

Prevention: Key to healthy ageing

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H. Bouma, V.T. Taipale, J.E.M.H. van Bronswijk. Prevention: Key to healthy ageing. Gerontechnology 2015;14(1):4-20; doi:10.4017/gt.2015.14.1.003.00 **Aim** Prevention technology provides tools for realizing healthy ageing. Gerontechnology has evolved from 'technology for compensating restrictions of old age' to a scientific domain at the crossroad between gerontology and technology. It fosters cross-fertilization in research, engineering and design. Its mission is to enable good quality of life to the highest possible age including the prevention and delay of chronic conditions among which frailty and disabilities, in short: healthy ageing. **Method** Three-fold desk research on (i) analysis of existing successes and failures in prevention by public health engineering in main domains of life; (ii) different paradigms in gerontology for preventing disease and finding the best environmental fit including epigenetics; (iii) reflections on the role played by people themselves in taking care of their health, as exemplified by a recent shift in health paradigm for ageing people. **Results** Public Health Engineering has yielded impressive preventive gains in several domains but other domains remain to be conquered. Primary prevention of disease has come in three historic waves: Communicable diseases, non-communicable diseases, and mental illness of which prevention is still in its infancy. Prevention appears as a life-long issue. Contributions of technology are indicated together with their possible actors. Targets for secondary prevention of threats in old age are formulated. New vast resources, also of ageing people for realizing preventive gains are provided by Internet, tablets, and mobile phone technologies; but hindrances have to be cleared.

Keywords: prevention, healthy ageing, public health engineering, independence

This paper deals with how to reach and advance ageing in good health and well-being. For this, all throughout life, adverse agents have to be warded off and prevented from manifesting themselves sooner or later. Here, the focus is on technology tools for realising such prevention. Generally, such tools are not stand-alone, but rather embedded and integrated in environments, habits, and cultures.

Apart from external threats, of which there are many, the recipe all throughout life for healthy ageing is threefold: (i) regular exercise; (ii) sustained mental activity; (iii) maintained social contacts (*Table 1, Figures 1-3*).

Prevention comprises all interventions to avoid evil happenings, diseases, threatening circumstances, adverse ageing effects (primary prevention) and, once unwanted effects have manifested themselves nevertheless, to avoid further deterioration and diminish impacts and negative side effects on daily life (secondary prevention). For ageing people, of primary concern here, the goal of secondary prevention will often be to secure independence and social readiness for pursuing their own life and interests despite chronic conditions. The related issue of technology for compensating weakened individual faculties will be left outside the present scope, such as hear-

ing aids for the poor hearing of speech, walkers for maintaining balance in walking, platforms for ageing in place in multiple minor disabilities¹⁻³. Many compensatory aids are already accepted or even interwoven in the intrinsic fabric of everyday life in the industrial world such as spectacles and eye lenses, handrails, elevators, luggage on wheels, and electric bicycles.

Prevention can also be distinguished as to different targets. Health protection includes restricting exposure to health threatening agents in the environment such as providing clean air, safe drinking water, and restricting loud noise. Health promotion includes measures to enhance healthy lifestyles such as non-smoking, healthy nutrition, and safe driving. Disease prevention includes prevention and early detection of specific diseases such as in congenital predispositions and in taxing circumstances⁴.

Technology is a driving force and omnipresent in society. Part of this is its function as important tool for applications in prevention. Since technology is not a purpose in itself and often hidden in its applications, its indispensable role in healthy ageing will not always be recognized⁵.

Fruits of prevention are in the pleasure, dignity, and quality of life of older people (*Figure 1*). For

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Table 1. Three general pillars of healthy aging in a daily activity & duration matrix, both as life-long activities and specialised ones focussed on the after-retirement period

		Duration	
		LIFE LONG	AFTER RETIREMENT
Daily activity	PHYSICAL	-House-work -Healthy food -Exercise/Sport -Job/volunteering	-House-work/gardening -Healthy food -Volunteering -(Sensor-managed) exercise
	MENTAL	-Learning (a.o. digital competence) -Job/Volunteering -Sport/hobbies/games -Internet tasks	-Learning (digital competence) -Hobbies -Volunteering -Cross-word puzzles, Sudoku -Tele-bridge & other card games -Internet tasks
	SOCIAL	-Family -Friends -Colleagues -Social sites	-Family -Friends -Volunteering -Social sites

programs in a complex sphere of many interests inside and outside the health sector. The present overview provides general guidance but does not allow balanced assessments for implementation.

Prevention covers a wide field and concerns a great many actors responsible for people to reach old age in independence and in good health: government agencies in several departments

reasons of public health policy, for example in comparing gains against costs, such fruits may be quantified in added number of life years. Usually, the opposite is calculated, disease burden as healthy years lost, which includes adverse effects on daily life: DALY (Disease Adjusted Life Years) is expressed as the number of years lost due to ill-health, disability, or early death⁶. The present paper takes a qualitative rather than quantitative approach.

The effectiveness of preventive actions may vary, due to a great many actors and circumstances either detrimental or supportive. Also, likelihood, urgency, and seriousness of health problems to be prevented are to be taken into account, both immediate and on longer term. In the public sphere this requires long-term decisive action

and at several levels, non-government agencies (NGO's), businesses, medical and care professionals and their organizations, people and their families themselves: all are involved, also for applying available technologies. Since health is influenced extensively by factors outside the medical area, an effective health policy must involve all relevant policy areas, in particular social and regional policy, taxation, environment, education and research⁷. The treaty of the European Union (EU) requires all EU policies to follow this 'Health in all Policies' (HIAP) approach. To be fully effective, the HIAP approach needs to be extended to national, regional and local policies⁸. Scientific research has been and remains the powerful motor for identifying both opportunities and distractions, and for providing guidance in the complexities of the public domain caught between so many conflicting interests⁹.



Figure 1. Combining two pillars of healthy aging: Life-long physical and social activity; Completing the annual Nijmegen 4-days marches (30-50 km each day) on the 'Via Gladiola'; in 2015 participants were aged 12 to 92 years, and about half of the 40,000 participants fell in the 51-70 years age category and will usually need regular training to complete this yearly task (Photographer: Ingrid Kicken-van Criecken)

This paper concerns technology interventions all throughout life for the promotion of health and well-being of ageing people by primary and secondary prevention of accidents, disasters, diseases, and also of chronic conditions – minor multiple disabilities - that become more obvious at advanced age.

Starting with primary prevention, it will first deal with public health engineering in which six examples will be mentioned that are indicative of both impressive progress and great tasks ahead. Next, different types of disease will be mentioned in historical order of preventive global waves. Mental health and social embedding are just as important as physical health (Figure 2), but prevention largely remains to be developed and few suitable tools can be mentioned. It will appear that prevention directed at ageing people is a lifelong issue, starting even before birth. As ageing tends to weaken physical functions and threaten inde-

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Figure 2. Combining two pillars of healthy aging: Regular physical and mental exercise; At the 500m time-trial cycling (July 12, 2015) at the National Senior Olympics in Minnesota attracted about 280 male (aged 50-90) and around 100 female cyclists (aged 50-84 years) (Photographer: Shannon Neilon)

pendence, we will mention four targets for secondary prevention that merit specific attention.

The recent Internet revolution offers a host of options for empowerment also of older people to advance prevention in many types of accident, disease, and ageing effects. This is also causing a shift in medical paradigm in which persons themselves will take more responsibility for their own health and independence. Such self-active prevention is to be enabled by educational opportunities and a robust and reliable infrastructure in the health domain.

PRIMARY PREVENTION: PUBLIC HEALTH ENGINEERING

Public health refers to all measures in society that are directed at increasing or maintaining the health of the whole or certain sections of the population. Notice that by now any specific patient is hidden in the population, and populations are described by statistics, among which averages, medians, and standard deviations, of pain, of cost, of functionality, of adequacy of help, of quality of life, and of many other data of interest. Consequently, it will never be known which persons are still alive or healthy because of successful prevention programs. And, as we shall see, many have been so fortunate. The efficacy and success of prevention programmes shows at the population level at large.

Public health is concerned with ecology¹⁰ and with supportive environments for healthy living, and is as such directly coupled to promotion and prevention, as well as technology (PHE: Public Health Engineering). Public health is multi-disciplinary by definition; it is necessary to have an understanding of the communal, psychological, physiological and genetic backgrounds. Research on health determinants is in the early stages. An important present mediator for the

health of the population is people's educational and social status¹¹.

In 1920, the pioneer C-E Amory Winslow described public health as "the science and art of preventing disease, prolonging life and promoting health through the organized efforts and informed choices of society, organizations, public and private, communities and individuals"¹². A hundred years later we know how accurate this definition has been and how challenging it still is for today's world. Indeed, particularly in the rich countries, many infectious diseases nearly disappeared due to massive vaccinations; cholera and salmonellosis were eradicated by sanitation, and tuberculosis was decimated by better housing policy. But our challenges are not only concerned with any special community and its informed choices; nowadays the whole globe bears deep interdependency¹³. As ageing has become a global megatrend, we should look again at public health and its opportunities.

Landmarks of successful prevention in the sphere of PHE are the provision of clean drinking water and the presence of sewerage. However, this has taken decades in the industrial countries. These two central targets were included in UN Millennium Development Goals 2000-2015 as target 7 C, as compared with 1990: "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation"¹⁴. In 2012, 748 million people remained without access to an improved source of drinking water, and, despite progress, 2.5 billion in developing countries still lack access to improved sanitation facilities.

Six threats

In PHE, older people deserve separate consideration for at least three reasons: (i) Prevention is a lifelong issue and often its consequences become apparent in old age; (ii) Ageing persons are particularly susceptible to accidents, diseases, and threatening environments of crisis situations (which susceptibility they share with children)¹⁵; (iii) public health engineering for older people has a strong social and political dimension that deserves special attention.

Six examples of adverse circumstances fit for primary prevention of the health-protecting type will be mentioned, dealing with: (i) War as failed public prevention; (ii) Global poverty declined as millennium goal; (iii) Traffic accidents as diminished by long term efforts; (iv) Air pollution fought for the prevention of lung, heart and vascular diseases; (v) Flooding for protection against sudden disaster; (vi) Occupational hazards as hidden threats. Some examples are from the

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United States¹⁶, Finland¹⁷, and the Netherlands⁴, but all are of general significance.

Most of these preventive actions require strong national and international governance, either as direct actors or as enablers by making binding laws and upholding implementation. It follows that in countries with weak governments, people are more likely to suffer. International bodies start with global organizations, first and foremost the United Nations (UN) and its many sub-organizations among which the World Health Organization (WHO), the International Monetary Fund (IMF), the G20, followed by continental and regional organizations such as the EU and the African Union, and other multilateral or bilateral agreements between countries.

War

War situations are disastrous for public health. Not only soldiers are killed and wounded, leaving their families in bereavement and difficulties. Civilians are killed and wounded as well, despite war treaties that intend to prevent just that. Many will try to flee the war zones. Among those suffering, older people and children are specifically victimized because of their lesser mobility and increased vulnerability. Any recent war can be taken as example: The Serbian-Bosnia war, the Ruanda killings, the Iran-Iraq war, the Iraq invasion, the Afghanistan war, the Syrian civil war, the present wars in central Africa. Obviously, prevention has utterly failed. Diplomacy has proven unable to prevent the outbreaks of conflict, neither has it established control over the enabling 'lucrative' weapon plants and weapon trading.

On the other hand, the peace in Europe exemplified by the present EU is proof of the beneficial result of wise policies for peace after two devastating world wars in the 20th century that left tens of millions dead.

In war situations, technology shows its most devastating sides. Both manufacture of automatic weapons, and weapon and ammunition trade and traffic should be targeted for preventive control also by technological means. Prevention of armed conflict seems a most urgent international task for protecting and advancing public health^{18,19}.

The enormous technological efforts put into preparation and waging of war have also led to many peaceful applications. Such positive secondary effects may hold for any large scale and long term projects and investments, such as space missions. The lesson is that sizeable public-funded technological projects have lots of unforeseen benefits and other effects far outside their direct goals. However, this does not imply

that weapon and ammunition trade and traffic and resulting war should be welcomed.

Poverty

Poverty is an example of partly failed prevention. Poverty here is meant as insufficient means for the basic necessities of life: proper food, safe drinking water, shelter against the weather, primary health care. The UN has made poverty operational as a disposable income of less than US\$1.25/day. In a second line of poverty comes lack of primary education. As in war, particularly older people and children are facing the reality of poverty. It is well documented that the problems can be solved if given priority in the international community; in fact reduction of extreme poverty and malnutrition by 50% was one of the Millennium Development Goals (MDG) of the UN with already substantial success: in 2010 as compared with 1990 a reduction by 700 million people, but still 1.200 million to go¹⁴. The fight against poverty has deserved the long term and well-coordinated programme of the UN. Although during the period of MDG global poverty has been halved, this is not enough. Only a third of countries, covering 28% of global population, has comprehensive social poverty protection schemes²⁰. The Sustained Development Goals (SDG) as successor of the MDG is intended to end poverty in all its forms everywhere (target 1) with target 2 defined as: "Reduce at least by half the proportion of men, women, and children of all ages, living in poverty in all its dimensions according to national definitions".

However, the high and rising inequality of income in many countries threaten the interests of rich and poor alike, and the welfare of the whole population as well^{21,22}. In the prevention of poverty, it is the supply of technological provisions for basic necessities that defines the interest of gerontechnology. Among these are higher crops by better seeds and agriculture, drinking water systems, sewage systems, and educational facilities.

Traffic accidents

In 1970, the absolute number of traffic deaths in the Netherlands was about 3.000, corresponding to some 20 per 100.000 inhabitants. In 2013, this number had shrunk to about 570; corresponding to some 3 per 100.000 persons²³. The period from 1970 to 2013 had also seen an enormous increase in traffic. The spectacular gain of about 17 per 100.000 *not dead per year* has been realised by a long term program of preventive measures, among which obligatory seat belts and motor helmets, separation of fast and slow traffic, better roads and road markings, more roundabouts and other speed reducers, lower speed limits outside motor ways, more speed

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and alcohol checks, and better education of the general public. Equal development was reached in Finland through a strict structural policy in the seventies²⁴, and in the US¹⁶. Injuries have declined substantially as well, be it less so than casualties. Such figures are exemplary for gains in traffic safety by prevention in many countries. Young and older people are more likely to be involved in accidents and older people are generally more in risk of serious injuries. However, many older people take their own decision to avoid driving either altogether or in certain circumstances. Increased safety software in 'smart' cars holds promise for the near future.

The extensive and maintained technology effort in the traffic system has been undertaken also for reasons of economic mobility. Whatever the reason, the preventive results have been impressive and have met the declared purpose of the whole programme. In the Netherlands and in Finland the budget has come from the Ministry of Traffic rather than from the Ministry of Health, and thus was not in competition with the budget for cure and care. Prevention in public health belongs to a great many spheres and departments including the connected budgets. In fact, health budgets proper tend to be given only limited room for prevention, since, as compared to prevention, cure and care appear more immediate and urgent⁴.

As with automobile traffic, the general safety in global air travel has also increased enormously because of a sustained disciplined programme of trainings and safety protocols based among others on thorough analysis and consecutive action on any single accident.

Flooding

In 1953, a heavy North-Western storm raised the water level in the North Sea and broke several dikes in the Netherlands delta, which took over 2.300 lives. The shock resulted in the Delta plan, a long-term programme for preventing any future flooding by building and strengthening dikes and weirs alongside rivers and sea. The programme had to be made permanent with government funding guaranteed, because of the continuous rise of the sea level (2-3mm/year) and of river level peaks, both from climate warming. In some countries, among which the Netherlands, the rise in sea level is accompanied by movements of the earth crust due to such factors as the disappearance of ice masses in the past and the degradation of peat²⁵⁻²⁷. Since 1953, in the Netherlands only a few minor dike collapses have occurred and the occasionally large rainfalls in neighbouring countries, raising river levels and causing flooding there, have only once caused a serious risk of flooding, which in fact did not re-

alize. Here, the Ministry of Water Management is providing the budget. Similar preventive efforts in the USA exist in New Orleans and New York City, triggered by extreme hurricanes with extensive loss of life and property. The recent loss of life in the Philippines is another example, waiting to be kept from repetition. Many rich and poor countries will be facing similar serious problems for which technology is ready to display its indispensable side.

A rare but serious flooding danger comes from tsunamis of which those of 2004 and 2011 in East-Asia took together the astonishing number of over 200.000 human lives. Since then, a tsunami warning system has been set up.

Air pollution

Breathing clean, unpolluted air is an obvious condition for sustained health. Nevertheless in most countries and cities, this condition is only partly fulfilled. Pollution comes from many sources among which industry, traffic, power stations in particular from coal, animals, and people.

As an example, only pollution from smoking will be considered here. As from about 1960, the harmful effects of smoking became evident, resulting in lung-, stomach-, heart- and vascular diseases with deadly consequences. Programmes for counteracting smoking have had successes in many countries, despite doubt-advocating programmes by the affluent tobacco industry²⁸, out to capture people into addiction to nicotine. Since then, the dangerous effects of second-hand smoking have been recognized as well. Because smoking can be addictive, effects of information spreading, of price increases and of prohibition of smoking in all public buildings including restaurants and cafés, have had slow but steady success: in the Netherlands the percentage of male smokers fell gradually from 90% in 1960 to 35% in 2008⁴ and in Finland from 50% of the male population in 1970s to 20% in 2012²⁹. In the Netherlands, this policy has resulted in a yearly reduction of mortality of several thousands of people, apart from the reduction in functionality loss and connected diseases. In this case, the limited budget has been supplied by the Ministry of Health, which together with the resistance of vested interests may also explain its less than ideal success. Since smoking has long-term rather than short-term effects, many older people have to endure the negative effects assembled earlier in life.

In general, an unpolluted environment is among the fruits to be wrestled from prevailing counteractive narrow economic and quasi-economic interests, and, if allowed by politics, technology delivers the effective means by proper sensors

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including those from satellites, by cleaning exhaust gasses, and not the least by replacing polluting power stations by windmills, solar cells, and other sustainable solutions.

Occupational hazards

One has only to compare the sad stories from the work force a century ago (for instance³⁰) with those of today, or the recent accidents from too fast building processes such as stadiums, to realise how much safer and healthier working has generally become. All over occupations, working has become safer mostly by technological improvements implemented through stricter regulation. In the USA, both death rate and injury rate have about been halved between 1980 and 1995¹⁶, and more dangerous occupations such as mining have been identified and targeted for improvement. Technology plays an essential part in the progress of prevention on the work place. Since quite a few occupational diseases tend to become chronic (hearing problems, lung problems, back problems, accident effects), many older people suffer from their earlier exposures. Prevention technologies are readily available, waiting for implementation. Apart from government regulation, businesses, business organizations and worker unions are important actors.

Based on earlier papers, *Table 2* provides an overview of contributions from several technological disciplines to counteracting threats in the public domain in various domains of life. Multiple actors are involved and good governance is in the best position to coordinate efforts and see to actual implementation^{1,2,31}. A few cell entries have been marked as particularly relevant for either developing or industrial countries.

PRIMARY PERSON-DIRECTED PREVENTION: DISEASE Prevention is lifelong

Prevention is a lifelong issue, starting even before birth. The base of a number of current chronic conditions is laid in (early) childhood and could partly be prevented. Although many gerontechnology projects aim at supporting older adults in frailty or near frailty, the available theoretical and empirical knowledge allows for a more sustainable option: preventing or postponing chronic conditions through limited life-long exposures to certain potentially threatening agents, starting at birth or conception, that can foster immunities. For example, certain allergies can be considered as failed prevention³².

As example, the diet of a pregnant mother may influence her child's development through DNA-methylation or histone modification in the cells of the child. This effect is part of epigenetics and may be induced by a long list of environmen-

tal factors, mostly still not understood³³. It may alter development, fitness and susceptibility for disease in children. Epigenetic effects can be inherited for two or more generations, but will eventually disappear³⁴.

Epigenetics gives us reason to think that even environments and circumstances before our birth may have influenced our later life, including ageing³². Research here is yet scarce, but convincing. The conclusion from a systematic literature review on epigenetics and ageing provides compelling evidence about lifetime epigenetic modifications in the ageing process³⁵. The approach is from gene studies, in which an interaction was found between genetically determined and environmentally induced factors, affecting epigenetic patterns. These are correlated with both differences of inter-individual susceptibility to functional decline and of vulnerability to diseases of older people. The mechanisms are not yet fully understood, but the reversibility of epigenetic modifications provides new possibilities of interventions, both for clinical trials and rehabilitation³⁵⁻³⁷.

Apart from epigenetics, many unwanted long-term health effects exist, such as in unhealthy long-term food intake (too much, too little, too fat, too sweet, too salty), in polluted air, and in sedentary life. Older persons may have accumulated harm from all of their earlier environments, work conditions, and daily habits. In a sense this is also true for a lack of lifelong education. Health equity, i.e. similar health opportunities for all older people is hard to achieve at the population level, even in those countries where it is high on the political agenda. Indices for health in older populations show a clear-cut positive correlation with education level, resulting in the Netherlands in 6 years extra life expectation and even more years in healthy-experienced life years³⁸. Is it true that health service systems inadvertently discriminate against the lower social groups³⁹?

Global health waves

Global health and global ageing meet each other in many themes⁴⁰. In health promotion and in prevention of disease, history reveals three distinctive waves: prevention of (i) communicable diseases by infections, among which cholera, tuberculosis, malaria, smallpox and AIDS; (ii) non-communicable diseases, among which cancer, vascular and lung diseases; (iii) mental diseases which include dementia.

First wave: Communicable disease

In the first wave, the public health movement was and is directed at preventing communicable diseases. Sanitary provisions, vaccinations and vita-

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mins widely increased health long before doctors' services were available to the wider population. Nonetheless, research still faces huge challenges, as the recent Ebola-outbreak in Africa has shown. We do not know why infections spread to some but not all people. We do not know for all diseases whether there is an infection as an underlying cause. Successes have substantially contributed to the spectacular rise in life expectancy, uninterrupted since the 19th century.

However successful, prevention against communicable diseases is far from over as victims of malaria, tuberculosis, and Aids know all too well. As example, the continuing fight against tuberculosis has recently been documented in full detail⁴¹.

Second wave: Non-communicable disease

In 2008 non-communicable diseases took 36 million people's lives, representing 63% of the 57 million global deaths that year⁴². In 2030, such diseases are projected to claim the lives of 52 million people. However, the demography of lives lost is not readily apparent; people with non-communicable diseases often die relatively young, with nine million annual deaths of persons under 60yrs. The epidemic is fuelled by a combination of risk factors, including tobacco use, smog both in summer and winter, an unhealthy diet, lack of physical activity and harmful alcohol use. The four main non-communicable diseases: cardio-vascular, cancer, diabetes and COPD that share those risk factors cause almost 80% of all deaths from such diseases. Non-communicable diseases are concentrated in older people. Technical progress has allowed medical treatment to improve substantially such as in vascular and heart diseases and in cancer. For the last decades, the second wave has taken over as the motor for the rise in life expectancy.

Non-communicable diseases affect the developing world and lower-income populations hardest. Strong evidence links poverty, lack of education, and other social determinants to such diseases and their risk factors. A vicious cycle is created by the epidemic, whereby non-communicable diseases and their risk factors worsen poverty. "Non-communicable diseases and their risk factors are best addressed throughout the course of people's lives, through healthy behaviours and early diagnosis and treatment that begin before pregnancy and continue through childhood and adult life", states the report to the UN General Assembly of 2011⁴². Such a life course approach is also needed in gerontechnology.

Third wave: Mental disease and lack of social embedding⁴³

The 'third wave' of public health is still in its infancy and is concerned with mental health prob-

lems⁴⁴. There is a rather poor knowledge of mental health promotion, mental disease prevention, treatment and rehabilitation. This area is still strongly stigmatized. People are ashamed of mental health problems and may believe that people have them through their own (or their mother's) fault, and although the diseased people's needs could be partly addressed through multi-agency services and technological innovations, there are barriers to their development. There is a whole range of challenges: social stigma, scarce etiologic knowledge, a shortage of evidence-based treatment and prevention methods, lack of smart drugs, and inappropriate treatment systems, not to speak about scarce technological opportunities in prevention and treatment.

For older people, dementia of several types including Alzheimer and Parkinson are among the most frequent diseases. Recently, the protection of privacy has been gaining importance. For dementia and Parkinson disease, information is emerging that exposures sustained in the earliest stages of life, even in the womb and in the first years after birth, may have the potential to initiate changes in the brain that, decades later, result in forms of neurological degeneration⁴⁵. The recent downward trend of the incidence of dementia may be due to long term preventive effects of beneficial lifestyle habits, which, if generally endorsed, may lead to protecting about one third of the projected number of patients from dementia⁴⁶. Technologies are ever more ready to monitor lifestyle factors and to support and sustain improvements. Recent modification of Parkinson symptoms includes focused brain stimulation.

The division in primary and secondary prevention seems less applicable in general mental and social health of older people. This is because of the gradual increase of a taxing social environment and diminishing personal reserves. The circle of friends and older relatives tends to shrink because of decreased mobility and of death, making personal loss endemic in older life. Nevertheless, sufficient means remain for personal development and social embedding, including Internet opportunities for one's favorite activities and for communication. We shall devote a separate paragraph to Internet access for older people as self-active prevention.

As to social embedding, a human being is ready from birth on for loving interaction. Shared pleasure in early interaction predicts better social competence as well as lower levels of emotional and behavioural problems⁴⁷. Shared pleasure is important in all ages and especially in older age. Shared pleasure is mostly produced by friends

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and family, but pleasure can also be found by joining interesting clubs or networks, volunteer groups or NGOs, for which Internet offers supporting tools. The trend of living alone increases the importance of joining other people⁴⁸. Living alone does not mean explicitly feeling alone, but means that people need to build up consciously their contacts for friendship and closeness, and in need of help they have to be sure that someone is there to come.

Sharing means also giving. This does not mean any materialistic giving. In the nowadays materialistic world, at least in the western world, people are surrounded with their material property, with clothes, dishes, furniture, and so on. There was a study already in the 1990s on children's property in the Nordic countries. In 1910 children had on average five different things in their possession, maybe a pen, a ball, a doll etc., but in 1990 already over five hundred. Children, even grandchildren today are not in need of today's most favorite toy but of something immaterial⁴⁹. Giving is at best something emotional like caressing, holding children at one's lap or non-material as giving one's time, telling memories from old times.

Health promotion and promotion of well-being are concepts which have been developed early, then neglected until the 80s of the last century when a new era of health promotion started. Health promotion is the process of enabling people to increase control over, and to improve, their health⁵⁰. The basis is that there is no health without mental health and proper social embedding. Promoting one's own mental health, preventing both mental ageing and social isolation are activities that do not demand special education, skills or money. They are interwoven into simple everyday activities and thus can be reached and practiced by anyone⁴⁹. There are a few simple activities to be kept in mind. Keep joining, keep sharing, have hobbies, keep on learning, keep laughing⁵¹ (Figure 3).

As to ageing, there are numerous ways to promote one's health and well-being. 'Keep learning' should be a motto of older people. Bouma⁵² has explored the abilities of older people to learn and the pleasure and participation that it brings. Keep laughing! Sense of humor brings enjoyment into life, and is also healthy. Where a six-year-old child is laughing about three hundred times a day, it is estimated that people laugh in average 15-20 times a day in their adulthood. Laughing has positive psycho-physiological consequences on blood pressure, heart rate and immune system. And it is fun!⁵³.

SECONDARY PERSON-DIRECTED PREVENTION: TARGETS FOR PHYSICAL HEALTH

A selection of actions for mitigating negative health conditions common in old age will now be considered from the viewpoint of secondary prevention: (i) regular exercise; (ii) weight control; (iii) restricting falls; (iv) postponing frailty. Some of the actions to be considered have to be balanced against risks: falling is unlikely while sitting in a chair, but one's general condition will suffer; poor eye-sight may limit one's wish to walk or cycle safely. Compensatory aids may help to find common ground solutions.

Regular exercise

"Rust roest" (rest rusts) is an old proverb in Dutch that captures the essence of an important focus of prevention. "Use it or lose it" is an English equivalent, warning against sedentary life. Regular exercise is an essential component of healthy life habits and preventive for many diseases. The reason is not immediately clear, but a proper blood circulation together with usage of muscles and joints and strain of bones may belong to the beneficial causes. This is true at all ages and remains fully valid at old age (Figure 1). If impeded by disease, frailty, or otherwise, regular exercise requires continued attention at the risk of further loss of a good physical condition and independence.

So there are options for counteracting negative aspects of physical ageing⁵⁴. Starting at early childhood and continuing through working age physical activities show their importance. A human being is a whole: physical, mental, social, and spiritual activities influence each other; body and soul are in vivid interaction. Physical improvement may positively influence general well-being. An old person might improve her or his fitness even more rapidly than a young sporter and it is never too late to start regular exercise⁵⁵. However, the environment for this can be either facilitating for older people or full of barriers^{56,57}. Technologies are now readily available for monitoring individual exercise and offering suggestions for reaching daily targets.

Regular exercise as meant here should be distinguished from demanding or even dangerous sports, which often are the cause of injuries. Although risk of injury is connected to any regular exercise as well, the gains prevail over the risks by far. Nevertheless, precautions are sensible for diminishing the risks of falls and other hazards such as wearing helmets in bicycling and walking sticks in case of weak balance. In general, exercise should be subjected to a suitable regime. Normal daily activities such as house cleaning, walking and gardening may be just as effective as specific fitness programs.

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Figure 3. Combining two pillars of healthy aging: Mental and social exercise: Sharing pleasure in the extended family of 3 generations or more; Copyright: monkeybusinessimages, iStock photo ID:11900648

WHO's International Classification of Functioning, Disability and Health, (ICF)⁵⁸ includes environmental factors in assessing the functional ability of a person. In some countries the importance of environment is even taken into effect in legislation, for example in Finland where disability is regarded as a function of the physical and built environment which therefore should be designed and implemented for maximum health, obviously by technological means.

Weight Control

Overweight is an awkward and growing global health problem. Whereas lack of food is still a huge problem in many poor countries, worldwide obesity particularly in the rich countries has nearly doubled since 1980⁵⁹. In 2008, more than 1.4 billion adults, 20 and older, were overweight. Of these, over 200 million men and nearly 300 million women were obese. 65% of the world's population is living in countries where overweight and obesity are killing more people than underweight.

Obesity is preventable. It is caused by an increased intake of food that is energy-dense and/or high in fat combined with a decrease in physical activity due to such factors as the sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization. Healthy food intake should rest on the pillars of moderation, variety, and restriction of fat, sugar and salt. Together with regular physical exercise it is the best prevention of obesity. The message, however, has not penetrated sufficiently in the population, and is still actively opposed by certain commercial interests in the food industry. Proper specific sensors of food composition could help to bring the message home to the general public.

In the last ten years epidemiologists have found a phenomenon called 'Obesity Paradox'⁶⁰. This indicates that for people over 60yrs, the standards set for young adults do not match any more. Large epidemiological and longitudinal studies have shown that people with little overweight in their 60s and 70s live longer and healthier than

their leaner counterparts. So standard norms of overweight (BME>25) and obesity (BME>30) may not do for older people. The findings show that we need more research and understanding of the processes of ageing; the standards of younger people do not inevitably reflect or predict the well-being of older persons⁶¹.

Restriction of falls

Falls of older people often have negative consequences, in particular hip bone fracture followed by a sometimes risky operation. There are a number of precursors for the fall, which may be used for prevention^{62,63}. Ergonomically speaking, slippery floors, loose rugs and unsteady footwear should be avoided and wall supports may be of help. Climbing ladders is obviously dangerous. Even so, reduced balance, an unsteady gait, sedatives^{64,65} or an earlier fall are indicative of enhanced risk, open to be counteracted by technological means⁶⁶, such as a walking cane or walker with proper brakes or by a new method of walking on interactive tiles in unpredictable patterns⁶⁷. In principle, external protection of the hip preferably by padding is an option⁶⁸, but the load of permanent hoods will probably be prohibitive⁶⁹, whereas the interesting concept of protective air bags⁷⁰ is promising for the future. Since bone fractures are enabled by osteoporosis, prevention of osteoporosis is of great value and should be a permanent goal in old age, particularly for women^{71,72}.

In addition to community alarms and accelerometers worn by the potential victim, or motion sensors and cameras installed in the room, other home technologies have been proposed, such as smart floors⁶³ or the common vacuum cleaner robots⁷³. Even indoor drones were recently mentioned⁷⁴. Further testing will be needed to integrate the different phases of prevention programmes⁷⁵.

Postponement of frailty

Frailty is a condition of dependence that occurs in old age but not in healthy childhood or at working age. It has long been known and called a syndrome⁷⁶. The symptoms of frailty tend to increase incrementally in old age, which may make it difficult to discern for those who are living close. Frailty is more common in old women than old men, and is more prevalent in lower socio-economic groups.

The best known five criteria for frailty have been developed by Fried and her team in Johns Hopkins⁷⁷: (i) loss of weight, (ii) exhaustion, (iii) weakness (decline in grip strength), (iv) slowness, (v) low activity level, each with well-defined criteria. Older people who meet at least three of these criteria are defined frail. A simpler test is

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the 'Timed up and go' test, measuring how long it takes to rise from a chair, walk 3 meters to and fro and sit down again, with a frailty criterion of >20s⁷⁸, supplemented with a mini-nutritional test and assessment of serum albumin in blood for possible under-nourishment⁷⁹. Pending a generally accepted precise definition, the prevalence of frailty in specific groups of older people cannot be reliably assessed. Frailty means increased risk for major illnesses, hospitalization, falls, institutionalization and mortality; therefore the early detection and prevention of every dimension of frailty are most important.

Xue⁸⁰ has developed a theory in which 'constriction of life space' is a marker of declines in physiological reserve. Constriction of life space could lead to decreased physical activity and social engagement, creating a vicious cycle with exacerbated decline in physiological reserve, thereby contributing to the development of frailty. Future development of tools for the assessment of physiological reserve and analysis of its relations to behavioural mal-adaptations could help in delineating the hypothesized causal pathway. It may be the interplay of functional limitations and functional reserve that determines actual function and behaviour.

It is clear that frailty has to be prevented as far as is possible. However, the knowledge base to explain and understand the phenomenon is not yet solid enough. It is explained as decline of energy production, energy utilization and decline in repair systems of the body which all can affect the normal body functions. As the determinants (depletion of reserves) may build up long before frailty is actually realized, prevention may have to start early and in fact be part of normal life. Main preventive measures relate to daily exercise, furthering blood circulation and maintenance of muscles joints and bones, regular mental work keeping the spirit alive, and sustained social embedding, as the three basic entities for healthy ageing.

In addition to *Table 2*, *Table 3* provides an overview of contributions from several technological disciplines to counteracting threats and maintaining independence in the various domains of life. Here, private citizens are putting themselves increasingly in the driving seat, supported by professionals. A few cell entries have been marked as particularly relevant for either developing or industrial countries.

SELF-ACTIVE PREVENTION

Since good health is the obvious purpose of prevention, let us consider the changing concept of health in an ageing society. Health is a value

shared by all people in both industrial and developing countries. Health is more important for human life than economic success or a promising future. From the somewhat narrow viewpoint of economics, health is a production factor that ensures a good economic and operational environment.

Health is a human value with strong, physical, psychological, spiritual and socio-cultural aspects. As to the latter, a human being is a social creature that is not even able to develop without a social environment. A family – as understood in the broad sense – provides a human being with a communal culture and at the same time with the unique environment of one's own family. In addition, a child not only receives the genes of his or her own group of people and family but also a unique combination of these genes, ready to be expressed in favorable environments.

The spectrum of technologies for self-active prevention is wide. The selection here will be that of empowering older persons for active prevention to reach active ageing, thus promoting their independence, their own health and the health of people in their direct environment. The public aspect is in the provision and promotion of reliable and easily accessible information, in options and tools, and in the provision of favourable circumstances. Since the citizens themselves are the real actors, they should be reached, informed, motivated and encouraged to follow preventive paths.

Parallel health paradigms

The health paradigm still mostly in use in nowadays practice is directed at diagnosis, treatment, and also prevention of specific diseases. This is the century-old Hippocratic model. It is not well suited to deal with chronic diseases, of which older people tend to have several. If so, the purpose has become to live an independent life despite the chronic diseases. This causes a shift in problem ownership from the medical specialist to the older person⁸¹. The WHO has captured this spirit quite early with its focus on function rather than disease, although the formal definition of health has been left unchanged so far. A recent proposal defines 'positive health' as "the ability to adapt and self-manage one's own life against physical and emotional and social challenges of life"⁸². Widening 'emotional' to 'mental' captures the above purpose of older people. The new functional paradigm will be valid side-to-side with the Hippocratic paradigm, since diseases have to remain diagnosed, treated, and prevented as before. Examples of the increasing role of the individual person as to her/his health are the Internet options for personal health

Table 2. A selection of lifelong public engineering options for reaching and maintaining old age in good health, spread over disciplines and domains of life; most are characterized as primary prevention; in bold-regular type most effective measures in developing countries; in bold-italic strongly effective ones in industrial countries

		Technology discipline					
		(BIO)PHYSICS (BIO)CHEMISTRY BIOLOGY	ARCHITECTURE CONSTRUCTION	INFORMATION COMMUNICATION	MECHATRONICS ROBOTICS	ERGONOMICS DESIGN	BUSINESS MANAGEMENT ECONOMICS
Domains of life	HEALTH SELF-ESTEEM	-Sensors for: weather data, air pollution, water pollution, flooding & tsunami	-Indoor air purity -House-dust mite & cockroach abatement <i>Legionella</i> management	-Warnings for: weather danger, air pollution, water flooding, tsunami		-Coaches & warnings	-Balanced diet provision
	HOUSING DAILY LIVING	- <i>Avoiding a sedentary lifestyle</i>	- Safe & secure housing: -potable water provision, -sanitation, -refugee housing, - dike/weir construction	- Warnings for: hurricanes & flooding	- Smart economic appliances for heating and air-conditioning		- Sanitation - Potable & irrigation - water provision
	MOBILITY TRANSPORT		- Control weapon trade	- Control weapon trade -Food distribution	-Low emission cars, trucks & planes		
	COMMUNICATION GOVERNANCE	-Regulation & its implementation	-Regulation & its implementation	-Regulation & its implementation - Control weapon trade - Peace treaties	-Regulation & its implementation - Control weapon development	-Regulation & its implementation	-Regulation & its implementation
	WORK LEISURE		-Internet connectivity	-Internet connectivity	- Control weapon development & production		- Control weapon development & production

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Table 3. A selection of person-directed prevention options for reaching and maintaining old age in good health, focusses on the after-retirement period and, spread over technological disciplines and domains of life; medical applications are left out, among which vaccinations; in bold-italic strongly effective ones in industrial countries

	(BIO)PHYSICS (BIO)CHEMISTRY BIOLOGY	ARCHITECTURE CONSTRUCTION	INFORMATION COMMUNICATION	MECHATRONICS ROBOTICS	ERGONOMICS DESIGN	BUSINESS MANAGEMENT ECONOMICS
HEALTH SELF-ESTEEM	-Balanced diet -sensors for: blood pressure & daily exercise	-Indoor air purity -more strict Legionella management	-Life-long education - Digital competence -E-health coach for: daily exercise & balanced nutrition -Reliable websites -Privacy protection		-Easy access websites -Coaches & warnings	-Balanced diet -Relevant public & private goods
HOUSING DAILY LIVING	-Avoiding a sedentary lifestyle	-Building access	-Weather forecast	-Domotics -Household surveillance: robots, sensors, drones	-Domotics controls -Drone control	-Relevant public & private goods
MOBILITY TRANSPORT		- Construction of: safe-roads, cycle paths & sidewalks	-Traffic education -Public transport info	-Traffic-speed regulators -Navigation -Car automation -Separating slow and fast traffic -Seat belts & helmets	-Car control -Navigation -Electric bikes -Public transport info -Dedicated shoes	-Relevant public & private goods
COMMUNICATION GOVERNANCE	-Regulation & its implementation	-Regulation & its implementation	-Regulation & its implementation	-Regulation & its implementation	-Regulation & its implementation	-Regulation & its implementation
WORK LEISURE	-Balanced food production		-Leisure info -Social media -Mental exercise		-Safe tools	-Volunteering management

Domains of life

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checks and the allowed access to one's own medical record⁸³.

Obviously, prevention of accidents, diseases and infirmity remains of top priority, irrespective of the focus of the health definition, and dedicated research is the vital underlying stream for guiding focused action. The 2015 report of the WHO is concerned with 'Ageing and Health' and its primary conclusion is aligned with the present paper: "Comprehensive public-health action on ageing is urgently needed. Although there are major knowledge gaps, we have sufficient evidence to act now"⁸⁴.

The present paper identifies a number of such knowledge gaps together with opportunities to act.

Both in the medically inspired and in the functionally inspired health definitions, physical health, mental health, and social embedding are main components. For older persons, prevention of chronic conditions is of the utmost importance followed by prevention of deterioration of the chronic conditions that have occurred. Prevention should be directed at retaining the maximum of reserves in daily activities, including but not restricted to Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL). Active prevention means that the older person should feel her or himself the primary responsible, guided by health professionals and by public sources of information⁸⁵.

Older people in the ICT era

The main digital road that has recently been opened is by smartphone and tablet which provide relatively easy access to the Internet with its myriad of options. The applications eliminate the serious difficulties of special computer-mediated solutions such as in telecare. Present Internet permits general personal access to relevant data, communications, and actions for active prevention. The global spread is already wide and rapidly expanding. However, older people tend to be left aside in the developments. Yet, some hurdles will have to be overcome in order for such Internet data to become effective tools for self-active prevention^{85,86}. Let us first analyse the position of older people in the information society.

According to the UNFPA (United Nations Population Fund) report in 2012, globally nearly two out of three older people can use a mobile phone although they do not literally own one. Using a mobile phone is even possible to people who are illiterate. Studies from the USA and EU indicate that Internet use remains globally strongly positively correlated with education and household income, and negatively with age⁸⁷. Recent

surveys indicate that 6% of North Americans aged 65+ are using the Internet while in the EU 28% of the households with people aged 60+ have Internet access. In Finland 30% of people aged 75+ have access to the Internet, but there is a strong age gradient showing that only 6% of people aged 85+ are Internet users. When older people are asked for the main reason why they do not use the Internet, the most often cited reasons for staying offline relate to issues of functionality and usability. About one fifth in the USA and one third in Finland mentioned price-related reasons. It may also be supposed that peer pressure or the absence thereof is a relevant factor. Obviously, digital literacy of older people will continue to increase as new cohorts can rely on earlier experience and requirements of society become unforbidding. However, demands will keep on changing because of technological developments in products and services.

Older people need adequate health literacy in order to enjoy the information opportunities of the digital era. Health literacy is the capacity to obtain, process and understand information needed to make appropriate decisions regarding one's health and well-being. Especially marginalised older people may have limited health literacy, which correlates with worse physical and mental health condition⁸⁸.

Enabling self-active prevention

For an essential contribution to health by prevention, particularly by older persons themselves, two main hurdles have to be overcome:

- (i) Assuring sufficient digital competence of potential users, both older persons and their carers;
- (ii) Supplying reliable and easy-to-use websites and applications.

In the Prism project, Charness et al.⁸⁹ have provided a scheme for preventing isolation in old age, which covers both aspects and can serve as example to other active preventions. Wright⁹⁰ has shown that tablets can be quite effective and rewarding for older users, once initial hesitance has been overcome by proper directed training. She also showed that further standardization of functions is necessary. The finding corroborates the conviction of older people that they can learn to use the Internet, when given the relevant teaching and guidance⁹¹.

For older people, earlier preventive measures could have harvested easy access to digital services as a basic public interest and as a powerful tool for optimal health. Two of these are (i) digital competence and (ii) reliable content.

(i) Digital competence. Because the Internet era is relatively young, many older persons have had

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insufficient opportunity to get familiarized with using computers in general. There is no doubt that they can learn to use smartphones and tablets on a daily base, but they have to overcome hurdles that require encouragement, positive motivation and sustained effort in practising. A general educational program to make this happen is highly needed⁵².

(ii) Reliable websites and applications. The Internet has a myriad of information in which laymen can easily get lost. Once one thinks to have found relevant information, one is often unsure whether the information is just intended for commercial purposes or rather carefully checked and guaranteed. Many websites are overloaded with distracting static and dynamic information and advertisements, and deeper in hierarchical trees, oversight is easily lost.

What is needed is a selection of websites made for the purpose of specific preventive actions and guaranteed for being reliable and up-to-date. Good governance can provide for this by initiating that independent learned bodies take up such tasks and that the resulting sites are optimised for easy access, also for older persons, similar to what has been done in the Prism project⁸⁹. Although the websites need to be provided in national languages, the actual professional work can be international, followed by translation and adaptation, as is common procedure in many international bodies such as EU or WHO. Commercial services offered should clearly be marked as such. The relatively unknown Web Accessibility Initiative provides guidelines for people with challenged functionalities among which many older people⁹². What is true for websites applies to apps as well. It is of general public interest that the reliability of health apps can be quickly assessed.

CONCLUSION

Healthy ageing is a widely desired goal all over the world. Prevention is a key for approaching and attaining this goal. However, health protection and promotion by preventive means is a complex and wide-ranging issue involving the interplay of many public, business, and private organizations and professionals including proper

governance by legislation and law enforcement. Conflicts of interest are likely. Prevention is an indispensable public goal that should not be put at budgetary risks, for example by making it compete with the costs of cure and care.

Prevention has already a whole history of fruitful technologically mediated solutions and many more to come. Many sectors of daily life have greatly profited from public health engineering: lives have been saved and injuries avoided, and while victims can be indicated, no one can tell who have escaped harm because of public health measures. Six examples of public health engineering display both impressive positive results and demanding tasks ahead both in implementation and in R&D.

Healthy ageing is a life-long effort, based upon the preventive pillars of regular exercise, healthy eating, mental effort, and social engagement, in addition to disease- or accident-specific preventive measures. Public health measures should be directed at creating the enabling technological and educational environments. As to primary prevention of disease, three global waves are distinguished: communicable disease with a long effective history; incommunicable diseases since more recently effective, and currently prevention of mental and social problems still in its infancy and of growing concern. In secondary prevention, risks of old age have to be tackled by proper public, technical and educational interventions fighting sedentary style, obesity, falls, and frailty.

Recently, the concept of functional health has gained weight particularly for people with multiple chronic diseases for which no further cure is available. In this situation the aim is to nevertheless continue an active and independent life. Smartphones or tablets with Internet access hold great promise by making professional fields accessible for general consumers. For ageing people in particular this requires good enough health literacy, training in digital competences as well as an easily identified infrastructure of reliably sourced and relevant websites. Good governance can play an important role in initiating and organizing such prevention.

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