
# Physiology Passport:

## Putting personalised prevention at the heart of resilient health systems

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The Physiological Society

making science work for health | PHG FOUNDATION

# Contents



## Steering Group

We are grateful to the members of the Steering Group who offered their time and expertise to ensure the success of the project.

The views expressed in this report should not be attributed to any one individual or organisation that contributed to this work unless otherwise stated. The findings and recommendations in the report do not necessarily reflect the views of individuals on the Steering Group or their organisations.

Professor Dame Melanie Welham, Former Executive Chair, BBSRC (Steering Group Chair)

Professor Alastair Burt, University of Newcastle

Professor Colleen Clancy, University of California, Davis

Professor Brendan Cooper, Academy for Healthcare Sciences

Professor Heidi de Wet, University of Oxford

Professor Rob Horne, UCL

Dr Victoria McGilligan, Ulster University

Professor Jonathan Mill, University of Exeter

Professor Catherine Ross, Scottish Government

## Authorship

The Physiological Society worked with PHG Foundation to develop this report which was developed by the following team:

Tom Addison, The Physiological Society

Andrew Mackenzie, The Physiological Society

Shania Pande, The Physiological Society

Dr Chantal Babb de Villiers, PHG Foundation

Dr Laura Blackburn, PHG Foundation

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# Foreword from the Steering Group Chair

**Professor Dame Melanie Welham, DBE, FRSB**
*Former Executive Chair of the BBRSC*

**It has been well documented, even before the COVID-19 pandemic, that health systems across the four nations of the UK are experiencing an increasing demand for their services. This demand has been driven by a combination of a rise in non-communicable diseases (NCDs) and an ageing population. NCDs now account for an estimated 89% of deaths in the UK, with health inequalities having a disproportionate effect on health outcomes for individuals.[1]**

To give one example of the impact of the pressures on health systems, waiting lists for hospital treatment through the NHS in England rose to a record of 7.7 million in September 2023 and the 18-week treatment target has not been met since 2016.

Despite health systems absorbing an increasing proportion of governmental budgets throughout the UK, it is clear that the 'supply' of health services cannot keep up with the additional levels of 'demand'. As the new Secretary of State for Health and Social Care, Wes Streeting MP, said when launching *Change NHS: help build a health service fit for the future*, 'our NHS is under rising pressure; we are diagnosing ill health too late and not doing enough to prevent it in the first place…and costs are escalating'. He has also focused on the need for greater levels of care to be provided away from hospitals in community settings and the need to rapidly digitise health systems.

## Personalised prevention

It is clear that innovative strategies aimed at improving health, with an emphasis on prevention, will be needed to alleviate pressures on health systems across the UK, complementing strong public health interventions. It is against this backdrop that The Physiological Society has brought together expert stakeholders from academic, clinical and funding backgrounds to explore the contribution that can be made by physiology research, translation and innovation to personalised prevention.

During my time as Executive Chair of the Biotechnology and Biological Sciences Research Council (BBSRC), I recall discussions which highlighted the potential of a personalised prevention approach and the underpinning science that would be required to make it a success. It has been very encouraging to see the early promise of this approach starting to come to fruition. However, further research and acceleration of innovation will be crucial in creating a truly personalised approach to the prevention, treatment and care of the future.

This report proposes the concept of a 'Physiology Passport' as a means to collect, manage and present a person's physiological health information in their existing electronic health record to establish the parameters that define good health for them as an individual.

The 'Physiology Passport' concept is likely to stimulate debate and raises a whole series of research, ethical and practical questions. The expert Steering Group that supported this project debated many of these questions, including the importance of clinical validation of physiological biomarkers, data ownership and security, reducing health inequalities and integration into existing healthcare records. We recognised that many of these areas will require much more in-depth consideration. New areas of physiology research and interdisciplinary approaches were identified as being central to the success of personalised prevention and the eventual overall improvement in public health.

It has been a real pleasure to chair this project and explore how physiology can help put personalised prevention at the heart of resilient health systems. Its success or failure will have an impact across all four nations of the UK and beyond.

1. Robbins, A. J. et al. Emergency hospital admissions associated with non-communicable diseases 1998–2018 in England, Wales and Scotland: an ecological study. Clin Med (Lond). 2021 Mar;21(2):e179–e185. doi: 10.7861/clinmed.2020-0830. PMID: 33762384; PMCID: PMC8002810.

# 1. What is preventive healthcare and why is it important?

**Our population is ageing.** According to projections from the Office for National Statistics (ONS), the proportion of the UK population aged over 65 is estimated to rise from 18.9% in 2024 to 21.8% in 2034.[2] While life spans have, until recently, increased, health spans – the proportion of life spent in good health – have not increased at the same rate.[3] The consequence of these demographic trends is a reduction in the proportion of working to non-working people and an increase in the cost to government of caring for a greater proportion of people aged over 65. The Institute for Fiscal Studies noted in March 2022 that 'the Office for Budget Responsibility (OBR) forecast that government health spending will rise from its pre-pandemic level of 7.2% of GDP in 2018–19 to 13.8% of GDP in 2067–78 as the population ages and healthcare costs rise.'[4] This means that unless action is taken to increase the focus on prevention, an ever-increasing and potentially unsustainable proportion of public spending will be directed towards managing the burden of disease and long-term morbidity.

In terms of prevention, the ONS estimates that 8.2% of all healthcare funding in 2022 was on preventive care; however, spending in other areas (e.g. transport, food policy) also contributed to improved health outcomes.[5]

**Burden of non-communicable diseases (NCDs).** The rising costs of more people living with long-term conditions throughout their life course mean that it is becoming more common for people to live with morbidity.[6] Therefore, people are spending longer periods of their later life in ill health.

The impact of a long-term diagnosis on an individual's financial and physical health varies from condition to condition.[7] For example, one Swedish study showed that people diagnosed with Parkinson's disease left the workforce earlier than matched individuals without the condition. According to *Health in an Ageing Society*,[8] data from the 2019 Global Burden of Disease Study show that musculoskeletal disorders (such as arthritis), neurological conditions (such as Parkinson's disease), sense organ diseases (such as hearing or visual impairment) and unintentional injuries (such as falls or fractures) make the biggest contribution to years lived with disability in later life. In addition, many of the leading causes of mortality, including neurological and cardiovascular diseases and cancer, progress over years, requiring long-term medical care.

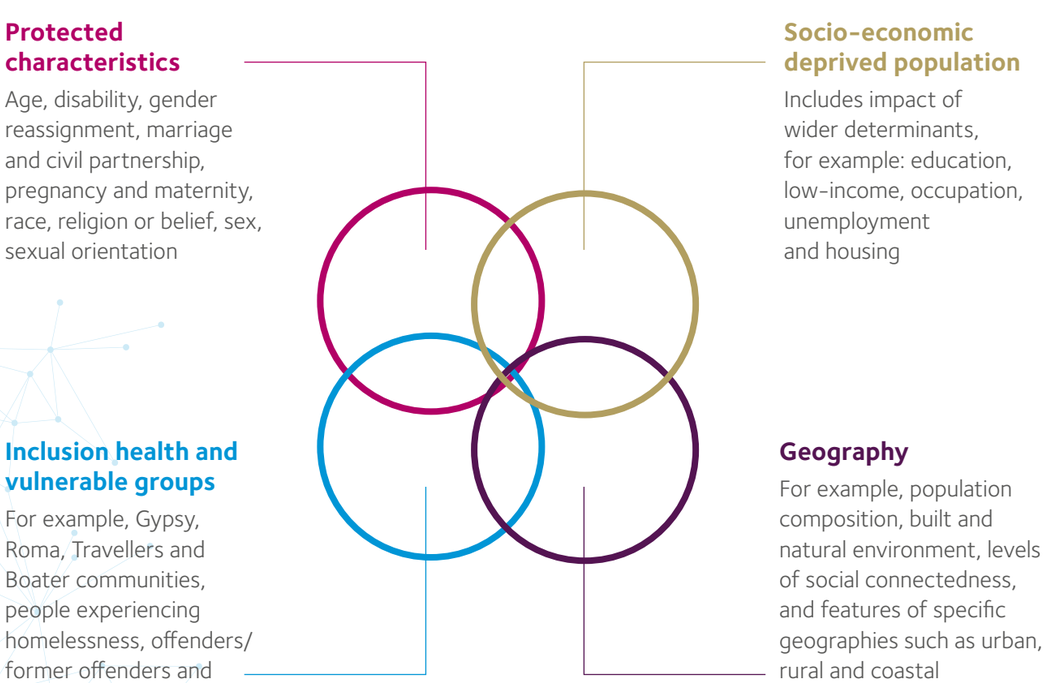
**Climate change** has been described by the World Health Organization as presenting a fundamental threat to human health.[9] It impacts health significantly by increasing the frequency

2. Office for National Statistics. (January 2024). Principal projection – UK population in age groups. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/tablea21principalprojectionukpopulationinagegroups
3. The Physiological Society. (May 2024). Healthy Ageing. https://www.physoc.org/policy/healthy-ageing/
4. Institute for Fiscal Studies. (October 2023). The economic consequences of the UK's ageing population. https://ifs.org.uk/articles/economic-consequences-uks-ageing-population
5. Office for National Statistics. (May 2024). Healthcare expenditure, UK Health Accounts. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthcaresystem/bulletins/ukhealthaccounts/2022and2023
6. Department of Health and Social Care. (November 2023). Chief Medical Officer's annual report 2023: health in an ageing society. https://www.gov.uk/government/publications/chief-medical-officers-annual-report-2023-health-in-an-ageing-society
7. Timpka, J., Dahlström, Ö., Nilsson, M. H., Iwarsson, S. & Odin, P. (2023). Time to workforce exit after a Parkinson's disease diagnosis. Npj Parkinson's Disease, 9(1). https://doi.org/10.1038/s41531-023-00513-0
8. Department of Health and Social Care. (2023b, November 16). Chief Medical Officer's annual report 2023: health in an ageing society. https://www.gov.uk/government/publications/chief-medical-officers-annual-report-2023-health-in-an-ageing-society
9. World Health Organization (WHO). (October 2023). Climate change. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

and severity of extreme weather events, such as heatwaves, floods and storms, leading to injuries, illnesses and deaths. It also exacerbates chronic conditions like respiratory and cardiovascular diseases due to worsening air quality or heat. Physiologists are also at the heart of exploring the link between climate-driven extreme heat and mental health. These health challenges place immense pressure on health systems, straining resources and infrastructure.

**Health disparities and inequalities** in the UK present significant challenges to health systems. Disparities in health outcomes and access to services are driven by socio-economic status, ethnicity and geography, as well as strained resources and infrastructure. These inequalities increase the demand on the NHS, requiring targeted interventions and resource allocation. Poor health outcomes among affected populations have broader social and economic implications.

**Figure 1 Domains of health inequality**[10]




10. GOV.UK. (October 2022). Health disparities and health inequalities: applying All Our Health. https://www.gov.uk/government/publications/health-disparities-and-health-inequalities-applying-all-our-health/health-disparities-and-health-inequalities-applying-all-our-health



Together, the trends outlined in Figure 1 have combined to increase the pressure on health systems across the UK, creating an **unmanageable rising demand for healthcare and a drain on wider national productivity.** However, we know that if they can be detected early, many long-term health conditions are preventable or can be treated to slow or halt the progression to severe illness. Hence, efforts to reduce future health burdens through a greater focus on the *prevention* rather than treatment of disease are becoming more significant among policymakers, including the Secretary of State for Health and Social Care, Wes Streeting MP, who is responsible for the NHS in England.

The prize of preventing non-communicable disease is a significant one. A June 2024 report from Nesta indicated that health spending, driven by increasing chronic conditions over and above ageing, will need to grow at roughly 4% annually in real terms (excluding productivity gains). As such, if we could stop the growth in chronic conditions over and above population growth – i.e. holding the prevalence of illness where it is today – **they estimate we could avoid cumulative health spending growth across the UK of almost £500 billion by 2040.**[11] One review estimated that for every £1 spent on preventive measures, there would be a return on investment of £14.[12] Prevention in all forms needs to be turbocharged if we are to continue to be able to deliver health services through the current financial model of free at the point of care.

**Preventive healthcare** focuses on averting diseases through proactive measures, enhancing quality of life and ensuring better long-term health outcomes. Reducing the incidence and severity of disease decreases the need for costly treatments and hospitalisations, alleviating financial burdens on healthcare systems and boosting productivity by lowering the number of illness-related work absences. This reduction in demand eases the strain on healthcare systems, allowing more efficient resource allocation, while a healthier population contributes to a more vibrant and economically stable society. Integrating preventive with reactive healthcare is crucial for optimal health outcomes, improving quality of life and reducing long-term costs while providing necessary treatments for existing conditions.

In the UK, preventive health and public health responsibilities are devolved matters with different arrangements across England, Scotland, Wales and Northern Ireland. Each government manages health and social care within its jurisdiction, with shared responsibility across various government departments, organisations and at different levels of government, each playing a specific role in promoting public health and preventing illness.

11. Nesta. (no date). Here's why it's impossible to save the NHS unless we invest in prevention right now. https://www.nesta.org.uk/blog/heres-why-its-impossible-to-save-the-nhs-unless-we-invest-in-prevention-right-now/#:~:text=Stopping%20the%20growth%20in%20chronic,in%20health%20spending%20by%202040

12. Masters, R. et al. (2017). Return on investment of public health interventions: a systematic review. Journal of Epidemiology & Community Health, 71(8), 827–834. https://doi.org/10.1136/jech-2016-208141

## Precision medicine and personalised prevention

Precision medicine is an innovative approach to healthcare. Its aim is to transform how we diagnose, treat and prevent diseases by considering the unique genetic, environmental and lifestyle factors of each person. Precision medicine tailors disease prevention and treatments by taking into account differences in people's **physiology**, measured via biomarkers, their environments and lifestyles.

### Box 1. Physiology: key definitions

**Physiology** is the branch of biology that aims to understand the mechanisms of living organisms, from the basis of cell function at the molecular level to the behaviour of the whole body and how it responds to the external environment.

**Physiology research** helps us to understand how the body works in health, how it responds and adapts to everyday challenges, and what goes wrong in disease.

**Clinical physiology** applies physiology research knowledge to diagnose and treat diseases by examining how physiological processes are altered in various clinical conditions.

**Biomarkers** are a defined characteristic that is measured as an indicator of normal biological processes, pathogenic processes, or responses to an exposure or intervention, including therapeutic interventions. Molecular, histologic, radiographic and physiologic characteristics are types of biomarkers.[13]

**Physiological biomarkers** are measurable indicators of the body's physiological or pathological status and its response to stimulus or disease. Examples of a physiological biomarker include heart rate, blood glucose levels, maximal oxygen consumption and blood pressure.

Precision medicine embodies the 'four Ps' of medicine – predictive, preventive, personalised and participatory.

### Box 2. Four Ps of medicine

**Predictive:** Identifies an individual's risks of developing diseases based on key biomarker profiles.

**Preventive:** Disease prevention measures are delivered throughout the life course at different stages of the healthcare pathway: primary (reduction of the risk of developing certain diseases), secondary (early diagnosis) or tertiary (improvement of patient quality of life).

**Personalised:** Considers the biomarker characteristics of each person, as well as their medical, environmental, social and cultural context.

**Participatory:** Individuals are empowered to take part in managing their own health.

13. https://www.fda.gov/drugs/biomarker-qualification-program/about-biomarkers-and-qualification#:~:text=Molecular%2C%20histologic%2C%20radiographic%2C%20or,feels%2C%20functions%2C%20or%20survives



Within the broader scope of precision medicine, **personalised prevention** is a key element aimed at preventing the onset, progression and recurrence of disease through the adoption of targeted interventions that consider biological information, environmental and behavioural characteristics, and the socio-economic and cultural context of individuals. These interventions should be timely, effective and equitable to maintain the best possible balance in the lifetime health trajectory. To achieve this, they need to take account of the psychosocial factors that influence peoples' motivation and ability to engage with intervention. The psychosocial element has been referred to by some, as the 'fifth P' of 4-P medicine (for more information, see Box 2).[14]

Various technologies and approaches, underpinned by **physiology research**, will be integral to the success of personalised prevention approaches. Examples include optimising the use of current tests and technologies, developing new diagnostic and monitoring tests, strategies for monitoring conditions in real time, and the integration and analysis of a variety of health information and data. Data, including physiological data, are crucial in identifying health trends, targeting interventions and improving the efficiency of healthcare services, which enhances prevention efforts.

**This report highlights the key role of physiologists and physiological research in supporting the development and use of precision medicine, with a specific focus on personalised prevention, to meet aspirations to improve people's health across the four nations of the UK.**

14. Horne, R. (2017). The Human Dimension: Putting the Person into Personalised Medicine. The New Bioethics, 23(1), 38–48. https://doi.org/10.1080/20502877.2017.1314894

# 2. Precision medicine and personalised prevention – UK policy landscape

Preventing ill health and maintaining good health are high on the health policy agenda. In their 2024 election manifesto, 'Five Missions for a Better Britain', the Labour Party noted the importance of harnessing the power of personalised medicine, referring to the significance of innovating and leveraging new healthcare technologies to transform the NHS.[15] Lord Darzi's September 2024 report[16] highlights many of the challenges currently facing the NHS in England due, in part, to the substantial increase in the number of people living with multiple long-term conditions.[17] In a speech responding to the report's findings,[18] the Prime Minister acknowledged the pressure on the health system caused by an ageing society and preventable illnesses, stating: 'We've got to be much bolder in moving from sickness to prevention.'[19]

Research by The Health Foundation showed that between 2013 and 2023 there were at least 30 published health policy documents in England that contained ambitions relevant to personalised prevention.[20] For example, the *Genome UK: 2022 to 2025 implementation plan for England* includes the role of genomics in risk prediction and screening strategies aimed at improving the prevention and early detection of disease.[21] In Scotland, the Genomic medicine strategy 2024 to 2029 aims to improve health outcomes through using genomic information to support disease prevention and early detection.[22] The 2023 Major Conditions Strategy from the Department of Health and Social Care promotes personalised prevention as a key pillar in helping to tackle the following six conditions responsible for 60% of the burden of ill health and early death in England: cancers, cardiovascular disease (including stroke and diabetes), musculoskeletal disorders, mental ill health, dementia and chronic respiratory disease.[23] As such, it is clear that there is an opportunity to build on the well-established role for genomics in risk prediction with the dynamic information provided by physiological biomarkers to enhance prevention strategies.

The breadth and scope of physiology research brings great opportunity to the fast-growing and increasingly relevant healthcare approach of precision medicine, and particularly personalised prevention. As outlined in Box 1 (page 8) in the previous chapter, physiology and physiology research cover a broad range of areas exploring how living things work, and what is happening in health and disease.

15. Labour Party. (2023). Build an NHS fit for the future. https://labour.org.uk/wp-content/uploads/2023/05/Mission-Public-Services.pdf
16. Department of Health and Social Care. (November 2024). Independent investigation of the NHS in England. https://www.gov.uk/government/publications/independent-investigation-of-the-nhs-in-england
17. Office for National Statistics. (July 2023). Rising ill-health and economic inactivity because of long-term sickness. https://www.ons.gov.uk/employmentandlabourmarket/peoplenotinwork/economicinactivity/articles/
18. GOV.UK. (September 2024). PM: 'Major surgery, not sticking plaster solutions' needed to rebuild NHS. https://www.gov.uk/government/news/pm-major-surgery-not-sticking-plaster-solutions-needed-to-rebuild-nhs
19. GOV.UK. (September 2024). PM speech on the NHS: 12 September 2024. https://www.gov.uk/government/speeches/pm-speech-on-the-nhs-12-september-2024#:~:text=Reducing%20the%20strain%20on%20our,moving%20from%20sickness%20to%20prevention
20. Personalised prevention in England. (September 2024). The Health Foundation. https://www.health.org.uk/publications/long-reads/personalised-prevention-in-england
21. Department of Health and Social Care. (December 2022). Genome UK: 2022 to 2025 implementation plan for England. https://www.gov.uk/government/publications/genome-uk-2022-to-2025-implementation-plan-for-england
22. The Scottish Government. (April 2024). Genomic medicine strategy 2024 to 2029. https://www.gov.scot/publications/scotlands-genomic-medicine-strategy-2024-2029/
23. Major conditions strategy: case for change and our strategic framework. (August 2023). https://www.gov.uk/government/publications/major-conditions-strategy-case-for-change-and-our-strategic-framework/major-conditions-strategy-case-for-change-and-our-strategic-framework--2

## **Case study 1:** Experience from Europe's PROPHET study coordinating the development of a European approach to personalised prevention

Personalised prevention is a complex challenge that research and health initiatives are striving to address. One of these is the 'PeRsOnalised Prevention roadmap for the future HEalThcare' (PROPHET) project, which aims to highlight gaps in personalised preventive approaches and develop a Strategic Research and Innovation Agenda for the EU. Three rapid scoping reviews were conducted to map biomarker research in cancer, cardiovascular and neurodegenerative diseases for personalised prevention. A biomarker is understood to be a substance, structure, characteristic or process that can be objectively measured as an indicator of normal biological processes, pathogenic processes or biological responses to an exposure. Biomarkers were classified into molecular, cellular, imaging, physiological (i.e. functional) and anthropometric types, each of which has different subtypes. Biomarker research is most extensive in cancer, followed by cardiovascular diseases, while it is less comprehensive in neurodegenerative diseases, with most of it being focused on Alzheimer's disease. Molecular biomarkers (genetic and biochemical) are prevalent across all diseases, especially in cancer. Imaging biomarkers are particularly relevant for the prevention of neurodegenerative diseases. Digital technologies, AI and machine learning have been primarily used in molecular and imaging studies. These reviews underscore the research landscape and the need for further studies to enhance personalised prevention strategies.

The PROPHET project highlights the importance of using diverse biomarkers to enhance personalised prevention strategies, and the use of digital technologies like AI for integrating data – which are often represented by various physiological markers. It underscores the need for balanced research efforts across different diseases and emphasises the importance of strategic, coordinated planning to address gaps in personalised prevention. A holistic approach, combining various biomarkers and advanced technologies, is essential for developing effective and tailored prevention methods.



Professor John Deanfield, the 'Government Champion for Personalised Prevention', published his independent report, 'Making prevention everyone's business', in May 2024, making recommendations around creating a 'digital-first National Prevention Service', and moving prevention services (including the associated testing) outside of traditional healthcare settings nearer to where people live, work and socialise.[24] The importance of precision medicine and prevention is being reflected in health policy across the UK. A 2019 written statement from the Welsh government on precision medicine outlines a vision that includes integrated diagnostics and advanced targeted therapeutics, involving support for technologies such as digital pathology and genomics.[25]

The Chief Medical Officer for Scotland's suite of reports on 'realistic medicine' calls for greater emphasis on prevention in healthcare.[26,27] In Northern Ireland, the precision medicine sector received £7.5 million in launchpad funding from Innovate UK in 2023,[28] and work in this area is ongoing at the Precision Medicine Centre of Excellence at Queen's University Belfast[29] and the Personalised Medicine Centre at Ulster University.[30]

24. Department of Health and Social Care. (May 2024). Making prevention everyone's business. https://www.gov.uk/government/publications/making-prevention-everyones-business
25. Welsh government. (April 2019). Written Statement: Precision Medicine. https://www.gov.wales/written-statement-precision-medicine
26. Scottish government. (June 2023). Realistic Medicine – Doing the right thing: Chief Medical Officer for Scotland annual report 2022 to 2023. https://www.gov.scot/publications/realistic-medicine-doing-right-thing-cmo-annual-report-2022-2023/documents/
27. Scottish government. (September 2024). Realistic Medicine – Taking Care: Chief Medical Officer for Scotland annual report 2023 to 2024. https://www.gov.scot/publications/realistic-medicine-taking-care-chief-medical-officer-scotland-annual-report-2023-2024/pages/1/
28. Department for the Economy. (October 2023). Department announces £7.5m boost to precision medicine sector. https://www.economy-ni.gov.uk/news/department-announces-ps75m-boost-precision-medicine-sector
29. Queen's University Belfast. (November 2018). Precision Medicine Centre. https://www.qub.ac.uk/research-centres/PMC/
30. Ulster University. (no date). Personalised Medicine. https://www.ulster.ac.uk/personalised-medicine

## **Case study 2:** Personalised prevention approach to weight management

Weight management and the treatment of obese and diabetic patients is an excellent example of an area where personalised prevention can play a key role in preventing obesity-related disease. It is well established that patients can lose weight, and keep to their new weight initially, following a period of restricted calories on a liquid replacement diet.[31,32] Furthermore, similar studies using the weight loss drug liraglutide in combination with exercise, or employing exercise alone, highlighted the mood-boosting effects of physical activity.[33] Precision interventions allow us to combine a variety of proven interventions to help individuals with long-term weight management in a tailored way.

GLP-1 receptor agonists are medications that help lower blood sugar, reduce appetite and aid with weight loss by mimicking a natural hormone in the body that regulates blood sugar and hunger. They have changed the way we approach weight loss in obese patients, but due to side effects in some patients and existing co-morbidities such as depression and low mood, it is essential that a weight loss programme is tailored to maximise a positive outcome for these patients.

For many people, preparing and eating food is an important aspect of their lives, and taking drugs that reduce appetite is not an attractive option for all and may not be feasible or desirable for patients and their families. We also know that exercise also combats loneliness and feelings of isolation, and access to green and blue spaces is essential for both health and mental well-being.

We now have a powerful tool in GLP-1R agonist drugs for treating obesity, especially in patients who have not responded to previous interventions to lose weight. But the maintenance of weight loss and the adaption of a healthy lifestyle post treatment will remain an area in need of precision intervention to meet the needs and cultural expectations of the individual.

*Professor Heidi de Wet, University of Oxford*

31. Lean, M. E. et al. Primary care-led weight management for remission of type 2 diabetes (DiRECT): an open-label, cluster-randomised trial. Lancet. 2018 Feb 10;391(10120):541–551. doi: 10.1016/S0140-6736(17)33102-1. Epub 2017 Dec 5. PMID: 29221645.
32. NHS England. (no date). NHS Type 2 Diabetes Path to Remission Programme. https://www.england.nhs.uk/diabetes/treatment-care/diabetes-remission/
33. Lundgren, J. R. et al. Healthy weight loss maintenance with exercise, liraglutide, or both combined. N Engl J Med. 2021 May 6;384(18):1719–1730. doi: 10.1056/NEJMoa2028198. PMID: 33951361.



## **Case study 3:** Precision medicine social prescribing for rehabilitation/treatment

Standardised prescriptions often fail to account for individual differences in functional capacity, patient background and motivational factors. To address this, a health and well-being academy within a university ecosystem is tackling local health inequalities while providing students with clinical experience. Operating within the local NHS Primary Care Network, the academy offers 12-week exercise interventions in a safe, controlled environment for referred individuals. Social prescribing, a non-medical referral from GPs, aims to address various health and mental conditions through activities like walking football and gardening. However, many patients lack the physical ability or confidence to participate in these programmes. The academy's 12-week programme helps bridge this gap.[34]

Physiological measures, such as risk factors for cardiovascular disease, diabetes and respiratory disease, are assessed before and after the programme. Preliminary data show significant physiological improvements and higher adherence rates than traditional rehabilitation or exercise referrals. This approach demonstrates the potential of personalised social prescribing to enhance patient outcomes and engagement.

*Professor Angus Hunter, Nottingham Trent University*

## **Case study 4:** Machine learning for detecting the misplacement of ECG electrodes

Machine learning is emerging as a valuable tool for detecting misplacement of ECG electrodes, especially chest electrodes. Misplacement of these electrodes can lead to incorrect diagnoses, such as misinterpreting myocardial infarction or missing heart conditions like left ventricular hypertrophy. Research from Ulster University has shown that machine learning, particularly deep learning, outperforms physicians in detecting these errors, offering high accuracy in identifying misplacement and flagging flawed ECG data. This could improve diagnostic accuracy and reduce clinical errors caused by incorrect electrode positioning. This work was selected to be indexed as an evidence document with The National Institute for Health and Care Excellence (NICE) and also showcased in the Cardiology Advisor network.

*Dr Victoria McGilligan, Ulster University*

34. Nottingham Trent University. Sport and Wellbeing Academy. (May 2024). https://www.ntu.ac.uk/study-and-courses/academic-schools/science-and-technology/sport-science/sport-and-wellbeing-academy

# 3. Physiology research in the context of personalised prevention

**This research is distinctive because it integrates molecular, cellular, systems and whole-body function. Within healthcare, this supports a holistic view of a patient and their condition(s) and the development of more accurate monitoring tools and diagnostic tests that use a range of biomarkers – factors that you can measure to tell you about the health or disease status of a cell, an organ, tissue or the whole body. This is essential for the effective diagnosis, treatment and prevention of various health conditions.**

Physiology research is key to identifying and integrating a broad range of biomarkers that can be, and are, used in healthcare tests, including:

- molecular (biological molecules such as genetic and biochemical)
- cellular (cell features/components)
- functional (changes in the body, e.g. blood pressure, breathing patterns)
- imaging (features identified on MRI, X-ray, etc.)
- anthropometric (the body's physical characteristics).

Physiological data comprise the bulk of information about a person's health, and tests that measure and analyse biomarkers provide details about their health status. This information influences the prevention and management of the non-communicable diseases that are becoming increasingly prevalent in our society, such as cancer, cardiovascular diseases, respiratory conditions (particularly COPD, asthma), neurodegenerative diseases, diabetes (particularly type 2), obesity and mental health problems.

Research by the EU-funded PROPHET project (see case study 1 on page 12) demonstrates a range of research activity into biomarkers that could be used to support personalised prevention of cancer, as well as cardiovascular and neurodegenerative diseases. The project also indicates that there are still many knowledge gaps, particularly in relation to neurodegenerative diseases, and therefore great opportunities for physiology-led research to lead the way in preventive biomarker research and discovery.

## Physiology-led personalised prevention

Until very recently, there has been a focus on a genomics-led view of precision medicine and personalised prevention, due to intense research efforts and the establishment of the NHS Genomic Medicine Service.[35] Genomics has had the biggest impact in the management of cancer, and in inherited rare diseases, where disease causes can be linked to variants in one or a small number of genes. However, the impact of multi-gene, or polygenic, genomic analysis on prevention is much less clear, and evidence is still being gathered about its clinical usefulness. In addition, genomics provides insight into only one component of an individual's health.

35. Genomics England. (May 2022). NHS Genomic Medicine Service. https://www.genomicsengland.co.uk/genomic-medicine/nhs-gms#:~:text=The%20NHS%20Genomic%20Medicine%20Service%20(NHS%20GMS)%20is%20the%20arm,the%20country's%2055%20million%20people

## **Case study 5:** Liverpool Lung Project (LLP) risk model for prediction of lung cancer

Lung cancer is the leading cause of cancer-related deaths, accounting for 21% of cancer fatalities in the UK between 2015 and 2017, with an economic burden of approximately £630,000 per case in 2023.[36] Early-stage lung cancer can be treated with surgery, but late-stage detection often results in poor prognosis. The Liverpool Lung Project (LLP) Risk Model provides a clinically efficient and cost-effective method for targeting high-risk individuals for low-dose computed tomography (CT) screening. This is crucial for several reasons, including, for example, that by focusing on high-risk individuals, healthcare resources are used more effectively, ensuring that those most likely to benefit from screening receive it. This model, used in the UK Lung Cancer Screening (UKLS) Randomized Controlled Trial, identified 85% of early-stage lung cancer cases, with 83% being suitable for surgery. Its success led to its incorporation in the NHS England Targeted Lung Health Check national rollout. Future enhancements could include integrating validated biomarkers and AI analysis to refine risk scores, thus further improving the effectiveness of lung cancer screening programmes.

*Professor John Field, University of Liverpool*

The varied, multimodal view of a patient's health provided by physiological biomarkers will be essential in supporting preventive efforts in diseases with many causative factors. Genomics and other 'omics technologies will continue to be an important part of the picture, since the power of using a physiology-led approach will come from combining information from a variety of sources to build a global view of a person's health over their life span through the development of a richer data set of 'normal' range for the individual. Physiological biomarkers are dynamic and change according to the state of the individual in sickness and health, providing feedback on how the body's systems are changing in response to environmental and lifestyle factors, while also giving context to genetic information.

Recent advances in machine learning and artificial intelligence (AI) tools are making it possible to analyse physiological data in combination with other data sets on a scale not previously possible, even a few years ago. This means that clinicians will more easily be able to identify patterns and relationships in data that otherwise would not be visible using current techniques, thereby providing new insights into disease.

36. Frontier Economics. (2023). The societal and economic costs of preventable cancers in the UK. https://www.frontier-economics.com/media/edwnhnlc/frontier-economics-the-societal-and-economic-costs-of-preventable-cancers-in-the-uk.pdf



## **Case study 6:** AI-driven cardiovascular risk prediction

Cardiovascular diseases are a leading cause of death, making early detection and personalised prevention crucial. The University of Oxford, supported by the NIHR Oxford Biomedical Research Centre, developed an AI tool to predict the 10-year risk of fatal heart attacks.[37] This tool analyses routine cardiac CT scans to detect inflammation in the fat around arteries, a key indicator of potential cardiac events. Trained on data from over 40,000 patients, the AI integrates clinical risk factors like age, sex, smoking status, diabetes and high blood pressure to generate a comprehensive risk score.

Patients undergoing cardiac CT scans for chest pain are assessed using this AI tool, which helps clinicians identify high-risk individuals and tailor prevention strategies. These strategies may include lifestyle changes, medication adjustments and closer monitoring. In trials, the AI tool improved treatment plans for up to 45% of patients, potentially saving thousands of lives by identifying those at risk who might otherwise be missed. This technology is cost-effective and enhances the UK health system's ability to provide precise, proactive care, reducing the burden of cardiovascular diseases.

*NIHR Oxford Biomedical Research Centre, University of Oxford*

However, currently health systems across the UK are not able to fully benefit from the advances resulting from this integrative and holistic approach, as expertise is often developed within silos of specific specialisms of organ or body systems. There is an opportunity for physiology research and scientists to become the convening umbrella under which an interdisciplinary, cross-cutting approach to health research and, crucially, disease prevention can take place. This will be crucial in building integrated and collaborative approaches between specific specialisms of organ or body systems and between physiological and genomic data sets.

To harness the benefit of a physiology-led approach, health systems need to develop prevention strategies that capture this dynamic information over the life course through a variety of different methods. These data would be stored within electronic patient healthcare records and made accessible to both the individual and their healthcare providers. By engaging people in this process and making these data accessible to them, they can be supported and empowered to moderate their disease risk profile. Recent developments in health policy and plans for developing the health service across the UK, such as the 10-Year Health Plan in England, provide a background context and opportunity as to how this could happen.

37. NIHR Oxford Biomedical Research Centre. AI tool could help thousands avoid fatal heart attacks. (November 2023). https://oxfordbrc.nihr.ac.uk/ai-tool-could-help-thousands-avoid-fatal-heart-attacks/

# 4. How can physiological research support national priorities in health and prevention?

The upcoming 10-Year Health Plan for England and the 10-Year Population Health Plan in Scotland present a once-in-a-generation opportunities to reshape the delivery of healthcare towards disease prevention. A personalised approach rooted in an individual's physiology will be essential to the success of this new model.

Health systems across the UK share similar challenges, and the principles of this approach are relevant in Scotland, Wales and Northern Ireland.

In response to the Darzi report in England, the UK government has announced that it intends to develop a 10-year plan for health and care. This new plan is expected to be published in spring 2025, with the largest ever consultation of staff and the public underway, and is focused around three 'big shifts':

**Shift 1:** Moving more care from hospitals to communities

**Shift 2:** Making better use of technology in health and care (analogue to digital)

**Shift 3:** Focusing on preventing sickness, not just treating it.

These shifts will underpin how the NHS in England delivers healthcare in the years to come. Physiology-led personalised prevention will have an impact on, or be impacted by, the proposed changes outlined in each of these shifts.

While this new plan will apply to England only, the challenges and principles outlined during its development, and the contribution of physiology-led research to developing solutions, can be applied to all health systems in the UK.

Through the case studies included in Appendix 1 and within the report, we illustrate how the breadth and depth of current physiological research is contributing knowledge relevant to delivering these shifts and for understanding personalised health risks in the context of prevention, ultimately supporting the evolution of a more proactive and patient-centred healthcare system.

## Shift 1: Moving more care from hospitals to communities to reduce the burden of demand on traditional healthcare settings

**The delivery of more community-based care presents opportunities for physiology-led personalised prevention, which relies on monitoring, apps, wearables or tests that can be delivered by point-of-care devices.**

Community-delivered health management is gaining momentum in the UK, driven by the need to improve health outcomes, reduce inequalities and make healthcare more accessible. Encouraged by the NHS and the Office for Health Improvement and Disparities (OHID), these initiatives leverage local resources and engage populations directly in their health management. The following case studies showcase how physiological research is being applied within community settings to deliver personalised preventive care. These examples highlight innovative approaches that not only address specific health risks but also foster a proactive, inclusive approach to community health, ultimately enhancing the well-being of diverse populations and preventing the rise of misinformation.

### **Case study 6:** Supporting engagement and adherence: lessons from medicines

The World Health Organization and Organisation for Economic Co-operation and Development (OECD) estimate that about half of medicines prescribed for long-term conditions are not taken as advised impacting the health of individuals and societal costs.[38,39] Research across medical conditions, countries and healthcare systems shows that engagement with medicines is strongly influenced by peoples' personal beliefs about medicines and the disease being treated or prevented.[40] These beliefs influence how people judge their personal need for the treatment against their concerns about it. Not following the treatment recommendations can seem to the person to be the common-sense option: e.g. 'I am not convinced I need to follow this advice when I feel fine' even for preventative therapies for cancer[41]. Although these beliefs seem logical to the individual, they are often misplaced.

Research into patient and public understanding of disease and treatment can be applied to support informed choice and engagement by addressing misplaced beliefs, doubts and concerns.[42] These approaches can be applied to support engagement with the Physiology Passport and personalised prevention, by following a 3-step Perceptions and Practicalities Approach.[43,44]

1. **Necessity** - Communicate the intervention in way that convinces the person of their personal need to engage with it.
2. **Concerns** - Address any concerns about the perceived downsides.
3. **Practicalities** - Make it as easy and convenient as possible.

*Professor Rob Horne, University College London*

38. Khan R, Socha-Dietrich K: Investing in medication adherence improves health outcomes and health system efficiency. 2018.
39. Sabaté E: Adherence to long-term therapies: evidence for action: World Health Organization; 2003.
40. Horne R, Chapman SC, Parham R, Freemantle N, Forbes A, Cooper V: Understanding patients' adherence-related beliefs about medicines prescribed for long-term conditions: a meta-analytic review of the Necessity-Concerns Framework. PloS one 2013, 8(12):e80633.
41. Thorneloe RJ, Horne R, Side L, Wolf MS, Smith SG, Adamson V, Ainsworth S, Akerlund M, Baker I, Barwell J et al: Beliefs About Medication and Uptake of Preventive Therapy in Women at Increased Risk of Breast Cancer: Results From a Multicenter Prospective Study. Clin Breast Cancer 2019, 19(1):e116-e126.
42. Horne R, Chapman S, Glendinning E, Date HL, Guitart J, Cooper V: Mind Matters: Treatment Concerns Predict the Emergence of Antiretroviral Therapy Side Effects in People with HIV. AIDS and behavior 2019, 23(2):489-498.
43. Horne R, Cooper V, Wileman V, Chan A: Supporting Adherence to Medicines for Long-Term Conditions. European Psychologist 2019, 24(1):82-96.
44. (NICE) NIfHaCE: Medicines Adherence: Involving patients in decisions about prescribed medicines and supporting adherence: Full Guideline (CG76). In.; 2009.



### **Case study 7:** Screening in the community for obstructive sleep apnoea by monitoring jaw activity

Screening for obstructive sleep apnoea (OSA) uses the Nomics Brizzy device, which monitors jaw activity through chin and forehead pads worn at home. The data are analysed remotely and can accelerate pathways for continuous positive airway pressure (CPAP) treatment. Physiological insights into jaw activity help in detecting OSA, with improved detection, diagnosis and treatment resulting in improved patient outcomes. These devices help in identifying individuals whose sleep apnoea can be managed through primary care and general well-being advice, such as losing weight, and those who require more specialist interventions. By leveraging these screenings in the community, larger-scale implementations could significantly address undiagnosed OSA, thus reducing associated risks.

*Professor Brendan Cooper, Academy for Healthcare Science (AHCS)*

## Shift 2: Making better use of technology in health and care to build and record a better picture of an individual's health, risk and disease throughout life

**The proposed ambitions in terms of digital health infrastructure, including integrated electronic health records (via the NHS app), are essential to ensure that the opportunities for physiology-led personalised prevention can be realised.**

Physiology research is at the forefront of transforming healthcare, driving innovations that promise to revolutionise personalised prevention. By delving deeper into the mechanisms of the human body, researchers are uncovering new ways to predict, prevent and manage diseases before they fully develop. Physiology research is using technological advancements to significantly progress its potential, such as continuous health monitoring, enhanced risk prediction and the integration of artificial intelligence to foresee and mitigate health issues. These developments are aimed at creating a more proactive and tailored approach to healthcare, ultimately improving patient outcomes and quality of life.

### **Case study 8:** AI for predicting Alzheimer's disease

AI is changing personalised prevention in Alzheimer's disease. AI algorithms analyse physiological biomarkers such as amyloid-beta levels, tau proteins and brain imaging data to predict disease onset. By integrating these biomarker data with genetic and lifestyle information, AI algorithms could potentially identify individuals at higher risk of developing Alzheimer's. This allows for early interventions, such as cognitive training and lifestyle modifications, to delay disease progression and improve quality of life. Despite these advancements, more research is needed to enhance the accuracy of AI models and validate their predictions in larger, more diverse cohorts. Understanding the physiological changes that precede symptoms of Alzheimer's disease will also be crucial for developing more effective preventive strategies.

Scenario: Maria (70) shows early signs of cognitive decline. AI algorithms analyse her physiological data, including brain imaging and genetic markers, to predict her risk of developing Alzheimer's disease. Personalised interventions, such as cognitive training and lifestyle modifications, are implemented based on these insights. Research needed: Further research is needed to refine AI models to take into account gender/sex, ethnicity, etc. for early detection and to understand how different physiological markers interact in the progression of Alzheimer's disease.

### Shift 3: Focusing on preventing sickness and shifting the burden from disease to risk management and patient empowerment

**The shift towards prevention will not be successful without renewed focus on research and interventions to make these ambitions a reality.**

There is active research occurring in the development of tools and techniques for identifying diseases or health conditions at an early stage, often before symptoms appear. Early detection of disease is a critical component of effective screening programmes, allowing for timely intervention and improved health outcomes. This proactive approach is a key component of the shift towards prevention. It not only improves individual health outcomes but also reduces the overall burden on the healthcare system by potentially lowering the need for more intensive treatments later in the patient journey.

**Case study 9:** Risk prediction in NHS Health Check[45]

NHS Health Checks use a combination of physiological biomarkers and lifestyle information to predict the risk of cardiovascular diseases. Biomarkers such as blood pressure, cholesterol levels and BMI are measured and analysed alongside lifestyle factors like smoking and physical activity. This integrative approach allows for personalised prevention strategies, including tailored advice on diet, exercise and medication to manage risk factors and prevent heart disease. However, more research is needed to improve the accuracy of risk prediction models and validate their effectiveness in diverse populations. Understanding the physiological interactions between different risk factors will also enhance the precision of personalised prevention strategies.

*NHS England, 'What is an NHS Health Check?'*

45. NHS Health Check. NHS England. (November 2024). https://www.nhs.uk/conditions/nhs-health-check/



## The need for a Physiology Passport

While the case studies highlight innovative approaches supporting personalised prevention and delivery of the proposed shifts, they also raise important questions about how we consistently collect the data from individuals, throughout their lifetimes, needed to support the delivery of prevention within healthcare systems.

Personalised prevention is a complex and multifaceted challenge that involves tailoring healthcare strategies to the unique characteristics of each individual. Throughout their lifetimes, and as they interact with the health system, individuals will have a number of physiological health tests carried out, and it can be anticipated that technological advancements will increase the potential for collecting different types of data relevant to prevention. Having this information collected, organised and presented in a useful manner can contribute to self and clinical health management and will be vital in ensuring the consistent equitable delivery of personalised prevention to each individual. This principle is at the heart of our call for a dynamic, long-term and integrated personal physiology health profile – the Physiology Passport – to be a core component of an individual's health record.

## How can a Physiology Passport support personalised prevention?

For prevention to become a reality, an understanding of what parameters define good health for each individual is needed so that any changes indicative of disease can be detected earlier and action taken. Research and innovation around physiological data generation are enabling more accurate disease prediction and determining which interventions need to be implemented, and when. The collection and integration of physiological data by the health system, and by individuals, will be critical in making this happen. This information can be collected from individuals who are currently healthy, and those who live with one, or multiple, diseases, with options in the future to collect 'in the wild' to reduce the burden on primary care and hospitals, thus contributing to shifting care to community settings.

The Physiology Passport must have a significant focus on reducing, rather than exacerbating, healthcare disparities and ensure that all populations, including under-represented and marginalised groups, benefit from current and future advances in personalised prevention. Currently, access to health and well-being is disproportionately found among wealthier, more health-literate populations. The Physiology Passport is designed to highlight and address barriers to gaining access to personalised prevention technologies, such as digital platforms and wearables. Its development will need to sit alongside public engagement campaigns to increase awareness and trust in personalised prevention initiatives.

### Developing a Physiology Passport

The Physiology Passport could be the means through which physiology-led healthcare contributes to prevention. It will involve the collection and management of a person's physiological health information and its presentation in their existing electronic health record through the digital health platforms currently being developed by all four UK nations. These are the NHS App in England, the NHS Wales App, Digital Front Door (Scotland), and Digital Health and Care Northern Ireland.[46,47,48,49]

46. NHS England. (April 2023). NHS App. https://www.nhs.uk/nhs-app/
47. https://app.nhs.wales/login
48. Digital Front Door – Digital Healthcare Scotland. (July 2024). Digital Healthcare Scotland. https://www.digihealthcare.scot/our-work/digital-front-door/
49. Digital Health & Care, Northern Ireland. (August 2024). DHCNI. https://dhcni.hscni.net/

As a core component of the data being captured, an individual's physiological biomarkers would be collected over time, providing a longitudinal overview of their physiological health and well-being.

As a first step, the Passport would optimise the use of current and commonly collected parameters such as blood pressure, weight, cholesterol and blood sugar levels with a focus on more consistent collection of these in a variety of clinical settings (e.g. pharmacies). This approach would use commonly available tools already approved for clinical use, rather than relying on new technologies/tests to ensure the quality and standardisation of data.

**Table 1 Rollout measurements and future ambitions for the Physiology Passport**

| Possible initial physiological biomarkers for the Physiology Passport |
|---|
| Blood sugar |
| Cholesterol |
| Height |
| Weight |
| Blood pressure |
| Heart rate |
| Waist measurement |
| **Ambitions for future inclusion within the Physiology Passport** |
| Greater focus on wearable technology |
| Citizen-led data collection |
| Screening programmes for unmet needs |
| Integration of behavioural data |
| Integration of genetic data |
| Detection of truly abnormal heart rhythms |
| Lung health index for risk of respiratory disorders |

Vital research – led by the physiology community – will be needed to determine how more regular and detailed measurement of these physiological markers could be delivered and to determine from whom, when and how often measurements are taken. The goal will be to establish cost-effective, fair, equitable and consistent practices in accessing the measurement of physiological biomarkers, in establishing what is healthy for each individual, and in building a foundation of information that can support a collaborative approach to personalised prevention between people and healthcare providers.

Building the Physiology Passport information into existing efforts to digitise and record health data will not only prevent the duplication of current platforms and initiatives but will also stop the cost of the programme becoming disproportionately expensive. The Passport could be integrated into existing patient-facing digital platforms and present this information as a 'health and well-being' record that complements and supports ongoing healthcare management rather than being a distinct entity in and of itself.

Considerations include healthcare systems engaging with individuals in defining how the data can be used for self-management and empowering them to take an active role in managing their own health. How information might be used for automated monitoring of individuals' health, with the purpose of identifying those who would benefit from an intervention to prevent disease later in life, would also need to be considered to minimise the risks of causing anxiety to the 'worried well' or exacerbating health inequities or those with body dysmorphic disorders or eating disorders.

In the future, information in the Physiology Passport could be captured from a wider range of technologies, including wearables. To build on the proposed first step in establishing the Passport, approaches such as the use of regular glucose monitoring for those at risk of developing type 2 diabetes or home blood pressure monitoring could be considered. However, should wearables be used for data collection, and these data uploaded to the Passport by individuals, consideration would be needed concerning the regulation of these wearables as medical devices and how we ensure that the data can be collected equitably, authenticated and verified Clear quality assurance mechanisms would need to be in place.

### **Case study 10:** Virtual clinics for glaucoma monitoring

Virtual clinics use telemedicine to monitor glaucoma patients remotely. Patients can perform eye tests at home using specialised equipment, and the data are transmitted to their healthcare provider. This approach leverages physiological measurements such as intraocular pressure and visual field tests to manage the disease effectively. Research is needed to enhance the accuracy of home-based tests and to integrate them seamlessly into clinical practice.

Scenario: David (65), who has early-stage glaucoma, uses a virtual clinic for regular eye pressure and optic nerve monitoring. His physiological data are remotely analysed, allowing timely adjustments to his treatment plan without frequent in-person visits. Research needed: Research into the accuracy and reliability of virtual monitoring tools compared to traditional methods, and their impact on long-term patient outcomes.

*Guidance from the Royal College of Ophthalmologists*

### **Case study 11:** Wearable technology in personalised prevention

Wearable technology is revolutionising personalised prevention in healthcare. Devices such as smartwatches and fitness trackers monitor physiological biomarkers including heart rate, sleep patterns and physical activity levels. By continuously collecting these data, wearables provide real-time insights into an individual's health status. Despite these advancements, further research is needed to validate the long-term effectiveness of wearables for health management. Studies should focus on the accuracy of wearable devices in different settings and their impact on health outcomes over time. Additionally, understanding how to best integrate wearable data equitably into clinical practice will be crucial for maximising their potential in personalised prevention.

Scenario: Sarah (35) uses a wearable device to monitor her heart rate, sleep patterns and physical activity. These data helps her and her healthcare provider personalise her fitness and wellness plan, thereby reducing her risk of cardiovascular disease.

## How can physiology research support development of the Physiology Passport to improve personalised prevention?

### Biomarker information

**Physiology provides biomarker information** about a range of body systems, from single cells up to the whole body and a deep understanding of how the body functions in health and disease.

### Integrative expertise and overview

The physiology research community can provide a bridge between research and clinical practice and drive an integrative, multidisciplinary approach to research by responding to interdisciplinary research funding calls that address clinical challenges through multimodal approaches. This ensures that research findings are effectively translated into practical healthcare solutions.

Innovation, in terms of approaches to measuring biomarkers, can be incorporated into different devices and tests including wearable technology. This variety supports a multimodal approach to prevention by providing a holistic view of a person's health. This technology will allow the combination of genetic, physiological and behavioural data to provide a more complete understanding of the individual's 'normal' homeostatic range, which will build a better picture of health and early precursors of a loss of physiological function or disease. Research and development will be vital in understanding how technologies of this type can be used to gather information for inclusion in the Physiology Passport.

### All-encompassing health understanding

The long-term goal for the Physiology Passport will be to integrate physiological data, along with genetic and behavioural data, into existing health system records, providing a more complete understanding of an individual's 'normal' homeostatic range. Physiology researchers are uniquely positioned to explore how we can gather the evidence needed to best implement this goal. Physiology-led personalised prevention will be realised through combining the benefits listed above to facilitate a **multimodal approach** to healthcare, which will be reflected in the information contained within the Passport. By integrating diverse data sources about a range of biomarkers, as well as people's behaviour and experiences, healthcare providers will be able to tailor treatments and preventive measures to individuals. Predictive accuracy can be improved by analysing data from multiple modalities – examples of tools already in use include the QRISK tool[50] for predicting cardiovascular disease risk, as used in the NHS Health Check programme in England.

Combining data sets from multiple sources can be data-intensive (examples include imaging and genetics) so may require AI and machine learning to process and interpret the data. More broadly, the development of AI models supports the analysis of much larger data sets and unlocks greater potential from physiological data sets that otherwise would have taken much longer to explore, or that would not have been possible. For example, AI is showing the potential in terms of complex image analysis to support the diagnosis and management of eye diseases such as age-related macular degeneration.[51] The use of digital twins – virtual replicas of physical entities – further enhances this process. This comprehensive approach allows for more accurate predictions and personalised prevention strategies, ultimately improving patient outcomes.

Their multifaceted expertise makes physiologists integral to the successful implementation of multimodal healthcare, which is becoming increasingly feasible with advances in technology, risk prediction and 'omics, especially in developed healthcare systems. Multimodal healthcare is widely recognised for its potential to improve patient outcomes by integrating various data sources and intervention options.

50. QRISK3. (n.d.). https://qrisk.org/

51. Dow, E. R. et al. Collaborative Community for Ophthalmic Imaging Executive Committee and the Working Group for Artificial Intelligence in Age-Related Macular Degeneration. From data to deployment: the collaborative community on ophthalmic imaging roadmap for artificial intelligence in age-related macular degeneration. Ophthalmology. 2022 May;129(5):e43–e59. doi: 10.1016/j.ophtha.2022.01.002. Epub 2022 Jan 10. PMID: 35016892; PMCID: PMC9859710.



### Case study 12: Digital twin for pulmonary arterial hypertension

Imperial College London's digital twin project for pulmonary arterial hypertension (PAH) uses health data, scans and wearable devices to create virtual replicas of patients' hearts. These digital twins simulate heart function, allowing real-time monitoring of disease progression and treatment response. By accurately reflecting individual heart conditions, they enable personalised treatment plans, thus enhancing patient outcomes. This innovative approach exemplifies the integration of physiology and advanced technology for improved management of complex cardiovascular diseases.

## How could we get there?

*'Our ambition for population health is a society where we all spend more years in good physical and mental health. To achieve this requires a cross-government approach to ensuring we are world leading for health outcomes and reducing inequalities. This is vital to secure the long-term sustainability of the NHS' (British Medical Association).*[52]

Shifting a greater proportion of attention and healthcare resources towards prevention requires bold action and a fundamental shift in how we think about the role of the health system and long-term data management. This will involve:

### Integration of multiple health data sources

*Our Future Health*[53] is an ongoing example of a UK population-wide study that is collecting physiological and genomic data on individuals, linked to medical records. The project aims to recruit up to five million adult volunteers, combining data from these individuals from a range of sources to support research into health and assist in understanding factors that contribute to disease risk. The *Our Future Health* project should be viewed as a case study due to the way in which information in the Physiology Passport is collected and used.

In the project currently, there are options for participants to receive personalised feedback on the information they provide, and there are future plans for linking different data types, including self-reported data and digital data – for example, from wearables. This is one example of how 'real-world' data collection and integration could be done, while also highlighting areas of consideration around population engagement and data sharing. Other projects with a more targeted focus could be considered for this purpose – for example, the use of wearables for detecting Parkinson's disease, mammography results being integrated with other health data for predicting breast cancer risk using CanRisk, the use of handheld single-lead ECG recorders for early detection of atrial fibrillation, or digital technology for managing mental health.

53. British Medical Association. (2019). Prevention before cure – prioritising population health. https://www.bma.org.uk/media/2106/prevention-before-cure-prioritising-population-health-report-bma-march-2019-1.pdf

54. Our Future Health. (December 2024). Our Future Health.https://ourfuturehealth.org.uk/

## **Case study 13:** Stratified screening for breast cancer using CanRisk[55]

Stratified screening – determining how often a person needs screening based on their risk – using integrated risk tools can lead to more effective and personalised prevention strategies, ultimately improving outcomes for individuals at risk of breast cancer. By leveraging a comprehensive risk assessment, healthcare providers can offer more precise and proactive care, addressing the unique needs of each patient and potentially reducing the incidence and impact of breast cancer. Clinical trials like MyPeBS and WISDOM are currently underway to evaluate the effectiveness of risk-adaptive or stratified screening programmes.

The potential use of stratified screening for breast cancer using integrated risk tools, such as the CanRisk tool, represents a significant advancement in personalised prevention. Currently, a very small % of people with BRCA mutations are aware of their status, despite the mutations being relatively common (approximately 1 person in every 450 according to Cancer Research UK). CanRisk uses the BOADICEA model, which combines data on genetic (including polygenic scores), mammography, lifestyle and hormonal factors to provide a comprehensive risk assessment for breast cancer, enabling tailored screening and prevention strategies. While tools like CanRisk are promising, further research is needed to refine risk models, evaluate their utility and validate their effectiveness across diverse populations. Studies should focus on integrating additional biomarkers and improving the accuracy of risk predictions. Understanding the physiological mechanisms underlying the development of breast cancer will also enhance the precision of these tools. Implementing a stratified screening programme for breast cancer, such as using the CanRisk tool, requires comprehensive research to ensure its effectiveness, feasibility and cost-efficiency.

### Population engagement and empowerment

Population engagement and empowerment will be essential for successful adoption and utilisation of the Physiology Passport to improve prevention. This engagement needs to be lifelong and collaborative, with ongoing public voice in terms of feedback around how prevention works at both the personal and population level, based on people's abilities and experiences. This should consider the perceptions that determine motivation to engage with preventative interventions as well as the practicalities influencing ability to do so. People are often reluctant to adhere to evidence-based prescriptions because they have doubts about the necessity of an intervention or concerns about potential adverse consequences.[56] Similar beliefs may act as a barrier to engagement with personalised medicines.[57] Communicating interventions in a way that takes account of personal doubts and concerns can support informed choices and optimal engagement.[58]

55. Welcome to CanRisk. (n.d.). https://www.canrisk.org/
56. Horne R, Chapman SC, Parham R, Freemantle N, Forbes A, Cooper V. Understanding patients' adherence-related beliefs about medicines prescribed for long-term conditions: a meta-analytic review of the Necessity-Concerns Framework. PloS one. 2013 Dec 2;8(12):e80633.
57. Green, D.W., Horne, R. and Shephard, E.A., 2013. Public perceptions of the risks, benefits and use of natural remedies, pharmaceutical medicines and personalised medicines. Complementary Therapies in Medicine, 21(5), pp.487-491.
58. Horne, R., Chapman, S., Glendinning, E., Date, H.L., Guitart, J. and Cooper, V., 2019. Mind matters: treatment concerns predict the emergence of antiretroviral therapy side effects in people with HIV. AIDS and Behavior, 23, pp.489-498.



Particular attention is needed to support and engage populations who currently face health inequalities, including those who choose not to engage with the health system. A key component will be empowering individuals to feel that their health is their own and that they can manage it, and to change how we think about the role of the health system: it is there to help everyone to remain healthy. In the longer term, this will also involve consideration of how individuals can use technology such as wearables and point-of-care tests to collect data about themselves, and how these efforts link to the ongoing broader background work on tackling other determinants of health inequity, e.g. socio-economic determinants, geography, cultural barriers, diet and exercise.

### Engagement of the healthcare workforce

In parallel, the Physiology Passport presents a different paradigm for how the healthcare system could interact with the population. Consideration will be needed around the roles needed for delivering the Passport and the digital skills and expertise required for managing any technologies and the data they produce.

### Generating rigorous and reliable data

Technology, including novel technologies and wearables, will be important in terms of gathering much of the information required to support future prevention. However, the concept of co-creation between users, the health system and the technology developers will be vital to ensure that these devices and tools, many of which are developed for more general 'wellness' (e.g. Fitbits), are fit for purpose. This is not only important in terms of usability and social acceptability but also in relation to device regulation, ethics, safety, validation and demonstration of clinical utility.

## Prevention – the wider landscape

While this report focuses on the role of physiological research in personalised prevention, it is important to acknowledge that implementing new approaches involves broader considerations that require input from various stakeholders, including the public, patients, clinicians, the healthcare community, the commercial sector, and governmental and non-governmental organisations. Addressing all these issues comprehensively is beyond the scope of this report, but we wish to mention a few.

For personalised prevention approaches and interventions to be successful, it is vital that the multifaceted and complex challenges that are driving the disease burden in the UK, including mental health, are also addressed. The **wider determinants of health** – including diet, physical activity, smoking and alcohol consumption, as well as social determinants of health such as poor housing and poverty leading to health inequalities – are well described, and managing them will require complex and long-term policy decision-making. As The Physiological Society's 2019 report into the ageing population *Growing Older, Better* notes, 'physiological research is already at the heart of public health measures designed to offer population-level advice for healthier lifestyles. More broadly, physiology research can contribute to personalised prevention by providing essential understanding of the disease mechanisms and biomarker-led, integrated approaches to manage disease'. One study from the British Medical Journal's commission on the future of the NHS outlines the role that the NHS can play in improving the social determinants of health, while also acknowledging the vital role of wider government policy – this is not a challenge that health systems can tackle on their own.[59]

59. Hiam, L., Klaber, B., Sowemimo, A., Marmot, M. NHS and the whole of society must act on social determinants of health for a healthier future. BMJ 2024; 385 :e079389 doi:10.1136/bmj-2024-079389

The **healthcare data landscape** is receiving much attention, most recently with the publication of the Sudlow Review on Uniting the UK's Health Data.[60] The review outlines the role of national health data as critical national infrastructure and highlights the importance of linking varied health data sources for the benefit of patients, public health and beyond. Within these recommendations are vital considerations around safe and secure data access, particularly adherence to the internationally accepted 'Five Safes Framework'.[61]

To be useful, life enhancing and cost saving, the Passport data must be valid, accurate and predictive at the level of the individual. Linking various personal data sources relevant to health to create a Physiology Passport will raise significant legal, regulatory, ethical and technical implementation challenges. Those challenges include data protection, as well as ownership of data, privacy and intellectual property; public trust and confidence; data governance and responsibility; and technical barriers in harmonisation and the creation of common data models, among others. Skilful navigation of the complex environment in which health data exist will be essential in protecting against breaches and misuse. While there are already guidelines available from the British Medical Association around the retention of medical records,[62] further work will be required to determine how these guidelines might need to change in order to accommodate the further collection of data from healthy individuals, with appropriate safeguards in place. Engagement with the public and health systems will be an integral part of the development of the principles around long-term data collection, retention and storage by health systems.

Similarly, there is a risk that personalised prevention strategies may exacerbate **health disparities** if access to these advanced technologies is not equitable, and they also raise ethical questions, such as how to handle incidental findings and prevent discrimination, necessitating clear guidelines and policies to ensure all populations benefit fairly.

Finally, evidence is needed to demonstrate the **cost-effectiveness** of any preventive approaches, such as the use of the Physiology Passport. Personalised prevention can be resource-intensive, requiring advanced technology and specialised personnel. This can strain healthcare budgets and resources, especially in public health systems. However, any interventions need to be considered in the context of other measures that impact health but are not under the direct control of the health system – for example, transport, access to green space, air pollution and access to healthy food. These measures have proven to deliver a clear return on investment and are essential in reducing pressures on the health system.

The move towards personalised prevention should complement existing strategies and work alongside the public health system to deliver a holistic, comprehensive approach to healthcare that enhances overall health outcomes.

To achieve this, we would propose developing a series of pilot studies, particularly in areas such as Greater Manchester that have integrated systems[63] designed to cover responsibility for devolved areas, including health.


60. HDR UK. The Sudlow Review. (December 2024). https://www.hdruk.ac.uk/helping-with-health-data/the-sudlow-review/
61. UK Data Service. What is the Five Safes framework? https://ukdataservice.ac.uk/help/secure-lab/what-is-the-five-safes-framework/
62. British Medical Association. Retention of health records. (June 2024). https://www.bma.org.uk/advice-and-support/ethics/confidentiality-and-health-records/retention-of-health-records
63. Research and Planning. (February 2024). GM Care Record. https://gmwearebettertogether.com/research-and-planning-using-the-gm-care-record-and-the-secure-data-environment/

# 5. Recommendations for action, further research and conclusion

The proposed Physiology Passport would be built into personalised health records to collect, track and integrate an individual's physiological data – such as blood pressure, heart rate and other biomarkers – over their lifetime. By combining these data with information from other sources, such as wearables and medical tests, it will be possible to build a detailed picture of a person's health.

## The purpose of the Physiology Passport is to:

- **detect health changes** early by identifying deviations from an individual's normal baseline collected through clinically validated existing systems;
- **empower individuals** to manage their own health through personalised insights and preventive strategies;
- **support healthcare providers** in making informed, tailored decisions for treatment and prevention;
- **enable proactive care** by focusing on preventing illness rather than just treating diseases;
- **reduce healthcare disparities** by improving equity of access to, and collection of, physiological data.

By initially using parameters that are currently and commonly collected by healthcare professionals and integrating such data into existing digital health platforms (e.g. like the NHS app in England), the Physiology Passport's aim is to improve health outcomes, reduce healthcare system pressures and help individuals lead healthier lives by harnessing, rather than duplicating, existing work in this area. As outlined in this report, this builds on the current approach used in health systems across the UK in terms of the frequency, consistency, usability, transparency and comprehensiveness of the data collected.

The Physiology Passport will support the establishment of fair, equitable and consistent practices in accessing the measurement of physiological biomarkers, in establishing what is healthy for each individual, and in building a foundation of information that can support a collaborative approach to personalised prevention between people and healthcare providers.

## How do we drive the development of a Physiology Passport?

The prize of preventing non-communicable disease is a significant one. One review estimated that for every £1 spent on preventive measures, there would be a return on investment of £14.[64] Prevention in all forms needs to be turbocharged if we are to continue to be able to deliver health services through the current financial model of free at the point of care.

Health systems across the UK share similar challenges and all governments are seeking to pivot towards prevention. For example, the upcoming 10-Year Health Plan for England and the 10-Year Population Health Plan in Scotland present once-in-a-generation opportunities to reshape the delivery of healthcare towards disease prevention. A personalised approach, rooted in an individual's physiology, will be essential to the success of this new model.

64. Masters, R. et al. (2017). Return on investment of public health interventions: a systematic review. Journal of Epidemiology & Community Health, 71(8), 827–834. https://doi.org/10.1136/jech-2016-208141

## Recommendations for governments across the UK

The purpose of the Physiology Passport is to support the ambition to shift the healthcare model from reactive disease management to proactive prevention. This will reduce long-term healthcare costs and improve population health outcomes.

Governments across the UK will be central in piloting this integrative physiology-led prevention approach to establish its real-world benefits, areas of greatest priority and likely costs.

To achieve this, UK governments should support the development of the Physiology Passport in the following ways:

### 1. Support the integration of physiological data into health records:

- **Purpose:** To ensure seamless integration of physiological data into health records to support personalised prevention via the Physiology Passport.
- **Actions:** Efforts already underway across the UK's four nations to consolidate health data resources should support seamless integration of physiological, genomic and behavioural data sets that can be deployed in a Physiology Passport. Invest in digital health platforms that present patient data in a way that empowers individuals, facilitates data sharing with trusted healthcare providers and researchers, and supports proactive health management.

### 2. Focus prevention initiatives on improving health equity:

- **Purpose:** To reduce healthcare disparities and ensure that all populations, including under-represented and marginalised groups, benefit from advances in personalised prevention.
- **Actions:** Prioritise funding for initiatives targeting under-represented communities, addressing barriers to gaining access to personalised prevention technologies, such as digital platforms and wearables. Support public engagement campaigns to increase awareness of, and trust in, personalised prevention initiatives.

### 3. Empower and enable individuals:

- **Purpose:** To foster a culture where individuals play a key role in actively managing their health, enhancing health outcomes by bringing care into the community.
- **Actions:** Through the Physiology Passport and other initiatives, encourage individuals to participate in collecting and owning their health information using established health technologies within and outside the health system, and work with healthcare providers to implement prevention strategies based on this information. Collaborate with public advocacy groups to ensure community engagement and equity in these initiatives.

### 4. Adopt digital health innovations:

- **Purpose:** To leverage technology for real-time health monitoring, enabling early intervention and reducing the progression of chronic diseases.
- **Actions:** Utilise validated wearables and AI-driven tools to support real-time health monitoring and targeted interventions. Collaborate with technology developers to ensure devices meet clinical standards and integrate seamlessly into care pathways. Ensure these technologies are accessible to all, thereby reducing disparities in care.

### 5. Future-proof adoption of patient-centric technologies through co-creation:

- **Purpose:** To ensure future healthcare technologies are tailored to patient and healthcare system needs and provide data for integration into the Physiology Passport.
- **Actions:** Ensure that partnerships between technology developers, researchers, patients and the healthcare system are established to design and validate wearables, digital tools and monitoring systems that will provide information for the Physiology Passport. This co-design process should ensure the usability, safety and accessibility of these technologies for all stakeholders while maintaining regulatory and clinical validation standards.



For UK governments to be successful in their aspirations regarding improving health, greater support and emphasis on physiology research and development in the area of personalised prevention will be required. We have identified the recommendations set out below for researchers and research funders.

## Recommendations for researchers:

### 1. Foster interdisciplinary research collaboration:

- **Purpose:** To accelerate innovation by integrating diverse expertise, creating comprehensive approaches to disease prevention and treatment.
- **Actions:** Encourage partnerships between physiology, genomics, data science and technology development disciplines to create multimodal approaches to disease prevention and treatment. Collaborate with healthcare providers and policymakers to align research with the needs of the public and healthcare systems.

### 2. Expand biomarker research:

- **Purpose:** To investigate and discover biomarkers that enhance early detection, monitoring and prevention of a wider range of diseases, providing a scientific foundation and practical framework for the proposed Physiology Passport.
- **Actions:** Contribute to research that gathers evidence on the use of already validated physiological biomarkers (e.g. blood pressure, cholesterol) to predict disease in the wider population. In addition, focus on areas with current gaps, such as neurodegenerative conditions and respiratory disorders, to support biomarker discovery and future integration of additional biomarkers into the Physiology Passport.

### 3. Develop more comprehensive longitudinal data sets:

- **Purpose:** To create robust predictive models and prevention strategies that reflect changes in health over time and support dynamic prevention strategies.
- **Actions:** Initiate longitudinal studies that sustainably collect diverse physiological data and link them to healthcare records to improve the accuracy of disease prediction. Incorporate consideration of the long-term energy and climate impacts of long-term data collection, curation and storage into research plans.

### 4. Embed patient and public involvement and engagement (PPIE) in research:

- **Purpose:** To ensure that research outcomes are co-developed with, and directly relevant to, the public, particularly those from disadvantaged groups, enhancing trust and engagement with innovations such as the Physiology Passport.
- **Actions:** Embed PPIE into the co-creation of research goals, with a focus on emphasising technology accessibility, addressing barriers to its use and considering people's behaviours and preferences in terms of using technology to gather data for the Physiology Passport and support prevention.

## Recommendations for research funders:

### 1. Incentivise multimodal translational research:

- **Purpose:** To advance interdisciplinary and multi-stakeholder approaches that combine physiology, genomics, technology and behavioural science for personalised prevention, with the goal of supporting clinical translation.
- **Actions:** Develop funding calls that explicitly prioritise integrated approaches to prevention, focusing on projects that combine data from multiple modalities and align with healthcare system priorities, including specific funds for scaling successful pilot projects into broader applications.

### 2. Support pilot studies and longitudinal research:

- **Purpose:** To test the feasibility, cost-effectiveness and impact of physiology-led interventions such as the Physiology Passport, and to gather data over time for predictive models.
- **Actions:** Fund pilot studies to evaluate the practical and financial implications of physiological data collection and integration into healthcare systems through the Physiology Passport. Support longitudinal research in building dynamic data sets that can enhance prevention strategies.

### 3. Promote health equity in research:

- **Purpose:** To ensure funding is allocated to address health disparities and include under-represented populations in research.
- **Actions:** Require funded projects to include diverse populations and address barriers to accessing technologies, ensuring outcomes are equitable and representative.



## Appendix: Further examples of personalised prevention

### Case study: Digital mobility outcomes – next-generation tools for measuring, monitoring and managing health

Mobility, or the way we walk, is a key indicator for detecting, diagnosing and monitoring conditions like neurodegenerative disorders. Continuous real-world mobility assessment can drive therapeutic innovation and provide personalised health insights. Digital health technologies (DHTs), such as wearables, utilise advances in data science, including machine learning, to offer transformative approaches for clinical trials and care. However, developing and validating these solutions requires collaboration.

The Mobilise-D consortium, a multidisciplinary team from academia and industry, has created a comprehensive solution for measuring real-world mobility. Their standardised, validated and freely available method is feasible, scalable and applicable to various health conditions, including Parkinson's and multiple sclerosis. The availability of validated algorithms has encouraged commercial adoption, with companies integrating Mobilise-D methods into clinical trials. These advancements represent a significant step towards regulatory acceptance, emphasising mobility as a crucial metric to be measured, monitored and targeted therapeutically.

### Case study: Non-invasive surrogate markers for the assessment of liver fibrosis: development of the Extended Liver Fibrosis (ELF) test

The Extended Liver Fibrosis (ELF) test, developed as a non-invasive surrogate marker for liver fibrosis, measures blood proteins involved in liver scarring. It offers a less invasive alternative to biopsies, addressing sampling issues. Widely adopted globally, the ELF test accurately predicts liver complications and is cost-effective. It has been combined with another blood test – FIB4 – for the screening of advanced liver disease and is used in clinical trials for treating steatotic liver disease. Physiologists' understanding of liver function and fibrosis has been key to developing and implementing such tests.

### Case study: Screening for abnormal breathing

Physiology is fundamental in analysing breathing patterns to detect respiratory and chronic conditions. Employing a PneumaCare device, structured light plethysmography (SLP) is used to film five minutes of quiet breathing in order to identify issues like small airways disease, paradoxical breathing or dysfunctional breathing. This technology helps in screening patients for COPD, neuromuscular disease and post-COVID-19 conditions. This technology could be used as a screening device in primary care to detect who needs further respiratory follow-up with spirometry or other lung function testing. There are now preliminary reference values so that a 'traffic light' system can be used to determine normality/abnormality in different parameters, meaning that further lung function testing can be targeted, thus saving resources.

## The Physiological Society

As the largest network of physiologists in Europe, with academic journals of global reach, The Physiological Society continues a 145-year tradition of being at the forefront of the life sciences. We support the advancement of physiology by promoting collaboration between physiologists around the world, organising world-class conferences and publishing the latest developments in our scientific journals. Research in physiology helps us to understand how the body works in health, what goes wrong in disease, and how the body works in health, what goes wrong in disease, and how the body responds to the challenges of everyday life.

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## PHG Foundation

The PHG Foundation is a non-profit think tank with a special focus on how genomics and other emerging health technologies can provide more effective, personalised healthcare and deliver improvements in health for patients and citizens.