



Growing Older, Better

Physiology's role in meeting
the UK Government's healthy
ageing mission

Growing Older, Better Expert Group

The Physiological Society is enormously grateful to the members of the Expert Group who offered their time and expertise to ensure the success of the project.

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This report highlights the integral role of physiology in achieving the UK Government’s target of “at least five extra healthy, independent years of life by 2035, while narrowing the gap between the experience of the richest and poorest” as outlined as part of the Industrial Strategy’s *Grand Challenges*¹.

The findings of the report are a summary of evidence and discussions with over 60 experts in lifelong health and Government policy across research, policy and funding. Any views expressed in the report are a reflection of the Expert Group as a whole and not the individuals that participated or the organisations they represent.

¹ Gov.uk (2019), *The Grand Challenges missions: Ageing Society*. [Online] Available at: [gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions#healthy-lives](https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions#healthy-lives) [Accessed 3 Sept 19]

Executive summary

Chapter conclusions and recommendations

What are some of the current areas of physiological research into ageing?

While The Physiological Society welcomes the Government's funding for a healthy ageing agenda, we are concerned that the Government is too focused on responding reactively to ageing, rather than being proactive in challenging the causes of ageing and the ageing process itself. We believe that this means the Government, health service and associated public bodies will not make the step change we need to see in their response to this ageing challenge.

Recommendation 1: The Physiological Society will demonstrate the value of physiological research consistently and clearly to Government departments, executive agencies and other scientific disciplines.

Contemporary physiological research is core to providing answers to some of the questions that will need solving in order to meet the Government's "Healthy Ageing" Grand Challenge by 2035. For example, to understand how physical activity influences immunosenescence and whether it also leads to improved responses to infections and vaccinations.

Recommendation 2: The Physiological Society will collaborate more closely with other organisations to build consistent messaging on the most urgent steps required to meet the Government's ambition in this area.

Personalised medicine is an important part of the Government's health strategy but not currently understood within the context of physiology and the benefits it can offer in promoting lifelong health and healthy ageing.

Recommendation 3: The Physiological Society will look to build consensus with other organisations around supporting tailored advice for maintaining physiological function.

Ageing is a multifaceted process that impacts all the systems of the body. The most important system for ageing, therefore, is the system that fails first in the individual.

Recommendation 4: Biomedical research should place greater emphasis on the maintenance of function, the slowing of functional decline, disease prevention and a coordinated approach to multimorbidity rather than a single-organ curative approach.

Recommendation 5: The Physiological Society will encourage a dialogue between physiologists and other researchers in emerging research on biomarkers to ensure biomarkers are rigorous.

Recommendation 6: The Physiological Society will engage those involved with public messaging and those who work with people most at risk from rapid functional decline to share physiological research on the impact that one system's failure can have on the development of co-morbidities.

Where should funding bodies direct funding into healthy ageing?

There is currently a lack of standardised benchmarking for funding into physiological research across funders and within UK Research and Innovation (UKRI), making it hard to assess the value and impact of funding over time.

Recommendation 7: We would encourage funders to work with The Physiological Society to develop a more exhaustive and rigorous system of benchmarking the overall number of successful physiology grants awarded, overall value and average value of grants over time.

The main sources of funding for physiological research in the UK are the Biotechnology and Biological Sciences Research Council (BBSRC), Medical Research Council (MRC) and the Wellcome Trust. While BBSRC awards the most grants in physiology, the average value of the grants awarded is smaller than those of the Wellcome Trust and MRC.

Recommendation 8: The Physiological Society will work with funders to better understand reasons for trends in physiology grant funding into ageing over time.

Funding for physiology can fall through the gaps between basic and applied research funding pools.

Recommendation 9: UKRI should develop programmes of work to promote research underpinning the biological processes of ageing across the research councils.

Recommendation 10: UKRI should co-fund more projects where mechanistic research is coupled with a medical application of preventing age-related decline to prevent disease and reduced healthspan.

There is a perception among physiologists that physiology research is underrepresented in successful grant applications.

Recommendation 11: Physiologists must ensure they are aware of the requirements and expectations of funding bodies and engage more with funders throughout the application process where possible in what remains a highly competitive funding landscape.

Recommendation 12: The Physiological Society will encourage a diverse selection of members to participate in grant panels and parliamentary scrutiny as experts in the value of physiology into ageing. The Physiological Society will embed dialogue with funders into its engagement with the physiological community through events such as our Annual Conference.

There is a lack of recognition from funders and research institutions of the financial contribution of physiology to UK research and development and the wider UK economy.

Recommendation 13: The Physiological Society will work on distinct projects such as its joint report *Sport and Exercise Science Education: Impact on the UK Economy* with GuildHE to build a bank of evidence in support of the economic, as well as scientific, benefits that the discipline offers.

Unique challenges of human ageing acceleration such as the heterogeneity of the population and sedentary lifestyles need a step change in attitudes to modelling to include a greater focus on human models.

Recommendation 14: Funders should fund projects that harness technological advances in both invasive and non-invasive human physiology to gain better insight into the molecular-level ageing process as it specifically affects humans.

Recommendation 15: The Physiological Society will assess what proportions of articles published in physiology journals use more than one type of model for their research to establish a benchmark to monitor this.

Funders have a strong sense of the impact of multimorbidity but are not funding sufficient projects into common underlying mechanisms and precursors to disease.

Recommendation 16: Physiologists should act as principal investigators on multidisciplinary research to bring other specialists together.

Recommendation 17: The focus and prioritisation of resources to chronic diseases can only be a stopgap solution and reinforces the need to support science that is focused on prevention.

How can we develop an integrative approach to the physiology of healthy ageing research?

Physiology as a discipline is core to understanding all the different components associated with age, health and well-being.

Recommendation 18: The Physiological Society will engage in greater advocacy, including developing case studies, to ensure that physiological insight is included in the healthy ageing research of other disciplines to understand how specific aspects of research affect wider function.

Recommendation 19: The Physiological Society will promote synergistic links between physiologists and psychologists to understand how good mental health has a physiological benefit and vice-versa.

The population is ageing, and an increasing proportion of older people are spending extended periods in ill health receiving treatment that maintains current function rather than looking to improve it even in later life.

Recommendation 20: The Physiological Society will facilitate closer links with clinicians including geriatricians to promote physiology-based interventions to promote lifelong health.

Recommendation 21: The Physiological Society will engage systematically with a broad range of civil society groups and learned societies with an interest in lifelong health to ensure an alignment of goals and build our footprint in the lifelong health space (e.g. Centre for Ageing Better, the British Society for Research into Ageing and the British Geriatrics Society).

Physiology is underrepresented in medical and nursing training qualifications.

Recommendation 22: The Physiological Society will foster links with Health Education England, Medical Schools Council and the Royal College of Nursing to better understand the self-identified knowledge gaps among early career healthcare professionals and contribute positively to addressing these gaps.

Funders are interested in understanding how research outputs can be translated into behaviour change.

Recommendation 23: Physiologists should form greater links with behavioural scientists to deliver sustainable, impactful interventions.

Recommendation 24: The Physiological Society will continue to develop evidence to support the financial return on investing in physiology and its related sub-disciplines.

Interdisciplinary working faces additional barriers of added complexity which can lead to a lack of available funding for integrated physiological projects that bridge the gap between basic and applied research.

Recommendation 25: Institutions should put structures and support in place to reward and incentivise collaborative working between research groups, departments and institutions.

How can we translate physiological evidence into policy implementation?

There is a gap between physiological insight and policy decision-making for healthy aging.

Recommendation 26: Public health agencies should ensure that guidelines, while achievable, should be rigorously evidenced and tailored to different stages of the life course.

Recommendation 27: The Physiological Society will work to engage policymakers to ensure that their behaviour change work is supported by physiological insight.

Significant sections of the population do not engage with healthy ageing campaigns or recognise the impact of positive lifestyle changes on the quality of later life. It is vital that public health guidance is built on robust physiological research and insight.

Recommendation 28: The Government needs to support healthy ageing in a multifaceted way, by supporting individuals to make healthy choices, ensuring that wider determinants of health are addressed and making nationwide decisions to support healthier living.

Those that are socioeconomically disadvantaged are less likely to be engaged in activities and lifestyles that promote healthy ageing.

Recommendation 29: The Physiological Society will work with charities and health organisations to communicate the benefits of the latest physiological research to as wide and varied an audience as possible.

Recommendation 30: Health systems in the UK must deliver joined-up policymaking that incentivises decisions to be made at the right point within the system.

Health conditions are understood by the public as being independent of one another.

Recommendation 31: The Physiological Society can contribute to better communication around the causal relationship between declining physiological function, declining healthspan and multimorbidity.

Recommendation 32: The Physiological Society will develop closer links with societies and organisations that explore the link between psychosocial interventions and physiology as an area which demonstrates how an integrative, physiological approach can support health throughout life.

Foreword



It is to the credit of modern medicine and improvements in public health, and those in the NHS tasked with its delivery, that a child born in the UK today can expect to live to nearly 80 for males and 83 for females² and one in three born in 2016 will live to celebrate their 100th birthday³. At the same time, someone 65 years old today can expect to live to 85, five years longer than their parents' generation.

However, these headlines give little indication of the *quality of life* we will be enjoying in later life. Since 2009, healthy life expectancy has remained stable while life expectancy has continued, for the most part, to rise, even if this rise is small and not uniform across the population⁴. As such, the number of years lived in poor health has increased slightly, as has the proportion of life spent in poor health. While those born today can expect to live to 80, they are forecast to spend up to a quarter of their lives in poor health. We must therefore ensure that greater focus is given to expanding healthy lifespan; *healthspan*.

This is why The Physiological Society's report *Growing Older, Better* is so timely. Having met a number of physiologists, including some of those who gave their time to support this report, I can attest that physiology is core to understanding the changes in how our bodies work as we age, which will be crucial in solving some of the major challenges of our generation. Understanding the healthy ageing process, causes of age-related diseases and frailty can result in lifestyle and medical interventions to allow people to keep contributing longer into their lifespan. This will have benefits for the individual by increasing their quality of life in older age as well as easing the burden on health and care systems.

These are challenges that I recognise as part of my constituency work as a Member of Parliament. Although, there has been a welcome decline in the number of early deaths caused by cancer in my constituency of 20% since 2002, there remains much to be done to keep people healthy and active throughout life. If we want to extend the amount of time people spend in good health as they age, it is clear, as this report highlights, that more must be done to promote the science of physiology to improve quality of life.

With challenges, however, come opportunities for innovation, particularly with the Government's joined-up approach to health and industry with the inclusion of healthy ageing as a key pillar of the Government's Industrial Strategy. I also welcome the Government's commitment to raise the amount that we spend on research and development to 2.4% of GDP by 2027, with an aspiration to get it up to 3%. Ensuring that physiology is at the heart of the Government's healthy ageing agenda will be crucial to support the public to grow older, better.

Stephen Metcalfe MP

Member of Parliament for South Basildon and East Thurrock
Chair of the Parliamentary and Scientific Committee
Member of the House of Commons Science and Technology Committee

² Office for National Statistics (2019), *National Life Tables, United Kingdom, 1980-82 to 2015-2017*. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/datasets/nationallifetablesunitedkingdomreferencetables [Accessed 3 Sept 19]

³ Office for National Statistics (2019), *What are your chances of living to 100?* [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/whatareyourchancesoflivingto100/2016-01-14 [Accessed 3 Sept 19]

⁴ Office for National Statistics (2019), *Healthy life expectancy at birth, years lived in "Not Good" health and the proportion of life spent healthy, by sex: UK, 2009-2011 and 2015-17*. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/healthstatelifeexpectanciesuk/2015to2017 [Accessed 3 Sept 19]

Notes of thanks

Physiology is fundamentally the study of functions within the body. Central to this is understanding how to maintain optimum function and the circumstances under which things begin to go wrong. As you will see in the report, the slow decline of physiological function associated with ageing is being challenged from a variety of different approaches. In this vein, The Physiological Society is committed to ensuring an environment that facilitates The Society and its members working along like-minded researchers and clinicians to ensure that the most cutting-edge science informs an individual and public health approach to lifelong health.



I would like to thank all those that gave their time to support this important initiative. I want to extend particular thanks to Paul Greenhaff for his work chairing the Expert Group, as well as Janet Lord, Diana Kuh, Steve Harridge and Susan Mitchell for coordinating the individual workshops. With so much expertise in each workshop, it is a testament to them that the report has reached conclusions and recommendations that are by no means exhaustive, but demonstrate the gaps in lifelong health knowledge and funding that physiology can fill. Special thanks must also go to Stephen Metcalfe MP for his support for this project through both his foreword and hosting the launch of the report in Parliament. We look forward to working alongside him and other colleagues on the Parliamentary and Scientific Committee and Science and Technology Select Committee to inform the debate on UK science in the coming months to ensure that people are empowered to grow older, better.

A handwritten signature in black ink that reads "Bridget Lumb".

Bridget Lumb

University of Bristol
President, The Physiological Society

As a physiologist with over 30 years' experience and someone who has worked collaboratively to ensure that physiology is at the heart of a lifelong approach to health, I was delighted to serve as Chair of The Physiological Society's *Growing Older, Better* project into lifelong health. Through my research, I know that better understanding of physiological change throughout the life course, including acute episodes of marked physiological stress, is crucial to improving the healthspan of individuals and meeting the Government's ambition for a healthier ageing society.



The reality is, however, we do not, as yet, have a complete picture of why physiological function declines with age, what aspects of ageing are inevitable and how to best support the clinical application of physiological research to ensure that the public benefits from our research. Ensuring that we understand the current landscape and have a clear picture about what needs to change to ensure physiology is at the heart of meeting the challenges of an ageing society is a crucial first step.

I would like to take this opportunity to thank all of the organisations and individuals that participated in the Expert Group, workshops and one-to-one interviews. The Expert Group purposefully reaches out beyond physiologists to include funders and policymakers. I believe this approach shows the commitment of The Physiological Society to not only reflect the breadth of research that physiology encompasses, but also its determination to work collaboratively across the sector to further understanding of the human body. This report highlights some of the most up-to-date research being conducted in the field, the challenge of translating that research into meaningful action for members of the public and clinical staff, and evidence on how and where physiology is currently being funded and how it could be funded in the future. This report is not the end for the project – rather, it is the beginning – and I am certain that the hard work from those that participated has put it on solid ground for an evidence-based response.

A handwritten signature in black ink that reads "Paul Greenhaff".

Paul Greenhaff

University of Nottingham
Chair of the *Growing Older, Better* Expert Group

Glossary of key terms

Biomarker

A measurement that can be used as an indicator of a particular disease state or some other physiological state of an organism.

Epidemiology

The study and analysis of the distribution, patterns and determinants of health and disease conditions in defined populations.

Frailty

Frailty is not an illness, but a syndrome that combines the effects of natural ageing with the outcomes of multiple long-term conditions, a loss of fitness and reserves. Research suggests that changes in the immune system, longstanding inflammation, and decline of the musculoskeletal and endocrine systems all contribute to the onset of frailty. Frailty occurs more often as people become older. Of people over 85 years of age about one in four is living with frailty and increasingly it is suggested that frailty needs to be thought of as a long-term condition⁵.

Functional ability/function

Functional ability is a combination of an individual's intrinsic capacity and their environment. For example, the use of a walking stick for those with poor mobility (and therefore lower intrinsic capacity) will increase their functional ability, thereby making it more likely they will continue to function at a similar level to someone with a higher intrinsic capacity.

Healthspan

Healthspan (or healthy life expectancy) is the average number of years a person might expect to live in "Good" health in their lifetime based on people self-assessing their health and the extent to which long-standing illness, disability or infirmity limits their activity⁶.

Homeostasis

The state of steady internal physical and chemical conditions maintained by living systems. This dynamic state of equilibrium is the condition of optimal functioning for the organism and includes many variables, such as body temperature and fluid balance, being kept within a pre-set range. Other variables include blood sugar level which must be regulated despite changes in the environment, diet, or level of activity. Each of these variables is controlled by one or more regulators or homeostatic mechanisms, which together maintain life.

Interdisciplinary working

In the context of the report, this is related to integrating knowledge, expertise and methods from different research disciplines to answer a single question or group of questions (see "How can we develop an integrative approach to the physiology of healthy ageing research?" for more information).

Intrinsic capacity

Intrinsic capacity is a composite of all the physical and mental attributes on which an individual can draw, not only in older age, but across their lives. Healthy ageing of an individual ("the process of developing and maintaining the functional ability that enables well-being in older age") depends upon their intrinsic capacity and their socio-economic and physical environments and the interactions between them⁷.

Multimorbidity

A situation in which a patient is living with two or more long-term conditions. Care for people with multimorbidity is complicated because different conditions and their treatments often interact in complex ways. Despite this, the delivery of care for people with multiple long-term conditions is still often built around the individual conditions, rather than the person as a whole. As a result, care is often fragmented and may not consider the combined impact of the conditions and their treatments on a person's quality of life⁸.

Pathophysiology

A state of disordered physiological processes that cause, result from, or are otherwise associated with, or a precursor to, a disease or injury.

Physiology

A fundamental science that aims to understand the mechanisms of living, from the atomic basis of cell function to the integrated behaviour of the whole body and the influence of the external environment. Research in physiology helps us to understand how the body works and determine what goes wrong in disease. This understanding ultimately informs new ways of treating disease and decline in the performance of the body.

⁵ Royal College of Nursing (2019), *Frailty in older people*. [Online] Available at: rcn.org.uk/clinical-topics/older-people/frailty [Accessed 3 Sept 19]

⁶ Office for National Statistics (2019), *Health expectancies at birth and at Age 65 in the United Kingdom: 2009-11*. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletinhealthexpectanciesatbirthanddataage65intheunitedkingdom/2014-11-18 [Accessed 3 Sept 19]

⁷ De Carvalho IA *et al.* (2017), Operationalising the concept of intrinsic capacity in clinical settings. *WHO Clinical Consortium on Healthy Ageing*, November 21-22 2017, Geneva, Switzerland.

⁸ Bramley D, Moody D (2016), Multimorbidity – the biggest clinical challenge facing the NHS?. [Online] Available at: england.nhs.uk/blog/dawn-moody-david-bramley/ [Accessed 3 Sept 19]

Introduction

This report highlights the integral role of physiology in achieving the UK Government's target of "at least five extra healthy, independent years of life by 2035, while narrowing the gap between the experience of the richest and poorest" as outlined as part of the Industrial Strategy's *Grand Challenges*⁹. In order to achieve this ambitious and timely objective, The Physiological Society, in collaboration with experts from across the health and research sectors, have identified key areas and action points to ensure an environment in which the significance of physiology to lifelong health is recognised and physiology can flourish to the benefit of individuals and communities.

What are the challenges facing healthy ageing?

The policy environment has never been as fertile for a report such as this. As Figure 1 demonstrates, the only age groups set to increase as a proportion of the UK population by 2039 are those aged 60 and over. At the same time, those members of the public that make up these age categories are getting older, with the over 85s contributing one in four people roughly of pensionable

age (from 65) in England alone (Figure 2)¹⁰. As Figure 3 demonstrates, increases in life expectancy do not necessarily equate to healthy life expectancy, which needs to more closely resemble life expectancy to ensure that older people are able to live full lives and contribute to the UK economy through continued employment, volunteering or care giving. It should be noted that based on 2012 – 2014 data, workers in the UK spend on average the last 18 months of their *working* lives in poor health and this will increase to nearly three years with changes in the state pension age by October 2020. This effect is not uniform. For males born in England between 2015 and 2017, the top 10% least deprived will, on average, reach State Pension age in good health; those in the bottom 10% will, again on average, reach retirement having spent the previous 17 *years* in poor health¹¹. This trend is also important to understand within the context of a stagnating or in some cases declining overall life expectancy, with the slowing of remaining life expectancy in England (in those aged 65 and over) linked to the increase in deaths from dementia and Alzheimer's and the relationship between social determinants of health and life expectancy, in terms of inequality, education and employment¹². The ageing of

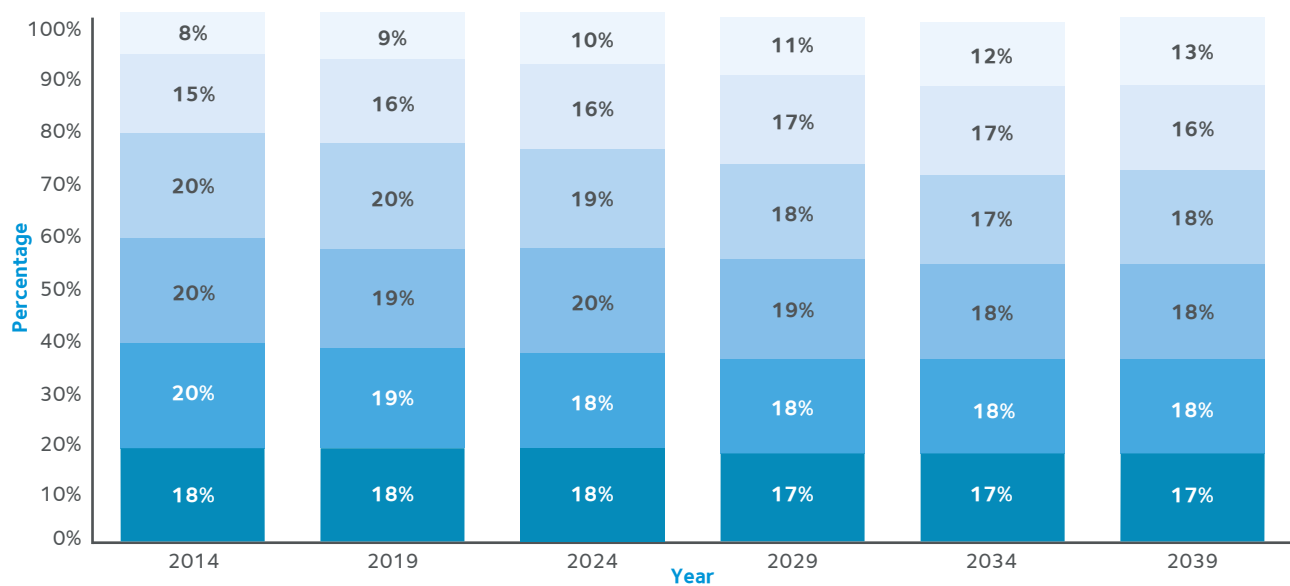


Figure 1 Population estimates by age group 2014 – 2039¹³.

Age: ■ 0-14 ■ 15-29 ■ 30-44 ■ 45-59 ■ 60-74 ■ 75+

⁹ Gov.uk (2019), The Grand Challenges missions: Ageing Society, [Online] Available at: [gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions#healthy-lives](https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions#healthy-lives) [Accessed 3 Sept 19]

¹⁰ Office for National Statistics, Figure 1.3: Projected distribution within the oldest age group (65 and over) between 2014 and 2039, England, [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/compendium/subnationalpopulationprojections/analysis/2014basedprojections/howthepopulationofenglandisprojectedtoage#the-changing-balance-between-age-groups-the-65-and-over-age-group-is-projected-to-grow-more-than-5-times-as-fast-as-the-working-age-population [Accessed 3 Sept 19]

¹¹ Office for National Statistics (2019), Health state life expectancies by national deprivation deciles, England and Wales: 2015 to 2017 – Figure 3: Male healthy life expectancy at birth and years lived in poorer states of health: by national deprivation deciles, England, 2015 to 2017, [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthinequalities/bulletins/healthstatelifeexpectanciesbyindexofmultipledeprivationimd/2015to2017#comparing-inequalities-in-life-expectancy-and-healthy-life-expectancy-between-2012-to-2014-and-2015-to-2017-england, [Accessed 3 Sept 19]

¹² UCL, Life expectancy rises "grinding to halt". [Online] Available at: ucl.ac.uk/epidemiology-health-care/news/2017/jul/life-expectancy-rises-grinding-halt [Accessed 9 Aug 2019]

¹³ Adapted from data from Jones R *et al.* (2016). Future of an Ageing Population. *UK Government Office for Science* page 18, based on ONS principal population projections, 2014.

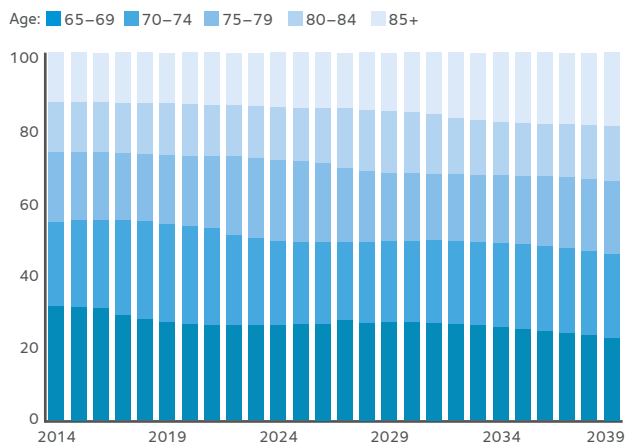
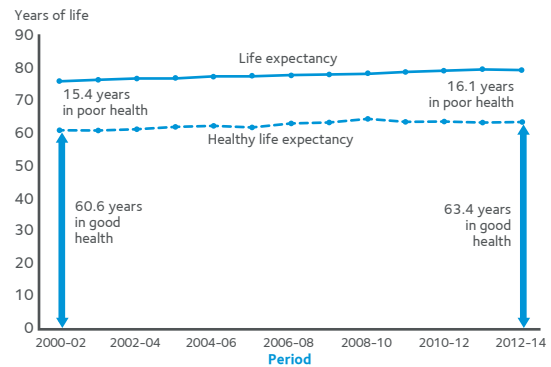


Figure 2 Projected increase in the share of people aged 85 and over within the oldest age group in England 2014 – 2039¹⁴.

society adds to the existing challenges for governments and health services. The “dependency ratio”, i.e. the number of people not in work compared to the working population, is expected to increase primarily due to those of State Pension age increasing rather than those who are yet to join the workforce (i.e. aged between 0 and 15 years old). An older population that has the same expectations of their health and retirement as their grandparents would put huge pressure on health systems, not least because they are living on average five years longer in retirement than their parents^{15 16}. As such, greater focus needs to be placed on ensuring that healthy life expectancy increases and makes up as large a proportion of life expectancy as possible.



Source: Healthy life expectancies and life expectancies from ONS reports, with prevalence of good health derived from their surveys: General Household Survey/General Lifestyle Survey for years 2000 to 2002 up to 2008 to 2010, and the Annual Population Survey for years 2009 to 2011 up to 2012 to 2014.

Note: Data for 2000 to 2002 up to 2004 to 2006 have been adjusted to account for later methodology and survey changes.

Figure 3 Healthspan and lifespan for men in England 2000 – 2014¹⁸.

What is healthy ageing and how does it relate to physiology?

Figure 4 demonstrates an almost obvious statement – that getting older carries a significantly increased risk of disease and mortality. A 95-year-old woman is 20 times more likely to be living with cardiovascular disease than a 45-year-old counterpart.

The graph also highlights some of the challenges of adequately addressing ageing in a disease-specific manner. As Figure 4 shows, risk of death is not uniform across all diseases. In addition, older adults rarely acquire only one age-related disease and the majority are multi-morbid¹⁹. If we are to make a significant impact upon healthspan then

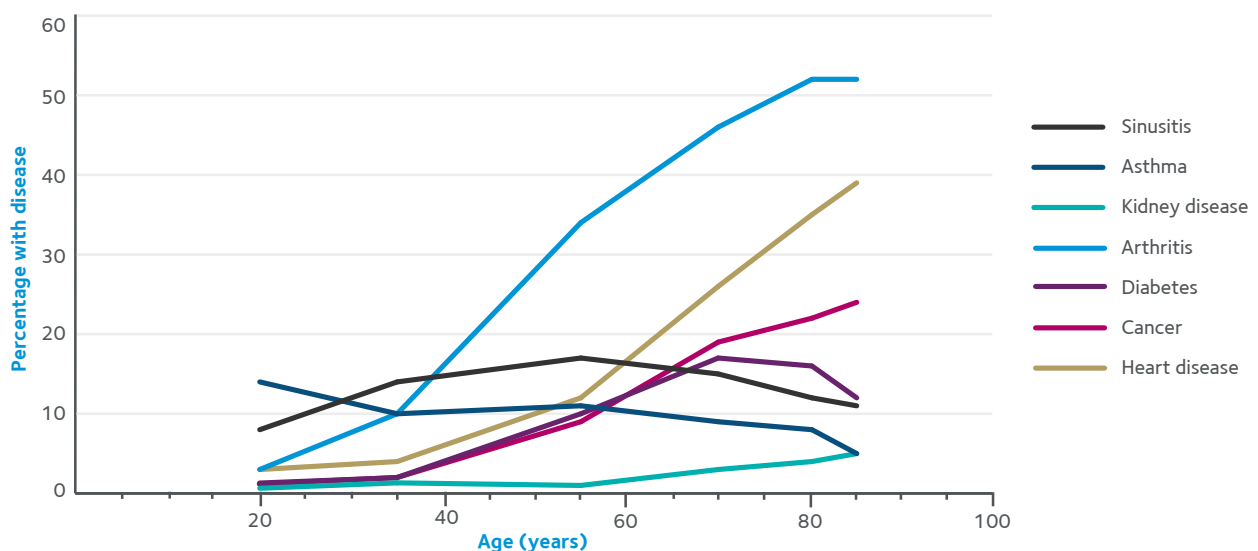


Figure 4 Prevalence of selected chronic conditions as a function of age for the US population 2002 – 2012. All forms of cancer and heart disease are featured¹⁷.

¹⁴ Office of National Statistics (2016), Figure 1.3: Projected increase in the share of people aged 85 and over within the oldest age group in England between 2014 and 2039. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/compendium/subnationalpopulationprojectionsandcommunityanalysis/2014basedprojections/howthepopulationofenglandisprojectedtoage#the-changing-balance-between-age-groups-the-65-and-over-age-group-is-projected-to-grow-more-than-5-times-as-fast-as-the-working-age-population [Accessed 9 Aug 2019]

¹⁵ Office for National Statistics (2017), What is my life expectancy? And how might it change?. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/articles/whatismylifeexpectancyandhowmightitchange/2017-12-01 [Accessed 3 Oct 19]

¹⁶ Office for National Statistics (2019), National Life Tables, United Kingdom, 1980–82 to 2015–2017. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/datasets/nationallifetablesunitedkingdomreferencetables [Accessed 3 Sept 19]

¹⁷ National Center for Health Statistics (2019), National Vital Statistics System: Mortality data. [Online] Available at: www.cdc.gov/nchs/nvss/index.htm cdc.gov/n

¹⁸ Gov.uk (2017), 3.3 Figure 2: Life expectancy, healthy life expectancy and years spent in poor health from birth, males 2000 to 2002 up to 2012 to 2014. [Online] Available at: gov.uk/government/publications/health-profile-for-england/chapter-1-life-expectancy-and-healthy-life-expectancy [Accessed 3 Sept 19]

¹⁹ Academy of Medical Sciences (2018), *Multimorbidity: a priority for global health research*. [Online] Available at: acmedsci.ac.uk/file-download/82222577 [Accessed 3 Sept 19]

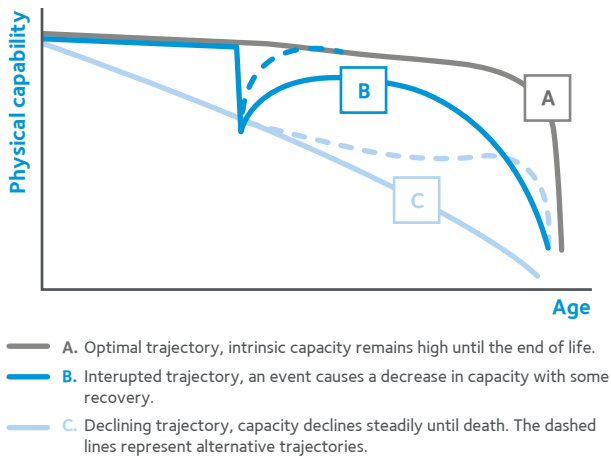


Figure 5 WHO figure on intrinsic capacity²⁰.

the issue of multi-morbidity has to be front and centre. The graph also ignores those changes in physiology that may not be fatal in and of themselves but are crucial to maintaining quality of life as we age. It is in better understanding the mechanisms behind how to maintain this function in older age and prevent multimorbidity that physiology has a central role to play.

Underpinning all of the report's findings, therefore, is the fundamental challenge that ageing is not a disease, rather a significant risk factor in almost all diseases and adverse health events. Physiology is a discipline under-represented in public knowledge because it is not disease-specific but it pervades all aspects of ageing and progression into pathophysiology²¹. A dysregulation of physiology if not rectified can lead to pathophysiology and ultimately disease. This remains a significant barrier to developing interventions to retain intrinsic capacity.

While this report focuses on healthy ageing, one of the main contributions physiological research can make is ultimately to underpin epidemiological insight with mechanistic science and understand how best to maintain homeostasis (optimal function) throughout life and promote better lifelong health. Ultimately, the purpose of physiological research into ageing is focused on ensuring that as many people as possible follow the optimal trajectory of physical capacity and ageing as noted in line A of Figure 5 and ensure that physiological research is focused on supporting those whose ageing trajectories look more like lines B and C in later life, to take proactive steps to more closely resemble line A.

As the Science Advice for Policy by European Academies (SAPEA) notes in its recent report *Transforming the future of ageing*, "Functional ageing is the best possible approach to address ageing across the life

World Health Organization (WHO) definition of healthy ageing

WHO defines Healthy Ageing "as the process of developing and maintaining the functional ability that enables well-being in older age"²². Functional ability is about having the capabilities that enable all people to be and do what they have reason to value. This includes a person's ability to:

- meet their basic needs;
- learn, grow and make decisions;
- be mobile;
- build and maintain relationships; and
- contribute to society.

Functional ability is made up of the intrinsic capacity of the individual, relevant environmental characteristics and the interaction between them.

Intrinsic capacity comprises all the mental and physical capacities that a person can draw on and includes their ability to walk, think, see, hear and remember. The level of intrinsic capacity is influenced by a number of factors such as the presence of diseases, injuries and age-related changes. Environments include the home, community and broader society, and all the factors within them such as the built environment, people and their relationships, attitudes and values, health and social policies, the systems that support them and the services that they implement. Being able to live in environments that support and maintain your intrinsic capacity and functional ability is key to Healthy Ageing.

The WHO has recently announced that 2020 – 2030 will be the "Decade of Healthy Ageing". The Decade of Healthy Ageing is an opportunity to bring together governments, civil society, international agencies, professionals, academia, the media and the private sector for ten years of concerted, catalytic and collaborative action to improve the lives of older people, their families and the communities in which they live²³.

course, knowing the importance of acquiring the most important functional abilities at a young age and preserving them during the whole life. This approach can support the policy objective for citizens to live healthier as well as longer"²⁴.

²⁰ Adapted from World Health Organization (2015), *World Report on Ageing and Health*. [Online] Available at: apps.who.int/iris/bitstream/handle/10665/186463/9789240694811_eng.pdf, page 31 [Accessed 12 Aug 2019]

²¹ YouGov, "Question 7c: To what extent do you agree that an understanding of physiology has an important role to play in helping you to live a healthier life" and "Question 7f: Physiology is a topic that I would like to know more about", *The Physiological Society: Healthy Ageing*, 4-7 January 2019

²² World Health Organization (2019), *Healthy Ageing and functional ability*, [Online] Available at: [who.int/ageing/healthy-ageing/en/](https://www.who.int/ageing/healthy-ageing/en/), [Accessed 27 Aug 19]

²³ World Health Organization (2019), *What is the Decade of Healthy Ageing?*, [Online] Available at: [who.int/ageing/healthy-ageing/en/](https://www.who.int/ageing/healthy-ageing/en/), [Accessed 27 Aug 19]

²⁴ Science Advice for Policy by European Academies (2019), *Transforming the future of ageing*. [Online] Available at: sapea.info/wp-content/uploads/tfa-report.pdf, page 52 [Accessed 12 Aug 2019]

What is the healthy ageing challenge?

Government at all levels across the UK are focused on addressing some of the challenges posed by an ageing society. In Scotland for example, the Scottish Government published the *National Strategy for Older People* in 2011 which outlines a 10-year vision and programme of action for housing for older people. In Wales, the Welsh Government has partnered with the European Innovation Partnership on Active and Healthy Ageing to develop *Ageing Well in Wales 2014–19*, which is targeted at making age-friendly communities, improving learning and employment opportunities and reducing the health impacts of falls and social isolation. Similarly, the Scottish Government recently published *Scotland's Digital Health and Care Strategy: enabling, connecting and empowering*, designed to embed digital technology within health and care services to improve outcomes for citizens²⁵.

The UK Government launched its Industrial Strategy *Building a Britain fit for the future* in November 2017, and at its heart are four “Grand Challenges”, developed in consultation with the Government Office for Science, UK Research and Innovation (UKRI), the Council for Science and Technology and the national academies. The four Grand Challenges included “harness the power of innovation to help meet the needs of an ageing society”,²⁶ and central to this is the Government target of “ensur[ing] that people can enjoy at least five extra healthy, independent years of life by 2035, while narrowing the gap between the experience of the richest and poorest”²⁷. It is with this target in mind that The Physiological Society has reached out to experts to get their views on the likelihood of this target being met under current circumstances and, if not, what must change in order to see the exponential growth required in average healthspan within the next decade.

UKRI describes the healthy ageing challenge as supporting the Government’s five healthier years target by supporting “people to stay in their homes for longer, tackle loneliness, and increase independence and well-being”²⁸. To this end, UKRI is investing £98 million into research and innovation that supports people as they age, while also helping those who care for them, and is broken down by the Centre for Ageing Better, as part of their independent advice and guidance to UKRI, into the following categories:

1. Sustaining physical activity
2. Maintaining health at work
3. Designing for age-friendly homes
4. Managing common complaints of ageing
5. Living well with cognitive impairment
6. Supporting social connections
7. Creating healthy and active places

The role of The Physiological Society in healthy ageing

As Europe’s largest society of physiologists, The Physiological Society has an active membership of over 4,000 members drawn from across a wide range of disciplines and career stages.

This report was written in conjunction with our Members and external experts to explore the contribution that physiology can make to the Government’s *Ageing Society* agenda and where the current barriers exist to maximising this support.

The Physiological Society’s Members are committed to improving human health and improving our dialogue with those working in decision-making roles to ensure that the most rigorous research is made available in a timely and easily understandable format so that positive changes can be made in areas such as prevention messaging and personalised medical care.

What is physiology and why is it important in understanding healthy ageing?

Physiology is a broad science that aims to understand the mechanisms of living, from the atomic basis of cell function to the integrated behaviour of the whole body and the influence of the external environment. Research in physiology helps us to understand how the body works and determine what goes wrong in disease. This

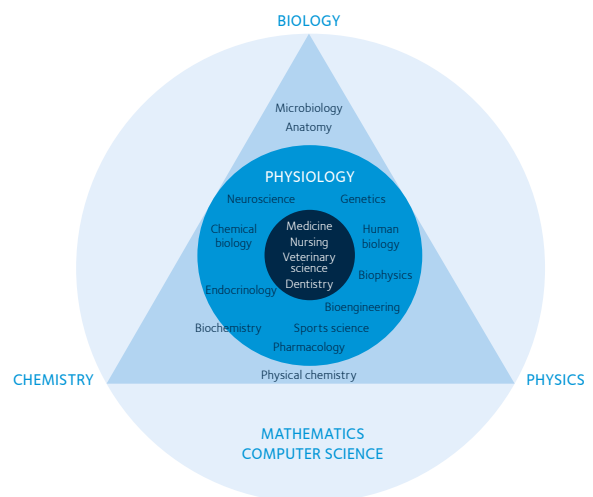


Figure 6 The role of physiology in other disciplines from “Understanding Life”.

²⁵ Scottish Government (2018), *Scotland's Digital Health and Care Strategy: enabling, connecting and empowering*, [Online] Available at: gov.scot/publications/scotlands-digital-health-care-strategy-enabling-connecting-empowering/, [Accessed 22 Aug 19]

²⁶ Gov.uk (2017), *Industrial Strategy: building a Britain fit for the future*, [Online] Available at: assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf [Accessed 22 Aug 19]

²⁷ Gov.uk (2019), *The Grand Challenges missions: Ageing Society*, [Online] Available at: gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions#healthy-lives [Accessed 3 Sept 19]

²⁸ UK Research and Innovation (2018), *What is the healthy ageing challenge?*, [Online] Available at: ukri.org/innovation/industrial-strategy-challenge-fund/healthy-ageing/ [Accessed 23 Aug 19]

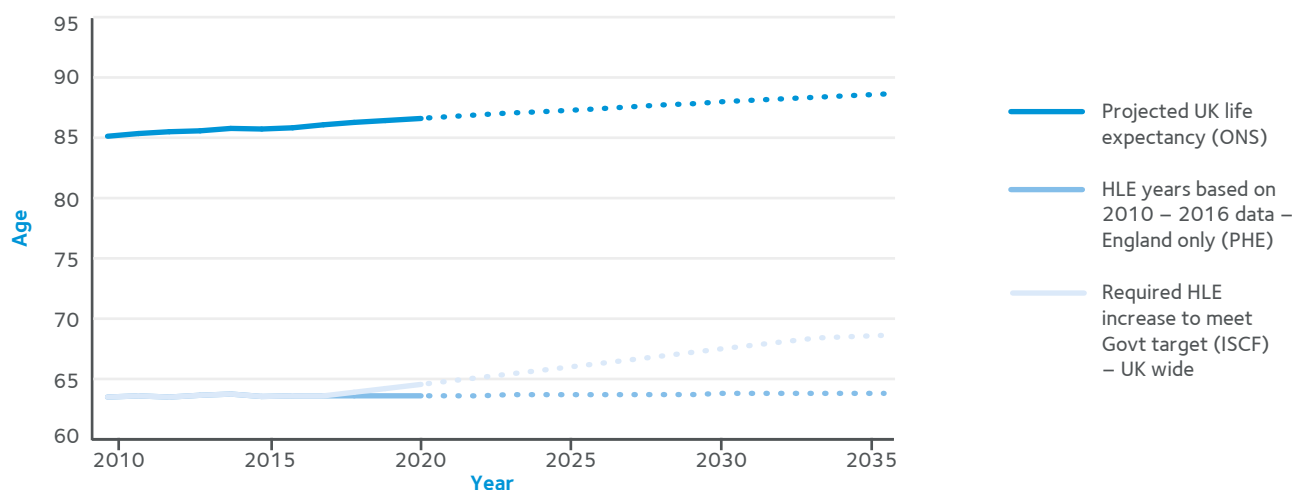


Figure 7 Comparing the Government's Healthy Ageing target for 2035 with required and projected year-on-year improvements in Healthy Life Expectancy (HLE)²⁹.

understanding ultimately informs new ways of treating disease and decline in the performance of the body.

The emphasis on understanding the interaction between molecules, cells, systems (such as the cardiovascular system) and whole-body function is what distinguishes physiology from the other life sciences. While all the sub-disciplines of physiology tell us more about how specific aspects of the body work (such as the brain or muscles), physiology seeks to understand how these functions impact other parts of the body (specific examples of this whole-body approach can be found in the section entitled "What are some of the current areas of physiological research into ageing?")

While there are a number of competing theories on the causes and inevitability of ageing, physiology is at the heart of ageing, its causes and how best to maintain quality of life for as long as possible. As a discipline that focuses on the functions and mechanisms of the body and their maintenance throughout life, ageing is an excellent lens through which to demonstrate the benefits of the broad and interconnected nature of physiology and how its continued study will be crucial to learn more about the interdisciplinary effects of ageing.

To highlight the contribution of some of the most contemporary physiological research into ageing, members of The Physiological Society, its Expert Group and other experts that have been engaged as part of the evidence-building process, have very kindly offered short "research spotlights" into their area of expertise. These research spotlights can be found throughout the different sections of the report as they relate to different barriers facing physiology in its support for the Government's goal of five healthier, more independent years by 2035.

Research spotlights

Growing Older, Better is targeted at policymakers, research funders, biomedical researchers and other organisations interested in the fields of lifelong health and healthy ageing. The report identifies gaps in the current landscape that The Physiological Society is well placed to respond to, develops a series of objectives for key decision makers and offers a roadmap as to how The Physiological Society can advocate and collaborate with other organisations to ensure that the correct evidence is in place for positive change in the public response to healthy ageing.

While The Physiological Society welcomes the Government's funding for a healthy ageing agenda, we are concerned that the Government is too focused on responding reactively to ageing, rather than being proactive in challenging the causes of ageing and the ageing process itself. We believe that this means the Government, health service and associated public bodies will not make the step change we need to see in their response to this ageing challenge. As Figure 7 shows, in order to meet the 2035 target, the average healthy life expectancy will have to increase by nearly six months every year between now and 2035, and we do not believe that this can be achieved exclusively through managing pathophysiology and its symptoms as they manifest. An ambitious target for healthy ageing requires an ambitious response, and we believe that this can only be achieved by placing physiology at the heart of this response.

²⁹ Based on Office of National Statistics (2017), *Past and projected data from the period and cohort life tables, 2016-based, UK: 1981 to 2066*. [Online] Available at: ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/bulletins/pastandprojecteddatafromtheperiodandcohortlifetables/2016baseduk1981to2066 [Accessed 2 Sept 19]; Public Health England (2019), *Public Health Profiles: Healthy life expectancy at birth (male) 2009 to 2017. and Healthy life expectancy (female) 2009 to 2017*. fingertips.phe.org.uk/search/healthy%20life%20expectancy [Accessed 3 Oct 19]; Gov.uk (2019), *The Grand Challenges missions: Ageing Society*, [Online] Available at: gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions#healthy-lives [Accessed 3 Sept 19]

What are some of the current areas of physiological research into ageing?

Ageing is not a disease. The physiology of ageing is a heterogeneous process, with individuals ageing differently depending on their genetic background, environmental exposures and other factors. Add in societal misconceptions of ageing, such as ideas that there are certain conditions or behaviours which are part of ageing (e.g. aching joints or reduction in social interaction) or are no longer appropriate for people as they get older (e.g., long-distance cycling), and what we mean by ageing, and the factors that contribute to it, is undoubtedly complex.



RESEARCH SPOTLIGHT



Musculoskeletal ageing research

Sarcopenia is the age-related loss of muscle mass and quality that occurs from the age of 40 onwards in both men and women. At the moment we do not know the mechanisms that drive sarcopenia, but based on published literature it is likely to be multi-faceted, including reduced habitual physical activity and anabolic resistance to nutrition (a reduction in stimulation of muscle protein synthesis to protein/amino acids). Sarcopenia is also exacerbated by acute periods of ill-health during which energy intake and physical activity can be markedly reduced, and infection and inflammation increased, all of which will induce muscle mass loss and muscle metabolic dysregulation. Sarcopenia is associated with loss of independence, reduced quality of life in old age and increased falls-related injuries.

Physiology is indispensable to understanding the mechanistic basis of sarcopenia, which is currently missing from insight gained from epidemiological and community-based investigation. Without such insight it will be very difficult to arrive at effective strategies to minimise sarcopenia and stimulate muscle mass and functional gains during rehabilitation in older people. Furthermore, longitudinal physiological-centred studies need to be performed in humans, as there are fundamental differences too between human and rodent muscle responses to ageing.

Advances in research techniques and technology mean it is now possible to make measurements in humans that were impossible just a few years ago. So, for example, muscle quality can be determined non-invasively using magnetic resonance spectroscopy and the relationship between brain and muscle response is now achievable using non-invasive magnetic resonance imaging (MRI) based approaches. This provides integrated system-level insight of the physiological drivers of musculoskeletal decline with age.

Collectively, these tools combined with clinical physiology and “omics” technologies will provide unprecedented insight of human sarcopenia (and beyond), particularly if longitudinal study designs are adopted in people – the best model of ageing! This will allow us to understand the causes of sarcopenia and pinpoint and develop the most effective strategies to diminish it and stimulate rehabilitation.

Paul Greenhaff

MRC/ARUK Centre for Musculoskeletal Ageing Research, Centre for Sport, Exercise and Osteoarthritis Research Versus Arthritis, National Institute for Health Research (NIHR) Nottingham Biomedical Research Centre, University of Nottingham

RESEARCH SPOTLIGHT



The role of the microbiota on development and ageing throughout the life course

Colonisation of the microbiota, a wide variety of bacteria, viruses, fungi and other single-celled animals that live in the body, begins at birth. Composition of the gastrointestinal microbiota is influenced by multiple factors including mode of birth (vaginal vs c-section) and feeding patterns (breast vs formula feeding) and remains malleable for the first few years of life. The microbiota has historically been understood primarily by its diversity; how many bacterial species are present and how abundant they are. More recently, characterisation of bacterial genes within the microbiome has allowed assessment of function, or “what do they do” in addition to “who is there”. Changes to the microbiota can occur due to infection, administration of antibiotics or changes in diet, but it is thought that in adulthood the microbiota remains fairly stable. In the absence of stability, or following a particular insult, disease can occur, although whether this is causative or correlative remains to be determined.

As we move into later life our microbiota changes, with decreasing diversity occurring due to multiple factors associated with ageing, including changes in diet, multiple prescription drugs and suppression of the immune system. Maintaining the diversity within the microbiota may serve as a novel way to improve healthy life in older populations, reducing disease and maintaining autonomy in individuals. Studies have found that the microbiota in older populations is associated closely with lifestyle, with individuals having the greatest diversity being those who live in their own home and those with the least diversity being those in assisted care living. Finding new ways to maintain microbial diversity in individuals as they age would be an exciting way to improve quality of life.

A critical knowledge gap remains in identifying the causes of decreased diversity in the microbiota as people age and how best to improve or delay loss of diversity. The impact of common medications administered to older patients, including anti-inflammatory, cholesterol-lowering, blood pressure lowering, and diabetes drugs on microbial diversity would help identify beneficial species that are lost. Establishing the changes associated with ageing in gut physiology, immune response and composition of the microbiota are ways through which we could have a significant impact on understanding healthy ageing and provide novel avenues to study this phenomenon. In addition, there are emerging links between the microbiota and neurodegenerative diseases, with the microbiota responsible for modulating deposits of protein in the brain that can lead to conditions such as Alzheimer’s disease, but more research is needed into the relationship between the two aspects of the body.

Melanie Gareau

Assistant Professor, College of Biological Sciences, UC Davis, USA

Personalised medicine is an important part of the Government's health strategy but currently has insufficient focus on physiology and the benefits it can offer the healthy ageing process

Personalised medicine is an approach that uses information from an individual's genome, combined with other clinical and diagnostic information, to determine someone's risk of developing disease; detect illness earlier; and determine the most effective interventions to help improve our health from pharmacological approaches to lifestyle choices or effective diet and exercise plans.

The UK Government has invested heavily in projects to understand more about how genome sequencing can support lifelong health. Genomics England, a company wholly owned and funded by the Department of Health & Social Care, was set up in 2012 to deliver the 100,000 Genome Project which has now sequenced 100,000 whole genomes from NHS patients. Its four main aims were to create an ethical and transparent programme based on consent; to bring benefit to patients and set up a genomic medicine service for the NHS; to enable new scientific discovery and medical insights; and to kick start the development of a UK genomics industry³⁰. Similarly, the UK Biobank is following 500,000 volunteers for the next 20 years to better understand the respective contributions of genetic predisposition and environmental exposure (including nutrition, lifestyle, medications, etc.) to the development of disease³¹. The long-term ambition of this project is for five million fully sequenced genomes. Physiology has an important role to play in ensuring the success of these technologies. A personalised medicine approach will only be as successful as the physiological phenotyping of these volunteers, i.e. relating genome differences to physiological differences. Knowing the genome alone is not enough – the potential is in applying it to physiological differences between these individuals, which will identify susceptibility to ageing processes, and predict response to, ill health and disease.

As a result of this physiological insight, The Physiological Society has the ambition to ensure that the benefits of personalised physiology plans based on a better understanding of biological age are communicated to policymakers and the public as part of the Government's commitment to personalised medicine. In order to achieve this, we will look to build consensus with other organisations around supporting tailored advice for maintaining physiological function (more on how we will look to achieve this can be found in the "How do we translate physiological evidence into implementation?" section).

RESEARCH SPOTLIGHT



"Epigenetic clock" – the future of measuring ageing?

The field of epigenetics addresses chemical modifications of DNA and associated proteins. Epigenetic marks contextualise the information in a cell's genome, telling a cell which genes it should and should not use. Although the genome largely stays constant, epigenetic information changes throughout life and is influenced by a combination of developmental cues and environmental effects on cells. It is thought that epigenetic information degrades with age, which would impede function as cells become unable to use genetic information appropriately, and this has been observed across a variety of organisms.

A particularly exciting discovery is that the biological age of a human can be calculated based on the epigenetic information from a few hundred locations in the human genome. The existence of this epigenetic "clock" has huge implications for ageing because the clock works uniformly from birth in almost all tissues regardless of how often the cells divide or their metabolism. In other words, irrespective of the location or function of a cell, some underlying ageing process is progressively and consistently acting long before any disease or decline occurs.

Physiological insights into this system are critical, especially in analysing how the clock measures differ in individuals with particularly healthy or unhealthy lifestyles, or with various medical conditions. This means lifestyle factors such as diet and exercise which have primarily physiological responses must be communicated across all cells to the underlying mechanism of the epigenetic clock.

The great challenge lies now in understanding the underlying mechanism that causes the progressive epigenetic changes measured in the clock. It is unlikely that ageing is a result of the epigenetic changes, rather the clock is likely one manifestation of an underlying ageing process that we do not yet understand. Understanding this mechanism will be of great benefit in advancing lifelong health. Since the clock reflects ageing health, understanding what drives the clock will reveal critical mediators of healthy ageing. For example, we understand that diet and exercise are important but not why, nor whether more specific advice and interventions are possible to improve ageing health.

Jon Houseley
Senior Research Fellow, The Babraham Institute

³⁰ Genomics England, "History of the 100,000 Genomes Project: 100,000 Genomes project", www.genomicsengland.co.uk/about-genomics-england/the-100000-genomes-project

³¹ UK Biobank, "About UK Biobank", www.ukbiobank.ac.uk/about-biobank-uk, [Accessed 27 Aug 19]

There is a lack of consensus on biomarkers of healthy ageing

A biomarker is an indicator that can be used to identify a particular disease or the physiological state of an organism. As ageing is not a disease, there has been a frustration among physiologists that there is a lack of consensus on reliable biomarkers of healthy ageing that are consistent across different cell and tissue types as they age, which are also inexpensive and easy to monitor³². For example, vaccination response is used as a measure of immune response but this is very expensive. Recent developments in epigenetics have revealed a series of DNA methylation marks, termed “epigenetic clocks” (please see the research spotlight “epigenetic clock” – *the future of measuring ageing?*). These “epigenetic clocks” correlate with chronological age, and deviations from the association are therefore indicative of altered risk of mortality. This method is, however, currently expensive and impractical on a large scale. Physiologists with a focus on ageing felt that in order to support an integrative approach to ageing across different aspects of physiology, a group of biomarkers

would need to be established that is rigorously evidenced, recognises the diversity of effect of ageing within different cells and how they are monitored and is sufficiently inexpensive to be replicated across long-term studies as necessary.

The Physiological Society will encourage a dialogue between physiologists and other researchers in emerging research on biomarkers to ensure biomarkers are rigorous and easily replicable in large-scale studies. Any biomarker will only be as good as the quality of the physiological measurement that the biomarker is purportedly predicting.

The most important system for ageing is the system that fails first

It is clear that there is a significant body of research focusing on healthy ageing as it relates to a single organ, disease or condition. While there has been a concerted effort to balance this research with a greater emphasis on whole-system integrative research, greater physiological insight has the opportunity to promote the message that the most important system in the

RESEARCH SPOTLIGHT

Understanding the relationship between ageing and sleep

Sleep is a highly dynamic process showing systematic changes across the night but also across the lifespan. In humans, sleep is deepest up until adolescence, after which it progressively becomes more fragmented and superficial. The fundamental question remains as to whether sleep disturbances in the elderly are related to a reduced function of the circadian clock, impaired homeostatic sleep regulation, or a diminished capacity to generate and sustain deep consolidated sleep. One possibility is that the age-dependent changes in sleep represent physiological compensatory responses, in which sleep plays an active and increasingly important role in maintaining cellular homeostasis and optimal waking functions. It is also possible that the age-dependent changes in sleep are a reflection of anatomical or physiological changes, such as a loss of synaptic connectivity, or a decline in the function of specific brain circuits.

It is well established that the level of electroencephalogram (EEG) slow-wave activity (SWA, 0.5–4Hz) reflects sleep homeostasis, and that in humans SWA is reduced with ageing. This led to the belief that sleep homeostatic mechanisms may be disrupted with ageing. Studies in laboratory animals have been fundamental in addressing this, with rodent studies often able to recapitulate at least some aspects

of human sleep. However, rodent studies have also shown conflicting evidence for the effects of ageing on sleep. For example, mice sleep more when they get older, not less. Since both sleep need and sleep depth are mechanistically and functionally related to the expression of SWA within local cortical networks, in our recent study we performed chronic recordings of cortical neural activity and local field potentials (LFP) from mice. Surprisingly, we found that ageing had little effect on sleep-related neural activity within local cortical networks in mice. We must therefore critically reconsider the notion that core brain mechanisms of sleep regulation are deficient in older humans. These studies also highlight the necessity to combine human and animal studies in order to achieve a better understanding of what happens to our sleep as we get older.

Laura E McKillop
Novo Nordisk Postdoctoral Research Fellow

Vladyslav V Vyazovskiy
Associate Professor of Neuroscience, Department of Physiology, Anatomy and Genetics, University of Oxford



³² Lara *et al.*, “A proposed panel of biomarkers of healthy ageing”, *BMC Medicine*, vol.13, p.222.

RESEARCH SPOTLIGHT

The ageing immune system and its impact on achieving “Healthy Ageing”

The immune system plays a key role in maintaining health, protecting us from infections and cancer, and facilitating preventive medicine measures such as vaccinations. However immunity declines with age, *immunesenescence*, contributing significantly to poor health in old age including reduced efficacy of vaccinations, increased susceptibility to infections and viruses, and reduced immune surveillance leading to increased cancer risk with age. Another aspect of ageing that is in part influenced by immunesenescence is the increase in systemic inflammation, so-called ‘inflammaging’. Importantly the degree of inflammaging has been related to increased risk of most chronic conditions of old age and is a biomarker of how well or badly an individual is ageing. Identifying the factors influencing immunesenescence will make an important contribution to the Government’s target of improving healthy life expectancy by five years by 2035.

A good example of the impact physiological research has had on understanding immune system ageing and health is the role played by physical activity. In most developed countries regular physical activity declines dramatically with age: in the UK less than 10% of adults aged over 65 years meet the Chief Medical Officer’s recommendations for physical activity of 150 minutes of aerobic exercise

per week. However, the immune system is significantly influenced by physical activity.

One of the major unanswered questions was just how much of immunesenescence was due to increased physical inactivity with age. To address this we analysed the degree of immunesenescence in older adults, aged 55 – 79 years, who had maintained high levels of physical activity throughout middle and old age (regular long-distance cycling). These older adults showed few signs of an aged immune system and had high levels of immune hormones important for maintaining immunity.

Bearing in mind the low involvement of most older adults in regular exercise, what we now need to know is just how little physical activity is required to achieve this immune-sparing effect! Additionally, we need to understand how physical activity influences immunesenescence and whether it also leads to improved responses to infections and vaccinations. These are key research gaps that are being met by physiological research.

Janet Lord

Director of the Institute of Inflammation and Ageing and the MRC-ARUK Centre for Musculoskeletal Ageing Research, University of Birmingham



RESEARCH SPOTLIGHT

Exercise physiology and healthy human ageing

As our population demographics are changing and people are living longer, attention is focusing not so much on extending our lifespan but how we can maximise our “healthspan”. Being healthy at any age is dependent upon a number of factors, which include not smoking, eating a well-balance diet, moderate alcohol consumption and sleeping well. One factor increasingly being recognised as essential for maintaining health throughout the life course, reducing the risk of numerous diseases and maintaining good physiological function is exercise.

Exercise physiology is the branch of physiology that concerns itself with the body’s responses and adaptations to exercise, physical activity or simply the increase in energy expenditure caused by movement. Exercise involves the integration of multiple physiological systems requiring neural pathways originating in the brain to initiate movement, skeletal muscles to contract and produce force through to the cardiovascular and respiratory systems delivering adequate supplies of oxygenated blood to match increasing energy demands. These physiological processes are remarkably integrated and carefully controlled and occur in the context of trying to maintain our body’s homeostasis, such that we don’t overheat, become too acidic or lose flow to the brain and other essential organs.

As we age our physical capabilities and ability to exercise decline. Our muscles get smaller and weaker, our

hearts pump less blood and our ability to perform simple tasks of everyday living are progressively reduced. We know this to be due to an ageing process, because it is evident even in the most vigorously active master athletes whose performances decline as they get older. However, the performances of these older athletes are quite remarkable and in general highly active older people show levels of physiological function that are far superior to those of inactive people. Thus, one of the challenges for ageing physiological research is determining how much of the decline is due to the ageing process itself and how much due to factors relating to lifestyle.

Being physically active is important in both optimising healthy ageing and in improving function in the previously inactive older person. In many respects exercise can be considered as a physiological and natural “pill”. It activates multiple physiological pathways and benefits health across numerous systems – including muscle, the cardiovascular and immune systems through to mental health. One of the biggest public health challenges we face is getting people to reduce sedentary behaviour and increase levels of physical activity.

Stephen Harridge

Professor of Human & Applied Physiology, Centre for Human & Applied Physiological Sciences, King’s College London



body related to ageing is the *one that fails first for the individual as this leads to a domino effect and ultimately multimorbidity*. In some, sarcopenia will lead to decreased muscle strength, problems with mobility, frailty, weak bones (osteoporosis), falls and fractures, decreased activity levels, diabetes and middle-age weight gain. In others, poor eyesight or a more sedentary lifestyle brought about by changes to working habits will make it harder for the body to maintain a higher proportion of functionality. Chronic sleep deprivation is also associated with increased risk of anxiety or depression, cardiovascular disease and increased inflammatory markers in the body.

The Physiological Society will therefore promote the message to policymakers and the public that the most important system in the body related to improved lifelong health and healthy ageing is the one that fails first for the individual. For policymakers, this means that a focus on interdisciplinary working and interdisciplinary sciences such as physiology are crucial and policymakers must give these disciplines the prominence and recognition they require. This will be particularly significant in the shift towards lifelong health as a process of maintaining and improving intrinsic capacity for as long as possible to boost healthy life years. To achieve this, The Physiological Society will look to engage those involved with public messaging and those who work with people most at risk from rapid functional decline to share physiological research on the impact that one system's failure can have on the development of co-morbidities. In turn, we hope that other external actors will shift from a managing multimorbidity model of health to a more proactive model of prevention focused on maintaining or regaining function.

Conclusions and recommendations on current physiological research

While The Physiological Society welcomes the Government's funding for a healthy ageing agenda, we are concerned that the Government is too focused on responding reactively to ageing, rather than being proactive in challenging the causes of ageing and the ageing process itself. We believe that this means the Government, health service and associated public bodies will not make the step change we need to see in their response to this ageing challenge.

Recommendation 1: The Physiological Society will demonstrate the value of physiological research consistently and clearly to Government departments, executive agencies and other scientific disciplines.

Contemporary physiological research is core to providing answers to some of the questions that will need solving in order to meet the Government's "Healthy Ageing" Grand Challenge by 2035. For example, to understand how physical activity influences immunosenescence and whether it also leads to improved responses to infections and vaccinations.

Recommendation 2: The Physiological Society will collaborate more closely with other organisations to build consistent messaging on the most urgent steps required to meet the Government's ambition in this area.

Personalised medicine is an important part of the Government's health strategy but not currently understood within the context of physiology and the benefits it can offer in promoting lifelong health and healthy ageing.

Recommendation 3: The Physiological Society will look to build consensus with other organisations around supporting tailored advice for maintaining physiological function.

Ageing is a multifaceted process that impacts all the systems of the body. The most important system for ageing, therefore, is the system that fails first in the individual.

Recommendation 4: Biomedical research should place greater emphasis on the maintenance of function, the slowing of functional decline, disease prevention and a coordinated approach to multimorbidity rather than a single-organ curative approach.

Recommendation 5: The Physiological Society will encourage a dialogue between physiologists and other researchers in emerging research on biomarkers to ensure biomarkers are rigorous.

Recommendation 6: The Physiological Society will engage those involved with public messaging and those who work with people most at risk from rapid functional decline to share physiological research on the impact that one system's failure can have on the development of co-morbidities.

CHAPTER 2 | FUNDING

Where should funding bodies direct funding into healthy ageing?

In understanding how best funders can direct healthy ageing funding, we must first recognise the breadth of funding organisations operating in the bioscience space. Funders that have been included as part of this report are based in the UK and Europe and range in size from awarding less than 50 grants per year all focused on ageing-related research, to funders which award hundreds of grants into biological research, of which some is into the physiology of ageing. With the creation of UK Research and Innovation (UKRI) and the Government's commitment to increase research and development (R&D) spending to 2.4% by 2027, there is an excellent opportunity to review how funders establish priorities for their funding calls and the extent to which physiology research projects are funded and understood as critical to multidisciplinary responses to healthy ageing.



The Society convened evidence-gathering workshops bringing together a number of funders as well as former members of funding panels. The Society also undertook a short piece of research to better understand the number of physiology research projects based in the UK that had been commissioned by public and private funders since 2010, the value of those projects and changes year on year. In addition, The Society met with representatives of UKRI to understand how they promoted cross-council working through joint proposals.

The findings outlined below reflect these discussions with more information about the data used in this section of the report in Appendix 2.

As we have highlighted in the physiological spotlights in this report and the first chapter, physiology is fundamental to improving healthy ageing. The following section is focused on physiology research funding across subject areas, rather than specifically physiological research into ageing.

What is the funding landscape for physiology?³³

One of the challenges of understanding the funding landscape for physiology is the multitude of different ways that physiology is recorded by the different organisations that fund projects related to the discipline. The graphs in this section are designed to give an approximate overview of the funding landscape for physiology. We would encourage funders to work with The Physiological Society to develop a more exhaustive and rigorous system of benchmarking the overall number of physiology grants awarded, overall value and average value of grants over time.

Part of the challenge of identifying the success of physiological grant applications over time is that funders do not always disclose the percentage of applications that are unsuccessful or their projected costs (Alzheimer's Research UK is a notable exception in this case). An additional challenge is the breadth of science covered by physiology. Figures 8, 9 and 10 therefore are designed to work in concert to give a sense of the funding landscape for physiological research from a cross-section of funders.

Using available data from research councils and other funding bodies collated by *Dimensions*, we can see from Figure 8 that the main sources of funding for physiological research in the UK are the Biotechnology and Biological Sciences Research Council (BBSRC), Medical Research Council (MRC) and the Wellcome Trust. However, it should be noted that funding from European sources forms a significant minority of physiological funding which could be threatened in the face of Britain's changing relationship with the European Union and specifically the future Horizon Europe research funding programme.

While it appears that the number of grants awarded for physiological research has oscillated over the past 10 years among most funders, there has been a slight decrease in the number of successful grants awarded by the Wellcome Trust. It is noteworthy to see the increase in funding for "physiology" projects funded through the Engineering and Physical Sciences Research Council (EPSRC). This could be due to cross-council funding being assigned to a lead council or an increased focus on harnessing technology for health including areas such as portable medical scanners³⁴ and 3D printing³⁵.

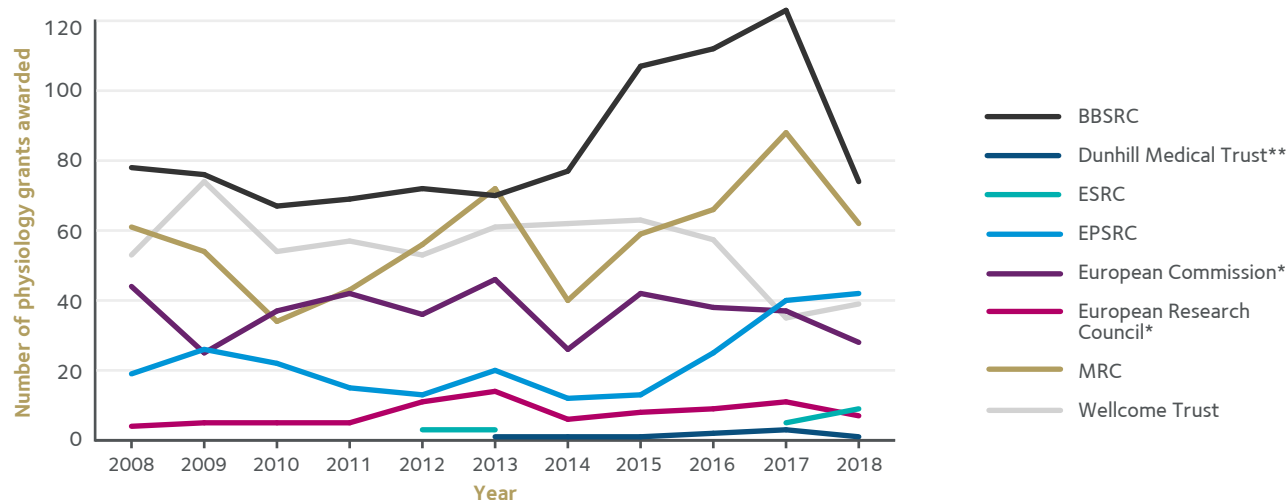


Figure 8 Number of grants awarded including the term "physiology" or "physiological" by major funders 2008 – 2018.

³³ Data drawn from Dimensions software that captures all UK and European funders that fund projects based in the UK 2010–2018. More information about how this information was processed can be found in Appendix 2

³⁴ Engineering and Physical Sciences Research Council (2017), *Portable medical scanner – quantum physics meets medical diagnosis*. [Online] Available at: epsrc.ukri.org/newsevents/casestudies/lori/lifestyle/health/portable-medical-scanner-quantum-physics-meets-medical-diagnosis/ [Accessed 17 Sept 19]

³⁵ Engineering and Physical Sciences Research Council (2017), *3D-printed implant tech – transforming lives*. [Online] Available at: epsrc.ukri.org/newsevents/casestudies/3d-printed-implant-tech-transforming-lives/ [Accessed 19 Sept 19]

* For the purposes of the graphs, "European Research Council" funding includes "FP7-IDEAS-ERC" or "H2020-EU 1.1" projects. All other European Commission funding is recorded as "European Commission".

** Please note that the increase in physiology grants as a proportion of overall grants in 2017 for the Dunhill Medical Trust is likely to be due to the relatively small number of grants awarded by this funder year on year. For example, Dunhill Medical Trust awarded 34 grants in total in 2016 and 24 grants in 2017, compared to over 1000 BBSRC grants each year 2014 – 2018.

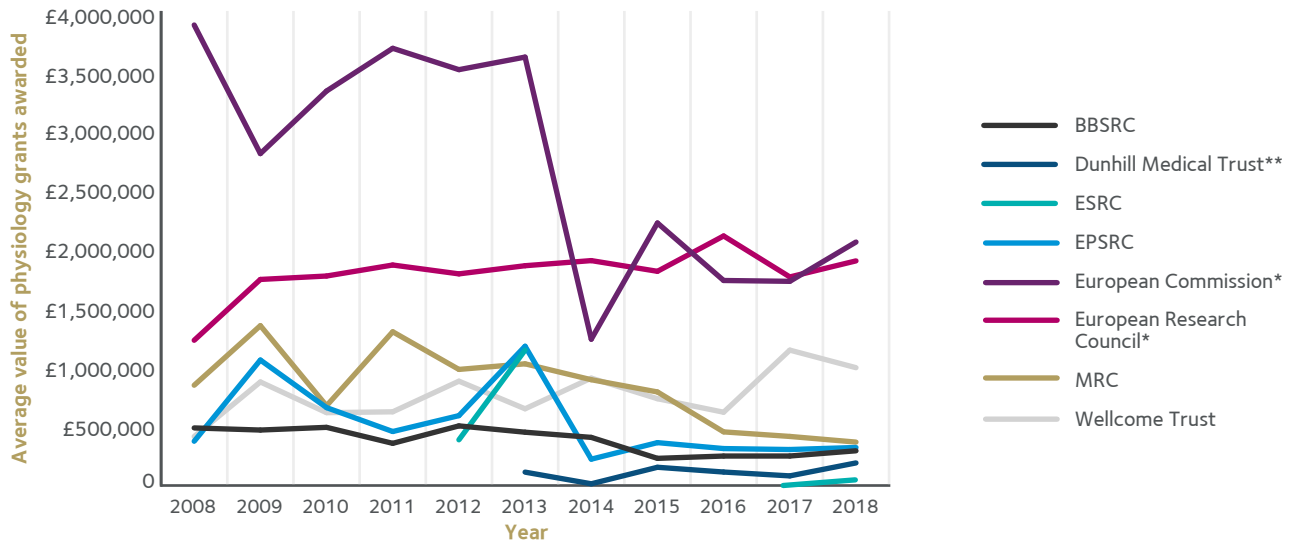


Figure 9 Average value of funding for projects including the term “physiology” or “physiological” from selected funders 2008 – 2018.

It is also interesting to compare the number of successful grants with the average amount those grant recipients are awarded (Figure 9). It is clear from comparing these data from Figure 8, that while BBSRC awards the most grants in physiology, the average value of the grants awarded is smaller than those of the Wellcome Trust, MRC and the European funders. The discrepancy between UK and European funders is likely to be caused by the size of the consortia developed for European grant applications.

It is worth noting that different “types” of science have different costs associated with them. UKRI have noted, for example, that costs associated with animals in research are more common and higher in MRC grants and that the proportion of funding made available through responsive mode streams can also have an impact on the size of the applications made by researchers.

The Physiological Society is interested in better understanding the average value of grants awarded in physiology by MRC compared to BBSRC grants between 2008 – 2018, recognising that while historically MRC grants have been larger, the gap has closed since the foundation of UKRI in 2018.

There is a perception among physiologists that physiology research is underrepresented in successful grant applications

Throughout the course of the workshops The Physiological Society convened, it became clear that there was a discrepancy between the expectation of **funders** and **researchers** applying for funding for physiological projects.

Funders spoke of a desire to fund physiological research; from the perspective of **researchers**, physiologists felt

that a disproportionate number of their research proposals did not receive funding. It was suggested that this could be caused by a number of different factors such as:

- a lack of physiological expertise among panel members;
- the relatively low impact factor of physiology journals compared to discipline-leading journals in other areas;
- the added complexity of multidisciplinary projects which required additional explanation or a concern that multidisciplinary projects shackled researchers within the proposal to certain aspects of research that fed into a wider objective rather than focusing on the researcher’s primary interests.

Regardless of cause, it seems from Figure 10 that the number of grants awarded to physiological research as a proportion of total grants awarded since 2013 has remained either static or declined**. It is also apparent that the proportion of grants awarded to the discipline of physiology overall is modest at best. With the Government committed to focus on healthy ageing and increased R&D spending, there is an opportunity for more funding to be made available into the kind of physiological insight into healthy ageing highlighted in the “research spotlights” in chapter one of this report.

Funders were keen to engage with **researchers** during the application process to help them better understand the expectations of proposals and review applications pre-submission, but some noted that there were often challenges related to resourcing that limited their ability to do this.

Researchers encouraged funding organisations to publish the success rate and number of applications for different grants so as to help improve the transparency of the grant-giving process. There is currently too little dialogue between **funders** and applicants on funders’ expectations

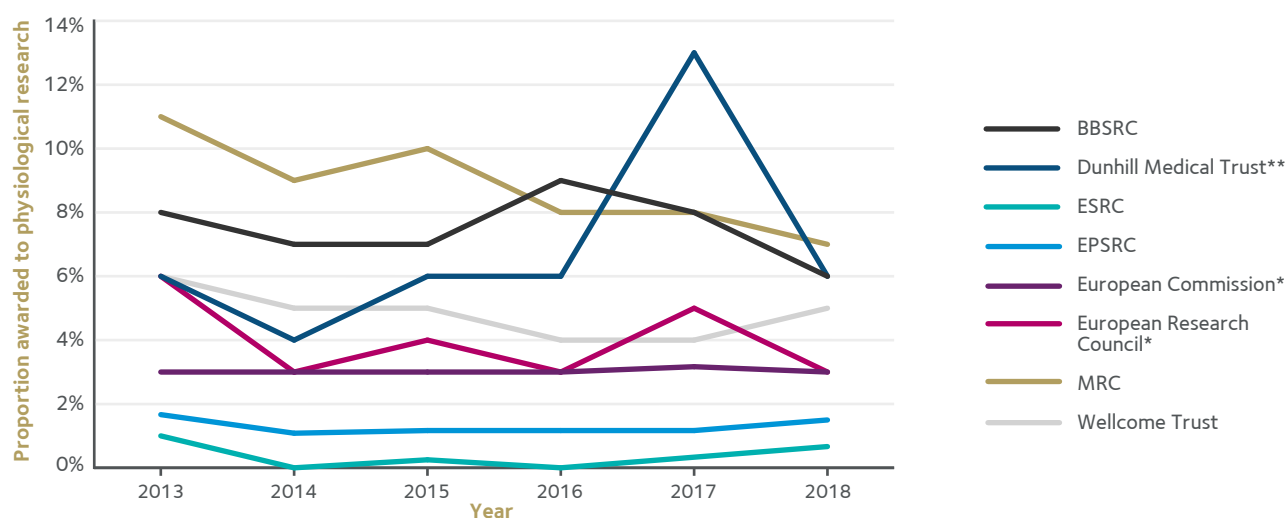


Figure 10 Proportion of all grants awarded by selected funders that include “physiology” or “physiological”.

for applications. These expectations vary across different **funders** and, for UKRI, could be remedied through a more effective cross-council application process.

Funders are looking to fund innovative, multidisciplinary and impactful research and **researchers** must do more to demonstrate their research meets these criteria. Some **funders** suggested that the integrative nature of physiological research meant that physiologists are uniquely placed to be principal investigators for multidisciplinary research applications bringing together other specialists, with geriatrics and the Government’s prioritisation of antimicrobial resistance being given as examples of where this could be particularly beneficial.

Funders also expressed concerns that grant applications are too often focused on one area of scientific research and that grant applications would be strengthened by including demonstrable expertise from other disciplines.

Funders and **researchers** who took part in our project workshops highlighted the need for more physiologists to be members of grant panels to improve the understanding of the value of physiology across the scientific community. This would help physiologists to be able to meet the expectations of grant reviewers, who are looking for clear impact, implementation and originality. To this end, The Physiological Society will embed dialogue with **funders** into its engagement with the physiological community through events such as our Annual Conference. The Physiological Society will also look to increase dialogue with individual **funders** to understand better the challenges their funding streams are looking to address

and how physiologists can support this. For example, one funder that has been involved in the project made it clear that research projects need to be clearly distinct to previous research and targeted at a defined outcome or impact. The Physiological Society will also work to upskill members on grant application writing and this process has already begun with the first policy event at The Society’s conference, *Physiology 2019* in Aberdeen.

Researchers who have applied for funding expressed concern that the scale of the grants being awarded is not sufficient to undertake the longitudinal research required. As such, The Physiological Society will continue to engage proactively with **funders** at our conferences. We will also promote opportunities to join funding panels to our membership to ensure that physiology has champions as part of decision-making processes that can explain the value of physiological insight in research, or suggest that a better understanding of the mechanisms being targeted in the grant application is included as part of submissions.

“An awful lot of physiological research is studying models of pathophysiology because it’s easier to get funding that way.”

Workshop participant

Part of demonstrating the wider value beyond research is highlighting the significant economic contribution that physiology makes to the UK economy and the different aspects of the economy that rely on physiology to underpin their work. The Physiological Society will work with other organisations to demonstrate the economic

* For the purposes of the graphs, “European Research Council” funding includes “FP7-IDEAS-ERC” or “H2020-EU 1.1” projects. All other European Commission funding is recorded as “European Commission”.

** Please note that the increase in physiology grants as a proportion of overall grants in 2017 for the Dunhill Medical Trust is likely to be due to the relatively small number of grants awarded by this funder year on year. For example, Dunhill Medical Trust awarded 34 grants in total in 2016 and 24 grants in 2017, compared to over 1000 BBSRC grants each year 2014 – 2018.

benefits of physiological research and teaching on local and national economies. The Sport and Exercise Science project The Society undertook in conjunction with GuildHE and institutions across the UK is a useful case study for this. For example, the report highlighted the research being undertaken at Northumbria University, investigating the important role of tailored exercise programmes in improving the quality and duration of life for people living with breast, prostate and bowel cancer, which largely affect older people and are increasingly common in western societies³⁶.

Funding of physiology research into healthy ageing

Funders have a strong sense of the impact of multimorbidity but are not funding sufficient projects into common underlying mechanisms and precursors to disease. This can lead to physiology falling through the gaps between basic and applied research funding pools.

During evidence-gathering workshops related to both cutting-edge physiological research into ageing and discussions about the funding available for physiology, it became clear that there was a perception among **researchers** that **funders** have a strong sense of the impact of multimorbidity but there is currently insufficient funding for projects into common underlying mechanisms of ageing.

While **funders** such as Dunhill Medical Trust are focused on ageing as a whole, **researchers** must better communicate the mechanistic insight provided by physiology and the underlying commonality between different diseases to funders. **Researchers** expressed concerns that medically focused research into healthy ageing is targeted primarily at disease-specific age-related decline. Ageing occurs in all cells and is the main risk factor for the most prevalent diseases in higher-income countries³⁷. Yet because it is not a disease with a specific set of targets³⁸, demonstrating impact for funding streams which relate to specific organs or therapy areas is made harder, even if the research may have application across different organs simultaneously or may prevent the manifestation of disease. We understand that multimorbidity-specific funding streams are expected and may alleviate this, and The Society will work to ensure that they are publicised among its Members.

Health policy experts expressed concern that although the public were engaged with messaging about the value of early diagnosis, this was not supported by evidence or a wider understanding of health as being more complex than a binary state between “healthy” and “in ill health”. Similarly, those involved with interdisciplinary studies noted the inadequacy of current models of “health” which were static in their evaluations and did not reflect physiological understandings about the impact of exercise, diet, sleep and stress that could be indicators

RESEARCH SPOTLIGHT

Understanding the benefits of physical activity at a mechanistic level in humans

The Molecular Transducers of Physical Activity in Humans (MoTrPAC) programme is the largest targeted investment of funds from the US National Institutes of Health (US NIH) into the mechanisms of how physical activity improves health and prevents disease. Through the program, researchers across the United States will receive \$170 million over six years to study the molecular changes that occur during and after exercise and ultimately to advance our understanding of how physical activity improves and preserves health.

Although researchers have demonstrated that physical activity has positive benefits, little is known about the molecules that cause these improvements. An analysis of NIH’s 2013 research grant portfolio, combined with a review of published scientific articles, found few studies examining how physical activity promotes overall health. Most are looking at exercise as a treatment or prevention strategy for a single health condition (e.g. addiction, mood disorders, dementia, diabetes, obesity, cancer, heart disease, stroke, osteoporosis, chronic pain)³⁹.

While animal models will be used for tissue samples that cannot be taken from humans (e.g. brain and lung samples), MoTrPAC has been specifically designed to use human models over an extended period.

Funding for MoTrPAC is being provided from a joint fund managed by representatives from National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS), National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), National Institute on Aging (NIA), and National Institute of Biomedical Imaging and Bioengineering (NIBIB). As such, it represents a cross-funder approach to understanding the common underlying mechanisms that underpin age-related decline and the emergence of a variety of diseases.

of future ill health and remedied earlier at considerably smaller cost.

With this in mind, it is clear that **funders** should engage with physiologists to understand where current physiology research can add value to scientific understanding of the complexities of ageing such as multimorbidity. The Physiological Society will facilitate this by developing case studies highlighting how physiological research has wider implications for translational research and

³⁶ Emsi UK (2019), *Sport and Exercise Science: Impact on the UK Economy*. [Online] Available at: physoc.org/policy/sport-exercise-science-education-impact-on-the-uk-economy/ [Accessed 1 Oct 19]

³⁷ Niccoli T, Partridge L (2012), Ageing as a Risk Factor for Disease. *Current Biology* **22** (17), R741-R752.

³⁸ Alliance L (2018), Opening the door to treating ageing as a disease. *The Lancet Diabetes & Endocrinology*, **6** (8), 587.

³⁹ National Institutes of Health (2016), *Molecular Transducers of Physical Activity in Humans*, [Online] Available at: commonfund.nih.gov/MolecularTransducers/FAQs, [Accessed 1 Oct 19]

medical interventions. The Society should also survey its Members and the wider physiological community, to produce quantitative and qualitative data about the barriers to increased funding for physiology projects. This includes developing a better understanding of success rates of funding, the number of applications being submitted and the organisations who are receiving physiology funding applications.

Unique challenges of human ageing need a step change in attitudes to modelling to include a greater focus on human models

While cell and animal models will continue to provide valuable insight into the ageing process, some **researchers** identified challenges with the current prevalence of rodent models used in research into human ageing. As one example of this, it is difficult to apply information from one strain of rodent to a diverse human population while at the same time controlling for genetic differences in the mice. Likewise, in areas such as inflammation and physical activities, differences in the evolution and behaviour, respectively, make it difficult to translate findings in rodents into humans. Ultimately, no one model will be perfect. It is key that we integrate knowledge for different systems and models.

As such, there is an opportunity for **funders** to support more long-term physiological ageing research in human models. As technology progresses, we are now able to conduct both invasive and non-invasive human physiology experiments and measurements as never before, and the emergence of affordable “omics” techniques presents an opportunity to gain better insight into the molecular-level ageing process in people.

In order to increase the number of successfully funded human trials related to lifelong health and ageing, we will assess what proportion of articles in physiology journals use more than one type of model for their research so that we can assess the current levels and set targets on which we can advocate to funders.

Healthy ageing and UKRI

Researchers also expressed concern that while cross-council funding is available from UKRI, a lack of clarity from research councils as to the extent that this is happening creates a perception in the physiology community that there is a lack of understanding of the value of physiology to ageing research.

Overwhelmingly, there was a perception among **researchers** who had applied for funding for physiological research into ageing that the discipline faces the challenge of often falling between the gaps of different research council priorities.

“**Integrative human physiology is not quite epidemiological enough on the one hand and it’s not mechanistic enough on the other...It just falls between these two funding gaps.**”

Workshop participant

A number of physiologists highlighted a perception that BBSRC funding is limited to research focused on basic mechanistic activity with animal models and other research **funders** (such as MRC) focused on applied research. In this model, physiological research related to healthy ageing such as integrated human physiology falls between the two funding streams.

Researchers were optimistic that creation of UKRI would present an opportunity for the research councils to work in more regular and closer partnership in support of integrative sciences such as physiology. During our evidence gathering, The Physiological Society met with representatives of UKRI who suggested that this opportunity is already beginning to be realised. The research councils continue to recognise ageing as a multidisciplinary challenge requiring an integrative response. We recommend that UKRI take a multi-council approach to healthy ageing funding. **Funders**, including UKRI, should promote opportunities for physiologists to work collaboratively with other disciplines to address basic understanding of the healthy ageing process and the common challenges that underpin non-communicable, age-

“**We’ve a tension in terms of the research strategy and how you divide up the funding. If ageing became a disease, then we simulate drug development because that would be a therapeutic target. Whereas when it’s not a disease, then there’s more emphasis on lifestyle and other intervention.**”

Workshop participant

related diseases such as diabetes, obesity, cardiovascular disease, musculoskeletal disorders, respiratory disease, neurodegeneration, cancer and poor mental health and chronic fatigue and pain. The Physiological Society would support MRC and BBSRC to communicate calls for co-funded projects where mechanistic research is coupled with a medical application of preventing age-related decline to prevent disease and reduced healthspan.

In chapter one of this report we highlighted examples of innovative physiological research currently undertaken related to healthy ageing. It is areas such as these, which are inherently interdisciplinary, that require a joined-up approach between **funders**. The approach taken in the individual ageing funding streams highlighted in the box above should become the norm. We recommend that UKRI takes full advantage of its position to establish such a joint council approach. Given the importance of physiological research to tackling the healthy ageing Grand Challenge we also recommend that BBSRC plays a central role in such interdisciplinary funding models to ensure sufficient focus on common underlying biological mechanisms.

Meeting the 2.4% target requires a balanced approach to translational and basic science

The Physiological Society supports the Government’s mission-led strategic thinking within the context of increasing investment in R&D to 2.4% of GDP by 2027.

Highlighted examples of recent cross-council ageing funding streams

The **Lifelong Health and Wellbeing programme** that was established by the UK research councils in 2015 gives an indication of the type of cross-council and interdisciplinary funding pools which could be created, and the value of funds such as these is noted in the research spotlight provided from the LiveWell Programme that received funding in 2009 to develop more effective interventions in diet, physical activity and social connections to promote health and well-being in later life.

The **UK Prevention Research Partnership (UKPRP)** was a £25 million investment into understanding and influencing the social, economic and environmental factors that affect our health, with a focus on non-communicable diseases (NCDs). It was a new model of public health funding in the UK that sought to build and support interdisciplinary research teams. While this funding stream is welcome, none of the four consortia awards explicitly mention the importance of a better understanding of physiology although the focus of two of the network awards (maternal and child health and nutrition) provides an excellent opportunity for engagement with physiology research. A second wave of funding has been made available with a deadline for applications in November 2019.

The UKRI-NSFC joint call “**Understanding and Addressing Health and Social Challenges for Ageing in the UK and China**” is funded by UKRI, through the Economic and Social Research Council (ESRC) and the MRC, in collaboration with the National Natural Sciences Foundation China (NSFC). The call invites high-quality proposals between researchers in the UK and China which aim to enhance the evidence base on understanding and addressing health and social challenges facing ageing societies through interdisciplinary collaborations.

Healthy ageing is a major research challenge in the UK and China so it is hoped that collaborative working will build networks and capacity while making novel contributions to the evidence base on healthy ageing and providing evidence for key stakeholders in policy and practice in the UK and China.

RESEARCH SPOTLIGHT



Demonstrating the value of ageing-specific multi-disciplinary research funding

There is strong evidence that lifestyle factors including diet and physical activity influence the ageing trajectory. However, there is a significant knowledge gap in how to develop interventions that are acceptable and effective in changing these behaviours and that have demonstrable benefit in improving health and well-being during ageing. In addition, there is a lack of outcome measures that can be used to evaluate such interventions.

In the LiveWell Programme of research, we focussed on retirement as a window of opportunity for interventions with potential to reduce the risk of age-related conditions, to improve health and well-being and to reduce health and social care costs. We used funding from the Lifelong Health and Wellbeing initiative to develop and to pilot a web-based intervention platform (called LEAP) that provides individualised support to facilitate and sustain healthier dietary choices, to increase physical activity and to enhance social connections. In addition, we developed a measurement toolkit for healthy ageing that assesses a wide range of physiological, psychological and sociological functions, each of which is affected adversely by the ageing process.

Our research within the LiveWell Programme provides an evidence base and practical tools for the development and implementation of scalable interventions to help everyone to age better and to reduce the personal, community and societal burdens associated with population ageing. For example, in the MedEx-UK research project (funded by Alzheimer’s Research UK), we are using a tailored version of the LEAP platform to deliver a personalised diet and physical activity intervention to older people at increased cardiovascular risk that aims to slow or halt age-related decline in cognitive function and to reduce dementia risk.

John C Mathers

Principal Investigator for The LiveWell Programme, Human Nutrition Research Centre, Newcastle University

Physiology is central to understanding the processes that are fundamental to the “ageing society” priority that has been identified by the Government. It is clear that there is a focus on the need for healthier ageing and the Government has included the ambition for “five healthier life years” in the Industrial Strategy, shifting the emphasis away from increasing lifespan to increasing *healthspan*.

In order to achieve this, the research pipeline needs to be maintained to ensure that the Government can meet the objectives set out within the Industrial Strategy Challenge Fund (ISCF). Translational businesses and technologies that are attractive from an investment perspective do not exist in a vacuum and pure research is able to develop ideas and solutions for problems that have not as yet been identified by national governments. Investment in research should therefore look to representatives from across the whole research spectrum to ensure a balance.

The Society has a crucial role to play in raising the profile of physiology as a crucial discipline in promoting a holistic approach to lifelong health and healthy ageing.

Conclusions and recommendations on future physiology funding

There is currently a lack of standardised benchmarking for funding into physiological research across funders and within UKRI, making it hard to assess the value and impact of funding over time.

Recommendation 7: We would encourage funders to work with The Physiological Society to develop a more exhaustive and rigorous system of benchmarking the overall number of successful physiology grants awarded, overall value and average value of grants over time.

The main sources of funding for physiological research in the UK are the Biotechnology and Biological Sciences Research Council (BBSRC), Medical Research Council (MRC) and the Wellcome Trust. While BBSRC awards the most grants in physiology, the average value of the grants awarded is smaller than those of the Wellcome Trust and MRC.

Recommendation 8: The Physiological Society will work with funders to better understand reasons for trends in physiology grant funding into ageing over time.

Funding for physiology can fall through the gaps between basic and applied research funding pools.

Recommendation 9: UKRI should develop programmes of work to promote research underpinning the biological processes of ageing across the research councils.

Recommendation 10: UKRI should co-fund more projects where mechanistic research is coupled with a medical application of preventing age-related decline to prevent disease and reduced healthspan.

There is a perception among physiologists that physiology research is underrepresented in successful grant applications.

Recommendation 11: Physiologists must ensure they are aware of the requirements and expectations of funding bodies and engage more with funders throughout the application process where possible in what remains a highly competitive funding landscape.

Recommendation 12: The Physiological Society will encourage a diverse selection of members to participate in grant panels and parliamentary scrutiny as experts in the value of physiology into ageing. The Physiological Society will embed dialogue with funders into its engagement with the physiological community through events such as our Annual Conference.

There is a lack of recognition from funders and research institutions of the financial contribution of physiology to UK research and development and the wider UK economy.

Recommendation 13: The Physiological Society will work on distinct projects such as its joint report *Sport and Exercise Science Education: Impact on the UK Economy* with GuildHE to build a bank of evidence in support of the economic, as well as scientific, benefits that the discipline offers.

Unique challenges of human ageing acceleration such as the heterogeneity of the population and sedentary lifestyles need a step change in attitudes to modelling to include a greater focus on human models.

Recommendation 14: Funders should fund projects that harness technological advances in both invasive and non-invasive human physiology to gain better insight into the molecular-level ageing process as it specifically affects humans.

Recommendation 15: The Physiological Society will assess what proportions of articles published in physiology journals use more than one type of model for their research to establish a benchmark to monitor this.

Funders have a strong sense of the impact of multimorbidity but are not funding sufficient projects into common underlying mechanisms and precursors to disease.

Recommendation 16: Physiologists should act as principal investigators on multidisciplinary research to bring other specialists together.

Recommendation 17: The focus and prioritisation of resources to chronic diseases can only be a stop-gap solution and reinforces the need to support science that is focused on prevention.

CHAPTER 3 | INTERDISCIPLINARY WORKING

How can we develop an integrative approach to the physiology of healthy ageing research?

As can be seen in Figure 11, exciting, innovative physiological research covers “translational physiology, cognitive neuroscience, systems biology and basic biology” of what *Seals et al.* call “physiological geroscience”. In order for this research to help support the improvement of function and achieve Figure 11 checklist goals, physiological research needs to be coupled with a variety of different disciplines focused on lifelong health. Physiology, with its focus on function, systems and the relationships between different parts of the body, is the integrative biological science. It is uniquely positioned to support other disciplines with its mechanistic insight into how maintaining or improving function can have a tangible outcome as we age.



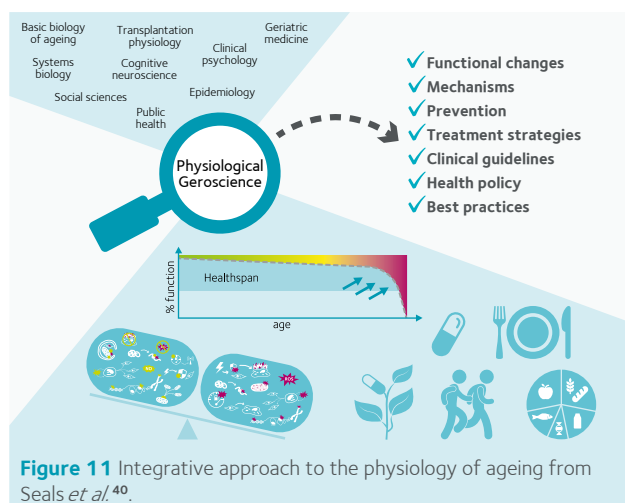


Figure 11 Integrative approach to the physiology of ageing from Seals *et al.*⁴⁰.

Throughout the research for this project, The Physiological Society has engaged with experts who have expressed concerns that there are a number of barriers to putting interdisciplinary working front and centre despite its clear benefits and the need to work collaboratively to address challenges in lifelong health, which are by their nature multi-faceted and closely interconnected. Preventing falls among elderly people, for example, involves physiological insight into gait, balance, delirium, sarcopenia, vision, motor and cognitive impairment, pharmacology, dehydration and impact of infections or pain as well as other disciplines. Once these complex relationships are understood, there is then the process of working with clinical staff and allied healthcare professionals to ensure that this insight is translated into clinical practice.

The main challenges that were raised through our expert workshops related to:

- a lack of recognition of the value that physiological insight into the basic processes of ageing that are being targeted in other areas of research;
- a lack of funding available for integrated projects that bridge the gap between basic and applied research;
- a shift in current educational practices away from focusing on physiology in medical and nursing qualifications and a lack of cooperation with clinical staff that work with patients who could benefit from physiological insight.

Physiology as a discipline is core to understanding all the different components associated with age, health and well-being

As previously discussed, physiology is the integrative biological science because of its focus on integrating molecular, cellular, systems and whole-body function. Putting exercise programmes, diets, sleep hygiene and adapted built environments in place can only be effective

RESEARCH SPOTLIGHT



Using physiological insights to better monitor healthy ageing and prevent adverse events

Physiological resilience – how the body responds to and recovers from a stressor – is integral to health in older age. Resilience is a dynamic property, so it can only be determined through “stress testing”, that is, measuring both the stressor and response. Examples include blood pressure response to the stress of standing up from lying down, or blood flow to the brain during the stress of a cognitive task. Acute syndromes common in older people, such as delirium or falls, essentially arise through impairments in resilience.

We have been developing methods to define physiological changes in response to controlled stressors in clinical studies. Age-related changes are likely to reveal themselves optimally under physiological stress conditions. Our overall strategy is to perform these laboratory measures (controlled stressors and responses) in participants being followed in a longitudinal study capturing acute events such as illness and hospitalisation.

We hope that this research will achieve three things: establish measures of physiological resilience as a way of predicting future acute health events; develop mechanistic insights into physiological resilience as a target for clinical trials to improve healthy ageing; and impact the assessment and management of older people in clinical practice through a Comprehensive Geriatric Assessment that helps healthcare professionals assess older people and tailor their treatment or care plans accordingly to maximise their intrinsic capacity.

Ultimately, better understanding of physiological resilience is likely to have direct clinical utility through individualised risk for therapeutic decision-making; enhancing acute care through rapid detection of adverse risk; and more targeted rehabilitation strategies before surgery or after acute illness. Taken together, we envisage that our methods to predict and assess resilience and vulnerability in older persons will thus contribute to preventing disease and disability and reduce health and social care costs.

Dan Davis
Senior Clinical Researcher and Consultant Geriatrician, MRC Unit for Lifelong Health and Ageing at UCL

⁴⁰ Seals DR *et al.*, Physiological geroscience: targeting function to increase healthspan and achieve optimal longevity. *Journal of Physiology*, **594** (8), 2001 – 2024

when coupled with an understanding of the processes that are happening in the body and how to maximise positive changes.

Experts that have been consulted throughout this project have expressed concerns that other disciplines do not sufficiently benefit from the advantages of including physiology as part of grant applications or joint working. The research spotlight in this section is an excellent example of where interdisciplinary working has resulted in positive change for patients, using physiological research and insight to minimise adverse effects on the body.

Central to achieving a collaborative approach is the clear and consistent articulation of the value of physiology to the work of other disciplines and within the discipline itself. As such, The Physiological Society will work to develop case studies of interdisciplinary working to highlight where The Society's Members and the wider physiological community have added insight to research in further areas. In addition to bringing together physiologists from across the world, we will invite other disciplines to our conferences to share the application of physiological insight. This includes work such as The Physiological Society report published in collaboration with GuildHE, *Sport and Exercise Science: Impact on the UK Economy*. While this report was primarily focused on highlighting the economic impact of a sub-discipline of physiology to policymakers and senior academics in higher education, the report's case studies clearly demonstrate how physiological insight can be applied in scenarios as diverse as elite athlete rehabilitation, exercise oncology and preventing drowning through cold water immersion⁴¹. This has been achieved through collaboration with non-physiologists in the Sport and Exercise Science field and has clear application to the lifelong health agenda, but should be expanded to include other areas of physiology which could provide insight into areas such as disease prevention, progression and potential treatment options.

Likewise, we will work to ensure that other disciplines inform the focus of physiologists, fostering strong two-way dialogue between physiology and other disciplines. We will achieve this by bringing physiologists and other specialists together along with funders to better understand how physiology can demonstrate its value to funders. We will also share insight provided by funders

“Just because your blood pressure is okay, and your cholesterol levels are fine and so on, you're tick box healthy. But if you are completely sedentary at that point, is that likely to mean that some incipient thing is going to happen further down the line, that hasn't been picked up by your clinical tests at that point? It's an extremely important question. We don't know.”

Workshop participant

through the *Growing Older, Better* evidence-building process, that they are keen to learn more about both linking physiological science with behavioural science and barriers to the public adhering more closely to widely understood messages around lifelong health and healthy ageing. To achieve this, we will work in partnership with organisations such as Public Health England to ensure that their behavioural science work is complemented by physiological insight.

The population is ageing and an increasing proportion of older people are spending extended periods in ill health receiving treatment that maintains current function rather than looking to improve it even in later life

Through evidence-building for this report, it has been suggested that insight gleaned from physiological research, particularly in the area of exercise, is under-employed in the care of older people. Simultaneously, there were also concerns that research into older people is limited by the type of older person that is part of lab-based experiments. Understanding the optimum ageing process is integral to physiological research (see Harridge case study). Geriatricians noted that the study of improving function in later life was limited by focusing on trial participants that were often fitter than the average older person and with a

“I realised about three years ago that although I say I'm doing ageing research, I've mainly been studying people who are healthy. We also need to study the frail old lady who weighs 35 kg and we have no idea what her regional distribution of muscle mass is or the quality of that muscle.”

Workshop participant

substantially lower biological age compared to someone who lived in a care home or had recently experienced a major adverse health event such as a fall. As such, those involved in multidisciplinary research agreed that there was a significant amount of value to be gained in The Physiological Society working closely with organisations such as the British Geriatrics Society to promote reciprocal information sharing between organisations and researchers on ways to inform better ageing among those that currently have the most limited function. This was seen as particularly relevant in areas such as prescribing bedrest and preventing readmission to hospitals following acute adverse health events and proactively educating people about the importance of improving their own function to keep people out of hospital as much as possible.

In order to shift perceptions around ageing, The Physiological Society will engage with a broad range of civil

⁴¹ For more information please see Emsi UK (2019), *Sport and Exercise Science: Impact on the UK Economy*. [Online] Available at: physoc.org/policy/sport-exercise-science-education-impact-on-the-uk-economy/ [Accessed 1 Oct 19]

society groups and learned societies with an interest in lifelong health to ensure an alignment of goals and build our footprint in the lifelong health space and our role in consensus building (e.g. British Heart Foundation, Centre for Ageing Better, the British Society for Research into Ageing and the British Geriatrics Society). We will also form better links with clinicians (such as geriatricians, GPs, personal trainers, healthcare professionals and allied healthcare professionals) as an area rich in opportunities to translate basic physiological research into applied positive health outcomes for those facing the challenges of ageing most frequently. This link into lifelong health includes areas such as mental health and the reciprocal relationship between good mental health and improved physiology. This recognises the important link between physical and mental health.

Interdisciplinary working faces additional barriers of added complexity which can lead to a lack of available funding for integrated physiological projects that bridge the gap between basic and applied research

In developing this report, The Physiological Society found that there were a number of additional barriers to successful applications for interdisciplinary working including the promotion and coordination of interdisciplinary applications and ensuring that different aspects of the project are integrated together rather than viewed in the application as being distinct from one another. In order to facilitate interdisciplinary working becoming a norm, rather than disincentivised by more complex application processes, The Physiological Society will work with funders and those that have submitted successful inter-discipline projects to understand whether there is a need for supplementary application materials (such as FAQs, "how to" guides and case studies) to streamline the application process. Academics that participate in interdisciplinary working should also be more clearly rewarded for doing so either as part of their career progression or through the Research Excellence Framework process.

Physiology is underrepresented in medical and nursing training qualifications

As a result of The Physiological Society's Member engagement but also as part of our discussions for the lifelong health project, it has become clear that while physiology is still at the heart of medical and nursing degrees, it is no longer visible or explicitly taught as such. While the impact of this shift in focus is difficult to assess, it can lead to a lack of understanding about the contribution that physiological research can make to the practice of a new generation of clinical staff and allied health professionals.

RESEARCH SPOTLIGHT

Integrating physiology as part of a case-based approach to medical curricula



Scenario-based medical curricula are designed to develop students' understanding of basic science and clinical skills in a cohesive manner. However, there are concerns that the discipline of physiology could lose its identity within such curricula and that, as a result, students may fail to recognise the fundamental nature of physiology as a keystone of medicine. My colleague Jeff Allen and I recently evaluated the impact of our integrated curriculum on students' recognition and perception of physiology content. We found that although our students value physiology as a keystone of their medical training and recognise its relevance in principle, they have difficulty identifying specific physiology content in the case-based curriculum. Furthermore, although all students judged that knowledge of basic physiology is important in understanding the symptoms, process and treatment of disease, fewer recognised that basic science would be an important component of their future clinical practice. Our work suggests that the physiology content of integrated medical curricula should be identified more explicitly to emphasise the relevance of the discipline and to ensure appreciation of the significance of physiology research in informing clinical research and practice.

Sarah Hall

Reader, School of Biosciences, Cardiff University and Chair of The Physiological Society's Education, Public Engagement and Policy Committee

In order to combat this, The Physiological Society will foster links with Health Education England, Medical Schools Council and the Royal College of Nursing to better understand the self-identified knowledge gaps among early career healthcare professionals and contribute positively to those working with patients to ensure that they have access to the most up-to-date and relevant physiological research into lifelong health and healthy ageing.

Close and constant collaboration between the research and clinical communities will provide a feedback loop to ensure the latest research is always informing clinical actions related to healthy ageing and lifelong health in a manner described by Dan Davis in his research spotlight.

“ [Physiology] could inform the whole process from [clinical] intervention to support the public with healthy ageing...you want the public to age healthily and keep people out of hospital...and inform more clinically related questions when they are in bed. ”

Workshop participant

Conclusions and recommendations on how we can support integrative physiological approaches to healthy ageing

Physiology as a discipline is core to understanding all the different components associated with age, health and well-being.

Recommendation 18: The Physiological Society will engage in greater advocacy, including developing case studies, to ensure that physiological insight is included in the healthy ageing research of other disciplines to understand how specific aspects of research affect wider function.

Recommendation 19: The Physiological Society will promote synergistic links between physiologists and psychologists to understand how good mental health has a physiological benefit and vice-versa.

The population is ageing, and an increasing proportion of older people are spending extended periods in ill health receiving treatment that maintains current function rather than looking to improve it even in later life.

Recommendation 20: The Physiological Society will facilitate closer links with clinicians including geriatricians to promote physiology-based interventions to promote lifelong health.

Recommendation 21: The Physiological Society will engage systematically with a broad range of civil society groups and learned societies with an interest in lifelong health to ensure an alignment of goals and build our footprint in the lifelong health space (e.g. Centre for Ageing Better, the British Society for Research into Ageing and the British Geriatrics Society).

Physiology is underrepresented in medical and nursing training qualifications.

Recommendation 22: The Physiological Society will foster links with Health Education England, Medical Schools Council and the Royal College of Nursing to better understand the self-identified knowledge gaps among early career healthcare professionals and contribute positively to addressing these gaps.

Funders are interested in understanding how research outputs can be translated into behaviour change.

Recommendation 23: Physiologists should form greater links with behavioural scientists to deliver sustainable, impactful interventions.

Recommendation 24: The Physiological Society will continue to develop evidence to support the financial return on investing in physiology and its related sub-disciplines.

Interdisciplinary working faces additional barriers of added complexity which can lead to a lack of available funding for integrated physiological projects that bridge the gap between basic and applied research.

Recommendation 25: Institutions should put structures and support in place to reward and incentivise collaborative working between research groups, departments and institutions.

How can we translate physiological evidence into policy implementation?

Closing the gap between physiological insight and policy interventions

There are significant gaps in public, clinical and policymakers' understanding of the physiological evidence that can help people live longer and healthier lives. The Physiological Society believes that physiological insight is essential to support the development of relevant and impactful interventions – whether public awareness raising, activities and initiatives for individual behaviour change or broader national government interventions.



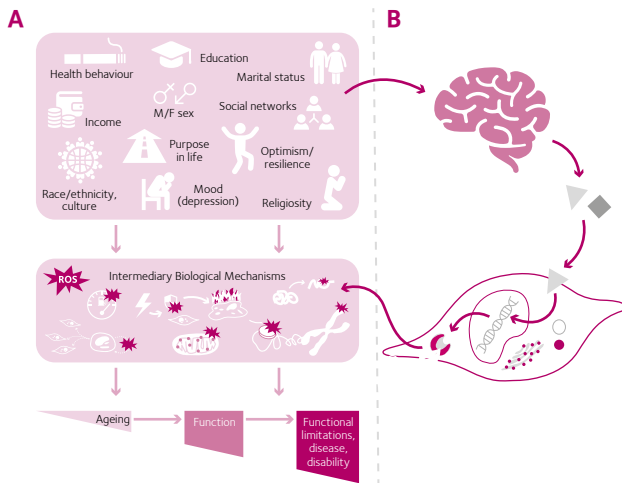


Figure 12 Image from Seals *et al.*, highlighting the reciprocal link between well-being indicators and cell health⁴².

At the same time, this evidence-based approach must be combined with a reframing of the public’s perception of “normal ageing” to support extended healthy life expectancy (or “healthspan”). We have found professional concern that the public often perceives ageing and loss of function as inevitable. This perception of ageing can prevent people from making positive changes to their lifestyle to maintain or improve function in later life or can lead to cessation of positive behaviour, such as physical activity. This further decreases function and speeds up the process of ageing.

Evidence from physiological research can enable individualised messaging for different groups in areas such as active lifestyles and eating well to have significant impacts on individual health outcomes.

Public perceptions of health and ageing

In order to widen the breadth of insight for this project, The Physiological Society commissioned a public perception survey to ask respondents their views on health, healthy decision-making and ageing. The survey was conducted by YouGov and a breakdown of respondents by gender, age, social class, region of the UK and working status is available in Appendix 1.

Significant sections of the population do not engage with healthy ageing campaigns or recognise the impact of positive lifestyle changes to the quality of later life. It is vital that public health guidance is grounded in physiological research and insight

Experts from both research and public health have reinforced concerns within the wider public health environment that the messages that are presented to the public are not fully received or acted upon. This could be because there are too many conflicting public health messages being communicated, dislike of government oversight, or because making sustainable, positive change is difficult in societies which are increasingly sedentary⁴³ and obese⁴⁴ and for a range of socio-economic reasons such as poverty, housing and “food deserts”. As Figure 13 shows, publicly

How likely, if at all, would you say that each of the following sources are to encourage you personally to make healthier life choices in the long-term?

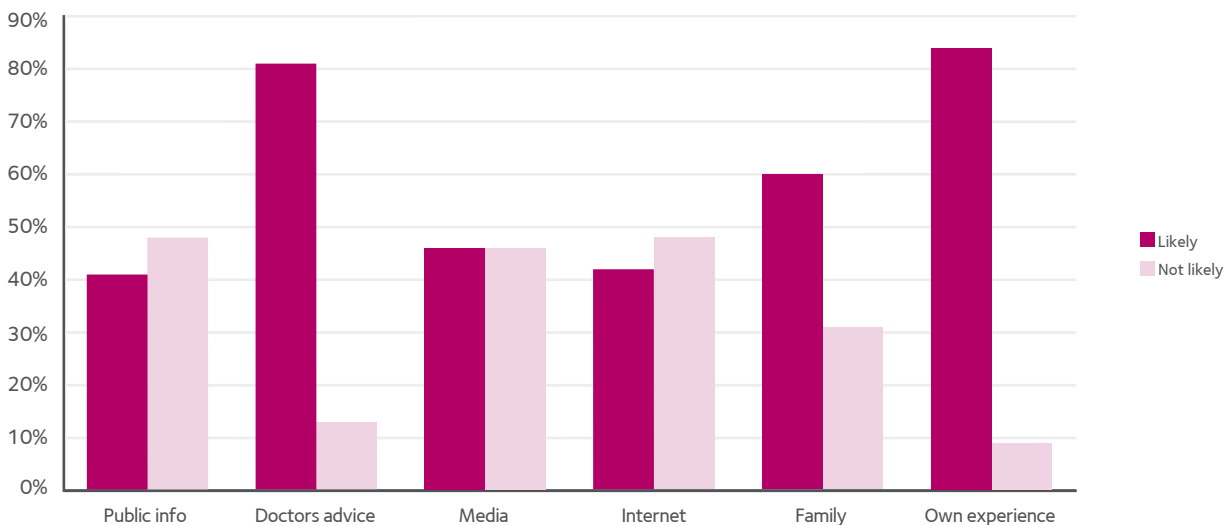


Figure 13 Responses to survey question “How likely, if at all, would you say that each of the following sources are to encourage you personally to make healthier life choices in the long-term?”.

⁴² Seals DR *et al.*, ‘Physiological geroscience: targeting function to increase healthspan and achieve optimal longevity’, *Journal of Physiology*, **594** (8), 2001 – 2024.

⁴³ Owen, N *et al.* (2010), Sedentary Behavior: Emerging Evidence for a New Health Risk. *Mayo Clin Proc.* **85**(12): 1138 – 1141.

⁴⁴ Baker C (2018), Obesity Statistics. *House of Commons Library Briefing Paper* 3336.

“I would like more information to make informed choices about improving my health”

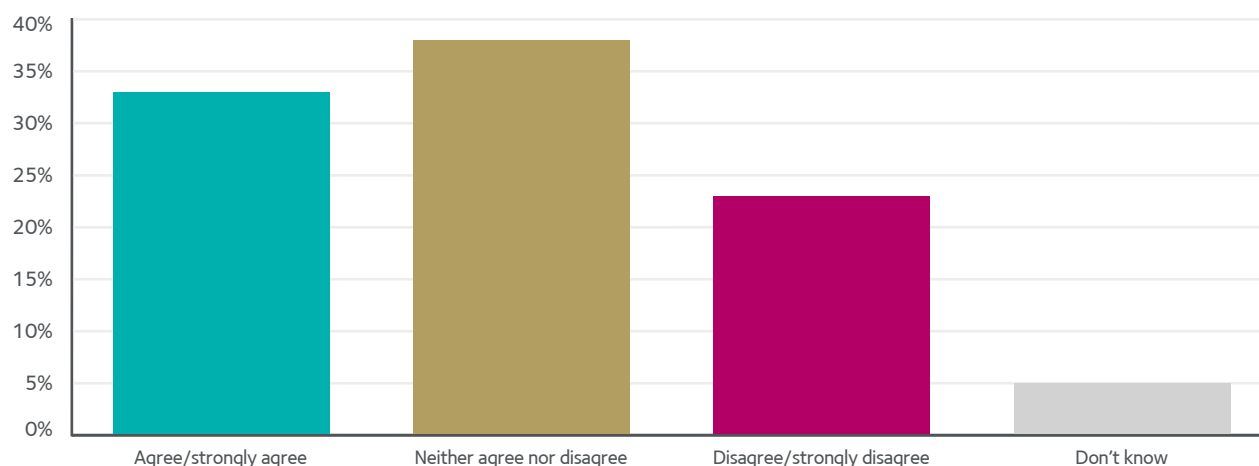


Figure 14 Responses to survey question “In general, to what extent do you agree or disagree with the following statement? ‘I would like more information to make informed choices about improving my health’”⁴⁵.

available information (such as public health campaigns, media promotion and information on the internet) scored significantly lower as effective methods of encouraging change than more individual experiences such as personal experience, influence of family or medical professionals. When we asked the public to agree or disagree with the statement “I would like more information to make informed choices about improving my health”, 33% agreed with the statement, 23% disagreed with the statement, and 43% neither agreed nor disagreed or didn’t know (Figure 14). The split between the responses may reflect an uncertainty within the responses given; are the public educated but not engaged or so overwhelmed with conflicting information that inertia sets in? It is clear that the general population is heterogeneous and as such, messaging around making positive lifestyle changes to improve healthy life expectancy needs to be tailored both in terms of the action required and the benefits it promises. We should also take into consideration that those involved in the survey did not believe themselves to be the target demographic for lifelong health messaging and as such, more work into behavioural science needs to be conducted to better understand how to communicate both the short- and long-term benefits of improved lifestyles. Understanding how we can best engage and support the public with up-to-date information given this trust barrier will be crucial in developing successful and proactive lifelong health messaging.

Figure 15 demonstrates a divergence between different age groups about what would motivate people to improve their health. Those aged 55+ years were more likely to value improvements to specific aspects of health (such as improved lung capacity, maintaining eyesight, etc.), whereas younger respondents were more likely to support a healthy lifestyle for wider benefits (such as being

cheaper). All age groups overwhelmingly agreed that greater feelings of happiness and being more energetic would be advantages that would motivate them to maintain a healthier lifestyle. This evidence suggests that tailoring public health messages is not just about ensuring the correct amount of exercise or diet for people in different stages of the life course, but also how these interventions are communicated. General happiness and longevity are of course important, but we must recognise that certain interventions will be more attractive to older people if they are positioned as having a measurable improvement on common manifestations of ageing.

There is agreement from our workshop participants and NICE public health guidance that the late 40s to mid-50s is likely to be the key time in the life course for putting in place actions to improve physiological state as a means to prolonging healthspan later in life. However interventions at later ages may well also be impactful as those in their 60s are likely to be approaching milestones such as the birth of grandchildren⁴⁶ and beginning to plan for retirement which are opportunities for successful interventions.

Challenging the perception that aging and physiological decline is inevitable

A recurring theme throughout this project has been how to challenge the prevailing view that physiological decline is an inevitable part of ageing that cannot be slowed through lifestyle changes. Physiological insight is increasingly demonstrating that it is possible to maintain intrinsic capacity until much later life (see Figure 5), if a series of health-positive decisions are made. It is of note that when surveyed on ways of increasing the number

⁴⁵ YouGov, “Question 4: In general, to what extent do you agree or disagree with the following statement? ‘I would you like more information to make informed choices about improving my health’”. The Physiological Society: Healthy Ageing, 4 – 7 January 2019.

⁴⁶ Leopold T, Skopek J (2015) The demography of grandparenthood: an international profile. *Social Forces* **94** (2) 809.

RESEARCH SPOTLIGHT

Using home-based High Intensity Interval Training (HOME-HIIT) to improve health and fitness among obese members of the public in Liverpool area



Having previously demonstrated that HIIT programs of three, 20-minute sessions per week are equally effective as endurance exercise training in improving exercise capacity, the EMARG team have now developed HOME-HIIT to remove known barriers to exercise, which include the costs of gym membership and the need to attend public gyms. HOME-HIIT can be delivered in the privacy of a home setting or with groups of equals in community centres without the need to access exercise equipment.

The studies involved 150 volunteers (with nearly a third recruited in collaboration with Sefton Council) and have shown that HOME-HIIT is as effective as HIIT and endurance training, performed in controlled exercise laboratories, in reducing cardiovascular risk and in improving VO₂max (the maximum or optimum rate at which the heart, lungs, and muscles in the human body can effectively use oxygen during incremental exercise) and recognised measures of metabolic health. In addition, online heart rate monitoring using a mobile app has revealed high adherence and compliance rates, further increased by weekly feedback by telephone.

The next step is to roll out HOME-HIIT into the Liverpool community in collaboration with Sefton Council. On the basis of the size of the improvements seen with HOME-HIIT and epidemiological studies, we expect that HOME-HIIT will add a minimum of five years to the healthy lifespan, in individuals managing to sustain long-term increases in habitual physical activity levels, with a particularly significant impact among individuals from a low socio-economic status.

Anton Wagenmakers

Exercise Metabolism and Adaptation Research Group (EMARG), Liverpool John Moores University

of years that people live in good health, survey respondents were more like to identify behavioural changes (such as eating a balanced diet, regular exercise and stopping smoking) than they were to rely on a genetic predisposition. Nevertheless, these pieces of evidence can work collaboratively to highlight that the public overwhelmingly recognise that there are positive steps that can be made to ensure better future health, even if they don't explicitly link it with healthy ageing. The role of The Society is to work with a range of organisations that can share key messages, such as public health agencies and charities, to ensure that this information is appropriately tailored and targeted at the correct audiences. This is particularly significant owing to the rise and accessibility of non-traditional sources of information for advice on human exercise physiology and nutrition⁴⁷. 42% of those we surveyed said that they use the internet including social media, videos and blogs as a source of information on healthier life choices and this was particularly pronounced in the 18 – 24 age group⁴⁸.

There is some suggestion from The Society's survey results that targeted messaging is already having an effect among certain groups. In our survey, respondents aged over 55 were more likely to agree that they had sufficient information about how to improve their general health and were more likely to recognise public health campaigns that are targeted at their age group (such as Drink Free Days and NHS Health Check) than younger audiences⁴⁹. However, public health campaigns will need to better use physiological evidence and research findings to ensure they maximise the benefits that can be made throughout the life course.

It is important that policy decisions around healthy ageing are multifaceted in approach, encompassing both individual responsibility and wider government policy. This includes supporting individuals to make healthy choices but also to ensure that wider determinants of health are considered (such as education, socio-economic background and town planning, and loneliness) to support healthier living. Policies such as salt reformulation, restricting smoking in public and sugary drinks tax have the potential to make a significant contribution to individual decisions regarding diet, smoking and exercise⁵⁰.

Physiological research can support these lifelong health policies by promoting credible and targeted evidence to fill gaps in public health messaging. Some experts

“A lot of early symptoms that could be treated effectively are put down to, ‘well it’s just my age’.”

Workshop participant

⁴⁷ Onambele-Pearson G, Tsintzas, K (2017), The rise in eminence of the pseudo ‘exercise guru’ in social media: A threat or opportunity for HE researchers. *Physiology News*, **108**, 22.

⁴⁸ YouGov, “Question 5: How effective or ineffective do you consider the following public health messages or campaigns to be in changing your personal behaviour?”, The Physiological Society: Healthy Ageing, 4 – 7 January 2019.

⁴⁹ YouGov, “Question 2: How likely, if at all, would you say that each of the following sources are to encourage you personally to make healthier life choices in the long-term?: Information from the internet (social media/ blogs/ websites/ YouTube videos, etc.)”, The Physiological Society: Healthy Ageing, 4 – 7 January 2019.

⁵⁰ He, FJ *et al.*, (2013). Effect of longer term modest salt reduction on blood pressure: Cochrane systematic review and meta-analysis of randomised trials, *BMJ*, 346:f1325.

were concerned that arbitrary targets (such as the amount of exercise achieved per week or the number of steps per day) were not supported by the most up-to-date physiological research and may act as a barrier to participation for some members of society as they are considered unattainable. *The UK Chief Medical Officers' Physical Activity Guidelines*, for example, recognises the need to reinforce the message that there is no minimum amount of physical activity required to achieve some health benefits, the importance of muscle strengthening and segmentation of the country by age range⁵¹. This reiterates that there is heterogeneous population and that The Physiological Society can work to ensure that physiological evidence is used as the basis of personalised plans, such as heart age or brain health tools.

The importance of multimorbidity

Decline in quality of life as we age is likely to reflect the combination of multiple health conditions and therefore the interplay between conditions can be significant. While there is growing recognition of the importance of multimorbidities, there is the challenge that much of the UK Health Service has been set up on a condition-by-condition basis. Health problems are understood by the public as being independent of one another, and they underestimate the extent to which they have agency of their own healthspan. The evidence basis around policy interventions that support multiple conditions is starting to develop. The Physiological Society would like to engage

more regularly with other public health organisations, local authorities and charities to better communicate the causal relationship between declining physiological function, declining healthspan and multimorbidity.

One approach would be to ensure that the research is in place to find answers for the benefits of personalised physiology plans based on a better understanding of biological age, and these are communicated to the public as part of the Government's commitment to personalised medicine. Personalised medicine is an important part of the Government's health strategy but is not currently focused on physiology and the benefits it can offer in lifelong health. Existing data sets such as the 100,000 Genomes Project should be harnessed to better understand which treatments are best suited to particular patients and facilitate a more individual and tailored approach to lifelong health, supported by the mechanistic understanding provided by physiology.

Health problems are understood by the public as being independent of one another

One of the benefits of an improved understanding of the insight of physiology among the public, would be a move away from disease-specific motivation towards a more integrative approach to lifelong health. As can be seen from examples such as the work of the Royal Osteoporosis

RESEARCH SPOTLIGHT



Using current and future physiological insight in the fight against neurodegenerative conditions

Further physiological research is crucial to understanding the function of the brain and the mechanisms in diseases like Alzheimer's that underpin the progression of dementia. In the meantime, public perceptions that dementia is an inevitable part of ageing are a serious barrier to the risk-reducing benefits of physiological interventions, such as diet and exercise. We also know the public don't make the link between their heart health and their brain health, so we need to use all relevant insight from physiological research to develop clearer public messaging.

Susan Mitchell
Policy Manager, Alzheimer's Research UK

RESEARCH SPOTLIGHT



Exercise physiology research underpins updated public health guidance for older people

The most disseminated general exercise guidelines, up to very recently, recommended 150 minutes of exercise a week. However, our research at Manchester Metropolitan University (MMU) suggests that older people, especially older women, who regularly move throughout the day, are more likely to have better bone health than those who carry out just one bout of high-intensity exercise a day.

The new UK Chief Medical Officers (CMO), updated advice on *Physical Activity for Older Adults Recommendations* notes that MMU's research "supports the benefits of being active throughout the day, such as better maintenance of bone health with higher volumes of light intensity activity spread throughout the day".

Gladys Onambele-Pearson
Deputy Director of the Musculoskeletal Science and Sports Medicine Research Centre, Manchester Metropolitan University

⁵¹ UK Chief Medical Officers (2019), UK Chief Medical Officers' Physical Activity Guidelines. [Online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/832868/uk-chief-medical-officers-physical-activity-guidelines.pdf [Accessed 3 Oct 19]

Society on their consensus statement *Strong, Steady and Straight*, part of the recovery process of a fracture is ensuring that other systems in the body are sufficiently well-maintained to compensate for the loss of bone strength⁵². Shifting perceptions away from limiting people's activity, unless there is robust physiological evidence, should be welcomed as a starting point for a "something is better than nothing" approach to lifelong health that is inclusive regardless of age or current physiological function. This has application throughout the body and presents an opportunity to leverage existing public interest to improve the quality of lifelong health dialogue with the public. For example, there has been a welcome shift in the public conversation around mental health and well-being and this is something that The Society should support as an area which demonstrates how an integrative, physiological approach can support whole-system approaches throughout life.

The Physiological Society's evidence on the public's attitude to ageing has identified the importance of happiness and mental well-being. When asked in our survey what advantages would make them more likely to adopt healthier lifestyle choices, 62% of respondents chose "happiness", which was the second most popular option across all age groups (behind "feeling less tired"), see Figure 17. Demonstrating how improved physiological

“If we take physiology as a holistic, integrative discipline, it will absolutely include [mental health]... Particularly the emerging evidence of the benefits of exercise, not just on muscle mass and function but also in mental health.”

Workshop participant

Understanding the relationship between social isolation and physiological decline

The recent Science Advice for Policy by European Academies (SAPEA) report into *Transforming the future of ageing*, notes the "strong evidence that socioeconomic position and social isolation are key determinants of health and ageing... a lack of social interaction is associated with all-cause mortality, cardio-metabolic and respiratory impairments and diseases, as well as reduced physical and cognitive performance".

The report notes the impact of the built environment, workforce discrimination and climate change as some of the drivers of social isolation but notes that this isolation can be associated physiologically with a heightened risk of cardiovascular disease, cognitive decline and an increased risk of dementia^{53 54 55}.

Physiology has a critical role in understanding the mechanistic reasons behind the link between social isolation and conditions associated with acceleration of the ageing process as the burden of these conditions increases both in terms of an ageing population and the length of time individuals are spending in ill health as they age.

Which one, if any, of the following health advantages would MOST encourage you to make healthier lifestyle choices starting today? (by age group)

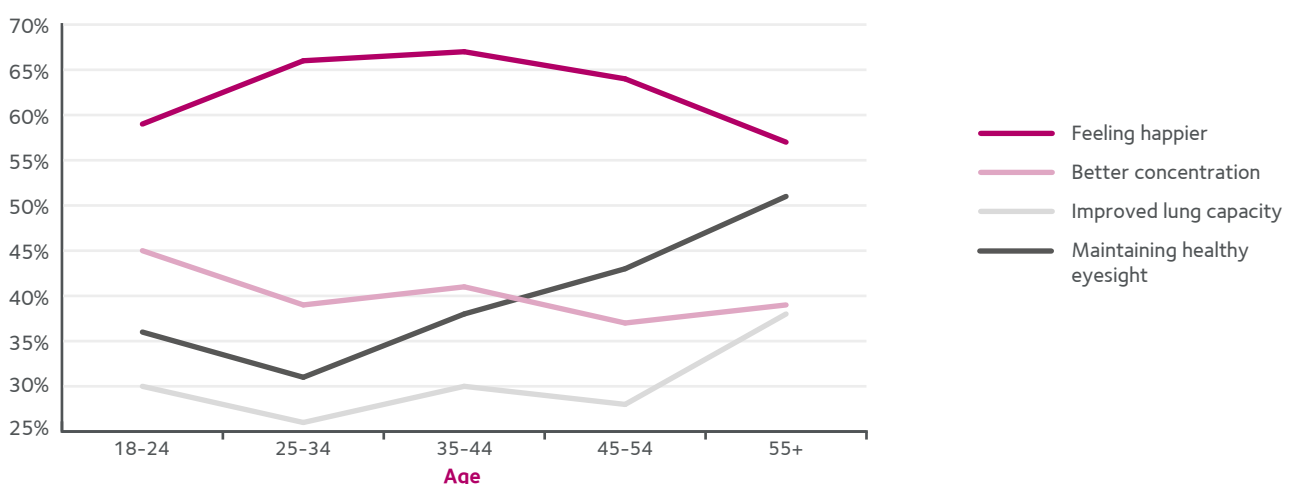


Figure 15 Responses to survey question "Which one, if any, of the following health advantages would be MOST encourage you to make healthier lifestyle choices starting today?" by age group.

⁵² Royal Osteoporosis Society, strong, steady and straight: an expert consensus statement on physical activity and exercise for osteoporosis. theros.org.uk/forms/documents/strong-steady-and-straight/, [Accessed 14 Aug 2019]

⁵³ Gow, AJ, & Mortensen, EL (2016). Social resources and cognitive ageing across 30 years: The Glostrup 1914 cohort. *Age and Ageing*, **45**(4), 480 – 486

⁵⁴ Kuiper, JS *et al.*, (2015). Social relationships and risk of dementia: A systematic review and meta-analysis of longitudinal cohort studies. *Ageing Research Reviews*, **22**, 39 – 57

⁵⁵ Kuiper, JS *et al.*, (2016). Social relationships and cognitive decline: A systematic review and meta-analysis of longitudinal cohort studies. *International Journal of Epidemiology*, **45**(4), 1169 – 1206

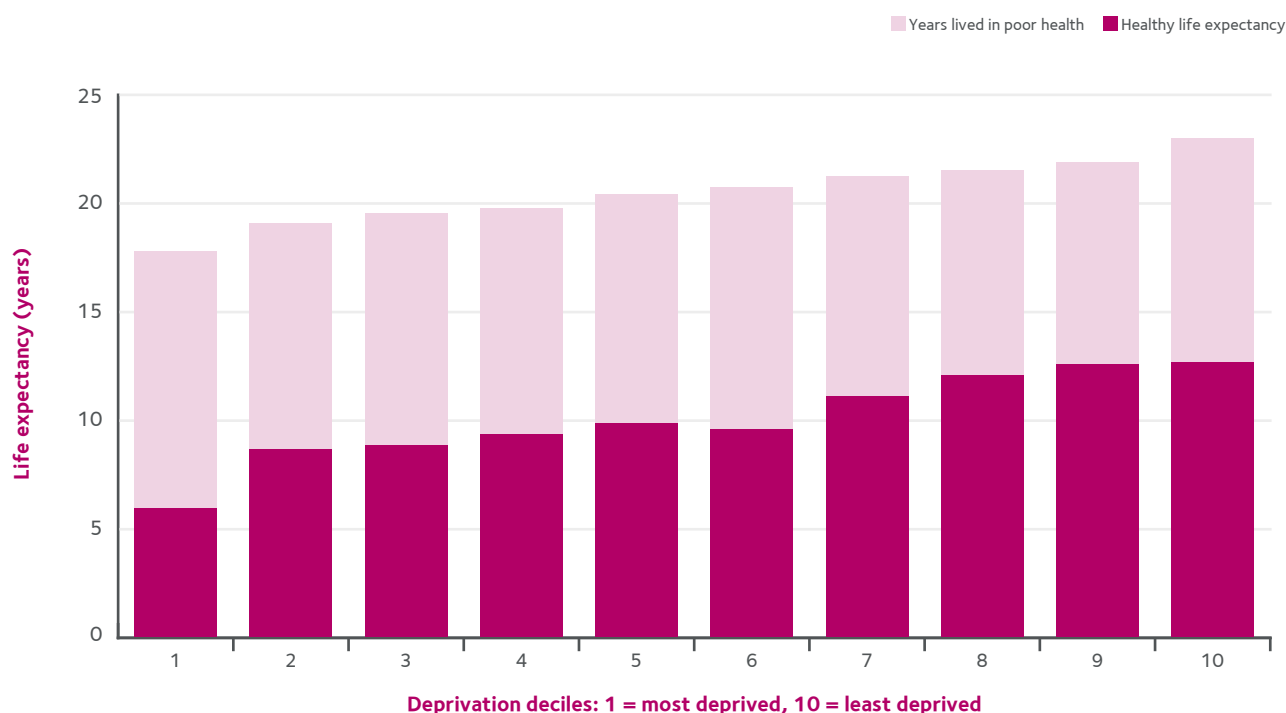


Figure 16 Life expectancy and healthy life expectancy (HLE) for women in Wales at age 65 2015 – 2017 by deprivation levels⁵⁶.

function can improve mental well-being could be of considerable public and policymaker interest. With this in mind, The Physiological Society will develop closer links with societies and organisations that explore the link between psychosocial interventions and physiology and encourage other organisations to ensure that physiological understanding is at the heart of understanding the physical and mental impact of social policy decisions.

Those that are socioeconomically disadvantaged are less likely to be engaged in activities and lifestyles that promote healthy ageing

Throughout evidence-gathering for the report, experts have regularly noted the correlation between socio-economic status and health and well-being indicators. As the Office for National Statistics data shows, for women aged over 65, the top 10% most affluent in society will live over twice as long in good health as women from the bottom decile (see Figure 16). At the same time, both life expectancy and healthy life expectancy increase as the levels of affluence increase.

The Society's independent survey results corroborate the strong correlation between affluence and improved health outcomes. Those from low-income backgrounds were less likely to feel sufficiently informed to improve their general health⁵⁷ and those from lower socio-economic backgrounds were over twice as likely to say that there was no tangible benefit that would encourage them to make healthier lifestyle choices⁵⁸. At the same time, those from low-income groups⁵⁹ are less likely to be confident that any change they make to their lifestyle is likely to have a positive impact on their health in later life (see Figure 17). This is undoubtedly a key challenge to meeting overall improvements in population-wide health, and therefore will need to be addressed in any healthy ageing policy agenda.

The risk of governmental fragmentation on policy implementation

The fragmentation of commissioning between local and national government in England for various aspects of lifelong health encourages a siloed approach to policy making. This has the potential to create barriers that will make it difficult to achieve healthy ageing targets.

⁵⁶ Office of National Statistics, "Female healthy life expectancy at age 65 years and years lived in poorer states of health: by national deprivation deciles, Wales 2015 to 2017", ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthinequalities/bulletins/healthstatelifeexpectanciesbyindexofmultipledeprivationimd/2015to2017#comparing-inequalities-in-life-expectancy-and-healthy-life-expectancy-between-2012-to-2014-and-2015-to-2017-england

⁵⁷ YouGov, "Question 3: I feel sufficiently informed about how to improve my general health should I wish to do so", The Physiological Society: Healthy Ageing, 4 – 7 January 2019.

⁵⁸ YouGov, "Question 6: Which ONE, if any, of the following health advantages would be MOST encourage you to make healthier lifestyle choices starting today?", The Physiological Society: Healthy Ageing, 4 – 7 January 2019.

⁵⁹ The C2DE social classes from the NRS social grades refer to households in which the chief income earner is a skilled manual worker; semi-skilled and unskilled manual worker; and state pensioners, casual and lowest grade workers, or unemployed with state benefits, respectively.

Insight into BAME perceptions of dementia

As part of the charity's 2018, Dementia Attitudes Monitor Wave 1 Report, Alzheimer's Research UK compared responses given by participants from a white ethnic group with those given by participants from black, Asian and minority ethnic (BAME) backgrounds.

Findings from the report include:

- People from BAME backgrounds are more likely to agree with the misconception that dementia is an inevitable part of getting older: a third (33%) agree, compared with 21% of those who are white.
- 29% of people from BAME backgrounds consider it possible to reduce the risk of developing dementia, compared with 35% of adults who describe themselves as white⁶⁰. This may reflect the younger age profile of BAME respondents, with 15 to 24-year-olds of all ethnic backgrounds less likely to consider it possible to reduce dementia risk than all adults (28% compared with 34%).

Structural barriers between commissioning organisations, separate budgets and differing organisational priorities make it much more difficult to implement broad, ambitious projects that may have the most potential to improve health outcomes. Initiatives such as Scotland's integration joint boards (IJBs) to which the NHS board and local authority both delegate the planning, governance and resourcing of existing responsibilities, give a clear responsibility to one actor in the system to deliver a more integrated system, a Chief Officer⁶¹. While these Chief Officers face similar barriers to integration as the English system, there is at least recognition that the integration requires an actor that is recognised as being responsible for driving change in a complex environment that is still heavily dependent on trust and goodwill between local stakeholders.

The Government should deliver joined-up policymaking that incentivises the most beneficial decisions to be made at the right point within the system. There is a tension between local government's responsibility for public health and leisure activities and the "savings" accrued to the nationally commissioned health service from healthier ageing and this is leading to reluctance among policymakers to invest in preventative services. The King's Fund has noted in its analysis of the Government's recently published *The Prevention Green Paper: A chance to turn talk into action*, that spending through the public health grant is up to four times as cost-effective as NHS spending⁶².

It is not that this benefit is not understood by policymakers, it is that the fragmented health service structure

Which one, if any, of the following health advantages would MOST encourage you to make healthier lifestyle choices starting today?

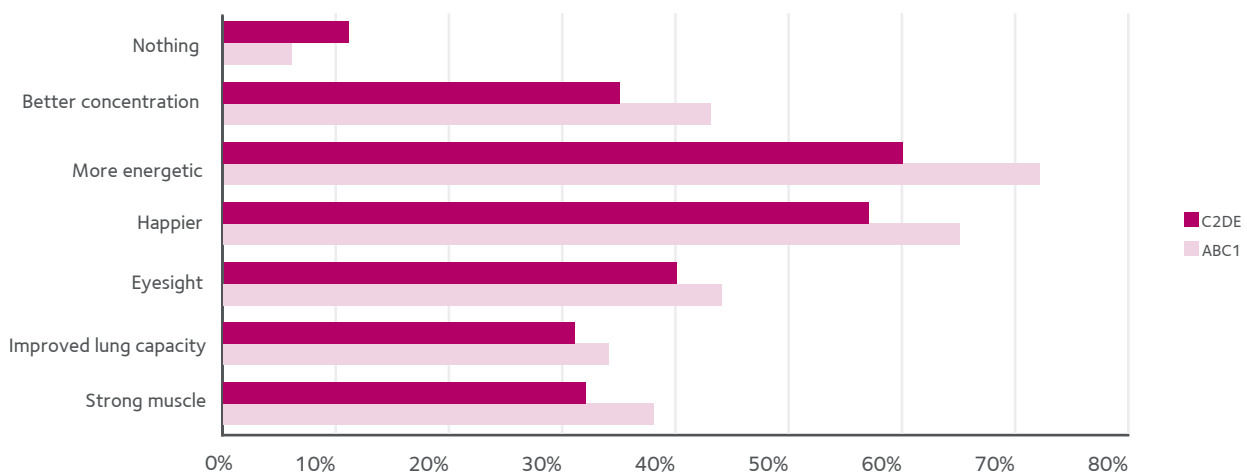


Figure 17 Survey responses to the question "Which ONE, if any, of the following health advantages would be MOST encourage you to make healthier lifestyle choices starting today?" by socio-economic group.

⁶⁰ Alzheimer's Research UK (2018), Dementia Attitudes Monitor: Wave 1 2018. dementiastatistics.org/wp-content/uploads/2019/02/Dementia-Attitudes-Monitor-Wave-1-Report.pdf#zoom=100, page 26

⁶¹ The King's Fund, Leading across health and social care in Scotland Learning from chief officers' experiences, planning next steps. kingsfund.org.uk/sites/default/files/2018-07/Scottish_officers_full_final.pdf, [Accessed 9 Sept 2019]

⁶² Buck, D, *Public health spending: where prevention rhetoric meets reality*, King's Fund, kingsfund.org.uk/blog/2019/07/public-health-spending-blog

To what extent, if at all, do you think the following factors are likely to increase the number of years you live in good health? (Very likely/fairly likely responses by socioeconomic group)

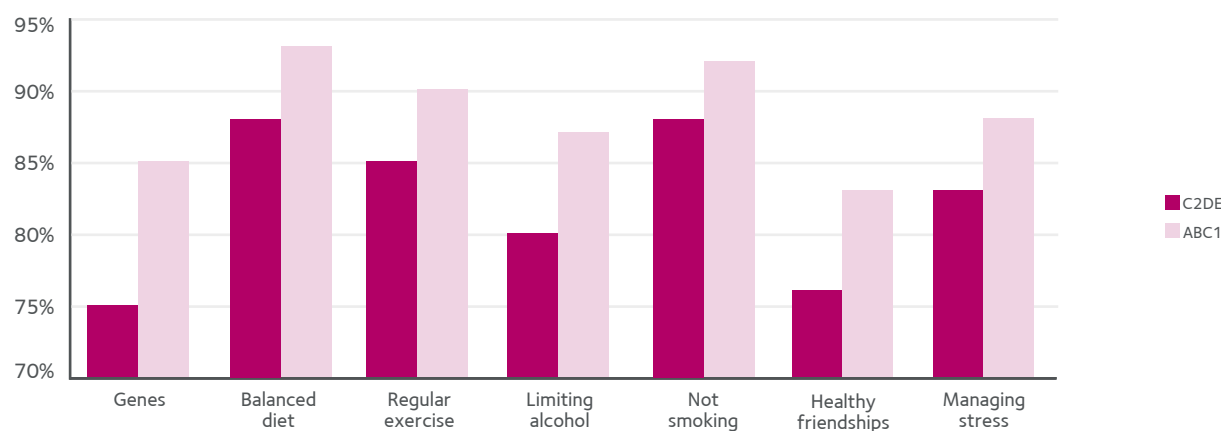


Figure 18 Survey responses to the question “To what extent, if at all, do you think the following factors are likely to increase the number of years you live in good health?” (Very likely/fairly likely responses by socioeconomic group).

disincentivises such joined-up thinking. At a national level, there is also the risk that individual departments focus on different priorities within the “healthy ageing” agenda to the detriment of maintaining or improving function in later life.

Using existing data sources to leverage change

The Public Health Outcomes Framework (PHOF) compiled by Public Health England sets out a high-level overview of public health outcomes, at national and local level in England, supported by a broad set of indicators, which include several relevant to physiology:

- the proportion of adults meeting the recommended five-a-day on a “usual day”;
- the percentage of “physically active/inactive adults”;
- “smoking prevalence in adults”;
- “admission episodes for alcohol-related conditions”.

The PHOF forms a “league table” for local authorities to compare their statistics on 159 indicators with other local authorities in England over previous years and the national average. While this is a useful for the purpose of data collection, transparency and monitoring the effect of interventions, the PHOF is not linked to local authority funding and Public Health England (PHE) has no mechanism with which to support underperforming local authorities. Local authorities are better positioned to deliver effective health promotion given that they are responsible for the provision of adult social care. Through devolved powers models such as Greater Manchester Combined Authority, local regions

are also able to realise the benefits of public health messaging in the form of reduced onward costs to integrated systems.

Having the four main indicators of physiological function being recorded in every local authority in England over nearly a decade gives a wealth of information to identify local authorities that are making progress in engaging with their local populations about healthy ageing and provides an opportunity to target key areas that require additional support beyond using aggregated socio-economic data.

The Physiological Society will encourage PHE or other appropriate organisations to use publicly available information to highlight the correlation between preventable early disease and local authorities that are below average for the four main indicators of increased risk.

It has been proposed that for 2019 – 2022, a new PHOF indicator will be added: Disability Free Life Expectancy (DFLE), which The Physiological Society welcomes. However, given the underlying physiology that is responsible for a proportion of ill health and disability, The Physiological Society would recommend that a better mechanistic understanding of the drivers of ill health will be required in order to meet the Government’s twofold target of at least five extra healthy, independent years of life by 2035 and reducing inequalities within socio-economic groups.

The Physiological Society can also provide insight and evidence about which are the most effective measures of “healthy, independent years” to use. There is a risk that there is insufficient understanding of the mechanisms behind healthy ageing and any new PHOF indicator will not genuinely impact health outcomes and support healthy ageing.

RESEARCH SPOTLIGHT

Demonstrating economic, as well as societal, value of physiological research



Stair falls are the leading cause of accidental death in older people. Falls on domestic stairs cause over 350,000 injuries to older UK residents each year, with personal consequences such as loss of independence, hospitalisation and even death, not to mention £2 billion in demands on the NHS.

In hopes of understanding the mechanisms underpinning stair falls and developing the first stair fall screening tool for older people, we run “Research to Improve Stair Climbing Safety” (RISCS). This is a multidisciplinary group with experience in empirical research, data analytics, community health provision and policymaking who are supported by both external and institutional funding to investigate how stair safety in old age can be improved.

The RISCS group uses state-of-the-art stair gait biomechanics and gaze behaviour measurements to investigate the complex relation of functional capabilities such as strength, balance and cognitive status; environmental design factors like step dimensions and illumination; and behaviour elements such as knowing proper stepping technique and where to look and when.

Over the last ten years our ongoing research has been disseminated to scientific meetings, and it hopes to achieve a positive societal impact in the near future by providing means and tools, applicable at the community level, to minimise stair fall risk for older people.

Our research will also make a significant contribution to designing built environments that are accessible to all.

Costis Maganaris

School of Sport & Exercise Sciences, Liverpool John Moores University



Conclusions and recommendations on translating the latest physiological research into implementation

There is a gap between physiological insight and policy decision-making for healthy aging.

Recommendation 26: Public health agencies should ensure that guidelines, while achievable, should be rigorously evidenced and tailored to different stages of the life course.

Recommendation 27: The Physiological Society will work to engage policymakers to ensure that their behaviour change work is supported by physiological insight.

Significant sections of the population do not engage with healthy ageing campaigns or recognise the impact of positive lifestyle changes on the quality of later life. It is vital that public health guidance is built on robust physiological research and insight.

Recommendation 28: The Government needs to support healthy ageing in a multifaceted way, by supporting individuals to making healthy choices, ensuring that wider determinants of health are addressed and making nationwide decisions to support healthier living.

Those that are socioeconomically disadvantaged are less likely to be engaged in activities and lifestyles that promote healthy ageing.

Recommendation 29: The Physiological Society will work with charities and health organisations to communicate the benefits of the latest physiological research to as wide and varied an audience as possible.

Recommendation 30: Health systems in the UK must deliver joined-up policymaking that incentivises decisions to be made at the right point within the system.

Health conditions are understood by the public as being independent of one another.

Recommendation 31: The Physiological Society can contribute to better communication around the causal relationship between declining physiological function, declining healthspan and multimorbidity.

Recommendation 32: The Physiological Society will develop closer links with societies and organisations that explore the link between psychosocial interventions and physiology as an area which demonstrates how an integrative, physiological approach can support health throughout life.

Conclusion

Exploring how physiological research can be best promoted and supported in pursuit of the Government's "Healthy Ageing" target has highlighted a number of interrelated challenges. Throughout the life of this project, The Physiological Society and its external partners have reached the following four main conclusions:

1. Physiology, a fundamental and integrative science, is at the cutting edge of research into healthy ageing. It has the potential to have an enormous positive impact in the care and management of ageing and lifelong health. Physiological research is core to providing answers to many of the questions that will need solving in order to meet the Government's "Healthy Ageing" Grand Challenge by 2035.
2. This insight needs to be better supported through a more supportive funding landscape which is often perceived to prioritise single-disease studies. Cross-council initiatives are not seen as sufficiently robust to prevent physiology "falling through the cracks". This challenge is recognised by funders who are receptive to working with physiologists to ensure aligned expectations for grants.
3. The nature of the Government's aim to increase healthspan demands an interdisciplinary approach to research in this field. Physiology, as the interdisciplinary science, is in an ideal position to act as the interface, supporting interdisciplinary working between sub-disciplines that focus on researching treatments for patients who are often living with co-morbidities and embedding a better understanding of physiology among clinicians, nurses and allied healthcare workers.
4. Reaching these audiences will also inform the delivery of lifelong health policies designed to meet the Government's ambitious but necessary "Healthy Ageing" target by 2035. Health problems are understood by the public as being independent of one another and, therefore, the causal relationship between declining physiological function, declining healthspan and multimorbidity must be better communicated. We must also reflect that the "hardest to reach" in the field of healthy ageing are varied so physiologically informed guidance must be tailored and achievable for all.

The reality of course, is that these conclusions are all inextricably linked. Without appropriately targeted funding for basic science such as physiology, the high-quality and valuable science that is driving a better understanding of the heterogeneity of ageing is not sufficiently shared with other disciplines and the public to help them make positive change.

Growing Older, Better represents an overview of the current environment for physiology and highlights the opportunities that The Society can harness over the coming years to ensure that the Government is in a position to meet its "Healthy Ageing" target. More work must now be done to ensure achievable and concrete measures are in place. This report therefore is not the end of the process, rather it maps out some of the key challenges that will need to be addressed in order to ensure that the UK as a whole is growing older, better.

Acknowledgements

The Physiological Society would like to pay particular thanks to the Expert Group members, who gave their time to set the aims and objectives of the project, attended or chaired workshops and reviewed the progress of the report.

We would also like to thank all those who gave their time to attend workshops, participated in one-to-one interviews or drafted "research spotlights" that help to illuminate just some of the areas that physiology is working in to improve lifelong health. These meetings were fundamental in establishing the conclusions and

recommendations and provide quotations and nuance to the report's findings. All the quotes highlighted in the report reflect verbatim contributions by workshop delegates or those interviewed one-to-one.

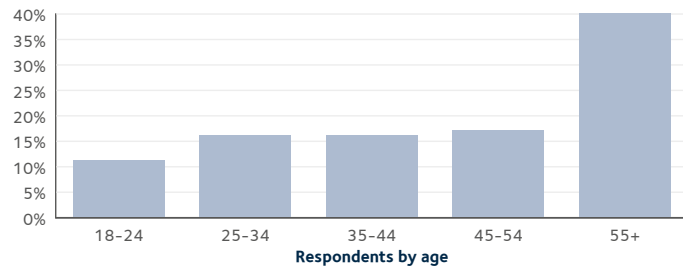
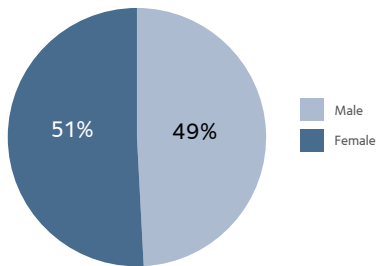
Finally, The Physiological Society would like to thank Stephen Metcalfe MP for his kind offer of writing a short foreword for the report and for hosting the formal launch of the report in Parliament. Stephen's opening remarks neatly summarise how we hope this report and its findings will inform the public debate around lifelong health and healthy ageing.

Appendix

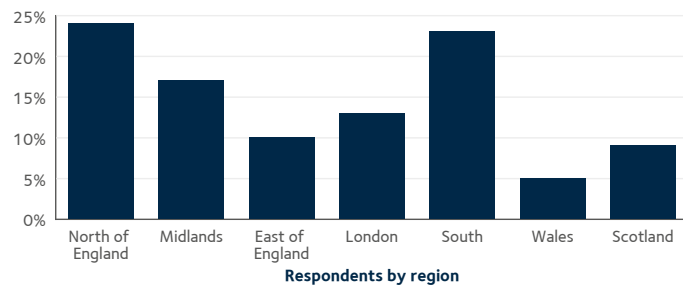
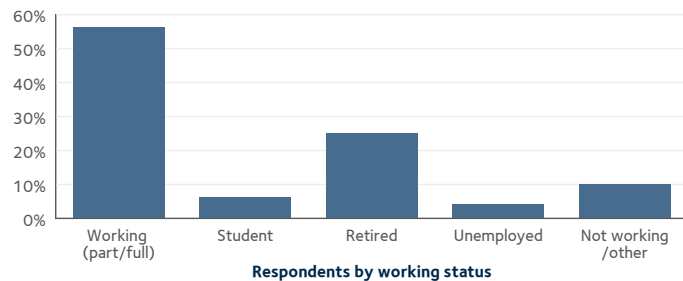
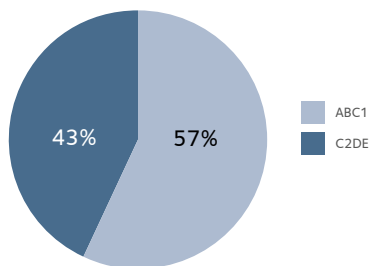
Appendix 1: Public perception survey results

The public perception survey was conducted by YouGov on behalf of The Physiological Society from 4 to 6 January 2019. 2000 adults were surveyed, and a breakdown of respondents by gender, age, social class, region of the UK and working status is outlined here.

Respondents by gender



Respondents by social grade



NRS social grades

Grade	Social class	Chief income earner's occupation
A	Upper middle class	Higher managerial, administrative or professional
B	Middle class	Intermediate managerial, administrative or professional
C1	Lower middle class	Supervisory or clerical and junior managerial, administrative or professional
C2	Skilled working class	Skilled manual workers
D	Working class	Semi-skilled and unskilled manual workers
E	Non working	State pensioners, casual and lowest grade workers, unemployed with state benefits only

Note on interpreting the p -value for YouGov survey datasets

The data below have been coloured to identify which are higher or lower than the full sample in the column. The colouring ranges from dark green (much higher) to dark red (much lower) according to the p -value of the difference of what would be expected if the row and column variables are independent.

$p < .001$	$p < .01$	$p < .05$	$p < .10$	$p < .10$	$p < .05$	$p < .01$	$p < .001$
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Question 1: Factors increasing good health

	Very likely	Fairly likely	Not very likely	Not at all likely	Don't know	Net: Likely	Net: Not Likely
The genes that you are born with (e.g. if your family has a genetic history of a specific health condition, etc.)	43%	38%	8%	2%	10%	81%	9%
Eating a balanced diet (e.g. fresh fruit, fresh vegetables, whole grains, lean proteins, etc.)	55%	36%	4%	1%	5%	91%	5%
Exercising regularly (being active and doing at least 150 minutes of aerobic activity a week such as cycling or brisk walking)	50%	38%	6%	1%	5%	88%	7%
Limiting alcohol consumption (i.e. staying within the recommended limit of 14 units a week)	41%	43%	8%	1%	7%	84%	9%
Not smoking	73%	17%	3%	2%	5%	90%	5%
Having healthy friendships and relationships	34%	46%	11%	2%	7%	80%	13%
Managing stress levels well (e.g. by limiting caffeine consumption, having enough sleep, trying relaxation techniques, etc.)	39%	47%	7%	2%	6%	85%	8%

Question 2: Effectiveness of campaigns

	Very effective	Fairly effective	Fairly ineffective	Very ineffective	Don't know	NA I have never heard of this public health message/campaign	Net: Effective	Net: Ineffective
10,000 steps a day	15%	38%	19%	7%	8%	13%	53%	26%
5 a day (i.e. fruit and vegetables)	21%	47%	19%	6%	5%	2%	68%	25%
150 minutes of exercise per week	13%	32%	19%	7%	8%	21%	45%	26%
Change4Life (i.e. the campaign run by the Department of Health to tackle the causes of obesity)	7%	30%	25%	9%	11%	19%	37%	33%
Stoptober (i.e. the campaign that challenges smokers to give up cigarettes during the month of October)	11%	26%	19%	13%	13%	19%	37%	32%
Drink Free Days campaign	9%	26%	20%	11%	10%	25%	34%	31%
NHS Health Check	16%	33%	15%	4%	9%	22%	49%	20%
"Blood in Pee" (i.e. the campaign to raise awareness of "blood in pee" as a symptom of bladder and kidney cancers)	17%	34%	8%	4%	9%	28%	51%	12%
Every Mind Matters (i.e. the campaign encouraging adults to look after their mental health as they do their physical health)	11%	27%	16%	5%	10%	32%	38%	21%

p<.001	p<.01	p<.05	p<.10	p<.10	p<.05	p<.01	p<.001
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Question 3:
Do participants have sufficient information for informed health choices?

	Age					
	18 – 24	25 – 34	35 – 44	45 – 54	55+	All
I feel sufficiently informed about how to improve my general health should I wish to do so (e.g. by public information campaigns, the media, the internet, etc.)	74%	79%	84%	87%	89%	85%
I do not feel sufficiently informed about how to improve my health should I wish to do so	11%	8%	8%	6%	7%	8%
Don't know	15%	13%	8%	7%	4%	8%

Question 4:
Demand for information regarding health choices

	Age					
	18 – 24	25 – 34	35 – 44	45 – 54	55+	All
Strongly agree	14%	9%	7%	5%	8%	8%
Tend to agree	28%	31%	24%	24%	24%	25%
Neither agree nor disagree	32%	31%	39%	44%	40%	38%
Tend to disagree	10%	14%	17%	17%	19%	16%
Strongly disagree	6%	3%	7%	7%	8%	7%
Don't know	9%	12%	6%	4%	2%	5%
Net: Agree	42%	39%	31%	29%	31%	33%
Net: Disagree	17%	18%	24%	24%	26%	23%

Question 5: Effectiveness of information sources

	Very likely	Fairly likely	Not very likely	Not at all likely	Don't know	Net: Likely	Net: Not Likely
Public information campaigns (e.g. Change4Life, Stoptober, etc.)	7%	34%	37%	11%	10%	41%	48%
Advice from doctors/ pharmacists/ nurses/ other healthcare professionals	36%	45%	10%	3%	6%	81%	13%
Information in the media (e.g. TV/ radio/ newspapers, etc.)	7%	38%	35%	11%	8%	46%	46%
Information from the internet (e.g. social media/ blogs/ websites/ YouTube videos, etc.)	9%	34%	34%	13%	10%	42%	48%
Advice from family and/ or friends	12%	48%	26%	5%	9%	60%	31%
Individual health experiences (e.g. putting on weight, being unable to run for the bus, no longer fitting into clothes, etc.)	41%	42%	7%	2%	7%	84%	9%

	p<.001	p<.01	p<.05	p<.10	p<.10	p<.05	p<.01	p<.001
Question 6: Health advantages encouraging healthier lifestyle choices	Age							
	18 – 24	25 – 34	35 – 44	45 – 54	55+	All		
Stronger and improved muscle mass	14%	9%	7%	5%	8%	8%		
Improved lung capacity	28%	7%	24%	7%	7%	25%		
Maintaining healthy eyesight	7%	7%	7%	44%	7%	38%		
Feeling happier	10%	7%	7%	17%	7%	16%		
Feeling less tired/ more energetic	7%	3%	7%	7%	7%	7%		
Better concentration	9%	12%	6%	4%	2%	5%		
Cheaper life or health insurance	42%	39%	31%	29%	31%	33%		
Healthy lifestyle choices being cheap	17%	7%	7%	24%	7%	23%		
Other	17%	18%	24%	24%	26%	23%		
Don't know	17%	7%	24%	24%	7%	23%		
Not applicable – there is no advantage in particular that would encourage me to make healthier life choices	7%	18%	24%	24%	26%	23%		

Appendix 2: Data on successful grant applications 2010 – 2018

Data used in the chapter entitled “Where should funding bodies direct lifelong health research?” was drawn from the data collected and processed by Dimensions (www.dimensions.ai). Dimensions compiles over \$1.3 trillion worth of global research grant funding and processes the data so that research themes are standardised across global funding organisations.

For the purposes of figures 8 – 10, the following search criteria were used:

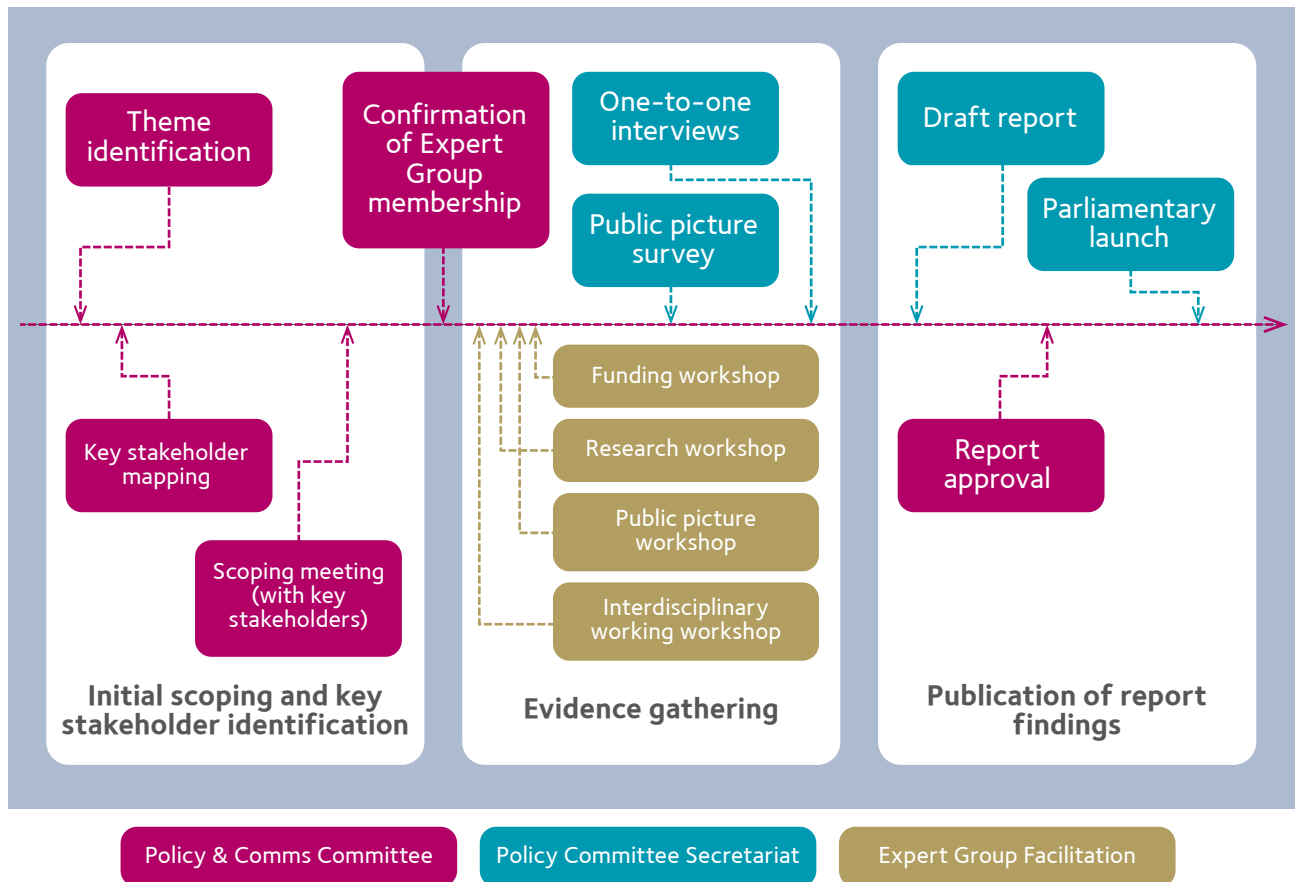
Start year: 2008 – 2018

Country of funder: Belgium or United Kingdom

Country/territory: United Kingdom

Free text in full data: “physiology” AND/OR “physiological”

Appendix 3: Report methodology



This report represents the culmination of an 18-month process involving over 60 expert stakeholders from a variety of different backgrounds including physiologists, other researchers, funders, charitable organisations and national executive agencies. The original scoping for the report began with The Physiological Society identifying lifelong health as an area of public policy which would benefit from increased involvement from The Society and its Members' research.

The committee then convened a scoping meeting with external members designed to establish the main themes and questions that would form the structure of the evidence-building phase and workshops. The main questions identified were:

- **What do researchers understand about ageing?**
- **What does the public understand about ageing?**
- **Where should funding bodies direct ageing research?**
- **How can different disciplines in the ageing arena better collaborate?**

The Expert Group then convened four workshops around these main questions of key expert stakeholders that could give a broad range of answers to different questions. Workshop delegates were drawn from the following organisations.

Academy of Medical Sciences	Public Health England
Alzheimer's Research UK	Science and Technology Facilities Council
Arts and Humanities Research Council	Sport and Recreation Alliance
Association of Medical Research Charities	Trinity College Dublin
Aston University	UCL
Babraham Institute	University of Birmingham
Biotechnology and Biological Sciences Research Council	University of Brighton
British Geriatrics Society	University of Bristol
Cancer Research UK	University of Cambridge
Dunhill Medical Trust	University of Newcastle
Economic and Social Research Council	University of Nottingham
King's College London	University of Oxford – Kennedy Institute of Rheumatology
Liverpool John Moores University	University of Southampton
Manchester Metropolitan University	University of Stirling
Medical Research Council	University of Surrey
Newcastle University	Wellcome Trust

Following the completion of all four workshops, the Expert Group reconvened to discuss the outcomes from all the workshops, identify preliminary findings and conduct further research to provide further evidence for some of the discussion points from the workshops through one-to-one research interviews in addition to the YouGov polling outlined in Appendix 1. The one-to-one interviews with academic researchers based in the UK were arranged based on study areas identified as having unmet need by the Expert Group.

The following questions formed the foundation of a wider free-flowing conversation in each case:

- 1.** What is the current understanding of your research topic both in the scientific community and by policymakers?
- 2.** Where do evidence gaps currently exist?
- 3.** Why do these gaps exist?
- 4.** What barriers exist to further research? (e.g. funding, collaboration, equipment, markers, animal/human models, etc.)
- 5.** What should the next steps look like?
- 6.** What is the potential impact of closing the gap?
- 7.** Are you aware of any other areas of research in lifelong health which have evidence gaps?



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