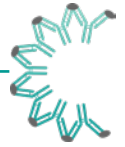




Immunity for Life: making immune health central to UK healthy ageing policy





About this report

This report draws on the work of the CARINA (CAlyst Reducing ImmuNe Ageing) Network, and particularly a policymakers' roundtable hosted by the CARINA Network and the British Society for Immunology in November 2025 and Chaired by Professor Janet Lord. Participants included government representatives, researchers, clinicians, public health specialists, representatives from charities and industry partners. Insights from these discussions have been considered alongside published evidence and relevant UK policy developments.



About CARINA

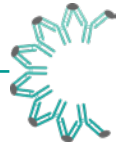
CARINA is a UK network dedicated to advancing understanding of immune ageing and its role in healthy ageing across the life course. Established in 2022 with support from the Medical Research Council and the Biotechnology and Biological Sciences Research Council, the network brings together researchers, clinicians, industry partners and people with lived experience to strengthen collaboration across this field.



About the British Society for Immunology

The British Society for Immunology is the leading UK membership organisation working with scientists and clinicians from academia and industry to forward immunology research and application around the world. Our friendly, accessible community consists of more than 6,000 immunologists, giving us a powerful voice to advocate for immunological science and health for the benefit of society.





"This report sets out why immune ageing should be firmly embedded in the UK's prevention and healthy ageing agenda, and the practical steps needed to make that happen. As our population grows older, government, funders and the NHS need a better understanding of why some people experience an earlier decline in immune health, how this is shaped by inequality, and what can be done to keep people well for longer. Bringing immune health into policies on vaccination, long-term conditions, frailty and population health would help translate a rapidly developing area of science into practical action, reducing avoidable illness and supporting healthier later lives."

Janet Lord

Professor of Immune Cell Biology, University of Birmingham
Co-Investigator and member of the CARINA Network Management Group



"The CARINA Network was established to connect expertise and build a stronger understanding of how the immune system changes across the life course. Developed with the British Society for Immunology, this report brings that knowledge together and identifies where research, collaboration and policy attention could make the greatest difference to prevention, recovery and healthy ageing."

Arne Akbar

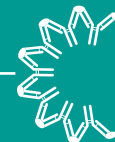
Professor of Immunology, University College London
Principal Investigator, Network Director and Chair of the CARINA Network Management Group



"Immune ageing is a priority for the British Society for Immunology and for immunologists across the UK because it is closely linked to some of the biggest challenges facing an ageing population. This report shows how stronger coordination across research, prevention, vaccination and NHS delivery could turn the UK's scientific strengths into practical improvements in resilience, recovery and healthy life expectancy. The BSI is committed to working with partners to help take this agenda forward."

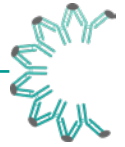
Graham Blair

Chief Executive, British Society for Immunology



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Executive summary

The population in the UK is living longer, but too many people are spending later life in poor health. Infection, frailty and poor recovery already place substantial pressure on individuals, families, the NHS, social care and public finances. These pressures will grow as the population ages unless prevention policy acts earlier.

This report argues that immune ageing is a missing part of the UK's healthy ageing agenda. Changes in immune function across the life course influence susceptibility to infection, vaccine response, inflammation, frailty, recovery and resilience. They help explain why some people remain healthy and independent into later life while others experience recurrent illness, slower recovery and loss of function much earlier.

These outcomes are deeply unequal. Healthy life expectancy in England's most deprived areas is around 19 years lower for men and 20 years lower for women than in the least deprived areas. In some communities, poor health and declining resilience begin in mid-life. Action on immune ageing must therefore reduce inequalities as well as improve outcomes across the population.

Government and public funders have already made significant investments in healthier ageing, including through the £98 million UKRI Healthy Ageing Challenge, which supported innovation to help people remain active, productive, independent and socially connected for longer. This report builds on that agenda by making the case for immune resilience to be recognised as a practical prevention goal across the life course.

The UK has major strengths in immunology, vaccine science, population cohorts, health data, clinical trials and NHS research infrastructure. COVID-19 studies including RECOVERY, Com-COV and OCTAVE showed how coordinated science, data and NHS delivery can change practice at pace. These capabilities should now be applied to immune ageing, prevention and healthy life expectancy.

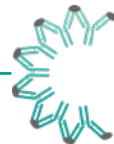
The main barrier is limited coordination and translation. Immune ageing has no clear policy home, there is no widely agreed measure of immune resilience, and too few routes connect discovery science with prevention, NHS delivery and population health.

The report proposes five actions:

- 1.** Give immune ageing a clear policy home.
- 2.** Treat immune resilience as a public health goal.
- 3.** Build a coordinated UK research agenda.
- 4.** Test how immune health can support NHS prevention and population health targets.
- 5.** Ensure immune ageing policy reduces health inequalities.

Together, these actions would connect research, vaccination, prevention, recovery and population health around a shared objective: helping more people remain healthy, resilient and independent for longer.





Immune health across the life course

A life course approach to prevention, protection, recovery and health ageing

1 Early life



- Vaccination and infection prevention
- Healthy development and early resilience
- Action on the wider determinants of health

2 Adulthood



- Physical activity, nutrition and smoking cessation
- Occupational health and long-term condition management
- Building immune resilience

3 Later life



- Adult vaccination and infection prevention
- Earlier identification of vulnerability
- Support to maintain function and independence

4 Recovery after health setback



- Timely recovery and rehabilitation
- Preventing deconditioning and lasting decline
- Helping people regain confidence, mobility and independence

Across every stage



Reducing inequalities



Trusted local delivery

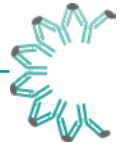


Research and real-world evaluation



Connecting prevention, immunisation and recovery

Immune resilience is shaped across the life course and strengthened through coordinated action before, during and after periods of ill health.



Policy actions at a glance

This report calls on government, funders, the NHS and public health bodies to make immune health central to healthy ageing through five priority actions. The action plan at the end of the report sets out the practical steps required.

ACTION 1: Give immune ageing a clear policy home within healthy ageing and prevention policy

Who should lead: Department of Health and Social Care (DHSC), working with the National Health Service (NHS), UK Research and Innovation (UKRI), the National Institute for Health and Care Research (NIHR) and other government departments.

What needs to happen: Ensure immune ageing is considered in relevant healthy ageing, prevention, vaccination, life sciences and NHS strategies, supported by clear senior leadership and cross-government coordination.

What progress would look like: Immune ageing is reflected consistently in national strategies and NHS population health planning.

ACTION 2: Treat immune resilience as a public health goal across the life course

Who should lead: DHSC and NHS, working with UK Health Security Agency (UKHSA), the Office for Health Improvement and Disparities (OHID), Integrated Care Systems and public health partners.

What needs to happen: Identify how existing prevention programmes, including vaccination, infection prevention, physical activity, smoking cessation, nutrition and long-term condition management, can support immune resilience.

What progress would look like: Immune resilience is recognised within prevention programmes, alongside action to improve adult vaccination uptake and reduce inequalities.

ACTION 3: Build a coordinated UK research agenda for immune ageing and resilience

Who should lead: UKRI and NIHR, working with medical research charities and other major funders.

What needs to happen: Establish a coordinated research programme spanning discovery science, biomarkers, cohorts, data, experimental medicine, prevention and implementation, including work to define and validate measures of immune resilience.

What progress would look like: Funders support a coherent research pathway, with progress towards validated immune resilience biomarkers, better use of cohort and health data, and more representative studies.

ACTION 4: Test how immune health can support NHS prevention and population health

Who should lead: NIHR, working with NHS, Integrated Care Systems, public health teams and research partners.

What needs to happen: Test how evidence on immune ageing can inform vaccination, frailty, recovery, rehabilitation, risk assessment and personalised prevention in NHS and population health settings.

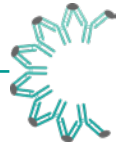
What progress would look like: Practical approaches are evaluated in real-world settings, generating evidence on earlier identification of vulnerability, prevention and recovery.

ACTION 5: Ensure immune ageing policy reduces health inequalities

Who should lead: DHSC, working with the Chief Medical Officer, the NHS, UKHSA, OHID, UKRI, NIHR, Integrated Care Systems, local authorities, funders and community partners.

What needs to happen: Make reducing inequalities a core target of research and implementation, prioritising communities with poorer healthy life expectancy, lower vaccine uptake and a greater burden of infection.

What progress would look like: Diverse populations are included from the outset, priority communities are identified consistently and new interventions are assessed for their impact on inequalities.



1. The problem: longer lives, too many years in poor health

Policy problem:

People are living longer, but too many are spending more years in poor health, with the burden falling most heavily on deprived communities. This is increasing pressure on the NHS, social care, the economy and unpaid carers.

The UK is living longer, but healthy ageing is deeply unequal

Longer life expectancy is one of the UK's greatest public health achievements. Advances in medicine, vaccination, sanitation, nutrition and living standards mean more people are reaching later life than ever before. However, these gains have not been matched by equivalent improvements in healthy life expectancy, independence and resilience.

Between 2022 and 2024, UK life expectancy at birth was 79.1 years for men and 83.0 years for women, while healthy life expectancy was just 60.7 and 60.9 years respectively, the lowest recorded since comparable ONS data began. On average, men can therefore expect to spend around 18 years and women around 22 years in less than good health. These national figures conceal stark inequalities.

In the most deprived areas of England, healthy life expectancy was 49.8 years for men and 48.2 years for women, compared with 69.2 and 68.5 years in the least deprived areas. This gap of around 20 years shows that, for many people, poor health and vulnerability emerge during working age, long before services focused on later life would typically intervene.

Poor health and loss of independence are not inevitable consequences of ageing. The Chief Medical Officer's 2023 report, *Health in an Ageing Society*, emphasised that prevention and effective treatment can delay disease and reduce the time spent in ill health. Around nine in ten people aged 80 to 84 do not have dementia, and around eight in ten people aged over 90 do not live in care homes.

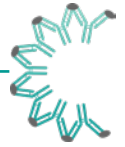
The conditions that shape healthy ageing accumulate across the life course. Housing, employment, income, environmental exposures, infection risk, long-term conditions, vaccination uptake, lifestyle and access to prevention all influence later health. A credible healthy ageing strategy must therefore act earlier and target support where need is greatest.

Understanding the contribution of immune health to infection risk, vaccine responses, resilience and recovery should form part of this approach. This could support government efforts to improve healthy life expectancy, narrow inequalities and reduce pressure on the NHS and social care.

Poor health in later life is already driving system pressure

For too many people, later life is marked by long-term conditions, reduced mobility, recurrent illness, frailty and slower recovery. These experiences can affect whether someone continues working or caring, lives independently, recovers after hospitalisation or needs support from already stretched services. The consequences extend beyond individuals and families to the NHS, social care and wider economy through increased demand, reduced productivity and higher public spending.

These pressures are already visible across the NHS and social care. Infection, frailty and delayed recovery contribute to avoidable hospital use, longer stays and rising care needs, strengthening the case for earlier and more coordinated prevention. Section 3 examines the scale and cost of these pressures in greater detail.



Recovery and resilience are under-recognised policy issues

Recovery is a critical but often overlooked aspect of healthy ageing. Infection, surgery, injury or even a short hospital stay can trigger lasting decline, leading to reduced function, new care needs or loss of independence.

In 2022/23, there were just over one million potentially avoidable emergency admissions involving older people, including 250,000 readmissions among people aged over 75 within 30 days of a previous admission. During winter 2023/24, around 12,000 hospital beds were occupied on a typical day by people who were medically fit for discharge but unable to leave, most of whom were older adults. Hospital-associated deconditioning can also have lasting effects on mobility, muscle strength and confidence.

Healthy ageing policy must therefore protect resilience and support recovery after setbacks, as well as prevent illness.

Why immune ageing matters

The immune system is central to protection against infection and the effectiveness of vaccination. As immune function changes with age, susceptibility to infections such as influenza, pneumonia and COVID-19 can increase, while vaccine responses may weaken and recovery can become slower.

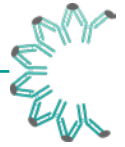
Understanding immune health should therefore form part of efforts to extend healthy life expectancy and reduce inequalities. The next section explains how immune ageing shapes resilience and why it remains under-recognised in current policy.

Policy takeaway:

The UK should recognise immune health as an important contributor to healthy life expectancy and independence. Policy must act across the life course to narrow inequalities and intervene before poor health, frailty and loss of independence become established.



'Immune ageing is a missing part of the UK's healthy ageing agenda.'



2. The missing piece: immune health and resilience

Policy problem:

Current healthy ageing policy does not adequately account for the role of immune health in shaping infection risk, vaccine response, recovery, frailty and long-term resilience.

Why immune health matters for healthy ageing

Healthy ageing policy often focuses on the visible consequences of later-life ill health, including frailty, multimorbidity, falls, hospital admissions, delayed recovery and loss of independence. Less attention is paid to the biological systems that help explain why people of the same age can respond very differently to illness, vaccination, treatment and recovery.

The immune system is central to this variation. It shapes responses to infection and vaccination, regulates inflammation, supports recovery from illness or injury and helps maintain physical function. Understanding immune health can therefore help explain why some people remain resilient into later life while others experience earlier vulnerability, poorer recovery and declining independence.

What is immune ageing?

Immune ageing describes changes in immune function across the life course that affect responses to infection and vaccination, the regulation of inflammation, and recovery from illness or injury. These changes do not occur uniformly. Two people of the same chronological age may have very different levels of immune function and resilience. One may respond well to infection and vaccination and recover quickly, while another experiences recurrent infection, weaker vaccine responses, chronic inflammation, frailty or slower recovery. Chronological age remains an important predictor of health outcomes, but does not fully capture vulnerability, resilience or capacity to recover.

Shingles provides a practical example. Following chickenpox, varicella zoster virus remains dormant in the body. Age-related changes in cellular immunity can reduce the body's ability to keep it under control, making reactivation more common and increasing the risk of complications such as post-herpetic neuralgia (shingles). The shingles vaccination programme demonstrates how understanding immune ageing can inform prevention

'Infectious diseases account for more than one in five hospital bed-days.'

and reduce avoidable illness in later life. Immune ageing is relevant beyond infectious disease and may also influence cancer risk, treatment response and recovery.

Immune health across the life course

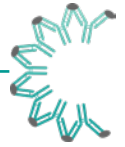
Immune ageing reflects experiences and exposures across life, including infection history, vaccination, deprivation, environmental exposures and long-term conditions. These influences are unequally distributed, contributing to earlier biological ageing and poorer outcomes in deprived communities. Immune health should therefore be considered throughout the life course, not only in older age.

Understanding immune resilience

Explainer: two important concepts in immune ageing

Immunosenescence describes age-related changes in immune function that can reduce the body's ability to respond effectively to new infections, vaccines and threats such as cancer. It is also associated with slower recovery following illness.

Inflammageing refers to persistent, low-grade inflammation associated with ageing. While inflammation plays an essential role in defence and tissue repair, chronic or poorly regulated inflammation can contribute to tissue damage and disease. It has been linked to cardiovascular disease, metabolic disorders, neurodegenerative disease, cancer, frailty and loss of physical function.



There is no single agreed definition of a healthy immune system in later life. Researchers increasingly use the concept of immune resilience: the ability of the immune system to respond effectively to challenge, recover following illness and maintain balance over time.

For policymakers, this links biological processes to outcomes that matter for people and services, including whether someone:

- avoids severe infection
- responds effectively to vaccination
- recovers well after hospitalisation
- maintains physical function
- avoids a step-change into dependency

Some changes in immune function are a normal part of ageing. Certain responses become less effective, while others become overactive or poorly regulated. The balance between these processes contributes to differences in vulnerability, recovery and long-term health.

Translating immune resilience into prevention and care will depend partly on developing practical and reliable ways to measure it.

Why immune health is missing from

Explainer: measuring immune ageing

Researchers are beginning to develop ways of measuring biological aspects of immune ageing. A US-led study used blood immune data from 1,001 people to develop iAge, an inflammatory ageing clock based on patterns of systemic inflammation. The measure was associated with multimorbidity, immunosenescence, frailty and cardiovascular ageing, demonstrating that aspects of immune ageing can be measured and related to meaningful health outcomes.

However, iAge relies on detailed immune profiling and computational analysis and is not currently practical for routine use in clinical or community settings. A key UK research priority is therefore to develop simpler, affordable and validated measures of immune ageing or resilience that can be applied across diverse populations and linked to outcomes that matter for prevention and care.



policy and what this means for prevention

Despite its relevance, immune ageing remains largely absent from healthy ageing, prevention and vaccination policy. Healthy ageing, vaccination, infection prevention, frailty and recovery are often addressed separately even though immune health connects them. Better integration within existing policy frameworks would strengthen prevention and support a more coherent approach across government, funders, researchers and the NHS.

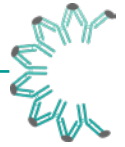
Recognising immune health within prevention would place greater emphasis on maintaining resilience before people become clinically vulnerable, frail or dependent on care. It could strengthen adult vaccination, infection prevention and recovery support, while improving the identification of people at risk of severe infection, weaker vaccine responses, prolonged recovery or loss of function.

Validated measures of immune health could eventually support more targeted vaccination, rehabilitation, long-term condition management and population health approaches. No measure of immune resilience is yet ready for routine clinical use, but this should not prevent emerging evidence from informing research priorities, prevention and service design.

'Immune ageing has no clear policy home.'

Policy takeaway:

Recognising immune ageing as a cross-cutting component of healthy ageing policy would help align prevention, vaccination, frailty and recovery around the shared goal of supporting resilience across the life course.



3. Why now: the rising cost of infection, frailty and delayed recovery

Policy problem:

Infection, frailty and delayed recovery already impose substantial costs, yet policy remains focused largely on managing decline after it occurs. A predominantly disease-specific approach can also overlook common drivers, including immune ageing, that may contribute to vulnerability across several conditions.

Why earlier prevention matters

Infection, frailty and delayed recovery already place substantial pressure on the NHS, social care and public finances. These pressures will grow as the population ages. Changes in immune function can increase vulnerability to severe infection, weaken vaccine responses, contribute to chronic inflammation and make recovery after illness, injury or surgery more difficult.

Healthy ageing policy must therefore consider how resilience can be maintained earlier in life, before vulnerability leads to illness, hospitalisation or long-term dependence on care.

Infection creates immediate and longer-term costs

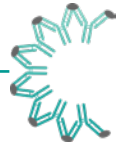
Infectious disease is a major challenge for an ageing population. UKHSA analysis found that infectious diseases accounted for more than one in five hospital bed-days in England in 2023/24, at an estimated annual cost to the NHS of almost £6 billion. Inequalities in infectious disease emergency admissions are estimated to generate up to £1.5 billion in avoidable NHS costs.

These pressures are not shared equally. During winter 2022/23, emergency hospital admission rates for influenza were 2.6 times higher in the most deprived communities than in the least deprived, while COVID-19 admission rates were 2.1 times higher. Vaccination, infection prevention and action to support immune resilience should therefore form part of efforts to reduce health inequalities and improve NHS sustainability.

The consequences of infection can extend well beyond the initial illness. For older adults, people with long-term conditions and clinically vulnerable groups, severe infection can lead to prolonged recovery, deconditioning, worsening frailty and greater need for health and social care support.

COVID-19 demonstrated these clinical and economic effects at scale. Hospital admission rates were highest among people aged 85 and over, while ICU and HDU admission rates were highest among those aged 75 to 84. UK hospital and intensive care costs for COVID-19 have been estimated at around £1 billion. A population-based study of hospitalisations in England also found that median healthcare costs per admission were substantially higher among older adults than younger people.





COVID-19 also provides evidence of a relationship between immune ageing and disease severity. Studies have associated stronger features of immunosenescence, including chronic inflammation, senescent or exhausted T cells and reduced B-cell diversity, with severe disease and hospitalisation. UK research has also identified accelerated immune ageing among survivors of severe COVID-19, although it remains unclear how far this preceded infection or resulted from severe illness.

Together, this evidence suggests that the relationship may be bidirectional: immune ageing may increase vulnerability to severe infection, while severe illness may further accelerate immune decline. This can contribute to higher treatment costs, prolonged recovery and loss of independence.

Frailty and delayed recovery are high-cost pressures

Frailty adds further pressure across health and care services. Around 47% of hospital inpatients aged over 65 are affected by frailty, while the associated costs across UK healthcare systems have been estimated at £5.8 billion per year. NHS England estimates that hip fractures alone cost NHS and social care services around £6 million per day, or £2.3 billion per year.

Research has shown associations between immune ageing and frailty, with inflammageing and immunosenescence both greater in those with frailty. Hip fractures are not a direct measure of immune ageing, but they illustrate the wider costs of declining resilience. Infection, inflammation and delayed recovery can worsen deconditioning, accelerate frailty and increase the need for rehabilitation, social care and unpaid support.

Earlier intervention can reduce avoidable demand

Evidence from prevention and frailty programmes suggests that earlier intervention can reduce pressure on acute services. A 2025 UCL trial of a personalised home-based intervention for people aged over 65 with mild frailty reduced unplanned hospital admissions by 35% and saved the NHS an average of £586 per person over one year.

This demonstrates the value of acting before vulnerability becomes acute service pressure. Similar principles should guide work on immune ageing: identify risk earlier, test interventions in real-world settings and focus on outcomes that matter to people and services, including infection, recovery, function and independence.

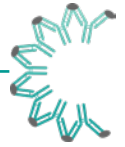
Use economic data to target prevention and measure impact

Better use of economic and health data could help identify where earlier prevention would deliver the greatest benefit. DHSC, working with UKHSA, OHID, funders and health economists, should use NHS and public health datasets, including NHS England's National Cost Collection, to assess the costs associated with infection, frailty, delayed recovery and immune-related vulnerability across different populations.

This should include modelling the potential impact of improved vaccine protection, earlier identification of vulnerability, stronger recovery support and interventions that maintain immune resilience. The findings could guide investment and help evaluate benefits for people, services and public finances.

Policy takeaway:

Infection, frailty and delayed recovery already create substantial costs and avoidable demand. Earlier action to prevent severe illness, protect resilience and support recovery could reduce pressure on the NHS and social care while helping more people maintain their independence.



4. The opportunity: new science, data and NHS capability

Policy problem:

The UK has exceptional scientific, data and NHS capabilities, but they are fragmented and are not yet being systematically applied to improve immune health and healthy ageing.

The UK already has the capability to act

The UK has the scientific, data and NHS capabilities to make immune ageing a practical part of prevention and healthy ageing policy. Strengths in immunology, population research, vaccine science, health data and clinical research provide a strong foundation for identifying vulnerability earlier and testing interventions that improve vaccine protection, prevent illness and support recovery.

However, these assets are spread across multiple research institutions, funders, NHS organisations and data platforms. A more strategic national approach could align priorities, improve health outcomes, strengthen NHS resilience and support life sciences innovation.

Scientific advances are creating new opportunities

Advances in immunology, immune profiling, multi-omics and data science are improving understanding of why some people remain resilient as they age while others become more vulnerable to infection, poor recovery and frailty.

A key priority is to develop reliable measures of immune health. As the iAge example in section 2 demonstrates, aspects of immune ageing can already be measured experimentally. However, simpler, affordable and validated measures are needed for use in clinical and population health settings.

Better biomarkers could help identify vulnerability, guide vaccination and prevention, support clinical trials and evaluate interventions. Progress is also making it increasingly possible to link biological changes with outcomes such as infection, hospitalisation, recovery, physical function and independence.

Case study: using UK population cohorts to unlock immune resilience

The UK's population cohorts provide a major national asset for understanding why some people maintain immune resilience as they age while others become more vulnerable to infection, poor recovery, frailty and loss of independence. Linking biological, genetic, behavioural and health data with NHS records can help identify indicators of immune resilience and test whether they predict outcomes that matter to individuals and services.

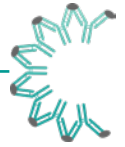
UK Biobank combines genomic, biological and linked health data from 500,000 participants, allowing researchers to explore potential measures of immune resilience and their relationship with infection, hospital admission and long-term recovery.

Our Future Health is building a cohort of up to five million UK adults, providing a platform to validate emerging biomarkers and risk models at population scale and across more diverse groups. TwinsUK provides longitudinal biological and multi-omic data that can help distinguish genetic influences from environmental and lifestyle factors.

These resources could support a national pathway for:

- discovering potential biomarkers of immune resilience
- validating them across large and diverse populations
- tracking changes in immune health over time
- determining whether they predict infection risk, vaccine response, frailty, recovery and independence

The challenge is to translate these research assets into practical benefit. This will require sustained investment, secure data linkage, representative participation and closer alignment between research priorities, NHS needs and public health objectives. Measures of immune resilience must be sufficiently robust, clinically useful and equitable to inform prevention, vaccination and healthy ageing strategies.



The NHS can support real-world evaluation

The NHS gives the UK a major advantage in translating immune ageing research into practice. Universal healthcare, national vaccination programmes, linked health data and embedded research infrastructure provide a platform for evaluating interventions across large and diverse populations.

Promising approaches will need to demonstrate benefits in routine care, including fewer infections and hospital admissions, improved vaccine responses, faster recovery and longer independence.

Early research suggests that aspects of immune function in later life may be modifiable. In a phase 2a trial involving 264 older adults, low-dose mTOR inhibition was associated with improved influenza vaccine responses, increased antiviral gene expression and fewer reported infections. Although this was an early-stage study, it supports further investigation of interventions targeting biological pathways associated with immune ageing.

The immediate priority is to test promising approaches through existing vaccination, prevention, frailty, rehabilitation and recovery pathways. Evaluation should take place across primary care, community services, Integrated Care Systems and public health settings, with a focus on outcomes that matter to people and services.

A strategic life sciences opportunity for the UK

Immune ageing sits at the intersection of healthy longevity, precision prevention, vaccines and diagnostics. It is therefore an area where biological research could contribute to both population health and economic value. The UK has the scientific expertise, population resources, clinical trials capability and NHS infrastructure to lead in this field. Better coordination could attract investment and accelerate the development, evaluation and adoption of new biomarkers, diagnostics, vaccines and interventions.

Progress should remain focused on NHS and public health priorities. New tools and interventions must be practical, affordable and validated across diverse populations. A coordinated programme could support healthy ageing, NHS productivity and life sciences growth.

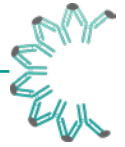
Turning capability into practical benefit

Realising this opportunity will require better coordination between research, data infrastructure, NHS evaluation and implementation. The goal is to develop practical measures of immune resilience, test promising interventions and ensure innovation works across diverse populations.

Stronger coordination could support earlier identification of vulnerability, more targeted vaccination and prevention, improved recovery after illness and longer healthy independence. It could also strengthen NHS resilience and establish the UK as a leader in immune ageing research and implementation.

Policy takeaway:

The UK has the scientific, data and NHS capabilities needed to advance immune ageing. The priority is to connect these assets more effectively, develop practical measures of immune resilience and test promising approaches in real-world settings. This would help translate scientific advances into improvements in vaccination, prevention, recovery and healthy ageing.



5. The barrier: fragmentation between research, prevention and delivery

Policy problem:

Limited policy awareness and fragmented responsibility across research, prevention and healthcare are limiting the translation of evidence on immune ageing into practical action.

Fragmentation is limiting translation into practice

The UK has strong scientific, data, NHS and life sciences capabilities, but they are not yet aligned around a shared approach to immune ageing. Responsibility, funding and delivery are spread across multiple organisations and policy areas, making it harder to move evidence from discovery into prevention, service design and population health. Addressing this will require clearer ownership and stronger coordination across research, funding and implementation.

Policy awareness has not kept pace with the science

Immune ageing is not yet consistently recognised in policy as a factor shaping infection risk, vaccine response, inflammation, frailty, recovery and multimorbidity. These issues are often addressed through separate disease or service areas, limiting opportunities to apply emerging evidence across prevention, vaccination, population health and NHS planning.

Greater awareness is therefore an important first step. Policymakers do not need detailed knowledge of immunology, but they do need to understand how immune health influences resilience, recovery and healthy ageing. Researchers, funders and professional organisations also have a role in communicating the science through outcomes and policy priorities that are meaningful to government and the NHS.

Immune ageing has no clear policy home

Immune ageing is relevant to prevention, healthy life expectancy, NHS sustainability, vaccination, life sciences and reducing health inequalities. Yet it does not sit clearly within any single policy area, leaving responsibility diffuse and accountability unclear.

The levers that influence immune resilience, including vaccination, infection prevention, frailty, rehabilitation, research funding and data infrastructure, are similarly dispersed and rarely coordinated around a shared objective. Clearer leadership and a mechanism for cross-system coordination would help align activity across research, prevention and NHS delivery, without requiring a separate immune ageing strategy.

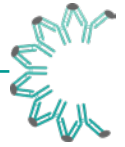
Funding structures do not yet reflect the science

Immune ageing spans immunology, ageing biology, infectious disease, public health, data science, behavioural science and experimental medicine. While this creates opportunities for collaboration, it can be difficult to support within funding systems organised around individual disciplines, diseases or stages of research.

Progress depends on connections across the research pathway, from discovery science and cohort infrastructure through to experimental medicine, implementation research and real-world evaluation. Gaps at any stage can prevent promising findings from reaching practical application. UKRI, NIHR, medical research charities and other funders should therefore support a more coherent pathway across discovery, data, population health and translation, helping research progress towards validated measures, testable interventions and evidence that can inform prevention, vaccination and care.

Measurement and biomarker gaps limit translation

There is no widely accepted definition of immune age or standard approach to measuring immune resilience, vulnerability to infection, vaccine response or recovery. Without robust and comparable measures, it is difficult to identify risk, evaluate interventions or compare findings across studies.



Existing approaches show that aspects of immune ageing can be measured. As discussed in section 2, iAge uses patterns of systemic inflammation, while IMM-AGE uses patterns in immune-cell populations to assess immune ageing. However, neither is currently practical for routine clinical or community use.

Progress is unlikely to depend on a single biomarker. A useful measure may combine biological, functional and clinical indicators to reflect the complexity of immune health. It must also be:

- linked to outcomes that matter to people and services
- practical and affordable to use
- validated across diverse populations
- capable of supporting prevention or clinical decisions
- acceptable to the people and communities in whom it is used

Developing and validating practical measures of immune resilience should therefore be a shared research and translational priority.

Fragmentation risks widening inequalities

The benefits of immune ageing research will not be realised equally unless equity is built into the field from the outset. Biomarkers, diagnostics, vaccination approaches and other interventions may widen inequalities if they are developed mainly in populations that are already well served.

Research must include communities experiencing poorer health, lower vaccine uptake and earlier biological ageing. Biomarkers and risk models should be tested across demographic and socioeconomic groups to ensure they are accurate, clinically meaningful and do not reproduce existing biases.

Acceptability must also be considered. Communities may have different views about blood tests, genetic information and other forms of biological measurement. Research and implementation should therefore be designed with communities and trusted local partners, with attention to accessibility, affordability and trust throughout the pathway from biomarker development to NHS and public health delivery.

Research assets are not yet fully connected to delivery

The UK's cohorts, biobanks, linked health data and clinical research infrastructure are not consistently aligned with NHS and population health priorities. Separate institutions, governance arrangements and research objectives can make it difficult to determine which findings are ready to inform prevention, service design or clinical evaluation.

Research infrastructure should be aligned around practical questions, including which measures predict weaker vaccine responses or prolonged recovery, which interventions maintain immune resilience and which populations would benefit most from earlier support.

Stronger coordination between UKRI, NIHR, the NHS and public health bodies would help existing research assets generate evidence that can inform vaccination, prevention and healthy ageing.

Partnerships remain difficult to establish and sustain

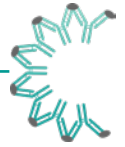
Progress will require sustained collaboration across academia, the NHS, public health, industry, charities and communities. Each brings different capabilities, from discovery and clinical evaluation to product development, public engagement and implementation.

Our Future Health provides a useful model of large-scale collaboration across public, charitable and private partners, supported by shared infrastructure and public participation. Although it is not focused on immune ageing, it demonstrates how research can be organised around common resources and cross-sector governance.

Partnerships of this kind remain difficult to establish. Misaligned funding cycles, incentives, governance requirements and organisational priorities can delay collaboration and weaken routes into practice. Funders and delivery partners should support longer-term models with shared objectives, clear responsibilities and agreed pathways from discovery through validation, evaluation and implementation.

Policy takeaway:

Limited policy awareness and fragmentation across ownership, funding, measurement and delivery are major barriers to progress. Clearer leadership and more coordinated routes from discovery to implementation would help turn the UK's scientific strengths into better prevention, recovery and healthy ageing.



6. What good looks like: immune health across the life course

Policy problem:

Prevention, vaccination, recovery and healthy ageing are often addressed separately, despite sharing the goal of maintaining resilience and independence throughout life.

A vision for healthier ageing

Success would mean that immune health is routinely considered within prevention, vaccination, frailty, recovery and population health. Existing policies and services would be better aligned around a shared objective: helping more people avoid severe illness, recover well after setbacks and maintain their independence for longer. This would not require a standalone immune ageing programme. It would strengthen existing approaches by connecting prevention, protection and recovery across the life course and creating clearer routes from evidence to practical action.

People feel the benefit in everyday life
Success should be measured through outcomes that matter to people: avoiding severe illness, recovering well after infection or hospitalisation, maintaining independence and remaining connected to work, family and community. Better understanding of immune ageing could help reduce the risk that temporary health setbacks lead to lasting decline.

“For most people, healthy ageing means staying well enough to keep doing everyday things. If understanding immune ageing can help people avoid infections, recover better and stay independent for longer, then it matters to all of us.”

Debs Smith, CARINA Patient and Public Involvement Representative

Immune resilience is supported before later life

A life-course approach recognises that immune health is shaped long before older age and can be supported at different stages of life. Vaccination, infection prevention, long-term condition management, physical activity, smoking cessation, nutrition, occupational health and action on the wider determinants of health all contribute to healthier ageing.

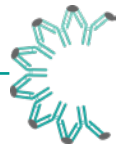
These approaches would be viewed as connected parts of prevention, with action taken before frailty, repeated illness or loss of independence become established. Support would also continue after illness or hospitalisation, when timely recovery and rehabilitation can help prevent lasting decline.

Prevention, vaccination and recovery are connected

A more coordinated approach would align prevention, vaccination and recovery around the needs of people and populations.

Vaccination policy would take account of differences in immune response associated with age, clinical risk and social circumstances. Infection prevention would be recognised as an important part of healthy ageing, particularly for people at greater risk of severe illness or prolonged recovery. Recovery and rehabilitation pathways would identify people who need additional support earlier, reducing the risk that illness, injury or hospitalisation leads to long-term loss of function.

The UK's respiratory syncytial virus vaccination programme provides a practical example of how these elements can be brought together.



Case study: RSV vaccination and immune resilience across the life course

The introduction of the UK's respiratory syncytial virus (RSV) vaccination programme in September 2024 demonstrates how immunology, surveillance, vaccination policy and real-world evaluation can be aligned around prevention.

Although often viewed as a childhood infection, RSV also places a substantial burden on older adults, particularly those affected by age-related changes in immune function, frailty, chronic disease or immunosuppression.

The programme targets two groups at highest risk of severe disease. Maternal vaccination is offered from 28 weeks of pregnancy, protecting newborns through antibodies transferred before birth. Vaccination is also offered to adults turning 75, alongside a catch-up programme for those aged 75 to 79.

Early real-world evidence indicates substantial benefit. UKHSA reported that vaccination was:

- 82% effective in preventing hospitalisation among older adults; and
- 72% effective in preventing hospitalisation among newborns when maternal vaccination was given at least 14 days before birth.

Interim surveillance also indicated around 30% fewer RSV hospital admissions among eligible adults aged 75 to 79 in England during winter 2024/25.

The programme provides a practical model for immune ageing policy: identifying preventable risks, delivering targeted interventions through existing services, monitoring outcomes and adapting approaches as evidence develops.

Immune health is embedded in NHS population health

Within the NHS and public health system, immune health would form part of routine prevention and population health planning. In many cases, this would involve strengthening existing vaccination programmes, frailty pathways, rehabilitation services, long-term condition reviews and community services rather than creating new pathways.

As practical measures of immune resilience are developed and validated, they could support earlier identification of vulnerability and more targeted approaches to vaccination, prevention and recovery. These approaches would need to demonstrate meaningful benefits in real-world settings before wider adoption.

Action reduces inequalities

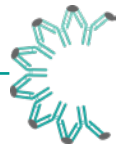
A successful approach must reduce, rather than reinforce, existing health inequalities. Policy and implementation should prioritise communities experiencing poorer health, lower vaccine uptake, greater exposure to infection and earlier loss of resilience.

Approaches should be designed with trusted local partners, including primary care, pharmacies, local authorities, voluntary organisations and community leaders, so that they reflect local needs and address barriers related to access, affordability and trust.

New biomarkers, diagnostics, vaccines and interventions should be assessed for their effects on inequalities as well as overall outcomes. Success would mean that advances in immune ageing improve prevention, recovery and healthy ageing for people and communities at greatest risk of poor health.

Policy takeaway:

A successful approach to immune ageing would connect prevention, vaccination, recovery and population health around the shared goal of maintaining resilience across the life course. It must be delivered through existing systems, evaluated in real-world settings and designed to reduce health inequalities.



7. Lessons for immune ageing: coordinated science, data and NHS delivery

Policy problem:

The UK has demonstrated, through our COVID-19 response, that coordinated research, data and NHS delivery can improve outcomes rapidly, but these capabilities have not yet been systematically applied to immune ageing and healthy ageing.

Applying lessons from the COVID-19 response

The COVID-19 response demonstrated that research, data, public health and NHS delivery can be aligned around clear national priorities. Scientific evidence was generated rapidly, evaluated in real-world settings, and translated into policy and clinical practice at scale.

Immune ageing is a different type of challenge. It is a long-term prevention agenda rather than a public health emergency, and research will often require longer follow-up and more complex outcomes. However, many of the capabilities needed to advance it already exist.

The central lesson is that progress is more likely when research, data, policy and delivery are connected from the outset, supported by clear questions, sustained infrastructure and practical routes into implementation.



Case study: RECOVERY and the infrastructure for rapid evaluation

The RECOVERY trial showed how national clinical research infrastructure can generate evidence quickly and influence practice at scale. Its design allowed multiple potential COVID-19 treatments to be evaluated efficiently within the NHS, including dexamethasone, which became part of standard care for patients with severe COVID-19.

Future interventions designed to support immune resilience, improve vaccine responses, reduce prolonged recovery or prevent loss of function will also require evaluation in real-world settings.

Studies will need to reflect the diversity of older adults, people living with long-term conditions and communities experiencing poorer health.

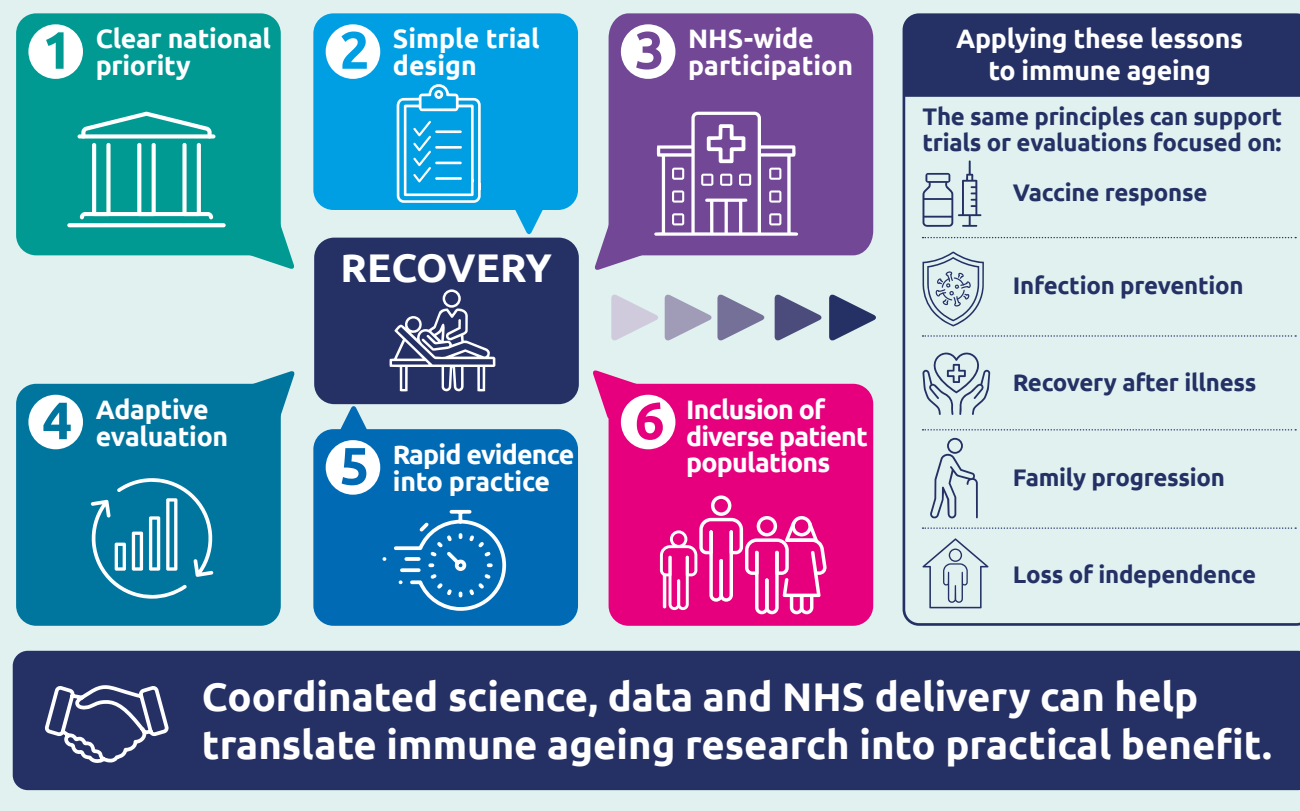
RECOVERY demonstrates the value of clear research questions, proportionate study design, national coordination, NHS-wide participation, diverse recruitment and rapid routes from evidence to implementation. These principles could help immune ageing research progress from biological insight to interventions that improve prevention, recovery and healthy ageing.

The model will need to be adapted for longer follow-up and outcomes such as infection, vaccine response, physical function, quality of life and independence.



What made RECOVERY work?

Lessons for immune ageing research and evaluation



COVID-19 research lessons for immune ageing

The wider research response provides further lessons for developing a coordinated immune ageing agenda.

COVID-19 lesson	Relevance to immune ageing
RECOVERY showed that the NHS can evaluate interventions rapidly at national scale.	Potential interventions to support immune resilience will require real-world evaluation across diverse populations.
Com-COV generated evidence to support flexible vaccination schedules.	Vaccination approaches for older adults and clinically vulnerable groups may need to reflect differences in immune response.
The UK Coronavirus Immunology Consortium (UK-CIC) coordinated immune profiling and immunology research across the UK.	Coordinated immune phenotyping could support the development and validation of biomarkers of immune ageing and resilience.
OCTAVE improved understanding of vaccine responses in immunocompromised groups.	Research and policy should account for people with weaker or more variable immune responses.
Population cohorts and linked data helped track infection risk, vaccine response and longer-term outcomes.	Cohorts and NHS data can identify patterns of immune resilience, vulnerability and recovery across the life course.

These examples demonstrate the value of bringing discovery science, immune profiling, clinical research, population data and NHS delivery together around shared questions.



Sustaining capability between crises

Research infrastructure, secure access to data, NHS participation and national coordination need to be sustained beyond emergencies. Building these capabilities takes time, and they are most effective when relationships, systems and governance arrangements are already in place.

For immune ageing, sustained infrastructure could support research to:

- understand the mechanisms driving immune ageing and resilience
- identify interventions that may prevent, slow or modify harmful changes in immune function
- develop practical measures and biomarkers
- evaluate effects on vaccination, infection, frailty and recovery
- test promising approaches through NHS and public health pathways
- assess whether benefits are equitable across populations

This would provide a clearer route from scientific discovery to prevention and care.

From evidence to prevention

A coordinated pathway would connect discovery science, measurement, real-world evaluation and implementation, with a clear focus on public benefit. This would support the development of interventions that reduce avoidable infection, improve vaccine protection, strengthen recovery and extend healthy independence.

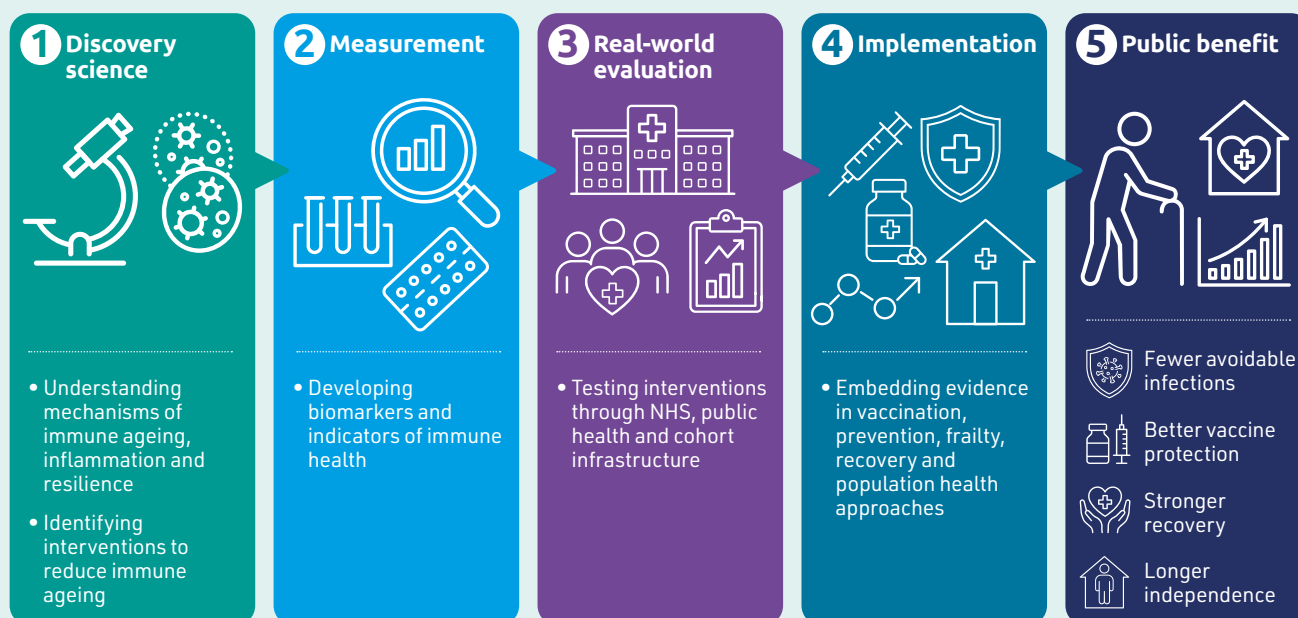
The UK already has many of the components required. The priority is to connect them around a sustained national agenda with clear research questions, representative participation and routes into policy and practice.

Policy takeaway:

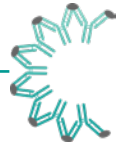
The COVID-19 response showed that coordinated science, data and NHS delivery can change practice at scale. Applying these principles to immune ageing would create clearer routes from discovery and measurement to real-world evaluation, implementation and public benefit.

From evidence to prevention

Turning immune ageing science into practical benefit



The UK already has proof that coordinated science and delivery can change practice. The next step is to apply that capability to immune ageing and healthy ageing.



Action plan for government, funders, the NHS and partners

This action plan sets out how immune ageing can be embedded within prevention and healthy ageing policy. It translates the report's evidence into practical steps for government, funders, the NHS, public health bodies, industry, charities and other partners.

The goal is to make immune resilience a clear policy priority, strengthening prevention and vaccine protection, supporting recovery, reducing avoidable health and care demand and helping more people remain independent for longer.

ACTION 1: Give immune ageing a clear policy home within healthy ageing and prevention policy

Government should recognise immune ageing as a core component of prevention and healthy ageing. DHSC should lead work with the NHS, UKHSA, OHID, UKRI, NIHR and other departments to ensure immune ageing is reflected in relevant strategies, delivery plans and funding priorities.

- Embed immune ageing within policy on prevention, vaccination, infectious disease preparedness, frailty, rehabilitation, life sciences and health inequalities.
- Coordinate these areas around the shared goal of supporting immune resilience across the life course.
- Identify clear senior leadership or a cross-government mechanism to connect research, prevention and delivery.

Immediate priority: Establish clear ownership and embed immune resilience within the policies that shape prevention, recovery and later-life health.

Progress would mean: Immune ageing is explicitly reflected in relevant national strategies and cross-government and NHS planning, and routinely considered in decisions on prevention, vaccination, frailty, rehabilitation and healthy ageing.

ACTION 2: Treat immune resilience as a public health prevention goal across the life course

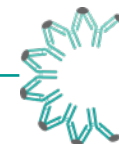
DHSC and the NHS, working with UKHSA, OHID, local authorities, Integrated Care Systems and public health partners, should treat immune resilience as a prevention goal across the life course, rather than only as a concern in later life or during illness.

- Identify how vaccination, infection prevention, physical activity, smoking cessation, nutrition, occupational health, long-term condition management and action on the wider determinants of health can support immune resilience.
- Reflect immune resilience within national and local prevention and population health planning.
- Improve adult vaccination uptake, support people at greater risk of infection or prolonged recovery, and recognise recovery, function and independence as prevention outcomes.

Immediate priority: Make immune resilience a visible goal within public health, prevention and local population health planning.

Progress would mean: Prevention programmes recognise immune resilience and recovery across the life course, supported by improved adult vaccination uptake, reduced inequalities and clearer public communication about immune health.





ACTION 3: Build a coordinated UK research agenda for immune ageing and resilience

UKRI and NIHR, working with medical research charities and other major funders, should establish a coordinated UK research agenda spanning discovery science, population data, experimental medicine and implementation.

- Agree priority questions on the mechanisms of immune ageing, the measurement of immune resilience, variation in vaccine response and recovery, and interventions that may prevent, slow or modify harmful immune change.
- Develop practical biomarkers and measures that are robust, affordable, validated across diverse populations and linked to outcomes that matter for policy and care.
- Make better use of UK cohorts, biobanks, linked health data, trusted research environments and NHS research infrastructure, with clear routes from discovery to real-world evaluation.

Immediate priority: Align funders and research infrastructure around practical questions that can move immune ageing evidence into prevention, vaccination and care.

Progress would mean: A coherent cross-funder research programme, agreed national priorities and stronger pathways from discovery and measurement to experimental medicine, implementation and public benefit.

ACTION 4: Test how immune health can support NHS prevention and population health

NIHR should work with the NHS, Integrated Care Systems, public health teams and research partners to test how evidence on immune ageing can inform prevention and care.

- Select priority settings in which to evaluate approaches to vaccination, frailty, rehabilitation, long-term condition management, recovery and personalised prevention.
- Support real-world evaluation through primary care, community services, population health programmes and NHS research infrastructure.
- Measure outcomes that matter to people and services, including infection, vaccine response, hospital use, recovery, physical function, quality of life, independence and inequalities.

Immediate priority: Test promising approaches through existing NHS and public health pathways, using evidence to guide adoption.

Progress would mean: Practical approaches are evaluated in diverse real-world settings. Those shown to be effective, equitable and affordable are adopted and scaled through existing NHS and public health pathways.

ACTION 5: Ensure immune ageing policy reduces health inequalities

Government, the NHS, public health bodies and funders should ensure that immune ageing research, policy and implementation prioritise people and communities experiencing poorer health, lower vaccine uptake, greater exposure to infection and earlier loss of resilience.

- Include diverse populations in immune ageing research from the outset, particularly communities that experience poorer health earlier in life.
- Validate biomarkers, risk models, vaccines, diagnostics and interventions across demographic and socioeconomic groups, and assess their impact on inequalities.
- Design research and services with trusted local partners, including primary care, pharmacies, local authorities, voluntary organisations and community leaders, addressing barriers related to access, affordability, acceptability and trust.

Immediate priority: Build equity into immune ageing research, policy and implementation from the outset, with clear monitoring of participation, uptake and outcomes.

Progress would mean: Research and prevention programmes reach underserved groups, new approaches work effectively across diverse populations, and measurable gaps in vaccination, infection, recovery and healthy ageing begin to narrow.

Taking the agenda forward

The UK has demonstrated that science, data, NHS delivery and public health action can be aligned around shared goals. Applying this capability to immune ageing would strengthen prevention and improve the response to infection, frailty, delayed recovery and loss of independence.

Government should provide clear policy leadership. Funders should coordinate research and infrastructure around practical priorities. The NHS and public health partners should test promising approaches in real-world settings. Industry, charities and communities should contribute to the development of solutions that are effective, trusted and equitable.

The UK has the expertise, infrastructure, health data and NHS capability to lead in this field. The priority now is coordinated implementation, connecting research, vaccination, prevention and recovery around the shared objective of helping more people remain healthy, resilient and independent for longer.

This would provide a practical route to improving healthy life expectancy, reducing avoidable pressure on health and care services, and turning scientific capability into sustained public benefit.



Glossary of terms

Key terms used throughout this report

- **Biological ageing:** changes in the body's biological systems over time which increase the risk of disease and death and which may occur at different rates between individuals.
- **Biomarker:** a measurable biological indicator associated with health, disease risk or response to an intervention.
- **Chronological age:** age measured in years since birth.
- **Immune age:** an emerging concept describing the functional state of a person's immune system relative to chronological age.
- **Immune ageing:** changes in the immune system across the life course that affect responses to infection and vaccination, the regulation of inflammation, and recovery following illness or injury.
- **Immune health:** the ability of the immune system to protect against threats, regulate inflammation and support recovery.
- **Immune profiling:** detailed measurement of immune cells, blood molecules and responses to challenges.
- **Immune resilience:** the ability of the immune system to respond appropriately to challenge, recover and maintain balance over time.
- **Immunosenescence:** age-related changes that reduce or alter aspects of immune function.
- **Inflammageing:** persistent, low-grade inflammation associated with ageing.
- **Multi-omics:** the combined analysis of different types of biological data, such as genomics, proteomics and metabolomics.

Vaccination and infection terms

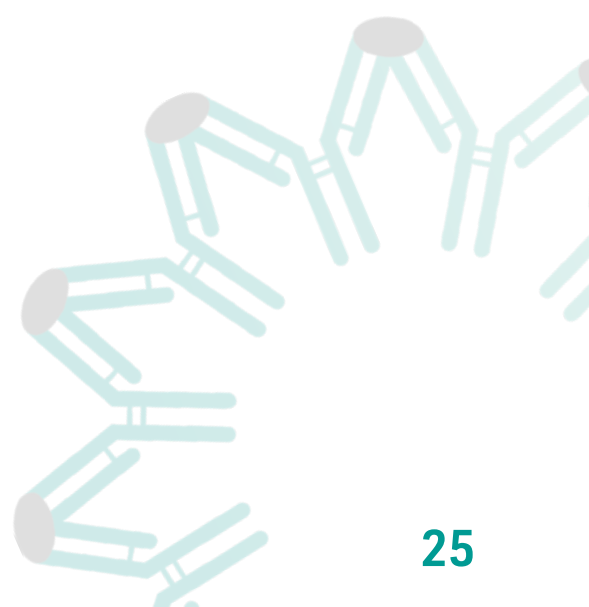
- **Immunocompromised:** having weakened or altered immune function because of genetics, illness, treatment or another factor.
- **Vaccine response:** the biological response generated by the immune system following vaccination.

Healthy ageing and recovery terms

- **Deconditioning:** loss of physical strength or function following inactivity, illness or hospitalisation.
- **Frailty:** increased vulnerability to health setbacks because of reduced physiological capacity.
- **Healthy life expectancy:** the average number of years a person can expect to live in good health.
- **Multimorbidity:** having two or more long-term health conditions.

Policy and research terms

- **Health inequalities:** avoidable and unfair differences in health between population groups.
- **Linked health data:** health information from different sources combined securely for analysis.
- **Population health:** an approach focused on improving health outcomes across groups or communities.
- **Precision prevention:** targeting preventive action according to the risk, characteristics or needs of individuals or groups.
- **Real-world evaluation:** assessing whether an intervention works in routine healthcare or public health settings.
- **Translation:** the process of moving scientific findings into practical use in policy, healthcare or public health.





British Society for Immunology
9 Appold Street
London
EC2A 2AP

 BSI@immunology.org
 www.immunology.org
 [@britsocimm.bsky.social](https://twitter.com/britsocimm.bsky.social)

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