
BEYOND LIFESPAN: HUMAN SUSTAINABILITY AS NEW PARADIGM FOR WOMEN'S EMOTIONAL LONGEVITY AND HEALTHY AGEING

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ABSTRACT

The rapid advancement of longevity science has transformed ageing research from disease treatment toward extending lifespan and health span. Despite significant progress in genomics, precision medicine, geroscience, regenerative medicine, and preventive healthcare, contemporary longevity research remains predominantly centred on biological ageing. While these developments have improved survival, they often underrepresent the influence of emotional resilience, psychological adaptation, social connectedness, caregiving responsibilities, purpose, and gender-specific life transitions that shape healthy ageing, particularly among women. This paper proposes Human Sustainability as an integrative conceptual framework that expands current longevity science by positioning healthy ageing as the lifelong capacity to sustain biological, emotional, cognitive, relational, occupational, financial, environmental, and existential well-being. Within this broader framework, two complementary concepts are introduced. First, Women's Sustainability is proposed as a multidimensional life-course model recognising the interaction of biological transitions with social, occupational, and psychological experiences that influence female longevity. Second, Emotional Longevity is introduced as a conceptual construct describing the long-term capacity to preserve emotional regulation, psychological flexibility, meaningful relationships, adaptive coping, and purpose throughout ageing. Drawing on evidence from geroscience, psychology, behavioural medicine, neuroscience, public health, and life-course theory, the paper develops the Human Sustainability Systems Model (HSSM) to illustrate how biological

and psychosocial determinants interact throughout the lifespan. Rather than replacing existing frameworks such as Healthy Ageing, Geroscience, Precision Medicine, or One Health, Human Sustainability integrates and extends them through a systems perspective. The paper argues that future longevity research, healthcare policy, and clinical practice should complement biological indicators with measures of emotional resilience, social participation, caregiving burden, and purpose. Extending lifespan alone is insufficient; sustainable longevity requires preserving the human capacities that enable individuals to live healthier, more meaningful, and socially connected lives.

INTRODUCTION: Beyond Living Longer

The twenty-first century has witnessed unprecedented improvements in human longevity. Advances in sanitation, vaccination, public health, precision medicine, genomics, regenerative therapies, and digital health have substantially increased life expectancy worldwide. Consequently, the focus of medicine has shifted from preventing premature death to promoting healthy ageing and extending health span. However, a critical challenge remains: living longer does not necessarily mean living better.

Although biomedical research has significantly advanced understanding of the biological mechanisms of ageing—including cellular senescence, genomic instability, mitochondrial dysfunction, inflammation, and epigenetic regulation—these mechanisms explain only part of the ageing process. Human ageing is simultaneously biological, psychological, social, occupational, and environmental. Emotional resilience, social relationships, financial security, caregiving responsibilities, and purpose also shape health trajectories across the lifespan. This limitation is particularly evident in women's health. Women generally outlive men but spend a greater proportion of later life living with chronic disease, disability, mental health challenges, caregiving responsibilities, and reduced quality of life. Their ageing experiences are influenced not only by biological transitions such as puberty, pregnancy, menopause, and post-menopause, but also by lifelong exposure to gendered social roles, occupational demands, emotional labour, and structural inequalities. These interacting influences remain insufficiently represented within conventional models of longevity.

Existing frameworks—including Healthy Ageing, Geroscience, Precision Medicine, and Longevity Medicine—have expanded understanding of lifespan and health span, yet they remain predominantly biomedical in orientation. While increasingly acknowledging psychosocial influences, they rarely provide an integrated systems framework capable of explaining how biological, emotional, cognitive, relational, occupational, financial,

environmental, and existential factors collectively shape long-term health. To address this gap, this paper proposes Human Sustainability as an overarching conceptual framework for healthy longevity. Human Sustainability is defined as the lifelong capacity of individuals and societies to sustain biological health, emotional resilience, cognitive vitality, meaningful relationships, occupational participation, financial security, environmental adaptability, and purpose throughout the lifespan. Rather than replacing existing biomedical approaches, it extends them by recognising that healthy ageing emerges through the interaction of multiple adaptive systems.

Within this framework, the paper introduces two complementary concepts. The first, Women's Sustainability, conceptualises female healthy ageing as a multidimensional life-course process shaped by biological transitions alongside psychological, social, occupational, and cultural influences. The second, Emotional Longevity, describes the lifelong capacity to maintain emotional regulation, psychological flexibility, meaningful relationships, adaptive coping, and purpose despite ageing and life adversity. Unlike traditional concepts of resilience, Emotional Longevity emphasises the sustained preservation and renewal of emotional functioning across the life course.

By shifting the central question from "How can we extend human lifespan?" to "How can we sustain human flourishing throughout longer lives?" this paper argues for a broader vision of longevity science—one that values not only survival but also resilience, connection, purpose, and quality of life. Finally, the paper proposes the Human Sustainability Systems Model (HSSM), an integrative framework illustrating how biological, emotional, cognitive, relational, occupational, financial, environmental, and existential systems interact to influence healthy longevity. The model is intended as a conceptual foundation for future interdisciplinary research, clinical innovation, and public policy.

Evolution of Longevity Science: From Survival to Human Sustainability

The pursuit of longevity has evolved alongside advances in medicine, public health, and scientific understanding of ageing. Historically, healthcare focused on preventing premature death from infectious diseases. As life expectancy increased, attention shifted toward preventing chronic disease, promoting healthy ageing, and more recently, slowing the biological processes of ageing itself. These successive developments have transformed longevity from a question of survival to one of sustaining health across increasingly longer lives.

Despite remarkable scientific progress, contemporary longevity research remains predominantly centred on biological mechanisms. Molecular ageing, genetics, biomarkers, and regenerative medicine have substantially improved understanding of healthspan, yet they explain only part of the human ageing experience. Individuals age biologically, but they also age emotionally, cognitively, socially, economically, and psychologically. This broader reality suggests that longevity science requires a more comprehensive framework capable of integrating these interconnected dimensions.

The development of longevity science can be understood as a progression through six overlapping paradigms.

Infectious Disease Control

The first major transformation resulted from improvements in sanitation, vaccination, antibiotics, maternal care, nutrition, and public health infrastructure. These advances dramatically reduced mortality from communicable diseases and increased average life expectancy worldwide. During this period, medicine measured success primarily by survival.

Preventive Medicine

As chronic diseases replaced infectious diseases as the leading causes of death, healthcare shifted toward prevention. Lifestyle modification, cardiovascular risk reduction, nutrition, physical activity, smoking cessation, and screening programmes became central strategies for reducing morbidity and extending lifespan. Preventive medicine demonstrated that health could be improved before disease developed, but it remained largely disease-oriented and focused primarily on reducing physiological risk.

Healthy Ageing

Recognition that longer lives should also remain functional led to the development of healthy ageing frameworks. The World Health Organization defined healthy ageing as maintaining the functional ability that enables well-being throughout later life. Similarly, successful ageing models expanded the concept of health beyond disease avoidance to include physical functioning, cognition, and active participation in society. These approaches broadened healthcare goals but remained relatively fragmented, with biological, psychological, and social determinants often examined separately.

Geroscience and Precision Medicine

Advances in molecular biology transformed ageing from an inevitable process into a potentially modifiable biological phenomenon. Research identified hallmarks of ageing including genomic instability, cellular senescence, mitochondrial dysfunction, inflammation, and epigenetic alterations. Precision medicine further personalised healthcare through genomic profiling, biomarkers, and targeted interventions. These developments established the biological foundation of contemporary longevity medicine and significantly advanced efforts to extend health span.

Longevity Medicine

Longevity medicine integrates preventive care, regenerative therapies, digital health, artificial intelligence, nutrition, and behavioural interventions to delay biological ageing and optimise physiological function. Unlike traditional medicine, it aims to intervene before disease develops by preserving biological resilience throughout adulthood. However, contemporary longevity medicine continues to focus primarily on measurable biological outcomes such as inflammatory biomarkers, metabolic health, cardiovascular fitness, and biological age. While indispensable, these indicators provide only a partial understanding of human ageing.

Limitations of Existing Models

Existing longevity frameworks have substantially improved our understanding of biological ageing, disease prevention, and health span. Nevertheless, they underrepresent several determinants that strongly influence long-term well-being. Ageing occurs within complex social and psychological environments. Emotional resilience, meaningful relationships, caregiving responsibilities, occupational identity, financial security, community participation, and purpose influence behavioural choices, stress physiology, immune regulation, and quality of life throughout adulthood. These determinants interact continuously with biological systems rather than functioning independently. Chronic stress can alter neuroendocrine and immune function, while supportive relationships, emotional regulation, and purpose promote healthier behavioural and physiological outcomes. Consequently, healthy ageing emerges from interactions among multiple adaptive systems rather than biological mechanisms alone. Women particularly illustrate these limitations. Female ageing is shaped by reproductive transitions, hormonal change, caregiving roles, workplace participation, and gendered social expectations. Existing biomedical models rarely integrate these experiences into a unified understanding of healthy longevity.

Human Sustainability as the Next Evolution

The next stage of longevity science should therefore extend beyond biological optimisation toward sustaining the whole person. This paper proposes Human Sustainability as an integrative framework describing the lifelong capacity to preserve biological health, emotional resilience, cognitive vitality, meaningful relationships, occupational participation, financial security, environmental adaptability, and purpose.

Unlike previous models, Human Sustainability does not replace geroscience, healthy ageing, precision medicine, or longevity medicine. Instead, it synthesises these disciplines within a systems framework that recognises health as the product of interacting biological, psychological, social, occupational, environmental, and existential processes.

Within this perspective, emotional resilience is not simply a psychological outcome but a determinant of behavioural choices, physiological regulation, cognitive functioning, and long-term health. Likewise, social participation, caregiving, financial security, and meaningful work become essential contributors to sustainable longevity rather than peripheral influences. Human Sustainability therefore shifts the emphasis of longevity science from extending biological survival to preserving the adaptive capacities that enable individuals to flourish across longer lives.

The evolution of longevity science reflects an expanding understanding of human health. Successive paradigms have progressed from preventing premature death to delaying biological ageing and extending health span. While these advances remain fundamental, they are insufficient to explain the full complexity of human ageing. Healthy longevity depends not only on biological resilience but also on emotional adaptability, cognitive vitality, supportive relationships, meaningful work, financial security, environmental conditions, and purpose. Human Sustainability integrates these dimensions within a single conceptual framework, providing the foundation for the remainder of this paper.

Human Sustainability: Why Longevity Science Needs a Broader Framework

Longevity science has made remarkable progress in understanding the biological mechanisms of ageing. Advances in geroscience, precision medicine, regenerative medicine, and preventive healthcare have shifted medicine from treating disease to delaying biological ageing and extending health span. Nevertheless, these approaches remain predominantly biomedical, emphasizing molecular pathways, physiological biomarkers, and disease prevention.

Although biological health is essential, it alone cannot explain why individuals with similar clinical profiles experience markedly different ageing trajectories. Emotional resilience, cognitive adaptability, supportive relationships, financial security, meaningful work, environmental conditions, and purpose substantially influence health behaviours, stress responses, functional ability, and quality of life throughout the lifespan. These determinants interact continuously with biological systems, yet they are often examined independently rather than within a unified framework. As populations live longer, healthy ageing must be understood not only as preserving physiological function but also as sustaining the adaptive capacities that allow individuals to thrive across extended lives. This conceptual gap provides the foundation for Human Sustainability, proposed here as the next evolution of longevity science.

Defining Human Sustainability

The lifelong capacities of individuals, communities, and societies to preserve, regenerates, and optimise biological health, emotional resilience, cognitive vitality, relational connectedness, occupational participation, financial security, environmental adaptability, and existential purpose in ways that support healthy, equitable, and meaningful longevity. Unlike traditional biomedical models that primarily target disease prevention or biological optimisation, Human Sustainability adopts a life-course perspective in which health emerges from the dynamic interaction of multiple adaptive systems. It recognises that sustainable longevity depends not only on maintaining physiological integrity but also on preserving the psychological, social, occupational, and existential resources required to navigate changing life circumstances. Within this framework, health is understood as a dynamic process of continuous adaptation rather than a static state or the absence of disease.

Human Sustainability as a Systems Framework

Human Sustainability is grounded in systems thinking, which views health as the product of continuous interactions among interconnected biological and social systems rather than isolated determinants.

At the **biological level**, health depends on genomic stability, immune competence, endocrine regulation, metabolic flexibility, cardiovascular function, and neurological integrity.

The **psychological system** encompasses emotional regulation, cognitive flexibility, adaptive coping, learning, and meaning-making.

The **social and relational system** includes family relationships, caregiving, social support, community engagement, and interpersonal trust.

The **occupational system** shapes identity, financial stability, opportunities for lifelong contribution, and work-related well-being.

The **environmental system** includes housing, neighbourhood safety, pollution exposure, climate resilience, healthcare accessibility, green spaces, and digital environments.

Finally, the **existential system** reflects purpose, identity, values, spirituality, creativity, and meaning throughout life.

These systems do not function independently. Chronic occupational stress may contribute to endocrine dysregulation, inflammation, sleep disruption, and depression, whereas supportive relationships, financial security, meaningful work, and emotional adaptability may buffer physiological stress responses and promote healthier ageing trajectories. Human Sustainability therefore conceptualises longevity as an emergent property of interacting biological, psychological, social, occupational, environmental, and existential systems.

Eight Domains of Human Sustainability

The proposed Human Sustainability framework integrates eight interconnected domains that collectively influence healthy longevity. Each domain includes key components, measurable indicators, assessment approaches, and evidence-informed interventions. These are summarised in Table X.

Domain	Key Indicators	Assessment	Example Intervention	Expected Outcome
Biological	Sleep, nutrition, biomarkers	Clinical assessment	Lifestyle medicine	Healthy ageing
Emotional	Resilience, regulation	Emotional Longevity Scale	CBT, mindfulness	Emotional longevity
Cognitive	Executive function	Cognitive tests	Lifelong learning	Cognitive reserve
Relational	Social support	Loneliness scale	Community engagement	Reduced isolation
Occupational	Meaningful work	Burnout scales	Flexible work	Purpose
Financial	Financial security	Financial wellbeing scale	Financial literacy	Reduced stress
Environmental	Green space, housing	Environmental audit	Urban planning	Better wellbeing
Existential	Purpose	Purpose in Life Scale	Meaning-centered interventions	Flourishing

Relationship to Existing Frameworks

Human Sustainability extends, rather than replaces, several established frameworks.

The **Healthy Ageing** model emphasises functional ability and intrinsic capacity but gives limited attention to occupational, financial, and existential determinants.

Geroscience focuses on biological mechanisms of ageing, including cellular senescence, inflammation, and genomic instability, without addressing broader psychosocial systems.

Precision Medicine individualises treatment using molecular and genomic information but remains primarily biologically oriented.

One Health recognises the interconnectedness of human, animal, and environmental health but does not comprehensively address psychological, relational, occupational, or existential dimensions.

Similarly, Planetary Health, the Social Determinants of Health, and the Biopsychosocial Model each explain important aspects of health but do not integrate all determinants within a single life-course framework focused on sustainable longevity.

Human Sustainability synthesises these complementary traditions by positioning biological, emotional, cognitive, relational, occupational, financial, environmental, and existential domains within one integrated systems model. Rather than asking only "How can disease be prevented?", it asks a broader question:

How can the whole person be sustained across an increasingly long life?

This shift represents the framework's principal conceptual contribution.

Human Sustainability as the Next Paradigm of Longevity Science

The evolution of longevity science can be viewed as a progression through successive scientific paradigms:

- Infectious Disease Control
- Preventive Medicine
- Healthy Ageing
- Geroscience
- Precision Medicine
- Longevity Medicine
- Human Sustainability (Proposed)

Each stage has expanded the goals of medicine. Human Sustainability represents the next logical step by integrating biological science with psychological, behavioural, social,

occupational, environmental, and existential perspectives. Success is therefore measured not only by increased life expectancy or delayed disease but also by an individual's capacity to remain emotionally resilient, cognitively engaged, socially connected, financially secure, environmentally supported, and purposeful throughout life.

Research Gap and Future Directions

Despite extensive research on healthy ageing, resilience, social determinants of health, and quality of life, no widely accepted framework currently integrates biological, emotional, cognitive, relational, occupational, financial, environmental, and existential sustainability into a unified model of healthy longevity. Human Sustainability addresses this conceptual gap by offering an interdisciplinary framework that can guide future research, clinical assessment, psychometric development, public health policy, and healthcare innovation.

Emotional Longevity: A New Conceptual Construct for Healthy Ageing

Why Emotional Longevity Matters

Advances in longevity science have substantially improved understanding of the biological mechanisms underlying ageing. However, extending lifespan without preserving emotional well-being may result in longer lives characterised by psychological distress, loneliness, reduced resilience, and diminished quality of life. Healthy ageing therefore depends not only on delaying biological decline but also on sustaining emotional functioning throughout the life course. Although resilience, psychological well-being, emotional intelligence, and positive psychology have each contributed to understanding emotional health, they explain only specific aspects of emotional functioning. Existing constructs rarely conceptualise emotional adaptation as a lifelong capacity that evolves across decades of changing biological, psychological, and social circumstances.

This paper proposes Emotional Longevity as a complementary construct within the broader Human Sustainability framework. Rather than focusing on recovery after adversity or current emotional well-being, Emotional Longevity describes the long-term preservation and renewal of emotional capacities that enable individuals to adapt, maintain relationships, and sustain purpose throughout ageing.

Defining Emotional Longevity

The lifelong capacity to preserve, regenerate, and adapt emotional functioning in ways that sustain psychological flexibility, emotional regulation, meaningful relationships, purpose, compassion, and overall well-being despite cumulative ageing and life adversity. This

definition emphasises emotional functioning as a dynamic process rather than a fixed state. Individuals inevitably encounter loss, illness, caregiving responsibilities, occupational stress, retirement, and changing social roles. Emotional Longevity reflects the capacity to adapt to these experiences while preserving psychological integrity and social connectedness. Unlike traditional measures of emotional well-being, Emotional Longevity is inherently longitudinal, recognising that emotional capacities may strengthen, weaken, and recover throughout the lifespan.

Distinction from Existing Psychological Constructs

Emotional Longevity builds upon established psychological constructs but extends them by conceptualising emotional adaptation as a lifelong determinant of healthy ageing rather than a transient psychological state. The principal distinctions are summarised in Table X.

Mechanisms Supporting Emotional Longevity

Emotional Longevity is hypothesised to emerge through interactions among biological, psychological, behavioural, and social systems. Neurobiological evidence suggests that adaptive emotional regulation depends on coordinated activity involving the prefrontal cortex, amygdala, hippocampus, and related neural networks. Chronic stress may disrupt these systems through dysregulation of neuroendocrine and inflammatory pathways, contributing to cognitive decline and poorer health outcomes.

Psychological mechanisms such as cognitive flexibility, adaptive coping, self-compassion, mindfulness, optimism, and meaning-making strengthen emotional adaptation across changing life circumstances. Behavioural pathways are equally important. Individuals with greater emotional adaptability are more likely to maintain healthy lifestyles, adhere to medical treatment, engage in preventive healthcare, and avoid maladaptive coping behaviours. Social relationships provide another protective mechanism. Supportive families, friendships, community participation, and secure interpersonal relationships buffer stress and enhance emotional recovery throughout adulthood. These interacting mechanisms suggest that Emotional Longevity is not simply a psychological attribute but an interdisciplinary construct linking emotional functioning with biological ageing and long-term health.

Dimensions of Emotional Longevity

The proposed framework comprises several interrelated dimensions:

- Emotional regulation
- Psychological flexibility

- Recovery following adversity
- Hope and optimism
- Meaning and purpose
- Self-compassion
- Relational connectedness
- Empathy and compassion
- Emotional literacy
- Social contribution
- Capacity for emotional renewal

These dimensions function collectively rather than independently, representing the sustainability of emotional functioning across the life course.

Emotional Longevity across Life Course

Emotional adaptation evolves across different stages of life. During adolescence, it supports identity formation and emotional awareness. Early adulthood introduces challenges related to education, employment, intimate relationships, and parenthood. Midlife often involves balancing occupational responsibilities, caregiving, financial pressures, and health transitions, while later life presents adaptation to retirement, bereavement, chronic illness, and changing social roles. Emotional Longevity therefore represents a developmental process requiring repeated adaptation while maintaining continuity of identity, relationships, and purpose.

Clinical and Public Health Implications

If empirically validated, Emotional Longevity may broaden current approaches to preventive medicine, psychology, psychiatry, public health, and longevity medicine. Clinical assessment could move beyond symptom reduction to evaluate emotional adaptability, social connectedness, caregiving burden, and purpose. Preventive interventions may focus on strengthening emotional regulation, psychological flexibility, and social participation before significant decline occurs.

Within workplace health programmes, emotional renewal, reflective practice, and supportive organisational cultures could complement traditional stress management strategies. At the population level, recognising emotional adaptation as a determinant of healthy ageing may inform policies promoting mental health, caregiver support, community engagement, and age-friendly environments.

Future Research

Such research will determine whether Emotional Longevity contributes independently to healthy ageing beyond existing measures of resilience and psychological well-being.

The future of longevity science extends beyond slowing biological ageing. Sustaining emotional regulation, psychological flexibility, meaningful relationships, and purpose is equally essential for enabling individuals to flourish across longer lives.

Emotional Longevity provides a conceptual framework that complements existing theories of resilience and well-being while extending the Human Sustainability paradigm. By recognising emotional adaptation as a lifelong determinant of healthy ageing, it offers a foundation for future interdisciplinary research, clinical innovation, and public health policy.

Women's Sustainability: A Life-Course Framework for Healthy Longevity

Women consistently outlive men across most populations; however, longer life expectancy does not necessarily translate into healthier ageing. Women experience a greater burden of chronic illness, disability, depression, anxiety, osteoporosis, autoimmune disorders, chronic pain, and caregiving responsibilities during later life. This phenomenon, often described as the female health–survival paradox, demonstrates that longevity should be evaluated not only by years lived but also by the quality and sustainability of those years.

Defining Women's Sustainability

The lifelong capacity of women to preserve, regenerate, and optimise biological health, emotional resilience, cognitive vitality, relational connectedness, occupational participation, financial security, environmental adaptability, and existential purpose across changing developmental, reproductive, and social transitions in ways that promote healthy longevity and equitable participation in society.

This definition extends beyond conventional biomedical models by recognising that women's health is influenced not only by reproductive biology but also by educational opportunities, employment, caregiving responsibilities, socioeconomic conditions, cultural expectations, and access to healthcare. Women's Sustainability therefore adopts a systems perspective in which healthy ageing reflects the interaction of multiple adaptive domains throughout the life course. To demonstrate the conceptual contribution of the proposed frameworks, Table X compares existing approaches to healthy ageing with Human Sustainability, Emotional Longevity, and Women's Sustainability. The comparison illustrates how the present

framework extends previous models by integrating biological, psychological, social, occupational, financial, environmental, and existential dimensions across the life course.

Framework	Primary Focus	Major Limitation	Contribution of This Paper
Healthy Ageing	Functional ability and intrinsic capacity	Limited integration of occupational, financial and existential domains	Expanded into Human Sustainability
Geroscience	Biological mechanisms of ageing	Focuses primarily on molecular ageing	Adds psychosocial and life-course systems
Precision Medicine	Personalised biological care	Predominantly biomedical	Integrates emotional and social determinants
Resilience	Recovery from adversity	Episodic rather than lifelong	Expanded through Emotional Longevity
Women's Health Models	Reproductive health and disease	Fragmented life-stage approach	Introduces Women's Sustainability across the life course
Human Sustainability (Proposed)	Integrated biological, emotional, cognitive, relational, occupational, financial, environmental and existential wellbeing	Multidimensional systems framework	Provides the overarching conceptual model for healthy longevity

The Eight Domains of Women's Sustainability

Women's Sustainability adopts the same eight domains described in the Human Sustainability framework but applies them to the unique biological, psychological, occupational, social, and cultural experiences of women across the life course. Rather than introducing additional domains, it emphasises how gender-specific transitions influence each dimension of healthy longevity.

Women's Sustainability across Life Course

Women's Sustainability adopts a life-course perspective in which each developmental stage influences subsequent health trajectories. Childhood establishes biological, educational, and social foundations. Adolescence is characterised by identity formation, emotional development, and reproductive maturation. Early adulthood introduces higher education, employment, intimate relationships, and parenthood. Midlife often involves balancing career advancement with caregiving responsibilities while navigating menopausal transition. Later

life increasingly emphasises functional independence, cognitive health, social participation, and purpose. These transitions are interconnected rather than independent. Advantages or disadvantages accumulated at one stage may influence health, resilience, and quality of life decades later. Consequently, interventions should support women continuously throughout the life course rather than focusing solely on reproductive years or old age.

Research, Clinical, and Policy Implications

Women's Sustainability provides a conceptual framework for integrating medicine, psychology, public health, sociology, economics, and environmental science.

Future research should develop validated measures of Women's Sustainability, investigate life-course trajectories, and evaluate interventions that strengthen multiple domains simultaneously. Clinically, the framework encourages healthcare professionals to assess emotional well-being, caregiving burden, occupational participation, financial security, and social support alongside biological health. Such an approach aligns with contemporary models of person-centred care and preventive medicine. From a policy perspective, Women's Sustainability supports investment in preventive healthcare, workplace equity, caregiver support, lifelong education, financial security, and age-friendly communities. These interventions have the potential to improve not only longevity but also quality of life across extended lifespans.

Women's healthy ageing cannot be understood through reproductive biology alone. It reflects the cumulative interaction of biological transitions with emotional resilience, cognitive vitality, relationships, work, financial security, environmental conditions, and purpose. The Women's Sustainability framework extends current approaches to women's health by integrating these domains within a life-course model. As the gender-specific application of Human Sustainability, it provides a conceptual foundation for future interdisciplinary research, clinical innovation, and public policy aimed at promoting healthier and more meaningful longevity for women.

Human Sustainability Systems Model (HSSM)

Longevity science has traditionally explained healthy ageing through biological mechanisms such as genetics, cellular senescence, inflammation, metabolic regulation, and physiological resilience. Although these mechanisms remain fundamental, they provide only a partial explanation of why individuals age differently despite similar biological profiles. Healthy ageing is increasingly recognised as the product of continuous interactions among biological,

psychological, behavioural, social, occupational, environmental, and existential systems. Emotional distress may alter endocrine and immune function, financial insecurity can influence health behaviours, supportive relationships may buffer chronic stress, and meaningful work can strengthen both psychological well-being and physical health. These reciprocal interactions cannot be adequately explained through linear biomedical models.

To address this complexity, this paper proposes the Human Sustainability Systems Model (HSSM) as the conceptual architecture underlying Human Sustainability. Rather than treating health determinants as isolated variables, HSSM conceptualises longevity as an emergent property of multiple interconnected adaptive systems operating across the life course.

Conceptual Foundations of HSSM

The Human Sustainability Systems Model is grounded in systems thinking, which assumes that complex outcomes arise through interactions among interconnected components rather than through single causal pathways.

Within HSSM, biological, emotional, cognitive, relational, occupational, financial, environmental, and existential systems continuously influence one another through dynamic feedback loops. Adaptation or disruption within one domain inevitably affects functioning across the others.

For example, chronic occupational stress may increase psychological distress, disrupt sleep, elevate inflammatory activity, reduce physical activity, weaken social relationships, and ultimately accelerate biological ageing. Conversely, supportive relationships, financial stability, emotional regulation, meaningful work, and healthy environments may strengthen resilience across multiple domains simultaneously.

Accordingly, healthy longevity is understood not as the absence of disease but as the sustained capacity of interconnected systems to adapt throughout changing life circumstances.

Components of the Human Sustainability Systems Model

The HSSM consists of eight interacting domains that together determine healthy longevity.

Biological System

The biological system includes genetic integrity, immune competence, endocrine regulation, metabolic flexibility, cardiovascular health, musculoskeletal function, neurological integrity, and other physiological processes that support healthy ageing.

Emotional System

The emotional system encompasses emotional regulation, psychological flexibility, adaptive coping, resilience, self-compassion, and emotional renewal. Within HSSM, this system is represented by the proposed construct of **Emotional Longevity**, recognising emotional adaptation as a central determinant of long-term health.

Cognitive System

The cognitive system includes memory, executive functioning, learning, creativity, attention, and cognitive reserve. Lifelong education, intellectual engagement, and neuroplasticity strengthen this domain throughout adulthood.

Relational System

Relationships provide emotional support, caregiving, social identity, and community participation. High-quality relationships contribute to resilience, healthier behaviours, and reduced morbidity, whereas loneliness and social isolation are associated with poorer health outcomes.

Occupational System

Employment influences financial security, identity, purpose, autonomy, and social participation. Sustainable work environments support psychological well-being and healthy ageing through opportunities for lifelong contribution and meaningful engagement.

Financial System

Economic resources determine access to healthcare, nutrition, housing, education, and opportunities for social participation. Financial resilience therefore functions as both a social determinant of health and a protective factor against cumulative adversity.

Environmental System

The environmental system includes housing quality, neighbourhood safety, healthcare accessibility, transportation, green spaces, climate resilience, digital infrastructure, and environmental exposures. These factors shape opportunities for healthy living throughout the lifespan.

Existential System

Purpose, values, spirituality, identity, creativity, and meaning contribute to adaptive functioning during major life transitions. Existential well-being supports resilience, motivation, and psychological continuity despite ageing and adversity.

Together, these domains operate as an integrated adaptive network rather than independent determinants of health.

Dynamic Interactions across Life Course

The defining characteristic of HSSM is the continuous interaction among its components.

Biological ageing influences emotional functioning through hormonal changes, chronic illness, and declining physiological reserve. Emotional adaptation, in turn, affects biological processes by shaping stress responses, inflammation, sleep quality, health behaviours, and healthcare utilisation.

Similarly, occupational participation influences financial security, which affects healthcare access, nutrition, housing, and psychological well-being. Social relationships influence emotional resilience, caregiving experiences, and cognitive engagement, while environmental conditions shape opportunities for physical activity, social participation, and disease prevention.

These multidirectional interactions create feedback loops that accumulate over time. Positive interactions strengthen resilience across multiple systems, whereas persistent disruption may contribute to accelerated functional decline.

HSSM therefore conceptualises ageing as a dynamic developmental process rather than a sequence of isolated biological events.

Application to Women's Sustainability

The Human Sustainability Systems Model provides the structural foundation for Women's Sustainability.

Women's health is influenced by biological transitions including puberty, pregnancy, postpartum recovery, menopause, and advanced ageing. However, these physiological changes occur simultaneously with occupational participation, caregiving, financial responsibilities, cultural expectations, and evolving personal identities.

HSSM illustrates how these experiences interact across multiple domains throughout the female life course. Rather than viewing reproductive health separately from emotional or social health, the model recognises their continuous integration within a single adaptive system.

Consequently, Women's Sustainability represents a gender-specific application of Human Sustainability rather than an independent framework.

Implications for Research and Practice

The Human Sustainability Systems Model extends existing approaches to longevity by integrating biological and psychosocial determinants within a unified systems framework.

Rather than conceptualising healthy ageing as the preservation of physiological function alone, HSSM recognises longevity as the sustained interaction of biological health, emotional resilience, cognitive vitality, supportive relationships, meaningful work, financial security, environmental quality, and existential purpose.

As the conceptual architecture underlying Human Sustainability, Emotional Longevity, and Women's Sustainability, HSSM provides a foundation for future interdisciplinary research, clinical innovation, and public policy aimed at enabling individuals not only to live longer but also to flourish throughout extended lives.

DISCUSSION

The increasing global emphasis on longevity has transformed medicine from extending survival to improving health span. Advances in geroscience, precision medicine, regenerative medicine, and preventive healthcare have substantially improved understanding of the biological mechanisms of ageing. However, this progress has also revealed an important limitation: biological longevity alone cannot fully explain how individuals experience ageing or why people with similar physiological profiles often demonstrate markedly different trajectories of health, resilience, and well-being.

This paper argues that healthy longevity should be understood as a multidimensional process emerging from continuous interactions among biological, emotional, cognitive, relational, occupational, financial, environmental, and existential systems. Rather than replacing established biomedical approaches, the proposed Human Sustainability framework extends them by integrating psychosocial and behavioural determinants within a single life-course model.

As summarised in Table X, the proposed Human Sustainability framework integrates and extends existing models of healthy ageing, resilience, and women's health within a unified systems perspective.

Collectively, these frameworks encourage a shift in emphasis from extending lifespan alone to sustaining the capacities that enable individuals to remain healthy, resilient, socially connected, and purposeful throughout longer lives.

Theoretical Contribution

The principal contribution of this paper is conceptual rather than empirical.

Existing frameworks such as Healthy Ageing, Geroscience, Precision Medicine, One Health, and the Biopsychosocial Model each explain important aspects of ageing but generally focus

on specific dimensions of health. Human Sustainability synthesises these perspectives into a unified systems framework that explicitly integrates biological, emotional, cognitive, relational, occupational, financial, environmental, and existential determinants across the life course.

By introducing Emotional Longevity as a distinct life-course construct and positioning Women's Sustainability within this broader framework, the paper expands the conceptual boundaries of longevity science beyond biological optimisation. This systems perspective provides a common language for integrating research across medicine, psychology, neuroscience, public health, sociology, economics, and environmental sciences.

LIMITATIONS

Several limitations should be acknowledged.

First, the proposed frameworks are conceptual and have not yet undergone empirical validation. Their scientific value will ultimately depend on rigorous testing across diverse populations and settings.

Second, the domains included within Human Sustainability and Women's Sustainability may require refinement as evidence accumulates. Additional determinants or alternative conceptualisations may emerge through interdisciplinary research.

Third, although the framework aims to be broadly applicable, cultural, socioeconomic, and healthcare differences are likely to influence how Human Sustainability is experienced and measured. Future work should therefore examine cross-cultural validity and ensure that assessment tools are appropriate across different populations.

Finally, the relationships among the proposed domains are likely to be dynamic and non-linear. Longitudinal studies will be required to clarify causal pathways and interactions over time.

Future Research Agenda

The concepts introduced in this paper provide a foundation for a broad interdisciplinary research agenda.

Future studies should focus on five priorities:

1. **Conceptual refinement** through expert consensus involving psychology, psychiatry, gerontology, public health, behavioural medicine, neuroscience, women's health, and longevity science.

2. **Measurement development**, including validated instruments for Human Sustainability, Women's Sustainability, and Emotional Longevity with demonstrated reliability, construct validity, and cross-cultural applicability.
3. **Longitudinal investigation** to determine whether these constructs predict healthspan, disability-free survival, cognitive ageing, healthcare utilisation, and quality of life independently of traditional biomedical risk factors.
4. **Intervention studies** evaluating whether programmes targeting emotional regulation, social connectedness, workplace well-being, caregiver support, financial resilience, and purpose improve healthy ageing outcomes.
5. **Implementation research** examining how these frameworks can be integrated into preventive healthcare, primary care, women's health services, workplace wellness programmes, longevity clinics, and public health policy.
6. Addressing these priorities will determine whether Human Sustainability can evolve from a conceptual model into a practical framework for research, clinical assessment, and policy development.

Research Priority	Objective	Potential Outputs
Conceptual refinement	Refine Human Sustainability, Emotional Longevity, and Women's Sustainability through interdisciplinary expert consensus	Consensus framework, theoretical refinement
Measurement development	Develop and validate multidimensional assessment instruments	Human Sustainability Index, Emotional Longevity Scale, Women's Sustainability Scale
Longitudinal validation	Evaluate predictive validity across the life course	Healthspan, disability-free survival, quality of life, healthy ageing
Intervention studies	Test multidomain interventions targeting biological, emotional, social, occupational, and environmental determinants	Evidence-based intervention models
Clinical implementation	Integrate frameworks into healthcare and longevity medicine	Screening tools, clinical guidelines
Public health and policy	Inform national and international healthy ageing strategies	Public health programmes, policy frameworks
Global observatory	Establish international monitoring of Human Sustainability indicators	Population surveillance, cross-country benchmarking

CONCLUSION

Longevity science has entered a new era. Extending lifespan is no longer the sole objective; the challenge is ensuring that additional years are characterised by health, resilience, dignity, and meaningful participation in society.

This paper proposes Human Sustainability as a multidimensional framework that broadens contemporary approaches to healthy ageing by integrating biological, emotional, cognitive, relational, occupational, financial, environmental, and existential determinants within a single systems perspective. Within this framework, Emotional Longevity highlights the importance of sustaining emotional adaptability throughout the life course, while Women's Sustainability addresses the unique biological and social experiences shaping female healthy ageing. These concepts are unified through the Human Sustainability Systems Model (HSSM), which conceptualises longevity as the product of interacting adaptive systems rather than isolated biological processes.

Although these frameworks require empirical validation, they offer a foundation for future interdisciplinary research and provide a broader vision of healthy ageing—one that values not only years added to life but also the capacity to live those years with purpose, resilience, connection, and well-being.

Ultimately, the future of longevity science may depend not only on understanding how long people live, but also on understanding how human capacities can be sustained throughout increasingly longer lives.

REFERENCES

1. Albert, P. R. (2015). Why is depression more prevalent in women? *Journal of Psychiatry and Neuroscience*, 40(4), 219–221.
2. Beard, J. R., Officer, A., de Carvalho, I. A., Sadana, R., Pot, A. M., Michel, J. P., Lloyd-Sherlock, P., Epping-Jordan, J. E., Peeters, G., Mahanani, W. R., Thiagarajan, J. A., and Chatterji, S. (2016). The World report on ageing and health: A policy framework for healthy ageing. *The Lancet*, 387(10033), 2145–2154.
3. Ben-Shlomo, Y., and Kuh, D. (2002). A life course approach to chronic disease epidemiology. *International Journal of Epidemiology*, 31(2), 285–293.
4. Bonanno, G. A. (2004). Loss, trauma, and human resilience. *American Psychologist*, 59(1), 20–28.
5. Campisi, J. (2013). Aging, cellular senescence, and cancer. *Cell*, 153(6), 1194–1217.

6. Collins, F. S., and Varmus, H. (2015). A new initiative on precision medicine. *New England Journal of Medicine*, 372(9), 793–795.
7. Cronbach, L. J., and Meehl, P. E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, 52(4), 281–302.
8. Destoumieux-Garzón, D., Mavingui, P., Boetsch, G., et al. (2018). The One Health concept: 10 years old and a long road ahead. *Frontiers in Veterinary Science*, 5, 14.
9. DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th ed.). Sage.
10. Diener, E., Suh, E. M., Lucas, R. E., and Smith, H. L. (1999). Subjective well-being: Three decades of progress. *Psychological Bulletin*, 125(2), 276–302.
11. Engel, G. L. (1977). The need for a new medical model: A challenge for biomedicine. *Science*, 196(4286), 129–136.
12. Franceschi, C., et al. (2018). Inflammaging and immunosenescence. *Nature Reviews Immunology*.
13. Fredrickson, B. L. (2001). The role of positive emotions in positive psychology. *American Psychologist*, 56(3), 218–226.
14. Furr, R. M. (2021). *Psychometrics: An Introduction* (4th ed.). Sage.
15. GBD 2019 Diseases and Injuries Collaborators. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019. *The Lancet*, 396(10258), 1204–1222.
16. GBD 2019 Mental Disorders Collaborators. (2022). Global, regional, and national burden of 12 mental disorders in 204 countries and territories, 1990–2019. *The Lancet Psychiatry*, 9(2), 137–150.
17. Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry*, 26(1), 1–26.
18. Heidari, S., Babor, T. F., De Castro, P., Tort, S., and Curno, M. (2016). Sex and gender equity in research: Rationale for the SAGER guidelines. *Research Integrity and Peer Review*, 1, 2.
19. Holt-Lunstad, J., Smith, T. B., and Layton, J. B. (2010). Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine*, 7(7), e1000316.
20. Horvath, S. (2013). DNA methylation age of human tissues and cell types. *Genome Biology*, 14, R115.
21. International Labour Organization. (2023). *Global Employment Trends for Women 2023*.
22. Kennedy, B. K., Berger, S. L., Brunet, A., et al. (2014). Geroscience: Linking aging to chronic disease. *Cell*, 159(4), 709–713.

23. López-Otín, C., Blasco, M. A., Partridge, L., Serrano, M., and Kroemer, G. (2013). The hallmarks of aging. *Cell*, 153(6), 1194–1217.
24. López-Otín, C., Blasco, M. A., Partridge, L., Serrano, M., and Kroemer, G. (2023). Hallmarks of aging: An expanding universe. *Cell*, 186(2), 243–278.
25. Marmot, M., Allen, J., Boyce, T., Goldblatt, P., and Morrison, J. (2020). *Health Equity in England: The Marmot Review 10 Years On*. Institute of Health Equity.
26. Marmot, M., and Wilkinson, R. G. (Eds.). (2005). *Social determinants of health* (2nd ed.). Oxford University Press.
27. Maslach, C., and Leiter, M. P. (2016). Understanding the burnout experience: Recent research and its implications. *World Psychiatry*, 15(2), 103–111.
28. McEwen, B. S. (1998). Protective and damaging effects of stress mediators. *New England Journal of Medicine*, 338(3), 171–179.
29. McGinnis, J. M., and Foege, W. H. (1993). Actual causes of death in the United States. *JAMA*.
30. Meadows, D. H. (2008). *Thinking in systems: A primer*. Chelsea Green Publishing.
31. Mishra, G. D., et al. (2021). Menopause and healthy ageing: A life-course perspective. *The Lancet Healthy Longevity*.
32. Mokkink, L. B., et al. (2018). COSMIN methodology for evaluating the content validity of patient-reported outcome measures. *Quality of Life Research*, 27(5), 1159–1170.
33. Nunnally, J. C., and Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.
34. OECD. (2023). *Health at a Glance 2023: OECD Indicators*. OECD Publishing.
35. Oksuzyan, A., Juel, K., Vaupel, J. W., and Christensen, K. (2008). Men: Good health and high mortality. *Aging Clinical and Experimental Research*, 20(2), 91–102.
36. Omran, A. R. (1971). The epidemiologic transition: A theory of the epidemiology of population change. *The Milbank Memorial Fund Quarterly*, 49(4), 509–538.
37. Porter, M. E. (2010). What is value in health care? *New England Journal of Medicine*, 363(26), 2477–2481.
38. Prince, M. J., Wimo, A., Guerchet, M., Ali, G. C., Wu, Y.-T., and Prina, M. (2015). *World Alzheimer Report 2015*. Alzheimer's Disease International.
39. Rowe, J. W., and Kahn, R. L. (1997). Successful aging. *The Gerontologist*, 37(4), 433–440.
40. Ryff, C. D. (1989). Happiness is everything, or is it? *Journal of Personality and Social Psychology*, 57(6), 1069–1081.

41. Seligman, M. E. P. (2011). *Flourish*. Free Press.
42. Slavich, G. M., and Irwin, M. R. (2014). From stress to inflammation and major depressive disorder: A social signal transduction theory of depression. *Psychological Bulletin*, 140(3), 774–815.
43. Steptoe, A., Deaton, A., and Stone, A. A. (2015). Subjective well-being, health, and ageing. *The Lancet*, 385(9968), 640–648.
44. Stern, Y. (2012). Cognitive reserve in ageing and Alzheimer's disease. *The Lancet Neurology*, 11(11), 1006–1012.
45. Terwee, C. B., et al. (2018). COSMIN methodology for evaluating measurement properties of patient-reported outcome measures. *Quality of Life Research*, 27(5), 1147–1157.
46. Topol, E. (2019). *Deep medicine: How artificial intelligence can make healthcare human again*. Basic Books.
47. United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*.
48. United Nations, Department of Economic and Social Affairs, Population Division. (2022). *World Population Prospects 2022: Summary of Results*.
49. Whitmee, S., Haines, A., Beyrer, C., et al. (2015). Safeguarding human health in the Anthropocene epoch: Report of the Rockefeller Foundation–Lancet Commission on Planetary Health. *The Lancet*, 386(10007), 1973–2028.
50. World Health Organization. (2007). *Global age-friendly cities: A guide*.
51. World Health Organization. (2015). *World report on ageing and health*.
52. World Health Organization. (2020). *Decade of Healthy Ageing: Baseline Report*.
53. World Health Organization. (2021). *Women's health and well-being in Europe: Beyond the mortality advantage*.