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Bridging the impactability gap in population health management: a systematic review

Andi Orlowski, Sally Snow, Heather Humphreys, Wayne Smith, Rebecca Siân Jones, Rachel Ashton, Jackie Buck, Alex Bottle

ABSTRACT

Objectives Assess whether impactability modelling is being used to refine risk stratification for preventive health interventions.

Design Systematic review.

Setting Primary and secondary healthcare populations.

Papers Articles published from 2010 to 2020 on the use or implementation of impactability modelling in population health management, reported with the terms ‘intervenability’, ‘amenable’ and ‘propensity to succeed’ (PTS) and associated with the themes ‘care sensitivity’, ‘characteristic responders’, ‘needs gap’, ‘case finding’, ‘patient selection’ and ‘risk stratification’.

Interventions Qualitative synthesis to identify themes for approaches to impactability modelling.

Results Of 1244 records identified, 20 were eligible for inclusion. Identified themes were ‘health conditions amenable to care’ (n=6), ‘PTS modelling’ (n=8) and ‘comparison or combination with clinical judgement’ (n=6). For the theme ‘health conditions amenable to care’, changes in practice did not reduce admissions, particularly for ambulatory care sensitive conditions, and sometimes increased them, with implementation noted as a possible issue. For ‘PTS modelling’, high costs and needs did not necessarily equate to high impactability and targeting a larger number of individuals with disorders associated with lower costs had more potential. PTS modelling seemed to improve accuracy in care planning, estimation of cost savings, engagement and/or care quality. The ‘comparison or combination with clinical judgement’ theme suggested that models can reach reasonable to good discriminatory power to detect impactable patients. For instance, a model used to identify patients appropriate for proactive multimorbidity care management showed good concordance with physicians (c-statistic 0.75). Another model employing electronic health record scores reached 65% concordance with nurse and physician decisions when referring elderly hospitalised patients to a readmission prevention programme. However, healthcare professionals consider much wider information that might improve or impede the likelihood of treatment impact, suggesting that complementary use of models might be optimum.

Conclusions The efficiency and equity of targeted preventive care guided by risk stratification could be augmented and personalised by impactability modelling.

Strengths and limitations of this study

- Comparing data was difficult due to widespread in-consistency in terminology.
- The quality of the articles included in this review was not graded.
- This is a growing area of interest and few studies are available for assessment.
- We were as inclusive as possible with types of artic- le, including abstracts and grey literature.
- To make the findings most applicable to population health management, we excluded studies of specific diseases.

INTRODUCTION

The triple aim is targeted towards improving the individual experience of care, improving the health of populations, and reducing the per capita costs of care,1 and has become a popular healthcare objective. Risk stratification is one type of population health management (PHM) tool used by health system managers to achieve the triple aim2,3 and identifies groups that are at high risk of poor outcomes so that they can be offered preventive care aimed at lowering this risk. For instance, care in accident and emergency has high costs and a cohort of patients experience frequent attendances, making this cohort a potential target for increased preventive spending. However, within this high-risk cohort, some individuals may be labelled as being ‘beyond help’ because they their attendance is perceived by clinicians to be non-preventable (eg, because of age, sex or chronic conditions, including alcohol or drug abuse).2,3 For these individuals, preventive care interventions will have little or no effect and they will continue to be at risk of so-called triple-fail events (in this case accident and emergency attendances), which are harmful, costly and result in poor patient satisfaction.4-9
While risk stratification models may accurately predict which individuals are at risk of future adverse health outcomes, such as readmission or 1-year mortality, their use has not consistently led to improvements in health outcomes across the population. Calculating and understanding the probability of a particular outcome for an individual may not be enough for healthcare professionals to intervene in the most efficient way to delay or prevent that outcome or divert the course of a disease. This often needs to be supported by additional information to determine the most accurate or appropriate model. Furthermore, as many risk stratification models predict future adverse health outcomes through current or previous healthcare activity and use a limited number of variables, they may miss out on valuable additional information that could better direct resources to patients amenable to benefit. Lewis defined a different type of model—impactibility models—that are aimed at identifying the subset of at-risk patients for whom preventive care is expected to be successful. Lewis found that impactibility was being assessed by many healthcare systems for PHM, reflecting a growing recognition that not all high-risk patients will benefit from preventive care. He described the ideal impactibility model as one that ‘would use information about the differential effects of a specific preventive intervention offered at random to patients and controls, so as to identify the characteristics of the ‘perfect patient’ for that preventive programme’. However, suitable data are rarely available in real-world records. Instead, he found that models were being formulated in three main classes: (1) giving priority to patients with diseases that are particularly amenable to preventive care; (2) excluding patients who are least likely to respond to preventive care or (3) identifying the form of preventive care best matched to each patient’s characteristics. While such impactibility models have considerable potential to improve the efficiency of preventive care delivery, certain approaches could increase health inequalities if used indiscriminately without catering to individual needs. The aim of this current study was to describe broadly how and in what contexts impactibility modelling has been implemented or assessed in PHM since 2010. We defined impactibility as the identification of patients most likely to respond to care based not only on quantitative but also on qualitative factors, and whose treatment would maximise the likelihood of achieving the triple aim. It was beyond the scope of this review to consider how impactibility modelling might affect management of individual diseases, heterogeneity in treatment effects and different types of health programmes.

**METHODS**

A systematic literature review was carried out to identify all papers published between January 2010 and May 2020. The Ovid search platform was used to search four relevant databases: Embase Classic and Embase, Global Health, Healthcare Management Information Consortium and Ovid MEDLINE. Additional searches for grey literature were performed in OpenGrey.

Search strategies were built iteratively, with relevant keywords and subject headings for each database added based on initial reviews of relevant publications. The final set of search terms (see online supplemental information pp 1–28) included alternative spellings of impactibility and synonyms, including ‘intervenability’, ‘amenability’ and ‘propensity to succeed’. We also included words associated with the following themes: ‘care sensitivity’, ‘characteristic responders’, ‘needs gap’, ‘case finding’, ‘patient selection’ and ‘risk stratification’. Where relevant, these search terms were linked with the Boolean ‘and’ operator to synonyms for ‘predictive model’, ‘population health’ or ‘preventive healthcare’. No additional restrictions were applied in terms of language, date or status of publication.

Database search results were exported to the systematic review software Covidence. Two reviewers (AO and SS) independently screened titles and abstracts for relevance and reviewed the full texts that specifically referenced analyses of amenability, impactibility, and propensity to succeed (PTS) in relation to future events. Papers that concerned youth offending, aimed to increase screening detection rates, and looked only at identifying individuals at high risk of a specific disease or health event were excluded. Full inclusion and exclusion criteria are shown in online supplemental information (pp 29–31). To achieve the widest possible overview of work in this emerging field, studies were not excluded based on assessment of methodological quality. Conflicts were discussed with a third reviewer (WS) at each review stage. A pragmatic forward citation search was subsequently conducted using PubMed for all articles included in the initial review round. These were added to Covidence, and the screening process was repeated. A targeted Google search (see online supplemental information pp 32) was conducted to identify any additional publications containing the term ‘impactibility’.

Data extraction was performed by SS, HH and WS. For studies describing impactibility models, information about country of implementation, data sources, population studied, intervention and any reported outcome measures were extracted into a data table. Qualitative synthesis was performed to assess themes and to group papers by approach to impactibility modelling. Outcome measures, where reported, were not comparable across studies so meta-analysis was not considered to be appropriate.

**RESULTS**

Of 1244 records initially identified, 179 full-text items were assessed for eligibility after removal of duplicates and initial exclusion based on title and abstract. Of these, 81 were found to be ineligible and 78 were commentaries. Thus, 20 studies related to the development, application
or validation of impactibility models for use in PHM and were included in the review (figure 1).

In the qualitative synthesis, we grouped papers under three themes representing different approaches to assessing impactibility: health conditions amenable to preventive care (n=6); PTS (n=8) and comparison or combination with clinical judgement (n=6; see online supplemental information pp 33–43).

**Health conditions amenable to preventive care**

Several studies inferred participants’ potential to benefit from preventive care if it is targeted after they have received a diagnosis of a specific health condition\(^{18-21}\) or if they have a multimorbid cluster of health conditions.\(^{22-23}\) Many of these studies specifically targeted people with ambulatory care sensitive conditions (ACSCs), including chronic obstructive pulmonary disease, chronic heart failure and diabetes, for which evidence suggests that optimal management in the community should not result in unplanned hospital admission.\(^{10,16,24,25}\) Preventive interventions (eg, case management) that were targeted based on the presence of one or more ACSC did not consistently lead to reductions in hospital admissions or secondary care costs, and indeed, in some cases led to increases in emergency hospital admissions.\(^{18-22}\) However, the success

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**Figure 1** PRISMA diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
of these impactibility strategies may be hindered by ineffective implementation. In one of these studies, for example, the authors indicated that the targeted intervention was not effectively integrated into primary care practice during the observation period.21

Propensity to succeed

PTS modelling is an analytical approach to identify traits associated with improved engagement with or outcomes from particular preventive health intervention(s)—outcomes such as cost or care quality.26–32 Of the eight studies identified that used this approach, three used PTS modelling in relation to specific case management interventions.30–32 One model was developed explicitly for ‘low-risk’ participants to assess who would be most likely to benefit from a digital health platform.28

In these studies, PTS regression analyses were performed using various sociodemographic factors,26–28 30–32 health status (eg, presence of chronic conditions, prescription data, prior health resource utilisation and various health risk scores26–28 30–32 or previous programme engagement metrics.28 One study found that high costs and high needs did not equate to high impactability, as only small proportions of people with diseases that would be expected to have high burden had scores indicating high impactability. The authors suggested that targeting a larger number of individuals with disorders associated with lower costs could improve impact substantially and that better predictors of impactibility might be medication adherence and historical healthcare resource utilisation that was unexplained by disease burden.31

Five of the identified studies reported the statistical validity of PTS models for projecting cost savings, improved engagement and/or care quality improvements,26–28 30 32 however, prospective or comparative outcome data on the use of these models in real-world situations were extremely limited in the literature. Two studies reported improved engagement (defined as enrolment of contacted participants) with case management interventions after implementation of a PTS model: Ozminkowski et al27 reported an 11% increase in programme enrolment in the 9 months after implementation of a PTS model, compared with the 3 months prior. Hommer et al29 likewise reported increased enrolment in a depression management programme but did not quantify the change.

Hsueh et al33 evaluated the Behavioural Response Inference Framework (BRiEf), a machine learning impactibility model derived from a large observational dataset of care management records from a private healthcare network. They tested the ability of the model to predict individual-level behavioural responses to multiple interventions used in care planning. Input data included participants’ personalised goal attainment history across 16 goals set in a programme to reduce hospital readmissions after discharge for acute care. They covered a wide spectrum of care needs (eg, tobacco cessation, knowledge of healthy eating, medication adherence, actions to resolve care gaps, and fall prevention) and were categorised as ‘met’, ‘abandoned’, ‘not met’ or ‘open’. Data on goal attainment were extracted for 131 different care coordination activities in the categories referral, education, coordination, screening, coaching or other tasks, that were classified as met or otherwise. The BRiEf model was applied to assess behavioural responses at the individual patient and population levels. Covariates used in the model were demographic information (eg, age and gender), care programme context (eg, programme experience and days in the programme) and the interactions between care managers and patients (eg, the day of making the recorded call). The authors described the results of the model as ‘promising’, with the individual-level care planning strategy showing the greatest accuracy in terms of correct intervention recommendations, which outperformed a population-level care planning approach where the one-size-fits-all approach reduces precision.

Comparison or combination with clinical judgement

We identified six impactibility models that—either formally or informally—incorporated a healthcare provider’s opinion of whether an individual patient was likely to benefit from a particular preventive health intervention.16 34–39 In one study, clinical judgement was applied as a final (filtering) step to estimate how care management would impact patients after they had undergone risk stratification by a predictive analytical tool.40 A predictive tool calculated a risk score for emergency department visits in the next 12 months based on 19 variables. Physicians then added information on medical and social factors that could alter the impact of care management. This combined improved identification of higher-risk patients, reflected by an increase in the average risk score for patients enrolled in care management from 33.4% to 40.4%.

Cohen et al41 designed a predictive model to identify patients who would benefit from proactive multimorbidity care management based on inclusion and exclusion criteria refined from a physician survey of 375 cases and on risk of future high costs based on data extracted from a health services database. Recommended reasons for exclusion due to risk of future high costs were active cancer, schizophrenia, dialysis, residence in nursing homes or long-term care facilities and age 95 years or older. The model was used to assess 5341 high-risk patients. The discriminatory power of the model before and after clinical exclusions was c-statistic 0.80 and 0.75, respectively. Age, number of chronic conditions and healthcare utilisation were associated with high-risk of high-cost care. The authors concluded that the model had acceptable discriminatory power for identifying who would benefit from proactive care management even after the highest-risk patients were excluded.

HCPs consider a range of factors when assessing an individual’s suitability for a preventive care intervention. These include perceived hospitalisation risk; feelings of sympathy or aversion towards the patient and a judgement...
of the patient’s willingness and ability to participate in the intervention.\textsuperscript{16, 38} HCPs also reported excluding patients from preventive healthcare interventions because of language barriers.\textsuperscript{16}

Flaks-Manov et al\textsuperscript{42} investigated whether risk scores for 30-day readmission from an electronic health records model were aligned with nurses’ and physicians’ perceived impactibility of a readmission prevention programme for hospitalised patients aged 65 years or older. The clinical and model decisions for 435 patients were concordant in 65\% of cases. Among the remaining 35\%, 19\% with high model scores were not referred by healthcare professionals and 16\% with low model scores were referred. Decision-tree analysis indicated that as well as high models scores, eligibility for a nursing home, having a condition not under control, need for social-services support and need for special equipment at home were statistically associated with referral. The authors concluded that better understanding is needed of whether combining perceptions and modelling could improve selection of patients.

Freund et al\textsuperscript{43} assessed areas in which impactibility modelling might be helpful. They invited 12 primary-care physicians in ten practices to review records for 104 hospitalisations in 81 patients who had ACSCs and rate whether they felt each was avoidable. The doctors deemed 43 (41\%) hospitalisations to be avoidable. Reasons fell into five main categories: system related (eg, unavailability of ambulatory services), physician related (eg, suboptimum monitoring), medical (eg, medication side effects), patient related (eg, delayed help-seeking) and social (eg, lack of social support). Further reasons were after-hours referral required in the absence of the treating physician, not using ambulatory services, patients’ fears, cultural background, language skills, medication errors, non-adherence to medication and overprotective caregivers. In discussing implications for clinical practice and policy, it was suggested that the risk stratification modelling could be enhanced by considering patients’ social situation, medication adherence and self-management capabilities and sharing responsibility across sectors.

**DISCUSSION**

**Key findings**

As health systems turn to data-led approaches to deliver the triple aim of improving individuals’ experience of care and the health of populations while reducing per capita care costs,\textsuperscript{1} many are finding that allocating resources based on risk stratification alone is suboptimal. Targeting patients for preventive care based only on health conditions amenable to preventive care does not necessarily lead to reductions in resource use and might even increase it,\textsuperscript{10} and recognition is growing that these goals will only be met if treatment is successful. This is the impactibility gap. Thus, rather than trying to identify patients by negative outcomes (eg, high cost of care, most severe disease), the importance of identifying patients in whom care options will be most effective is being realised.

The evidence reviewed shows varying attempts to make prediction tools more impactful and effective by considering the probability of success of interventions. PTS modelling showed some of the most promising results when broader information, such as sociodemographic factors, medication adherence or previous programme engagement, was included. The accuracy of predicting behavioural responses seems to be greatest at the individual level, but more data on real-world outcomes are needed, as implementation could affect PHM potential. Of note, there was some incongruence between modelling and HCP decisions, and better understanding is needed of how perceptions and data analysis affect one another.

**Risk stratification versus impactibility**

Risk stratification models may accurately predict which individuals are at risk of future adverse health outcomes,\textsuperscript{2–5} allowing resources to be allocated. However, allocation is inefficient because not all patients will be amenable to the offered intervention. A stratum cut-offs risk not allocating care to people with lower risk who would be amenable and achieve better outcomes that those at higher risk.\textsuperscript{44} Additionally, since risk is deemed equal for all people within a stratum, resources are also allocated equally (figure 2A) and those made available for patients who refuse or do not respond to treatment cannot be reallocated to patients who will respond. Therefore, opportunities to maximise care for the most amenable people will be missed. Impactibility modelling provides an extra layer of information that can help predict where, to whom, when and how to target preventive resources and allow weighting of investment (time, resources and costs) towards these individuals, which can improve efficiency. As shown in figure 2B, the likelihood of success for a given intervention is not necessarily determined by risk level, and individuals amenable to a specific intervention, due to their ‘impactibility’, can be found throughout the stratified population.

**Types of models considered**

The models described in the literature fell into three key themes: ‘health conditions amenable to care’, ‘PTS modelling’ and ‘comparison or combination with clinical judgement’. In the first theme, we found that changes in practice did not reduce hospital admissions and care, and sometimes increased them.\textsuperscript{10} 16–20 It was suggested in one study that although input on organisational change from modelling was well accepted, it was not well integrated.\textsuperscript{21} As a result, depression as a factor for unscheduled care in patients with long-term conditions remained unaddressed. This finding might suggest that these models are too similar to risk stratification because they focus on diseases but leave underlying factors, such as psychosocial and socioeconomic factors, insufficiently addressed.\textsuperscript{21} Bardsley et al\textsuperscript{40} showed that different ACSCs follow different trends, possibly even at the national or...
international level, which highlights the need to consider how the population for assessment should be selected.6

The PTS models assessed in this review included a wide range of clinical, social and behavioural factors mainly assessed by logistic regression to assess in whom treatment had been most successful (see online supplemental information pp 33–43). Repeatedly, the results underscored that considering the highest levels of risk and treatment costs did not equate to high impactibility. For example, Dubard et al concluded that variables related to medication adherence and historical use of care unexplained by disease burden were more important predictors of impactibility than diagnosis, specific events, disease profile and overall costs of care.31 PTS modelling generally led to improved accuracy in care planning, estimation of cost savings, engagement and/or care quality. These findings support moving away from delineated risk groups towards continuous risk predictions.44

The comparison or combination with clinical judgment theme indicated that HCPs are routinely able to access real-time ‘soft intelligence’ about their patients that is not available to modellers.43 However, this approach is subjective, involving perceptions at system, HCP, clinical, patient and social levels.16 Gathering such information can be highly resource intensive and how it informs decisions can depend on the quality and openness of the patient–provider relationship. The same information for two different patients might be affected by HCP sympathy or aversion, how well the patient is known, perceived patient characteristics or abilities (eg, willingness to participate, language skills or cognitive status) and manageable care needs.36 Impactibility models could have a complementary role in decision making and might improve the individualisation of care management, even with a broad range of therapeutic options.32

**Optimisation of impactibility modelling**

There are many possible reasons for differences in impact, including urban/rural setting, deprivation, literacy, language barriers, mental-health challenges, behavioural or personality traits and practicalities, such as inflexible work or childcare constraints.35–48 The challenge for PHM, therefore, is to identify which interventions are most likely to succeed for an individual based on their wider circumstances and how those interventions may be delivered in a way that is most likely to achieve a positive outcome, thereby closing the impactibility gap (figure 3).

To optimise impactibility modelling, large amounts of data are needed on people’s health behaviours and socioeconomic, clinical and environmental statuses, as well as broader data where possible, such as genomic data. Many data are held by private companies but are not always accessible to or affordable for health system analysts. Completeness of data may affect modelling and, for example, are known to be less complete for people with higher levels of deprivation.49 The different modelling approaches have various limitations and benefits (table 1),7 16 18–21 23 27–33 35–38 42 50–53 which might further determine the choice. If these issues can be overcome, impactibility models have potential to reduce the clinical burden in making decisions about resource allocation and improve the accuracy and objectiveness of decision making in PHM.

Potential biases towards groups that are perceived as likely to respond well to treatment, which could exclude some of the most vulnerable groups, has been identified as an important potential limitation of using impactibility

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**Figure 2** Use of impactibility modelling enhances identification of individuals most likely respond to preventive care and allows weighted resourcing. (A) Population with a given condition at risk of an outcome over a specific period of time, stratified by risk. (B) After impactibility analysis, different options can be targeted to the most amenable people. The numbers and positions of dots per intervention highlight that the likelihood of treatment success can be found throughout the stratified population and is not necessarily determined by risk level.
as a PHM tool.\textsuperscript{6,37,53-56} Thus, it should be borne in mind that the purposes of considering impactibility PHM are to improve access and equity of care and avoid unnecessarily wasting resources on providing additional interventions that are costly and will not benefit the recipients. Resources should be directed towards closing gaps in the evidence\textsuperscript{55} and using the knowledge to develop better-tailored approaches to more people, possibly in medium-risk and low-risk categories (figure 2). This approach, based on the learning healthcare system model, in which best practice is implemented and updated by expanding knowledge of science, informatics, incentives and culture,\textsuperscript{39} will provide practical case studies that can support efforts to develop and trial alternative ways of delivering care to meet the needs of people in different circumstances.

To achieve the triple aim using predictive models will require those models to have broad insights on which to base predictions. Additionally, no single strategy used in the studies assessed can conclusively point to what information is required, but all go beyond previous healthcare resource utilisation. Some approaches are more easily adopted, as the data required are more readily available or they are less resource intensive to implement.

**Study strengths and limitations**

This study had several limitations. Interpreting and comparing the data was difficult due to widespread inconsistency in terminology. Even at the most basic level, ‘high-risk individuals’ was conflated with ‘those most likely to benefit’ in some papers\textsuperscript{26,58} despite evidence indicating that these can be highly separated groups.\textsuperscript{5,31,42} The quality of the articles included in this review was not graded. However, as this is a growing area of interest and few studies are available, it is a strength of the study that we were as inclusive as possible. Owing to the substantial differences in approaches to categorising model outputs and in outcome measures and the lack of reporting these in some studies, it was not possible to perform a quantitative analysis. Finally, in order to make the findings most applicable to PHM, we excluded studies of specific diseases. Of note, given the descriptive nature of this review, it was not registered and no protocol was published.

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**Figure 3** Use of impactibility modelling (step 03) to enhance identification of patients amenable to benefit and likelihood of achieving the triple aim. ACSC, ambulatory care sensitive condition.
Impactibility builds on other key PHM concepts, such as the subject of our future research. Would be beneficial. Disease for ACSCs have not been reduced as much as anticipated. Additionally, better understanding of why hospital admissions relevant data, should be included in these studies. Add biases and prejudices and accuracy and availability of factors, such as model implementation, the effects of propensity to succeed (behavioural response) identifies groups where an intervention is/is not likely to provide benefit, thereby is designed to avoid wasting resources where they are of no benefit. Care planning strategies are optimised at an individual and/or population level, based on previous behavioural responses to a range of potential interventions. Propensity to succeed (behavioural response) identifies groups where an intervention is/is not likely to provide benefit, thereby is designed to avoid wasting resources where they are of no benefit. Care planning strategies are optimised at an individual and/or population level, based on previous behavioural responses to a range of potential interventions. Comparison or combination with clinical judgement based on ad hoc, real-time information about capacity to access and engage with care. Healthcare professionals may be able to predict future deterioration in ‘low-risk’ patients with relatively good current health status. Models would be enhanced by including educational, behavioural, psychological, social, economic and/or health information, but data would need to be consistently recorded and accessible. Requires interventional data rather than retrospective patient data.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Benefits</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>Health conditions amenable to preventive care (gap analysis)</td>
<td>► Diagnosis data are readily available.</td>
<td>► Does not factor in psychosocial and behavioural variables, such as willingness or ability to engage with care.</td>
</tr>
<tr>
<td></td>
<td>► Programmes are relatively simple to model and implement.</td>
<td>► Suitable data to assess gaps are rarely available in real-world records.</td>
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<tr>
<td></td>
<td>► Widely available data can be used to identify specific, evidence-based and scalable actions to address gaps in care.</td>
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<td></td>
<td>► May reduce inequalities, as preventable health conditions are more common in deprived communities.</td>
<td></td>
</tr>
<tr>
<td>Propensity to succeed (behavioural response)</td>
<td>► Identifies groups where an intervention is/is not likely to provide benefit, thereby is designed to avoid wasting resources where they are of no benefit.</td>
<td>► Models would be enhanced by including educational, behavioural, psychological, social, economic and/or health information, but data would need to be consistently recorded and accessible.</td>
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<tr>
<td></td>
<td>► Care planning strategies are optimised at an individual and/or population level, based on previous behavioural responses to a range of potential interventions.</td>
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<tr>
<td>Comparison or combination with clinical judgement</td>
<td>► Based on ad hoc, real-time information about capacity to access and engage with care.</td>
<td>► Highly resource intensive</td>
</tr>
<tr>
<td></td>
<td>► Healthcare professionals may be able to predict future deterioration in ‘low-risk’ patients with relatively good current health status.</td>
<td>► Relies on the quality and openness of the healthcare professional and patient relationship, and the ability of the data to capture this.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>► May perpetuate biases or prejudices.</td>
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CONCLUSIONS
Impactibility builds on other key PHM concepts, such as risk stratification, by assessing more qualitatively which people might benefit the most from certain health interventions and when proactive treatment might be appropriate (eg, preventive care before an adverse health event or a programme to prevent hospital readmission). It is important, to note that not all people requiring medical care have the potential to benefit from preventive interventions in a PHM sense. Nevertheless, although limited research is available so far, it seems that impactibility models can augment access to and equity of care when coupled with clinical insights and provide an opportunity to personalise preventive care delivery. Using this approach, it should be possible achieve the triple aim—simultaneously improving the individual experience of care, improving the health of populations and reducing the per capita costs of care for populations. PTS models seem to improve accuracy of selection patients amenable to care, but very few prospective or comparative outcome data from real-world settings are available, and this would be judicious to explore further. Potential confounding factors, such as model implementation, the effects of biases and prejudices and accuracy and availability of relevant data, should be included in these studies. Additionally, better understanding of why hospital admissions for ACSCs have not been reduced as much as anticipated would be beneficial. Disease-focused applications will be the subject of our future research.

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Contributors AO conceptualisation, methodology, validation, formal analysis, writing-original draft, writing-review and editing. SS: methodology, formal analysis, data curation, writing—original draft, writing-review and editing. HH: formal analysis. WS: formal analysis. RSJ: methodology, RA: writing-review and editing. JB: methodology, AB: writing-review, editing, and guarantor.

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Patient consent for publication Not applicable.

Ethics approval As this is a systematic review of published literature and assessed data at the population level, ethics approval was not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

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50 Knabel T, Louwers J. Intervenability: another measure of health risk. by coupling predictive modeling with evidence-based medicine, health plans can identify patients who will benefit the most from care management intervention. *Health Manag Technol* 2004;25:36–9.


APPENDIX

Appendix Table S1: List of search strings

Database: Ovid MEDLINE(R) ALL <1946 to May 14, 2020>
Search Strategy:

-------------------------------------------------------------------
1  impact?bility.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (9)
2  ’propensity to succeed’.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (6)
3  interven?bility.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (3)
4  case finding.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (4937)
5  casefinding.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (86)
6  Patient selection.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (83162)
7  Patient Selection/ (64332)
8  target* patient*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (2387)
9  (target* adj2 segment*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (947)
10  case selection.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1810)
11  risk stratif*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (32437)
12  (predict* adj3 risk factor*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (7856)
13  risk factors/ (815581)
14  protective factor*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (21359)
15  protective factors/ (4040)
16  (risk adj2 population*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (34671)
17  susceptible population?.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (2135)
18  Vulnerable Populations/ (10281)
19  (risk adj2 analy*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (26586)
20  risk assess*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (298996)
21 Risk Assessment/mt, sn [Methods, Statistics & Numerical Data] (33887)
22 risk segment*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating
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23 Health Status Indicators/ (23314)
24 (characterist* adj4 respon*).mp. [mp=title, abstract, original title, name of substance word, subject heading
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31 (Likel* adj2 succe*).mp. [mp=title, abstract, original title, name of substance word, subject heading word,
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32 (Likel* adj2 prevent*).mp. [mp=title, abstract, original title, name of substance word, subject heading word,
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34 (Predict* adj2 accept*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1508)
35 Predict* responder*mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (192)
36 (Predict* adj2 success*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (13782)
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41 (Probab* adj2 prevent*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1058)
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56 "Patient acceptance of health care"/ (46068)

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58 Adverse Outcome Pathways/ (83)

59 Markov Chains/ (14167)

60 logistic* model*.mp. (143517)

61 logistic models/ (137961)

62 population model*.mp. (3652)

63 Patient-Specific Modeling/ (969)

64 patient specific model*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1904)

65 ambulatory care sensitive condition?.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (561)

66 Hospitalization/ (105786)

67 Patient Admission/ (24023)

68 Patient Readmission/ (16915)
69  preventive medicine.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (16812)

70  Preventive Medicine/ (11679)

71  preventive health*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (17200)

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73  secondary prevention/ (20153)

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75  Early Medical Intervention/ (2939)

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78  (Target* adj3 care*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (4252)

79  (prevent* adj3 intervention*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (40728)

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81  population health*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (12278)

82  Population Health/ (792)
Decision Support Systems, Clinical/ (7841)

Health Policy/ (65651)

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public health administration/ (15359)

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Models, Organizational/ (18878)

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"Delivery of Health Care"/ (89529)

"Delivery of Health Care, Integrated"/ (12500)

Managed Care Programs/ (24211)

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102 4 or 5 (5020)
Annotation: Case finding
103 6 or 7 or 8 or 9 or 10 (88016)
Annotation: Patient selection
104 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 (1128808)
105 24 or 25 (19768)
Annotation: Characteristic response
106 26 or 27 (2827)
Annotation: Care sensitivity
107 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46
or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 (172438)
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109 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 (251550)
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110 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 95 or 96 or 97 or 98
or 99 (614599)
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Annotation: Preventive health and population health management
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Annotation: Preventive healthcare or population health management
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Database: HMIC Health Management Information Consortium <1979 to March 2020>  
Search Strategy:

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2  'propensity to succeed'.mp. [mp=title, other title, abstract, heading words] (0)  
3  interven?bility.mp. [mp=title, other title, abstract, heading words] (0)  
4  case finding.mp. [mp=title, other title, abstract, heading words] (201)  
5  casefinding.mp. [mp=title, other title, abstract, heading words] (3)  
6  screening/ (3706)  
7  Patient selection.mp. [mp=title, other title, abstract, heading words] (93)  
8  Patient selection/ (47)  
9  target* patient*.mp. [mp=title, other title, abstract, heading words] (81)  
10  (target* adj2 segment*).mp. [mp=title, other title, abstract, heading words] (6)  
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13  exp "Risk adjusted monitors of outcome"/ (20)  
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15  susceptible population*.mp. [mp=title, other title, abstract, heading words] (10)  
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Annotation: Risk stratification
24 or 25 (163)
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Annotation: Care sensitivity
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111  98 and 108 (8)
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113  107 and 112 (6)
114  100 and 108 (9)
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116  95 or 96 or 110 or 111 or 113 or 114 or 115 (79)

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Search for: 84 or 96 or 99 or 100 or 102 or 104 or 105

Results: 163
Database: Global Health <1973 to 2020 Week 18>
Search Strategy:

1. impact?bility.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (4)
2. 'propensity to succeed'.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1)
3. interven?bility.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (0)
4. case finding.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1946)
5. casefinding.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (5)
6. Patient selection.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (611)
7. target*.patient*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (283)
8. (target* adj2 segment*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (144)
9. case selection.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (88)
10. (risk adj2 population*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (11708)
11. susceptible population*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1174)
12. risk stratif*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (2127)
13. (predict* adj3 risk factor*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1472)
14. protective factor*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (6071)
15. exp protective factors/ (279)
16. (risk adj2 analy*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (10280)
17. exp risk analysis/ (58968)
18 risk assess*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (63092)
19 risk segment*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (19)
20 (characterist* adj4 respon*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (2195)
21 (characterist* adj3 nonrespon*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (18)
22 (care adj3 sensitiv*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (447)
23 (receptiv* adj3 care).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (10)
24 (Likel* adj2 benefit*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (982)
25 (Likel* adj2 accept*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (281)
26 (Likel* adj2 respon*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1060)
27 (Likel* adj2 succe*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (413)
28 (Likel* adj2 prevent*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (236)
29 (Predict* adj2 benefit*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (138)
30 (Predict* adj2 accept*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (292)
31 Predict* responder*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (8)
32 (Predict* adj2 succe*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1054)
33 (Probab* adj2 benefit*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (108)
34  (Probab* adj2 accept*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (74)
35  (Probab* adj2 respond*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (800)
36  (Probab* adj2 succe*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (198)
37  (Probab* adj2 prevent*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (183)
38  (propensity adj2 benefit*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (0)
39  (propensity adj2 accept*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (2)
40  (propensity adj2 respond*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (19)
41  (propensity adj2 succe*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (3)
42  (propensity adj2 prevent*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (3)
43  (Potential* adj benefit*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (4703)
44  (Potential* adj2 accept*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (267)
45  (Potential* adj2 respond*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1196)
46  (Potential* adj2 succe*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (302)
47  (Potential* adj2 prevent*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (3556)
48  (Model* adj2 benefit*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (185)
49  (Model* adj2 accept*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (500)
50  (Model* adj2 responder*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (5)
51  (Model* adj2 prevent*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (619)
52  (predict* adj3 model*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (16099)
53  logistic* model*.mp. (2180)
54  population model*.mp. (497)
55  patient specific model*.mp. (4)
56  exp mathematical models/ (20591)
57  ambulatory care sensitive condition?.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (133)
58  exp hospital admission/ (7087)
59  exp Preventive Medicine/ (5152)
60  preventive medicine.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (6066)
61  preventive health*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1554)
62  prevention/ (24792)
63  (early adj3 intervention*).mp. (4352)
64  early intervention/ (0)
65  Target* health*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (727)
66  Target* healthcare.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (44)
67  (Target* adj3 care*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (808)
68  (prevent* adj3 intervention*).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers,
cabicodes] (13708)
69  (care adj3 management).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (2707)
70  population health*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (4811)
71  exp health policy/ (21123)
72  Health* management.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (2399)
73  System? management.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (295)
74  public health*.mp. (263888)
75  exp public health/ (114710)
76  exp public health services/ (5031)
77  health service? management.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (79)
78  health care system?.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (7683)
79  health* system?.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (22197)
80  multidisciplinary service?.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (27)
81  integrated service?.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (314)
82  amen?bility.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (96)
83  animal*.mp. (2706683)
84  1 or 2 or 3 (5)
Annotation: Impactibility
85  4 or 5 (1950)
Annotation: Case finding
86  6 or 7 or 8 or 9 (1121)
Patient selection
87 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 (90642)

Risk stratification
88 20 or 21 (2208)

Characteristic response
89 22 or 23 (457)

Care sensitivity
90 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 (16886)

Likelihood benefit
91 52 or 53 or 54 or 55 or 56 (35958)

Model
92 57 or 58 or 59 or 60 or 61 or 62 or 63 or 65 or 66 or 67 or 68 (56126)

Preventive
93 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 (299016)

Population
94 92 and 93 (8599)
95 92 or 93 (346543)
96 82 and 95 (15)
97 90 or 91 (52153)
98 85 and 97 (58)
99 95 and 98 (20)
100 86 and 97 (41)
101 87 and 97 (3893)
102 94 and 101 (42)
103 88 and 97 (82)
104 95 and 103 (17)
105 89 and 97 (25)
106 84 or 96 or 99 or 100 or 102 or 104 or 105 (163)
Search for: 104 or 116 or 118 or 121 or 123 or 125 or 128

Results: 320

Database: Embase Classic+Embase <1947 to 2020 May 14>

Search Strategy:

1. impact?bility.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (12)
2. 'propensity to succeed'.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (7)
3. interven?bility.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (2)
4. case finding.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (8308)
5. casefinding.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (200)
6. case finding/ (4164)
7. Patient selection.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (106833)
8. Patient selection/ (93046)
9. target* patient*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (4078)
10. (target* adj2 segment*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1381)
11. case selection.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (21)
manufacturer, device trade name, keyword, floating subheading word, candidate term word) (2699)
12  (risk adj2 population*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (170420)
13  high risk population/ (121003)
14  vulnerable population/ (16512)
15  susceptible population/ (1056)
16  risk stratif*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug
manufacturer, device trade name, keyword, floating subheading word, candidate term word] (58670)
17  (predict* adj3 risk factor*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (12148)
18  risk factor/ (1025885)
19  protective factor*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug
manufacturer, device trade name, keyword, floating subheading word, candidate term word] (24469)
20  protection/ (67132)
21  susceptible population*.mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (3245)
22  risk stratif*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug
manufacturer, device trade name, keyword, floating subheading word, candidate term word] (58670)
23  (risk adj2 analy*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug
manufacturer, device trade name, keyword, floating subheading word, candidate term word] (95347)
24  risk assess*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug
manufacturer, device trade name, keyword, floating subheading word, candidate term word] (585434)
25  risk assessment/ (558053)
26  risk segment*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug
manufacturer, device trade name, keyword, floating subheading word, candidate term word] (137)
27  (characterist* adj4 respon*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (26743)
28  (characterist* adj3 nonrespon*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (147)
29  (care adj3 sensitiv*).mp. [mp=title, abstract, heading word, drug trade name, original title, device

22
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (3472)
30  (receptiv* adj3 care).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (85)
31  (Likel* adj2 benefit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (14595)
32  (Likel* adj2 accept*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1390)
33  (Likel* adj2 respon*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (14021)
34  (Likel* adj2 succe*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, device trade name, keyword, floating subheading word, candidate term word] (4394)
35  (Likel* adj2 prevent*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1613)
36  (Predict* adj2 benefit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (3898)
37  (Predict* adj2 accept*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1966)
38  Predict* responder*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, device trade name, keyword, floating subheading word, candidate term word] (385)
39  (Predict* adj2 succe*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (19014)
40  (Probab* adj2 benefit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1190)
41  (Probab* adj2 accept*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (648)
42  (Probab* adj2 respon*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (8877)
43  (Probab* adj2 succe*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (3579)
44  (Probab* adj2 prevent*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1538)
45  (propensity adj2 benefit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (21)
46  (propensity adj2 accept*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (21)
47  (propensity adj2 respon*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (141)
48  (propensity adj2 succe*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (67)
49  (propensity adj2 prevent*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (26)
50  (Potential* adj2 benefit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (53571)
51  (Potential* adj2 accept*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1587)
52  (Potential* adj2 respon*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (15605)
53  (Potential* adj2 succe*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (2679)
54  (Potential* adj2 prevent*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (18959)
55  (Model* adj2 benefit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1562)
56  (Model* adj2 accept*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (4879)
57  (Model* adj2 responder*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (144)
58  (Model* adj2 prevent*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (3286)
59  (predict* adj3 model*).mp. [mp=title, abstract, heading word, drug trade name, original title, device
manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (155268)
60 adverse outcome pathway/ (358)
61 logistic* model*.mp. (11456)
62 population model*.mp. (10416)
63 information model/ (253)
64 process model/ (8488)
65 population model/ (7092)
66 markov chain/ (5170)
67 patient specific model*.mp. (1434)
68 ambulatory care sensitive condition?.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (687)
69 ambulatory care/ (38902)
70 hospital readmission/ (62928)
71 hospital admission/ (194263)
72 hospitalization/ (376388)
73 hospital utilization/ (2228)
74 Preventive Medicine/ (28102)
75 preventive medicine.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (34859)
76 preventive health*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (33684)
77 preventive health service/ (28680)
78 prevention/ (283203)
79 (early adj3 intervention*).mp. (64519)
80 early intervention/ (24768)
81 Target* health*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (1919)
82 Target* healthcare.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (213)
83 (Target* adj3 care*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer,
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (6204)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (52335)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (62219)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (14536)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (7921)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (959)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (7921)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (138922)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (103788)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (406)
drug manufacturer, device trade name, keyword, floating subheading word, candidate term word} (14536)
safety net hospital/ (2077)

amen?bility.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug

26
manufacture, device trade name, keyword, floating subheading word, candidate term word] (1356)
103 animal*.mp. (6389036)
104 1 or 2 or 3 (21)
Annotation: Impactibility
105 4 or 5 or 6 (8461)
Annotation: Case finding
106 7 or 8 or 9 or 10 or 11 (114598)
Annotation: Patient selection
107 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 (1764975)
Annotation: risk
108 27 or 28 (26841)
Annotation: Characteristic response
109 29 or 30 (3557)
Annotation: Care sensitivity
110 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49
or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 (176187)
Annotation: Likelihood of benefit
111 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 (189338)
Annotation: Predictive modelling
112 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 (1060770)
Annotation: Preventive healthcare
113 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 95 or 96 or 97 or 98 or 99 or 100 or 101 (840792)
114 112 or 113 (1821615)
115 112 and 113 (79947)
116 102 and 114 (51)
117 107 and 110 and 111 (877)
118 115 and 117 (30)
119 110 or 111 (360103)
Annotation: likely benefit or modelling
120 109 and 119 (192)

27
121  115 and 120 (37)
122  108 and 119 (948)
123  114 and 122 (66)
124  106 and 119 (4043)
125  115 and 124 (52)
126  105 and 119 (166)
127  115 and 126 (9)
128  105 and 114 and 119 (67)
129  104 or 116 or 118 or 121 or 123 or 125 or 128 (320)
### Appendix Table S2: Full inclusion and exclusion criteria

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Does the title or abstract talk about amenability?</td>
<td>Continue</td>
</tr>
<tr>
<td>2</td>
<td>Is the paper about youth offending or amenability of specific diseases to treatment?</td>
<td>Exclude/STOP</td>
</tr>
<tr>
<td>3</td>
<td>Does the title or abstract talk about impactibility/intervenability or ‘propensity to succeed’ modelling in a population health context?</td>
<td>Include/STOP</td>
</tr>
<tr>
<td>4</td>
<td>Is there an intervention that aims to prevent or ameliorate a future health event?</td>
<td>Continue</td>
</tr>
<tr>
<td>5</td>
<td>Is the intervention solely aiming to increase screening programme detection rates?</td>
<td>Exclude/STOP</td>
</tr>
<tr>
<td>6</td>
<td>Does the study include case finding or selection of potential responders from the wider population?</td>
<td>Continue</td>
</tr>
<tr>
<td>7</td>
<td>Is modelling limited to identifying subjects at ‘high risk’ of a disease or health event?</td>
<td>Exclude/STOP</td>
</tr>
<tr>
<td></td>
<td>Does the extended modelling identify subjects who may respond better to the intervention?</td>
<td>Include/STOP</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Does the extended modelling identify subjects who are more likely to start and complete the intervention?</td>
<td>Include/STOP</td>
</tr>
</tbody>
</table>

**INCLUSION**
- Papers that include Impactibility OR intervenability OR ‘propensity to succeed’ modelling OR Amenability in a population health context OR
- Studies that include ALL of:
  1) an intervention that aims to prevent or ameliorate a future health event AND
  2) case finding OR selection of potential responders from the general population AND
  3) extended modelling that identifies subjects who may respond better to the intervention OR extended modelling that identifies subjects who are more likely to start and complete the intervention

**EXCLUSION**
- Amenability AND youth offending
- Amenability of specific diseases to treatment
- Modelling limited to identifying subjects at ‘high risk’ of a disease or health event
- Intervention solely aiming to increase diagnoses or screening programme detection rates

**Definitions:**
**Case finding:** a systematic or opportunistic process that identifies individuals (e.g. people with COPD) from a larger population for a specific purpose for example, ‘Flu vaccination’


**Intervention:** A health intervention is an act performed for, with or on behalf of a person or population whose purpose is to assess, improve, maintain, promote or modify health, functioning or health conditions.  

https://www.who.int/classifications/ichi/en/

In medical terms this could be a drug treatment, surgical procedure, diagnostic test or psychological therapy. Examples of public health interventions could include action to help someone to be physically active or to eat a more healthy diet. Examples of social care interventions could include safeguarding or support for carers.

Appendix Table S3: Google search string

| # results (2 November 2020) | 207 | ("impactability" OR "impactibility") AND (site:nhs.uk OR site:cdc.gov OR site:.ac.uk OR site:.gov.uk OR site:.edu OR site:.gov OR site:.ac.au OR site:.ac.ca OR site:elsevier.com OR site:researchgate.net) AND "case finding" AND (guide OR protocol OR process OR method) |
## Appendix Table S4: Studies of the development, validation or application of impactibility models included in the qualitative synthesis

<table>
<thead>
<tr>
<th>Study Name/Ref</th>
<th>Population studied</th>
<th>Impactibility model</th>
<th>Results/author conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buja et al. 2019</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Italy (Azienda ULSS4-Veneto local health unit)</td>
<td>Patients over 65 years, residing in the area served by. All patients had heart failure and “complex health care needs”, as defined by Resource Utilization Band 4 or 5 (respectively high morbidity or very high morbidity) out of 5.</td>
<td>&quot;Impactibility model&quot; based on ACG created by identifying homogenous clinical subgroups of patients with a high risk of at least 1 &quot;preventable admission&quot; that may be addressed using case management</td>
</tr>
<tr>
<td>Data source</td>
<td>Routinely collected administrative data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aims</td>
<td>Case management by development of an impactibility model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcomes and measures</td>
<td>Predictive performance of algorithm to identify common sets of diseases most predictive for hospital admission or readmission compared with ACG risk scores.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Guthrie et al. 2017</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>UK</td>
<td>Patients with ACSCs who had &quot;psychosocial risk factors for increased use of unscheduled care&quot;, including recent use of unscheduled care, depression, living alone or social stressors.</td>
<td>ACSC diagnosis</td>
</tr>
<tr>
<td>Data source</td>
<td>CHOICE: Choosing Health Options In Chronic Care Emergencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aims</td>
<td>Assess relationship between psychological morbidity and use of unscheduled care in people with long-term conditions by a literature review and prospective study of care use to develop a targeted intervention.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcomes and measures</td>
<td>Identification of factors that could reduce use of unscheduled care.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>McCormick 2012</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>USA</td>
<td>Patients with cardiovascular ACSCs (congestive heart failure, angina, hypertension)</td>
<td>ACSC diagnosis</td>
</tr>
<tr>
<td>Data source</td>
<td>Acute hospital admission data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aims</td>
<td>Outcomes and measures</td>
<td>Country</td>
<td>Data source</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------</td>
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<td>-------------</td>
</tr>
<tr>
<td>Difference-in-differences analysis of the impact of healthcare reforms aimed at improving access to care and coverage for preventable ACSCs.</td>
<td>Hospital admission rates before and after reform versus control states without changes</td>
<td>UK</td>
<td>HES data for England, mortality, (May 2008 to November 2009)</td>
</tr>
<tr>
<td>Steventon et al. 2012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steventon et al. 2013</td>
<td>UK</td>
<td>Primary care data (not specified)</td>
<td>Assess the effects of a personalised telephone health coaching service</td>
</tr>
<tr>
<td>Steventon et al. 2016</td>
<td>UK</td>
<td>Hospital administrative data and linked telehealth referral data</td>
<td>Assess the effects of home-based telehealth management of existing</td>
</tr>
</tbody>
</table>

<p>| 34 |</p>
<table>
<thead>
<tr>
<th>Outcomes and measures</th>
<th>Changes in time to first emergency hospitalisation or death versus usual care</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conditions</strong></td>
<td>Conditions by a monitoring centre in a rural setting</td>
</tr>
<tr>
<td><strong>Country</strong></td>
<td>USA (North Carolina)</td>
</tr>
<tr>
<td><strong>Data source</strong></td>
<td>Administrative data available for the whole population (January 2010-May 2017) including eligibility and enrolment files; Medical and pharmacy claims paid by Medicaid and encounter claims from all managed care organisations; Disease burden categorised by hierarchical Clinical Risk Group (CRG)</td>
</tr>
<tr>
<td><strong>Aims</strong></td>
<td>Development of an impactibility score to estimate intervention effects and achievable savings for community-based care management</td>
</tr>
<tr>
<td><strong>Outcomes and measures</strong></td>
<td>Multivariable modelling including costs various risk stratification strategies to build a predictive model of expected cost savings versus usual care</td>
</tr>
<tr>
<td><strong>Impactibility based on PTS</strong></td>
<td>Medicaid beneficiaries who received some level of care management support and had at least 1 potentially preventable admission, readmission or ED visit in the year prior to initiation of case management. Patients were considered to have received care management support if they had at least 1 direct encounter with a care manager by phone or face to face.</td>
</tr>
<tr>
<td><strong>Impactibility score developed using linear regression analysis.</strong></td>
<td>Impactability score developed using linear regression analysis.</td>
</tr>
<tr>
<td><strong>Independent variables:</strong></td>
<td>Age, sex, race, ethnicity, disability status, foster care status ED visit count, inpatient visit count CRG weight Presence of specific chronic conditions Number of chronic conditions Number of chronic medications filled Number of acute medications filled Total cost of care</td>
</tr>
<tr>
<td><strong>Derived variables include:</strong></td>
<td>“Above expected potentially preventable costs” (AEPPC), which includes costs related to potentially preventable</td>
</tr>
<tr>
<td><strong>Model variables related to medication adherence and historical utilization unexplained by disease burden were more important predictors of impactibility than any given diagnosis or event, disease profile, or overall costs of care. Impactibility based targeting could lead to two to three times greater return on investment that risk stratification by high ED use or inpatient admissions and high-risk disorders.</strong></td>
<td>This study helps highlight the difference between “high-frequency/high-cost” users and “highly impactible” users, noting that there’s a real difference between the two groups which makes traditional algorithms unhelpful.</td>
</tr>
</tbody>
</table>

p < 0.001. Authors recommend investing resources in other forms of preventive care for which an evidence base exists.
<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Data sources</th>
<th>Aims</th>
<th>Outcomes and measures</th>
<th>Methods</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawkins et al. 2015</td>
<td>USA (pilots in California, Florida, New York, North Carolina and Ohio)</td>
<td>United Healthcare (AARP Medicare Supplement plan provider) December 2008-December 2011.</td>
<td>Develop and validate a PTS score to support a high-risk-case management programme</td>
<td>Identify among programme members those most likely to: 1) engage with the programme (yes/no) 2) receive the highest quality of care (meeting 70% or more of the relevant clinical care guidelines) and cost savings associated with the HRCM program</td>
<td>Individuals with Medicare Supplement plans with multiple chronic health conditions who may benefit from additional care coordination and ancillary support. Patients are referred either directly from a provider or Nurse HealthLine, or data-driven referrals based on Hierarchical Condition Category risk score &gt;3.74.</td>
<td>PTS model based on logistic regression. Independent variables included: • dates and locations of service • indicators of the types of services, drugs, and procedures provided • AmeriLINK Data Sourcing system (generated by the KBM Group) to find information about socioeconomic status • Local supply of health care services in areas where qualified members lived was derived from the Dartmouth Atlas of Healthcare</td>
</tr>
<tr>
<td>Hommer et al. 2013</td>
<td>USA</td>
<td>United Healthcare (AARP Medicare Supplement plan provider) combined</td>
<td>Patients with depressive symptoms measured by PHQ-9 and AARP Medigap supplement insurance.</td>
<td>PTS model based on characteristics of “engaged patients” compared with qualified but non-engaged patients.</td>
<td></td>
<td>The score enabled more efficient utilisation of health resources by refining targeting and outreach efforts to those...</td>
</tr>
</tbody>
</table>
with inferred sociodemographic data (Dec 2009-Dec 2010)

Predictors of outcomes of interest included:
- patient demographics
- plan type
- location
- participation in other programmes
- health status measures
- various supply side measures
- most likely to be successful in the programme.

### Aims
Develop and validate a PTS score to support a depression management programme

### Outcomes and measures
Changes in identification of patients likely to engage, individual-level costs (ROI >1) and health-care quality outcomes (hospital readmission, EBM metrics)

#### Hsueh et al. 2018

**Country**
USA

**Data source**
The GOAL dataset: care management records from a private not-for-profit healthcare network (Jan 2016 to Feb 17)

**Aims**
Develop models of conditional probability distributions for individual-level effect estimation to enable recognition of behavioural responses that could affect care planning

**Outcomes and measures**
Improved likelihood of goal attainment, categorised as: education (e.g., post-discharge understanding); medication (e.g., adherence); reducing risk (e.g., resolve care gaps); self-care (e.g., heart failure home self-management); implementation (e.g., installing fall prevention facility), and others (e.g., obtaining accurate patient information) in an observational data set.

#### Mattie et al. 2019

**Country**
USA

**Aims**
A random forest machine learning model to

**Outcomes and measures**
The impactibility model reached an overall
<table>
<thead>
<tr>
<th>Data source</th>
<th>Anonymised insurance claims data (June 2015 to May 2018) combined with inferred sociodemographic and patient-generated data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aims</td>
<td>Develop machine learning models to identify patients most likely to benefit from a digital health intervention for care management</td>
</tr>
<tr>
<td>Outcomes and measures</td>
<td>Expected cost savings compared with no predictive intervention</td>
</tr>
</tbody>
</table>

**Aims**

Develop machine learning models to identify patients most likely to benefit from a digital health intervention for care management.

**Outcomes and measures**

Expected cost savings compared with no predictive intervention.

---

**Menard et al. 2018**

**Country**

USA

**Data source**

Birth certificate pregnancy outcome data from the 2011-14 birth cohort

**Aims**

Development and validation of a pregnancy care management strategy to identify women most likely to benefit from pregnancy care management to reduce the rate of low birthweight.

**Outcomes and measures**

Associations between low birthweight and number of completed care management tasks during pregnancy.

---

**Ozminkowski et al. 2015 (MyCarePath)**

**Country**

USA

**Data source**

Administrative claims data and health risk assessment from AARP Medicare Supplement Insurance Plan insured.

---

**Outcomes and measures**

PTS summary scores were calculated through logistic regression to generate predicted probability that an qualified individual:

<table>
<thead>
<tr>
<th>PTS summary scores</th>
<th>PTS models had higher specificity than sensitivity, suggesting they were better able to predict who would not participate/achieve cost</th>
</tr>
</thead>
</table>

---

**Expected cost savings compared with no predictive intervention**

<table>
<thead>
<tr>
<th>Aims</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop machine learning models to identify patients most likely to benefit from a digital health intervention for care management.</td>
<td>Expected cost savings compared with no predictive intervention.</td>
</tr>
</tbody>
</table>

---

**Aims**

Develop machine learning models to identify patients most likely to benefit from a digital health intervention for care management.

**Outcomes and measures**

Expected cost savings compared with no predictive intervention.

**Menard et al. 2018**

**Country**

USA

**Data source**

Birth certificate pregnancy outcome data from the 2011-14 birth cohort

**Aims**

Development and validation of a pregnancy care management strategy to identify women most likely to benefit from pregnancy care management to reduce the rate of low birthweight.

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**Country**

USA

**Data source**

Administrative claims data and health risk assessment from AARP Medicare Supplement Insurance Plan insured.

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**Outcomes and measures**

PTS summary scores were calculated through logistic regression to generate predicted probability that a qualified individual:

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<tr>
<th>PTS summary scores</th>
<th>PTS models had higher specificity than sensitivity, suggesting they were better able to predict who would not participate/achieve cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aims</td>
<td>Describe how big and small data are used to support care coordination programmes</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Outcomes and measures</td>
<td>Change in calculation of risk scores after implementation of PTS modelling was</td>
</tr>
</tbody>
</table>

Note: Individuals purchasing AARP Medicare insurance are asked to complete a health risk assessment after purchasing the plan. Answers to these questions may trigger referral to MyCarePath.

Independent variables included:
- Demographic data
- Health status
- Medigap plan type
- Healthcare supply
- Location variables

External consumer-generated variables have been studied but did not increase the model’s predictive ability.

Navratil-Strawn 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data sources</td>
<td>United Healthcare (AARP Medicare Supplement plan provider) combined with inferred sociodemographic data</td>
</tr>
<tr>
<td>Aims</td>
<td>Increase use of a nurse telephone triage programme</td>
</tr>
</tbody>
</table>

Patients covered by an AARP Medicare Supplement (Medigap) plan

PTS modelling by means of logistic regression to identify characteristics associated with programme engagement.

Model covariates included: savings/improve care quality.

Comparing the 3 months prior to the implementation to the 9 months after implementation, the average number of new participants rose by 11%.

"To date, program evaluations have reported positive returns on investment and improved quality of healthcare among program participants."

PTS modelling was found to be "stable and valid" according to a K-fold cross-validation study.

"PTS modelling may help to target and engage callers, thus increasing use..."
### Outcomes and measures

Changes after PTS in
1) Utilisation of the Nurse Healthline
2) Triage engagement
3) Adherence to nurse recommendations

Compared with no intervention

- demographic measures (age, sex)
- residential location: rural vs urban, census region, residence in 1 of 5 locations with other care coordination pilots ongoing
- socioeconomic variables (zip code level proxies of race and income)
- health status (OptumInsight ImpactPro prospective risk score)
- local supply of health services (hospital beds per 1000, primary care physicians and specialists per 100,000 residents)
- Previous emergency healthcare use in 6 months (yes/no)
- Time of call (weekday/weekend)

This in turn should lead to more efficient use of healthcare services and reduce unnecessary health care expenditures.

---

### Studies incorporating or comparing clinical judgement of impactibility

<table>
<thead>
<tr>
<th>Cohen C et al. 2015</th>
<th>Country</th>
<th>Exclusion criteria based on physician input were: active cancer, schizophrenia, dialysis, residence in nursing homes or long-term care facilities, and age 95 years or older.</th>
<th>Model based on ACG predictive model risk scores for risk of future high costs, augmented with a survey of clinical considerations from six physicians</th>
<th>C-statistics for the model before and after exclusions applied were 0.80 and 0.75, respectively. After exclusion, the PPV for the 6% highest risk patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data source</strong></td>
<td>Israel</td>
<td>Clalit Health Services’ (managed care organization) database 2010-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aims</strong></td>
<td></td>
<td>Develop a patient selection process for multimorbid care management based on physician knowledge and predictive model risk scores</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Outcomes and measures

Improve discriminatory power for selecting multimorbid patients most amenable to proactive management

was 40%. High-risk patients' age, number of chronic conditions, and utilization were substantially higher than those of all other patients.

This study shows that a validated predictive modelling tool provides acceptable discriminatory power for selecting multimorbid patients for participation in proactive care management, even after some of the highest risk patients are excluded because of priori clinical considerations.

**Corbin et al. 2019**

**Country**  | USA  
**Data source**  | Primary care database (not specified)  
**Aims**  | Develop and validate a patient selection tool to guide allocation of care management based on physician knowledge and predictive model risk scores  
**Outcomes and measures**  | Changes in  
1) Average risk score of patients under care management  
2) Number of ED visits  
3) Number of hospitalisation in the next 12 months after introduction of tool  
**Outpatient primary care patients “at risk of hospitalisation in the next 12 months”**  
**Clinical team assessment of the “potential of care to impact outcomes” based on medical and social factors as an adjunct to a risk predictive model developed by EPIC, which identified 19 variables predictive of ED visits or hospitalisation in the next 12 months.**  
**Validation showed an average C-statistic of 0.71. Average risk score of patients under care management increased from 33% to 40.4% over the first 2 months of the programme. Full results for other outcomes not yet available.**

**Flaks-Manov et al. 2020**

**Country**  | Israel  
**Data source**  | HCP interview May 2016-June 2017  
**Aims**  | Explore healthcare providers’ perspectives of patients’ characteristics associated with decisions about which patients should  
**Patients aged 65 years and older who were hospitalized for at least 1 night in an internal medicine ward**  
**Nurse and internal medicine physicians [in charge of direct patient care] assessment of impactibility, compared with a risk prediction model**  
**Physician assessment of likelihood to benefit vs risk prediction model showed 65% overlap, 19% of patients had high predicted risk scores but...**
<table>
<thead>
<tr>
<th>Studies</th>
<th>Country</th>
<th>Data source</th>
<th>Aims</th>
<th>Outcomes and measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleming et al. 2017</td>
<td>USA</td>
<td>HCP interview conducted 2015 to 2016</td>
<td>Investigate how health care providers describe engagement for high-cost patients requiring complex care management</td>
<td>Assess accuracy of health-care professional and provider definitions of engagement in relation to socioeconomic status</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High cost “superutilizers” at two public urban safety-net hospitals</td>
<td>Physician assessment of patient engagement to determine “likelihood to benefit” determined through interviews and ethnographic research</td>
<td>Providers considered ‘likelihood to benefit’ assessments to be highly challenging and oftentimes inaccurate, particularly because they understood low patient engagement to be the result of difficult socioeconomic conditions...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Health-care professionals look for more subtle signs of engagement and considered fluctuating trajectories of engagement due to living circumstances</td>
</tr>
<tr>
<td>Freund et al. 2010, 2011, 2012, 2013</td>
<td>Germany</td>
<td>10 primary care practices in southwestern Germany</td>
<td>Assess accuracy of health-care professional and provider definitions of engagement in relation to socioeconomic status</td>
<td>Predictive modelling was numerically more accurate than physicians at predicting risk of future hospitalisation, but rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Family physician assessment of likelihood to benefit (vs risk predictive model)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Index condition: T2DM, COPD, asthma, CHF or late-life depression (age &gt;60 years).</td>
</tr>
</tbody>
</table>

Outcomes and measures

Identify similarities and differences in recommendations for referral to a readmission prevention program based on physicians’ opinions and a risk prediction model.
**Aims**

Compare physician referrals with risk prediction based on insurance claims data

Exclusion criteria: age under 18, dementia, palliative care, or nursing home residents, active cancer or dialysis

**Outcomes and measures**

Selection of patients for primary-care-based management of complex and chronic illness, assessed by:
1) Hospitalisation within 12 months
2) Mortality

The authors recommend a combined approach between risk prediction and physician-determined impactibility.

---

<table>
<thead>
<tr>
<th>Hudon et al. 2018</th>
<th>Country</th>
<th>Data source</th>
<th>Aims</th>
<th>Outcomes and measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>VISAGES (Vulnerable Patients in Primary Care: Nurse Case management and Self-management support)</td>
<td>Assess effects of case-management intervention on psychological distress and patient activation in frequent health-care users</td>
<td>Effects of intervention on Psychological distress Patient activation Stakeholder’s perceptions of interventions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Randomised control trial of intervention and thematic analysis of in-depth interviews</td>
<td>Patients with at least one chronic disease, including diabetes, CVD, respiratory, musculoskeletal or chronic pain, with “complex care needs whom family physicians felt could benefit from a case management intervention” and at least three ED visits or hospital admissions. Patients with serious cognitive problems were excluded.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The intervention reduced psychological distress (OR 0.43, 95% CI 0.19–0.95, p=0.04), but did not have any significant effect on patient activation</td>
</tr>
</tbody>
</table>

Patients and spouses benefitted from the case management intervention, gaining a sense of security, and stakeholders noted better patient self-management of health

“Case management is a promising avenue to improve outcomes among frequent users of health care with complex needs”

---

**Abbreviations:** ACG=adjusted clinical groups. ACSCs=ambulatory care sensitive conditions. OR=odds ratio. PTS=propensity to succeed.