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ICT for the Prevention of Noncommunicable Diseases and Health Promotion in Europe

An IEEE European Public Policy Committee Technology Whitepaper

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Contents

Executive Summary

The Charter of Fundamental Rights of the European Union grants everyone "the right of access to preventive health care and the right to benefit from medical treatment under the conditions established by national laws and practice[67 Article 35]." Healthcare for chronic conditions costs the European Union countries approximately €700 billion per year. By large, this sum is associated with the most toll taking noncommunicable diseases (NCDs) in Europe: cardiovascular diseases, cancer, diabetes, chronic respiratory diseases, and mental disorders. Effective methods to prevent NCDs exists, but still, only 3 % of the healthcare spending is used for prevention.

The importance and capabilities of medical treatments and the associated ICT are generally well understood. However, the extent and roles of information and communications technology (ICT) systems for broader long-term interventions to promote health and fight the NCDs are less well recognized. ICT can be applied to enhance healthcare, health promotion, and societal functions for the benefit of NCD prevention.

The IEEE European Public Policy Committee (IEEE EPPC) finds it important to raise awareness of the potential of ICT systems for NCD prevention and health promotion. IEEE EPPC has set forth recommendations for more effective utilization of ICT in a previously published position statement "ICT for the Prevention of Noncommunicable Diseases and Health Promotion in Europe"[100]. This Whitepaper acts as the background information for the Position Statement[100]. In this Whitepaper, we describe the most pressing NCDs along with a summary table (Table 1) of the deaths and costs associated with the five leading NCDs in Europe, and the basis of NCD prevention. Thereafter, we introduce the healthcare ICT ecosystem in a broad sense and list numerous existing or thinkable ICT applications from simple personal gadgets to population intervention planning to enhance the NCD prevention and health promotion. The European Code Against Cancer[182] is used as an example.

The previously published IEEE EPPC Position Statement[100] and this Whitepaper have been motivated by:
1) the EU Health Policy[46], which aims to protect and improve the health of EU citizens, support the modernization of health infrastructure, and improve the efficiency of Europe's health systems;
2) the concepts of eHealth & ICT for wellbeing — a part of the Commission's eHealth Action Plan 2012–2020[41]; aiming amongst other things to support research, development, and innovation of eHealth, and to promote interoperability of eHealth services; and
3) the identified potential of ICT systems to enhance the NCD prevention and health promotion work.

The European Commission promotes investing in health[46] by
- "Promoting effective, accessible and resilient health systems[46];"
- "Investing in health through disease prevention and health promotion[46]" and
- "Fostering health coverage as a way of reducing inequalities and tackling social exclusion[46]."

"The EU approach to the challenge of non-communicable diseases involves an integrated response focusing on prevention across sectors and policy fields, combined with efforts to strengthen health systems.[61]" ICT systems can support and enhance all these approaches set forth by the European Commission.

A wealth of scientific and popular literature, scientific projects, and position statements exist on NCD prevention and on ICT technologies and applications for the prevention of specific NCDs. However, to the best of our knowledge, little has been written holistically on ICT for NCD prevention and health promotion. We have not identified organizational Position Statements or Whitepapers in addition to this Whitepaper and the associated Position Statement[100] aiming to address ICT for NCD prevention and health promotion in a broad sense. Moreover, medical NCD prevention guidelines usually do not explicitly consider the usage of ICT-based solutions.

This Whitepaper aims to describe NCDs and their prevention, along with the related ICT systems. With this, we hope to bridge a possible gap between the ICT related stakeholders and the healthcare-related stakeholders on NCD prevention and health promotion. The document is aimed at the European decision-makers and both the ICT and healthcare communities to increase their awareness of the NCD problematics and the great potential of ICT systems. Working together with a shared understanding, we may have a better chance to create an effective ICT-enhanced NCD prevention and health promotion ecosystem for the healthcare professionals and to empower the citizens to better take care of themselves.

Part 1: Introduction

1. Introduction

In Europe, chronic care takes up 70 % to 80 % of healthcare costs[62]. In the European Union (EU), €700 billion is spent per year on healthcare costs associated with chronic care. The most toll taking noncommunicable diseases (NCDs)[i] in Europe are cardiovascular diseases, cancer, diabetes, chronic respiratory diseases, and mental disorders. The healthcare costs are expected to increase in the future[62], e.g., due to the aging population and increasing overweight. ***97 % of the funds are spent on treatments, and only 3 % on prevention***[ii,20]**.** The number and severity of diseases are increased by inadequate identification of risk factors[iii], late diagnosis and intervention, and inadequate disease management. Healthy lifestyle and interventions based on identified risk factors before the onset of NCDs could often prevent or delay chronic diseases[62] and prevent complications. A person may exhibit several distinct risk factors for a prolonged period before the onset of a chronic disease. Thus, there is room for highly effective preventive work by tackling the risk factors as soon as identified. WHO has described several tools to prevent and control noncommunicable diseases[207,215]. Anything that makes us use our muscles, eat healthier, avoid consumption of and exposure to harmful substances, and helps us live normal happy lives, prevents NCDs. The principles of NCD prevention and health promotion are thus elementary. Nevertheless, numerous people do not tend to live accordingly.

The ongoing NCD epidemic[11,194] is causing great human suffering, loss of health and life, and the consumption of enormous amounts of funding and other resources of society and industry. In the modern European information society, ICT is being employed in the fight against NCDs. However, ICT technology is available for more wide application and deployment than currently implemented. ***In this Whitepaper, we give an overview of the extent of the NCD epidemic and the multiplicity of ICT based solutions for NCD prevention and health promotion. We also note some associated challenges.***

For example, personal health education and counseling for NCD prevention and health promotion are still mostly based on infrequent personal contacts and information campaigns, which individuals encounter in a more or less random fashion. Support for lifestyle changes is also generally insufficient. The health ICT revolution could transform this into a continuous NCD prevention and health promotion process that can operate, e.g., on-demand or immediately-upon-need. ICT-empowered systems exist for a wide range of NCD prevention and health promotion functions, such as internet-based self-assessment tools, multi-professional help systems to identify high-risk individuals, and nation-wide information delivery systems usable for interventions. Structural changes, such as legislation, restrictions, universal services, taxation, and pricing policies, are known to be highly effective in NCD prevention and health promotion. To steer such structural actions to maximize the health effects and the overall wellbeing of the citizens, it is crucial to know the effectiveness of such population-wide interventions. Thus, public health surveillance[iv,v,134,174,200,214] of NCDs, and the outcomes of the interventions need to be implemented along with the interventions themselves. For example, the effects of changes in taxation may have led to different responses depending on social differences, and future actions may need to be steered and tailored accordingly. The effects of structural changes could be enhanced by ICT-based approaches, such as information sites and campaigns, public online services, and providing the citizens with feedback based on ICT-enabled surveys of peoples' opinions and knowledge, and habit surveillance. Further, to get the best results for the society and its members, preventive actions on high-risk persons and at the population-level need to be balanced.[168]

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[i] In contrast with the NCDs, communicable diseases (CDS)[33,172,186,199] or "infectious diseases are caused by pathogenic microorganisms, such as bacteria, viruses, parasites or fungi; the diseases can be spread, directly or indirectly, from one person to another.[199]" Prevention of CDS includes, for example, personal and food hygiene, vaccinations, isolation of the infected persons during the contagious period of the disease, social distancing, and in extreme cases, quarantines. Alike for NCDs, surveillance is crucial for CDS control. There are over 50 diseases, such as hepatitis A, B and C, cholera, HIV, and smallpox, on the list of diseases under epidemiological surveillance in the EU[32]. For CDS, surveillance takes the form of "epidemiological surveillance," whereas for NCDs "public health surveillance" is important. (See the definition of "public health surveillance" in section 2. Definitions.)

[ii] Includes prevention, and protecting and improving the population's overall physical and mental health.

[iii] "A risk factor" is any property, trait, condition, or alike, which may increase the risk. (See also the definition of in section 2. Definitions.)

[iv] In this Whitepaper, "surveillance" is used only with the meaning defined by WHO (see the definition in section 2. Definitions) with regard to public health.

[v] "Surveillance" is "the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice.[214] *WHO guidelines on ethical issues in public health surveillance***"**

It cannot be predicted with certainty if a person will get an NCD or not. Risk factors, such as overweight, smoking, alcohol consumption, unhealthy diet, and the lack of exercise, increase the probability of a person getting one or several NCDs. On the other hand, the enhancement of protective factors[vi] cannot guarantee that a person will not get an NCD. However, population-wide preventive interventions that result in healthier lifestyles do save numerous persons from NCDs. A small reduction in disease risk can prevent a large number of cases. For example, many cardiovascular events and deaths, as well as many other NCD cases, could be avoided by lower blood cholesterol levels, lower blood pressure, or abolishing smoking in a population. A small change in diet, exercise, or other habits can make a real difference to society.

The fight against childhood obesity[25,125,157,201,217] was identified as one of the most urgent priorities by the Maltese Presidency of the Council of the EU[137,151] in 2017. Childhood obesity, if not defeated, will have a substantial negative impact on Europe. Besides, mental problems are often already manifested during childhood[202]. In Europe in 2018, 89 % of the homes had internet, and 69 % of the population[vii] used mobile internet.[82] The high level of internet penetration enables both parents and children to access instructive and interventional services online. Also, the European youth is utilizing the internet: In 2017, the portion of youth aged 15–24 in the European population was 11.5 %, and their portion of the internet users was 13.8 %. The European Strategy for a Better Internet for Children[34] aims to give children the digital skills and tools for safe online life. A part of this work is the Better Internet for Kids portal[29], and the strategy is also supported by the Happy Onlife[116,117] to promote safe and responsible uses of the Internet among children and adults.

The eHealth Action Plan 2012-2020[41] of the European Commission calls for health and care systems, which are ICT enabled, personalized, preventive, patient-centric, integrated, interoperable, and sustainable, thereby empowering citizens to manage their health, well-being, NCD prevention, and diseases. NCD prevention and health promotion is a vast and multifaceted domain. It can be enhanced at many levels, ranging from personal gadgets, SMS services, mobile apps, and other internet-based services, via health promoter and care provider systems, and large-scale mHealth and eHealth systems, to national and international ICT-based health information systems.

The NCD prevention and control priorities set forth in the WHO action plan for NCDs in Europe[168] are:
- "governance for NCD, including building alliances and networks, and fostering citizen;"
- "strengthening surveillance, monitoring and evaluation, and research;"
- "promoting health and preventing disease;"
- "reorienting health services further towards prevention and care of chronic diseases."

In the same document[168], the intervention foci are given as:
- "promoting healthy consumption via fiscal and marketing policies;"
- "elimination of trans fats in food (and their replacement with polyunsaturated fats);"
- "salt reduction;"
- "cardio-metabolic risk assessment and management;"
- "early detection of cancer."

Furthermore, "active mobility" and "health in settings" are promoted.

In a nutshell, NCD prevention and health promotion fight chronic diseases, which are greatly affected by:
- Genetic factors
- Psychological factors
- Lifestyle and behavior
- External environmental factors
- Social and societal factors, including culture and religion
- Market forces

All the ICT application domains associated with the factors listed above are at our disposal to fulfill the tasks above defined by WHO and EU for the benefit of all. In Europe, the ICT systems being used by society and individuals

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[vi] "A protective factor" is any property, trait, condition, or a like which may decrease the risk. (See also the definition in section 2. Definitions.)
[vii] Individuals aged 16 to 74 within the EU-28.

offer an excellent ecosystem for NCD prevention and health promotion. The societal dimension also calls for strategic ICT tools to lead the work. The severity of the NCD problem (see Table 1) and the multiplicity of the associated ICT tools (see Tables 2 and 3) are outlined in this document.

The actors in the NCD prevention and health promotion include the decision and policymakers at local, national, and EU levels, healthcare professionals and industry, patient and other non-governmental organizations, food industry, and the citizens. This document is intended for all of the actors concerned. *The recipe for effective NCD prevention is straightforward: Live a healthy life. We "just" need to get the true evidence-based information through to the public and the other actors and lower the societal barriers of healthy life. To affect the public (and the other actors and stakeholders), science-based, coordinated, and well-marketed ICT solutions can be of great help.*

2. Definitions

Health is defined in the Constitution of the World Health Organization[187] as: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

Health promotion "is the process of enabling people to increase control over, and to improve their health.[197]" It means any action targeted[viii] to an individual or group to affect their habits or environment with the aim of improving or sustaining their health. On one side, this involves the promotion of physical activity, healthy nutrition, and any other aspects of healthy living. This can be aided by providing information and by otherwise facilitating healthy activities, living, and habits, and promoting a change for the better. It may also take the form of increasing consciousness of one's health and choices. On the other hand, health promotion can also be effectively realized and enhanced by structural changes in the society, such as legislation, restrictions, universal services, pricing policies, and monitoring intervention implementations and the associated health outcomes.

Prevention[142] is realized by targeted actions based on scientific evidence, e.g., by reducing major risk factors[205]. The actions are usually targeted on 1) a specific individual or group, for example, on a population at high-risk from a certain NCD, or on 2) a regional or national population to prevent a particular NCD, commonly of great public health interest. Preventive actions may be initiated by individuals targeting themselves, by special interest groups, associations, companies, cities and municipalities, healthcare providers and districts, and local and national healthcare authorities. For clearly defined high-risk individuals or identified public health issues, prevention may also be realized as medical treatment-based prevention.

Primary prevention[111] takes place when the target individual has not yet acquired an NCD, i.e., the person does not exhibit any manifestations of the disease. The aim of primary prevention is to keep the person healthy. **Secondary prevention**[111] is associated with early detection and aims at improving the change of positive health outcomes. Secondary prevention is often initiated because of early symptoms or findings in a screening. Contrary to primary prevention, secondary prevention is by definition associated with healthcare services, so that abnormalities can be promptly treated or corrected, thus preventing the condition from developing to a full-scale disease. The term "secondary prevention" is also sometimes used to describe the prevention of a second or later outbreak of an NCD attack, i.e., to keep an already treated or healed abnormality from reoccurring.

Public health surveillance is defined by WHO as "the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice.[134 p. 52]" WHO further states, "Public health surveillance is the bedrock of outbreak and epidemic response, but it reaches far beyond infectious diseases. It can contribute to reducing inequalities: pockets of suffering that are unfair, unjust, and preventable cannot be addressed if they are not first made visible. It is central to understanding the increasing global burden of noncommunicable conditions.[214]" "Surveillance, when conducted ethically, is the foundation for programs to promote human well-being at the population level. … But surveillance is not without risks for participants and sometimes poses ethical dilemmas. Issues about privacy, autonomy, equity,

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[viii] In this whitepaper, "to target" means to design and provide an action for an identified person, group, or population; or to design and take an action against a certain disease, condition, habit, or alike.

and the common good need to be considered and balanced, and knowing how to do so can be challenging in practice.[214]" For the ethical guidelines for public health surveillance and a schematic presentation of the many aspects of surveillance, see the WHO guidelines on ethical issues in public health surveillance[214] and the paper by R. Collier[19] for a short discussion on the guidelines. For illustrations on public health surveillance frameworks, among many other things, and examples of projects on surveillance and data, see [14,15], respectively.

U.S. Surgeon General (1998–2002) David Satcher has been quoted to having said: "In public health, we can't do anything without surveillance. That's where public health begins.[86,161]"

eHealth – Electronic health[40] is the use of ICT for health. eHealth has, for long, been in the focus of the EU. For example, the European Commission is building an EU-wide eHealth digital service infrastructure[42,43] for cross-border health data exchange in the EU to which the member states will be able to connect their health systems. eHealth systems exist or can be devised to support preventive actions targeted at either high-risk individuals or populations.

mHealth – Mobile health[58] is a part of eHealth. mHealth is concerned with supporting medical and health practices by mobile phones, tablets, patient monitoring devices, personal digital assistants (PDAs), and other mobile devices. At its core are the mobile voice and short messaging services (SMSs) along with more complex applications involving mobile data and positioning subsystems of modern mobile devices.[203] There are over 100 000 mHealth related mobile apps on the market[58].

Care chain (also: integrated care pathway[1], clinical pathway, critical pathway, critical path, care path, or care map) is a standardized chain of events (including, for example, medical examinations, procedures, interventions, check-ups, referrals, recalls, and consultations) for taking care of a patient with a particular condition or threat. The care chains are evidence-based and designed to ensure the overall quality of care and improve clinical outcomes. The care chains may be multidisciplinary.

Risk factor[208] has been defined by WHO as "any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or injury.[24]"

Protective factor has been defined by the National Cancer Institute as "something that may decrease the chance of getting a certain disease.[141]"

3. Scope and Limitations of the Usage of the Whitepaper

This Whitepaper is concerned with ***ICT for NCD prevention and health promotion in Europe***. NCD prevention is discussed primarily from the primary prevention point of view. Thus, in the sequel, "prevention" refers to "primary prevention" (see section 2. Definitions). However, many of the matters discussed in this Whitepaper are relevant and applicable to most phases of NCD control, including secondary prevention, care, and treatment. It is to be noted that ***this document is concerned with ICT***, its usage, and possibilities.

This Whitepaper may not be used to discourage or promote any particular means of health promotion, NCD prevention, treatment, or other action. No medical advice may be drawn from this Whitepaper. Possible legal aspects related to the matters presented have not been considered; nothing presented in this Whitepaper may be taken to imply legality.

Cybersecurity, privacy, and ethics are highly complex matters and are treated in this Whitepaper only in passing. Cost-effectiveness and standards would also warrant more thorough treatment than what is possible within this Whitepaper. Risk analysis regarding the health ICT ecosystem (Fig. 2) and ICT functions and devices is beyond the scope of this Whitepaper. These issues and challenges need to be attended to for any health ICT system.

Several cited references are web pages that may be updated, moved, or removed by their respective owners. The Whitepaper may contain data from previous versions of the references.

Part 2: Noncommunicable Diseases

4. Historical Perspective and Outlook

Disease prevention and cures have been attempted long before the actual nature and causes of diseases have been understood. These actions to repel harm may have included bleeding or sacrifices, for example. In the beginning, prevention took place in simple forms through personal teaching, and the information spread through travel. After that, written works started to allow more efficient spreading of information. The collection of medical information can be traced back to Hippocrates, Rufus, and Galen. They collected medical information using categories such as "nosology," "symptomatology," "prognosis," and "therapeutics"[120]. Such work focused on the illness rather than specific patients[91]. Work from Hippocrates and Greek Scientific texts were translated into Arabic in the medieval period[136]. However, European medicine took a step backward at this time[118].

With the emergence of scientific understanding of diseases, prevention, and cures became effective tools to relieve human suffering. For example, after the discovery of bacteria, the importance of washing hands was promoted. However, it took time for the discovery and the recommended new practices to be widely accepted. Prevention also started to alleviate the societal and economic burden of preventable diseases. However, most of the actual preventive work had to be done by healthcare experts in personal contacts. When print media, radio, and television started to become available to masses, health educational material could also be delivered to the public more widely than ever before. Preventive interventions still took place during personal contacts with healthcare personnel, for example, during hospitalization or visits to healthcare centers. Consistent measurements of disease risk factors were also not really possible otherwise. Population-wide risk-assessment and intervention campaigns required manual labor but were nevertheless conducted.

The ICT revolution brought about the next change in the fight against diseases: Information became available on-demand from numerous sources. Information on risk and protective factors, how to live healthily and try to avoid NCDs and communicable diseases was now available to everyone, even without consulting a healthcare professional. Personal devices made it possible for everyone to measure their risk factors, such as weight, blood pressure, and blood sugar, and report them to the healthcare practitioners for further assessment and possible intervention. Large-scale health information systems allowed the scientific assessment of population health. Mass and social media are now used to realize population-wide risk assessment and preventive actions, usually targeted at a particular risk factor, such as smoking or improper diet.

One of the critical educational challenges for public health is the persistent popularity of non-scientific belief-based "preventive measures" and "cures," especially when these dogmas stop people from following scientific evidence-based health practices. Examples include religious belief-based opposition to reproductive health practices, pseudo-scientific homeopathic treatments, and anti-vaccination movements that are based on discrediting rigorous scientific evidence. To the public, simple explanations and quick methods may naturally be more appealing than the science-based facts and methods, which may often demand unpleasant lifestyle changes from people. Understanding how science-based methods work also requires a strong understanding of statistics. ICT systems, and especially the Internet, are playing an increasingly important role in this confrontation between beliefs and scientific knowledge. Increasingly, (pseudo-)medical websites, search engines, and social media are the first source of information for the public. The spread of health mis- and disinformation via the Internet is significantly hurting NCD prevention work. Although technologies to detect false information are being developed[124,139,140], such automatic methods to detect non-scientific information is not yet widely utilized. However, governmental bodies, healthcare companies, patient organizations, and other professional public and private health-related organizations, and other qualified actors are in a position to provide the public with science-based ICT systems and information for NCD prevention and health promotion.

The power of current ICT systems is available for NCD prevention and health promotion applications. The possibilities are enormous, and the approaches range from personal science-based smartphone apps and gadgets, via personal measurement device mediated automated professional intervention, to large-scale population-wide or targeted information and risk assessment campaigns and preventive interventions, and further to utilizing large-scale health informatics systems in planning population-wide preventive and health promotion measures, including international ICT enhanced collaborative efforts.

> IEEE EPPC has recommended in its Position Statement[100] that "Information and communications technology (ICT) should be utilized to enhance NCD prevention and health promotion at many levels and in numerous ways" and that the "evidence-based ICT solutions should also be effectively advertised." The Position Statement[100] further notes that "In Europe, ICT capabilities and infrastructure are already at a level capable of supporting NCD prevention and health promotion tools. Many individuals are drawn to ICT-based solutions. These facts are now at our disposal to create an effective coordinated and evidence-based ICT ecosystem for all levels of NCD prevention and health promotion. Further, ICT should be utilized throughout the self-care and healthcare practices in an integrative and holistic fashion."

5. Noncommunicable Diseases

Globally, 40 million persons a year die of NCDs; this means that NCDs are responsible for 70 % of all the deaths. 81 % of these deaths are caused by cardiovascular diseases (17.7 million deaths), cancers (8.8 million deaths), respiratory diseases (3.9 million deaths), and diabetes (1.6 million deaths)[190, see also 194].

In Europe,
- cardiovascular diseases[47,179],
- cancer[53,59,178],
- diabetes[48,180],
- chronic respiratory diseases[75,171], and
- mental disorders[60,175],

account for 77 % of the total disease burden and 86 % of all deaths[168,177, see also 183,204]. In addition to the deaths and associated economic losses, NCDs naturally cause enormous personal suffering. The key figures on the five NCDs affecting Europe the most are presented in Table 1; the numbers of affected persons, healthcare costs, and other economic losses for the society are huge. "Of the six WHO regions, the European Region is the most affected by noncommunicable diseases, and their growth is startling.[177]"

Many of the mental disorders belong to NCDs, and approximately 14 % of the global NCD burden is caused by neuropsychiatric disorders. Their effects are mostly due to chronically disabling depression and other common mental disorders, alcohol and substance use disorders, and psychoses. Many mental disorders are highly associated with obesity and smoking, which are risk factors for many other NCDs, alike are using alcohol and other harmful substances. There is also strong evidence for comorbidity between, for example, diabetes and mental disorders.[150] Thus, successful prevention of mental disorders is highly likely to prevent many other NCDs, and vice versa.

In addition to the major NCDs mentioned above, for example, the following NCDs and inflicted conditions cause severe human suffering and healthcare costs:
- Oral Health Problems
- Injuries and Violence
- Alcohol and Other Substance Abuse

For example, the direct costs of alcohol dependency have been estimated to be 0.04 %–0.31 % of the gross domestic products (GDPs) of the individual European countries. The indirect costs can have been annually as large as 0.64 % of the GDP of a country.[123] Prevention of these costs and the associated human suffering, like those caused by other substance abuse, oral health problems, injuries, and violence, should be possible at least to a large extent.

Table 1. The prevalences, numbers of deaths, and estimated costs in a year due to the five major NCDs in Europe, along with the global cost-of-illness estimates (incl. direct and indirect costs), and the percentages of cases considered preventable.[‡]

	Diabetes	Cardiovascular Diseases	Cancer	Chronic Respiratory Diseases[o]	Mental Disorders
Number of Persons with the NCD	463 million[a,113] 59 million[h,94]	N/A[c]	3.7 million new cases in a year[170]	6 million hospital admissions[90]	83 million[u,176]
Percentage of Population with the NCD	9.3 %[a,113]	9.2 %[g,164]	N/A[c]	10.0 %[p,85]	27 %[u,176]
Deaths	627 000[b,113]	4 million[h,76] 1.5 million[i,76] 1.9 million[j,76]	1.9 million[170]	671 000[q,84]	177 000[v,w,83]
Health Expenditure in Europe	$ 161 billion[a,113]	€ 106 billion[k,76]	€ 86 billion[m,218]	€ 55 billion[r,74]	N/A[c]
Total Cost to the European Economy	$ 760 billion[y,113] $ 825 billion[z,113]	€ 196 billion[76]	€ 126 billion[n,126]	€ 380 billion[s,74,90]	€ 461 billion[x,93]
Global Cost-of-illness	$ 500 billion[d,10] $ 745 billon[e,10]	$ 863 billion[d,10] $ 1.04 trillion[e,10]	$ 290 billion[d,10] $ 458 billion[e,10]	$ 2.1 trillion[d,10] $ 4.8 trillion[e,10]	$ 2.5 trillion[d,10] $ 6.0 trillion[e,10]
Preventability	Type 2 largely preventable [f,173]	90 %[l,133]	30–50 % of cases[185]; > 50 % of deaths[27]	N/A[t] (Some forms preventable)	N/A[c]

[‡] The figures given in the table for the different diseases may be based on different models of calculation and estimation, and involve different corrective factors due to, e.g., differences in data collection in different countries, among other matters possibly affecting the figures. Thus, only indicative comparisons should be made based on the figures in the table, not exact numerical comparisons. Also, different sources may give different estimates.

[a] Adults age 20–79 years, including type 1 and 2, and diagnosed and undiagnosed cases.

[b] Of 20–79-year olds in Europe region in 2015.

[c] No estimate was found in the literature when preparing this document.

[d] 2010 estimate.

[e] 2030 prediction.

[f] No estimate was found in the literature when preparing this document.

[g] People reporting heart or circulation problems in 12 months in the European Social Survey in Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, Finland, France, Ireland, The Netherlands, Norway, Poland, Sweden, and Slovenia combined.

[h] In Europe.

[i] Premature deaths before the age of 75 in Europe.

[j] In the EU.

[k] In the EU in 2009.

[l] Of heart attacks and coronary heart diseases.

[m] In the EU in 2014.

[n] In the EU in 2009.

[o] The figures may include communicable diseases like tuberculosis.

[p] Self-reporting in EU-28 countries in 2014: Chronic lower respiratory diseases (excluding asthma): 4.1 %; asthma: 5.9 % of population.

[q] Including lung cancer, which accounted for 40 % of the deaths due to respiratory diseases.

[r] Direct primary and hospital healthcare, at least in EU-28.[90]

[s] In EU-28. 50 % of which is due to smoking. The total cost of tobacco consumption in the EU is annually €517 billion.[90]

[t] No estimate was found in literature when preparing this document. However, "major preventable chronic respiratory diseases include asthma and respiratory allergies, chronic obstructive pulmonary disease (COPD), occupational lung diseases, sleep apnea syndrome, and pulmonary hypertension.[195]"

[u] Adults between 18–65 who had experienced at least one mental disorder in a year before the study in the EU countries, and in Iceland, Norway, and Switzerland, including mental problems arising from substance use, psychoses, depression, anxiety, and eating disorders.

[v] Deaths due to mental and behavioral disorders in EU-28 countries in 2013.

[w] Mental illness is considered to account for 90 % of suicides in high-income countries, with 22 % of all suicides linked to alcohol use[176].

[x] Mood disorders, psychotic disorders, anxiety disorders, addictive disorders, mental retardation, personality disorders, child and adolescent disorders, somatoform disorders, and eating disorders in 2010.

[y] Estimated diabetes-related health expenditure in a 2019 from a 2019 publication.

[z] Estimated diabetes-related health expenditure in a 2030 from a 2019 publication.

6. Risk Factors of NCDs

Introduction to NCD Risk Factors

To combat NCDs, it is necessary to know their risk factors. Risk factors pertain to individuals and are behaviors or characteristics, which increase the probability that the person acquires an illness or condition, such as an NCD. Modifiable risk factors come in two primary forms:
- Behavioral risk factors
- Metabolic and physiological risk factors

Behavioral risk factors, which increase the risk of NCDs include[190]:
- Tobacco use
- Physical inactivity
- Unhealthy diet
- Harmful use of alcohol

Globally in a year, 7.2 million deaths are estimated to be caused by tobacco, including from the effects of exposure to second-hand smoke[190]. This count is expected to increase. Insufficient physical activity accounts for about 1.6 million deaths annually[190]. Harmful drinking causes 3.3 million annual deaths, with half of the deaths caused by NCDs associated with drinking[190]. Harmful use of alcohol is a major modifiable risk factor for neuropsychiatric disorders, cardiovascular diseases, cirrhosis of the liver, and cancer[169]. Considering an unhealthy diet, for example, in 2010, 4.1 million annual deaths were due to excess salt/sodium intake[190]. 42 % of EU citizens never exercise[49], which has been estimated to cost EUR 80.4 billion[ix,114] annually.

Also, insufficient sleep and the use of harmful substances other than alcohol belong to modifiable behavioral risk factors. Insufficient sleep affects several physiological functions and cognitive performance[6], and short sleep duration is a risk factor for weight gain and obesity[8], which in turn is a risk factor for many NCDs.

Metabolic and physiological risk factors, which increase the risk of NCDs, contribute to the following four key risk factors[190]:
- Hypertension (elevated blood pressure)
- Overweight and obesity
- Hyperglycemia (high blood glucose levels)
- Hyperlipidemia (high levels of fat in the blood)

Nineteen percent of all global deaths are attributed to elevated blood pressure, which is the globally leading metabolic risk factor, followed by overweight and obesity, and raised blood glucose[190]. For example, 20 % of men and 23 % of women are obese[181] (body mass index greater than 30), which has been estimated in Europe to cost 70 billion euro annually and cause 337 000 premature deaths[31]. A particular problem is the increase in the number of overweight young children, which is rising fast[25,201,217]. One in three 11-year old children is overweight or obese in the WHO European Region[181]. There is a risk that the next generation is at high risk for NCDs from its very beginning[110].

Genetic risk factors of NCDs[146] are genetic factors that predispose a person to an NCD[193]. Family background[219] is routinely used by physicians to assess the NCD risk of a person. For example, heart disease, asthma, cancer, and diabetes can run in families. Accordingly, the ancestral history of diagnosed NCDs is often an essential factor in prescribing preventive interventions. Genetic testing[28,144] is, in some cases, available to augment family history in risk assessment and prevention planning. For public healthcare settings, genetic screening methods exist for targeting preventive interventions[138,193,219].


[ix] In EU-28 in 2012 due to coronary heart disease, type II diabetes, colorectal and breast cancer, and the indirect costs of inactivity-related mood and anxiety disorders.

Considering that the five major NCDs are by and large preventable (c.f. Table 1) *and linked by common risk factors*[184]*, NCD prevention has enormous potential to ease human suffering and to decrease healthcare expenditure and economic losses.* The risk factors linking the different NCDs include high blood pressure, tobacco use, harmful use of alcohol, high blood cholesterol, overweight, unhealthy diet, and physical inactivity. These risk factors are greatly affected by lifestyle and demographics[177]. They also provide us with great opportunities for NCD prevention, which can be supported through the utilization of ICT.

Childhood Obesity

In the world, the prevalence of childhood overweight and obesity has risen by 47.1 % from 1980 to 2013[201], and the number of overweight or obese children under the age of five is estimated to be 41 million[191]. Childhood Obesity Surveillance Initiative[213] of WHO monitors the changes in overweight in primary-school children; they have found that the prevalence of overweight (including obesity) in 13 European countries[x] ranges from 18 % to 57 % for boys and from 18 % to 50 % for girls, with 6–31 % of boys and 5–21 % of girls being obese[217], depending on the country.

Childhood obesity[25,125,157,167,201,217] is a crucial risk factor for numerous NCDs and other complications. As illustrated in Fig. 1[25], childhood obesity may cause a multitude of severe health problems, which may also persist later in life. "Overweight and obese children are likely to stay obese into adulthood and more likely to develop non-communicable diseases like diabetes and cardiovascular diseases at a younger age.[156]" "Obese children develop serious medical and psychosocial complications and are at greatly increased risk of adult morbidity and mortality.[25]" Children and adolescents could benefit of mHealth for weight control[149,153]: "Evidence is limited and mixed, but argues for an impact of mobile app use on motivation and goal-setting behavior, and supports further study of the impact on childhood obesity-related outcomes such as attitudes, perceptions, physical activity, and dietary habits.[153]"
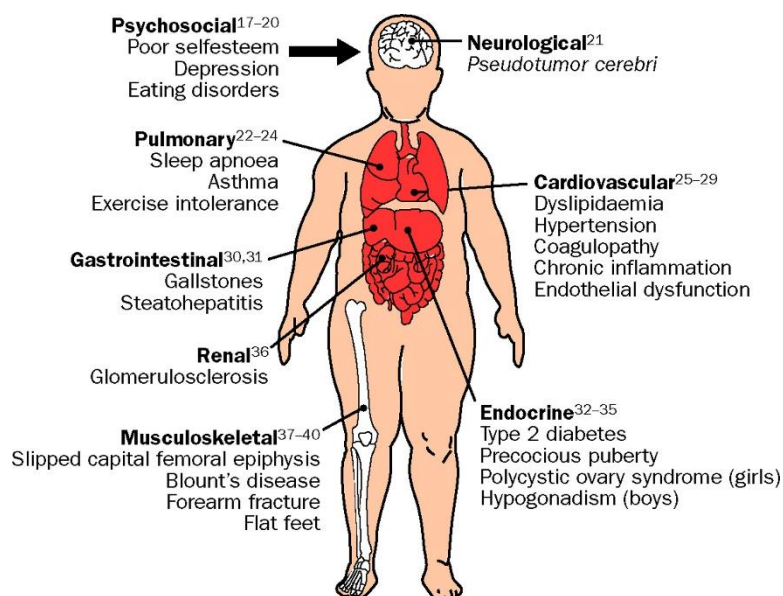
Fig. 1. Possible complications due to childhood obesity. (The references cited in the figure are references of Ebbeling et al.[25]) (Reprinted from[25] The Lancet, Vol. 360, Cara B. Ebbeling, Dorota B. Pawlak, David S. Ludwig, "Childhood obesity: public-health crisis, common sense cure," Pages 473–482, Copyright 2002, with permission from Elsevier.)

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[x] Belgium, Czech Republic, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Portugal (excl. Madeira), Slovenia, Spain, and the former Yugoslav Republic of Macedonia.

Mental Disorders and Substance Abuse

Many mental disorders and substance abuse types belong to NCDs, which could, by and large, be preventable[206]. The nature of their risk and protective factors is different from those of the other NCDs. However, substance abuse itself is a risk factor for diabetes and heart disease, for example. Prevention of mental disorders ranges from supporting normal happy life to suicide prevention and can be realized via enhancing the protective factors, such as "self-esteem, emotional resilience, positive thinking, problem-solving and social skills, stress management skills and feelings of mastery[206]," which are natural components of general positive mental health. Individual, family-related, social, economic, and environmental matters can be either risk or protective factors for mental disorders. Digital psychiatry[163] is already here, and the prevention of mental disorders is strongly called for in the Mental Health Action Plan of WHO[202], which also recommends integrating mental health in the routine health ICT systems, including data collection for designing preventive strategies.

For up to half of the adults with mental disorders, the onset of the mental disorders occurred before age 14[202]. Thus, mental health during childhood is crucial. In a study in seven countries[xi], approximately 10 % of primary school children between 6 and 11 years of age would have required mental healthcare. However, on average, 76 % of them did not see a mental health professional[121].

Similarly, to the fight against the other NCDs, mental disorder prevention builds on enhancing protective factors. Protective factors against children's mental disorders include positive physical development, academic achievement and intellectual development, high self-esteem, supportive relationships with family members, and physical and psychological safety, among other matters (see [220]). Protective factors against children's substance abuse include structural approaches, such as tobacco and alcohol legislation and restrictions, pricing and taxation, individual self-control and impulse control, and parental monitoring, among other matters (see [145]).

7. Protective Factors of NCDs

Protective factors decrease the probability that an individual acquires an illness or condition, such as an NCD. They also support health and functional ability. For example, whereas the risks arising from smoking can best be reduced by removing the risk factor, insufficient physical activity or unhealthy diet might be better influenced by the associated positive enhancement of protective factors than by removal of risk factors (which naturally should also happen). Many of the ICT gadgets, such as pedometers, have been designed to promote protective factors.

Protective factors[4,160] include[22,130,131,132,129]:
- Consuming a healthy diet
- Physically active lifestyle
- Not smoking
- Healthy weight
- No or low alcohol consumption
- Sufficient rest and sleep

An individual implementing these protective factors has a lower risk of encountering several of the risk factors of NCDs (such as raised blood pressure, obesity, hyperglycemia, and hyperlipidemia) than an individual without the protective factors. For a person changing his or her lifestyle to comply with the protective factors, the overall risk of getting an NCD is generally significantly reduced. ***The protective factors and their enhancement are the basis of the preventive work.***

In some cases, NCD prevention may also be realized through medical intervention. Especially if protective factors and removal of the observed risk factors have failed, protective medication may be necessary for NCD prevention, such as heart disease prevention by drug therapy for eligible persons[211].

[xi] Italy, Netherlands, Germany, Romania, Bulgaria, Lithuania, and Turkey.

8. A Prevention Case Study

To motivate the following discussion, let us describe an imaginary exemplary scenario of an ICT empowered individual at high risk of diabetes[xii], but who does not (yet) have an NCD that could be diagnosed.

Initial anamnesis[xiii]: Sex: female, age: 40 years; height: 160 cm; weight: 68 kg; body-mass-index: 27 (overweight, not obese); waist circumference: 79 cm; no physical activity; no daily intake of vegetables, fruits, or berries; on hypertension medication; has exhibited elevated blood sugar in a health checkup during pregnancy; father has been diagnosed with type 2 diabetes. She takes the FINDRISC diabetes risk test[87,88] and, with this status, gets the total risk score of 16, which means that her risk of acquiring diabetes is high. Estimated one out of three persons with the total risk score between 15 and 20 will get diabetes during the next ten years.[87]

Current recommendation: Contact an appropriate healthcare professional for risk assessment and tailored health plan, which takes into account the capabilities and goals of the person. Have blood glucose measured to check for the existence of asymptomatic diabetes, strive to lose weight, get a thinner waist, take up physical exercise, go for a healthy and balanced diet, including whole grains and vegetables, and avoid excess "hard" fats and favor "soft" fats.

Current possible ICT usage: She is using personal gadgets to monitor exercise and blood sugar and pressure. The devices also help her remember to take the measurements. She utilizes online services and perhaps also social media to keep on track of weight loss and exercise. She is aware of the quality of her self-monitoring data, i.e., she knows which of her devices are trustworthy medical devices and which mere gadgets or toys. Her information is stored in the service providers' databases, and she is aware of what companies are storing what data and where. (However, if she did not read the terms and conditions of the gadgets and toys, she probably consented to the use of this data for "improving service provision," which allows the commercial provider to use the data fairly freely.) Self-monitoring and service provider services do not, in general, lead to interaction with healthcare personnel or to guided intervention. Her medical history is stored in a healthcare provider's database and the medication information in the national ePrescription database.

A glimpse into an ICT enhanced future: A well-informed and ICT-empowered citizen is living in an intelligent home, which she could connect to a public or commercial healthcare provider if and when she desires. At will, she could initiate health assessment by transmitting her measurement data for risk factor assessment, and in return, receive offers for different levels of intervention. She could subscribe to the services of her liking, possibly with recommendations from healthcare authorities for qualified service providers. (The system has means to fight fraudulent and non-science-based service providers.) These services could check for the fulfillment of criteria for a personal consultation with qualified professionals and propose to schedule a consultation. She may subscribe to screenings, e.g., for cardiovascular diseases or cancers, in addition to the screenings automatically offered by society.

The automatically measured data could include several physiological parameters, like weight, blood pressure, blood sugar, electrocardiograms, and electroencephalograms[xiv]. Sleep duration and quality diaries, as well as other related information, like diaries of exercise, food intake, smoking and drinking, online time and TV watching, and walking activity and patterns[xv] at home may also be automatically recorded if desired. On the other hand, inactivity and sedentary lifestyle monitors can also be subscribed. Individuals are likely to prefer effortless and automatic yet controllable measurement systems. Through a paid commercial subscription, or free from public healthcare or patient organization, she can receive risk assessment and protective factor information. Goal-oriented and guided peer support, or crowd intelligence, is also available; these systems are specifically designed not to nullify the previous work done by the professionals.

[xii] Risks for other NDCs are not considered in this example although they could exist.

[xiii] Note that only the matters considered in the FINDRISC diabetes risk test[87,88] are taken into account here. In healthcare expert consultation, also other factors and diseases would be considered, such as weight trend and the risk of cardiovascular diseases indicated by hypertension medication.

[xiv] Brain activity, i.e., electroencephalogram (EEG), can be measured by home automation brain-computer interface devices. EEG can be telling, e.g., of stress levels. In addition, different kinds of EEG based health testing could be made via home automation.

[xv] Walking activity at home can be measured by intelligent home automation, and can be telling, e.g., of the changes in the person's mental state.

Home automation can be set up by a health service provider to support food and exercise scheduling and choices, and to reduce harmful habits. If she opted for ICT enhanced interventions, they could be initiated upon request, or upon detection of harmful behavior or a lack of protective behavior. Simple but effective small-step reminders may also be integrated into the personal automation, such as shopping basket content reminders (e.g., pointing out products specifically good for blood pressure patients), and notifications upon sitting for too long. Even a tooth-brushing reminder may be useful at times of slight depression.

Information transfer can be expected to be transparent, understandable, and trustable. Also, self-assessment kits for specific illnesses could be available with automated direction to appropriate qualified professional healthcare chains. Preventive medication could be personalized based on her behavior, medical history, and genetic data.

Part 3: ICT for NCD Prevention and Health Promotion

9. Introduction to ICT Systems

ICT systems for NCD prevention and health promotion require ICT resources and capabilities to interface with users, for telecommunications and data transfer, and local or remote data processing and storage. This all requires that local, regional, and national ICT infrastructures are in place. The infrastructures and services need to be accessible with varying types of terminal devices, such as landline telephones, speech- and SMS-only capable mobile handsets and intelligent mobile devices, and gigabit data connections and continent-wide eHealth systems. The infrastructure may also need to support artificial intelligence (AI) systems for more advanced services. During recent years, the increase in ICT capacity has been enormous. For example, the total internet bandwidth has increased from approx. 30 000 Gb/s in 2008 to 185 000 Gb/s in 2016[115]. However, this data transfer capacity is distributed highly unevenly on the globe. Data transfer capacity ranges from 6 kb/s per inhabitant in Africa to 131 kb/s per inhabitant in Europe, or from 1 kb/s per inhabitant in the least developed countries to 93 kb/s per inhabitant in developed countries[115]. The developmental stage of ICT naturally dictates the form of ICT empowered prevention. Accordingly, ICT empowered NCD prevention and health promotion systems can be developed for different levels of ICT infrastructure.

In the EU member states in 2017, the household internet access ranged from 98 % in the Netherlands to 67 % in Bulgaria. The portion of individuals aged 16–74 using mobile internet away from home and work varied from 87 % in the Netherlands and Sweden to 32 % in Italy (however, the household internet access in Italy was at 81 %)[82]. European Commission is promoting free Wi-Fi connectivity by granting WiFi4EU[66] vouchers to municipalities (EUR 15,000 per municipality) to install public wireless access points, WiFi4EU hotspots. Besides, healthcare ICT for professionals and other communal ICT-based services naturally benefit also those without personal access to the internet. ***With advanced ICT infrastructure in place, Europe is in an excellent position to develop and utilize ICT empowered NCD prevention and health promotion methods and systems***.

10. Health ICT Ecosystem

In Fig. 2, a possible view of the health ICT ecosystem is illustrated. Individuals utilize gadgets, mobile apps, internet-based services, and home automation, which receive information from the system providers, such as qualified healthcare organizations and companies. The systems used by the individuals can also include an engagement aspect, such as gamification, and support directing identified high-risk individuals to professional healthcare chains. Schools and educational systems can be employed to enhance the health literacy of the children and adolescents, steer them towards healthy habits using gamification, and provide easily accessible information for the students and teachers. Most systems can be augmented by virtual reality for added information content and attractiveness.

Decision support systems can aid both the public and healthcare professionals in their daily healthcare and treatment decisions. On the other hand, decision support systems can guide healthcare professionals and public officers in preventive action planning, for example. Information feeds and resources provide the data and other information via the data transfer systems to all the other ecosystem components, healthcare professionals, and members of the public as appropriate. Information transfer systems also provide electronic health records across borders in Europe.

Healthcare authorities can perform population screenings for diseases of public health interest. Besides, early warnings of possible public health emergencies, and public health policy priorities, could be derivable from such information. Public health surveillance and the monitoring of habits can be employed to steer population-wide interventions. Screenings, public health surveillance, and habit monitoring can be performed using the commonly used systems or systems particularly designed for this purpose. Intervention impact analysis is crucial in designing future interventions.

Healthcare companies, non-governmental organizations, cities and municipalities, hospital districts and regions, national governments, EU, and other international healthcare-related actors, such as WHO, all employ a diversity of healthcare-related ICT systems relevant to their operations.

Electronic health records form the basis of the continued healthcare of the citizens. Other healthcare-related data include all other data and information possibly needed in a healthcare setting, such as public and professional databases and libraries, carrying, for example, best treatment practices documents and scientific literature, statistics, and public health surveillance data. New data is continuously generated by healthcare professionals, citizens, and the ecosystem components themselves.

AI systems are usually designed for decision support for a particular task[xvi]. However, they could also serve in planning large-scale NCD preventive interventions and health promotion activities. They also may provide tools for information- and knowledge-based management and leadership. In contrast, individuals would benefit from lifestyle modification support tools. Data and computing clouds provide location-independent access to the data and the computer power for the large-scale analysis of healthcare data, possibly employing AI.

All the above ideally takes place in multi-professional health actor environments and utilizes the know-how of medical professionals and other healthcare professionals in concert with ICT professionals as best required for each application. The scale of a multi-professional environment can vary from a small group of healthcare professionals from different fields helping a single patient to a multi-agency effort building a national or international NCD prevention plan and an ICT ecosystem to support implementing that plan. The healthcare ICT ecosystem is ever advancing due to research and innovation regarding ICT, medicine, and healthcare practices. The business landscape, public and commercial service palette, and regulatory environment, including, for example, the laws and taxation, are essential in defining and creating the healthcare ICT ecosystem.

The healthcare ICT ecosystem components depicted in Fig. 2 also provide the tools for ICT empowered NCD prevention and health promotion. Each component can include NCD prevention and health promotion functions. Examples of ICT applications for NCD prevention that the components in Fig. 2 can host are given in Table 2. As an example of the multitude of ICT systems that can be of help in preventing a particular NCD, some possible ICT aids for cancer prevention are listed in Table 3. The example in Table 3 has been built around the European code against cancer[182], which lists 12 ways of helping people to adopt healthier lifestyles and to decrease the probability of cancer.

[xvi] See section 13. About Artificial Intelligence and Robotics for NCD Prevention and Health Promotion.
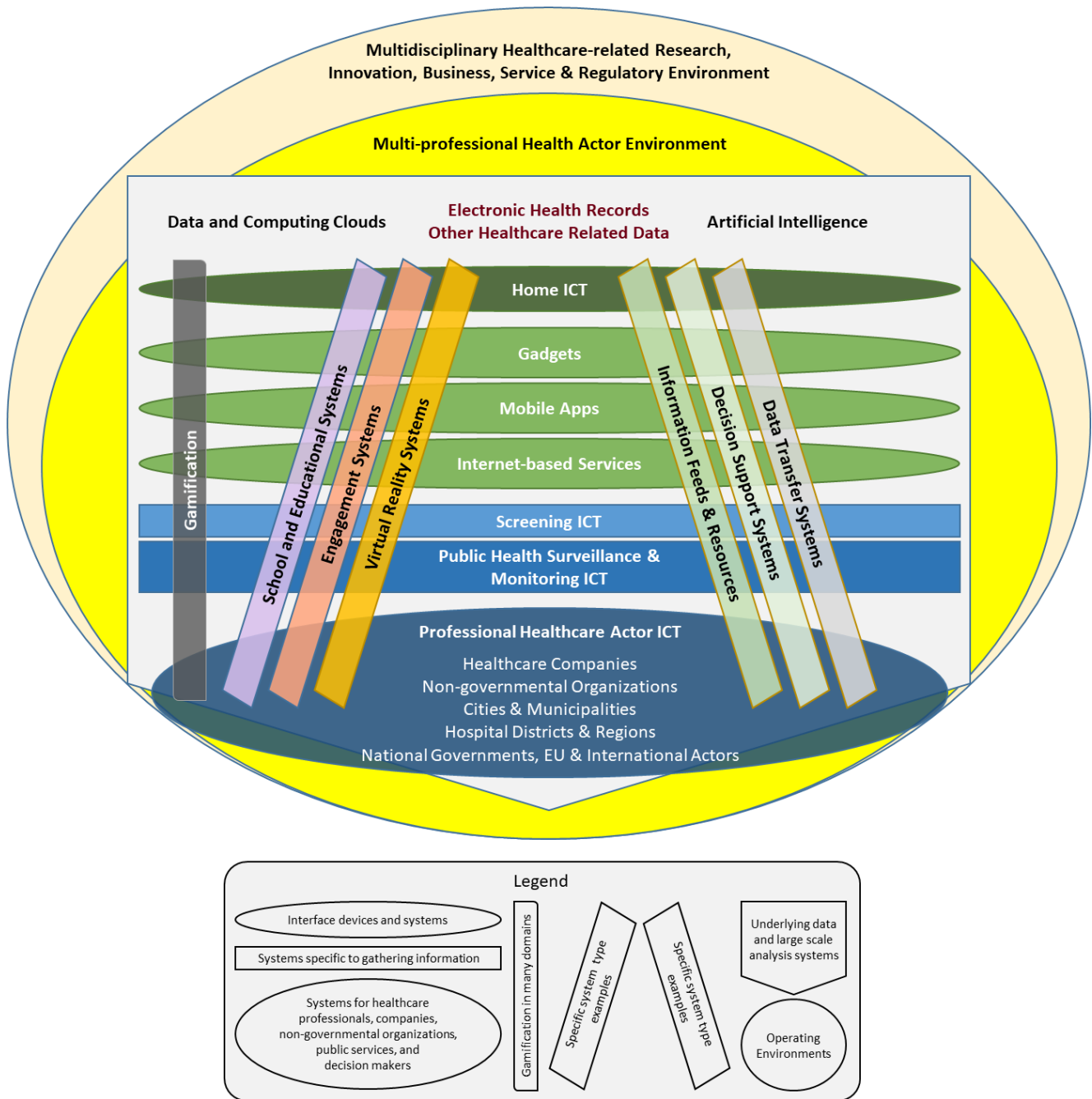
Fig. 2. Health ICT ecosystem. Home automation, gadgets, mobile apps, internet-based services offer services to individuals and interface them with other ecosystem components. At schools and educational institutions, ICT-based systems can be used to enhance health literacy, steer students towards healthy habits, and provide information, also for the teachers. Systems can be augmented by engagement aspects and virtual reality, and offer decision support for both the public and healthcare professionals. Data transfer systems are backbones of the ecosystem, providing secure data between the ecosystem components when granted. Information feeds and resources serve the public and professionals alike with on-demand and continuous information and data. Healthcare authorities and other qualified healthcare providers can perform population screenings for diseases of public health interest and do public health surveillance and monitoring of the habits to analyze the impacts of population-wide interventions. Gamification can be employed to enhance user compliance. Organizations, companies, and governmental bodies, for example, can have their own or shared ICT systems. The ecosystem components operate in multi-professional health actor environments. The ecosystem is advanced by research and innovation and operates within a business, service, and regulatory environment. All the depicted health ICT ecosystem components can include NCD prevention and health promotion functions.

Table 2. Health ICT ecosystem components and some exemplary existing or potential applications for NCDs and health promotion. Applications may utilize a combination of several ICT ecosystem components.

Form of ICT	Application Examples	
Home ICT	Daily tasks & schedules management Health status monitoring Habits monitoring	Promotion of healthy habits Enforcement of healthy habits Acute crises alarms
Gadgets	Pedometers Sports watches & wrist computers Muscle exercise gadgets Physiology monitoring gadgets	Medicine reminders ICT augments sports equipment Blood sugar meters Weight scales & body composition meters
Mobile Apps	Consumer support Peer support Healthy food choices Cooking tips & recipes Tobacco avoidance support Sports & Exercise enforcement	Weight lose aids & motivators Food & exercise diaries Medication information & reminders Medical appointment making & reminders Mobile games supporting protective factors
Internet-based Services	Peer support mailing lists Online chat rooms & discussion forums Topical & patient group support	Information sites for public and professionals Risk assessment tools with directions to interventions Professional help services, e.g., chat doctor
Data and Computing Clouds	Personal data storage & sharing data with healthcare professionals Personal data analysis for risk assessment Electronic patient records Population data collection, screening, risk assessment, and population-wide preventive intervention planning	
Artificial Intelligence	Data analyses for specific tasks, such as medical image interpretation Scrutinizing societal, behavioral & health data, and medical records Decision support at an individual or specific task levels, and for large-scale preventive intervention planning	
Gamification	Physical activity inducing games Physical therapy Social activity promotion & generation Peer support groups	Tobacco avoidance support Relaxation Medication reminders Cognitive capability enhancement
School and Educational Systems	Health literacy training apps & websites eBooks & eJournals for self-study Healthy eating gamification Physical activity gamification	Gadget augmented sports Gamified family engagement for healthy life ICT-based tools for teacher training & engagement
Engagement Systems	Mental health support, integrated model-based prevention Intervention compliance support Habit modification support	
Virtual Reality Systems	Libraries & other information sources Physical exercise with augmented reality Peer support communities	Professional communities Healthcare centers Augmented reality for selecting healthy restaurants when walking on the street

Table 2. (Cont'd.)

Form of ICT	Application Examples	
Information Feeds & Resources	Health information campaigns & public opinion steering "Brainwashing" for health, incl. mobile info campaigns General information systems Mobile advertising systems Peer-to-peer discussion boards	Discussion boards providing professional aid Medicine databases Medical information, incl. medicine package leaflets Exercise information Online helplines eBooks & eJournals
Decision Support Systems	Health-promoting decision support for the public NCD risk assessment toolkits & decision support for the public Automated identification of high-risk individuals and groups Decision support for healthcare professionals Planning & customization of preventive interventions for individuals, groups, and populations	
Data Transfer Systems	Secure data transfer between users, homes, gadgets, mobile apps, internet-based services, and healthcare providers Instructional data & data requests from healthcare providers to individuals Secure data transfer between healthcare ICT systems, including internationally	
Screening ICT	Systematic information collection facilitating follow-ups and quantification of the impacts of changes Electronic health records Digital trails & social media	
Public Health Surveillance & Monitoring ICT	Quantification of the impacts of legislative changes Quantification of the impacts of intervention campaigns Public health surveillance systems[174] Big data & social media surveillance	
Professional Healthcare Actor ICT	Electronic patient records Decision support systems Identification of high-risk individuals Hospital & patient management systems	Habit & pattern surveys Daily goods market analysis Digital trails Public health surveillance & health monitoring studies & research
Multi-professional Health Actor Environment	Multi-professional intervention planning & execution for individuals and populations Multi-professional design of effective ICT solutions for individuals and populations ICT usability & deployment research Care chain enforcement for high-risk individuals Integrated systems for multiple NCD prevention ICT systems to enhance & enforce NCD prevention and treatment[5]	
City Traffic and Civil Engineering ICT (not depicted in Fig. 2)[xvii]	Environmental measurement systems Transportation planning Traffic surveillance	Air quality data for citizen information Air quality data for urban planning & zoning

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[xvii] Although traffic and civil engineering ICT are not usually associated with NCD prevention and health promotion, several aspects of them contribute to the general well-being and living normal happy lives. Air quality data is directly utilizable in NCD prevention.

Table 3. The European code against cancer: "12 ways to reduce your risk for cancer[182]" and examples of possible ICT-based aids and how they could help.

12 Ways to Reduce Cancer Risk[182] (direct quotes)	Examples of Possible ICT Aids	Examples of How ICT Aids Could Help
1. Do not smoke. Do not use any form of tobacco. 2. Make your home smoke free. Support smoke-free policies in your workplace.	Information sources & services ICT based peer support groups Quitting support apps Electronic information campaigns to enrolled smokers	Automated or on-demand information feeds to mobiles to remind what smoking is doing to you. Persons in similar situations can quickly contact each other at the spot when the urge is getting too strong. Get mental support from healthcare professionals when wishing to quit smoking, during the process, or on the spot.
3. Take action to have a healthy body weight.	Healthy food choice apps ICT-based peer support groups Electronic information campaigns for enrolled persons Internet services for weight control Exercise support ICT	Make good choices at a grocery store; information to mobile at will; you make the shopping list or select recipe, the app suggests alternatives. Join groups positively sparring for a healthy life to reduce weight. Receive motivational messages, reminders, and track exercises. Collect and transfer information to healthcare professionals or support organizations for further advice or intervention.
4. Be physically active in everyday life. Limit the time you spend sitting.	Physical activity monitor gadgets Physical activity internet services, connected to monitoring gadgets ICT based peer support groups Mobile apps to detect excessive sitting Mobile apps to schedule physical activity	Receive motivational messages, reminders, and track exercises and sitting. Collect and transfer information to healthcare professionals or support organizations for further advice or intervention. Join physically active peer groups. Attend online exercise classes; schedule in-persons exercise classes. Get online coaching.
5. Have a healthy diet: • Eat plenty of whole grains, pulses, vegetables, and fruits. • Limit high-calorie foods (foods high in sugar or fat), and avoid sugary drinks. • Avoid processed meat; limit red meat and foods high in salt. 6. If you drink alcohol of any type, limit your intake. Not drinking alcohol can prevent cancer.	Information sources & services Food item identification and information apps Food choice apps Alcohol intake counter apps ICT based peer support groups	Make good choices at a grocery store; information to mobile at will; you make the shopping list, the app suggests alternatives. Keep food and drink diary; get suggestions for changes to better. Collect and transfer information to healthcare professionals or support organizations for further advice or intervention.
7. Avoid too much sun, especially for children. Use sun protection. Do not use sunbeds.	Ultraviolet radiation level warning apps Information sources & services Electronic information campaigns	Quickly get information on the effects of ultraviolet radiation and on how to protect yourself, also via public information campaigns. If you are inclined to sunbathe, get automated real-time high ultraviolet radiation level warnings, and sunscreen usage reminders. Get ultraviolet weather forecasts automatically.

Table 3. Cont'd.

Ways to Reduce Cancer Risk[182] (direct quotes)	Examples of Possible ICT Aids	Examples of How ICT Aids Could Help
8. In the workplace, protect yourself against cancer-causing substances by following health and safety instructions.	Automated chemical safety information sheet systems Electronic reminders upon entry to hazardous environments Automatic detection and enforcing of safety clothing and equipment usage	Get motivated for safety via receiving automated information feeds. Motivate safe working culture. Decrease exposure to hazardous chemicals by enforcing the usage of safety equipment. Chemical safety data sheets available at site as automated feeds to worker's mobile, or otherwise on sight and immediately accessible. Entry to a room with chemical hazards allowed only upon acknowledging safety precautions and completed personnel training.
9. Find out if you are exposed to radiation from naturally high radon levels in your home. Take action to reduce high radon levels.	Electronic radon measurement systems Geography based information sources & services Zoning systems, construction guidance for radon risk areas Housing construction information systems	Get informed about the local risk levels. Get in contact with radon measurement and radon removal renovation companies. Geographical radon risk data to steer zoning and construction. Continuous radon monitoring.
10. For women • If you can, breastfeed your baby. Breastfeeding reduces the mother's cancer risk. • Limit use of hormone replacement therapy, which increases the risks for certain cancers.	Breastfeeding apps Electronic information systems Electronic information systems Decision support systems for healthcare professionals	Track breastfeeding. Join peer groups. Easily contact professional healthcare. Easily receive information produced by qualified professional healthcare services, including on baby care: what to do and how. Healthcare professionals get a treatment recommendation for specific patients. Electronic patient records bring the patient's disease-specific family background automatically to the doctors' attention.
11. Ensure that your children are vaccinated against • Hepatitis B (for newborns) • Human papillomavirus (for girls)	Vaccination information in electronic patient records Healthcare ICT systems with automated vaccination invitations & online time reservations Automatic epidemic detection systems based on electronic patient records	Unvaccinated individuals receive information about the risks of not being vaccinated. Unvaccinated individuals receive information about close-by vaccination possibilities and can schedule vaccinations online. Population vaccination statistics can be automatically produced for public authorities for prevention planning. Automatic alerts to healthcare authorities upon a detected rise in disease prevalence.

Table 3. Cont'd.

Ways to Reduce Cancer Risk[182] (direct quotes)	Examples of Possible ICT Aids	Examples of How ICT Aids Could Help
12. Take part in organized cancer screening programs for: • Bowel cancer (for men and women) • Breast cancer (for women) • Cervical cancer (for women)	Healthcare ICT systems with automated screening invitations & online time reservations Electronic medical records AI systems for identification of new groups at high risk for cancer Healthcare ICT systems with automatically enforced cancer care chains	Individuals receive information about cancer risks. Individuals are automatically called for screening and can reserve screening time online. Automatically direct cancer patients to appropriate care chains and treatments. Enforce the realization of the care chains after in professional healthcare.

As another example, ICT for mental disorder prevention can be considered. The prevention of several mental disorders is possible[202,206,220]. An ICT system that positively enhances any of the protective factors, e.g., helps in achieving a normal happy life, contributes to mental disorder prevention. On the other hand, for mental disorders and their prevention, ICT systems have been designed for information access, screening, assessment, monitoring, intervention, and social support[7,13,26,122]. For example, there are computerized or web-based self-help interventions to prevent depression[13,17]. Mobile-based automated apps, context-aware, and SMS-based programs[152] have also been created for the task. Further, ICT systems have been proposed for reaching persons who are at risk of mental disorders but are hard to reach by the traditional means[158].

11. Some Potential Caveats with the Evolution of ICT for NCD Prevention and Health Promotion

Prediction of the future is, in general difficult, except for that the demand for healthcare services and the associated costs will grow and probably do so at an increasing speed. NCDs as a general burden are not likely to diminish, on the contrary. ICT and medicine will continue to be advanced, hopefully also contributing to NCD prevention and health promotion. However, some potential caveats related to the developments exist, including those shortly outlined in this section.

With the recent evolution of ICT for NCD prevention and health promotion, a few hazardous phenomena have appeared:

- Ineffective or even dangerous information and practices are being offered by non-professionals.
- Healthcare chains break due to self-assessment systems with inadequate functionality to direct the found high-risk persons to appropriate professional care chains.
- Self-monitoring data is often produced, but not made available in the health care ICT systems for the professionals.

ICT solutions offered by non-professionals may give advice and promote practices that are not based on science, but, for example, on the individuals' own observations. In general, there is no control over the quality of such advice and practices. These practices may even be dangerous, at least to specific individuals with particular conditions, or even to the public at large, if harmful practices gain popularity and last long. Wide-spread mis- and disinformation is especially alarming as the public is more and more inclined to search for information from the internet and mobile apps rather than from healthcare professionals. People may also have difficulties to recognize whom they should believe. Therefore, there is a need for verified health information to be available from qualified healthcare professional organizations and for the information to be promoted through science-based ICT solutions whose information quality is publicly recognizable.

ICT solutions can assist in self-monitoring of personal health-related parameters and traits, such as intake of nutrition, sports, symptoms, weight, blood pressure, glucose, lipids, HbA1c (for long-term glucose assessment), and body fat and muscle content. Often the systems provide only tracking or monitoring and maybe some further information. On the other hand, such systems may direct individuals, e.g., to buy books or dietary supplements, or to join commercial exercise or weight loss programs. Nevertheless, such ICT solutions may be significant in enforcing healthy lifestyles; self-monitoring is an essential part of NCD prevention and control. In general, the following matters have become evident:

1) No direction to qualified professional intervention is offered by such ICT solutions; such systems usually do not direct the identified high-risk persons to more holistic qualified professional healthcare, i.e., to the appropriate healthcare chains. Thus, the healthcare chains are broken.

2) The data from self-assessment systems is not transferred into the healthcare ICT systems and is not available to professionals. However, this data would be of great value in identifying persons at high risk, and in monitoring and follow-ups of patients and high-risk individuals.

Medical devices in the EU are subject to strict approvals and certification[21,57]. The medical devices that have been approved carry the CE marking[xviii]. The letters "CE signify that products sold in the EEA[xix] have been assessed to meet high safety, health, and environmental protection requirements.[35]" The CE marking procedure for medical devices is tedious and costly. There are numerous consumer health-related apps, gadgets, and online services on the market that do not carry CE marking. The public is naturally free to use any legal consumer products, and such devices may help in the assessment and maintenance of health. However, the data produced by uncertified devices may not be used by medical professionals.

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xviii Note, however, that CE marking per se is not specific to medical devices.
xix EEA – European Economic Area

It can be expected that, for example, health-related apps and gadgets that are not approved medical devices include systems that are not science-based, do not fully conform to good practices of a healthy life, or do not provide proper information security, among other possible shortcomings. Some of such systems may be malfunctioning, provide questionable and untrustworthy data or advice, or for example, their sole purpose may be to generate revenue for the providers.

Nevertheless, reviewing self-assessment data by medical professionals would be highly beneficial for determining the need for actual NCD risk assessment and medical diagnostics. It would also be beneficial to allow storing trustworthy self-assessment data in patient databases.

The European Commission has been working on the privacy code of conduct for mobile health apps[36,38,39], and on the mHealth assessment guidelines[38,63]. In a draft of the guidelines for assessing mHealth solutions[64], certification of apps that do not carry CE marking was called for. Unfortunately, the working group concluded, "A minimal level of consensus between the members of the Working Group was not reached. It was thus impossible to achieve and endorse any guidelines.[63]"[xx] This demonstrates that the mHealth app guidelines issue is not trivial, and the challenges outlined above remain to be solved.

3)   A part of the public is searching for one truth and simple solutions. These types of solutions may be offered by companies and individuals purely out of monetary interests and may or may not always be scientifically sound and safe.

The above, among other identified matters, are addressed by the recommendations in the accompanying Position Statement[100]. Still, two potential risks are worth noting: 1) Extensive self-measurements of one's physiological parameters, combined with a sea of health and medical information available on the internet, may put the individual at risk of hypochondria or undermine the work of healthcare professionals. 2) Insurance companies gaining access to personal electronic health information might lead to adjustments in insurance premiums.

12. About Genetic Testing for NCD Prevention and Health Promotion

NCD prevention and intervention based on genetic testing of individuals and at a population level is currently emerging[28,127,144,193,198]. Genetic analysis may enhance the effectiveness of NCD prevention[216]. Should genetics-based population screening become a reality, population-based prevention could rise to an entirely new level of effectiveness. The effectiveness of ICT-based methods could probably be greatly increased by genetics-based prevention, since the interventions could be more precisely targeted to the most influential harmful behaviors pointed out by the genetic analysis. Genetic analysis could also revolutionize medical treatment-based prevention, since preventive drugs could be designed to be much more specific, i.e., personalized drugs could target the actual problem more precisely than most of the drugs do today. Genetic analysis and screening based preventive intervention strategies can be included in the designs of new healthcare ICT systems.

Twenty EU countries have agreed to cooperate in linking genomic data across the borders in the effort: "Towards access to at least 1 Million Genomes in the EU by 2022." They aim to improve understanding and prevention of disease, and personalized treatments.[22,45,54]

13. About Artificial Intelligence and Robotics for NCD Prevention and Health Promotion

Medical and healthcare-related AI[9,89] systems have been designed mostly for decision support for specific tasks of limited scope. For many AI applications, the term "intelligence" can be regarded as somewhat of an overstatement; in principle, AI systems are taught with training data, and thereafter classify the presented case data (Fig. 3A). Such systems may also search for relationships in the data. However, the complexity of the underlying com-

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xx The reasons stated in [63]: The stakeholders could not agree on "the meaning of the term "effectiveness" and whether this criterion should be included in the Guidelines." "… it appeared that… the work to be done goes beyond the original mandate of the Working Group. A minimal level of consensus between the members of the Working Group was not reached. It was thus impossible to achieve and endorse any guidelines."

putational systems and the natures of possible input and output formats, such as natural language communications or unstructured input data, warrant the usage of "AI." The systems may, for example, classify or interpret medical images, or provide information from a local database or internet based on spoken queries. Such systems can be beneficial in medical practice; they can free human labor for more essential tasks, or for example, tirelessly scrutinize patient data providing information and guidance for medical professionals. In medical imaging and image processing, AI methods are routinely used to process and segment medical images, and even to prepare draft medical treatment plans. Beyond that, AI algorithms, and especially big data methods and deep learning, have been used progressively to analyze medical records to determine co-occurrences, risk factors, and specific diagnoses on a population level. Possible schematics of an AI system for healthcare is presented in Fig. 3B, where the basic AI system in Fig. 3A is augmented by a data mining system, which searches for new information based on an available large database, i.e., big data. The a priori knowledge and confirmed findings form the problem-related knowledge base. The AI system analyses data from an individual based on this knowledge base and may propose preventive interventions after making a risk analysis and possible prognosis. Monitoring the outcome of the preventive intervention helps the patient in the future, and the data gained is added to the knowledge base. Similar AI structures (Fig. 3B) might also be employed in population-level NCD prevention and health promotion.

Like machine learning in general, AI systems must be validated. For healthcare AI systems, correct functionality is naturally crucial. General practice in AI is to use a part of the available data to train the AI system, and post-training, test the system with the data that the system has not yet seen. The training and test data set must be well designed to represent the possible clinical cases adequately. However, using only test data available at the production site at the time of system construction, may not always adequately represent the full spectrum of cases. Therefore, it has been argued preferable to perform prospective validation with newly recruited patients or during actual system use to confirm diagnostic or predictive results. Beyond the validation of on-the-spot diagnostic and predictive results, patient outcome-based validation can be made.[148]
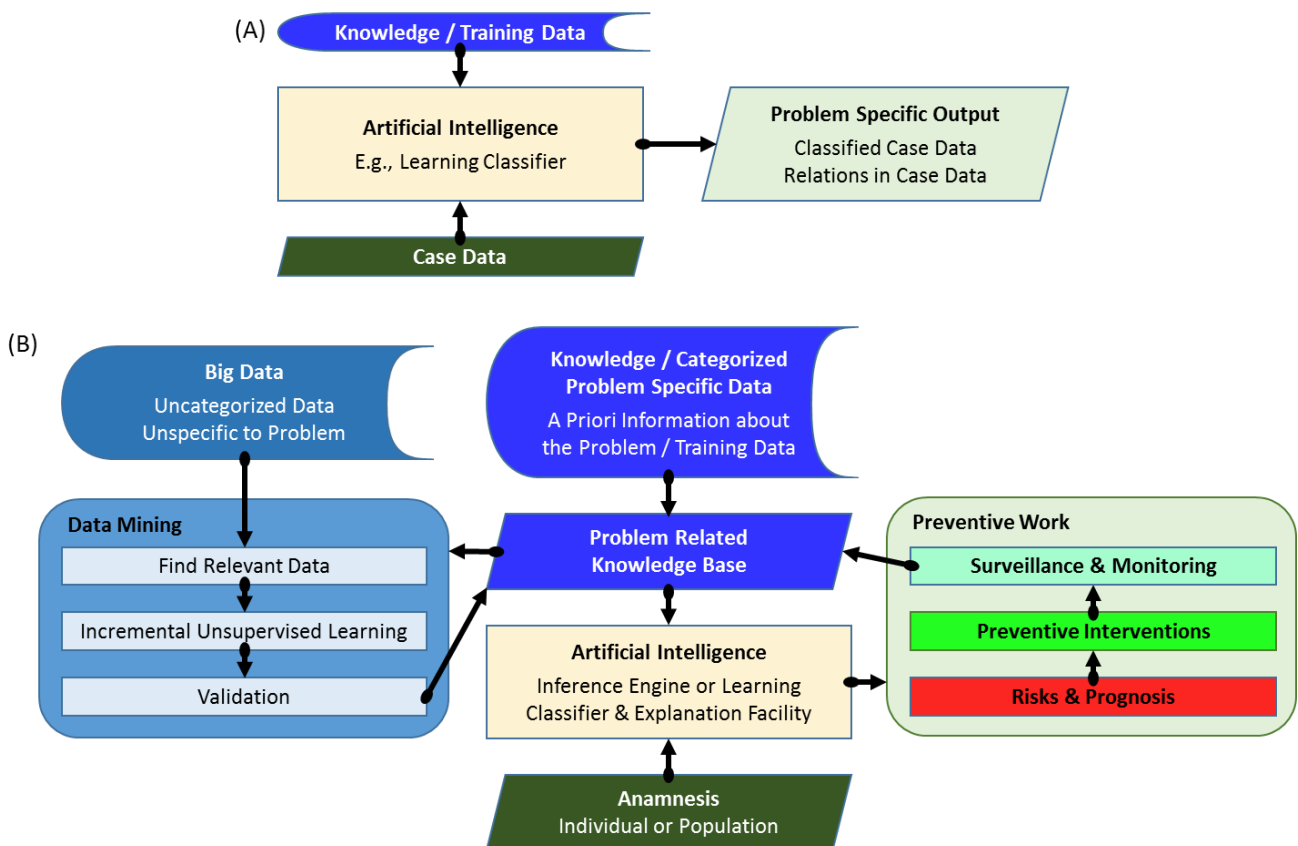
Fig. 3. (A) A schematic general presentation of a possible problem-specific AI system. Here, AI is a learning classifier that is trained using a priori classified training data. After the AI system has learned the training data, payload case data is input, and the system produces problem-specific output. **(B)** A schematic general presentation of a possible healthcare AI system with a possible level of detail and data mining functionality added compared to **(A)**.

Nowadays, it is easy to construct AI systems using readily available tools and environments[e.g., 3,92,97,98,135]. The number of healthcare-related AI applications proposed in the scientific literature is exploding. Related to NCDs, examples of proposed AI-based systems include diabetic retinopathy detection via smartphone-based imaging[154], diabetes care in general[12], and breast cancer screening[96]. Also, other automated computational methods have been proposed, e.g., for proactive screening for depression[143], and proactive health computing in general[162]. AI-enhanced app-based (smart device-enabled) life-style monitoring solutions and ambient assisted living solutions are available. Whereas AI-based systems show great promise, AI systems for true NCD prevention and health promotion are still few. One challenge hindering the development of grander AI systems for NCD prevention is legal barriers to access personal and patient information and to link it with other relevant data. Such data linkage was also addressed in our Position Statement[100] related to this Whitepaper.

Let us note that the scope of "AI" varies from one discipline to another, and some consider it newer than others. The term "AI" was coined in 1956[119], the first issue of Elsevier's Artificial Intelligence was published in 1970[xxi], and IEEE Transactions on Pattern Analysis and Machine Intelligence was established in 1979[xxii]. In machine vision, image processing, pattern recognition, signal classification, and natural language processing, for example, AI systems have been designed long before the current AI hype.

> IEEE, IEEE European Policy Initiative, and IEEE-USA have published positions statements on AI[106,99,108, respectively], with specific recommendations. AI and autonomous systems pose ethical questions that need to be addressed, including questions about decision-making authorizations and liabilities. The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems[104] has been established "to ensure every stakeholder involved in the design and development of autonomous and intelligent systems is educated, trained, and empowered to prioritize ethical considerations so that these technologies are advanced for the benefit of humanity[104]." To this end, the IEEE Global Initiative published a reference document on the Ethics of Autonomous and Intelligent Systems called "Ethically Aligned Design (first edition)[104]" on March 25, 2019. IEEE also contributes to ethical development via standardization, including with the 7000 family of standards[101], and through the development of The Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS)[102].

Robotics is being applied in healthcare settings, for example, in surgery[159], rehabilitation[165], elderly care[166], and for socially assistive purposes[2]. Such robots can range, e.g., from automated freezer-heater meal dispensers, via intelligent home testing and drug delivery systems, and fine-electromechanical extensions of surgeons' hands, to interactive humanoid-like robots with high dexterity and mobility and access to vast information resources. In NCD prevention and health promotion settings, robots can be employed as interfaces between the person, family, other members of the public, professional healthcare personnel, internet-based information sources, and AI systems. Technically, robots can be the effectors and remote care delivery arms of the healthcare professionals and serve as AI-supported diagnostics and monitoring tools. Robots can physically support humans in home care and elderly care settings. Still, minimally invasive robotic bariatric surgery[16] can also be considered an NCD prevention technology. Robotics can serve to enhance further ICT-enhanced NCD prevention and health promotion methods and technologies.

[xxi] The first issue of Artificial Intelligence can be found at https://www.sciencedirect.com/journal/artificial-intelligence/vol/1/issue/1.
[xxii] The first issue of IEEE Transactions on Pattern Analysis and Machine Intelligence can be found at https://ieeexplore.ieee.org/xpl/tocresult.jsp?isnumber=4766865&punumber=34.

15. About Cost-effectiveness of ICT for NCD Prevention and Health Promotion

As we have seen in this document, the ICT ecosystem (Fig. 2) for NCD prevention and health promotion is a highly complex system. It offers a multitude of possibilities to enhance the NCD prevention and health promotion work. The main goals of the work are to save lives, ease human suffering, and to reduce the economic burden to society and industry. Upon the individuals affected by NCDs and their close social circles, the burden is thrust in several forms of physical, financial, social, and mental problems. The burden to the society comes via many direct and indirect effects of NCDs, including spending on medical care and social benefits, and the loss of productivity (including, e.g., loss of work output and production, increased cost of work, work inefficiency, and smaller working population). Costs on the European economy are enormous (Table 1). Correspondingly huge are the potential savings from the alleviation of NCDs, or ideally, from the eradication of preventable NCD cases.

On the other hand, the fight against the NCDs is not free. It incurs direct costs (and perhaps also indirect costs). However, if successful, it also decreases the costs and burden of NCDs. A full cost-efficiency analysis is a complex matter. Here, only some aspects of it are noted. Firstly, usually, the cost-efficiency of NCD prevention is considered without considering the costs of ICT aspects. The CHOICE (CHOosing Interventions that are Cost-Effective) program[188] of WHO assesses the cost-effectiveness of different NCD prevention targets, e.g., risk factors and diseases, and has defined the Best Buy interventions[192] that are cost-effective. They include, for example, on a population level, targeting the use of tobacco[xxiii], harmful use of alcohol[xxiv], and unhealthy diet and physical inactivity[xxv,209]. On a personal level, they include, for example, the prevention of cancer[xxvi], cardiovascular diseases, and diabetes[xxvii,209].

The menu of policy options and cost-effective interventions, the Best Buy interventions of WHO, are being updated[212,196]. Also, a description of the methodology used to identify and analyze interventions is being drafted[196]. It includes the summary of the WHO-CHOICE economic analyses[xxviii] for interventions for NCD prevention and control also in upper-middle and high-income countries, in addition to those for low and lower-middle-income countries.

The creation of ICT systems for the fight against the NCDs is not free, and cost-effectiveness assessments would be necessary. However, it could be reasoned that if preventive functions were included in the large-scale systems when they are created, the construction costs could be lower. Coordinating and guiding the entire field (c.f. Fig. 2) appropriately could also reduce the overall costs. ICT systems for NCD prevention and health promotion may naturally have effects also on which NCD prevention targets are cost-effective.

Population aging will increase expenditure; "population aging can reasonably be described as both an outcome of, and a challenge for, European health systems."[155] In this context, effective ICT solutions for NCD prevention and health promotion may help to increase life expectancy, thus possibly increasing costs. Also, more persons entering NCD prevention schemes due to effective ICT enhanced risk analyses may increase the associated costs. On the other hand, ICT will play an essential role in taking care of the aging population. ICT will be of great help in accommodating the larger numbers of persons in the NCD prevention and control schemes, probably at lower costs than possible by traditional means. For example, some NCD prevention schemes could be fully automated, whereas in other schemes, manual labor needs could be greatly reduced.

[xxiii] Core interventions: "Tax increases; smoke-free indoor workplaces and public places; health information and warnings about tobacco; bans on advertising and promotion.[190]"

[xxiv] Core interventions: "Tax increases on alcoholic beverages; comprehensive restrictions and bans on alcohol marketing; restrictions on the availability of retailed alcohol.[190]"

[xxv] Core interventions: "Salt reduction through mass media campaigns and reduced salt content in processed foods; replacement of trans-fats with polyunsaturated fats; public awareness programme about diet and physical activity.[190]"

[xxvi] Core interventions: "Prevention of liver cancer through hepatitis B immunization; prevention of cervical cancer through screening (visual inspection with acetic acid [VIA]) and treatment of pre-cancerous lesions.[190]"

[xxvii] Core interventions: "Multi-drug therapy (including glycaemic control for diabetes mellitus) to individuals who have had a heart attack or stroke, and to persons with a high risk (> 30%) of a CVD event in the next 10 years; providing aspirin to people having an acute heart attack.[190]"

[xxviii] In [185], it is stated that the "detailed description of the WHO-CHOICE methods for these analyses, including the assumptions, strength of evidence and the individual studies used to inform the development of models for each intervention, will be published separately as peer-reviewed scientific papers, which will be publicly available through open access.[185]"

Regarding selecting NCD preventive interventions: "Cost-effectiveness analysis is a useful tool but it has limitations and should not be used as the sole basis for decision-making. When selecting interventions for the prevention and control of noncommunicable diseases, consideration should be given to effectiveness, cost-effectiveness, affordability, implementation capacity, feasibility, according to national circumstances, and impact on health equity of interventions, and to the need to implement a combination of population-wide policy interventions and individual interventions.[212]" This also applies to ICT for NCD prevention and health promotion. ***As outlined in this Whitepaper, ICT can be utilized in numerous ways.***

Since cost-effectiveness is not seen here as an ICT challenge issue per se, the accompanying Position Statement[100] does not include recommendations regarding cost-effectiveness. This section is not intended as a complete discussion on the matter. However, it is included in this Whitepaper for completeness and as a reminder of the matter.

16. About Standards and Healthcare ICT

The IEEE Standards Association[105] describes standards[103] as follows:

> Standards are published documents that establish specifications and procedures designed to maximize the reliability of the materials, products, methods, and/or services people use every day. Standards address a range of issues, including but not limited to various protocols to help maximize product functionality and compatibility, facilitate interoperability and support consumer safety and public health.

> Standards form the fundamental building blocks for product development by establishing consistent protocols that can be universally understood and adopted. This helps fuel compatibility and interoperability and simplifies product development, and speeds time-to-market. Standards also make it easier to understand and compare competing products. As standards are globally adopted and applied in many markets, they also fuel international trade.

> It is only through the use of standards that the requirements of interconnectivity and interoperability can be assured. It is only through the application of standards that the credibility of new products and new markets can be verified. In summary, standards fuel the development and implementation of technologies that influence and transform the way we live, work and communicate.[103]

Standards are highly relevant for healthcare ICT, and numerous areas of standardization are crucial. For example, standards for medical and related devices, telecommunications, information security, electrical safety, and electrical interference control, are absolutely necessary to establish interoperability, reliability, and safety. In the European context, compliance with specific standards and associated certifications is required by EU laws and regulations, and compliance with standards can additionally be required at the national level. Besides, manufacturers or implementers can voluntarily follow standards in their products or implementations to provide a level of interoperability and confidence in a broader product ecosystem.

Relevant standardization activities are captured in the section "eHealth, healthy living and ageing" of the Rolling Plan for ICT Standardisation[55], a document released on an annual basis by the European Commission. IEEE contributes to the development of this document, as it has relevant standards, including the 11073 family of standards on personal health device communication[107]. European Commission web page on references of harmonised standards and other European standards published in the Official Journal of the European Union, including regarding healthcare engineering, can be found here [52].

17. About Cybersecurity and Privacy

Healthcare ICT cybersecurity and privacy are crucial for the individuals in the healthcare system, the public acceptability of healthcare ICT, and the functioning of the healthcare itself. Electronic health records and healthcare ICT, in general, are fundamental for providing care to the European citizens and hold promise for enhancing the NCD prevention and health promotion. However, without effective cybersecurity and privacy, individuals' health data could be compromised regarding both secrecy and trustworthiness, possibly leading to compromised patient safety and public distrust, and endangering individuals and subpopulations for stigmatization. Regarding health devices, compromised cybersecurity could lead to unauthorized control of connected medical devices or illicit rewriting of medication prescriptions. Cybersecurity and privacy and their implications are highly complex issues; within the scope of this Whitepaper, only a glimpse of the issues can be given.

Patient privacy and healthcare data privacy and security start with the Charter of Fundamental Rights of the European Union[67] that provides everyone "the right to the protection of personal data[67 Article 8]." Thereafter, the European General Data Protection Regulation (GDPR)[70 Article 9] prohibits "processing of personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health or data concerning a natural person's sex life or sexual orientation," except under the ten circumstances listed in the GDPR. The GDPR[70 Article 4] also provides the definitions of "'personal data," "genetic data," and "data concerning health" for data protection purposes and defines genetic data as a part of the personal data. All data, regardless of de-identification, encryption, or pseudonymization, that can be used to re-identify a person is personal data and falls within the scope of the GDPR; conversely, truly irreversibly anonymized data is no longer personal data[65]. GDPR is also technology-neutral, i.e., personal data is subject to protection regardless of the storage media and whether processed manually or using ICT[65].

Health data, including genetic data, can be in categorized as personal data under GDPR, anonymous individual data, summary data (such as statistics), and metadata (data about the data without any original data). The data minimization principle[81 section 3.3.] states, among other matters, that "the processing of personal data should only take place when the purpose of the processing cannot be reasonably fulfilled by other means." For research, for example, this would mean using at most anonymous individual data, not personal data under GDPR. Using anonymous data guarantees privacy and is usually sufficient for health-related research.

Cybersecurity in Europe rests on EU Directives, such as the Directives on a high common level of security of network and information systems[68] and patients' rights in cross-border healthcare[69]; EU Regulations, such as the Cybersecurity Act[71]; standardization[78,79]; and data protection certification[77]; among other legal, regulatory, and technical measures. Of particular personal data protection and cybersecurity interests is the exchange of electronic health records across the EU[37,43,45,51,56].

> European Patients' Forum has published a guide on data protection for patients and patients' organizations[73] and a Position Paper on eHealth[72]. IEEE-USA has published a Position Statement on cybersecurity[109]. In Europe, the European Union Agency for Cybersecurity (ENISA)[80] is "working to make Europe cyber secure."

18. About Ethics

Healthcare ICT related ethics is crucial for the individuals in the healthcare system, for the public acceptability of healthcare ICT, and thus for the functioning of the healthcare itself. Unethical practices could lead to the stigmatization of individuals and subpopulations and public distrust in the healthcare system. Although generally accepted ethical guidelines by EU and WHO related to healthcare exists and range from research ethics[44,50,189,210] to public health surveillance[214], ethics is often a topic with multiple viewpoints. Health ethics also evolves in time[1]. Generally, the ethical questions are not concerned with the healthcare ICT or ICT for NCD prevention and health promotion per se, but rather with the practices independent of the media or technology. However, due to the massive amounts of sensitive information, healthcare ICT ethics warrant special attention.

Examples of unethical practices related to NCD prevention and health promotion include unethically conducted clinical trials, leaking and unauthorized access of health or other personal data, publishing and promoting non-scientific or harmful practices and information, blaming socioeconomic groups for imposing a burden on the healthcare system and stigmatization of certain health conditions, unlawful profiling, discrimination, dismissal of safety guidelines, and not providing protective equipment to the employees, to mention a few.

AI in healthcare has raised ethical concerns. For example, it has been observed that AI algorithms may develop discriminatory bias[147]: When two groups of patients were in equal need of care, but less money had been spent on the treatment of group A, the algorithm concluded that the group A was healthier and discriminated against it in providing care; eliminating cost data from the system, also eliminated the bias. Seven key requirements of trustworthy AI systems[95] have been identified: According to the AI ethics guidelines[95], the AI systems should empower human beings and employ human oversight, be resilient and secure, ensure privacy and data protection, be transparent, foster diversity and be non-discriminatory and fair, benefit all human beings, including future generations, and be accountable.

The usage of genetic data is another currently hot ethical topic. In general, genetic testing in a professional healthcare setting for NCD prevention is regarded to be for the benefit of the individual in question and public health. An example of an ethically difficult question with contradicting recommendations[18] is whether to test asymptomatic children for NCDs that may be manifested later in adulthood, specifically in the absence of preventive measures applicable during childhood. Ethical concerns are also associated with the emerging direct-to-consumer genetic testing: "there are concerns about the accuracy and usefulness of such tests and their interpretation for providing health-related information, in the absence of individualised medical supervision and genetic counselling.[30]"

19. Discussion

"The disparity between our scientific knowledge about chronic disease and practical implementation of preventive approaches is now one of the most urgent concerns in healthcare worldwide and threatens the collapse of our health systems unless extraordinary change takes place.[128]" Here, ICT empowerment of NCD prevention and health promotion could make a difference. In Europe, we are in an excellent position to utilize ICT in the practical implementation of preventive and health promotion approaches. Further, we can aim at preventive life-course healthcare and preemptive medicine, thus reducing the ever-growing healthcare costs and transforming our healthcare systems from reactive to preventive[110].

A lot is being done with ICT for NCD prevention and health promotion. We stress the importance and possibilities of the work. Work is needed on all levels, by individuals, healthcare professionals, S&M companies, large enterprises, health care professional organizations, patient and other organizations, local, regional and national healthcare providers and authorities and other national actors, global standardization organizations, and by EU and the global community. Vast numbers of uncoordinated ad hoc actions have emerged to help individuals and groups. At the other end of the scale, a higher level of coordination and science-based steering could enhance the effectiveness of this work. Strong national and Europe-wide coordinated health initiatives and psychologically well-designed associated ICT systems might have the potential to turn the current devastating NCD trends, and the associated health expenditure development, around to a positive track.

Part 4: Back Matter

This statement was developed by the IEEE European Public Policy Committee (EPPC) Working Group on ICT and represents the considered judgment of a broad group of European IEEE members with expertise in the subject field. IEEE has nearly 60,000 members in Europe. The positions taken in this statement do not necessarily reflect the views of IEEE or its other organizational units.

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