

Evidence for **Supported Self Care at Scale**

Telehealth-based Chronic Care Management

A population approach to evaluating technology-enabled support for long term condition management

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Abstract

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This short report presents findings of a large scale supported self-care program in Liverpool, UK. Over 3 years, 2,234 COPD, HF and diabetes patients were recruited through their GP (primary care physician) practice. The program combines tele-monitoring equipment and TV or tablet user interface in the home with the support of a central telehealth team providing case management, monitoring, education and coaching.

A study cohort of 1,808 patients is matched to a pseudonymised control cohort that mirrors the study cohort in recruitment date, disease, age, previous unplanned admissions, future unplanned admissions risk, socio-economic status and polypharmacy.

Both cohorts are compared before and after the start of the program. These comparisons are studied in detail in terms of unplanned admission risk, length of time after the start of the program (of each individual patient) and length of time on the program.

These results show reductions in both unplanned admissions and hospital costs in comparison with the control group ranging from 22% to 32% (depending on subgroup) with above average risk (25% or more). Patient reported outcomes also show that 90% of patients feel more in control, have gained confidence and/or feel better able to cope with their condition.

This short report presents the findings so far of the Liverpool experience. We discuss the challenges in producing a robust evaluation and believe the results demonstrate that this can be an effective intervention for groups of patients with long term conditions; demonstrating improvements in patient experience, outcomes and a reduction secondary care utilization where currently the majority of system costs exist.

Looking ahead, the results indicate how programs may be better customized and targeted in the future based on risk score to achieve ever-improving results. We hope that our work will add to and inform the evidence base and we are confident that telehealth-enabled chronic care will become more important as the technology evolves, improves and costs are reduced.

1. Introduction



30% of people in Liverpool live with one or more long term conditions



The difference in life expectancy between areas of the city can vary by more than 10 years



The number of patients with Chronic Obstructive Pulmonary Disease offered rehabilitation varies between 24% and 79% in the city



Almost 26,000 older people have a long term illness that limits their day-to-day activities extensively



Over half of adults in Liverpool are overweight or obese



86% of people in Liverpool are not active enough to maintain good health

Figure 1: Healthy Liverpool challenges

1. Introduction

Liverpool Clinical Commissioning Group (LCCG) has committed to provide a health and social care system for Liverpool that is person-centred, supports people to stay well and provides the very best care. The “Healthy Liverpool” program³ describes the challenges and target outcomes.

Philips has developed a systematic approach to bring together products and services to address international healthcare challenges. Philips defines “Population Health Management” as “*The organization of, and accountability for, the health and healthcare needs of defined groups of people utilizing proactive strategies and interventions that are coordinated, engaging, clinically meaningful, cost-effective and safe.*”

Liverpool and Philips have worked together to use innovation to tackle healthcare challenges. In particular the ‘More Independent’ (MI) program was a UK government sponsored⁴ program which brought together healthcare organizations, charities and industry to deliver assisted living technologies at scale. It recognized that the only way in which increasing demand can be managed with decreasing resources is by more innovative solutions that focus face-to-face care where and when it is needed, and support people to manage their own long term conditions (LTCs) through technology.

The MI program has developed, through iterative design, community care based remote monitoring at scale. Through the ongoing program more than 2,500 people with LTCs have already received support and self-care coaching. Central to the design is a central telehealth team that supports patients and their physicians using technology in peoples’ homes. This paper reports the outcomes of the work.

2. Service design and implementation

2.1. Patient recruitment

The service in Liverpool has been created through continuous learning, informing the introduction of improved pathways, as new stakeholders have come on board and the processes have become more efficient and effective. The service is led by a central telehealth team that interfaces with patients and primary care physicians. This central telehealth team not only takes responsibility for the daily monitoring and case management, it also plays a crucial role in stakeholder engagement, patient recruitment and program development. The process is illustrated at high level in Figure 2. The first two steps involve engaging with each individual general (primary care) practice in Liverpool and using searches and local patient knowledge to generate patient lists. The next two steps involve contacting patients and with them deciding if the telehealth program is right for them. The final two steps cover the technical process of setting up a customized system for each patient, after which the monitoring and coaching program commences.

Each step of this process has challenges requiring specific skills and solutions to address them. Busy primary care practices have natural concerns around workload, information governance and evidence. These need to be worked through carefully and require high-level clinical leadership. Further down the process patients can be hard to reach and may be suspicious of a phone call they regard as cold calling. This requires robust processes for communicating with patients including mailings, staff coaching and staff motivation. These examples serve to illustrate only some of the complexity of running a home telehealth program at scale. Once the monitoring commences, people stay on service for as long as is deemed clinically appropriate through regular reviews.



Figure 2: Clinical hub process engagement and recruitment process

2.2. Intervention program

The program uses the Philips telehealth technology. The objective is to empower patients to actively manage their disease state and change their behavior by providing appropriate coaching and education. The patient interface consists of a tablet or TV set-top box which is wirelessly connected to scales, blood pressure cuffs and pulse oximeters. Patients also receive a schedule of videos, follow up questions and daily or weekly assessments. These check up on health parameters such as breathlessness, sputum production and medication compliance. There are also assessments issued at longer intervals (monthly or longer) to understand quality of life, mental health and engagement with self-management. The results of the vital sign measurements and assessments are processed through intervention rule-driven algorithms which set alerts and steer workflow. Agreed protocols define the measurement types, scheduling of assessments and videos and intervention rules. Protocols are customised according to disease type(s) and intervention level. Over the course of the program these protocols have been further developed and optimized to deliver against three service principles:



1. Safe and clinically sound processes for individual patients
2. Efficient and effective operation for the central telehealth team
3. Agreed outcomes for patients, providers, and payers

3. Unplanned admission risk calculations

3.1. Background

One of the top priorities in the UK health system has been to reduce avoidable admissions⁵. These account for 16% of unplanned admissions at a cost £1.42 billion in 2012 and are rising fast. Less than half of that increase can be explained by population growth and aging⁶. This suggests that other, modifiable, factors are related to the occurrence of these admissions. With the help of risk models it is possible to identify these factors; this has driven the development and use of such models⁷. The model chosen by Liverpool CCG is the Wales Predictive Model⁸ and a regular risk data report is prepared for the CCG. This paper makes some use of this risk data. The analysis was done by one of the authors (CvB) under honorary contract with the CCG. Data was accessed on the CCG premises and under the data governance and supervision of the CCG.

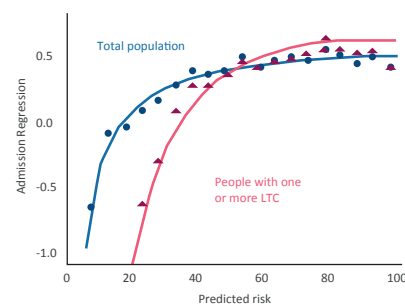
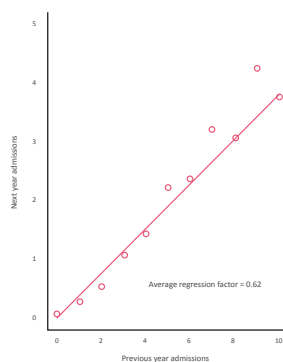
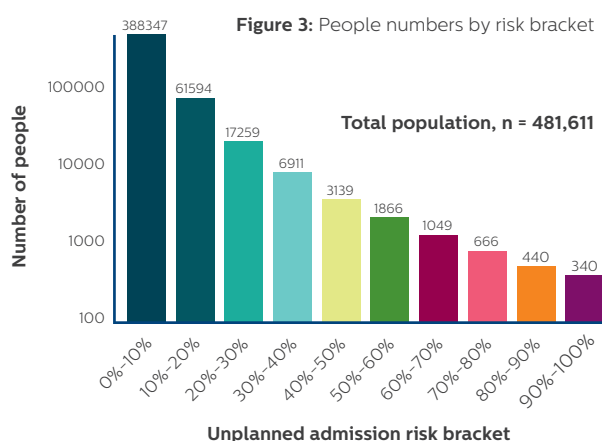


Figure 4: Population wide annual regression in unplanned admissions

Figure 5: Regression as function of risk

3.2. Distributions of risk

In Liverpool, the average number of unplanned admissions per person is 0.1 per year. For people over 55 it is 0.2 admissions/year, while for people with diabetes, HF or COPD it is 0.3 admissions/year. Clearly being older or having a long term condition is a risk factor for unplanned admissions. The risk calculation uses 35 such parameters from Inpatient, Outpatient, GP (primary care) and demographic data sources to calculate the probability that someone will have one or more unplanned admissions in the following 12 months. A report has been produced by the CCG in collaboration with Philips on results of the model⁹. Figure 3 illustrates the distribution of the predicted risk in the total population of Liverpool CCG.

3.3. Dynamics of risk

The number of unplanned admissions that an individual experiences is not the same year by year. For instance, because disease progression takes a turn for the worse and because people receive high quality healthcare, the number of unplanned admissions can be high one year and low the next. The data shows that, on average, people with one or more admissions in one year, will have fewer admissions in the following year. Figure 4 illustrates the average number of admissions in a following year as function of the number of admissions in the previous year. The circles illustrate the data, the full line illustrates a simple linear fit. On average, the number of admissions in the following year is reduced by 62%. Only people with no admissions in the previous year see an increase in the average number of admissions in the following year. This result has important implications for service design and evaluation as it illustrates that:

1. Past admissions can be a poor basis on which to select patients for proactive disease management.
2. Simple before/after comparisons can show large differences if poor selection criteria are used.

A better way to design and evaluate a service is on the basis of a combination of risk and other parameters. This is illustrated in Figure 5, which shows the relative reduction in admissions as a function of risk for all people (blue dots and curve) and for people with one or more long term conditions (red triangles and curve). As can be seen the relative change in admissions between one year and the next is a strong function of risk and is generally lower than the reduction observed in Figure 4. This means that a patient group selected by risk shows less regression in admissions than a patient group selected on the basis of past admissions alone. This not only means that combined population characteristics like risk, age and disease provide a better way to select patients, it also means that the regression is predictable and can be modelled. This in turn has implications for service evaluation.

4. Population analysis

4.1. Patient numbers and base line characteristics

There were 2,234 patients enrolled in the intervention program in the period March 2013 to September 2015. In practice, some patients stay on for only a very short time and some patients are enrolled twice having successfully completed a program once and then re-enrolled sometime later. There are 1,808 patients in the study cohort for this paper. To be included their records must satisfy the following criteria:

1. There must be sufficient baseline data to find matched controls.
2. They must have been on service for at least one month.
3. Their first enrollment is counted as 'start of service'.

	Jul -13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14
# patients starting	16	7	9	8	1	3	0	12	7	11	26	43	63	131
Average age	67.1	67.0	67.7	70.5	71.0	72.3	0.0	66.9	68.0	76.2	66.9	64.0	66.6	67.8
Risk at start	40%	46%	48%	43%	74%	41%	0%	52%	49%	29%	41%	28%	26%	29%
Unplanned Adms	1.2	2.6	1.9	1.4	1.0	0.7	0.0	2.1	1.1	0.5	1.7	0.4	0.4	0.5
Socio-economic status	57	48	58	49	77	46	0	61	49	36	59	50	37	53

	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Total
# patients starting	129	85	122	86	119	123	154	114	116	135	94	107	87	1808
Average age	64.4	67.3	64.5	66.9	67.6	65.6	65.8	66.1	65.9	64.5	66.6	68.2	66.6	66.3
Risk at start	26%	25%	26%	26%	26%	21%	23%	26%	28%	27%	23%	23%	26%	26%
Unplanned Adms	0.5	0.3	0.4	0.5	0.5	0.2	0.4	0.4	0.4	0.5	0.3	0.4	0.4	0.5
Socio-economic status	43	38	55	37	53	45	44	49	55	57	43	33	41	47

Table 1: Month by month recruitment characteristics

Table 1 shows month by month the characteristics of service recruitment. Not only how many people came on service, but also their average age, the average risk in the start month and the average number of admissions they had in the year prior to enrolment. The table reflects the challenges that have been faced and overcome in building the service. Figure 6 shows the spread of risk in the recruited population. The coloured bars represent the absolute numbers in each risk band with respect to the left hand axis. The average risk is 26% and the median is 22%. The broad spread of the population has been one of the factors for success for the program in that it facilitated broad clinical and patient engagement. However it means that overall only 1 in 3 of the patients in the cohort was expected to have an unplanned admission in the next 12 months. Hence while significant reductions in unplanned admission can be expected and measured in the top half of the cohort, for the bottom half the impact needs to be measured over longer periods or by different means. The green line in the figure illustrates, with respect to the right hand axis, the number of people

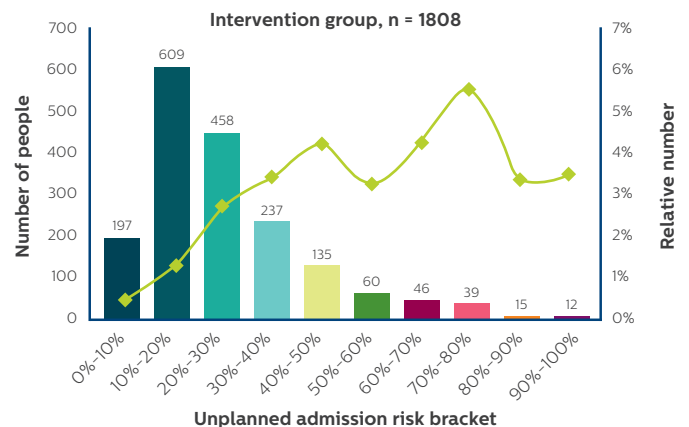


Figure 6: Risk-at-characteristics of intervention group

in each risk band as a proportion of the total number of people within each risk band across the entire population of Liverpool as shown in Figure 3. This makes the point that while the single largest group in the histogram is the 10%-20% risk band, admissions risk is actually quite a good indication for the intervention cohort.

	COPD	HF	DIABETES	Total
Number	1090	197	773	1808
Age	67.7y	71.0y	65.1y	66.3y
Risk	29.9%	37.5%	23.8%	26.4%
Adms	0.5	0.7	0.4	0.5
Months on Service	4.9	5.0	4.2	4.5

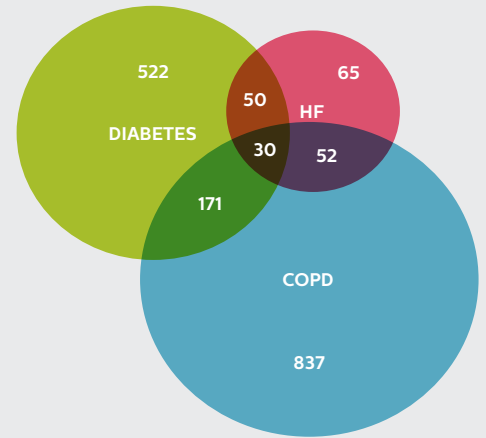


Figure 7: Disease characteristics

4.2. Clinical and psychosocial characteristics

Figure 7 illustrates the disease profile of the patient population at baseline. COPD is the single largest group. People in this cohort have poor health status; their average quality of life as measured by the EuroQol Time-Trade-Off is 60%. The national average for the 60–69 age group is 80%. Table 1 above also shows the average socio-economic status score of patients enrolled in each month. The variation is due to the fact that month by month different practices in Liverpool joined the program and characteristics of new patients would be dominated by the demographics of those newly joined practices. One of the challenges for Healthy Liverpool is the health inequalities across the city and this variety is reflected in the study cohort.

During their time in the program patients were also asked to fill in a questionnaire to assess their attitudes to health using both the Department of Health ‘Healthy Foundations¹⁰’ questionnaire and a proprietary questionnaire to assess preferred communication style. The results are illustrated in Figure 8. As can be seen the two largest groups in the cohort are ‘Unconfident Fatalists’ and ‘Health-conscious Realists’. It is known that the former group is over-represented among people with a long term condition, but the relative size of the second group is a surprise. Because the questionnaire took place when patients had been on service for 6 weeks, it is not known if this is due to the program or the result of unintentional patient selection bias. In any case, these results underline the importance of psychosocial as well as clinical characteristics in the design of a successful intervention program.

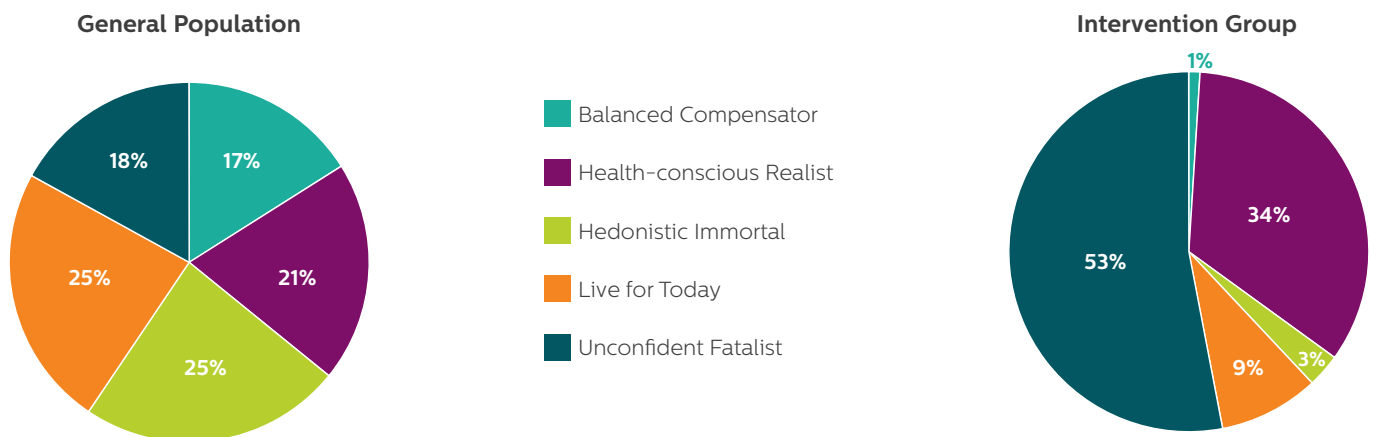


Figure 8: Segmentation for the general population (ref 10) and the intervention group

4.3. Service length

An important aspect of the service design is how long people are part of the service. Patients can be supported for 1 month to 12 months or more. The decision to continue, stop or step down to an alternative program is a shared decision between clinician and patient. Figure 9 provides a histogram of patient numbers as function of length on service. The histogram bars split into patients who have above median risk at start (blue) and patients that have below median risk at start (green). As can be seen, the balance between these subgroups changes with service length. Patients with higher risk tend to remain part of the program for longer. This observation illustrates once more the richness of population management in identifying and managing different subgroups.

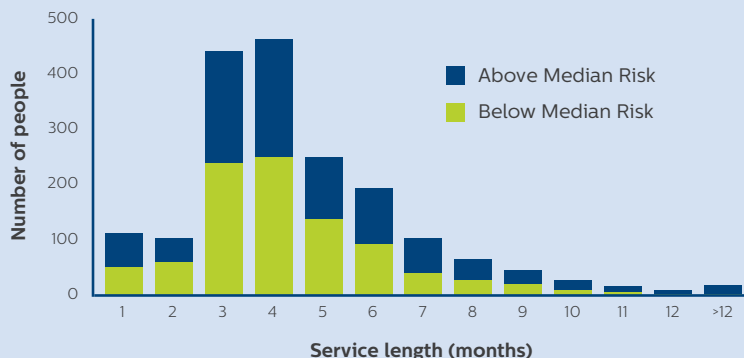


Figure 9: Number of patients as function of service length (Months)

4.4. Control group

To achieve a valid evaluation against the backdrop of continuously optimizing the service and supporting a broad patient cohort, it is important that the control group mirrors and tracks these characteristics. We built such a group through finding 3 matches in the de-identified risk data set for every individual enrolled onto the service. The matching occurs on a person by person and month by month basis. For example for everyone enrolled on the telehealth service in October 2013 we find 3 records that match at that time. The controls have the same long term conditions (COPD, HF and/or diabetes) and are within a narrow band in terms of age, risk, number of unplanned admissions in the previous 12 months, socio-economic status and polypharmacy. Controls are ‘assigned’ to the same intervention program as their match and recorded as part of the service for the same amount of time. Duplication is avoided by excluding people who are in the intervention group at any time or those already included in the control group for a different month. Also the algorithm corrects bias that might arise from the strongly skewed nature of the risk or polypharmacy distributions or the discrete nature of the admission distribution. The resilience of the control group is tested by creating different control sets by taking different draws and by varying the matching threshold slightly. We find that in general there is only 25% overlap between different draws. Table 2 summarises the characteristics of the intervention and control groups used in this paper. Successful matches were found in 99.5% of cases.

Note that the controls are not matched on geography GP (primary care) practice or gender. In principle, it is possible to do this, but this will restrict the number of available matches and may force a poorer match in terms of admissions, age and risk. A limitation of the control group is that we cannot know if the controls would be suitable for the program or would have consented to be part of the service. Nor can we know if someone in the control group had been approached as part of the process in Figure 2, but then refused to participate. Those details were not available for this study.

	Num	Age	M/F	COPD	HF	Diab	Risk	Unpl Adm	PolyPh	Socio-ec Status
Intrv	1808	66.3y	1.0	0.60	0.11	0.43	26.3%	0.46	11.08	51.3
Ctrl	5415	67.0y	0.9	0.60	0.11	0.43	25.9%	0.44	10.56	52.2

Table 2: Comparison of intervention and control set

5. Outcomes

5.1. Methodology

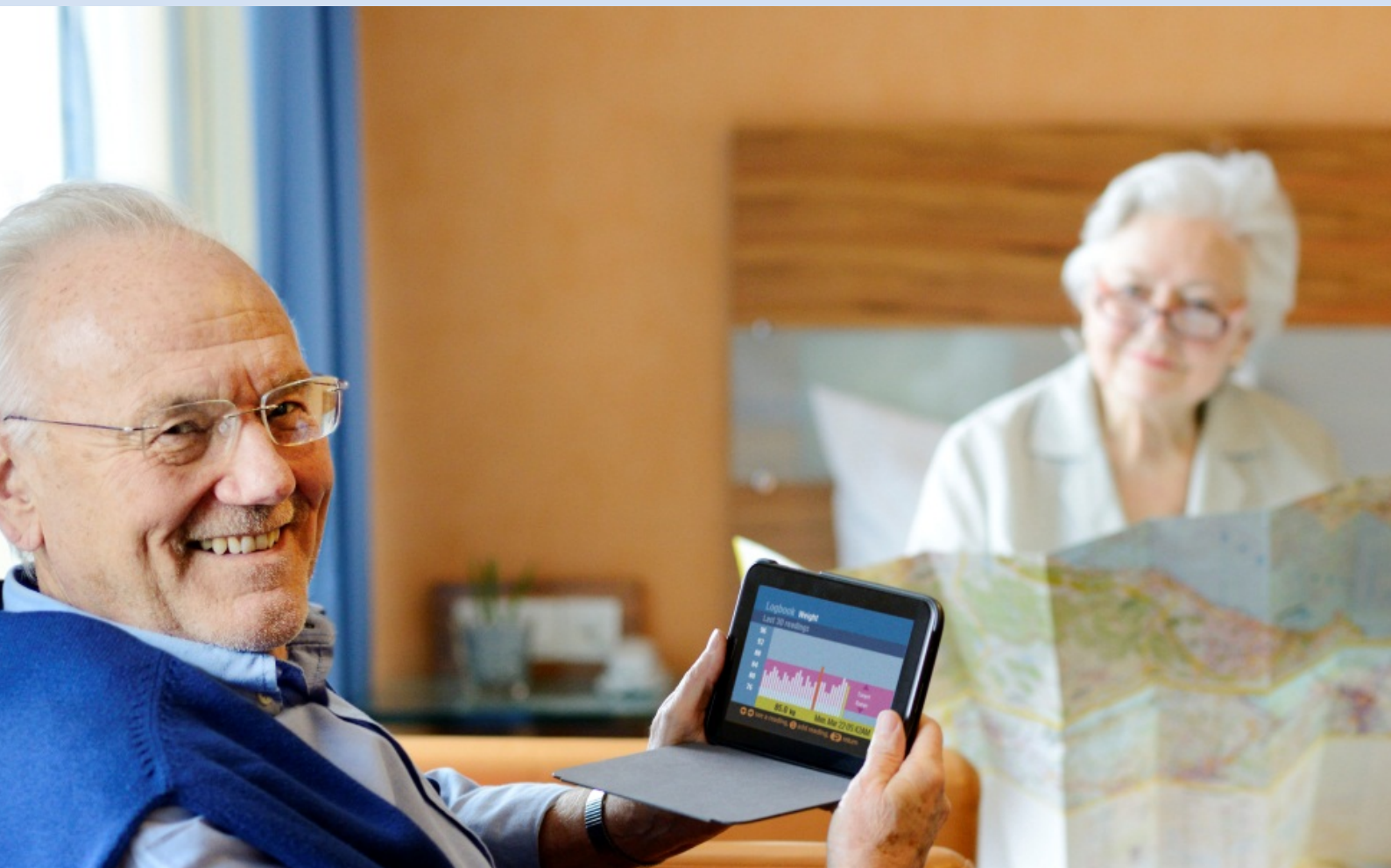
The impact on admissions of the service is assessed through a four way comparison. The before and after difference in unplanned admissions in the intervention group is compared with the before and after difference in the control group. A statistical significance test is then applied to the difference between the distributions of these two differences. The test used is Welch's t-test which is an adaptation of Student's t-test for two populations that have different size and different variance.

This approach enables a rich study of impact for people with different risk profiles, who have been part of the service for different amounts of time or who have different diseases. This provides insight into not only if the intervention works, but also for whom it works and over which time scale.

Table 3 illustrates an example result for intervention and control subjects who have a risk > 30% and who were on service for 6 months or more. Unplanned admissions over 12 months before and after as recorded in the risk extract data are compared. The first row shows that there were 119 people with a risk above 30% in the intervention (sub) group for whom 12 months of data was available. The average risk in this sub group at the start of service is 44.4%. The average number of unplanned admissions in the year before start is 1.09 admissions per person and the average reduction in the following year is 0.32 admissions. The second row in Table 3 gives the same parameters for the control group. As can be seen, they had a very similar risk and a similar number of admissions in the year preceding their match date. In the year after that they experienced, on average very little change in unplanned admission. Indeed there was a small rise represented by a negative Change in Admissions. The final column in the table provides the statistical test for a difference between the intervention and the control group. **The difference in reduction in admissions is 0.35 (~32%) and the p value is 2.5% meaning that we accept the difference as statistically significant.**

	n	Risk	Adm	Change in Admissions	Test
TH	119	44.4%	1.09	0.32	$\Delta = 0.35$
CT	284	45.1%	0.97	-0.03	p = 2.5%

Table 3: Results for 12 month admissions, R>30%, length on service > 6 months



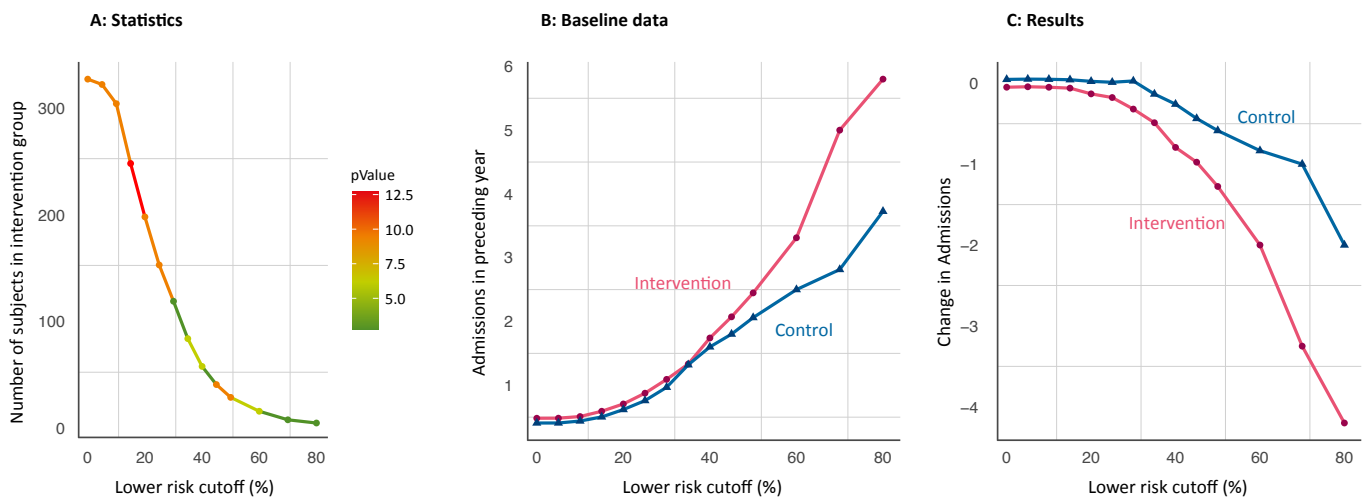


Figure 10 Unplanned admissions in 12 months for intervention (red) and control (blue), service length > 6 months

5.2. Dependence on service variables

The detailed analysis above can be repeated for different sub-groups by varying the risk cut-off, the minimum length on service, age, socio-economic status or by separating patients out by different disease. This section highlights some examples.

Figure 10 shows how the sample result in Table 3 changes as the risk cut-off is changed. The first (left) graph shows the number of patients, the second the number of admissions prior to start for intervention (red) and control (blue). The rightmost panel shows the change in admissions for intervention (red) and control (blue). For lower risk cut-off, the number of the patients in the intervention cohort is quite large, but the difference in the reduction of admissions change is quite small. This means that for a risk cut-off < 15% the differences are not considered statistically significant. On the other hand, for very high risk cut-off the effect is much larger and remains statistically significant even though there are fewer subjects in the risk subgroups. As can be seen, for the high risk group there is some divergence between the base line admissions of the intervention and control group.

Another aspect that can be investigated is how the results change as people participate longer or shorter in the program. Figure 11 shows an example for the subset of people with a risk of 40% or higher. Similar to the results shown in Figure 9, the people who remain on the program longer have more admissions to begin with. **The net reduction in admission is larger for the people staying on longer with the best results obtained at 7 months.** Results above 8 months have increasing p values and are not considered reliable.

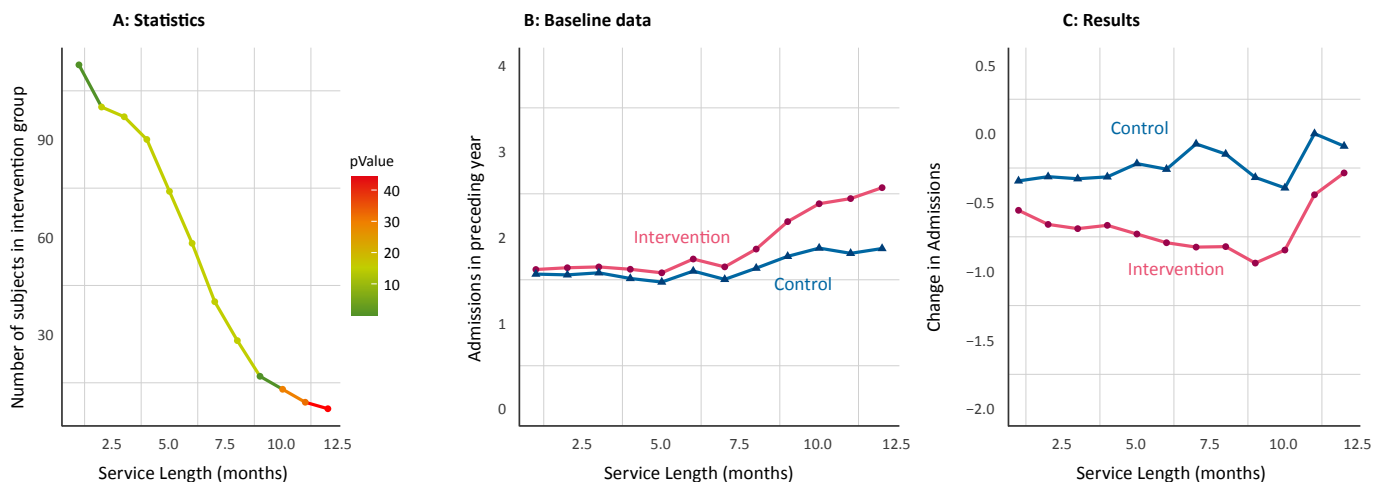


Figure 11: Unplanned admissions in 12 months as function of service length, risk > 40%

5.3. Secondary Use Service (SUS)

We have also used secondary care data available to the CCG through SUS. This enables a more detailed examination of the time dependence of the impact. Figure 12 illustrates how the comparison works. A time span after start of service (green) is compared with the same time span starting twelve months before the start of service (orange). This design avoids seasonal bias.

Figure 13 shows Inpatient secondary care Payment by Results (PbR) costs as function of risk cut-off. Figure 13B shows the average cost over a time span of 6 months, one year prior to start (the orange time blocks of Figure 12). Figure 13C shows the change in cost over 6 months after start of service (the green blocks of Figure 12). Figure 13 shows results for patients who were on service for 3 months or more. Similar results are obtained for other service lengths following trends shown in Figure 11. It can be seen in Figure 13B that intervention and control are well matched. Figure 13C shows that the change in cost is significantly larger in the intervention group than in the control group. For instance for risk >25%, there is a gross saving over six months of £499 (approximately \$800) (23%, $p=0.4\%$) over and above the control group.

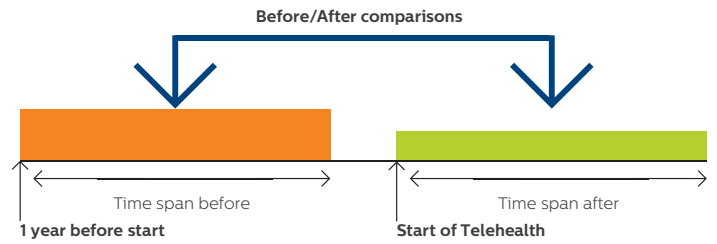


Figure 12: Illustration of time span choice

Figure 13 shows how long it takes for the benefits to build up. The second panel shows the 'before' costs over time spans ranging from one month to 12 months. The costs build up linearly over time and very similarly for intervention and control. The third panel then gives the differences with the same periods after start of service (the green blocks of Figure 12). The difference between the two lines suggests a 'quick win' in the first two months or so and then a general accumulation of benefit as time progresses.

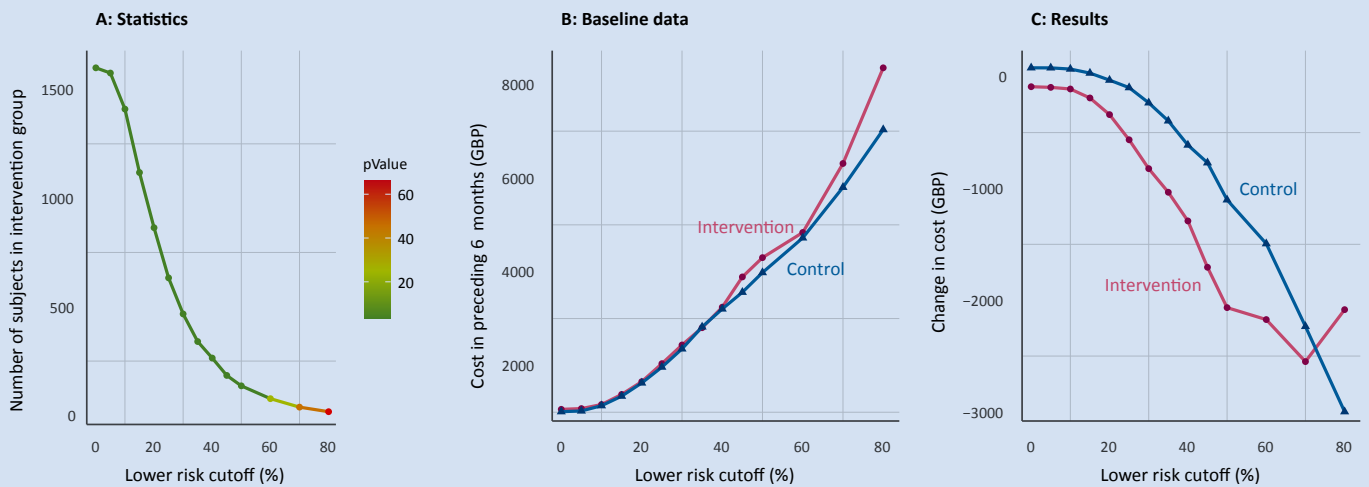


Figure 13 Six month cost as function of cut-off risk, service length > 3 months

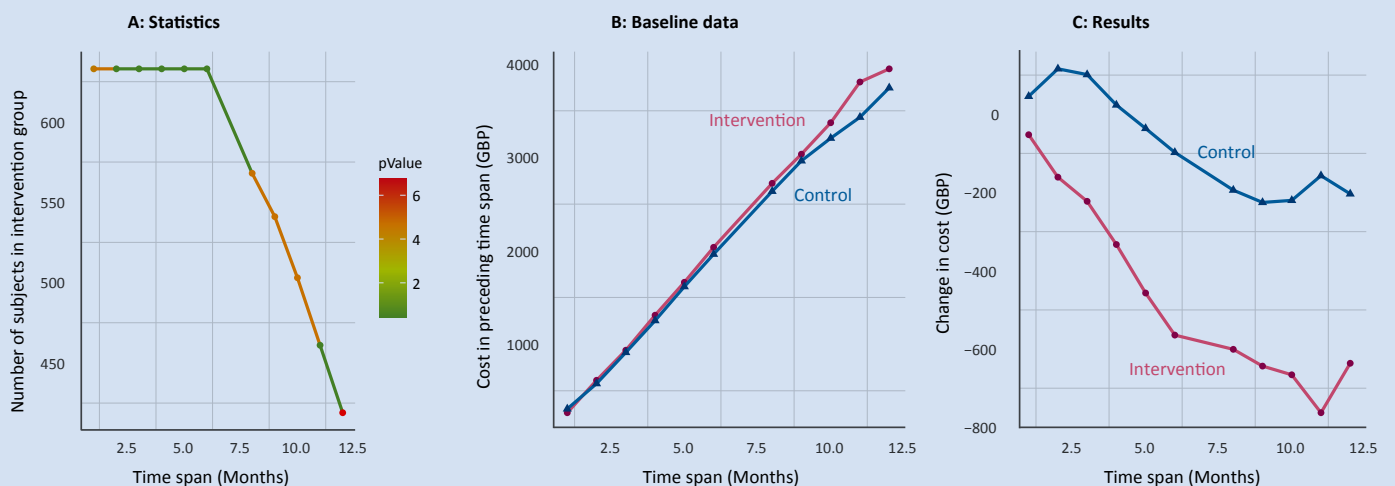


Figure 14: Cost as function of time, risk > 25%, service length > 3 months

5.4. Patient reported outcomes

Patients are asked to answer an engagement and satisfaction questionnaire after approximately 3 months of service on the Philips telehealth service. It contains 21 questions on aspects such as health care utilization including GP (primary care) or community (home health) nurse visits, lifestyle, education and whether they have shared their learnings and results with other people. In total 1,306 patients provided responses. Table 4 summarizes the main factors. Slightly more than half the patients have reported decreases in their health utilization in line with the results of the previous section. In addition, **90% of people feel more control, more confident, or better able to cope with their condition**. Half or more than half of the patients report improvements in lifestyle or health management. Patients tend to have a positive attitude to the service as witnessed by their willingness to use it in the future and the fact that they have shared the results with others. These factors have well known association with outcomes and this is shown in the table by the odds ratios in the table. For instance, patients who report more control or confidence are 6.5 times more likely to report a decrease in healthcare utilization than patients who do not.

	Reported Factor (n=1306)	Odds Ratios
Decrease in health care utilisation	55%	
More control, confidence or ability to cope	90%	6.5
Lifestyle (diet, exercise) improvement	52%	2.4
Sharing of self-care results with others	64%	2.4
Improved health or better health management	79%	4.6
Willingness to use Motiva in the future	76%	2.5

Table 4: User engagement results (main factors)

6. Discussion

Whether it has been research or evaluation, the assessment of telehealth technologies has often been difficult and sometimes controversial. Some of the difficulty appears to have arisen from the mistaken elevation of this technology from a means of intelligence gathering and monitoring to a form of treatment in its own right. By doing this we fail to evaluate and appreciate the real challenge of technology: the machine will do what it was built to do, it's the way that we use it that determines its effectiveness.

It can be seen from the results of the whole system demonstrator (WSD) that randomised control trials (RCT) are not usually the best way to reflect the effectiveness of technological interventions in the real world¹¹. WSD demonstrated that technology requires patient engagement for it to be used effectively and deploying such an intervention to people who do not completely want to use it will not produce a significant benefit or cost reduction. This is not a surprise but an inevitable result of an RCT approach in this environment.

We need to be brave in establishing new methodologies to identify the effectiveness of technologies and other interventions that allow us to implement solutions in a real world environment while accepting the limitations this approach brings. The Liverpool program was designed to look at a telehealth intervention at scale with a focus on the implementation for the benefit of the patient and correct care pathway design.

Given the challenges faced by the healthcare systems both in the NHS and beyond there is an imperative to re-design systems to improve productivity, make best use of resources and leverage the use of 'new' technology. Healthcare in general appears to be lagging behind other industries in embracing the use of technology for the benefit of both consumer and provider. Translating this into healthcare delivery has proven challenging due to the lack of evidence base, understandable professional skepticism and low levels of awareness in the general population.

7. Conclusion

The analysis of this large scale disease management and telehealth program has demonstrated the breadth and variety of the recruited population in terms of risk, long term conditions, and also in terms of socio-economic status, their attitude to health and the length of time that different people remain engaged with the program. This variety reflects the nature of a real world, large scale program in which a diverse population is not only unavoidable but is indeed a key ingredient of an inclusive program that engages with patients and clinicians at scale.

A matched control cohort is used that tracks the time, clinical and socioeconomic variation of the intervention group. This enables assessment of impact for different groups and plotting the impact as function of risk, time, disease or socio-economic status. This short report has presented a limited set of such results. Overall these show reductions in unplanned admissions and secondary care costs in comparison with the control group ranging from 22% to 32% for patients with above average risk (25% or more).

The data also suggests reduced healthcare utilization for the lower risk cohort. However because this cohort has a relatively low number of admissions, the effect size over the time periods available appears to be too small in absolute numbers to pass a statistical test. Complementary evidence for the program comes from patient reported outcomes which show that 90% of patients feel more in control, have gained confidence and/or feel better able to cope with their condition.

The work in this paper provides a foundation for building Population Health Management programs with services and technologies tailored for defined groups of people with proactive strategies and interventions that are coordinated, engaging, clinically meaningful, cost-effective and safe.

References

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