

Digital Technologies for Healthy Longevity: A Policy Agenda from the Einstein Circle on Inclusive, Data-Driven Ageing Societies

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Abstract

Background: Rapid population ageing presents one of the defining global health challenges of the twenty-first century. While digital technologies are increasingly used to support older adults, their deployment often remains fragmented, inequitable, and insufficiently guided by ethical and legal frameworks. This paper proposes an integrated policy agenda for healthy longevity, based on the interdisciplinary work of the Einstein Circle Longevity – Healthy Ageing Assisted by Digital Technologies. **Methods:** Drawing on literature, expert deliberation, and practical exemplars, we developed a conceptual framework encompassing seven interrelated domains—medical, technical, practical, interactive, psycho-social, ethical, and legal. The framework highlights the need to reframe health and ageing policy around functional ability and healthspan, not merely disease outcomes, and to embed equity and participation throughout the design and governance of digital health systems. **Interpretation:** Digital technologies can extend preventive and personalised care, foster independence, and enhance participation across the life course. Yet

their benefits remain unevenly distributed because of disparities in digital access, usability, and representation in data and design. Policies must ensure that technologies respect human rights, protect autonomy, and strengthen – rather than replace – social relationships and professional care. **Policy implications:** Realising the potential of digital health for healthy longevity requires investment in interoperable infrastructure, participatory design, and ethical and legal safeguards. Cross-sector collaboration and transparent governance are essential to ensure that technology adds not only years to life, but life to years.

Introduction

Healthy longevity is increasingly recognised as a defining challenge of the twenty-first century. Population ageing is progressing across all world regions. By 2050, one in six people globally will be aged 65 years or older. Population ageing coincides with a surge in chronic multimorbidity and a digital revolution transforming the organisation of care. This transformation offers opportunities to reimagine how societies support wellbeing across the life course. Yet it also exposes weaknesses in health, social, and legal systems designed for a different era. Digital transformation has become a central driver of this shift, promising more personalised, preventive, and participatory care while also raising new ethical, technical, and governance challenges.

Building on the collaborative work of the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies”, this paper outlines a multidimensional framework to guide research, policy, and practice. It addresses seven interlinked domains, as illustrated in **Figure 1**: Medical, Technical, Practical, Interactive, Psycho-Social, Ethical, and Legal, each reflecting key determinants of healthy longevity in our digital world. Further, illustrative best-practice examples are summarised in **Table 1**, and overarching policy priorities are listed in **Panel 1** at the end of the article. To illustrate how the seven domains can be operationalised in practice, we compiled a set of diverse, cross-cutting examples from medicine, design, informatics, and community care. These examples highlight how real-world initiatives naturally draw on multiple domains at once and show how the principles of the framework can be translated into actionable strategies across different contexts and sectors.

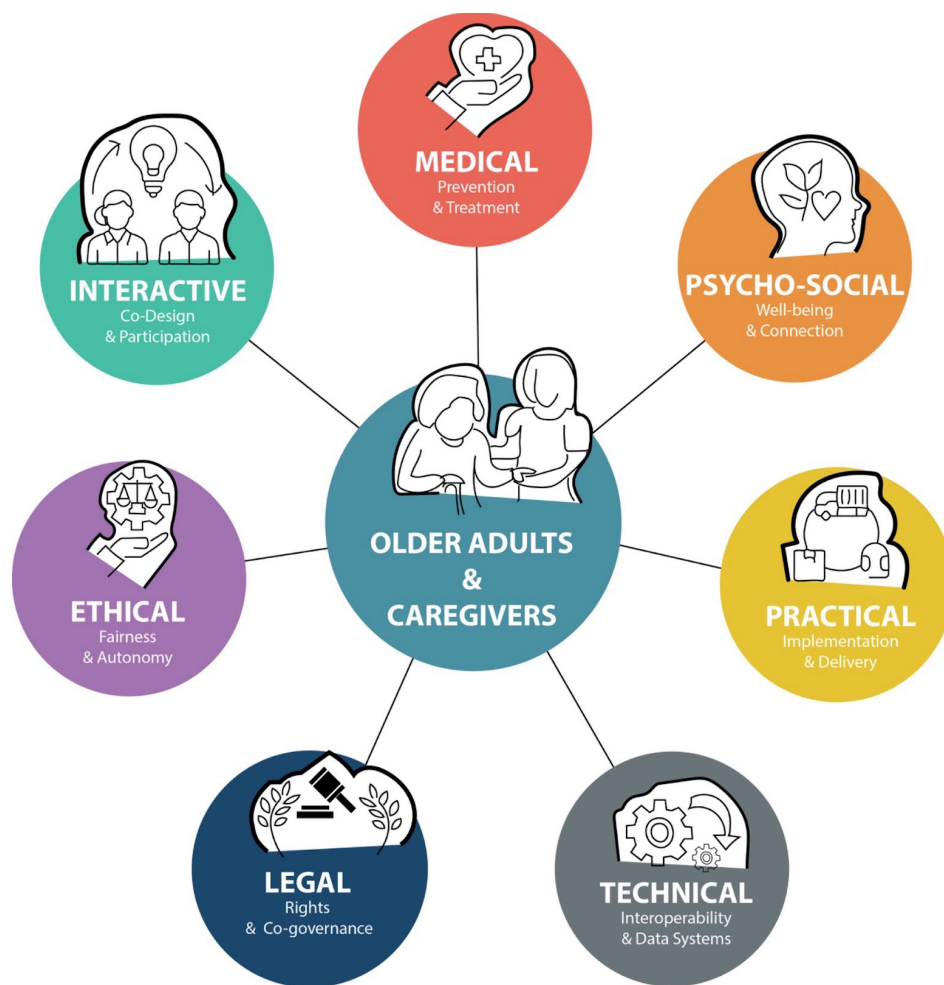


Figure 1: The seven domains of the Einstein Circle framework for digital technologies and healthy longevity. The framework integrates seven interrelated domains (Medical, Technical, Practical, Interactive, Psycho-Social, Ethical, and Legal) that together define the determinants of healthy ageing in the digital era. Each domain represents a distinct yet interconnected dimension of how technology, care, and society interact to promote functional ability, equity, and well-being across the life course.

Table 1: Best practice examples of digital technologies and participatory frameworks supporting healthy longevity. Illustrative best-practice examples demonstrating how the seven-domain framework can be applied across real-world settings. The examples are intentionally diverse: each reflects multiple interacting domains, highlighting that healthy longevity emerges from cross-sector, interdisciplinary, and context-specific approaches rather than from siloed interventions. Together, they offer practical insights into how innovation, governance, prevention, and participation can reinforce functional ability, equity, and dignity in later life.

Example	Description and Key Insights	Domains
Hospital@Home Models	Originating in the 1970s and revitalised through telemedicine and remote monitoring, these programmes provide hospital-level care at home for selected conditions such as heart failure, COPD exacerbations, and post-operative recovery. Mobile teams, point-of-care diagnostics, and wearable sensors enable acute and rehabilitative care while preserving autonomy and reducing institutionalisation. Evidence shows comparable or improved outcomes and satisfaction relative to inpatient care. Implementation	Medical, Practical, Technical

	requires aligned reimbursement, governance, workforce training, and interoperable digital infrastructure.	
#WeAreNotWaiting (Open-Source Diabetes Technology Movement)	A global, community-driven initiative in which people with diabetes, caregivers, and technologists co-develop interoperable software for automated insulin delivery (AID). It illustrates user-led innovation and the role of lived experience in advancing responsible, transparent, and person-centred technology development. Open-source AID solutions address diverse needs, including voice-enabled control, accessibility for visual or motor impairments, and caregiver monitoring. This model shows how user-driven ecosystems can complement regulation and inspire inclusive policy frameworks for chronic-disease management. ¹	Medical, Technical, Interactive
Digital Twin Models for Personalised Ageing	Simulation and prediction engines applying artificial intelligence to multimodal data – clinical, behavioural, and environmental – model an individual’s ageing trajectory and response to interventions. Although still in early development, digital twin models demonstrate how real-world data can support personalised prevention, scenario testing, and adaptive care planning. ²³ When validated and applied equitably, they hold potential to guide proactive, context-sensitive approaches to healthy longevity across diverse populations.	Medical, Technical
Open-Standards Health Data Infrastructure	International interoperability standards facilitate secure exchange of clinical and self-generated data across hospitals, outpatient settings, and home monitoring. By promoting consistency in content representation, semantics (e.g, SNOMED), data exchange (e.g., FHIR), and privacy and security (e.g., HIPAA, GDPR), such standards underpin longitudinal data ecosystems essential for continuity of care and healthy longevity. Sustained governance and workforce capacity are key for equitable implementation.	Technical, Legal
Federated Learning and Privacy-Preserving Data Analytics	Federated and privacy-preserving analytical methods enable the collaborative use of distributed health data without transferring or centralising sensitive information. ⁴ In ageing and longevity research, these approaches allow institutions to generate cross-cohort insights while maintaining data sovereignty and local control. Techniques such as differential privacy, federated learning, and blockchain-based audit trails strengthen compliance with data protection regulations and enhance public trust. When paired with equitable access to computing infrastructure and transparent governance, these methods can expand participation in global research networks, including institutions in low- and middle-income countries.	Technical, Ethical, Legal
Dynamic Consent Models in Health Data Ecosystems	Adaptive consent frameworks enable individuals to exercise ongoing control over how their personal health data are accessed and used. ^{5,6} Through user-friendly digital interfaces, individuals can modify permissions, monitor secondary data use, and withdraw consent at any time. Such models enhance transparency, autonomy, and accountability in data governance, aligning with participatory ethics and international data protection standards such as the EU General Data Protection Regulation. When adapted for low-literacy or low-connectivity environments, dynamic consent can also strengthen trust and engagement in global and cross-border health research.	Legal, Ethical, Technical

Algorithmic Auditing and Fairness Frameworks in AI for Ageing	Systematic auditing of artificial intelligence models – through transparent documentation of training datasets, age-stratified performance evaluation, and regular recalibration using diverse real-world data – helps prevent discrimination and bias against older adults. Such frameworks translate ethical and legal principles of justice, beneficence, and accountability into practice, ensuring that AI systems support equitable and context-sensitive care across populations. Incorporating data from varied geographic, socioeconomic, and health system contexts is essential to avoid exporting bias from high-income to low-resource settings.	Ethical, Technical, Legal
Living Lab Approaches for Digital Health Innovation	Living labs are real-world settings in which older adults, caregivers, clinicians, and developers collaboratively design and test technologies within authentic everyday environments. These participatory ecosystems enable iterative improvement, ethical foresight, and evaluation of usability and impact under practical conditions. By linking research directly to community needs, living labs bridge the gap between innovation and implementation. When adapted for diverse cultural and infrastructural contexts, they can support equitable digital health development across income settings.	Interactive, Practical, Ethical
Participatory Design of Assistive Robots	International multi-year research programmes have integrated older adults, caregivers, clinicians, and engineers in the co-design of assistive robots for daily living and care environments. ⁷ Through iterative workshops, prototyping, and real-world field testing, participants directly informed the refinement of usability, aesthetics, emotional interaction, and ethical acceptability. Findings demonstrated that early and sustained involvement of users enhances trust, emotional connection, and long-term adoption, while mitigating perceptions of paternalism and dependence.	Technical, Interactive, Psycho-Social
Systemic and Experience Design Frameworks	Design methodologies that integrate system-level complexity with user experience (UX) principles align digital health solutions with the psychological needs of older adults—particularly autonomy, competence, and relatedness. Frameworks such as those developed by Hassenzahl offer heuristics for creating emotionally positive, inclusive, and accessible technologies that promote well-being and engagement across diverse populations.	Interactive, Psycho-Social
Interdisciplinary Collaboration Models	Transdisciplinary initiatives bring together clinicians, engineers, designers, and social scientists to build a shared understanding of ageing, care, and technology. Structured collaboration methods—such as co-creation workshops, journey mapping, and rapid prototyping—enhance communication and integration across disciplines, ensuring that innovations align with real-world workflows, ethical principles, and user values. Such models strengthen translation from research to implementation and foster innovation ecosystems that are both context-sensitive and sustainable.	Interactive, Practical
Community-Based Digital Health and Ageing-in-Place Programs	Digital care programs that integrate remote monitoring, mobile health applications, and community health workers enable older adults to remain safely at home while maintaining continuity of care. Effective programs enhance the technical infrastructure embedded with workflows in care provider organizations and support adoption among older adults to improve self-management	Medical, Practical

	and collaboration with the clinicians. * In low- and middle-income countries, such programmes illustrate how low-cost, decentralised digital solutions can extend access to essential services, enhance equity, and reduce pressure on hospitals. When embedded within existing primary care and community structures, they also strengthen trust and ensure culturally appropriate delivery.	
Age-Friendly Cities and Active Citizenship Initiatives	Municipal and community programmes that promote digital literacy, intergenerational learning, and social participation help older adults engage meaningfully in civic and community life. These initiatives bridge the gap between digital inclusion and active citizenship, reinforcing autonomy, purpose, and belonging—key social determinants of healthy ageing. When embedded in local governance and supported by accessible digital infrastructure, they foster inclusion, intergenerational solidarity, and lifelong participation.	Interactive, Practical, Psycho-Social
Music- and Art-Based Digital Therapies	Digital platforms delivering music-based activities, movement-to-music training (for example, Curaswing), and virtual-reality art programmes have shown measurable benefits for cognitive function, mood, motor coordination, and social connectedness among older adults, including those living with Parkinson’s disease or dementia. These creative, evidence-informed interventions illustrate how technology can nurture emotional well-being and neuroplasticity, particularly where access to qualified therapists or rehabilitation services is limited.	Medical, Psycho-Social, Interactive
AI-Powered Medication Management	AI-powered medication management systems, combining intelligent pill dispensing with conversational AI interactions, support older adults and individuals with cognitive impairment in medication adherence, daily routines, and overall well-being. Companion devices and mobile interfaces enable seamless communication with caregivers and healthcare professionals, providing real-time insights into health, activity, and adherence. These evidence-informed, user-centred technologies illustrate how AI can enhance autonomy, safety, and connectedness, particularly for individuals living independently or in assisted care settings, while complementing traditional healthcare support.	Medical, Psycho-Social, Interactive
Design-Based Digital Occupational Therapy	Digital tools that support art- and design-based occupational therapy, combining interactive clay modelling with 3D printing to foster creative self-expression, fine motor skills, and emotional well-being. Tangible artistic outputs serve as meaningful reminders of accomplishment and shared experiences, extending access to therapeutic activities in home or care settings.	Technical, Interactive, Psycho-Social
Age-Friendly Health Systems	The Age-Friendly Health Systems (AFHS) initiative provides a framework for hospitals, primary care practices, pharmacies, nursing homes, and home-care organisations to deliver care that is safe, evidence-based, and tailored to the needs of older adults. Centred on the “4Ms” model – What Matters, Medication, Mentation, and Mobility – AFHS promotes consistent, person-centred care across the continuum. Implementation requires coordination across health and public-health sectors to embed healthy ageing and equity as core functions of service delivery. Collaboration across organisations and communities enables shared measurement and improvement strategies that reduce avoidable	Medical, Practical, Ethical

	hospitalisations, support recovery at home, and enhance quality of life for older adults.	
Quality Health Information Networks	Under the U.S. Trusted Exchange Framework and Common Agreement (TEFCA), QHINs provide a national infrastructure for secure, standardised exchange of clinical data between health systems, public health agencies, and digital health providers. The “connect once, access many” architecture enables interoperable data flow across settings, reducing fragmentation and improving care coordination. For ageing populations, longitudinal data exchange through QHINs can support continuity of care, especially for older adults managing multiple conditions across providers. While currently specific to the U.S. context, the model illustrates how large-scale, standards-based data networks could strengthen equitable, person-centred, and preventive care for older adults in other regions.	Technical, Medical, Legal
California Data Exchange Framework	The California Data Exchange Framework (DxF) establishes a statewide legal and technical foundation for secure, real-time sharing of health and social data across hospitals, physician groups, nursing facilities, health plans, laboratories, and community organisations. By leveraging existing health information networks and modern interoperability standards (e.g., FHIR, HL7), the DxF enables coordinated, “whole-person” care that integrates clinical and social determinants of health. For older adults, event-based alerts and linked social-care data support timely follow-up after hospital discharge, prevent care gaps, and help maintain functional ability and independence. The DxF demonstrates how regional, standards-based data ecosystems can enhance continuity, safety, and equity in ageing populations.	Technical, Practical, Legal
Real-World Evidence Collaborative	Real-world data—derived from electronic health records, laboratory systems, claims databases, and patient-generated sources—capture how medical interventions perform in routine practice. When analysed systematically, such data generate real-world evidence (RWE) that can complement clinical trials, inform regulatory and reimbursement decisions, and guide person-centred care. For ageing populations, RWE helps identify treatment effects in multimorbid and frail individuals often excluded from traditional studies. Integration of patient-generated health data further enriches understanding of functional ability and lived experience. Globally, collaborative initiatives are developing methodological and ethical standards to ensure that RWE strengthens safety, precision, and equity in digital and population health research.	Legal, Practical, Medical
Participatory AI Frameworks	Participatory AI builds on co-design principles that develop technologies with rather than for affected populations. By involving older adults and other underrepresented groups in model design, data selection, and evaluation, these frameworks aim to create fairer, more accurate, and trustworthy AI systems. Moving beyond deficit-based assumptions, participatory AI recognises older adults as experts in their lived experience and supports technologies that enhance independence, accessibility, and dignity. Applied in ageing contexts, this approach ensures that AI-driven health tools—such as adaptive medication reminders, remote monitoring, or cognitive support applications—reflect real user priorities, cultural contexts, and functional needs.	Legal, Practical, Interactive, Psycho-social

AgeTech Collaborative	The AgeTech Collaborative from AARP is a mission-driven, business-to-business ecosystem advancing technology innovation for healthy ageing. The Collaborative convenes startups, researchers, caregivers, investors, and older adults to co-create solutions that enhance physical independence, support chronic-disease management, and reduce social isolation. Through its accelerator and virtual community, it provides mentorship, pilot-testing opportunities, and partnerships that help scale inclusive, evidence-based, and sustainable technologies. By focusing on prevention, health promotion, and cognitive and social well-being, the Collaborative exemplifies a whole-of-society approach to ageing innovation rooted in participatory design and real-world validation.	Interactive, Practical, Ethical. Psycho-social
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Medical Domain

The prevalence of chronic and complex health conditions increases with age. Cardiovascular disease, diabetes, cancer, chronic respiratory illness, dementia, depression, musculoskeletal disorders, and sensory decline frequently coexist, producing multimorbidity that challenges traditional, single-disease models of care.⁹ Globally, at least two-thirds of older adults live with multiple health challenges, underscoring the need for personalised and coordinated approaches that extend beyond episodic treatment to continuous, person-centred support.¹⁰ The COVID-19 pandemic further exposed vulnerabilities in long-term care facilities and underscored the importance of resilient systems that ensure safety, social connection, and adequate staffing.¹¹

Oral health is an important component of healthy ageing, supporting essential functions such as eating, speaking, breathing, and social interaction, and contributing to dignity and societal participation.¹² Oral conditions, including dental caries, periodontal disease, tooth loss, and oral cancer, are among the most prevalent non-communicable diseases worldwide and disproportionately affect older adults.¹³ Oral health and systemic health care are closely linked: for instance, diabetes and periodontitis have a bidirectional relationship, and further associations have been shown with cardiovascular disease, chronic respiratory illness, and cognitive decline.¹⁴

The World Health Organisation defines functional ability – the capacity to do what one values – as the central outcome of healthy ageing.¹⁵ Addressing geriatric syndromes such as frailty, falls, delirium, incontinence, and pressure injuries requires strategies that integrate physical, psychological, and environmental factors. This reframing shifts the focus from single conditions to overall capacity, aligning with person-centred perspectives, and from extending lifespan to enhancing healthspan, which refers to the years lived in good health and with functional ability. This concept of compression of morbidity emphasises delaying the onset of functional decline so that added years are quality years.¹⁶

Prevention and health promotion are critical to achieving this goal. Evidence shows that modifiable factors – nutrition, physical activity, reduced smoking and alcohol use, and social engagement – substantially influence well-being in later life.^{17–22} Yet preventive measures remain underused because of fragmented systems and the misconception that prevention yields limited benefit in older age. Digital health technologies can bridge this gap by extending the reach of preventive interventions and strengthening continuity of care.^{23–25} In many low- and middle-income countries,

mobile-first health interventions, text-based counselling, and task-shared community programs already demonstrate how digital approaches can enhance prevention and follow-up care, even where specialist resources are limited.²⁶

Wearables, sensors, and mobile applications provide continuous feedback on activity, sleep, and vital signs, allowing early detection of deviation from baseline. Predictive analytics can identify risk for frailty or functional decline and guide timely interventions. Digital platforms also enable remote rehabilitation and support self-management.²⁷ These tools promote agency and shared responsibility for health, reinforcing the active role of older adults in maintaining independence. However, benefits remain unevenly distributed. The digital divide—driven by disparities in connectivity, literacy, and usability—continues to exclude many who might benefit most. Beyond usability, disparities in infrastructure, affordability, and internet access—particularly in rural and low-resource settings—further constrain participation and adoption.^{28–31} Bridging this divide requires not only investment in accessible infrastructure and inclusive design but also in lifelong digital literacy and locally adapted implementation strategies.³²

Effective management of multimorbidity demands collaboration across medicine, nursing, rehabilitation, social work, and informal care. In many resource-limited settings, community health workers and family caregivers play a pivotal role in ensuring continuity of care and monitoring functional ability.^{33,34} Digital systems can facilitate such collaboration by creating shared information environments, enabling multidisciplinary care planning, and connecting families and professionals across settings. When adapted to local health system structures and capacities, digital tools can extend the reach of care, strengthen autonomy, and enhance quality of life in later years.

Technical Domain

The digital transformation of healthcare offers unprecedented opportunities to promote healthy ageing, but the fragmentation of health data continues to limit its potential. Older adults interact with multiple providers, sectors, and technologies throughout their lives. Data generated across hospitals, general practice, rehabilitation, and home-care settings, together with information from wearables, apps, and sensors, is stored in isolated systems. This fragmentation prevents continuous monitoring, delays timely interventions, and undermines coordination across care pathways.

Even when individuals use digital devices for activity tracking or arrhythmia detection, clinicians often lack the means to access or interpret the resulting data within clinical systems.³⁵ Semantic and technical incompatibilities between consumer technologies and hospital infrastructures result in valuable information being left unused. Healthy ageing, therefore, requires data systems that connect health information seamlessly across the life course and enable both individual and collective learning.

An interoperable and standards-based infrastructure is essential to address this challenge. Frameworks such as FHIR (Fast Healthcare Interoperability Resources) and SNOMED CT enable semantic consistency and secure exchange of health information across sectors.³⁶ Yet technical standards alone are insufficient. Interoperability also depends on governance, long-term investment, and policy incentives that promote shared maintenance and accountability. Sustainable governance frameworks should ensure quality assurance, equitable access, and continuity of care across institutional and national boundaries.

Interoperability must also be human-centred. Systems should be designed for usability and workflow integration, thereby reducing the documentation burden and facilitating effective communication among professionals, patients, and caregivers. Aligning data architecture with the practical realities of daily care can transform interoperability from a technical goal into a catalyst for person-centred service delivery.

Healthy ageing is an individual and dynamic process shaped by the interaction between an individual's intrinsic capacity and their environment. Capturing this complexity requires longitudinal and context-rich data that extend beyond episodic medical encounters.

Real-world data (RWD) from wearables, lifestyle apps, and home sensors complement traditional medical records by revealing patterns of behaviour, function, and context in everyday life.³⁷ Integration of multimodal RWD with clinical data can detect subtle changes in health trajectories, guide personalised prevention, and support adaptive intervention.³⁸ These data also enable care teams to understand the lived experiences of individuals and tailor support to their unique priorities. Examples of interoperable data infrastructures and federated governance models that operationalise such integration are summarised in **Table 1**.

Existing health-data infrastructures largely focus on clinical and research data, with limited capacity for high-density, longitudinal, or patient-generated information. Complementary architectures centred on individuals are therefore needed.^{39,40} Personal data accounts or citizen-controlled data hubs allow individuals to consolidate their own data across silos and exercise dynamic consent over their use. These systems can enhance health literacy and agency while enabling ethically governed secondary use for science and innovation.^{41,42}

Trust is fundamental. Strong privacy, security, and consent mechanisms must safeguard autonomy while permitting responsible data sharing.^{43,44} Federated and privacy-preserving approaches, such as distributed learning models, allow cross-institutional collaboration without centralising sensitive data.⁴ Transparent governance and ethical oversight are prerequisites for public confidence.⁴⁵

Key challenges include data quality, standardisation, and analytical reliability. Data from consumer devices vary in precision, and longitudinal drift undermines comparability over time.^{46,47} Continuous validation and calibration are essential. Balancing privacy with utility remains difficult: excessive protection can restrict learning, while lax governance risks eroding trust.⁴⁵ Analytical complexity also increases as data become more heterogeneous, demanding models that remain interpretable and fair.⁴⁸

Sustainability is equally critical. Interoperable infrastructures should be recognised as public goods requiring long-term investment, evaluation, and stewardship. Fragmented pilot projects or temporary funding cannot provide the continuity necessary for lifelong data integration. Coordinated action across healthcare, research, technology, and policy domains is necessary to establish enduring, equitable systems that support the goal of healthy longevity.

Integrated, secure, and human-centred data ecosystems can thus form the technical foundation for ageing well. They enable individuals to remain active participants in their own care, support professionals with shared insights, and generate the evidence base for informed policy.^{41,42}

Practical Domain

Rapid population ageing will intensify demand for acute and long-term care worldwide, exposing structural weaknesses in health and social care systems. Without redesign, current models of service delivery will struggle to remain sustainable. Expanding institutional capacity through conventional means would require substantial investment to meet a temporary demand peak. Sustainable strategies must instead focus on redesigning care delivery; integrating digital technologies, community-based services, and user-led innovation to maintain independence and quality of life.

Digitally supported home-based and community care models provide promising alternatives to traditional institutional care. These models deliver acute or rehabilitative services in domestic settings, supported by telemedicine, mobile care teams, and remote patient monitoring. Evidence suggests that when implemented within well-coordinated systems, such approaches can reduce hospital stays, improve quality of life, and lower costs. Illustrative initiatives, including hospital-at-home programmes, are summarised in **Table 1**.

Implementation remains constrained by persistent structural and regulatory barriers. Health systems are commonly divided into distinct sectors – hospital, outpatient, rehabilitation, and long-term care – each with its own financing and accountability mechanisms. These divisions inhibit coordination and continuity, while reimbursement systems seldom reward cross-sector collaboration. Reforming payment models and governance frameworks will be essential to scale digitally enabled care beyond pilot projects.

Educational barriers also hinder progress. New models of care require health professionals who are trained in both clinical and digital competencies, capable of delivering effective home-based care. Many older adults face challenges in using digital tools due to limited literacy or accessibility. Addressing these disparities demands sustained investment in training, digital inclusion, and universal design that accommodates sensory and cognitive diversity.

Technical limitations further restrict the implementation of integrated care. Reliable broadband connectivity, telemedicine infrastructure, and interoperable electronic health records are essential prerequisites for safe and effective care coordination; however, they remain unevenly developed across regions. Secure data exchange and real-time communication between sectors are vital for accountability and continuity.

Achieving digitally supported, person-centred care for ageing populations requires coordinated action across industry, regulation, workforce, and infrastructure.⁴⁹ Policy frameworks should align

reimbursement and governance structures to facilitate integrated care, while investment in digital infrastructure and workforce training must ensure that innovation reaches all populations equitably. Policy must also take into account private sector companies and market forces which affect the supply of application digital solutions. Strengthening digital inclusion through accessible design and lifelong literacy initiatives will be essential to ensure that no group is left behind.

When structural, educational, and technical conditions are aligned, digitally enabled community care can become a foundation of healthy longevity – reducing unnecessary hospitalisation, maintaining autonomy, and enhancing wellbeing. These imperatives are echoed in the broader policy priorities outlined in **Panel 1**.

Interactive Domain

Despite growing recognition of their potential, many digital health technologies fail to address the psychological, social, and emotional dimensions of ageing. This gap often arises from the limited involvement of older adults in the design process and insufficient collaboration between disciplines. When designers, clinicians, engineers, and caregivers do not share common frameworks or tools, resulting technologies risk being fragmented, inaccessible, or misaligned with lived realities and user contexts.

Design for ageing populations frequently positions older adults as evaluators rather than as experts in their own lives. As a result, solutions may be technically effective yet socially or psychologically disconnected. Research consistently shows that authentic co-creation with older adults leads to greater acceptance, usability, and long-term engagement.⁵⁰ Participatory approaches that involve users and caregivers throughout the design process – rather than only at testing stages – reveal contextual barriers and enable the development of solutions that are embedded in real life.^{51,52} Situated co-design methods, conducted in everyday environments rather than laboratories, generate deeper insight into habits, routines, and social contexts that shape technology adoption.⁵³ In dementia care, for example, projects that engaged people living with dementia early in the design process achieved greater usability and emotional resonance than those that involved them only in the evaluation phase.⁵⁴ Yet participatory design is still too often treated as an optional add-on rather than as a foundational principle.⁵⁵ Embedding genuine co-creation as a standard of practice is essential to ensure that digital health solutions align with the psychological, cognitive, and social realities of older adults.

Digital health interventions tend to prioritise physical or clinical outcomes, overlooking psychological needs such as autonomy, competence, and relatedness. Evidence suggests that designs explicitly addressing these dimensions can enhance engagement, satisfaction, and overall well-being.⁵⁶ Frameworks for wellbeing-supportive design emphasise these universal needs and offer heuristics for creating technology that supports agency and connectedness, rather than merely functioning.^{57,58}

Understanding older adults' mental models – their internal representations of how systems work – is also critical. When design assumptions diverge from users' expectations, even well-intentioned technologies can provoke frustration or rejection.⁵⁹ Mapping and validating mental models through participatory and observational research improves usability, fosters trust, and increases adoption.

By grounding development in the lived contexts of ageing, designers can ensure that digital health tools are not only technically usable but also socially acceptable and emotionally supportive. But no single discipline can address the complex realities of ageing. Effective innovation requires collaboration among health, design, engineering, and social sciences.⁶⁰ Yet interdisciplinary teams often struggle to bridge methodological and linguistic divides. Design disciplines can provide unifying frameworks such as systemic design and user experience design, which establish shared development processes and evaluation criteria.^{61,62} Participatory design tools—workshops, prototyping, journey mapping, and co-creation sessions—help align stakeholders around common goals and foster communication between clinicians, technologists, and end-users.⁶³ Embedding structured co-creation frameworks within interdisciplinary teams ensures that solutions are not only technically sound but also contextually relevant and responsive to the psychological and physical needs of older adults.

Design practices for ageing frequently adopt a deficit-based lens, framing older adults as vulnerable rather than as knowledgeable agents. This perspective risks paternalistic solutions that limit autonomy and reinforce ageist assumptions. Participatory and co-creative design methods offer a corrective, positioning older adults as contributors and mentors who bring experiential expertise to innovation. Such engagement strengthens self-efficacy, ownership, and dignity, ensuring that digital health solutions promote empowerment rather than dependency.^{41,42} Ethical design for ageing must therefore move from protectionist frameworks toward partnership models that recognise capability, respect autonomy, and enhance wellbeing. When older adults are treated as collaborators and knowledge holders, technologies become vehicles for inclusion and agency rather than control.

Psycho-social Domain

Emotional health is a cornerstone of healthy ageing. It shapes motivation, resilience, social participation, and the ability to lead a meaningful life. As people age, changes in social roles, physical capacity, and social networks make emotional stability and connectedness increasingly important. According to the World Health Organisation, healthy ageing is “the process of developing and maintaining the functional ability that enables well-being in older age.” Well-being, therefore, is not merely the absence of disease but the capacity to do what one values. Emotional health is thus both a determinant and an indicator of functional ability and overall quality of life.

Digital technologies can promote emotional and psychosocial well-being in later life when designed with empathy, participation, and sensitivity to individual lived experiences. Digital innovation supports emotional health across multiple dimensions, including creativity, social connectedness, and self-regulation.

Creative and cultural engagement plays a critical role in emotional, cognitive and physical vitality. Music- and art-based interventions, digital musical instruments, and interactive dance or movement platforms stimulate neural networks involved in cognitive processes like auditory perception, attention, working memory and episodic memory, in motor functions, and in reward and emotion. Studies have shown that music interventions can reduce stress hormones, enhance mood, and strengthen cognitive, motor and social engagement in older adults, including those with

mild cognitive impairment.⁶⁴ Technology can extend access to such interventions through adaptive sensors, AI-supported feedback, and online group participation.

Social connectedness is equally vital to emotional well-being. Digital communication, telecare systems, and online communities can help reduce isolation and foster a sense of belonging, particularly for individuals with limited mobility or caregiving responsibilities. Yet, evidence underscores that emotional benefits arise from the *quality* rather than the frequency of digital interaction. Technologies that enable meaningful social exchange, rather than transactional communication, contribute most to overall well-being.

Self-regulation and mindfulness technologies, including digital diaries, emotion-tracking apps, biofeedback tools, and mindfulness platforms, can enhance awareness of emotional states and support stress reduction. These interventions show potential for strengthening coping mechanisms and maintaining emotional balance in daily life. However, their effectiveness depends on tailoring to cognitive and sensory capacities, as well as ensuring privacy and data security.

Emotional outcomes are rarely prioritised in the design and evaluation of digital health technologies. Most systems emphasise clinical or physical metrics, overlooking indicators such as joy, belonging, or a sense of purpose. Embedding emotion as a design parameter can ensure that digital tools support holistic well-being, rather than merely functional performance. Co-creation with older adults, caregivers, and therapists enables the inclusion of emotional priorities such as dignity, autonomy, and meaning from the outset.

As technologies become more responsive to emotional cues, ethical safeguards are essential. Emotion-sensitive systems must preserve transparency, respect, and psychological safety. Guidelines for empathetic and responsible AI should prevent manipulation and uphold dignity and consent in all human-technology interactions.

Digital technologies will contribute most to healthy longevity when they engage the full emotional and social spectrum of ageing. Integrating creativity, connection, and emotional awareness into the design and evaluation of digital health innovations can help ensure that technological progress enhances not only function but also fulfilment in later life.

Ethical Domain

Ethical considerations are central to the responsible development of digital health technologies for ageing populations.⁴⁵ Older adults are frequently portrayed as vulnerable or technologically passive, yet they represent a highly diverse group with distinct values, capacities, and life contexts.⁶⁵ Ethical reflection must therefore strike a balance between protection and empowerment, ensuring that digital innovation promotes agency, dignity, and inclusion rather than dependency or paternalism.

Equity is one of the most pressing ethical concerns in digital health and longevity. Unequal access to devices, connectivity, and digital literacy can exacerbate existing health disparities. The UN Decade of Healthy Ageing identifies combating ageism—changing how we think, feel, and act about ageing—as a cornerstone of global action.⁶⁶ To uphold justice, digital health initiatives must embed inclusivity as a design and policy imperative, addressing affordability, accessibility, and

representation. Inclusive and participatory design processes that involve older adults and their communities can help ensure that digital tools are relevant, acceptable, and equitable across socioeconomic and cultural contexts.⁶⁷ In low- and middle-income countries, where resource constraints are more significant, ethical digital innovation must also consider the distribution of limited connectivity, the affordability of mobile data, and competing priorities for essential health services. Collaborations with community organisations, non-governmental partners, and local innovators can ensure that technologies respond to contextual realities rather than replicate inequities.

In later life, decision-making about health and technology is often shared within families, communities, and care networks. Digital health tools should strengthen, not replace, these relationships. Ethical frameworks for digital ageing must therefore adopt a relational understanding of autonomy, recognising that agency is interdependent and often exercised collectively. At the same time, new forms of digital monitoring and automation challenge traditional notions of informed consent. Many systems collect or process personal information continuously and unobtrusively, sometimes beyond the user's awareness. Transparent communication, ongoing consent processes, and mechanisms for review or withdrawal are essential, particularly for individuals with cognitive impairment or fluctuating capacity. Ethical design must ensure that autonomy is supported rather than undermined by digital mediation. In settings with limited literacy or access to legal safeguards, consent procedures must be simplified, culturally adapted, and reinforced by trusted intermediaries such as community health workers or family caregivers.

Trust is foundational for sustained engagement with digital health technologies. Concerns about surveillance, data misuse, or loss of control are especially salient for older adults who may be less familiar with digital infrastructures.⁶⁸ Transparent governance, data minimisation, and participatory oversight mechanisms are necessary to protect privacy and reinforce confidence. Ethical digital ecosystems should ensure that users know how their data are collected, stored, and shared, and that they can meaningfully influence these processes. Building trust also requires institutional accountability – ethical review boards, certification standards, and public reporting can provide transparency and guard against misuse. In contexts where such formal mechanisms are not yet established, community advisory boards and local participatory governance structures can play a similar role in ensuring transparency and legitimacy.

AI-based decision-making offers opportunities for precision and efficiency but also introduces risks of bias and exclusion. Many predictive models used in digital health are trained on datasets that underrepresent older adults, particularly those with multiple conditions or limited digital literacy. As a result, algorithmic outputs can misclassify, misdiagnose, or deprioritise older individuals, perpetuating inequities in access and quality of care.^{69,70} To address this, algorithmic auditing should become a standard practice in the development and deployment of AI tools for ageing populations. Transparent documentation of training datasets, performance monitoring stratified by age, and recalibration using diverse real-world data are necessary safeguards. In global health contexts, it is equally important to ensure that AI models incorporate data from diverse populations and health systems, avoiding the export of biases from high- into low-resource settings. Ethical AI must adapt to the physiological, cognitive, and social heterogeneity of ageing, ensuring fair and context-sensitive outcomes.

The ethical agenda for digital longevity extends beyond harm prevention. It must also promote empowerment, co-creation, and solidarity across generations. Older adults should be recognised not merely as recipients of technology but as contributors to its governance, development, and evaluation. Embedding participatory ethics, where design, data use, and oversight are shared with affected communities, can ensure that digital innovation advances human dignity and social justice. Integrating global and intergenerational perspectives also reinforces that longevity and digital health equity are collective goals, not privileges of affluent societies. Fair, inclusive, and trustworthy technologies will not only protect but also enable older adults to shape their digital futures. Ethical digital health for longevity thus requires a dual commitment: to safeguard rights and to expand opportunities for agency and participation in later life.

Legal Domain

Law, like ethics and social norms, is always situated in a particular context. It reflects not only written statutes but also the local interpretations, practices, and objectives that give legal systems their texture and meaning. In the digital domain, however, there is a persistent tendency to overlook or flatten out these differences. This simplification extends beyond geographical boundaries to encompass variations in interpretation, legal purpose, and the relationships between individual rights and regulatory objectives.

Digital health policies frequently assume a degree of global convergence that does not exist. Standards developed in one jurisdiction, such as the U.S. Health Insurance Portability and Accountability Act (HIPAA) ⁷¹ are often treated as broadly equivalent to European frameworks like the General Data Protection Regulation (GDPR). ⁷² This assumption obscures crucial differences in legal purpose and protection. Whereas HIPAA focuses primarily on data privacy in a medical context, the GDPR seeks to safeguard all fundamental rights implicated in data processing, including those related to physical integrity, autonomy, non-discrimination, and fair working conditions. In the health and care sectors, these rights extend beyond patients to caregivers and families, underlining the deeply relational nature of legal protection. A narrow understanding of law as a checklist of procedural requirements risks overlooking these broader human rights dimensions. When compliance is reduced to documentation and consent forms, the law's fundamental purpose – protecting individuals and their fundamental rights – can be obscured by bureaucracy.

Recent European legislation, including the GDPR and the AI Act ⁷³, adopts a consequentialist logic, seeking to prevent harm from digital systems by translating broad principles into enforceable requirements. Yet as the corpus of regulatory provisions grows denser, their underlying aims often fade from view. The resulting compliance burden reinforces perceptions of regulation as a bureaucratic obstacle rather than as a human rights safeguard. This dynamic is especially evident in the overemphasis on informed consent as the principal basis for lawful data processing. Consent is only one of several legitimate grounds under the GDPR, but its dominance in public discourse has diverted attention from the law's broader intent: to uphold all fundamental rights in the digital age.

Effective rights protection requires practical, rights-based guidance that bridges the gap between legal abstraction and technological implementation. Legislators, regulators, and standardisation bodies have yet to provide such actionable frameworks for developers and operators of digital

health technologies. In their absence, professional and research communities must take the lead in interpreting and operationalising legal principles in ways that preserve the law’s emancipatory intent.

A growing number of legal instruments now explicitly require stakeholder participation in the governance and design of digital systems. Examples include data protection impact assessments under the GDPR and fundamental rights assessments proposed in the EU AI Act.^{73,74} Participation in this context extends beyond the giving or withholding of consent—it grants affected individuals and communities real power to shape outcomes. Stakeholder involvement is therefore not merely an ethical aspiration but a legal necessity. True participation demands governance processes that meet stakeholders as equals, valuing their lived experiences and perspectives. This requires facilitators who can translate between technical, legal, and social domains, ensuring that participation empowers rather than burdens those involved.

For stakeholder participation to be genuine, three principles are essential. First, digital systems should remain understandable in scale and complexity, following the idea that “small is beautiful.” Second, governance should proceed iteratively and transparently, allowing participants to engage meaningfully at each stage of the design and implementation process. Third, facilitators must assume responsibility for accessibility, bridging gaps in digital literacy, language, and knowledge.

Finally, digital governance must move from a paradigm of acceptance to one of acceptability. Rather than expecting individuals to adapt to technological systems, technologies themselves should be designed to align with human values, lived realities, and normative expectations. Legal frameworks should therefore prioritise the development of digital systems that are not merely compliant, but acceptable, usable, trustworthy, and consistent with the rights and dignity of the people they serve.

Policy Pathways

Panel 1: Key policy priorities for advancing healthy longevity in the digital age. Summary of cross-domain recommendations from the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies”. These priorities outline how digital transformation can support equitable, person-centred, and resilient systems for ageing populations.

1. Reorient ageing and health policy around functional ability and healthspan, embedding prevention, early intervention, and continuity of care across the life course.
2. Develop interoperable national and regional digital health infrastructures grounded in open global standards to enable secure data exchange and longitudinal care.
3. Implement transparent governance frameworks to ensure data quality, accountability, and coordination across health, social, and community sectors.
4. Adopt hybrid models of care that integrate digital, home-, and community-based services to strengthen accessibility, autonomy, and system resilience.
5. Promote lifelong digital literacy and inclusion for professionals, patients, and caregivers, addressing barriers related to affordability, accessibility, and usability.

6. Institutionalise participatory and co-creative design by involving older adults, caregivers, and frontline workers as co-developers of digital health solutions.
7. Integrate emotional and social well-being metrics into digital health evaluation and quality frameworks alongside clinical and economic indicators.
8. Ensure fairness, transparency, and independent oversight in the design, validation, and deployment of AI and data-driven technologies.
9. Translate human-rights principles into practical, adaptive regulation that safeguards autonomy, privacy, and equity in digital health systems.
10. Establish ethical and legal co-governance structures linking policymakers, clinicians, technologists, and communities to ensure inclusive and accountable innovation.

Conclusion

Healthy longevity in the digital age requires more than technological innovation. It demands interoperable infrastructures that connect data across the life course, as well as ethical and legal safeguards that uphold individual rights, and participatory processes that empower individuals and communities. The Einstein Circle's framework emphasises that ageing is a collective responsibility – encompassing medical, technical, social, and moral aspects. By aligning digital transformation with inclusion, dignity, and justice, societies can ensure that innovation adds not only years to life, but life to years.

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Contributors

TSch and DIB led the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies” and coordinated the collaborative process. KB and TSc developed the overall outline, integrated co-author input, and prepared the final manuscript. All authors contributed to the conceptualisation, drafting, and revision of their respective domain sections, critically reviewed the manuscript for intellectual content, and approved the final version. KB and TSc contributed equally. KB and MM are guarantors.

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