitted to hospital via Accident and Emergency departments in the UK has increased. Long-term Conditions including diabetes, heart disease, and clinical depression constitute most of these admissions. Patients who are able to participate in active self-management of their conditions experience fewer emergency admissions. Patients with long-term conditions may benefit from personalised interventions to support self-management and prevent readmission. In this context, the Artificial Intelligence enabled Proactive tele-Health Coaching intervention can help facilitate patients' identification at greater need of support, who may benefit from personalised care and improved self-management. This nested cohort study hypothesised that patients who received the intervention would be better able to self-manage their condition and experience improved general, physical and mental health outcomes. **Methods** - Nested within a Randomized Control Trial in UK health settings, this study included the intervention group from the trial and used a before and after design. Adult patients receiving the intervention (minimum one long-term condition and at high-risk of emergency readmission) were followed up between 2015-2019 in Vale of York. The primary outcomes of interest were the self-reported health outcomes from the Short Form 12v2 (SF12), and the secondary outcome was the patients' ability to manage their health assessed through 13 Patient Activation Measures (PAM13). Quantitative analyses included pre-intervention baseline characteristics, multivariate regression and variances before and after the intervention.

Results - There were 855 adult patients that met the criteria and who received the intervention, with a mean age of 75 years. Analysis confirmed a 33% increase in PAM13 scores ($p=0.002$, 95% CI 0.54 -0.67). PAM13 was a significant ($p<0.001$) predictor for SF12 General (95% CI 0.24-0.41), Physical (95% CI 6.39-10.13), and Mental (95% CI 5.14-8.48) health outcomes. Dichotomized and ANOVA tests confirmed variances of questionnaire scores. Showing a change in self-reported physical health ($MS=44.16$ $p<0.05$, 95% CI 41.47-46.86), but not in mental health ($p=0.06$) or general health ($p=0.12$). There was insufficient evidence that sex, age, living environment, housing, employment, health disability were impacting factors across levels.

Conclusions - The intervention improved the patient's ability to self-manage their conditions, and their self-reported physical health, but not their mental or general health. Therefore, the findings partially confirmed the hypothesis. Limitations in the study were possible causes of these findings e.g. sample size dropped due to complete cases analysis, may have lost power. No conclusion could be drawn about the effect compared to usual care.

Introduction

Over the last decade, UK emergency admissions increased by 42% from 4.25 to 6.02 million⁽¹⁾. 61% of patients admitted to hospital via Accident & Emergency (A&E) had at least one long-term condition (LTC) managed through continuous medication or treatment⁽²⁾. Interventions to support people with self-management of their conditions may reduce or prevent hospital admission. Patients who were better able to self-manage their conditions had fewer emergency admissions (38%) and attendances (32%), and were less likely to attend A&E with minor conditions (32%)⁽¹⁾. Artificial Intelligence (AI) technologies could support clinical judgement by facilitating the identification of patients at risk of hospital readmission. Within this context of preventing illness exacerbation and emergency admission, AI technology enables the prediction and identification of patients at high risk of readmission. In addition, interventions such as health coaching promote the shift towards more personalised care and reduced hospitalisation⁽³⁻⁵⁾.

Digitally enhanced health coaching interventions evidence

The health coaching intervention is an interactive personalised service to educate and motivate patients (also called patient activation) in achieving goals that enhance and improve health⁽⁶⁾. Health coaching comprised various formats, targeted different populations and consisted of the following components; 1) Patient identification, 2) Personalised health care planning, 3) Coaching⁽⁷⁾.

1. AI Patient identification and risk prediction

Risk prediction improves accuracy in identifying patients to target for interventions, for instance those at high risk of hospital admission⁽⁸⁾. AI and machine learning techniques apply risk prediction algorithms, automatic selection and regression methods to stratify patients, and results can be more precise than traditional tools⁽⁹⁾. However, evidence on AI or machine learning effectiveness in facilitating risk prediction related to hospital admission is very limited.

2. Personalised health care planning

As an integral part of health coaching the coach and patient agree on goals and actions for managing health problems⁽⁷⁾. This agreement of goals is an effective way to shift from professional-centred decision-making to support

the person in taking ownership of managing their condition. Various systematic reviews (19 RCTs, N=10,856) have found that health coaching resulted in small to moderate improvements in some indicators of self-management (PAM13), improved confidence and skills to manage own health (medication adherence), physical health, and mental health⁽⁷⁾⁽¹⁰⁾.

3. Coaching and tele-Health Coaching

Telephone health coaching intervention studies 94%(32/34 reviews) have reported positive results on improvements in health behaviours and outcomes⁽¹¹⁾. Telehealth coaching is defined as a *“regular series of phone calls between patient and health professional...to provide support and encouragement to the patient, and promote healthy behaviours such as treatment control, healthy diet, physical activity and mobility, rehabilitation, and good mental health”*⁽¹²⁾.

Telehealth coaching has demonstrated significant improvements in self-efficacy, health behaviours, physical activity, mental health status, weight management and medication adherence⁽¹³⁾⁽¹⁴⁾.

Impact on self-management and health outcomes

Self-management at a population level reduces the burden of LTCs on the healthcare system and improves population health outcomes⁽³⁾.

Promoting patients' self-management skills is expected to result in improved levels of activation, avoiding acute exacerbations, and better awareness of when to seek medical help, leading to reduced health care costs⁽¹⁵⁾⁽⁴⁾⁽⁵⁾. Research has furthermore confirmed the associations between self-management and improvement of LTCs. For example self-management has been found to be helpful for patients with LTCs in terms of pain management, quality of life, and health behaviours and status⁽¹⁵⁻¹⁷⁾.

Overall, a large number of studies confirmed that health coaching had an overall moderate effect in patients with LTCs specifically related to improved self-management and health outcomes. Findings on the effectiveness of self-management on improving physical and mental health outcomes were mixed or contradictory but generally, this was moderate. However, little evidence has been published about the impact of AI-supported interventions on patient health outcomes, suggesting that the use of AI products in health care is novel and under evaluated. In this context, this study evaluates the impact AI-supported Pro-active tele-Health Coaching

intervention (PHC) on health outcomes of an UK population cohort.

Health Navigator AI enabled PHC intervention¹

PHC enables non-clinical telephone support to educate patients on their conditions, plan their care, and navigate complex health and social care systems. It facilitates increased self-management with the aim to prevent disease progression, improve health outcomes and prevent emergency care. Patients receive help with identifying their reasons for contacting health services and addressing triggers for urgent access. This includes understanding and managing their condition(s), addressing social isolation and navigating the healthcare system. Over 6-9 months patients work with PHC coaches (including nurses, allied health professionals and medical doctors) who provide non-clinical services complementing existing clinical treatment. This includes motivational support, problem-solving, monitoring progress in implementing personalised plans as well as preparing for consultations. Patients receive proactive calls initially daily, reducing to three per week, weekly, fortnightly, and monthly as their risk of unplanned admission reduces. The higher the risk of admission and disease deterioration the higher the frequency of calls they receive.

The intervention is delivered in four phases: 1) Patient identification, 2) Intervention delivery, 3) Monitoring and evaluation, 4) Ending future bookings (figure 1).

Phase 1. Patient identification, exclusion, and inclusion

PHC employed AI-predictive risk stratification software was installed on the hospital system, to identify patients at risk of unplanned admission. AI enhanced the impact by identifying the patients who may benefit from PHC more accurately. The AI predicted which patients were at risk (1=low - 5=high) of disease deterioration and hospital admission in the next six months, and the probability of preventing admission (80-90%=high). Patients were then reviewed by the clinical and the PHC coaching team via the Health Navigator online system.

Phase 2. Intervention delivery

The intervention was designed to prevent readmissions and delivered the following activities: 1) Coaches met the patient face-to-face; 2) Coaches reviewed the patient's situation; 3) Patient led the agreement on goals, and outcomes; 4) Patients take ownership of their treatment plan that will achieve behavioural change through referral to health services, community or peer support; 5) The coach and patient agreed to regular telephone contact.

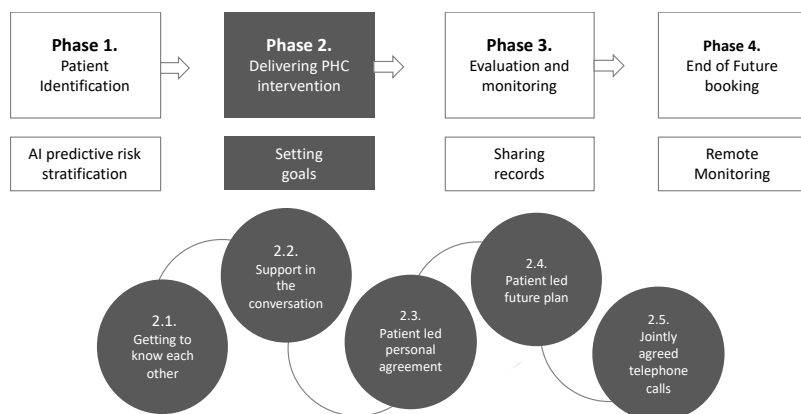
Phase 3. Evaluation and monitoring

Depending on the patient's need, coaches continuously checked progress of the agreed plan. Using the online system, they monitored patient's care actions, hospital admission trends, self-management and health improvement. This was supported by hospital discharge, primary and community care teams through providing specialist services and monitoring.

Phase 4. Ending future bookings

When the patient felt confident and was no longer at risk of readmission, a joint decision was taken to not further schedule bookings.

Figure 1. PHC Intervention



¹ Intervention description used information from Edgren G, et al, 2016, <http://www.health-navigator.co.uk/proactive-health-coaching/> and was verified by the lead nurse January 2019

PHC logic framework

Findings from the PHC RCT indicated that the intervention reduced hospital admissions of high-risk patients⁽¹⁸⁾⁽¹⁹⁾. The RCT furthermore collected PAM13 self-management and SF12 health outcomes data for the intervention group only. Understanding the factors which contributed to reduced hospital admissions was necessary to scale-up the intervention. A deeper comprehension of the PHC intervention's impact on the patient's PAM13 Level and SF12 general, physical and mental health was required.

The analysis framework for this study applied the following logic: The AI technology enabled PHC by accurately identifying patients most at risk based on multiple indicators. Patients were offered coaches who supported them to self-manage their condition, solve problems and pursue goals. This facilitated behaviour change (i.e. exercise, medication adherence), improved mood, and improved markers of disease control⁽¹⁶⁾. Coaching supported patients' actions to maintain self-management⁽³⁾. Better self-management skills were expected to result in a patient who was more engaged in their health care, better able to manage their disease, thereby avoiding acute exacerbations⁽⁴⁾. As the patient became more aware of when to seek medical help, they learned how to use health services, leading to reduced hospital utilisation⁽⁵⁾.

The framework consisted of five components: 1) AI risk prediction technology identified patients who would benefit from health coaching 2) Health coaching educated and supported the patients 3) Patients improved self-management 4) Improved

self-management resulted in improved general, mental and physical health disease management, which 5) Reduced hospital readmission and health care consumption (figure 2). The evaluation included components 2 to 4 to develop a deeper understanding of the impact of the PHC intervention on the patient's self-management and their general, physical and mental health.

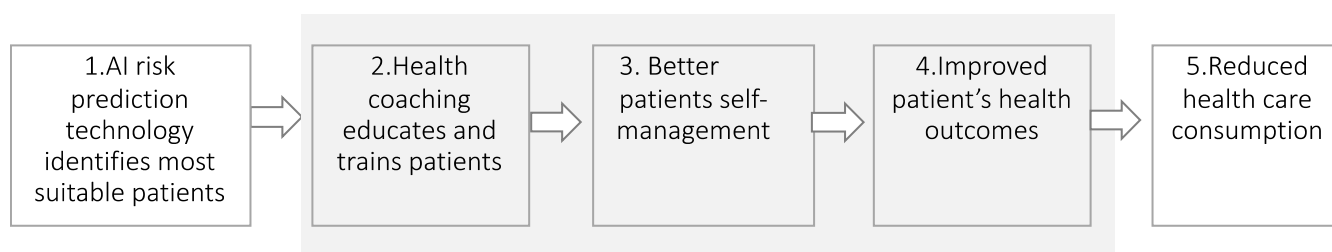
Aim and objectives

The aim of this study was to determine how the AI-enabled PHC intervention impacted a population's health by analysing self-reported SF12 health outcomes and PAM13 patient activation data collated between 2015 and 2019 in York. It used the PHC RCT data of the intervention group to create an insight into how self-management was linked with the improved health outcomes.

Specific objectives: 1) To determine if the intervention resulted in improved SF12 general, physical and mental health outcomes through increased PAM13 patient activation and; 2) To identify the association between general, physical, mental health, self-management outcomes and socioeconomic characteristics.

Previous studies have suggested that health coaching was associated with improved self-management and improved physical and mental health outcomes which led to reduced hospital admissions and costs⁽³⁻⁵⁾. This study hypothesised that patients who received the intervention were better able to self-manage their condition and experienced improved general, physical and mental health outcomes.

Figure 2. Model for analysis



Methods

Study design

The cohort study was nested in the multi-centre parallel, two group RCT replicated from Sweden

in UK health settings in 2015⁽¹⁸⁾. The sample included patients that met the inclusion criteria, described below, in eight hospital sites across the UK (figure 3). Patients were randomised to receive either the intervention or usual care in a 2:1 ratio applying the Zelen's study design. The

study only collated self-reported SF12 outcomes and PAM13 self-activation scores for the intervention group. Therefore, the research design was a longitudinal prospective nested cohort study using data from the intervention group. Data were collected at baseline before and after the intervention (at six, and/or eighteen months).

Figure 3. Setting



Patient recruitment

The selected patients included high-risk patients that were automatically identified through the risk-stratification AI software. Study eligibility was based on the inclusion and exclusion criteria previously described; patients were then manually screened by the clinical team and allocated a coach who contacted them for a baseline face-to-face meeting. Upon consent, the SF12 and PAM13 questionnaires were completed during the baseline face-to-face meeting. This was repeated at six and/or eighteen months, the patients received the self-reported questionnaires in the post, completed and returned this to the research team. Patients were included if they were aged 18 years or older, attended the emergency department in the past six months, considered to be at high risk (score of 5, 80-90% probability) of becoming recurrent users of unplanned hospital care in the next six months. Patients were excluded if they had contact with hospital services within the past twelve months and the hospital record included: dementia, psychotic disorders, mental disorders

Due to the high cost and lack of budget to collect data this study analysed data for York only. Patients recruited between 2015-2019 were followed for up to two years, starting from the date of randomisation.

caused by substance misuse, terminal cancer, severe hearing loss, language difficulties that required an interpreter, cognitive ability level which was not sufficient for receiving and responding to telephone counselling, no telephone connection, estimated remaining life expectancy <1 year, due or had major surgery in the last six months.

Outcomes and variables

Data were collated on the population's experience of health using the SF12 and PAM13 survey tools. Both tools have been found to be a valid, reliable and used for patients with LTCs ⁽¹⁵⁾⁽²⁰⁾⁽²¹⁾. The primary study outcome was whether the intervention improved health, as indicated by SF12 general, physical and mental health outcomes measures; and secondly whether the intervention confirmed a change in the ability to self-manage as indicated by the PAM13 outcomes. The study also looked at whether there was any association between SF12 and PAM13 scores and demographic characteristics. (table 1)

Table1.Outcomes measures

Outcomes	Measures	Instrument	Assessment time points
Baseline	Age, gender, IMD	Self-reported via SF12 and PAM13 IMD measures	Before intervention
Primary: <i>Health</i>	Physical Composite Scale	SF12 items:1-General Health, 2a,b-Physical Functioning, 3a,3b-Role Physical, and 5-Body Pain.	Before/after intervention
	Mental Composite Scale	SF-12 items: 6b-Vitality, 7-Social Functioning, 4a,b Role Emotional, and 6a,c Mental Health	
Secondary: <i>Self-management</i>	Self-activation	PAM13 items: include depression, health literacy, social support	

1. SF12 Health outcomes

The analysis of the SF12 outcomes identified the association between PHC intervention and general, physical and mental health outcomes. The self-reported SF12 questionnaire measures consisted of twelve descriptive items divided into eight domains: General health, Physical Functioning, Role Physical, Role Emotional, Mental Health, Body Pain, Vitality and Social Functioning. Patients scored their health on the day for each domain. The scores ranged from 1 to 5, 1 indicated that 'they had no problems' in that domain and 5 indicated that 'they had extreme problems'⁽¹⁵⁾. Improvement in health followed the categories of self-perceived health before and after the intervention and was estimated through the 'General health' domain of the questionnaire. General Health categories were defined as 'good' (answers 1) Excellent, 2) Very Good or 3) Good), and 'bad' (answers 4) Fair or 5) Poor). Physical Health was measured by composite scores including General Health (GH), Physical Functioning (PF), Role Physical (RP) and Body Pain (BP). Mental Health was measured by composite scores including the Vitality (VT), Social Functioning (SF), Role Emotional (RE), and Mental Health (MH).

2. PAM13 outcomes

The PAM13 analysis confirmed whether the AI-enhanced PHC intervention improved self-management in patients at risk of hospital admission. The change in the activation level (1=low to 4=high) was measured through the PAM13 questionnaire. PAM13 consisted of 13 patient statements related to their health care, managing health related tasks, and self-assessed knowledge of conditions, treatment options, self-

efficacy, activation, confidence, competence, and the ability to access relevant support ⁽⁷⁾⁽¹⁵⁾.

PAM13 measured the changes in these areas as described by Blakemore et al.(2016)⁽¹⁵⁾. Patients agreed or disagreed with the PAM13 statement on a response scale of 1-5 (1=strongly disagree, 4=strongly agree, 5=not applicable). Responses generated a continuous variable from 0-100 the higher the scores the more the patient was activated. "5=Not applicable" answers were treated as missing. The total score was generated where patients had answered a minimum of 10 out of 13 questions. The scores were categorised into four levels for descriptive analysis: Level 1='passive recipients of care who do not understand that they can play an active role in their own healthcare'; Level 2=those 'who lacked the basic knowledge and confidence to effectively self-manage'; Level 3=those 'with basic knowledge about their health, but they lack the confidence and skills to engage in positive self-management behaviours'; Level 4=patients with 'the knowledge and confidence to self-manage but who may need support during times of personal stress or health crisis'.

3. Demographic characteristics

The study was furthermore interested in identifying how SF12 and PAM13 outcomes were associated with demographic characteristics. Previous research has identified sex, age, education and diagnosed conditions (i.e. asthma, COPD, IBS, heart failure) to be risk factors⁽⁷⁾⁽¹⁰⁾⁽¹⁵⁾⁽¹⁶⁾. Therefore, as a minimum, available data on sex and age, socioeconomic status UK Index of Multiple Deprivation (IMD) 2015 decile scores, were analysed. IMD is a set of measures identifying aspects of deprivation at

an area level not individual level affluence. The variables included income, employment, education, health disability, crime, housing and living environment IMD decile scores 1=low level of deprivation to 10=high level of deprivation.

Statistical methods and analysis

Sample size

For maximum measurement power this study followed the PAM13 recommended minimal sample size of 200⁽²²⁾. High-risk patients were randomised at 2:1 ratio to receive intervention or regular care controls. Power of 90% and alpha $\alpha=0.048$ enabled a standardised effect size of 0.25 on continuous outcome measures. This approach resulted in a sample size of N=855 (intervention n=591, controls n=263).

Data integrity and quality

For the analysis, the mean with standard deviation, percentage of missing data, and SF12 and PAM13 percentage of 'not applicable' answers were considered. Internal consistency was measured as the Spearman correlation coefficient between summary scores, individual scales and different variables. Similar studies confirmed that strong correlations are rare and correlation $r \geq 0.50$ was considered strong, $r \geq 0.30$ moderate and $r \geq 0.10$ weak⁽²³⁾. In the sample, the distribution of self-reported health outcomes adjusted mean and overall scores was described by PAM13 level, gender and age before and after the intervention. For cases that were excluded due to missing data, differences between included and excluded cases at baseline were tested for similarity.

Descriptive statistics

Descriptive statistics described the distribution of SF12 and PAM13 outcomes, and changes in scores before and after the intervention. As the primary outcomes of interest for this study was the self-reported SF12 Health outcomes, complete cases were defined as patients who completed the questionnaire at baseline and post-intervention, without missing data for the SF12 primary outcomes, with available completed baseline sex and age data. SF12 and PAM13 outcomes were treated as continuous and categorical respectively and normally distributed. Baseline values of outcomes and pre-specified covariates included: SF12 Health outcomes (comprised General Health, Physical Composite Scale, Mental Composite Scale mean scores) and PAM13 mean score⁽²¹⁾⁽²⁴⁾. The mean \pm standard deviation for continuous

variables or n(%) for categorical variables included sex and age (categorised 20-29 to 90-99) and IMD socioeconomic decile scores⁽²⁵⁾.

Regression analysis

The analysis was based on intention-to-treat completed cases and a specifically developed analysis plan. The associations between baseline SF12 outcomes and PAM13 item scores and independent variables were investigated applying multiple linear regression to compare the change in outcomes before and after the intervention. The correlations coefficients between the variables and risk factors, and impact of potential predictors and risk factors were explored. Bivariate relations were examined prior to the regression analysis applying the Mantel-Haenszel test for homogeneity by matching interactions between the intervention group SF12, PAM13 variable and the variables for sex, age, socioeconomic and time period before/after the intervention. Continuous and categorical data were used in the multiple regression analyses model with independent variables regressors as predictors of change in the outcomes scores after the intervention between the baseline and follow-up. To analyse the mean differences from baseline before/after intervention, paired *t*-test for the total scale was performed and Wilcoxon signed-rank test for individual items.

Hypothesis testing

The hypothesis was tested applying the Wilcoxon test for the null hypotheses in relation to changes before/after the intervention outcomes. Including individual items and subscales to examine individual-level predictors e.g. IMD socioeconomic status, sex and age. Logistic regression calculated the odds of having poor self-management, mental and physical functioning. To compare the changes, analysis of variance (ANOVA) was performed. Effect sizes used Cohen's interpretation: small (≥ 0.20), medium (≥ 0.50) and large (≥ 0.80)⁽²⁶⁾.

Analysis of outcomes

The analysis of the outcomes aimed to 1) determine if the intervention improved SF12 outcomes and PAM13 outcomes and 2) Identify the association between SF12 general, physical and mental health and PAM13 outcomes and population health risk predictors. Stata version 15 was used in the analysis.

Selection bias was managed by utilising the data collected building upon an initial RCT study design approach. This approach addressed

sequence generation, allocation concealment, baseline comparability, intention-to-treat and loss-to-follow⁽²⁷⁾.

Recall bias, was not applicable as patients were asked at the point in time about their status of measurement rather than information referred to past events.

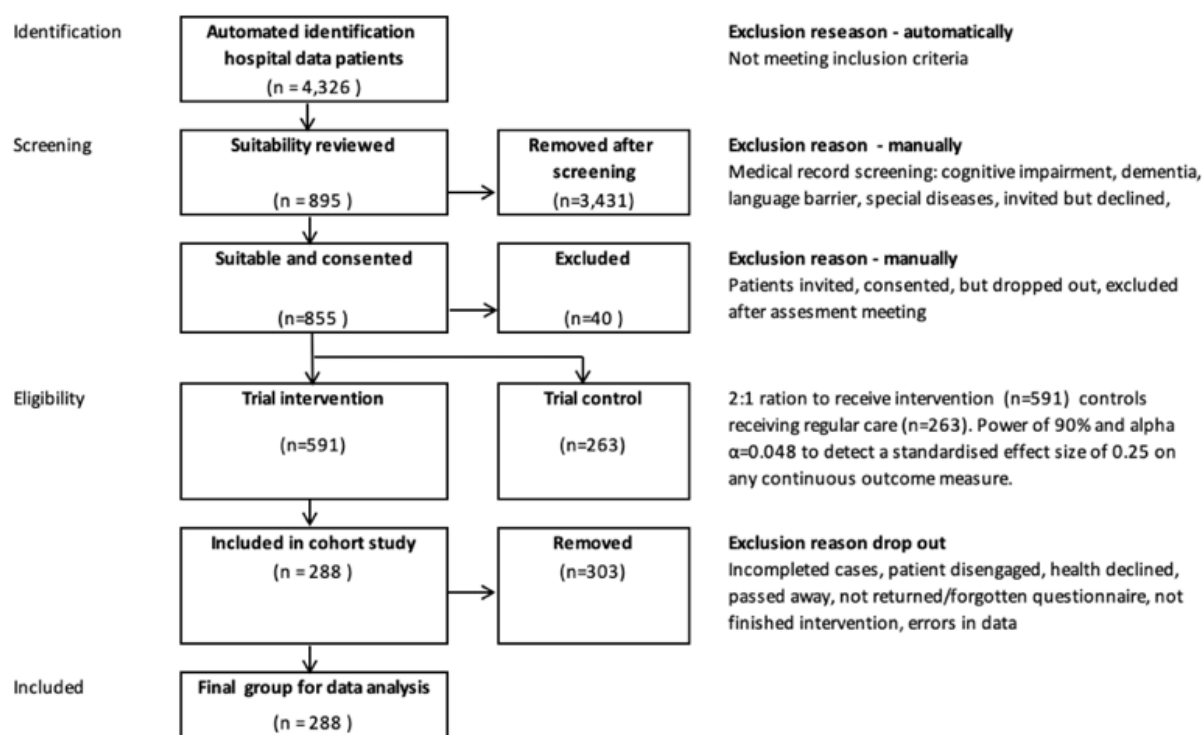
Results

Sample and data quality

The eligible consented sample included 855 patients. 591 subjects underwent the intervention and 264 were controls (figure 4). For SF12 and PAM13, 303/591 (51%) questionnaires were classified as 'incomplete' and were excluded. Reasons included data recording errors, missing data (≤ 3 missing items), duplication, non-returned or incomplete questionnaires. Causes for missing

data included patients disengaging from services due to declining health or death, withdrawal of consent to contact, and moving out of the area. For SF12, 288/591 (49%) of the recorded questionnaires were eligible for inclusion. For PAM13, 318/591 (50%) were eligible and after calibration against the 288 complete cases, 271 (78%) cases were included. Of the 288 complete cases, SF12 reported 0% item responses missing, and PAM13 between 27%-28% of all 13 individual item responses. There were no missing data for the baseline data sex and age and only 2% across socioeconomic status variables. For this study 'complete cases' analysis with 49% of the full eligible sample, was the most appropriate approach as per the regression and T-test results. Available data were insufficient to confirm the 'missingness' and the impact on the validity of the final results for the full cohort. The reason for the missing data may be due to input errors rather than related to the intervention.

Figure 4. Patients for inclusion



Descriptive statistics

For the 288 participants, the mean age was 75 years (range: 20-99 years), 50% were females. For IMD deprivation items the majority (78%-84%) were at the 'least deprived' end of the scale, for Housing and Environment the least deprived scores were slightly lower (60%-63%). On a binary scale, SF12 General Health was

'Poor' for 55% and 'Good' for 45%, the PAM13 Level was 'Low' for 39.5% and 'High' for 60.5% of the patients (Appendix 2. table 2).

Distribution was described by SF12 and PAM13 levels, and variables included time period, sex, age and IMD overall scores at the baseline level. In all variables for the SF12 and PAM13 outcomes, skewness was ≤ 1.0 and kurtosis ≤ 2.0 this was reasonable. Age was normally distributed with kurtosis=4.4 which showed a

slightly heavier tail or outliers (appendix 2. figure1).

The majority of patients scored their SF12 General health to be 'Fair' 43% or 'Good' 34% and there was a strong ($p < 0.001$) association with the PAM13 levels ($\chi^2=69$), and Age ($\chi^2=63$)

(table 3). Across the four PAM13 levels, data were equally distributed (23%=level 1, 24%=level 2, 30%=level 3, 22%=level 4). Across the PAM13 levels, there was a particularly strong ($p < 0.001$) association SF12 General ($\chi^2=39.8$), Mental ($\chi^2=102$) and Physical ($\chi^2=36$) health (table 4).

Table 3. SF12 General Health distribution

Exposure variable	Poor	Fair	Good	Very good	Excellent	Total	Pearson chi2	P-value
Sample N=574	89 (16%)	244 (43%)	198 (34%)	42 (7%)	1 (0.2%)	574		
Sex	89	244	198	42	1	574	3.16	0.53
Female	45	131	94	19	1	290		
Male	44	113	104	23	0	284		
Age	89	244	198	42	1	574	62.99	<0.001
20-29	2	0	0	0	0	2		
30-39	1	1	2	0	0	4		
40-49	1	1	3	1	0	6		
50-59	12	13	6	1	0	32		
60-69	14	51	34	12	0	111		
70-79	37	91	70	18	0	216		
80-89	21	79	69	8	0	177		
90-99	1	8	14	2	1	26		
PAM13 Level	64	176	150	30	1	421	69.34	<0.001
1.Disengaged&overwhelmed	31	46	17	3	0	97		
2.Aware&struggling	14	51	34	4	0	103		
3.Taking action	12	52	58	6	0	128		
4.Maintaining behaviours& pushing further	7	27	41	17	1	93		

Table 4.PAM13 distribution

Exposure Variable	Level 1 (n=97) 23%	Level 2 (n=103) 24%	Level 3 (n=128) 30%	Level 4 (n=93) 22%	Total (n=421)	Pearson chi2	P-value
Sex	97	103	128	93	421	3.19	0.36
Female	59	56	63	48	226		
Male	38	47	65	45	195		
Age	97	103	128	93	421	17.81	0.47
20-29	0	0	0	0	0		
30-39	0	0	0	2	2		
40-49	2	0	2	0	4		
50-59	6	4	4	5	19		
60-69	19	18	20	22	79		
70-79	31	35	52	32	150		
80-89	35	39	41	27	142		
90-99	4	7	9	5	25		
General health	97	103	128	93	421	39.80	<0.001
Poor	77	65	64	34	240		
Good	20	38	64	59	181		
Mental health	97	103	128	93	421	102.43	<0.001
Poor	76	71	70	34	251		
Good	21	32	58	59	170		
Physical health	97	103	128	93	421	36.23	<0.001
Poor	92	86	95	56	329		
Good	5	17	33	37	92		

Associations between PHC intervention and SF12 Health outcomes

The correlations between SF12 outcomes and PAM13 Levels showed that the associations were of varying strength, but in general, these were moderate ($r = 0.39-0.34$). Associations between PAM13 Level and Employment, Health disability, and Environment, between Physical health and Sex, Environment and between Mental health, Sex and age were significant ($p < 0.001$) but weak ($r = -0.10-0.16$) (appendix 2.4).

Risk factors, Odd Ratios (OR) and Confidence Intervals (CI) for the associations between SF12 outcomes and PAM13 levels and risk factors after the intervention showed likely improvements after the intervention. Generally, patients with higher PAM13 levels were significantly ($p < 0.001$) more likely to live in good General, Mental and Physical health. They further experienced less deprivation related to health disability and also the environment they lived in. More specifically, after the intervention older patients who lived in less deprived environments had better General health outcomes ($p = 0.03$, 95% CI 1.01-1.36). They also had more chance of having a higher PAM13 level ($p = 0.002$, 95% CI 2.02-4.68).

The study took into account the potential confounding effects that impacted PAM13 Level and Health outcomes. The most significant ($p \leq 0.03$) were identified for General (OR=3.0, 95% CI 1.27-7.15) and Physical (OR=1.03, 95%

CI 1.00-1.06) health. For SF12 General health time period was identified as a confounder.

Results showed that controlling for time period, patients were 2.99 times ($p = 0.002$, 95% CI 0.37-0.81) more likely to have better outcomes after compared with before the intervention.

PHC impact on PAM13 Patient activation

The analysis results confirmed the AI-enhanced PHC intervention improved PAM13. The multivariate regression and ANOVA before/after the intervention results confirmed an association for PAM13 level and Physical health and improved scores after the intervention. The General and Mental health association between 'poor' and 'good' health, after the intervention, confirmed no statistically significant difference in mean scores. All results were significant ($p < 0.05$) and trustworthy (Bartlett's test $p = 0.27-0.53$) (table 5).

Comparing the PAM13 levels before/after the intervention, the two-sample test with equal variances confirmed an improved score after the intervention (from 0.45 to 0.60, 95% CI 0.53-0.67) and increase in individual PAM13 levels mean score (from 2.36 to 2.69, 95% CI 2.55-2.84). The overall mean PAM13 level (23.16) was higher after, compared with before (22.40) the intervention. Although significant, the overall effect size in the difference was very small.

Table 5. Responsiveness to intervention ($n=288$) before/after intervention

Variable	Before					After					P-Value*	% change
	Obs	Mean	Std. Err.	Std. Dev.	CI	Obs	Mean	Std. Err.	Std. Dev.	CI		
PAM13 Level	226	0.46	0.03	0.50	0.54-0.67	195	0.61	0.04	0.49	0.54-0.67	0.002	33
General health	286	0.39	0.03	0.49	0.33-0.44	288	0.45	0.03	0.50	0.39-0.51	0.125	16
Mental health	286	55.04	1.18	19.87	52.72-57.35	288	58.17	1.24	20.97	55.74-60.6	0.067	6
Physical health	286	40.48	1.32	22.40	37.87-43.09	288	44.17	1.37	23.24	41.47-46.86	0.054	9

*Analysis for equal variance

PAM13 as a predictor for SF12 health outcomes

The study hypothesised that patients who receive PHC were better able to self-manage and experience improved General, Physical and Mental health outcomes. The analysis evaluated a change in activation level, applying multiple

regression including predictors of SF12 outcomes at baseline.

Earlier tests indicated significant associations between the SF12 outcomes and PAM13 level. Therefore, the regression estimated the numerical relationship using PAM13. The results confirmed that PAM13 Level predicts the SF12 outcomes. The linear regression level showed significant

($p < 0.001$) relationships for time period before/after the intervention (95% CI -0.12 to -0.03), General (95% CI 0.24-0.41), Physical (95% CI 6.39-10.13), and Mental (95% CI 5.14-8.48) health (table 6).

Risk factors analysis was interested in identifying whether the change in PAM13 Level scores associated with SF12 outcomes could be due to time period, sex, age, environment, health disability, or employment. By fitting these variables as predictors, it confirmed that only sex and age were significant impacting factors resulting in three models (table 7).

Model 1. SF12 General health, PAM13 and age
Results confirmed that for each increase in PAM13 Level patients had a better General health outcome compared to those with a lower PAM13 level (coeff=0.33, $p < 0.001$) after accounting for age. Per each year increase in age, there was an increase in General Health (coeff=0.18, $p < 0.001$, $R^2 = 15.78\%$).

Model 2. SF12 Mental health, PAM13 and sex and age

Patients with a higher PAM13 level had a better Mental health outcome scores (coeff=0.73, $p < 0.001$) compared to those with a lower PAM13 level (coeff=6.36, $p < 0.001$) after accounting for sex and age. For each level increase in PAM13 Level, Mental health increased by 1.50 ($p < 0.001$), after controlling for age and sex.

Model 3. SF12 Physical health, PAM13 and sex
Patients with a higher PAM13 level had better Physical health outcomes compared to those with a lower level score after accounting for sex (increase in Physical health score by 8.11, $p < 0.001$). For each level increase in PAM13 level, the Physical health increased by 1.50 ($p < 0.001$). In particular, women had higher Physical health scores compared to men by 11.53 ($p < 0.001$, 95% CI 19.94 -36.50) after accounting for PAM13 level. The total variability in Physical health explained by sex was however low ($R^2 = 15.12\%$).

Table 6. PAM13 Level as predictor ($n = 421$)

SF12 Health outcome	Prob> F	R-squared	Adjusted-square	Coef.	P>t	CI
Before/after&PAM13 Level	0.001	0.0248	0.0225	-0.0732	0.001	-0.12- -0.03
General health&PAM13 Level	<0.001	0.1216	0.1195	0.32585	<0.001	0.24-0.41
Physical Health&PAM13 Level	<0.001	0.1523	0.1503	8.25915	<0.001	6.39-10.13
Mental Health&PAM13 Level	<0.001	0.1329	0.1308	6.81066	<0.001	5.14-8.48

Table 7. Results multiple linear regression between SF12 and PAM13

PAM13 level		Health Outcomes Coef.(95% CI)		
	n	1.General Health ²	2.Mental health ³	3.Physical health ⁴
Unadjusted¹	421	0.33(0.24-0.41)	6.81(5.14-8.48)	8.26(6.39-10.13)
Level 1 Disengaged & overwhelmed	97	Reference	Reference	Reference
Level 2 Aware but struggling	103	0.39(0.13-0.65)	6.74(1.65-11.83)	9.05(3.22-14.88)
Level 3 Taking action	128	0.63(0.38-0.87)	11.84(6.98-16.70)	15.89(10.33-21.44)
Level 4 Maintaining behaviour	93	1.05(0.78-1.31)	20(15.00-25.51)	24.85(18.87-30.83)
R ²	421	0.16	0.20	0.16
Adjusted R ²	421	0.15	0.18	0.15
Prob>F*		<0.001	<0.001	<0.001

1) Unadjusted Health Outcome and PAM13 Level 2) Adjusted for age 3) Adjusted for sex and age 4) Adjusted for sex

*F-statistic test decides whether the model as a whole is significant, compared to no model at all. Test H0=model is not significant rejected if the Prob>F is less than 0.05.

Discussion

This study has created insight into the impact of AI-enabled tele-Health Coaching on a population's health. It hypothesised that patients who received the intervention were better able to self-manage their condition and experienced improved General, Physical and Mental health outcomes. The findings confirmed that the PHC intervention improved PAM13 activation in patients at risk of hospital admission and SF12 physical health.

The AI selected cohort appeared to be older, high-risk patients, with LTCs. Based on these characteristics, it was expected that patients would deteriorate over time, therefore minimal health related improvement was anticipated. The study explored SF12 outcomes associated with PAM13 level and socioeconomic demographics. Patients showed significant improvement in the PAM13 level which included knowledge, skills, and confidence for self-management. The most prominent factor associated with Health outcomes was the PAM13 level. Evidence showed that increased activation was associated with positive change in SF12 outcomes.

Associations between PHC intervention and SF12 health outcomes

The association between PHC intervention and General, Physical and Mental health outcomes were measured through the SF12 questionnaires. The correlation, OR and CI tests confirmed significant but weak correlations between PAM13 Level and SF12 General, Physical and Mental health outcomes. Overall, patients with higher PAM13 levels had a higher chance of better SF12 Health outcomes. The Mantel-Haenzel test verified that the confounders between PAM13 Level on SF12 Physical Health played a small role in the effect on the outcomes. It was confirmed that the associations between the PHC intervention and all SF12 health outcomes were determined by PAM13 levels. In other words, patients who received PHC were better able to self-manage their conditions and experienced improved SF12 Health outcomes.

Impact of PHC on self-activation

The study findings confirmed that the PHC intervention improved self-activation in patients at high-risk of hospital admission. This was measured through the PAM13 questionnaire and the change in activation level. The multiple regression analysis confirmed that patients with a higher PAM13 level experienced better health outcomes when controlled for sex and age. In

particular female patients with higher PAM13 Level compared to men had better Physical health outcomes.

Impact of PHC intervention on self-activation and health outcomes

In addition to the previous dichotomized tests for associations between the intervention and PAM13 and SF12 outcomes the ANOVA test again confirmed that the intervention improved patient's ability to better manage their conditions and improved their self-reported Physical health (Mean Square=44.16 $p < 0.05$, 95% CI 41.47-46.86). A limitation was that results show a weak correlation for all indicators and do not support improvements in self-reported General health or Mental health. Therefore, the conclusion was that the study findings only partially confirmed the hypothesis. These results will need to be interpreted with caution and no conclusion could be drawn about the effect compared to usual care.

Study strengths

There were only limited published data on AI-enabled interventions and no research specifically related to pro-active personalised health coaching and the impact on health outcomes. This longitudinal study included a large sample size and validated patient-reported measurements. It allowed the assessment of change in patient activation levels and health outcomes.

Limitations

Replicability - The PHC study outcomes for self-management and health outcomes scores were not collected for a control group. Therefore, a before and after study design was most suitable although less robust than an RCT. It meant however that no comparison could be made between the intervention and control groups and no conclusion drawn about the effect compared to usual care. The cohort consisted of older patients identified in a hospital setting for one area in the UK. The results may not be generalizable, and replication would be done with caution. Lastly, the study did not confirm the impact of patients' clinical diagnoses which were identified as an important predictor in the literature.

Selection bias - The cohort achieved a 49% response; this may lead to non-response bias. The data were therefore not a strong basis for representing the population, and as such the proportions at each level of activation should be used with caution. As this study only included 'complete SF12 cases' the completion of follow up on SF12 health outcomes measures was

100% and thus potential bias here was less. The PAM13 self-activation completion was 75%, and some scales did suffer additional missing data.

Statistical power - The 'complete cases' analysis, reduced the sample size which may have consequently lost the precision of the estimates impacting statistical power.

Study implications

Within the context of preventing illness exacerbation and A&E readmission avoidance, PHC utilised AI technology to enable personalised care resulting in improved health outcomes in certain population groups. The assessment of socioeconomic factors, validating the impact of the PHC intervention, could inform decision makers in the scale-up and focus on targeting wider population groups beyond the hospital population.

Conclusions

This study concluded that 1) people who received PHC were better able to self-manage their LTC and experienced improved self-reported physical outcomes. 2) PHC intervention improved PAM13 self-activation in patients at risk of hospital admission. 3) The associations between PHC intervention and General, Physical and Mental

health outcomes before/after the intervention was substantial.

Future research implications

Further hospital patient data including diagnosis and hospital utilisation were collated after the completion of the data analysis for this study. Assessing the relationship between these data and patient activation and health outcomes will be required. Future research should also include primary care data, and qualitative interviews with health coaches and patients to validate their views on the intervention impacts. This additional analysis may strengthen the evaluation of the effectiveness of AI predictive medicine in association with patient health outcomes.

List of abbreviations

A&E Accident and Emergency

AI Artificial Intelligence

ANOVA Analysis of Variance

CI Confidence Interval

COPD Chronic Obstructive Pulmonary

IBS Irritable Bowel Syndrome

IMD Index of Multiple Deprivation

LTC Long-Term Conditions

OR Odd Ratios

PAM13 Patient Activation Measures version 13 questionnaire

PHC Health Navigator Pro-active tele-Health Coaching

RCT Randomized Control Trial

SF12 Short Form12v2 questionnaire

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Declarations

Trial registration

International Standard Randomised Controlled Trial Number (ISRCTN): ISRCTN12724749
EudraCT: 2015-000810-23

Ethics approval and consent to participate

Ethical approval has been obtained from the NHS Research Ethics Committee IRAS Project ID 173319 and NIHR Number CPMS 19857.

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from Health Navigator LTD but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Health Navigator LTD.

Competing interests

The research was conducted on behalf of 'for-profit' companies Health Navigator AB and Health Navigator Ltd. The Nuffield Trust acted as the Chief Investigator (CSJ)², received funding of £30k from Health Navigator. The researcher MW³ conducted the analysis and was external to the study.

Funding

Not applicable

Authors' contributions

MW designed the study and methodology, oversaw the data input progress, validated and curated the data quality and worked with the research team for corrections where possible, completed the formal analysis using Stata 15. They further drafted, prepared the first version of the paper. FH, SP, BK and JW validated the study, reviewed and edited the final versions of the paper.

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APPENDICES

Appendix 1. SF12 and PAM13 Questionnaires

1.1 Medical Outcomes 12-Item Short Form Survey Instrument (SF-12)

1. In general, would you say your health is:

- | | |
|---------------|----------|
| 1 - Excellent | 4 - Fair |
| 2 - Very good | 5 - Poor |
| 3 - Good | |

2. The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
a. The kinds or amounts of vigorous activities you can do, like lifting heavy objects, running or participating in strenuous sports	1	2	3
b. The kinds or amounts of moderate activities you can do, like moving a table, carrying groceries, or bowling	1	2	3
c. Walking uphill or climbing a few flights of stairs	1	2	3
d. Bending, lifting, or stooping	1	2	3
e. Walking one block	1	2	3
f. Eating, dressing, bathing, or using the toilet	1	2	3

3. How much bodily pain have you had during the past 4 weeks:

- | | |
|---------------|-----------------|
| 1 - None | 4 - Moderate |
| 2 - Very mild | 5 - Severe |
| 3 - Mild | 6 - Very Severe |

4. Does your health keep you from working at a job, doing work around the house, or going to school?

- 1 - YES, for more than 3 months
2 - YES, for 3 months or less
3 - NO

5. Have you been unable to do certain kinds or amounts of work, housework, or schoolwork because of your health?

- 1 - YES, for more than 3 months
2 - YES, for 3 months or less
3 - NO

For each of the following questions, please mark the circle for the one answer that comes closest to the way you have been feeling during the past month.

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
6. How much of the time, during the past month, has your health limited your social activities (like visiting with friends or close relatives)?	1	2	3	4	5	6
7. How much of the time, during the past month, have you been a very nervous person?	1	2	3	4	5	6
8. During the past month, how much of the time have you felt calm and peaceful?	1	2	3	4	5	6
9. How much of the time, during the past month, have you felt downhearted and blue?	1	2	3	4	5	6
10. During the past month, how much of the time have you been a happy person?	1	2	3	4	5	6
11. How often, during the past month, have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6

12. Please mark the circle that best describes whether each of the following statements is true or false for you.

	Definitely true	Mostly true	Not sure	Mostly false	Definitely false
a. I am somewhat ill	1	2	3	4	5

	Definitely true	Mostly true	Not sure	Mostly false	Definitely false
b. I am as healthy as anybody I know	1	2	3	4	5
c. My health is excellent	1	2	3	4	5
d. I have been feeling bad lately	1	2	3	4	5

1.2. Patient Activation Measure (PAM-13)

[Patient Activation Measure \(PAM-13\)](#) describes the knowledge, skills and confidence a person has in managing their own health and care.

Below are some statements that people sometimes make when they talk about their health. Please indicate how much you agree or disagree with each statement as it applies to you personally by circling your answer. There are no right or wrong answers, just what is true for you. If the statement does not to apply you, circle N/A

1	I am the person who is responsible for taking care of my health.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
2	Taking an active role in my own health care is the most important thing that affects my health.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
3	I am confident I can help prevent or reduce problems associated with my health.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
4	I know what each of my prescribed medications do.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
5	I am confident that I can tell whether I need to go to the doctor or whether I can take care of a health problem myself.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
6	I am confident that I can tell a doctor or nurse concerns I have even when he or she does not ask.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
7	I am confident that I can carry out medical treatments I may need to do at home.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
8	I understand my health problems and what causes them.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
9	I know what treatments are available for my health problems.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
10	I have been able to maintain lifestyle changes, like healthy eating or exercising.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
11	I know how to prevent problems with my health.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
12	I am confident I can work out solutions when new problems arise with my health.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA
13	I am confident that I can maintain lifestyle changes, like healthy eating and exercising, even during times of stress.	Disagree Strongly	Disagree	Agree	Agree Strongly	NA

Insignia Health. "Patient Activation Measure" Copyright 2003-2015, University of Oregon. All Rights reserved." Contact Insignia Health at [www.insigniahealth.comhttps://www.insigniahealth.com/products/pam-survey](https://www.insigniahealth.com/products/pam-survey)

Appendix 2. Supplementary Tables and Figures

Table 2. Baseline before/after intervention

Exposure variable	After (n=288)	Before (n=286)	Total (n=574)	Before %	After %
Sex	288	286	574	50%	50
Female	145	145	290	50%	51%
Male	143	141	284	50%	49%
Age	288	286	574	50%	50%
20-29	1	1	2	0.3%	0.3%
30-39	2	2	4	0.7%	0.7%
40-49	3	3	6	1%	1%
50-59	16	16	32	6%	6%
60-69	56	55	111	19%	19%
70-79	108	108	216	36%	38%
80-89	89	88	177	31%	31%
90-99	13	13	26	5%	5%
SF General health	288	286	574	50%	50%
Poor	158	175	333	55%	61%
Good	130	111	241	45%	39%
PAM Level	195	226	421	34%	34%
Low	77	123	200	40%	54%
High	118	103	221	61%	46%
Deprivation	283	281	564	49%	49%
Most deprived	45	45	90	16%	16%
Least deprived	238	236	474	84%	89%
Income	283	281	564	49%	49%
Most deprived	45	45	90	16%	16%
Least deprived	238	236	474	84%	84%
Employment	283	281	564	49%	49%
Most deprived	44	43	87	16%	15%
Least deprived	239	238	477	84%	85%
Education	283	281	564	49%	49%
Most deprived	62	62	124	22%	22%
Least deprived	221	219	440	78%	78%
Housing	283	281	564	49%	49%
Most deprived	113	112	225	40%	40%
Least deprived	170	169	339	60%	60%
Environment	283	281	564	49%	49%
Most deprived	107	105	212	38%	37%
Least deprived	176	176	352	62%	63%
Crime	283	281	564	100%	100%
Most deprived	57	57	114	20%	20%
Least deprived	226	224	450	80%	80%
Health Disability	283	281	564	100%	100%
Most deprived	50	50	100	18%	18%
Least deprived	233	231	464	82%	82%

2.2. Excluded vs included group differences, missing data n=591

Table 1. Excluded vs included group differences, missing data n=591											
Variable	Patients excluded (N = 303)				Patients included (N = 288)				Differences N=591		
	n	Mean	SD	95% CI	n	Mean	SD	95% CI	Mean	95% CI	P-Value
Sex	303	1.76	0.80	1.67-1.85	288	2.50	0.77	2.44-2.55	-0.737	-0.85-0.63	<0.001
Age	257	74.77	11.72	73.33-76.21	288	74.79	10.80	73.54-76.04	-0.018	-1.91-1.88	0.9853
Education	251	6.79	2.69	6.46-7.13	281	7.29	2.62	6.99-7.59	-0.499	-0.94-0.05	0.02
Crime	251	7.51	2.68	7.18-7.84	281	7.94	2.43	7.66-8.23	-0.433	-0.87-0.002	0.05
Missing data											
	Missing				Total				Percent Missing		
Age					46	591			7.78		
Deprivation					59	591			9.98		
Income					59	591			9.98		
Employment					59	591			9.98		
Education					59	591			9.98		
Health disability					59	591			9.98		
Crime					59	591			9.98		
Housing					59	591			9.98		
Environment					59	591			9.98		
Sex					0	591			0		
Cohort					0	591			0		

2.3. Mean \pm SD for continuous variables for categorical variables outcomes age, sex, IMD socioeconomic score.

Exposure variable	After (n=288)	Before (n=286)	Total (n=574)	Pearson chi2	p- value	Mean	Std. Dev.	Min	Max
Sex	288 50%	286 50%	574	0.12	1.000	74.78	10.80	27	98
Age	288 50%	286 50%	574	0.01	1.000	74.78	10.80	27	98
SF General health binary	288 50%	286 50%	574	2.36	0.125	37.09	24.95	0	100
SF General health	288 50%	286 50%	574	6.70	0.152	2.48	1.00	1	5
SF Mental health composite	288 50%	286 50%	574	79.92	0.005	56.61	20.47	0.00	100.00
SF Physical health composite	288 50%	286 50%	574	81.02	0.218	42.33	22.88	0.00	98.13
PAM13 Level	195 34%	226 34%	421 68%	12.64	0.005	2.52	1.07	1	4
Deprivation	283 49%	281 49%	564 99%	0.04	1.000	7.80	2.20	2	10
Income	283 49%	281 49%	564 99%	0.02	1.000	7.72	2.24		
Employment	283 49%	281 49%	564 99%	0.04	1.000	7.63	2.18	2	10
Education	283 49%	281 49%	564 99%	0.03	1.000	7.30	2.55	1	10
Housing	283 49%	281 49%	564 99%	0.03	1.000	6.06	2.82	1	10
Environment	283 49%	281 49%	564 99%	0.03	1.000	6.12	2.60	1	10

2.4 r= Pearsons correlation coefficients between scales and summary scores of patients (n=288)

	SF12 General health	SF12 Mental health	SF12 Physical health	PAM13 Level
SF12 Mental Health	0.5212	1		
	<0.001			
	574	574		
SF12 Physical Health	0.7311	0.6763	1	
	<0.001	<0.001		
	574	574	574	
PAM13 Level	0.3486	0.3645	0.3903	1
	<0.001	<0.001	<0.001	
	421	421	421	421
Employment	0.0219	0.0212	0.0301	0.099
	0.6044	0.6149	0.4754	0.0444
	564	564	564	413
Health disability	0.0187	0.0197	-0.0075	0.1413
	0.6572	0.641	0.8586	0.004
	564	564	564	413
Environment	-0.052	-0.0557	-0.1168	-0.1093
	0.2179	0.1864	0.0055	0.0263
	564	564	564	413
Sex	0.0427	0.1785	0.1604	0.0732
	0.3066	<0.001	0.0001	0.1339
	574	574	574	421
Age	0.1085	0.1433	0.0121	-0.0326
	0.0093	<0.001	0.7715	0.5051
	574	574	574	421

2.5 SF12 General health and PAM13 Level binary Maximum likelihood estimate of the odds ratio

Exposure variable	Odds Ratio	chi2(1)	P-value	CI
SF12 General health binary Maximum likelihood estimate of the odds ratio				
PAM13	3.073	30.37	<0.001	2.02-4.68
Age	1.173	4.28	0.0386	1.01-1.36
Environment	0.939	3.66	0.0559	0.88-1.00
Period	1.062	0.03	0.8532	0.56-2.01
Sex	1.249	1.72	0.1897	0.90-1.74
Housing	0.999	0.00	0.9650	0.94-1.06
Health Disability	0.973	0.48	0.4862	0.90-1.05
Employment	0.979	0.30	0.5839	0.91-1.06
Deprivation	0.971	0.56	0.4534	0.90-1.05
Crime	0.965	1.04	0.3077	0.90-1.03

Education	0.989	0.12	0.7331	0.93-1.06
PAM13 Level binary Maximum likelihood estimate of the odds ratio				
Time Period	0.546	9.34	0.002	0.37-0.81
General Health	1.791	36.04	<0.001	1.48-2.17
Mental health outcome	1.031	40.03	<0.001	1.02-1.04
Physical health outcome	1.030	47.58	<0.001	1.02-1.04
health disability	1.122	6.39	0.011	1.03-1.23
Environment	0.928	3.63	0.056	0.86-1.00
Sex	1.341	2.23	0.1355	0.91-1.97
Age	0.942	0.41	0.5206	0.78-1.13
Housing	0.977	0.42	0.5146	0.91-1.05
Employment	1.084	3.14	0.0766	0.99-1.19
Deprivation	1.039	0.71	0.3994	0.95-1.13

* P>chi2

2.6 Association between binary measures of SF12 General health, PAM13 Level and risk factors

Exposure Variable	Unadjusted ¹		Adjusted ³				Final model ⁵		
	OR	95% CI	OR	95% CI	P-value ²	% reduction ⁴	OR	P-value	95% CI
Crude General Health Exposure PAM13 Level	3.07	2.02-4.68					3.01	0.008	1.27 - 7.15
Time period (before after intervention)	1.06	0.56-2.01	2.99	1.95-4.56	0.5653	4.21			
Environment	0.94	0.88-1.00	3.22	2.08-4.99	0.5822	-7.05			
Crime	0.97	0.90-1.03	3.16	2.05-4.85	0.3554	-4.07			
Crude Physical Health Exposure PAM13 Level	1.03	1.02-1.04					1.03	0.036	1.00 - 1.06
Sex			1.030	1.02-1.04	0.2989	29.82			
Age			1.030	1.02-1.04	0.9887	29.82			
Health and disability			1.031	1.02-1.04	0.8212	26.51			
Housing			1.031	1.02-1.04	0.4806	27.59			
Employment			1.031	1.02-1.04	0.9035	27.68			
Environment			1.030	1.02-1.04	0.1996	29.81			

1.Maximum likelihood estimates of the odds ratio unadjusted

2. Mantel-Haenszel (MH)estimate of the odds ratio hypertension comparing education, controlling for exposure variable. Test of homogeneity of ORs (approx.)

3.Adjusted (MH Odds pooled estimate)

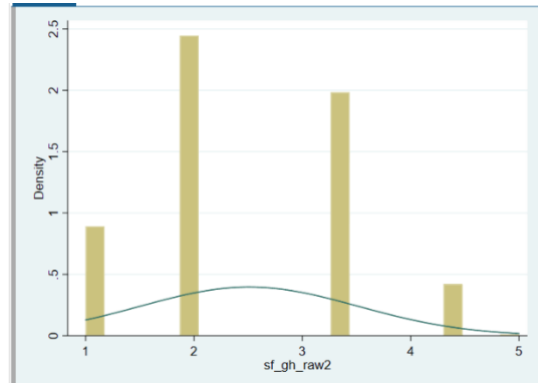
4.% Estimate of reduction in the effect of PAM13 Level and Health outcomes after adjustment for exposures. It was assumed that when a difference was below 5% the variable would influence the association, if over 10% the exposure variable could be a confounder.

5. Final model combined MH estimate of the odds ratio general health comes comparing PAM13 Level, controlling for period, environment and crime

2.Figure 1 Distribution skewness and kurtosis

SF12 General health

Skewness=0.17 Kurtosis=2.0

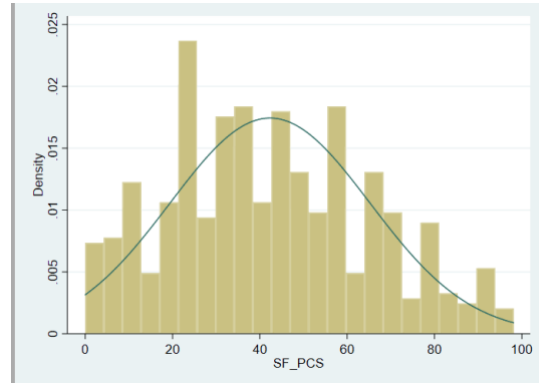


SF12 Mental health

Skewness=-0.2 Kurtosis= 2.4

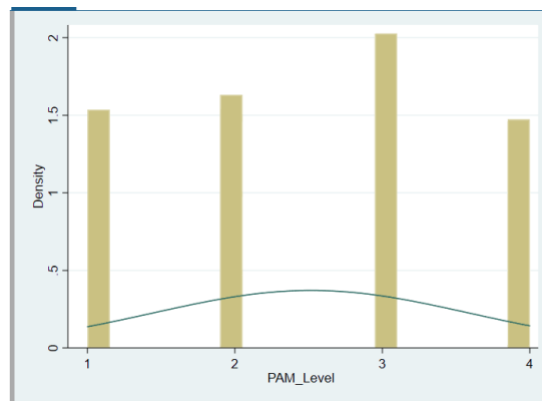
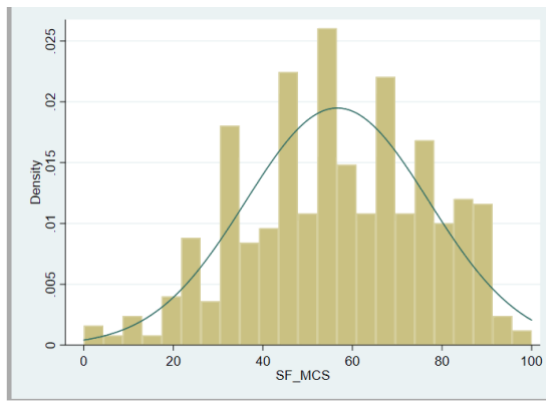
SF12 physical health

Skewness=0.2 Kurtosis=2.3

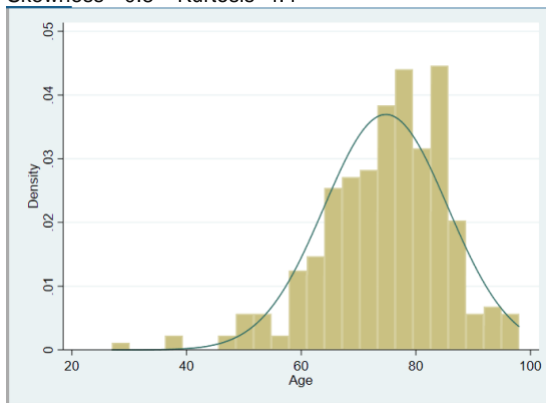


PAM13 Level

Skewness=-0.06 Kurtosis=1.7



Age
Skewness=-0.8 Kurtosis=4.4



2. Figure 2. Model adequacy

