Going digital for noncommunicable diseases

The case for action

ITU UN INTERAGENCY TASK FORCE ON NCDs #beatNCDs @un_ncd World Health Organization

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Going digital for noncommunicable diseases: the case for action

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Foreword

The global burden of noncommunicable diseases (NCDs) is one of the major challenges for development, as it undermines many aspects of socio-economic progress globally. The challenge is exacerbated by entrenched inequalities, as they have a disproportionate impact on vulnerable populations, and, recently, by the coronavirus disease 2019 (COVID-19) pandemic.

This report responds to requests fromWorld Health Organization (WHO) Member States and the United Nations Economic and Social Council to provide support in promoting and implementing digital solutions to address the growing burden of NCDs. It also builds on work by WHO and the International Telecommunication Union (ITU), such as the Global Initiative on Artificial Intelligence for Health.

Digital technologies hold great promise for improving the delivery of health services and helping countries to progress towards universal health coverage. This report summarizes initial systematic work to make the economic case for implementing a set of evidence-based digital health interventions for NCD prevention and management, including telemedicine, mobile health and health chatbots. It also highlights the importance of improving access to relevant digital tools and infrastructure.

The report shows that expenditure of less than US$ 0.67 per patient per year could save over two million lives and US$ 199 billion over the next decade. To realize the full potential of digital health, however, an equitable, affordable, reliable digital service and connectivity infrastructure must be built in a world in which one third of humanity remains offline.

By aligning national health systems, digital health strategies and digital transformation, WHO and ITU encourage Member States to use costed, evidence-based digital solutions to ensure that their health systems reach more people who have difficulty in accessing health services. Digital technologies are already used in diagnosis and clinical care, drug development, disease surveillance, outbreak response and health systems management.

The future of health is digital, which means we must work together to promote universal access to these innovations and prevent them from becoming another driver of inequality. While the new technologies hold great potential, strong governance, ethics, digital skillls and equity are essential to realize their potential and to avoid risks such as unethical data collection and biases encoded in artificial intelligence.

That is why it is so important to work with governments and the private sector to promote equity, including greater participation from low- and middle-income countries in research and development of digital health and artificial intelligence. This report is meant to help in harnessing the power of digital technologies and artificial intelligence to work towards a healthier, safer, fairer world for all.

Tedros Adhanom Ghebreyesus
WHO Director-General

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Abbreviations

AI	artifical intelligence
BHBM	Be Healthy, Be Mobile
CI	confidence interval
COPD	chronic obstructive pulmonary disease
COVID-19	coronavirus disease 2019
CVD	cardiovascular disease
FEV1	forced expiratory volume per 1 s
FG-AI4H	Focus Group AI for Health
GDP	gross domestic product
HbA1c	haemoglobin A1C
IRR	incidence risk ratio
ITU	International telecommunication Union
MD	mean difference
NCD	noncommunicable disease
ROI	return on investment
RR	risk ratio
SDGs	Sustainable Development Goals
TB	tuberculosis
UNIATF	United Nations Inter-Agency Task Force for the Prevention and Control of Non-Communicable Diseases

Key findings

Investing an additional US $ 0.24 per patient per year in telemedicine, mobile messaging and chatbots now, means that over the next decade

More than
2
MILLION LIVES
will be saved

Around
7
MILLION ACUTE EVENTS AND/OR HOSPITALIZATIONS
will be averted

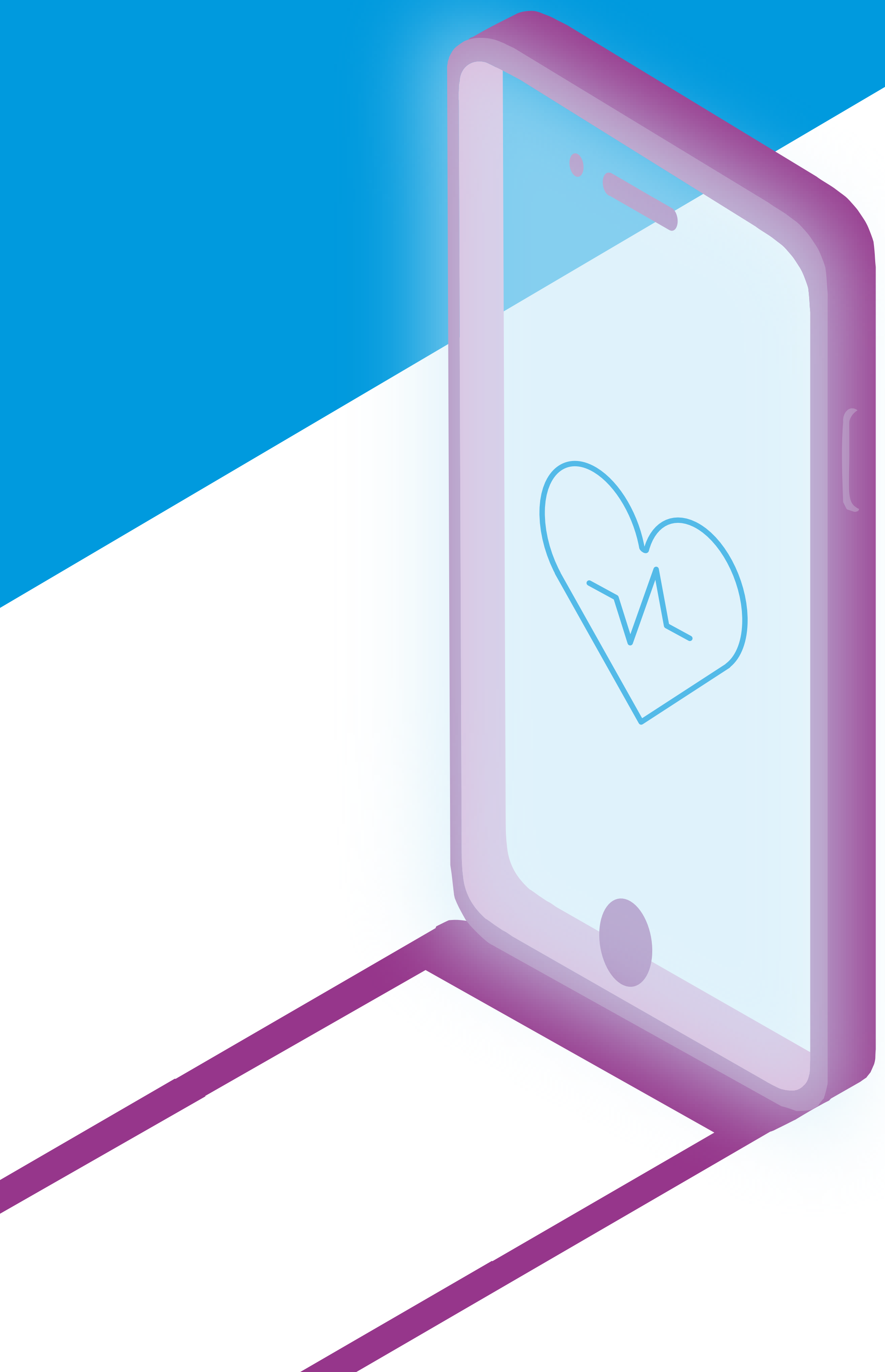
Around
5
MILLION LIFE YEARS
will be gained

An additional
199
US $ BILLION
in economic benefits realised

A return on investment of
19
US $ FOR EVERY US $ INVESTED

COUNTRIES DEVELOP NEW TOOLS AND INFRASTRUCTURE
to implement NCD Best Buys and other cost-effective NCD clinical and policy interventions

Introduction



NCDs, particularly cardiovascular diseases, cancers, diabetes and chronic respiratory diseases, are responsible for 74% of deaths globally (1) and negatively impact the lives of millions more.

In addition to NCDs, mental health conditions are a growing concern, as they account for the largest proportion of years lived with disability. Individuals with severe mental health conditions are at a high risk of dying prematurely, 10–20 years earlier than the general population, often from preventable causes *(2)*.

NCDs and mental health conditions impose a substantial economic burden, hindering global progress towards achieving the Sustainable Development Goals (SDGs) and impeding growth and development. These conditions not only strain social security systems and household budgets by increasing health-care costs but also result in significant productivity losses due to illness, disability and mortality. The projected cost of lost productivity due to the four major NCDs alone is estimated to reach a staggering US$ 30 trillion by 2030 *(3)*. When mental health conditions are included, this figure rises to US$ 47 trillion *(3)*, equivalent to about 50% of global GDP.

To address the growing burden of NCDs, the World Health Assembly in 2017 endorsed a package of 16 affordable, evidence-based NCD interventions, known as the NCD "best buys", which, when implemented in low- and lower–middle-income countries, could save nearly seven million lives and generate US$ 230 billion in economic gains by 2030 (Box 1) *(3)*. In 2023, the World Health Assembly extended the list of NCD best buys to 28 interventions *(4)* to support governments in prioritizing interventions according to their context.

Box 1
Saving lives and spending less with NCD best buys

The WHO 2021 report, "Saving lives and spending less" showed that by investing an additional US$ 0.84 per person per, countries and donors could save millions of lives lost to NCDs, avert nearly 10 million cases of heart disease and strokes and add a total of 50 million healthly life years by 2030. The NCD best buys are highly cost-effective interventions when implemented together, for each additional dollar invested in these interventions, a return of up to US$ 7 could be generated through reduced health costs and improved productivity gains.

Source: WHO *(3)*

We are not on track to achieving the NCD-related SDGs

Despite the devastating impact of NCDs and mental health conditions and the clear economic case for investing in effective interventions, major gaps remain in access to and the quality of services for NCDs and mental health (Box 2).

Box 2
Monitoring progress

Data from the 2022 WHO Noncommunicable Diseases Progress Monitor indicate that, while progress has been made in implementing the WHO-recommended NCD policies and measures, more than 50 countries have achieved fewer indicators than in 2020. Furthermore, fewer than half of the surveyed countries had fully implemented the WHO-recommended measures to reduce risk factors for NCDs.

Source: WHO *(5)*

NCDs are challenging to address even when cost-effective interventions are available, as they are often associated with multiple risk factors, which are intertwined with social determinants of health, such as income and social protection, working and living conditions, access to infrastructure and education, and the influence of commercial interests. In addition, NCDs often require long-term, specialized care, management and coordination from different providers, which can be costly and burdensome for both individuals and health-care systems. As less than 50% of the global population is covered by comprehensive social health protection schemes *(6)*, many people who seek treatment for NCDs are at risk of excessive out-of-pocket health expenditure.

Deficiencies in the availability of health-care services and resources are another major barrier to the NCD response worldwide. There will be a projected shortfall of 10 million health workers by 2030, with shortages of health workers that are more than twice as high in rural than in urban areas *(7)*.

Furthermore, there is little awareness of NCDs and their associated harms. A large international survey of people's perceptions of NCDs conducted in 2021–2022 found that the harm due to many NCDs is underrated, leading to risky health behaviour *(8)*.

Addressing NCDs therefore requires a comprehensive, integrated approach that involves multiple sectors and stakeholders and sustained political commitment, resources and work over the long term.

Contribution of digital technology

Digital interventions can close gaps in access to and the quality of NCD and mental health services and help raise awareness.

Digital technology has been shown to enhance health service delivery and to support public health policy.

In 2020, during the COVID-19 pandemic, 75% of countries reported complete or partial disruption to essential NCD and mental health services, while the rates of common mental health conditions, such as depression and anxiety, increased by 25% *(2)*. To mitigate disruptions to health care, the way in which services were delivered had to change, and various digital health solutions were rapidly adopted in more than 60% of countries *(9)*.

One enabler of digital health is the rapid proliferation of digital technology, which accelerated during the pandemic. In 2019–2020, the number of Internet users globally grew by a stunning 11%. According to the latest ITU data, more than two thirds of the world's population are online, more than 75% own a mobile device, and about 95% are covered by a 3G or a more advanced technology network *(10)*.

Digital health interventions include use of digital technologies such as online programmes, mobile applications (apps), virtual reality, telehealth and telemedicine, connected and/or wearable devices, online peer support, online counselling, and artificial intelligence (AI)-based, big data-enabled applications to improve health. These interventions can be used for various purposes, including disease prevention, diagnosis, treatment and management and for health promotion and lifestyle interventions. Digital health presents valuable opportunities to improve the efficacy, accessibility and quality of health-care delivery and also to empower individuals to take control of their own health and well-being *(11)*.

To strengthen health systems and achieve universal health coverage, WHO's Member States are increasingly exploring use of evidence-based knowledge in decision-making and leveraging new opportunities offered by digital technologies. WHO has therefore developed a Global Strategy on Digital Health 2020–2025 *(12)* to support countries in leveraging digital technologies to improve health outcomes (Box 3).

Box 3
WHO Global Strategy on Digital Health 2020–2025

Guiding principle	Strategic objective
• Acknowledge that institutionalization of digital health in the national health system requires a decision and commitment by countries.	• Promote global collaboration, and advance the transfer of knowledge about digital health.
• Recognize that successful digital health initiatives require an integrated strategy.	• Advance implementation of national digital health strategies.
• Promote appropriate use of digital technologies for health.	• Strengthen governance of digital health at global, regional and national levels.
• Recognize the urgency of addressing the major impediments faced by least-developed countries in accessing digital health technologies.	• Advocate for people-centred health systems enabled by digital health.

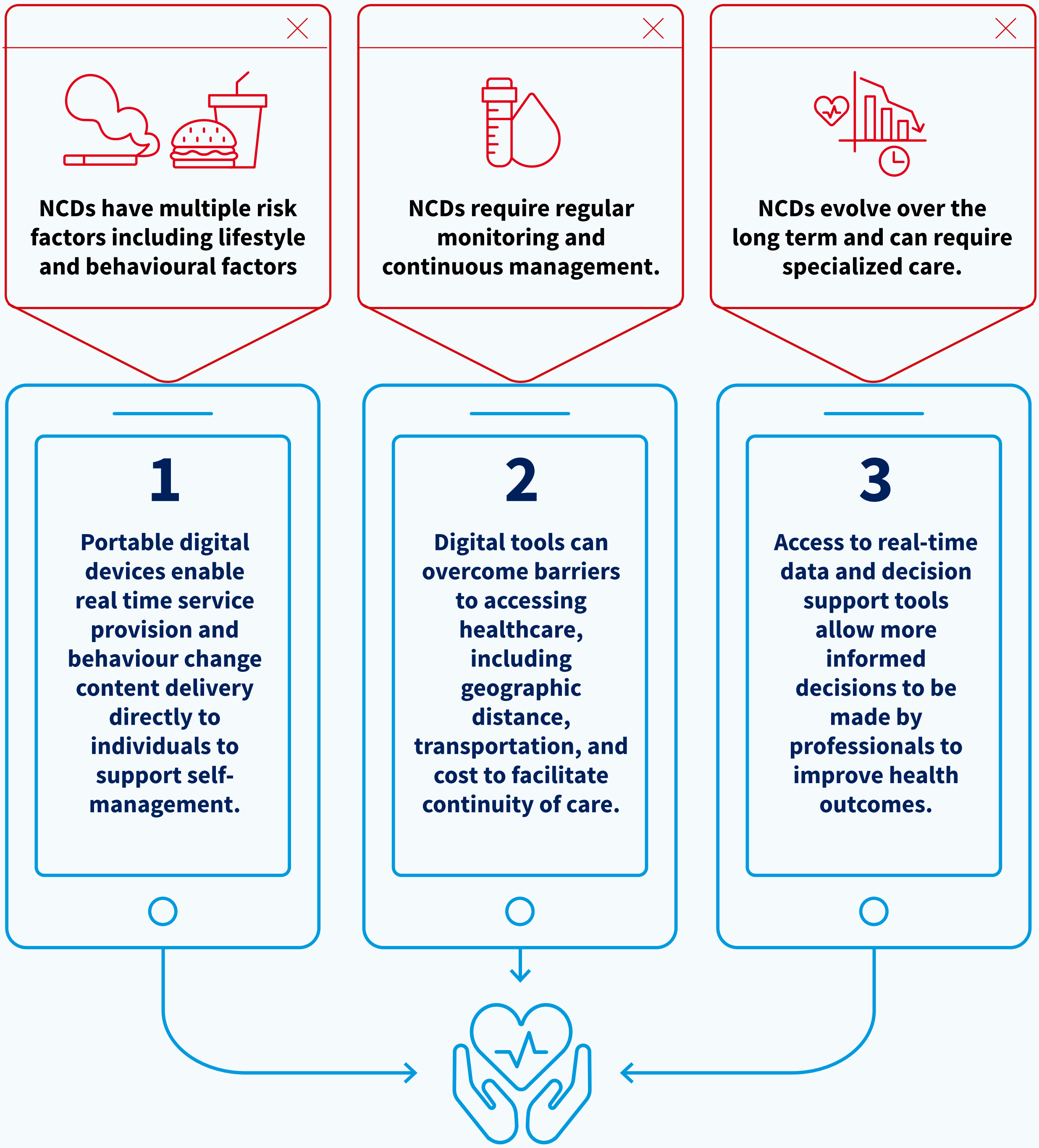
Source: WHO (12)

Since the pandemic, digital solutions have been used to optimize health service delivery and influence health-seeking behaviour. They are valuable for addressing NCDs for several reasons (Fig. 1):

- Long-term management and monitoring of chronic conditions: Digital health solutions, such as mobile health apps, wearable devices and remote monitoring tools, can help patients to track their symptoms, manage their medications and monitor their progress over time.
- Overcoming barriers to accessing health care, including geographical distance, transport and cost: Telemedicine, for example, allows patients to receive medical care remotely, which may be especially important for patients living in rural or otherwise underserved areas.
- Improving the quality of care: Giving health-care professionals access to real-time patient data and decision support tools can help them make more informed decisions about treatment.

Figure 1

Use of digital technology to overcome the challenges of NCD prevention and control



Digital solutions are being adopted increasingly to enhance many population-based, cost-effective measures for NCD and mental health management (Table 1).

Table 1
How digital solutions can support implementation of WHO-recommended policy and clinical measures for NCD and mental health prevention and care

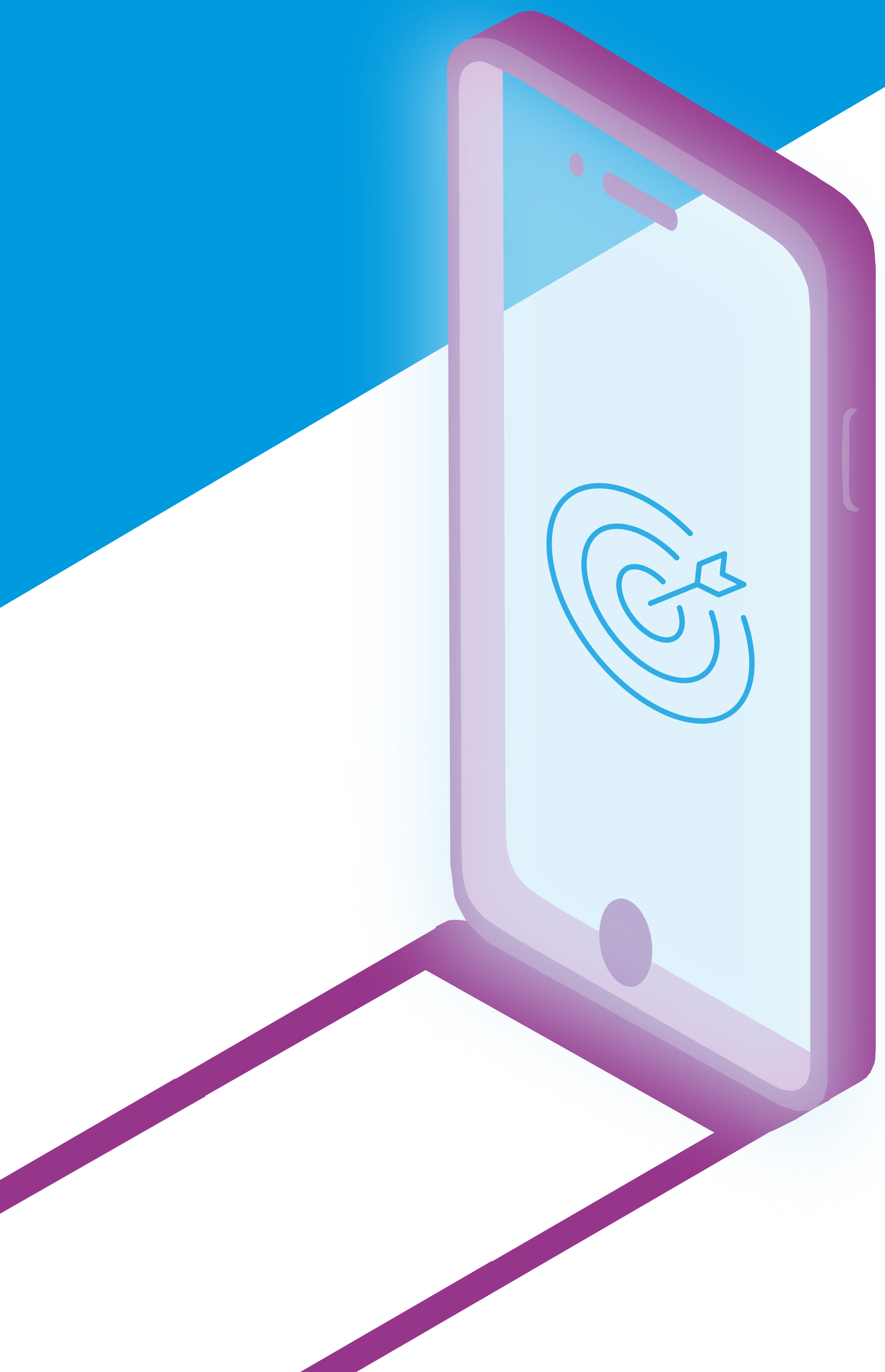
Recommended measure (NCD best buys or Mental Health Action Plan policy options)	Contribution of digital solutions	Example of intervention
Prevention of cervical cancer by screening women aged 30–49	Mass communication campaigns through digital channels (e.g. SMS, messenger apps, social media) to promote healthier lifestyles and choices, encourage timely, regular screening and raise awareness in the population	The Zambian Department of Health, in cooperation with WHO and ITU, implemented a Be Healthy, Be Mobile (BHBM) SMS messaging campaign in 2016 to promote cervical cancer screening. Evaluation of the mCervicalCancer programme in Zambia showed that 5.7% of women screened for cervical cancer at health facilities in the intervention site had been encouraged to do so by the SMS messages *(13)*.
Provide cost-covered, effective, population-wide support (including brief advice, national toll-free quit line services) for tobacco cessation to all those who want to quit. Provide mobile phone-based tobacco cessation services for all those who want to quit.	A chatbot or a mobile application to provide basic cessation guidance and advice to help smokers quit.	WHO, in partnership with Soul Machines, Amazon Web Services and Google Cloud, developed an AI bot in 2021, Florence, to support tobacco cessation during the pandemic. Florence is a 24/7 virtual health worker that can provide digital counselling services, 24 h/day, to people trying to quit tobacco.
Provide brief psychosocial interventions for people with hazardous and harmful alcohol use. Provide prevention, treatment and care for alcohol use disorders and comorbid conditions in health and social services.	A chatbot service to provide basic guidance and assistance for people with alcohol use disorders, helping them to quit.	WHO and the Pan American Health Organization launched an AI bot, Pahola, in Belize. It is designed to provide information and guidance to help people reduce their alcohol consumption and to prevent more than 200 health conditions linked to excessive alcohol intake.
Diabetic retinopathy screening for all diabetes patients and laser photocoagulation for prevention of blindness	Telemedicine to improve the availability of diagnostic services in rural areas, to enable timely screening of patients with diabetes for detection of diabetic retinopathy.	ITU and WHO, in cooperation with the Senegalese Ministry of Health and Social Action, launched a Diabetic Retinopathy Screening project in Senegal in 2020. Its aim is to improve the availability and coverage of diabetic retinopathy screening to ensure timely diagnosis.

Recommended measure (NCD best buys or Mental Health Action Plan policy options)	Contribution of digital solutions	Example of intervention
Provide at-home and other community support services for carers of children and of adults with psychosocial disabilities, including carer skills training and other multidisciplinary services (for example, physical and occupational therapy, nutritional support, housing, education and early childhood development support).	Online platforms and websites train people to promote healthier lifestyles, prevent possible suicide and develop recovery plans.	WHO and ITU, in the context of the BHBM initiative, launched an adaptation package to implement the Doing What Matters in Times of Stress guide through any channel that supports text or voice. The guide begins with information about stress, and the reader is guided through learning and practising skills to manage stress. The guide was used by 21 185 people in a WHO Health Alert chatbot on a popular social media channel. The intervention was very promising: 88% of users reported using the skills they had learnt at least once a week (30% reported using them daily), and 69% recommended the course to others.

The WHO recommendations on digital interventions for health system strengthening *(11)*, published in 2019, provides guidance based on a critical evaluation of the evidence on emerging digital health interventions that contribute to health system improvements. Annex 2 presents selected examples from countries, and Annex 1 presents considerations and principles for successful digital health intervention deployment.

Digital interventions can close gaps in access to and the quality of NCD and mental health services and help raise awareness.

Aim of the report



This report builds on existing WHO guidance and recommendations to assess the potential of digital health interventions to support the global NCD response (Fig. 2).

It includes scientific evidence that has emerged since 2019 and the inputs and perspectives of a wide range of stakeholders, including people with lived experience, public institutions, nongovernmental and civil society organizations and private companies.

While the evidence on the effectiveness of digital health solutions is evolving, the report provides an initial assessment of the projected costs of implementing and/or extending digital interventions for NCDs in countries during the next decade according to the available data and several empirical assumptions. In addition, the expected health impact is assessed on the assumption that that the digital interventions are implemented and scaled up in line with the best public health and clinical practices.

This report addresses three groups of digital health interventions in the categories of targeted client communication and telemedicine in the WHO digital classification framework (Box 4). The interventions were selected according to available evidence from a rapid literature review,[1] their relevance to the NCD best buys and wide-scale proliferation during the COVID-19 pandemic *(14)* and inputs received from the stakeholder community.

[1] Between July 2022 and February 2023, a rapid literature review was carried out to evaluate the scientific evidence on the clinical effectiveness of selected digital health interventions. A literature search, complemented by inputs from the expert community, yielded more than 440 meta-analyses and systematic reviews, 67 of which were included in the analysis after two rounds of screening. For more information on the study method, see Annex 3.

Figure 2

An overview of the process

- Rapid literature review
- Consultations with experts
- Interviews with stakeholders

1. Identify workable digital health interventions
2. Estimate costs required for implementation
3. Quantify health and economic benefits
4. Quantify return on investment

How the findings can be used:

- An advocacy piece aimed at policy makers for evidence-based decision making and promotion.
- An instrument for the Ministry of Health and the Ministry of Telecommunication to engage other stakeholders for resource mobilization and sustained commitment.
- A tool to foster cross-sectoral partnerships and impact-oriented action for digital health solutions and service delivery.

What was assessed?

This report assessed three groups of digital health interventions in the categories of targeted client communication and telemedicine in the WHO digital classification framework (Box 4).

The interventions were selected according to available evidence from a rapid literature review,[2] their relevance to the NCD best buys and wide-scale proliferation during the COVID-19 pandemic *(14)* and inputs received from the stakeholder community.

The health outcomes assessed were aligned with Appendix 3 of the WHO Global NCD Action Plan 2013–2030 *(15)* and the UNIATF guidance note on NCD investment cases (16). For the selected digital health interventions, the following health outcomes were analysed: types 1 and 2 diabetes, chronic obstructive pulmonary disease (COPD), cardiovascular diseases (CVD) and tobacco cessation (Fig. 3). Clinical evidence for digital health is still emerging, while efforts were made to derive robust evidence for health outcomes, effectiveness estimates could be subject to considerable uncertainty (see Annex 3 for methods and limitations).

The results are the numbers of lives saved, disease prevented and life-years gained, which are then translated into the economic benefits that would have been foregone in a business-as-usual scenario with no new or additional action.

[2] Between July 2022 and February 2023, a rapid literature review was carried out to evaluate the scientific evidence on the clinical effectiveness of selected digital health interventions. A literature search, complemented by inputs from the expert community, yielded more than 440 meta-analyses and systematic reviews, 67 of which were included in the analysis after two rounds of screening. For more information on the study method, see Annex 3.

Box 4.
Classification of digital health interventions

WHO has developed a classification system for digital health interventions to help stakeholders define and evaluate the interventions for their intended use, target population and level of evidence. It provides a shared, standardized vocabulary to promote an accessible, bridging language for health programme planners to describe the functionalities of digital health.

For this report, the analyses were based on the following subgroups of the intervention categories for which there was sufficient evidence in the literature in order to optimize the costing analysis.

Targeted client communication

- **Mobile messaging (sometimes referred to as "mHealth")**
  Mobile messaging includes use of text messages delivered over SMS or instant messaging platforms to provide health advice and information. mHealth interventions can improve patient engagement, self-management and adherence to treatment and also facilitate communication between patients and health-care providers.

- **Health chatbots**
  This intervention includes use of computer programs based on AI to simulate conversations with human users. Chatbots can be used to promote healthy lifestyle choices and to provide personalized recommendations based on an individual's health history and risk factors.

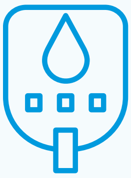
Telemedicine

Client-to-provider telemedicine
These interventions involve use of digital technologies such as video conferencing and remote monitoring to provide health-care services and consultations remotely. Telemedicine and telehealth can improve access to care, particularly in underserved and remote areas, and can help to reduce health-care costs.

Figure 3

Interventions and health outcomes assessed

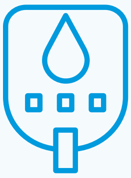
TELEMEDICINE



Improved levels of glycated haemoglobin (HbA1c) in people with Type 1 or Type 2 diabetes

Improved levels of blood pressure (mmHg) for people with hypertension

MOBILE MESSAGING



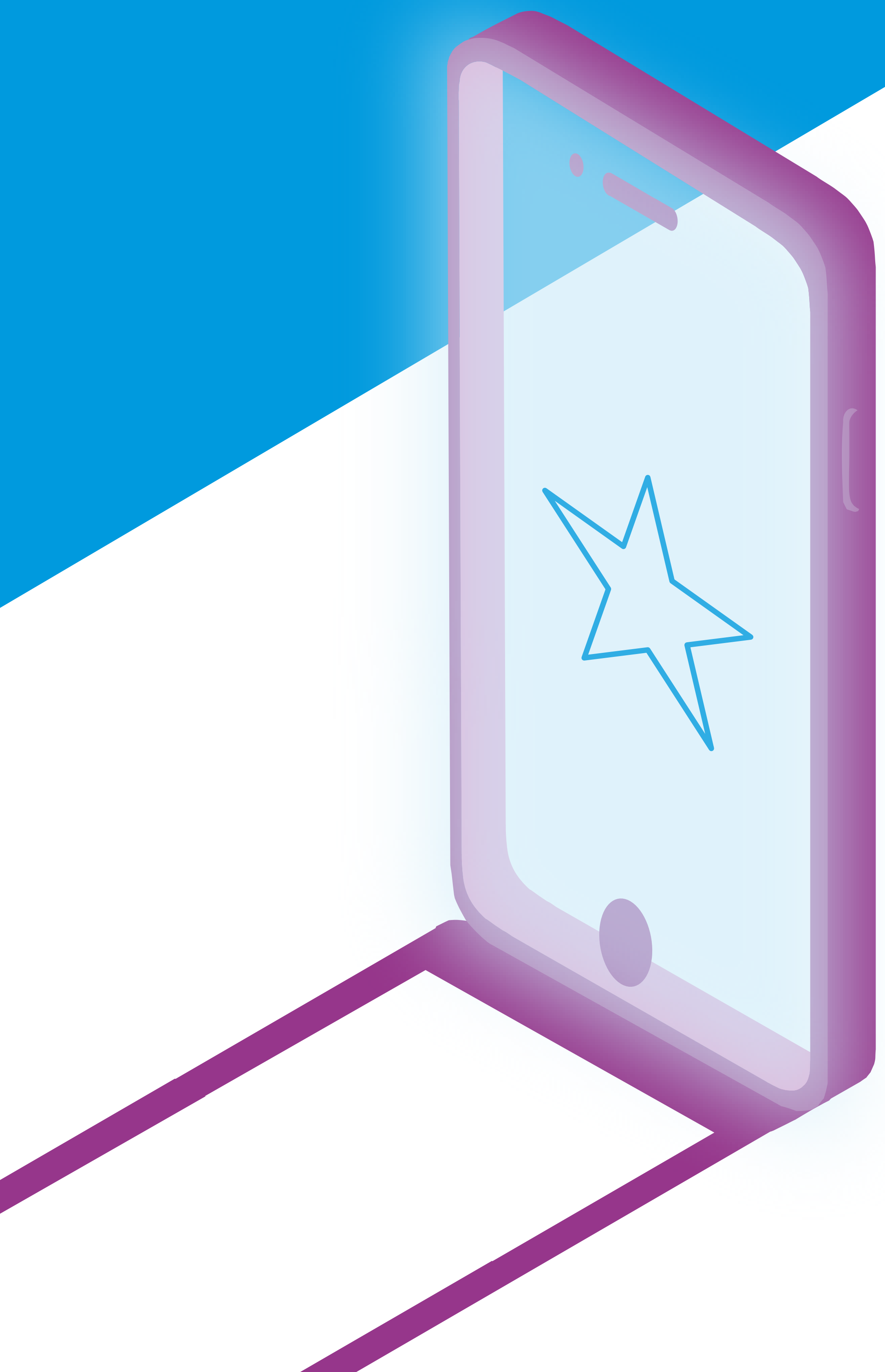
Improved levels of glycated haemoglobin (HbA1c) in people with Type 1 orType 2 diabetes

Increased probability of successful tobacco cessation among active tobacco users

CHATBOTS

Increased probability of successful tobacco cessation among active tobacco users

Benefits of digital health interventions



What could we get by investing in digital?

The results of the economic modelling suggest that, by 2033, the selected set of digital health interventions could save additionally over 2.1 million lives and contribute 4.9 million life years to the global population on a horizon of 10 years (Fig. 4). The interventions would improve access to services, increase public health awareness, improve health monitoring and increase health system efficiency, while empowering both patients and health workers.

In terms of economic benefits, the accrued health gains were conservatively estimated to surpass US$ 199 billion (Fig. 4). This staggering figure comprises the collective economic output of those individuals whose lives were preserved and the productivity gains (greater productivity and labour participation) arising from better disease management and control leading to fewer people experiencing acute events or hospitalization due to complications of NCDs.

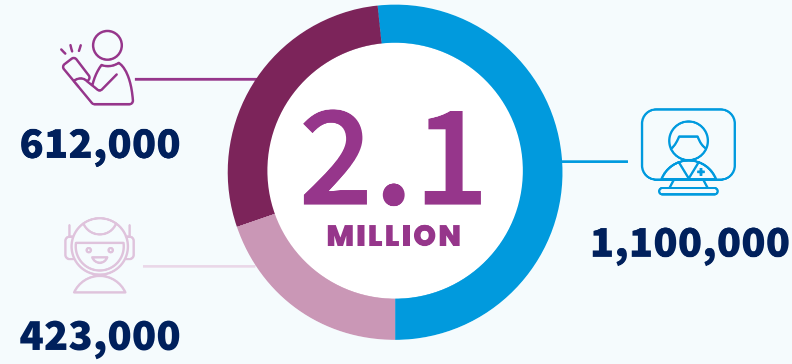
Figure 4

Total health and economic benefits over the next decade

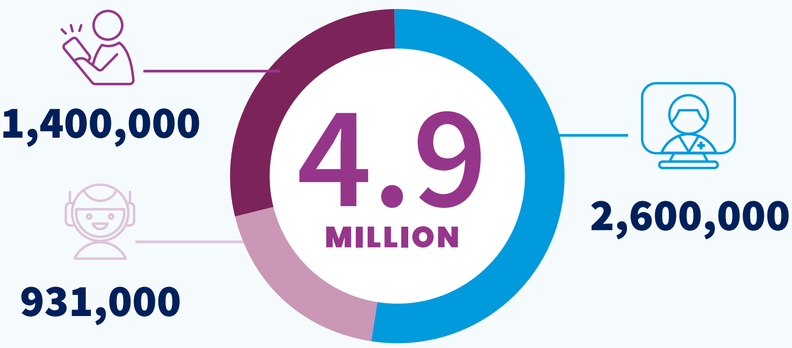
HEALTH BENEFITS

Telemedicine | Mobile messaging | Chatbots

LIVES SAVED



LIFE YEARS GAINED

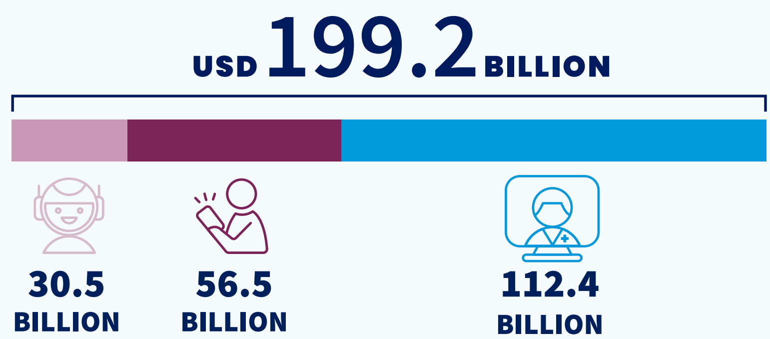


MORE THAN
7.4
MILLION ACUTE EVENTS
and/or hospitalizations avoided for people with CVD or COPD

MORE THAN
5.2
MILLION LIFE YEARS
without secondary complications preserved for people with type 1 and type 2 diabetes

ECONOMIC BENEFITS

TOTAL ECONOMIC BENEFITS IN US $



The projected health and economic benefits are conservative figures, as they take into account the impact on addressing only three groups of diseases (CVDs, COPD and diabetes). It should be noted that the same solutions could be used for other conditions at modestly increased cost per patient. For example, WHO has found that mobile messaging is effective in sexual, reproductive, maternal, newborn and child health *(11)*.

The investment required

To realize the above benefits, governments would have to invest US$ 1.6 per patient over 10 years on average, depending on the country income level (Fig. 5).

This would translate into annual spending of about US$ 0.24 per patient per year,[3] the average spending required being lowest for lower–middle-income countries (US$ 0.10), followed by low-income countries (US$ 0.12), upper–middle-income countries (US$ 0.16) and high-income countries (US$ 0.67) (Fig. 5). Globally, this would represent total spending of US$ 9.8 billion cumulatively for the development, implementation and delivery of the selected set of digital health interventions for NCDs. The cost also includes the human, capital and operational resources necessary for full implementation of the selected interventions in all countries.

Notably, the investment represents less than 0.03% (0.02% and 0.7% in high- and in low-income settings, respectively) of NCD health-care expenditure and 0.012% (0.01% and 0.9% in high- and low-income settings, respectively) of total global health expenditure in 2020 – a relatively small figure in view of the health burden it addresses.

The projected benefits therefore greatly outweigh the costs and yield considerable economic gains, following the first 3 years of investment. Full details of the method are presented in Annex 3.

The global investment of US$ 1.60 over the next decade represents less than 0.03% of NCD health-care expenditure and 0.012% of total global health expenditure – a relatively small figure in view of the health burden it addresses.

[3] As not all patients are included in the model for all 10 years, the estimated total cost for 10 years is less than the average annual amount spent per patient multiplied by 10.

Figure 5

Total investment required for telemedicine, mobile messaging and chatbots

TOTAL ESTIMATED SPENDING REQUIRED

10 YEARS

IS US $ 9.8 BILLION

US $ 1.60

PER PERSON WITH NCD

1 YEAR

THIS IS EQUIVALENT TO ANNUAL INVESTMENTS OF*

US $ 0.12 PER PATIENT IN **LOW-INCOME COUNTRIES**

US $ 0.10 PER PATIENT IN **LOWER MIDDLE-INCOME COUNTRIES**

US $ 0.16 PER PATIENT IN **UPPER MIDDLE-INCOME COUNTRIES**

US $ 0.67 PER PATIENT IN **HIGH-INCOME COUNTRIES**

THIS IS LESS THAN

0.1%

OF THE GLOBAL NCD HEALTH EXPENDITURE PER YEAR

LESS THAN

0.05%

OF THE TOTAL HEALTH EXPENDITURE PER YEAR

* This is the investment per income group averaged over 10 years

Return on investment (ROI)

A comparison of the estimated implementation cost of US$ 9.8 billion with the projected > 20 times economic gain of US$ 199 billion throughout the world over 10 years indicates a highly favourable ROI of US$ 2.02–24.68 for every additional US$ 1 invested between 2023 and 2033 (Fig. 6). This underscores the relevance of the digital health interventions as a means of preventing and controlling NCDs and affirms their economic value.

Worldwide, health-care budgets are under unprecedented constraint while nevertheless requiring substantial increases in spending. This situation is a compelling argument for adopting digital health interventions. With an additional investment of US$ 0.24 per patient per year, governments and donors can swiftly improve health outcomes, with a lasting ROI. This proactive approach will also enhance preparedness and strengthen the resilience of vulnerable populations against future pandemics.

Despite the strong economic rationale for digital health interventions, their use poses several challenges, including infrastructure and connectivity to ensure widespread access, sustaining initiatives beyond pilot phases by securing funding and government support, and maintaining adaptability to the evolving context. Annex 1 provides some considerations and guiding principles to optimize the value of the investments, enable equity in access and inclusiveness.

A highly favourable ROI of up to US$24 for every additional US$ 1 invested underscores the relevance of the digital health interventions as a means of preventing and controlling NCDs and affirms their economic value.

Figure 6

Return on investment by intervention category over 10 years

FOR EVERY US $ 1 INVESTED

RETURN ON INVESTMENT FOR TELEMEDICINE INTERVENTIONS

US $ 15.4

TYPE 1 DIABETES	TYPE 2 DIABETES	CARDIOVASCULAR DISEASES
US $ 7.0	US $ 19.5	US $ 14.0

FOR EVERY US $ INVESTED

RETURN ON INVESTMENT FOR MOBILE MESSAGING INTERVENTIONS

US $ 12

CHRONIC OBSTRUCTIVE PULMONARY DISEASE	TYPE 1 DIABETES	TYPE 2 DIABETES	CARDIOVASCULAR DISEASES
US $ 11.2	US $ 2.4	US $ 16.3	US $ 10.7

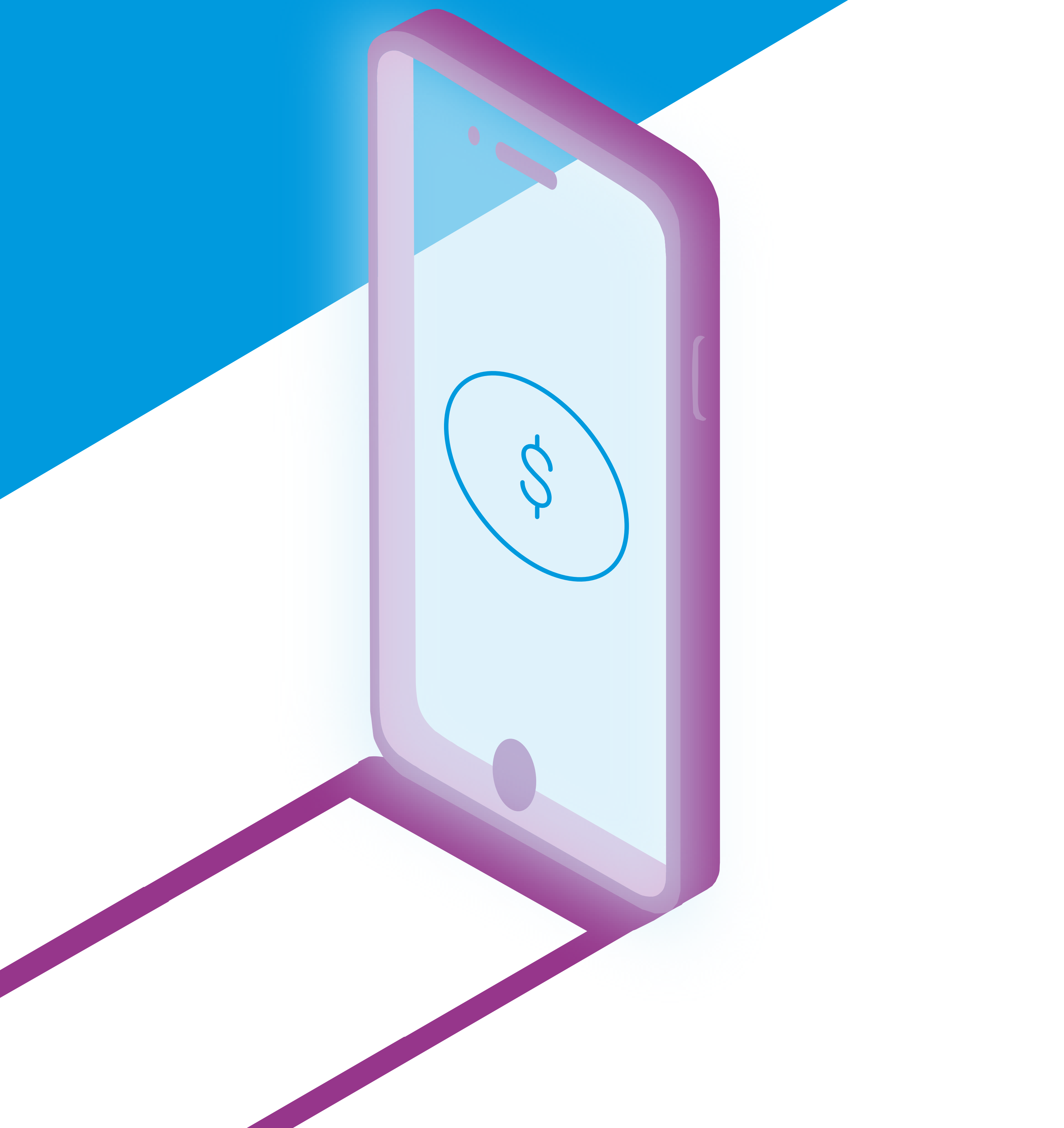
FOR EVERY US $ INVESTED

RETURN ON INVESTMENT FOR CHATBOT INTERVENTIONS

US $ 14.8

CHRONIC OBSTRUCTIVE PULMONARY DISEASE	CARDIOVASCULAR DISEASES
US $ 18.0	US $ 14.3

Impact beyond monetary gains



The economic analysis shows that health systems could make significant savings both monetarily and in productivity through use of mobile messaging services, telemedicine and chatbots.

Nevertheless, the analysis does not capture all the value of digital health to health, society and the economy.

Good health enables people to live well and to engage actively in society. This includes their emotional and physical well-being, which can improve economic and social productivity and reduce the costs of health and social care. When population health is seen as a public value, created collectively by a wide range of actors, stakeholders can support their governments in investing in digital health interventions to address issues related to NCDs. Investment in digital health interventions thus has many indirect benefits that contribute to a positive transformation within and beyond the health system.

The following benefits were identified by the stakeholders who were interviewed.

- **Empowerment of people with lived experience and communities**: With increased access to health information and services, individuals can take greater control of their well-being, thus improving their quality of life and livelihoods (Box 5). By providing accessible, user-friendly information, digital health interventions can promote health literacy in communities and facilitate self-management by patients by encouraging them to take an active role in monitoring and managing their conditions. At the same time, integration of patient data, electronic health records and real-time monitoring will allow health-care providers to offer targeted treatment and interventions, thus improving the efficacy of medical care (Annex 1, Box A1.3).

Box 5.
Maximizing value for people with lived experience

Interviews with people with lived of experience of NCDs and mental health conditions showed general consensus that digital solutions, when used appropriately, are beneficial and empowering and increase people's agency over their health.

All the participants used digital technology to manage their conditions, from search engines for access to health information to telemedicine for interaction with health providers and applications for self-management. They reported, for example, that telemedicine increased access to care, saving time and money. Their health-seeking behaviour also improved; for example, for a person living with dementia, virtual consultations overcame their anxiety in asking for advice from a practitioner, and solutions such as mobile messaging provided discreet access to support. Digital solutions also gave them more support from advocates and carers; for example, for a parent of a child living with type 1 diabetes, remote monitoring of glucose levels averts potential crises.

They also described concerns and challenges, such as limited interaction with health providers and feeling less supported, especially for an initial consultation when a relationship with a health worker had not yet been built. Digital technology was considered a barrier to access to health care in areas with unreliable Internet coverage or with high connection costs.

Other common challenges faced by patients in using the plethora of digital tools and apps for health on the market included: lack of knowledge of tools with clear health benefits; fragmentation of apps and lack of comprehensiveness, resulting in cumbersome navigation among several user interfaces and apps, each of which addressed different aspects of their conditions; and access to software, including lack of material or other support, particularly for elderly people.

The following solutions were proposed to address barriers to uptake and increase the impact of digital technology:

- a centralized catalogue of **evidence-based solutions** with demonstrated health benefits, drawn up by specialists. This would also be helpful for health-care professionals, who could make informed recommendations to patients after consultations;
- enforcement of **standards and regulations** to safeguard patients' data, privacy and well-being;
- **co-development** of solutions and strategic frameworks with patients and their advocates. Technology developers and policy-makers should create an advisory group, including people with lived experience, keep them engaged, give regular feedback and acknowledge their expertise;
- coordination of **culture change** in health care with digital health by sensitization to the value of digital technology to empower patients and digital literacy training to ensure uptake by health workers and appropriate use in daily clinical practice; and
- **partnerships** between Internet and telecom providers and governments or health providers to increase access to technology and ensure equitable coverage with digital health for all communities, regardless of economic status.

To fully realize the benefits of digital technology for patients, there must be meaningful engagement from the outset. People with lived experience should be systematically involved in developing solutions, policies and strategies to ensure that their priorities are addressed. A collective effort is required to accelerate the reach and impact of digital solutions for more patients in a responsible, equitable way, regardless of education, ability, economic level or location.

- **Platform and tools for provision of additional services and solutions:** Technology and platforms that are highly versatile and can be adapted and repurposed for various applications beyond their initial use allow for scaling up. For instance, a mobile messaging service or a chatbot application initially designed to deliver personalized health information and reminders to patients could be repurposed for risk communication during a disease outbreak, pandemic or other emergency (Box 6). Telemedicine platforms established for remote diagnosis and monitoring of NCDs could be used for management of other conditions or for provider-to-provider support. Electronic health records, introduced for more efficient, paperless management of patient profiles, could be integrated with other health information systems to facilitate processing of health insurance claims and planning health budgets.

Box 6.
Repurposing digital solutions for wider benefit

In Tunisia, a mobile messaging solution initially developed for tobacco control and prevention of diabetes in 2017–2019 was repurposed during the COVID-19 pandemic to deliver awareness-raising messages and public health advice and reached nearly 10 million people. The same solution was used to oversee the health of both Tunisian and foreign travellers during a mandatory 14-day medical quarantine upon arrival in Tunisia. This involved daily transmission of SMS with questions in Arabic, English and French) to monitor recipients' health and symptoms.

- **Emergence of local expertise and markets for jobs and innovations:** Implementation of digital health interventions fosters local technical capacity, including through collaboration with technology partners, hands-on experience in design and deployment of locally appropriate solutions, and emergence of networks of experts with relevant knowledge. Furthermore, development and maintenance of solutions such as electronic health records, telemedicine platforms and health chatbots naturally creates a market for local businesses and professionals with relevant health and expertise and skills in information technology, thus contributing to the local economy and the skilled labour force.

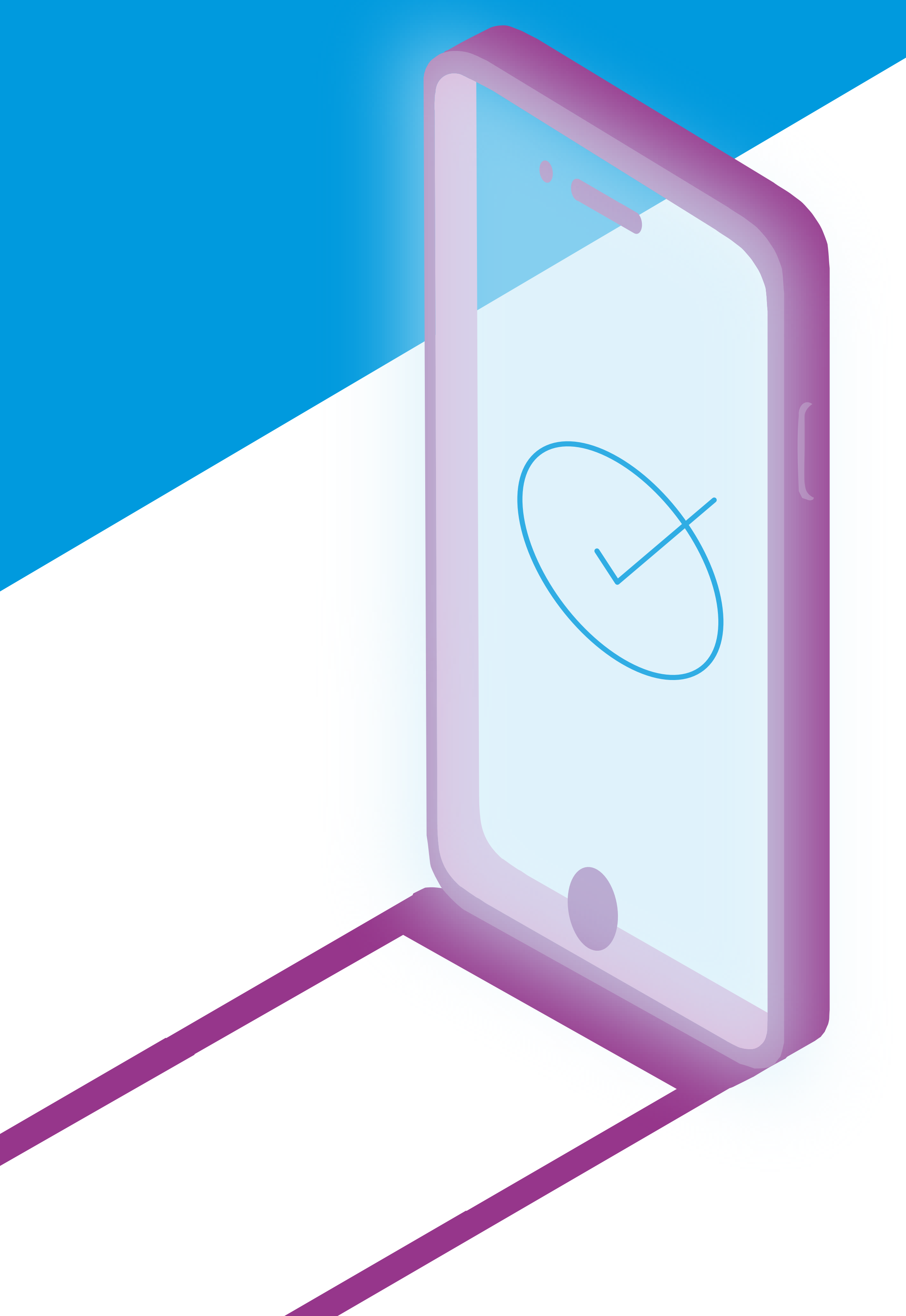
- **Partnerships and greater institutional capacity:** Multi-stakeholder collaborations that bring together government agencies, private sector entities, civil society organizations and other partners establish a solid foundation for advancements in health and development as a result of better coordination, capacity and resources (Annex 1, Box A1.1). For example, establishment of a framework agreement between a ministry of health and local telecommunications operators for introduction of a national health messaging service will facilitate future public–private collaboration in using mobile and broadband channels for disseminating health information to the public (Box 7). Collaboration on data regulation and privacy for the national health information system contributes to better national data governance and legislation. Active involvement of patient and medical associations in the design and adoption of telemedicine services strengthens civil society engagement and provides new mechanisms for testing and scaling up other new services or regulations.

Box 7.
Cross-sectoral partnerships for mHealth in the response to diabetes

The Government of Senegal organized the mRamadan campaign (see Annex 2) in partnership with WHO and ITU to raise awareness and provide practical advice to people with diabetes and their families on avoiding complications during fasting. The service is provided by the three major telecom operators in Senegal on a pro bono basis and is based on the BHBM Handbook on How to Implement mDiabetes. mRamadan promotes healthy lifestyles, including healthy diet and is now serving more than 200 000 users.

When population health is seen as a public value, created collectively by a wide range of actors, stakeholders can support their governments in investing in digital health interventions to address issues related to NCDs.

Conclusion



Digital is a once-in-a-generation opportunity to accelerate our pace towards achievement of the SDGs by 2030.

In an era when health-care systems are often overwhelmed, digital solutions are not only convenient but save lives.

This report shows that digital interventions have immediate, long-term health and economic benefits for populations. They are thus transformative and cost-effective for accelerating and increasing the NCD response. As countries embark on digital transformation, quantitative evidence is essential for decision-making and commitment, especially at the financial level.

Even relatively small investments in a narrow range of digital health interventions can provide substantial benefits that far outweigh the costs (Fig. 7).

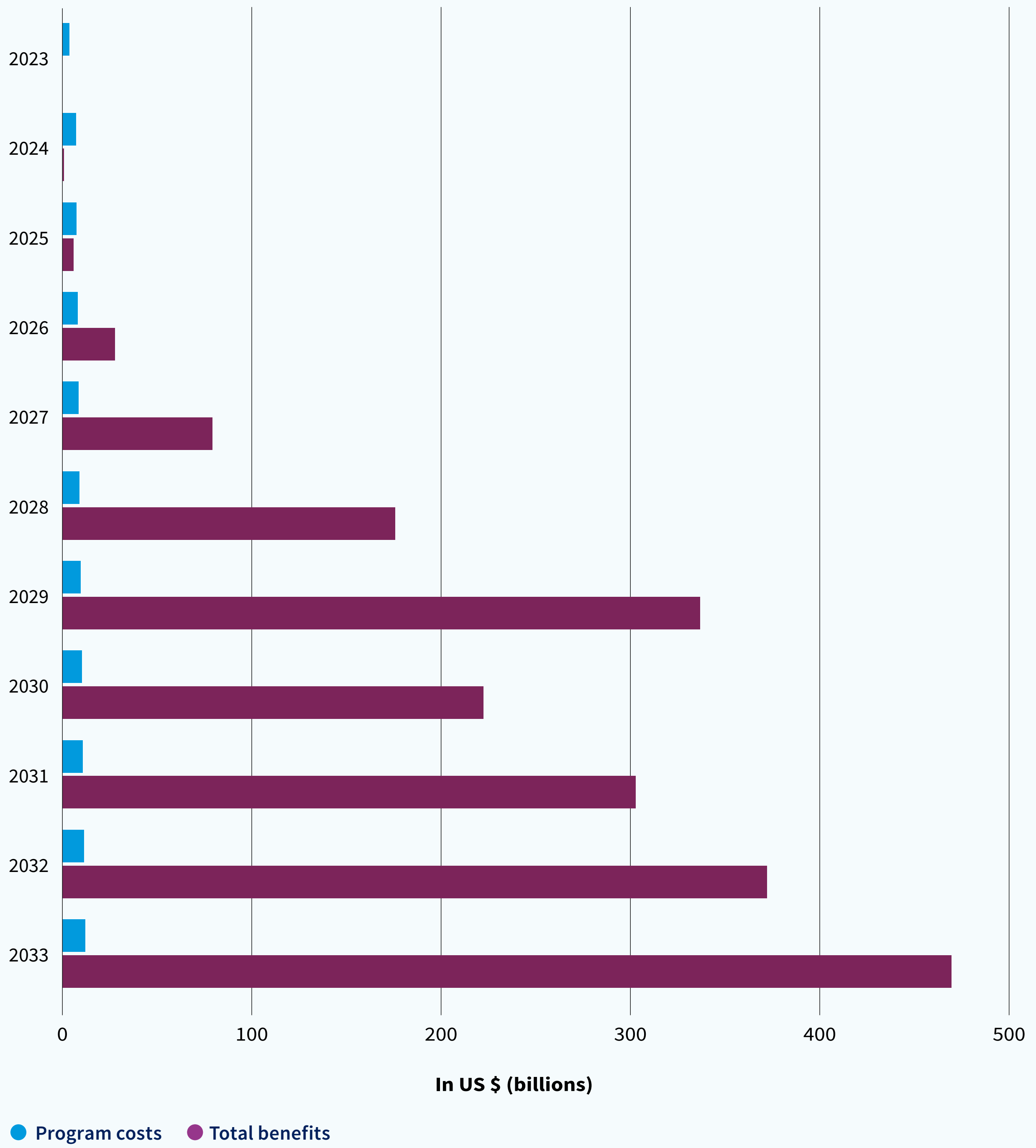
Better NCD outcomes will advance achievement of SDG target 3.4 and will provide major economic gains by preserving their workforce and achieving substantial health system savings. Furthermore, implementation of the selected interventions will lead to the emergence of more advanced digital health infrastructure and provision of new and better services for people.

Use of digital health solutions to complement conventional health-care services can significantly improve the efficacy and quality of and access to health care and give individuals more agency over their health and well-being.

Member States can ensure synergy in building a robust digital ecosystem for health. Governments, donors and other stakeholders can not only address NCDs effectively but also lay the foundation for a resilient health-care system. Using and scaling up digital health interventions can lead to partnerships, greater institutional capacity, provision of additional services, empowerment of vulnerable communities and the emergence of local expertise and markets for jobs and innovations.

Figure 7

Economic benefits vs costs of implementing telemedicine, mobile messaging and chatbots for NCDs, over 10 years



[*] Relative reduction in benefits at year 7 as beneficiaries reach retirement age and therefore leave the workforce.
See Annex 3 for methodological details.

The use of digital technology by Member States should be guided by a costed national plan for government funding allocation (Box 8), coordination and implementation, with the objective of sustained financing and response and clearly anticipated health benefits for all.

Box 8.
Supporting countries with resource mobilization and catalysing action

Since 2016, the UNIATF has been assisting countries in developing national health investment cases to mobilize funds and catalyse implementation of cost-effective, evidence-based measures to address NCDs and their risk factors and to support mental health. National health investment cases are based on local data to provide a tailored assessment of the health and economic burden of disease and the health and economic gains to be realized by implementing appropriate public health interventions. By demonstrating the social and economic value of investment in proven measures for prevention and management, the investment cases provide compelling, evidence-driven arguments for greater financing and help in advocacy for cross-sector cooperation.

Digital technology offers a future in which health care is not just curative but truly preventive. To overcome barriers and inequities in access to digital health, Member States must adopt a collaborative, whole-of-government, whole-of-society approach, taking cultural context into account. We must move away from pilot phases and fragmentation and learn, iterate and prioritize funding and resources to ensure sustainability and scaling up, so that the solutions transcend geographical boundaries and reach those most in need.

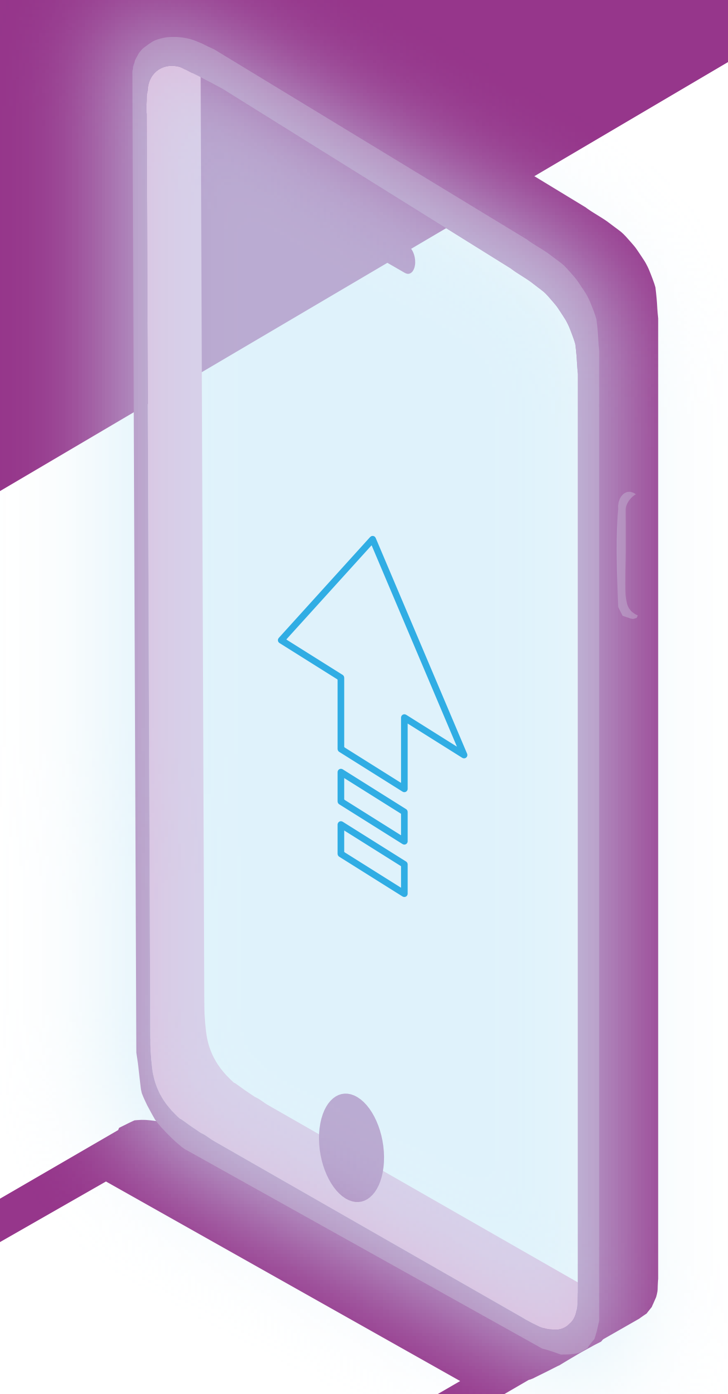
People-centred, collective work is necessary to optimize the value of these interventions for the well-being of communities and effective control of NCDs.

References

1. Global health estimates: leading causes of death. Cause-specific mortality, 2000–2019. Geneva; World Health Organization, Global Health Observatory; 2019 (https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death).
2. World mental health report: transforming mental health for all. Geneva: World Health Organization; 2022 (https://www.who.int/publications/i/item/9789240049338).
3. Saving lives, spending less: the case for investing in noncommunicable diseases. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240041059).
4. More ways, to save more lives, for less money: World Health Assembly adopts more Best Buys to tackle noncommunicable diseases. Geneva: World Health Organization; 2023 (https://www.who.int/news/item/26-05-2023-more-ways--to-save-more-lives--for-less-money----world-health-assembly-adopts-more-best-buys--to-tackle-noncommunicable-diseases).
5. Noncommunicable diseases progress monitor 2022. Geneva: World Health Organization; 2022 (https://www.who.int/publications/i/item/9789240047761).
6. World Social Protection Report 2020–22: Social protection at the crossroads – in pursuit of a better future. Geneva: International Labour Office; 2021 (https://www.ilo.org/global/publications/books/WCMS_817572/lang--en/index.htm).
7. Boniol M, Kunjumen T, Nair TS, Siyam A, Campbell J, Diallo K. The global health workforce stock and distribution in 2020 and 2030: a threat to equity and “universal” health coverage? BMJ Glob Health. 2022;7(6):e009316. doi:10.1136/bmjgh-2022-009316.
8. Invisible numbers: the true extent of noncommunicable diseases and what to do about them. Geneva: World Health Organization; 2022 (https://www.who.int/publications-detail-redirect/9789240057661).
9. Pulse survey on continuity of essential health services during the COVID-19 pandemic: interim report, 27 August 2020. Geneva: World Health Organization; 2020 (https://www.who.int/publications/i/item/WHO-2019-nCoV-EHS_continuity-survey-2020.1).
10. Measuring digital development: Facts and Figures 2023. Geneva: International Telecommunications Union; 2023 (https://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx).
11. Recommendations on digital interventions for health system strengthening. WHO Guideline. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/9789241550505).
12. Global strategy on digital health 2020–2025. Geneva: World Health Organization; 2021 (https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf).
13. Be He@lthy, Be Mobile Annual Report 2018. Geneva: World Health Organization; 2019 (https://www.who.int/publications-detail-redirect/978-92-4-151625-9).
14. Digital tools and strategies in the COVID-19 infodemic response: Case studies and discussion. Geneva: International Telecommunications Union; 2021 (https://www.itu.int/pub/D-STR-ICT_APP-2021-01).
15. Updated Appendix 3 of the WHO Global NCD Action Plan 2013–2030. Geneva: World Health Organization; 2022 (https://cdn.who.int/media/docs/default-source/ncds/mnd/2022-app3-technical-annex-v26jan2023.pdf?sfvrsn=62581aa3_5).
16. Non-communicable disease prevention and control: a guidance note for investment cases. Geneva: United Nations Interagency Task Force on NCDs; 2019 (https://uniatf.who.int/publications/i/item/non-communicable-disease-prevention-and-control-a-guidance-note-for-investment-cases).
17. WHO, ITU. Be hea@lthy Be mobile. A handbook on how to implement mDiabetes. Geneva: World Health Organization, International Telecommunications Union; 2016 (https://www.itu.int/en/ITU-D/ICT-Applications/Documents/Handbooks-BeHealthy-BeMobile/BHBM-mDiabetes.pdf).

Annex 1.

Optimization of digital health interventions



Lessons from WHO and ITU country projects and insights from stakeholder interviews and the literature demonstrate the significance of the following guiding principles for successful digital health interventions. The considerations are vital for national stakeholders embarking on digital health projects in order to optimize investments enabling equity in access and inclusiveness:

Apply digital health solutions to empower individuals and complement conventional health services – not replace them

Digital health solutions should be used strategically to empower individuals and complement traditional health services. By integrating digital solutions into health systems, their potential can be maximized to ensure seamless coordination between digital and traditional services. This approach not only preserves the invaluable role of health-care professionals but also fosters a patient-centred approach, ensuring that they receive the best of both worlds – the human touch of personal care and the convenience and effectiveness of digital health innovations.

Use a collaborative, whole-of-government approach to leveraging partnerships

Successful digital health interventions require collaboration among various stakeholders (Box A1.1), including government agencies, private sector organizations, civil society groups and international partners. A whole-of-government approach ensures that all relevant ministries and departments are engaged in planning, designing and implementation. By leveraging partnerships, resources and expertise from various sectors, digital health initiatives benefit from a wide range of perspectives, knowledge and capability, resulting in more effective, sustainable solutions.

Box A1.1.
The AI-for-health focus group for collaborative innovation in digital health

Multi-stakeholder collaboration ensures effective, safe application of digital technology in health. Collaboration and dialogue are necessary to develop and use transparent standards, promote a coordinated approach and leverage expertise and resources.

In response to the rapid development of AI technology, WHO and ITU in 2018 established the Focus Group AI for Health (FG-AI4H), a collaboration for harnessing the potential of AI to address health care worldwide, while promoting responsible, ethical adoption of AI. The Group is engaged with various partners, including researchers, policy-makers, health-care providers, software developers and patient groups. About 540 experts in 32 countries have worked with the group, 96 of whom are members.

In workshops, conferences and online platforms, FG-AI4H facilitates meaningful dialogue and promotes exchanges of ideas and experience to address common challenges in AI for health. The involvement of diverse stakeholders has resulted in holistic understanding of the challenges and facilitated co-creation of innovative solutions. Knowledge exchange among participants has accelerated progress and ensured replication of successful AI interventions in different contexts.

The FG-AI4H has achieved a number of milestones in advancing AI for health. Its flagship publications, such as guidelines for ethics and governance *(1)*, regulatory concepts *(2)* and clinical evaluation of AI for health *(3)*, have been used by policy-makers, developers and implementers. The group has also assembled open-code resources, including algorithms and datasets, that can be used by developers to design better, safer AI applications for the health sector *(4)*. It has also promoted inclusion of perspectives from the global South and has initiated pilot projects in low-resource settings to show the potential of AI for removing disparity in health care.

Ensure dedicated financing and adequate resource allocation

Dedicated financing reduces reliance on ad-hoc investments and project-focused donor contributions, which often result in fragmented, siloed approaches to digital health initiatives. With a reliable source of sustained funding, countries can better plan and prioritize digital health projects and ensure their continuity and coherence. Dedicated financing also contributes to the financial stability of digital health operations, ensuring the long-term sustainability of initiatives, beyond short-term project cycles. Stability is essential for continuous innovation, scalability and effective service delivery. Dedicated funding also demonstrates stronger commitment from governments and stakeholders, fostering greater engagement and trust among both national and international partners and facilitating collaboration and coordination in the digital health ecosystem.

Co-creation of solutions with users

User-centricity is fundamental to the success of digital health interventions. Involving end-users, such as patients, health-care providers and community members, from the early stages of design ensures inclusion of their needs, preferences and challenges into digital health solutions that are tailored to address real-world problems and are user-friendly, which will increase user acceptance and adoption. User feedback and iterative design are crucial in refining and optimizing interventions throughout their development.

Promote development and use of digital public goods

Digital public goods ensure unlimited access to information and technology and therefore reduce the global digital divide. With open access to information and technology, digital public goods counteract limited access to digital resources and inequality. Digital public goods should be considered and prioritized when implementing digital solutions, as they allow adoptability, scalability, project sustainability and transparency. In international cooperation, digital public goods are an essential factor for social and development change. Box A1.2 provides an example of a digital public good.

Box A1.2.
Increasing the efficiency of health workers through user-centric design

The Simple app, developed by Resolve to Save Lives, is a mobile, point-of-care electronic health record management tool, designed in collaboration with health-care workers from its inception *(5)*. By streamlining data entry and reporting, it reduces the time spent by health workers in non-clinical activities by 2.5 as compared with paper-based systems *(6)*, optimizing allocation of resources and improving the overall effectiveness of NCD services. Furthermore, its offline-first approach *(7)* has opened more opportunities for deployment, particularly where Internet access is inconsistent, ensuring last-mile service delivery for large hypertension and diabetes control initiatives *(8)*.

As a digital public good, the Simple app has been used both locally and internationally, with strong uptake in > 7200 health-care facilities in Bangladesh, Ethiopia and Sri Lanka by health-care workers who manage more than 3 million patients with hypertension and diabetes *(9)*.

Prioritize multi-functional solutions for various services and applications simultaneously

Multi-functional digital health solutions that serve several purposes can improve efficiency and cost-effectiveness by supporting various services, from telemedicine and health information systems to remote patient monitoring and health promotion campaigns. The versatility allows optimization of resources and infrastructure, while providing comprehensive support for various aspects of health-care delivery. Multi-functional solutions can also facilitate scaling up and sustainability by adapting to evolving health-care needs.

Promote adoption through community engagement

Community engagement is essential to gain trust, acceptance and adoption of digital health interventions. Involving local communities in planning and decision-making ensures that interventions are culturally appropriate, aligned with local norms and relevant to community needs. Engaging community leaders, health-care workers and other stakeholders in awareness campaigns and capacity-building can generate buy-in and support for digital health initiatives (Box A1.3).

Box A1.3.
Community-led service delivery

Digital community-led monitoring is a digital intervention for service delivery that can empower communities to hold decision-makers and service providers to account for improving the delivery of health services and addressing the broader social determinants of health. Monitoring by ccommunities can also accelerate, integrate and improve efficiency in the collection, analysis and use of data.

In 2016, the Stop TB Partnership, in collaboration with Dure Technologies, established a digital community monitoring platform, OneImpact *(10)*, which keeps communities at the centre of the tuberculosis (TB) response. Monitoring has increased awareness of TB, dispelled myths, reduced stigmatization and promoted understanding in the community. The data have also led to prompt action by national health programmes. For example, in Mozambique, data from community-led monitoring resulted in diagnosis of > 70 missed TB cases in children, prompting immediate treatment *(11)*.

While most community-led monitoring platforms were established as responses to HIV and TB, extending the approach to delivery of services for NCDs and mental health *(12)* will increase progress in leaving no one behind. After integration into national health programmes, the data will inform policies, programmes and services for an effective, real-time response to communities' needs and realities.

Support introduction and uptake by promoting digital literacy

Promotion of digital literacy facilitates implementation and adoption of interventions. Citizens must have the relevant digital skills to use emerging technologies and to participate actively in the digital economy and society for effective results. Digital proficiency also fosters trust among users, further enhancing their impact. Deployment of digital health solutions must therefore be accompanied by awareness-raising and provision of the necessary information and training, where needed, to facilitate adoption. Such activities can be integrated into community engagement. Digital literacy should be considered from the outset of the solution design stage. A user-centric approach and simplification of digital solution can reduce requirements for digital literacy, resulting in better uptake and engagement by users.

Ensure sustainability by local capacity-building and change management

Capacity-building and effective management of change ensure lasting, more impactful digital health interventions. Involvement of relevant stakeholders, from front-line workers to decision-makers to technical maintenance teams, and providing them with the necessary knowledge and skills ensures efficient use and maintenance of digital solutions and promotes local ownership by fostering commitment and responsibility. Additionally, effective change management strategies support integration of digital health solutions into the health-care system, system cohesion and long-term sustainability.

Support scaling-up and adoption with relevant legislation, regulation and policy

A supportive legal and regulatory framework is crucial for successful introduction of digital health interventions. Clear, appropriate regulations on data privacy, security and interoperability instil confidence among users and health-care providers. Effective legislation can address potential barriers to adoption and provide guidance on standards and best practices. The involvement of policy-makers and legal experts can shape an enabling environment for digital health interventions, promote ethical use of technology and safeguard patient rights.

By adhering to these general principles, stakeholders can enhance the effectiveness, sustainability and impact of digital health interventions for positive transformation of health-care delivery to improve the health of individuals and communities.

Table A1.1 outlines lists resources that provide a comprehensive overview of the recommended strategies and best practices for design, deployment and scaling up of digital health solutions tailored to countries' contexts and needs.

Table A1.1.
WHO and ITU resources for guidance on implementing digital health solutions

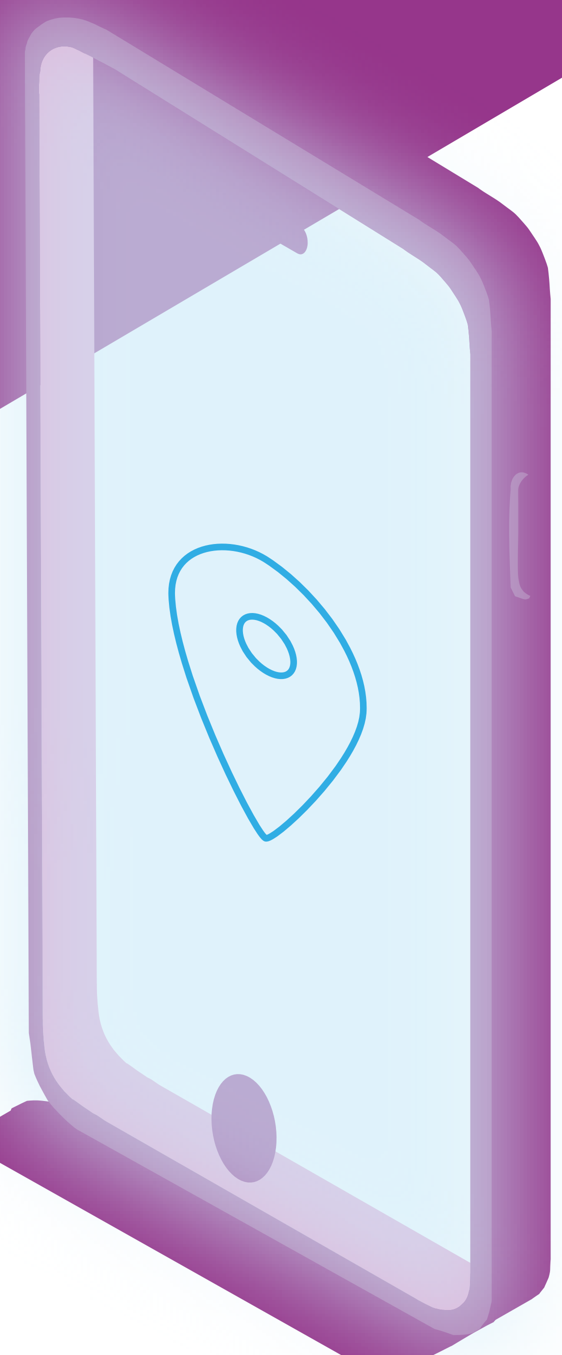
Resource	Utility
Digital health platform handbook: Building a digital information infrastructure (infostructure) for health *(13)*	The handbook outlines implemention of a national digital health infrastructure for rapid, sustainable, cost-effective deployment and scaling up of digital health services. It introduces the concept of a digital health platform and explains how governments can implement and leverage a platform approach to maximize the potential of digital technology for enhancing health service delivery.
Recommendations on digital interventions for health system strengthening *(14)*	The guidelines offer evidence-based recommendations for adoption and expansion of digital health interventions. They provide a practical evaluation of diverse digital health solutions, assess their impact on health systems and consider factors such as benefits, feasibility, acceptability, and equity. The aim is to address common challenges faced by countries and institutions by offering insights into appropriate alignment of health content, use discrete digital functionalities and use digital applications to achieve health objectives.
Digital implementation investment guide (DIIG): integrating digital interventions into health programmes *(15)*	The DIIG is as a companion to the WHO recommendations on digital interventions for health system strengthening. It provides a system for countries to use in developing a costed plan for implementing digital health in one or more health programme areas. The DIIG provides direction to ensure that investments are needs-based and contribute to effective interoperable systems. The DIIG facilitates planning and provides topical information.
WHO–ITU global standard for accessibility of telehealth services *(16)*	This publication introduces the WHO–ITU global standards for access to telehealth services, including technical requirements that telehealth platforms should include to ensure equitable access for individuals with disabilities, including those of vision, hearing, speech, mobility, mental health, development and learning. The standards can guide government regulations, procurement requirements and voluntary standards and policies by telehealth platform manufacturers or health-care professionals to ensure equal access to telehealth services for all.
Consolidated telemedicine implementation guide *(17)*	The guide provides an overview of steps and considerations for implementing telemedicine solutions and optimizing their benefits and impact. It offers practical recommendations for situation assessment, planning, monitoring and evaluation of telemedicine interventions from international best practices and research.
Be He@lthy, Be Mobile Personal toolkit	The toolkit provides guidance on use of "personas" to design content and delivery mechanisms for mHealth programmes for NCD. "Personas" represent the various users who may directly or indirectly benefit from a specific digital health intervention or programme. Understanding personas allow the design of solutions that are user-centred and are aligned with people's context and needs.
Classification of digital health interventions v1.0. A shared language to describe the uses of digital technology for health *(18)*	The document provides a classification of digital health interventions and of the different ways in which digital and mobile technologies are used to support health systems. It can guide decision-making and planning of the required digital services and functionalities according to identified health system challenges and provides a conceptual framework and a common terminology for research, evidence synthesis and landscape analyses.

REFERENCES

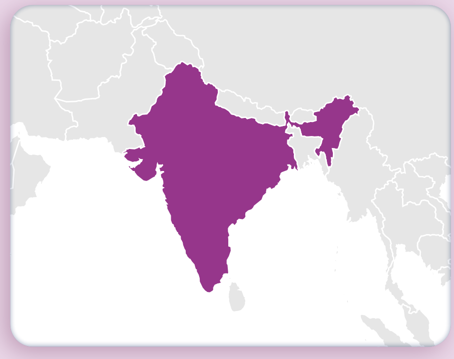
1. Ethics and governance of artificial intelligence for health. FG-AI4H DEL01. Geneva: International Telecommunication Union; 2022 (https://www.itu.int/dms_pub/itu-t/opb/fg/T-FG-AI4H-2022-PDF-E.pdf).
2. Overview of regulatory considerations on artificial intelligence for health (draft 3.3) (FG-AI4H-M-052). Geneva: International Telecommunication Union; 2021 (https://www.itu.int/en/ITU-T/focusgroups/ai4h/Documents/del/DEL02-A20220922-(Prepub).pdf).
3. Clinical evaluation of AI for health. Geneva: International Telecommunication Union; 2024 (https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/Deliverables/DEL07_4.docx).
4. FG-AI4H open code initiative (OCI). Geneva: International Telecommunication Union; 2024 (https://www.itu.int/en/ITU-T/focusgroups/ai4h/Pages/opencode.aspx).
5. Simple. GitHub. https://www.simple.org/about/.
6. Krishna A, Murali S, Moran AE, Saxena A, Gill SS, Hering D et al. Understanding the role of staff nurses in hypertension management in primary care facilities in India: a time–motion study. Prev Chronic Dis. 2023;20:E39. doi:10.5888/pcd20.220232.
7. Joshi G. Offline-first apps are appropriate for many clinical environments. Simple blog2 January 2020 (https://www.simple.org/blog/offline-first-apps/).
8. Operationalizing telemedicine through the Simple app. Last mile service delivery through Health & Wellness centres in India. New Delhi: WHO Regional Office for South-Easr Asia; 2021 (https://www.who.int/india/news/feature-stories/detail/operationalizing-telemedicine-through-the-simple-app).
9. Burka D, Gupta R, Moran AE, Cohn J, Choudhury SR, Cheadle T et al. Keep it simple: designing a user-centred digital information system to support chronic disease management in low/middle-income countries. BMJ Health Care Informatics. 2023;30(1):e100641. doi: 10.1136/bmjhci-2022-100641. doi:10.1136/bmjhci-2022-100641.
10. OneImpact CLM framework. Geneva: StopTB Partnership; 2024 (https://stoptbpartnershiponeimpact.org/).
11. OneImpact. Community-Led Monitoring Framework. Empowering communities to end TB. Geneva: StopTB Partnership; 2024 (https://stoptbpartnershiponeimpact.org/resources/Conceptual%20Framework/OneImpact%20CLM%20Conceptual%20and%20Implementation%20Framework%20FN.pdf).
12. Noncommunicable disease facility-based monitoring guidance: framework, indicators and application. Geneva: World Health Organization; 2022 (https://www.who.int/publications/i/item/9789240057067).
13. Digital health platform handbook: Building a digital information infrastructure (infostructure) for health. Geneva: International Telecommunication Union; 2020 (http://handle.itu.int/11.1002/pub/816d7541-en).
14. Recommendations on digital interventions for health system strengthening. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/9789241550505).
15. Digital Implementation Investment Guide (DIIG): Integrating Digital Interventions into Health Programmes. Geneva: World Health Organization; 2020 (https://www.who.int/publications/i/item/9789240010567).
16. WHO-ITU global standard for accessibility of telehealth services. Geneva: World Health Organization; 2022 (https://www.who.int/publications/i/item/9789240050464).
17. Consolidated telemedicine implementation guide. Geneva: World Health Organization; 2022 (https://www.who.int/publications/i/item/9789240059184)
18. Classification of digital health interventions v1.0. A shared language to describe the uses of digital technology for health. Geneva: World Health Organization; 2018 (https://www.who.int/publications/i/item/WHO-RHR-18.06)

Annex 2.

Country examples



INDIA



Leveraging digital public goods and public–private partnerships to optimize last mile delivery

In India, while more than 65% of the population lives in rural areas *(1)*, > 75% of health workers and > 60% of health facilities are based in urban areas *(2)*, challenging adequate, equitable distribution of health services. In rural areas, as people have to travel hundreds of miles and often spend a month's wages to see a doctor, they often ignore their health. To mitigate this urban–rural health care disparity, in 2019 the Indian Government launched the eSanjeevani telemedicine system *(3)*.

Telemedicine was found to be a safe, effective alternative when in-person care cannot be provided, without compromising acceptable standards of care, particularly for managing high-burden primary health conditions such as hypertension and diabetes, with 74% and 80% diagnostic and treatment concordance, respectively, between face-to-face and telemedicine services *(4)*.

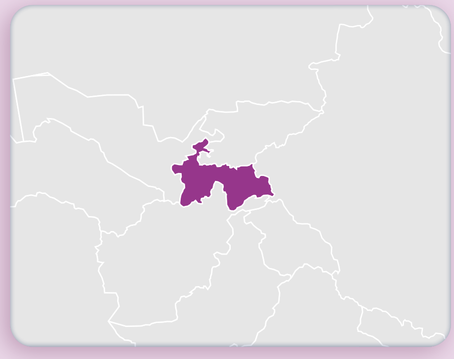
To support and extend telemedicine to underserved communities, local innovations by the private sector, such as Intelehealth *(5)*, are being used. Intelehealth set up a low-bandwidth, open-source provider-to-provider telemedicine platform to connect patients and front-line workers with distant doctors, thereby extending service delivery to people living in hard-to-reach areas with low Internet connectivity. With the platform's digital assistant app, Ayu, a decision-based AI system *(6)*, local health workers collect a comprehensive patient history on adapted questionnaires and conduct basic diagnostic examinations or identify treatments. The app can also connect a health worker or patient with a doctor through the telemedicine platform to provide further diagnosis, e-prescription, advice or referral. The platform has been implemented in over 14 projects across 12 states in India with non-profit and government partners *(5)*. Intelehealth led to the reduction in the distance travelled to access primary care by 70% and the average cost to patients by 60%.[4]

The success of this digital health-care model in rural India demonstrates how partnerships with local governments and private providers can accelerate access to health care by populations with low connectivity who are beyond the reach of traditional services. Partnerships with the private sector and encouragement for private companies to contribute innovative open-source digital solutions as "digital public goods" for a social cause, can accelerate progress towards use and scaling up of effective digital health services for hundreds of thousands of people.

[4] Unpublished data from Intelehealth evaluation report after a stakeholder consultation in October 2022.

KYRGYSTAN

Health Information systems to improve health system efficiency and save costs



Kyrgyzstan accelerated use of digital health infrastructure and health information systems during the COVID-19 pandemic. In line with the national digital transformation concept "Digital Kyrgyzstan 2019–2023", development of e-health was identified as a priority in the 2019–2030 Health Development Programme "Healthy Person – Prosperous Country".

Inefficient collection, processing and exchange of medical data, which constrain health planning and service provision to patients, were prevalent in Kyrgyzstan *(7)*. The Government therefore committed itself to create a unified health information system with seamless, standardized data processing. In 2016, the Government established the national e-Health Centre for digitalization of health information and collection and analysis of health statistics. The Ministry of Health also actively promotes use of solutions based on information and communications technology. Several electronic health record platforms have since been pilot-tested in hospitals and family health centres in collaboration with international partners. Capacity-building was conducted to increase training of medical personnel. E-clinical information forms were introdcued in primary health care to manage patient data.

While these developments did not lead immediately lead to integrated digital health infrastructure, they have set the country on the way to enhancing its digital health capacity. The strategic benefits of this transformation were manifested during the COVID-19 pandemic, when the Ministry of Health rapidly developed and deployed a digital register of people who had been vaccinated against COVID-19, with digital collection, processing and secure storage of data on these individuals. Since its launch, the service has provided more than 1.7 million vaccination certificates and a dataset of more than 3.4 million records. It was estimated that, by eliminating the need for paper forms, the register saved about 850 000 hours of work by health workers and other public employees.[5]

[5] Information provided by the Ministry of Health of Kyrgyzstan in an interview in February 2023.

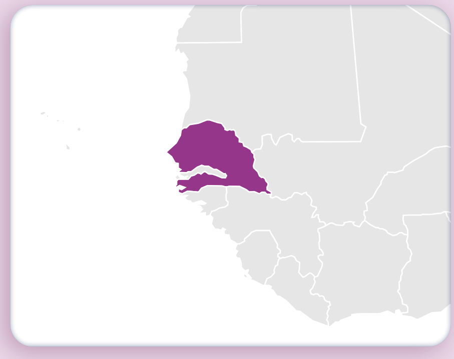
In addition, in late 2021, the Ministry of Health introduced an iLab information system for medical laboratories, which currently connects 36% of all laboratories in the country. iLab enables more efficient storage and processing of data from medical examinations, including the results of COVID-19 tests. More than one million laboratory results have been registered in the system. The Government projects that full-scale adoption of the system will result in savings of more than US$ 1 million annually just due to elimination of the expenses of printing and paper stocks.[5]

These developments have also increased resources, as the benefits of the novel solutions have attracted more resources from both the Government and donors, resulting in a 250% increase in the digital health budget.

The momentum initiated by the Ministry of Health and the Kyrgyz Government and its partners is leading to further progress in a comprehensive digital health infrastructure, including adoption of regulation of telemedicine and use of e-patient cards that will consolidate all health data (primary and secondary care) in a single resource that is accessible to both patients and health workers.

SENEGAL

Cross-sectoral partnerships for scale and sustainability of mHealth in the diabetes response



Senegal is a pioneer in the African Region in integrating mHealth solutions into the NCD response. In 2012, the Ministry of Health and Social Action, with WHO and ITU, designed a mobile messaging campaign for diabetes prevention and control based on the WHO–ITU Be He@lthy Be Mobile mHealth service model *(8)*.

Like many other developing countries, Senegal is experiencing a rise in the prevalence of diabetes. According to the International Diabetes Federation, the number of people aged 20–79 with diabetes in the country is expected to increase from around 150 000 in 2011 to nearly 280 000 in 2030 *(9)*. In response, the Government has conducted the mRamadan campaign, in which mobile technology is used to provide preventive advice and promote a healthy lifestyle, including a healthy diet. The first campaign was conducted in 2014 and has run for 10 years, supported by various national and international stakeholders, including the Senegalese Association for the Support of People with Diabetes. The campaign is delivered during the month of Ramadan to raise awareness and provide practical advice to people with diabetes and their families on avoiding complications during fasting. mRamadan has grown from serving about 1000 users to more than 200 000. The service is provided pro bono by the three major telecom operators in Senegal and is based on the BHBM handbook *(8)*.

The success of the campaign has been due largely to cross-sectoral partnership and alignment from its outset for scalability and sustainability. Collaboration among all the telecom providers in Senegal increased the trust of beneficiaries with lived experience and attracted long-term investment by the private sector. Another facilitating factor is the unifying mission, linked to a cultural tradition that is deeply significant for the country's Muslim population. Thus, by linking the mobile messaging service to Ramadan, the campaign achieved greater popular engagement and stakeholder buy-in.

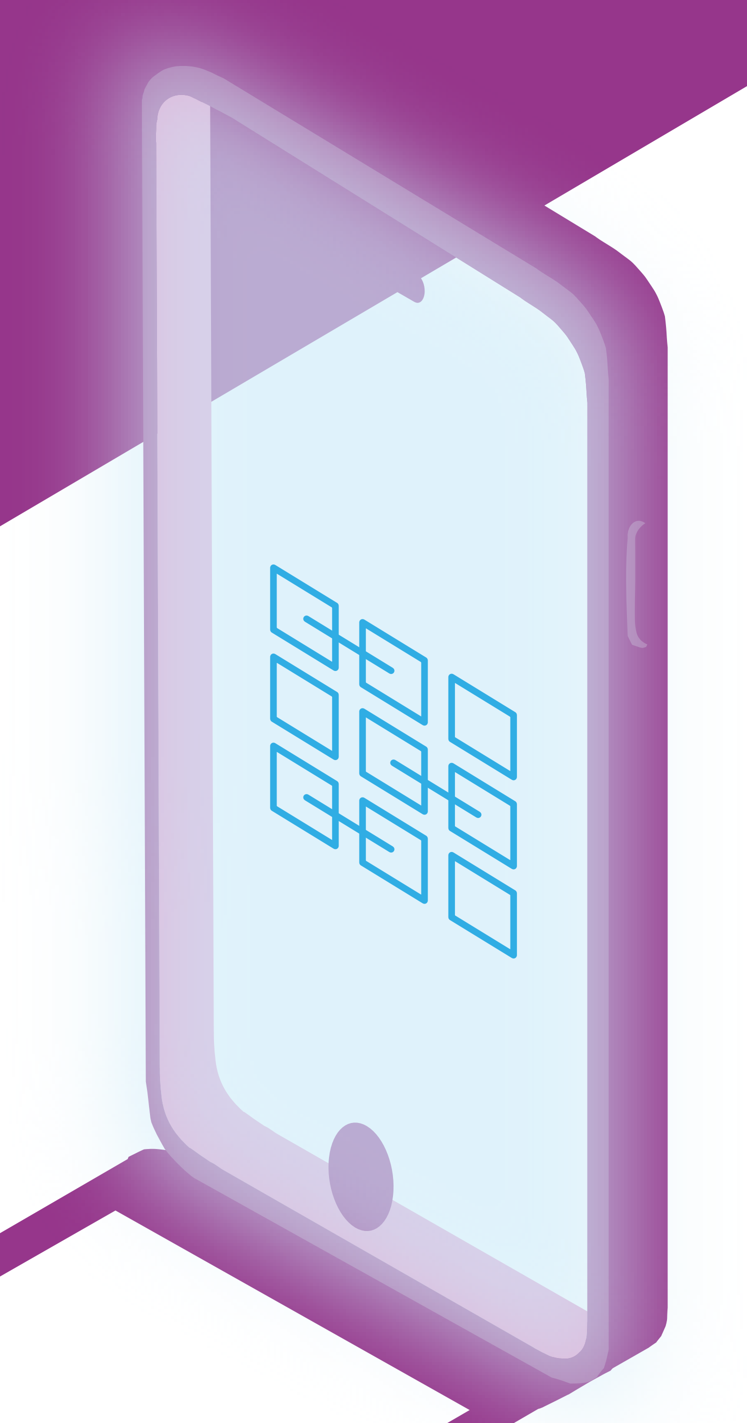
Furthermore, use of the technical platform has also advanced technical capability, improved local infrastructure and opened dialogue between the private–public and third sectors. Patient groups and associations have been empowered by the dialogue.

REFERENCES

1. World urbanization prospects 2018. New York: United Nations, Population Division; 2018 (https://population.un.org/wup/).
2. Health workforce in India: where to invest, how much and why? Geneva: World Health Organization; 2022 (https://cdn.who.int/media/docs/default-source/searo/india/publications/health-workforce-in-india-where-to-invest--how-much-and-why.pdf?sfvrsn=8ae98d85_2).
3. Esanjeevani – National Telemedicine Service. eSanjeevani. New Delhi: Goverbment of India; 2024 (https://esanjeevani.mohfw.gov.in/#/about).
4. Verma N, Buch B, Taralekar R, Acharya S. Diagnostic concordance of telemedicine as compared with face-to-face care in primary health care clinics in rural India: randomized crossover trial. JMIR Form Res. 2023;7:e42775. doi:10.2196/42775.
5. Deliver quality healthcare where there is no doctor via telemedicine. Thane (W) Maharashtra: India (Telehealth Innovations Foundation); 2024 (https://intelehealth.org/).
6. Verma N, Lehmann H, Alam AA, Yazdi Y, Acharya S. Development of a digital assistant to support teleconsultations between remote physicians and frontline health workers in India: user-centered design approach. JMIR Hum Factors. 2023;10:e25361. doi:10.2196/25361.
7. Moldoisaeva S, Kaliev M, Sydykova A, Muratalieva E, Ismailov M, Madureira Lima J et al. Kyrgyzstan: Health system review. Health Syst Transition. 2022;24(3):i–152 (https://www.ecoi.net/en/file/local/2084495/9789289059237-eng.pdf).
8. WHO, ITU. Be hea@lthy, Be mobile. A handbook on how to implement mDiabetes. Geneva: World Health Organization, International Telecommunications Union; 2016 (https://www.itu.int/en/ITU-D/ICT-Applications/Documents/Handbooks-BeHealthy-BeMobile/BHBM-mDiabetes.pdf).
9. IDF Diabetes Atlas, 10th edition. Brussels: International Diabetes Federation; 2021 (https://diabetesatlas.org/atlas/tenth-edition/).

Annex 3.

Methodology



This annex describes the methods used to provide an economic rationale for investing in digital health interventions for managing NCDs. The approach builds on previous methods and tools developed over the past 20 years for implementation of WHO "best buy" interventions for NCDs *(1-4)*. The method is also an extension of WHO–United Nations Development Programme guidance notes for NCDs *(5)* and for mental health investment cases *(6)* and the WHO global tobacco cessation investment case *(7)*. It includes insights from their practical application in various countries.

After preliminary research and consultations with stakeholders,[6] two categories of digital health intervention from the WHO Digital Classification Framework *(8)* were prioritized for this analysis: targeted client communication (mobile messaging and health chatbots) and telemedicine (client-to-provider). The nterventions were selected according to the:

- availability of academic literature on their impact;
- their relevance to the NCD best buys *(9)*;
- their proliferation and use during the COVID-19 pandemic; and
- feedback and suggestions received by the UNIATF secretariat during their work on national NCD investment cases.

A3.1 DERIVATION OF CLINICAL EVIDENCE AND INTERVENTION EFFECT SIZES

To evaluate the clinical evidence and to determine appropriate intervention effect sizes, a rapid review of literature was conducted according to the provisional recommendations of the Cochrane Rapid Reviews Methods Group *(10)*. The rapid review method for evidence synthesis was selected to expedite the analysis and enable review of outcomes across a broader spectrum of NCD and mental health conditions since 2019.

[6] Declarations of interests was collected from all external stakeholders and reviewed to avoid bias and /or conflicts of interest. Individuals (not representing institutions) with a conflict of interest were excluded from consultations. All other stakeholders, unless stated, declared no conflict of interest.

Systematic reviews and meta-analyses retrieved from PubMed were used as the primary source of evidence on the effectiveness of digital health interventions. A search strategy was developed, in which keyword tables were used to define the intervention, the potential effects and the people affected. Only articles published since 2017 and in English were considered. The outcome measures were limited to those that are relevant and have an established, measurable effect on primary outcomes that can be linked to morbidity and mortality from mental health and NCD health conditions and that are eligible for economic modelling *(5,6)*. Comparators were limited to "no care" and "care as usual" or "standard care".

Two rounds of screening were conducted to identify studies eligible for analysis. In the first round, titles and abstracts were reviewed independently by two researchers to exclude studies that did not meet the inclusion criteria. Any disagreements between the two researchers were resolved by a third researcher. In the second round, one researcher screened all the shortlisted full-text articles, and then another researcher screened all the excluded publications. Conflicts were resolved through consensus. The results were complemented by peer-reviewed publications suggested for inclusion by the WHO–ITU expert team or from reference lists of shortlisted articles. Additionally, evidence was selected from WHO's recommendations on digital interventions for health system strengthening (for client-to-provider telemedicine) *(11)* and the WHO global investment case for tobacco cessation (for targeted client communication for tobacco control) *(7)*.

A data extraction form was developed and revised after a pilot exercise. For each full-text article included in the review, data were extracted on the following: primary outcome, secondary outcome(s), comparator, number of studies reviewed, total size of the sample, population group(s) examined, cost components of the intervention, estimated quality of evidence (as reported by the authors), relevant observations and limitations. All extracted data were grouped by health condition. At least two reviewers independently rated the risk of bias in each intervention and for each health condition. The results of the meta-analyses were also systematized and compared to evaluate the state of scientific evidence on clinical effectiveness.

Certainty of evidence was rated independently by at least two reviewers according to: (i) the methods and limitations reported by the study authors (including study heterogeneity, risk of bias and assumptions in the analysis); (ii) consistency of results in different studies of the effects of a given intervention on a given condition or process; (iii) geographical representativeness; and (iv) sample size.

It was concluded that sufficient evidence[7] was available to model the benefits of implementation of digital health interventions listed in Table A3.1.

Table A3.1.
Health conditions selected for economic modelling of interventions

Intervention outcome	Relevant health condition(s)
Client-to-provider telemedicine:	
Improved levels of systolic blood pressure due to telemonitoring and remote consultations with medical personnel	CVD
Improved levels of haemoglobin A1C (HbA1c) due to telemonitoring and remote consultations with medical personnel	Types 1 and 2 diabetes
Mobile messaging:	
Improved levels of systolic blood pressure due to mobile messages (SMS) that provided basic health guidance and advice	CVD
Increased probability of successful tobacco cessation due to SMS or instant messaging platforms on support for quitting	COPD, CVD
Improved levels of HbA1c due to SMS for patient education, self-management support, medication reminders and behaviour change	Types 1 and 2 diabetes
Chatbots:	
Improved systolic blood pressure due to chatbots for blood pressure self-monitoring and automated feedback	CVD
Increased probability of successful tobacco cessation due to chatbots for support in quitting	COPD, CVD

[7] Effect estimates for mobile messaging interventions for diabetes and blood pressure are marginally significant and show considerable uncertainty and therefore might not be considered clinically meaningful.

A3.2 ECONOMIC MODELLING

The objective of economic modelling was to quantify the costs, benefits and ROI of digital health interventions for types 1 and 2 diabetes, CVD and COPD. It should be noted that digital health interventions were regarded as complements to, not substitutes for, in-person care. They are particularly advantageous in delivering care to patients in geographically isolated regions.

Each model was developed to accommodate four country income groups as per the World Bank classification: low, lower–middle, middle–upper and high income. Digital health interventions were cclassified into three groups: mobile messaging, chatbots (i.e. conversational agents) and telemedicine (i.e. remote health monitoring and counselling).

The method used in this analysis does not suggest or assess financing mechanisms or schemes applicable to the digital health interventions addressed within this exercise. Instead, it adopts an exclusively cost-benefit approach to gain insight into funding that would be essential for development and implementation of these interventions, with estimates of health outcomes, their cost and monetary benefits.

As the focus of the study was management of NCDs, the population studied was people with those conditions.

The following sections briefly describe the model structure, the data sources, assumptions and decisions made in estimating investment costs, including those directly related to digital health interventions. The approach taken to estimate the outcomes of the interventions and the main results of the NCD-specific models are also described.

A3.2.1 Model structure

The economic model consists of four disease-specific Markov models. All the models captured functional status, presence of comorbidities and/or acute events, long-term survival, health-care resource use, costs and impacts on productivity and the impact of digital health interventions for each condition. Markov modelling was considered the optimal approach for assessing progression of NCDs, given their long-term nature, and to allow consideration of different levels of intervention penetration. The models were constructed to include the population with current diagnoses (i.e. prevalent) of a given condition and the population with recently diagnoses of NCDs (i.e. incident) in every other modelling year.

While the set of health states and transition probabilities differ by model, all other modelling parameters, such as data sources, costing components and modelling assumptions, were harmonized, when possible.

A modelling cycle of 1 year was considered optimal for NCDs, given their slow progression over time. The time horizon was set to 10 years, 2023 being the preparation year and 2024 the implementation year, with costs and benefits calculated up to 2033. The models start with the initial patient cohort (i.e. the prevalent population) in year 1, each new cycle of patients (i.e. the incident population) being added.

In line with previous cost–benefit models developed for NCD investment cases *(5)*, discount rates for costs and monetary benefits were set to 3% per year; health outcomes were not discounted. For each model, results were presented as a comparison of the costs and benefits of two scenarios: base case (the current situation with digital health intervention coverage and minor growth over 10 years) and modelled scenario (showing faster coverage of digital health interventions implementation as a result of investments). As reliable data on current coverage of digital health interventions were limited, coverage rates (as percentage coverage of the population in need per year) were assumed for each intervention category and country income level.

Each model was used to assessed digital health intervention development, implementation and scale-up costs, direct medical costs associated with NCD management, as well as indirect costs, which are productivity losses by the economically active population (15–64 years) because of their condition and possible premature death.

A3.2.2 Data sources and effect sizes

Intervention effect sizes were derived from publications identified in the literature review and additional hand searches (described above). When data were unavailable from systematic reviews or meta-analysis, effect sizes were derived from randomized controlled trials.

For each NCD, different primary end-points were considered clinically relevant for disease progression. In most instances, outcomes were represented by measurable surrogate end-points, such as HbA1c for diabetes and systolic blood pressure for CVD. For smoking cessation, abstinence from smoking was used, in line with the WHO tobacco cessation investment case *(12)*.

In each NCD model, the primary surrogate outcomes impacted long-term health outcomes, to mimic patients' transition to more severe stages of disease, development of complications and acute events or death from an NCD or its complications. The models also included all-cause mortality and allowed assignment of costs for each health state and event.

The primary modelling end-points and their effect sizes are presented in Table A3.2.

Table A3.2.
Primary outcomes and effect sizes of digital health interventions for NCDs

Intervention	Outcome	Comparative effect size	Reference	Reason for selection
COPD				
Chatbots for smoking cessation	Abstinence from smoking	RR: 1.32; CI: (1.08; 1.63)*	*(12)*	Geographically representative and comparatively large sample
Mobile messaging for smoking cessation	Abstinence from smoking	RR: 1.54; CI: (1.19; 2.00)	*(13)*	Aligned with the WHO method for tobacco cessation *(11)*
Type 1 diabetes				
Telemedicine for HbA1c control	HbA1c level	MD: –0.39; CI: (–0.56; –0.21)	. *(14)*	Aligned with WHO Global NCD Action Plan 2013–2030 Appendix 3 *(15)* and UNIATF NCD investment case guidance note *(5)*.
Mobile messaging for HbA1c control	HbA1c level	MD: -0.19; CI: (-0.37; -0.02)	*(14)*	Aligned with WHO Global NCD Action Plan 2013-2030 Appendix 3 *(15)* and UNIATF NCD investment case guidance note *(5)*.
Type 2 diabetes				
Telemedicine for HbA1c control	HbA1c level	MD: -0.43; CI: (-0.8; -0.06)	*(16)*	Only meta-analysis reporting measurable outcomes
Mobile messaging for HbA1c control	HbA1c level	MD: - 0.38; CI: (-0.53;-0.23)	*(17)*	Aligned with WHO Global NCD Action Plan 2013-2030 Appendix 3 *(15)* and UNIATF NCD investment case guidance note *(5)*.
CVD				
Telemedicine for self-monitoring and telecounselling	Systolic blood pressure	MD: -6.1 mm Hg; CI: (-9.02; -3.18)	*(18)*	Specifically captures people with hypertension; results disaggregated by intervention used
Telemedicine for self-monitoring and automated web feedback and education	Systolic blood pressure	MD: –1.98 mm Hg; CI: (–3.74; –0.21)	*(18)*	Specifically captures people with hypertension; results disaggregated by intervention used
Telemedicine for self-monitoring and automated web feedback and education	Abstinence from smoking	RR: 1.32; CI: (1.08; 1.63)[a]	*(12)*	Geographically representative and comparatively large sample
Mobile messaging for treatment adherence support	Systolic blood pressure	MD: –2.2 mm Hg; CI: (–4.4; –0.04)	*(19)*	Only study suitable for modelling
Mobile messaging for smoking cessation	Abstinence from smoking	RR: 1.54; CI: (1.19; 2.00)	*(13)*	Aligned with the WHO Tobacco Cessation Method *(11)*

RR, risk ratio; IRR, incidence risk ratio; MD, mean difference; CI, confidence interval

[a] Based on random effects meta-analysis performed with source data.

The methods for each diseases-specific model are presented in more detail below.

A3.3.3 Costs and benefits

The cost components comprised the costs of investment in digital health intervention for programme development and implementation, direct medical costs and indirect costs representing the monetary value of productivity losses and potential gains. Costs were assigned in the model to each health state and event. Costs were harmonized among the models whenever possible. Costs for special health services such as dialysis were quantified for each disease area. Costs were adapted to country income level to simulate costs, staff compensation, purchasing power and the GDPs of different countries.

A3.3.4 Programme and implementation costs

To quantify the costs of digital health programme development and implementation, a costing tool was developed to derive the total cost of programme delivery in US$. The costs of programme delivery were calculated per country income level and per intervention. Assumptions were made when reliable cost estimates were not available, in consultation with the WHO–ITU team and based on experience in digital health projects and campaigns in countries (e.g. the Be Healthy, Be Mobile initiative).

Programme costs were categorized as:

- Capital expenses: for hardware and software acquisition at medical care sites and teams for development and delivery of digital health programmes (computers, tablets, smartphones, other mobile devices and Internet connectivity equipment). Depreciation was assumed every 5 years, which implies that capital equipment is to be replaced once every 5 years. Capital costs were sourced from published literature and ITU databases and materials *(20)*.

- Operational expenses: Costs necessary each year for operation of the digital health programme. Operational costs were further divided into fixed costs that did not depend on the number of patients enrolled in the digital health programme (technical services, promotion, administrative management), and variable costs, which depended on the number of patients enrolled in the digital health programme or on the number of medical sites involved in delivering the programme (communication, travel, connection, maintenance). Operational costs were sourced from published literature, the WHO CHOICE database *(21)* and ITU databases and materials *(20)*. Assumptions were made when reliable cost estimates were not available.

- Human resources expenses: Costs associated with the human workforce necessary to develop, deploy and monitor implementation and delivery of the digital health programme included recruitment of additional doctors and nurses to ensure the availability of digital care; administrative and management personnel for programme development and regional, national and facility administration teams; an administrative team including legal officers, technical experts, scientific advisors, independent evaluator, public health specialists and others; specialists in technical maintenance; personnel to manage soft- and hardware acquisition and installation; personnel for marketing and promotion campaign and others. Annual salaries for each specialist according to the four country income levels were derived from ILO statistics *(22)*. Assumptions were made to estimate the necessary number of personnel for each position and the necessary level of qualification for each unit of personnel.

A3.3.5 Direct medical costs

Direct medical costs were calculated from estimates of health-care resource use for each patient and type of care received, multiplied by the frequency of use, length of care (for inpatient care) and unit costs. The costs of special medical services, such as dialysis, were obtained from published literature. The main types of care were inpatient, outpatient, emergency department, rehabilitation for CVD and dialysis services for patients with diabetes and end-stage renal disease. The unit costs for outpatient and inpatient care were obtained from the WHO CHOICE database *(21, Annex 3, Appendix A.3.1 Table A3.1.1)* and were inflated to current prices with a consumer price index (annual, %) from the World Bank databank *(23)*. As WHO CHOICE presents the unit costs of inpatient and outpatient care by facility level, average unit costs for all facility types were used. The costs of emergency department care were obtained directly from the literature or approximated by applying a cost ratio of emergency department care to the unit cost of inpatient or outpatient care. Rehabilitation and dialysis unit costs were obtained from published literature. When costs were unavailable for each income group, the available data were extrapolated according to the relative distribution of unit costs of known cost components for each income level. The costs in all models were quantified in current US dollars.

To calculate the final costs for each medical service modelled, the unit costs of various types of care were multiplied by the percentage of patients requiring specific care, the frequency of care received (e.g. hospitalization rate) and the duration of care received (e.g. length of hospital stay). Most of the sources for the percentage of patients using care or the rate of care used were studies conducted in high- and middle-income countries, in which access to medical care is higher than in low–middle and low-income countries. Use of a high level of access to medical care in lower-income countries would result in an overestimate of costs in the base case and in potentially larger incremental costs than in the scenario of digital health implementation. To correct for lower total medical costs due to lack of access to care in lower-income countries, the costs of care coefficients were calculated with per-capita estimates of inpatient and outpatient care use *(24)*, on the assumption that access to care in high-income countries is 100% (implying that costs in high-income countries are tied to 100% access to care). Coefficients were then multiplied by the unit costs of all types of care.

The disease-specific costs and health-care resource use associated with specific NCDs are presented in detail in Appendix A3.1, Tables A3.1.2 (COPD), A3.1.4 (diabetes) and A3.1.6 (CVD).

A3.3.6 Indirect costs

Indirect costs consist of productivity losses in terms of GDP loss associated with NCDs and their complications in every health state, with account taken of relevant patient characteristics (e.g. smoking status, age), incurred by the active workforce of patients (aged 15–65 years) during the modelling period. Productivity losses were evaluated as absenteeism (absence from work due to disease), presenteeism (reduced productivity at work due to disease) and workforce dropout (early retirement or permanent work disability due to disease) as well as premature mortality. Estimates of GDP per capita, projected GDP growth rate, total labour force, labour force growth rate, labour force participation rate and unemployment were obtained from the World Bank databank *(23)* for each income level. Absenteeism, presenteeism and workforce dropout rates were collected from published literature for each health state and event for each NCD modelled. Usually, because of limited evidence, digital health interventions did not impact productivity directly (i.e. did not reduce absenteeism, for instance) but resulted in fewer patients with more severe disease, which indirectly reduced productivity losses and increased the total GDP produced by a cohort.

Disease-specific estimates for calculating indirect medical costs are presented in detail in Appendix A3.1 Tables A3.1.3 (COPD), A3.1.5 (diabetes) and A3.1.7 (CVD).

A3.4 RESULTS

Table A3.3 summarizes the results of modelling of the three interventions combined and for all NCDs. It shows that digital health could save nearly 2.1 million lives by 2033. The combined investment cost of these interventions would be US$ 1.6 per patient per year, or US$ 9.8 billion over the next 10 years. The model estimated a total economic gain of US$ 199 billion (representing additional GDP produced) and a ROI of US$ 2.02–24.68 in all countries for every US$ 1.0 invested (at the end of 2033).

Table A3.3.
Digital health costs and benefits per cohort of NCD patients (2023–2033)

Country income level	Investment required		Health benefits		Economic benefits	
	Total cost (US$ million)	Total cost per patient per year (US$)	Life years gained	Lives saved	Total monetary benefits gained (US$ million)	ROI
Low	300.7	0.12	306 515	132 695	908	2.02
Lower–middle	1 515.7	0.10	1 451 255	619 031	25 328	15.71
Middle–upper	2 529.8	0.16	1 853 979	807 360	64 970	24.68
High	5 430.1	0.67	1 324 187	582 128	108 012	18.89
Total	**9 776.2**	**0.24**	**4 935 935**	**2 141 214**	**199 219**	**19.38**

ROI considered an additional economic benefit in terms of additional GDP produced relative to total costs of digital health programme implementation

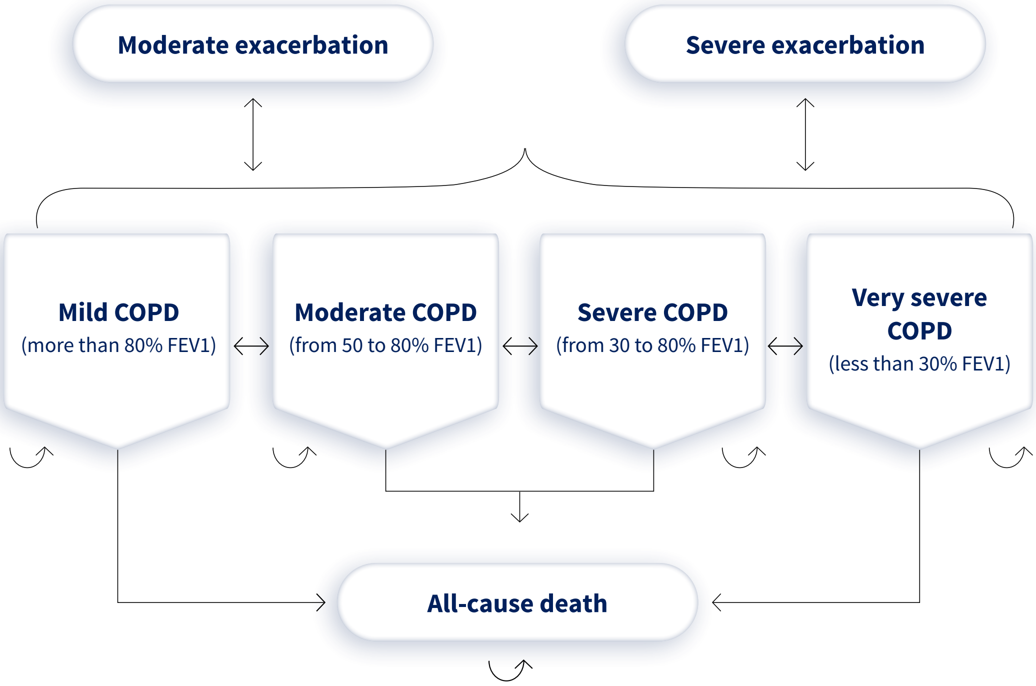
A3.4.1 NCD-specific models

COPD

Model structure

The COPD model structure was based on spirometric classification of lung state (severity of airflow obstruction based on percentage of predicted post-bronchodilator forced expiratory volume per 1 s (FEV1) according to the *NICE* guideline *(26,27)*. The model included four living states (Fig. A3.1): mild COPD (> 80% FEV1), moderate COPD (50–80% FEV1), severe COPD (30–50% FEV1) and very severe COPD (< 30% FEV1). In each health state, a patient could have had moderate (requiring antibiotics and/or corticosteroids but not requiring hospitalization) or severe exacerbations (requiring hospitalization) and could die from each cause, death state being accumulative.

Figure A3.1.
COPD model structure



Rectangular shapes, health states; round shapes, events

Transition probabilities were calculated according to change in FEV1. FEV1 naturally decreases with age but more abruptly in COPD patients, although FEV1 can improve in a patient who stops smoking. The probability of death in every health state was calculated from the results of the Global burden of disease study *(24)*, adjusted for the RR of patients' death in every model relative to the general population and adjusted for smoking status. The initial population is patients with diagnosed COPD and any FEV1. Patients' characteristics were extracted from a clinical trial on COPD *(26)*. Smoking rates were assumed to be the same as those of the general population in each country income group. As smokers with COPD have worse functional status (lower FEV1) and therefore progress more rapidly to more severe COPD, tobacco cessation would have a positive population effect on health and introduce cost savings to the health-care system.

Modelled interventions and coverage rates

Two digital health interventions for tobacco cessation were included: mobile messaging and chatbots. Mobile messaging was found to increase the chances of quitting tobacco by 1.5 times when compared with a cohort of people who were trying to quit without external clinical support *(13)* (Table A3.2). Chatbots were found to increase the chances of quitting by 1.32 times as compared with no clinical support (internal random effects meta-analysis based on source *(12)* data; Table A3.2). Each intervention lasted for 1 year. The coverage rates of the selected interventions are presented in Table A3.4.

Table A3.4.
Coverage rates as percentages of target COPD population receiving digital health interventions per year *(28)*

Country income level	Mobile messaging	Chatbots
Low	Base case: 2023 – 0.25%; 2033 – 0.25%; Modelled scenario: 2023 – 0.25%; 2033 – 7%	Base case: 2023 – 0.25%; 2033 – 0.25%; Modelled scenario: 2023 – 0.25%; 2033 – 10%
Lower-middle	Base case: 2023 – 0.25%; 2033 – 0.25%; Modelled scenario: 2023 – 0.25%; 2033 – 7%	Base case: 2023 – 0.25%; 2033 – 0.25%; Modelled scenario: 2023 – 0.25%; 2033 – 10%
Middle–upper	Base case: 2023 – 0.5%; 2033 – 0.5%; Modelled scenario: 2023 – 0.5%; 2033 – 5%	Base case: 2023 – 0.5%; 2033 – 0.5%; Modelled scenario: 2023 – 0.5%; 2033 – 10%
High	Base case: 2023 – 0.5%; 2033 – 0.5%; Modelled scenario: 2023 – 0.5%; 2033 – 5%	Base case: 2023 – 0.5%; 2033 – 0.5%; Modelled scenario: 2023 – 0.5%; 2033 – 10%

Patients in each health state have different coverage. This table shows coverage rates for very severe COPD. A linear growth pattern was applied.

Costs

The costs in the COPD model were quantified for each health state and acute event. The unit costs of inpatient, outpatient and emergency medical care and rehabilitation are presented in Appendix A3.1, Table A3.1.2.

Indirect productivity losses due to COPD were calculated with the method previously described. Cost calculations were based on estimates of absenteeism, presenteeism and workforce drop-out associated with each health state and event, measured as percentages of working time lost (Appendix A3.1, Table A3.1.3). As digital health interventions slowed the patients' progression to more severe health states, they resulted in a gain in GDP at cohort level when these interventions were compared with the modelled base case.

Results

Table A3.4 summarizes the results of the COPD model. It shows that, over the next 10 years, the digital health programme (two interventions) could save 141 000 lives by 2033. The combined investment cost of these interventions would be US$ 0.56 per COPD patient per year or US$ 559 million over the next 10 years. The estimated total economic gain is US$ 8.5 billion (additional GDP produced), and the returns are US$ 0.5–16.8 for all countries (measured at the end of 2033) for every US$ 1.0 invested.

Table A3.4.
Digital health costs and benefits per cohort of COPD patients (2023–2033)

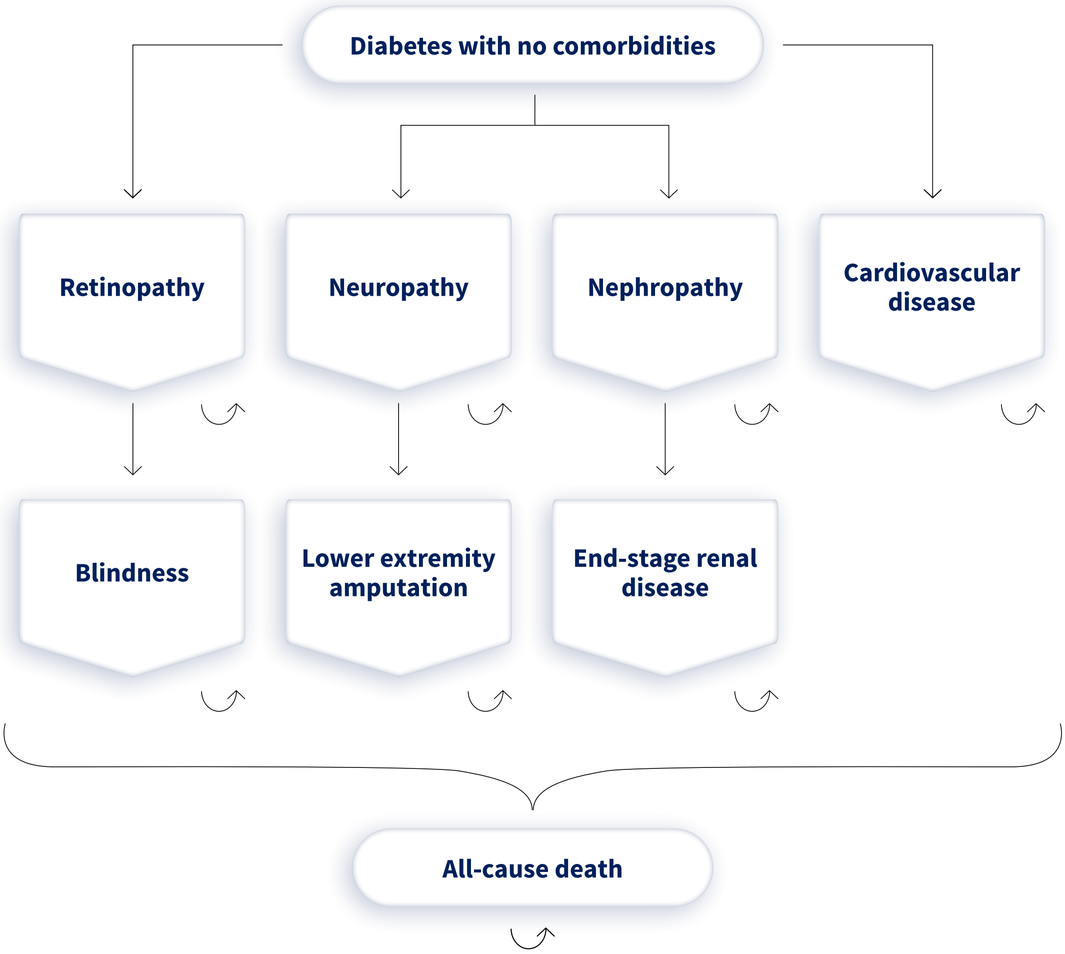
Country income group	Investment required		Health benefits			Economic benefits	
	Total cost (US$ million)	Total costs per patient per year (US$)	Life years gained	Hospitalization due to complications avoided	Lives saved	Total monetary benefits gained (US$ million)	ROI
Low	12.7	0.11	10 136	4 490	4 934	19	0.50
Low–medium	90.0	0.08	127 011	43 493	60 640	1 213	12.48
Medium–upper	137.0	0.10	90 677	57 774	44 835	2 442	16.82
High	318.9	0.27	60 498	59 498	30 506	4 842	14.18
Total	**558.6**	**0.56**	**288 322**	**165 255**	**140 915**	**8 517**	**14.25**

Types 1 and 2 diabetes mellitus

Model structure

The model structure for both type 1 and type 2 diabetes was based on the most frequent diabetes-related secondary comorbidities, with eight health states in the model for the all-cause death state *(28,29)* (Fig. A3.2). Patients without comorbid conditions at the beginning of the model could develop retinopathy, neuropathy, nephropathy or CVD (represented by myocardial infarction and any type of stroke; strokes are not accounted for in the type 1 model). Initial diabetes-related comorbidity could also lead to more severe health states. Patients with retinopathy could develop blindness; patients with neuropathy could require lower extremity amputation as a result of diabetic foot; and patients with nephropathy could develop end-stage renal disease requiring life-long dialysis or a kidney transplant.

Figure A3.2.
Model structure for types 1 and 2 diabetes mellitus



Rectangular shapes, health states

Transition probabilities were calculated according to haemoglobin A1C (HbA1c) level and differed for type 1 and type 2 diabetes. Probabilities of death were calculated from the results of the Global burden of disease study *(24)*. The initial distribution of patients by health state was extracted from the published literature *(30,31)*, while patient characteristics were extracted from large, published trials of diabetes *(32,33)*.

Modelled interventions and coverage rates

Two primary digital health interventions, telemedicine and mobile messaging, from a literature review on the clinical efficacy of various digital health interventions in diabetes were integrated into the model. The interventions were conducted lifelong. The interventions decreased the HbA1c level by –0.38% as compared with standard care *(34)* (Table A3.2). The coverage rates of the interventions for types 1 and 2 diabetes are presented in tables A3.5 and A3.6, respectively.

Table A3.5.
Coverage rates as percentage of type 1 diabetes target population receiving digital health intervention per year

Country income level	Telemedicine	Mobile messaging
Low	Base case: 2023 – 2%; 2033 – 5%; Modelled scenario: 2023 – 2%; 2033 – 25%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 5%
Lower–middle	Base case: 2023 – 3%; 2033 – 7%; Modelled scenario: 2023 – 3%; 2033 – 25%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 5%
Middle–upper	Base case: 2023 – 5%; 2033 – 15%; Modelled scenario: 2023 – 5%; 2033 – 25%	Base case: 2023 – 2%; 2033 – 3%; Modelled scenario: 2023 – 2%; 2033 – 5%
High	Base case: 2023 – 20%; 2033 – 30%; Modelled scenario: 2023 – 20%; 2033 – 40%	Base case: 2023 – 3%; 2033 – 5%; Modelled scenario: 2023 – 3%; 2033 – 7%

Table A3.6.
Coverage rates as percentage of the type-2 diabetes target population receiving digital health intervention per year

Country income level	Telemedicine	Mobile messaging
Low	Base case: 2023 – 2%; 2033 – 5%; Modelled scenario: 2023 – 2%; 2033 – 20%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 5%
Lower–middle	Base case: 2023 – 3%; 2033 – 10%; Modelled scenario: 2023 – 3%; 2033 – 20%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 5%
Middle–upper	Base case: 2023 – 5%; 2033 – 15%; Modelled scenario: 2023 – 5%; 2033 – 25%	Base case: 2023 – 2%; 2033 – 3%; Modelled scenario: 2023 – 2%; 2033 – 5%
High	Base case: 2023 – 20%; 2033 – 30%; Modelled scenario: 2023 – 20%; 2033 – 40%	Base case: 2023 – 3%; 2033 – 5%; Modelled scenario: 2023 – 3%; 2033 – 7%

Costs

Costs were quantified for every health state for both diabetes models. The unit costs of inpatient, outpatient and emergency medical care and rehabilitation are presented in Appendix A3.1, Table A3.1.4. Although it was assumed that the unit costs for types 1 and 2 diabetes would not differ, the total costs differed, as disease progression of type 1 and type 2 diabetes and the intervention effect sizes were not identical.

Indirect productivity losses due to diabetes were calculated with the method previously described, and cost calculations were based on estimates of absenteeism, presenteeism and workforce drop-out associated with each health state and event, measured as a percentage of working time lost (Appendix A3.1, Table A3.1.5). As the digital health interventions slowed patients' progression to more severe health states, comparison of the interventions with the modelled base case resulted in a gain at cohort level. Types 1 and 2 diabetes were assumed not to differ in terms of productivity losses, as similar comorbidity is likely to result in similar work impairment.

Results

Tables A3.7 and A3.8 summarize the results of the modelling exercise for types 1 and 2 diabetes, respectively. For type-1 diabetes, over the next 10 years, the digital health programme (two interventions) could save nearly 10 000 lives by 2033. The combined investment cost of these interventions would be US$ 3.92 per patient per year or US$ 267 million over the next 10 years. The estimated total economic gain would be US$ 2.3 billion (additional GDP produced) and a ROI of US$ 2.52–12.57 for all countries (measured at the end of 2033) for every US$ 1.0 invested.

Table A3.7.
Digital health costs and benefits per cohort of type-1 diabetes patients (2023–2033)

Country income level	Investment required		Health benefits			Economic benefits	
	Total cost per cohort of patients (US$ million)	Total cost per patient-year (US$)	Life years gained	Total life years without secondary complications	No. of lives saved	Total monetary benefits (US$ million)	ROI
Low	4.93	0.58	1 757	15 854	599	17.3	2.52
Lower–middle	34.8	0.45	13 052	118 871	4 373	472.8	12.57
Middle–upper	50.0	0.92	5 068	48 151	1 714	482.9	8.65
High	177.4	1.97	8 154	79 566	2 759	1 274	6.19
Total	**267.2**	**3.92**	**28 031**	**262 442**	**9 445**	**2 247**	**7.41**

For type-2 diabetes, over the next 10 years, the digital health programme (two interventions) could save over 238 000 lives by 2033. The combined investment cost of these interventions would be US$ 3.57 per patient per year, or US$ 2.5 billion over the next 10 years. The estimated total economic gain would be US$ 62 billion (additional GDP produced) and the ROIs US$ 4.18–34.1 for all countries for every US$ 1.0 invested (measured at the end of 2033).

Table A3.8.
Digital health programme costs and benefits per cohort of type-2 diabetes patients (2023–2033)

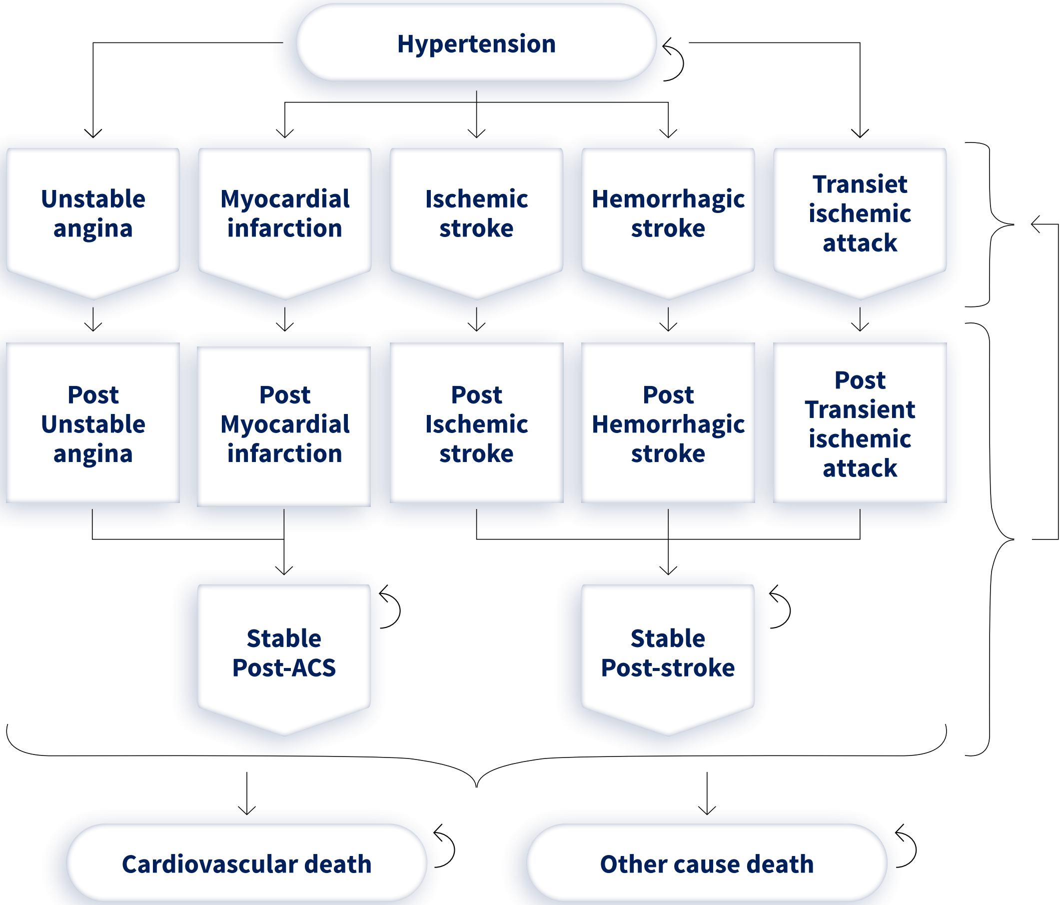
Country income level	Investment required		Health benefits			Economic benefits	
	Total cost per cohort of patients (US$ million)	Total cost per patient-year (US$)	Life years gained	Total life years without secondary complications	No. of lives saved	Total monetary benefits gained (US$ million)	ROI
Low	58.9	0.32	65 468	365 317	21 554	305.2	4.18
L0w–middle	418.6	0.30	336 323	2 114 099	113 390	11 771	27.12
Middle–upper	639.6	0.47	222 262	1 737 422	75 631	22 449	34.10
High	1 337.3	2.48	79 045	682 185	27 107	27 326	19.43
Total	**2 454.4**	**3.57**	**703 098**	**4 899 023**	**237 682**	**61 851**	**24.20**

CVD

Model structure

As CVDs are highly heterogeneous, the present model tracked the acute cardiovascular events that pose the highest health risks and a substantial burden on health-care systems. Patients with underlying hypertension (general cohort, not stratified by CVD risk) could have fatal or non-fatal myocardial infarction, ischaemic stroke, haemorrhagic stroke, transient ischaemic attack or unstable angina (Fig. A3.3). After each non-fatal acute event, patients could remain in the acute phase for 1 year and then change to a stable health state. For example, after myocardial infarction and unstable angina, patients enter a stable post-acute coronary syndrome state; after ischaemic stroke, haemorrhagic stroke or ischaemic attack, patients change to a stable post-stroke state. Patients could experience many acute events during the modelling period and could die from any cause in every disease state. Once a patient was in “death” state, they remained until the modelling time was over.

Figure A3.3.
Cardiovascular diseases model structure



Rectangular shapes, health states; round shapes, events

The probabilities of transition from stable disease states were calculated according to patients' clinical characteristics in published cardiovascular risk equations *(35,36)*. The probabilities of transition from the acute states were extracted from the published literature, and the probability of death due to other causes was calculated from the results of the Global burden of disease study *(24)*. The initial patient population consisted of patients with diagnosed hypertension and no history of acute cardiovascular events with clinical characteristics, from a large cohort study *(37)*.

Modelled interventions and coverage rates

Three digital health interventions were modelled for the CVD population: telemedicine for monitoring blood pressure and remote consultations; chatbots for self-monitoring of blood pressure with automated feedback and support and for tobacco cessation; and mobile messaging for blood pressure control and for tobacco cessation (Table A3.9).

Telemedicine was defined as individual remote monitoring and tailored support from medical personnel, a pharmacist or a clinician throughout the intervention. The support could include checking blood pressure, medication use, education or lifestyle counselling and could be delivered by telephone or electronically. Telemonitoring plus counselling was associated with a reduction in systolic blood pressure of 6.1 mm Hg *(18)* (Table A3.9). The intervention lasted 1 year.

Chatbots were used to support blood pressure measurement for self-monitoring with automated feedback. Chatbots were found to reduce systolic blood pressure by 1.98 mm Hg *(19)*. Chatbots for smoking cessation provided education about risks associated with smoking, encouraged smoking cessation and education about behavioural change strategies and offered psychological support. Chatbots increased the likelihood of tobacco quitting by 1.32 times as compared with no digital intervention (in an internal random effects model meta-analysis from source data *(12)*) (Table A3.9). The intervention lasted 1 year.

Mobile messaging for blood pressure control promoted medication adherence and hypertension education, reduced systolic blood pressure by 2.2 mm Hg *(19)* and increased the likelihood of tobacco quitting by 1.5 times as compared with a cohort that attempted to quit without external clinical support *(13)* (Table A3.9). The intervention lasted 1 year. The coverage rates of both interventions are presented in Table A3.9, with a linear growth pattern applied.

Table A3.9.
Coverage rates as percentage of CVD target population receiving digital health intervention per year

Country income level	Telemedicine	Mobile messaging	Chatbots
Low	Base case: 2023 – 1%; 2033 - 2%; Modelled scenario: 2023 – 1%; 2033 – 7%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 15%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 7%
Lower–middle	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 7%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 7%	Base case: 2023 – 1%; 2033 – 2%; Modelled scenario: 2023 – 1%; 2033 – 7%
Middle–upper	Base case: 2023 – 2%; 2033 – 3%; Modelled scenario: 2023 – 2%; 2033 – 10%	Base case: 2023 – 2%; 2033 – 3%; Modelled scenario: 2023 – 2%; 2033 – 10%	Base case: 2023 – 2%; 2033 – 3%; Modelled scenario: 2023 – 2%; 2033 – 10%
High	Base case: 2023 – 4%; 2033 – 5%; Modelled scenario: 2023 – 4%; 2033 – 15%	Base case: 2023 – 3%; 2033 – 4%; Modelled scenario: 2023 – 3%; 2033 – 15%	Base case: 2023 – 2%; 2033 – 3%; Modelled scenario: 2023 – 2%; 2033 – 15%

Costs

The costs in the CVD model were quantified for each health state and acute event. The unit costs of inpatient, outpatient and emergency medical care and rehabilitation are presented Appendix A3.1, Table A3.1.6.

Indirect costs associated with productivity losses due to CVDs were calculated with the method previously described. Cost calculations were based on estimates of absenteeism, presenteeism and workforce drop-out associated with each health state and event, measured as a percentage of working time lost or number of days of work lost (Appendix A3.1, Table A3.1.7). As digital health interventions slowed patients' progression to more severe health states, they resulted in a gain in GDP at cohort level when interventions were compared with the modelled base case.

Results

Table A3.10 summarizes the results of CVD modelling. It shows that, over the next 10 years, the digital health programme (three interventions) could save 1.8 millioin lives by 2033. The combined investment cost of these interventions would be US$ 0.89 per CVD patient per year, or US$ 6.5 billion over the next 10 years. The model estimated total economic gains of US$ 127 billion (additional GDP produced) and ROIs of US$ 1.5–22.3 for countries at different income levels (measured at the end of 2033) for every US$ 1.0 invested.

Table A3.10.
Digital health programme costs and benefits per cohort of CVD patients (2023–2033)

Country income level	Investment required		Health benefits			Economic benefits	
	Total cost per cohort of patients (US$ million)	Total cost per patient-year (US$)	Life years gained	Acute events avoided	Lives saved	Total monetary benefits gained (US$ million)	ROI
Low	224.2	0.10	229 154	446 371	105 608	567	1.53
Lower–middle	972.2	0.08	978 869	1 834 199	440 628	11 871	11.21
Middle–upper	1 703.1	0.13	1 535 971	2 820 263	685 181	39 596	22.25
High	3 596.5	0.58	1 176 490	2 137 529	521 755	74 569	19.73
Total	**6 496.0**	**0.89**	**3 916 484**	**7 238 352**	**1 753 172**	**126 604**	**18.49**

A3.5 CHALLENGES AND LIMITATIONS

This study has certain limitations. First, use of a rapid literature review rather than a full systematic review may have resulted in some evidence being missed from the analysis. Moreover, a substantial portion of research on the clinical effectiveness of digital health interventions is still nascent. Thus, the findings of the review are conditioned by the literature currently available which could be subject to considerable uncertainty; future research may yield more robust clinical evidence.

Secondly, the modelling exercise is primarily a global overview. To fully understand the costs and health benefits of extending the interventions in individual countries, their specific circumstances would have to be considered, which would involve comparisons of global data sources such the WHO and Global Burden of Disease databases with local data. Consideration should also be given to the actual local costs of different inputs, which may differ from those in global databases. This will improve understanding of how interventions are implemented in each country and whether they match the assumptions in the global model. The practicality of and strategies for implementation in each country should also be taken into account.

Thirdly, the ROI values in this analysis have three main limitations. The analytical framework does not account for the social value of health, including the social, institutional and developmental benefits that populations and communities are likely to experience through better health. For example, by preventing diseases and health complications, poverty could be reduced by the reduction in the risk of catastrophic health expenditure. In turn, greater financial security and higher socioeconomic status are associated with a range of benefits. It is, however, difficult to quantity such benefits because of limited research and the heterogeneity of data. Furthermore, the health impacts of all diseases were not modelled. For instance, we did not model other NCD risk factors or corbomodities, for example, cancers related to tobacco use, although these are unlikely to impact the ROI significantly over the 10-year period because of the time lag between quitting smoking and reduced cancer rates. The third limitation is the timeframe, which extends to 2033, whereas the health benefits of many preventive interventions would not be fully realized by then.

Another limitation of the current analysis is use of country income-specific data rather than country-specific inputs for all the states considered. More precise information on NCD epidemiology, costs and related estimates may be available at country level, which could significantly change the ROI. Additionally, reliance on estimates of GDP per capita and GDP per worker results in lower economic benefits for lower-income countries, creating a link between income level and ROI in this type of analysis. This does not, however, mean that only wealthier countries should invest in NCD control. As countries' GDP increases, even those currently classified as low-income countries will probably have greater productivity.

REFERENCES

1. Johns B, Baltussen R, Hutubessy R. Programme costs in the economic evaluation of health interventions. Cost Eff Resour Alloc. 2003;1(1):1. doi:10.1186/1478-7547-1-1.
2. Scaling up action against non-communicable diseases: How much will it cost? Geneva: World Health Organization; 2011 (https://iris.who.int/handle/10665/44706)
3. Bertram MY, Stenberg K, Brindley C, Li J, Serje J, Watts R et al. Disease control programme support costs: an update of WHO-CHOICE methodology, price databases and quantity assumptions. Cost Eff Resour Alloc. 2017;15:21. doi:10.1186/s12962-017-0083-6.
4. Saving lives, spending less: a strategic response to noncommunicable diseases. Geneva: World Health Organization; 2018 (https://www.who.int/publications/i/item/WHO-NMH-NVI-18.8).
5. Non-communicable disease prevention and control: a guidance note for investment cases. Geneva: World Health Organization, United Nations Development Programme; 2019 (https://www.who.int/publications/i/item/WHO-NMH-NMA-19.95).
6. Mental health investment case: a guidance note. Geneva: World Health Organization, United Nations Development Programme; 2021 (https://www.who.int/publications/i/item/9789240019386).
7. It’s time to invest in cessation: the global investment case for tobacco cessation. Methodology and results summary. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240039308).
8. Classification of digital health interventions v1.0. A shared language to describe the uses of digital technology for health. Geneva: World Health Organization; 2018 (https://www.who.int/publications/i/item/WHO-RHR-18.06).
9. Tackling NCDs: “best buys” and other recommended interventions for the prevention and control of noncommunicable diseases. Geneva: World Health Organization; 2017 (https://www.who.int/publications/i/item/WHO-NMH-NVI-17.9).
10. Garritty C, Gartlehner G, Nussbaumer-Streit B, King VJ, Harnel C, Kamel C et al. Cochrane Rapid Reviews Methods Group offers evidence-informed guidance to conduct rapid reviews. J Clin Epidemiol. 2021;130:13–22. doi:10.1016/j.jclinepi.2020.10.007.
11. Recommendations on digital interventions for health system strengthening. WHO guideline. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/9789241550505).
12. He L, Balaji D, Wiers RW, Antheunis ML, Krahmer E. Effectiveness and acceptability of conversational agents for smoking cessation: systematic review and meta-analysis. Nicotine Tob Res. 2023;25:1241–50. doi:10.1093/ntr/ntac281.
13. Whittaker R, McRobbie H, Bullen C, Rodgers A, Gu Y, Dobson R. Mobile phone text messaging and app-based interventions for smoking cessation. Cochrane Database Syst Rev. 2019 Oct 22;10(10):CD006611. doi: 10.1002/14651858.CD006611.pub5. PMID: 31638271; PMCID: PMC6804292.
14. Udsen FW, Hangaard S, Bender C, Andersen J, Kronborg T, Vestergaard P et al. The effectiveness of telemedicine solutions in type 1 diabetes management: a systematic review and meta-analysis. J Diabetes Sci Technol. 2023;3:782–93. doi:10.1177/19322968221076874.
15. Updated Appendix 3 of the WHO Global NCD Action Plan 2013–2030. Geneva: World Health Organization; 2022 (https://cdn.who.int/media/docs/default-source/ncds/mnd/2022-app3-technical-annex-v26jan2023.pdf?sfvrsn=62581aa3_5).
16. Lee SWH, Chan CKY, Chua SS, Chaiyakunapruk N. Comparative effectiveness of telemedicine strategies on type 2 diabetes management: a systematic review and network meta-analysis. Sci Rep. 2017;7(1):12680. doi:10.1038/s41598-017-12987-z.
17. Haider R, Sudini L, Chow CK, Cheung NW. Mobile phone text messaging in improving glycaemic control for patients with type 2 diabetes mellitus: a systematic review and meta-analysis. Diabetes Res Clin Pract. 2019;150:27–37. doi:10.1016/j.diabres.2019.02.022.
18. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP et al. Self-monitoring of blood pressure in hypertension: a systematic review and individual patient data meta-analysis. PLoS Med. 2017;14:e1002389. doi:10.1371/journal.pmed.1002389.
19. Bobrow K, Farmer AJ, Springer D, Shanyinde M, Yu LM, Brennan T et al. Mobile phone text messages to support treatment adherence in adults with high blood pressure (SMS-Text Adherence Support [StAR]): a single-blind, randomized trial. Circulation. 2016;133{592–600. doi:10.1161/CIRCULATIONAHA.115.017530.

20. Policy brief. The affordability of ICT services 2022. Geneva: International Telecommunications Union; 2023 (https://www.itu.int/en/ITU-D/Statistics/Documents/publications/prices2022/ITU_Price_Brief_2022.pdf).

21. Estimation of unit costs for general health services: Updated WHO-CHOICE estimates. Technical background report. Geneva: World Health Organization; 2011 (https://cdn.who.int/media/docs/default-source/health-economics/choice-estimates-updates2011.pdf?sfvrsn=ff4251be_1&download=true).

22. ILOSTAT database. Wages and working time statistics (COND database). Geneva: International Labour Organization; undated (https://ilostat.ilo.org/resources/concepts-and-definitions/description-wages-and-working-time-statistics).

23. DataBank. Consumer price index (CPI), (annual, %). Washington DC: The World Bank; 2023 (https://databank.worldbank.org/source/population-estimates-and-projections).

24. Burden of Disease Study 2019 (GBD 2019). Results. Seattle (WA): University of Washington; 2023 (https://ghdx.healthdata.org).

25. Agustí A, Celli BR, Criner GJ, Halpin D, Anzueto A, Barnes P et al. Global Initiative for Chronic Obstructive Lung Disease 2023 Report; GOLD Executive Summary. Am J Respir Crit Care Med. 2023;207(7):819–37. doi:10.1164/rccm.202301-0106PP.

26. Jenkins CR, Jones PW, Calverley PMA, Celli B, Anderson JA, Ferguson GT et al. Efficacy of salmeterol/fluticasone propionate by GOLD stage of chronic obstructive pulmonary disease: analysis from the randomised, placebo-controlled TORCH study. Respir Res. 2009;10(1):59. doi:10.1186/1465-9921-10-59.

27. National Institute for Health and Care Excellence. Chronic obstructive disease in over 16s: diagnosis and management. Economic model report. NICE guideline NG115. Evidence review December 2018.

28. Cameron C, Coyle D, Ur E, Klarenbach S. Cost-effectiveness of self-monitoring of blood glucose in patients with type 2 diabetes mellitus managed without insulin. CMAJ. 2010 Jan 12;182(1):28-34. doi: 10.1503/cmaj.090765. Epub 2009 Dec 21.

29. Health Quality Ontario. Continuous Monitoring of Glucose for Type 1 Diabetes: A Health Technology Assessment. Ont Health Technol Assess Ser. 2018 Feb 21;18(2):1-160.

30. Garofolo M, Gualdani E, Giannarelli R, Aragona M, Campi F, Lucchesi D et al. Microvascular complications burden (nephropathy, retinopathy and peripheral polyneuropathy) affects risk of major vascular events and all-cause mortality in type 1 diabetes: a 10-year follow-up study. Cardiovasc Diabetol. 2019;18(1):159. doi:10.1186/s12933-019-0961-7.

31. Kosiborod M, Gomes MB, Nicolucci A, Pocock S, Rathmann W, Shestakova MV et al. Vascular complications in patients with type 2 diabetes: prevalence and associated factors in 38 countries (the DISCOVER study program). Cardiovasc Diabetol. 2018;17(1):150. doi:10.1186/s12933-018-0787-8.

32. UK Prospective Diabetes Study (UKPDS) Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. Lancet. 1998;352(91310:837–53. PMID:9742976.

33. Bebu I, Braffett BH, Schade D, Sivitz W, Malone JI, Pop-Busui R et al. An observational study of the equivalence of age and duration of diabetes to glycemic control relative to the risk of complications in the combined cohorts of the DCCT/EDIC study. Diabetes Care. 2020;43(10):2478–84. doi:10.2337/dc20-0226.

34. Correia JC, Meraj H, Teoh SH, Waqas A, Ahmad M, Lapão LV et al. Telemedicine to deliver diabetes care in low- and middle-income countries: a systematic review and meta-analysis. Bull World Health Organ. 2021;99(3);209-219B. doi:10.2471/BLT.19.250068.

35. D'Agostino RB, Russell MW, Huse DM, Ellison RC, Silbershatz H, Wilson PW et al. Primary and subsequent coronary risk appraisal: new results from the Framingham study. Am Heart J. 2000;139(2_Pt_1):272–81. doi:10.1067/mhj.2000.96469.

36. Dorresteijn JAN, Visseren FLJ, Wassink AMJ, Gondrie MJA, Steyerberrg EW, Ridker PM et al. Development and validation of a prediction rule for recurrent vascular events based on a cohort study of patients with arterial disease: the SMART risk score. Heart. 2013;99(12):866–72. doi:10.1136/heartjnl-2013-303640.

37. Rapsomaniki E, Timmis A, George J, Pujades-Rodriguez M, Shah AD, Denaxas S et al. Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 1·25 million people. Lancet. 2014;383(9932):1899–911. doi:10.1016/S0140-6736(14)60685-1.

APPENDIX 1. COSTS AND USE OF HEALTH-CARE RESOURCES ASSOCIATED WITH THE ECONOMIC METHOD

This appendix presents detailed costs, health-care resource use and labour force participation associated with specific NCDs and used in the economic method presented in Annex 3.

Appendix table A3.1.
Costs of inpatient and outpatient care to health systems by facility level, estimates from WHO-CHOICE database (current US$, inflated to 2023)

Facility level[a]	High income	Upper–middle income	Middle–low income	Low income
Outpatient care (cost per visit)				
1	52.6	26.2	16.3	5.8
2	64.9	32.4	20.1	7.2
3	68.0	33.9	21.1	7.5
4	77.1	38.5	23.9	8.5
5	77.1	38.5	23.9	8.5
Inpatient care (cost per inpatient bed/day)				
3	652.6	212.3	92.6	20.1
4	678.9	220.8	96.3	20.9
5	884.8	287.7	125.5	27.3

[a] 1, health centre with outpatient services only; 2, health centre with a limited number of day beds (mainly maternity); 3, hospital mainly for simple cases (e.g. district hospital); 4, specialist hospital (e.g. referral hospital); 5, teaching hospital (level-4 hospital with teaching component)

Appendix table A3.2.
Costs of medical care for status of chronic obstructuve pulmonary disease (COPD) by country income level, US dollars (current, 2023)

Outpatient care						
Status of COPD	**Frequency of visits per year**	**Reference**	**L**	**LM**	**MU**	**H**
Mild	1.93		8.59	25.52	45.45	131.11
Moderate	2.52	*(1)*	11.21	33.32	59.34	171.18
Severe	3.56		15.84	47.07	83.83	241.83
Very severe	3.95		17.57	52.23	93.01	268.33
Outpatient visits for exacerbation						
Service	**Patients using service (%)**	**Reference**	**L**	**LM**	**MU**	**H**
Visit	100		7.53	21.04	33.91	67.93
Laboratory and diagnostic tests	32.23	*(2)*	1.95	5.45	8.78	17.59
Medication changes	86.06		3.19	8.91	14.35	28.75
Inpatient care for exacerbation						
State	**Length of stay, days**	**Reference**	**L**	**LM**	**MU**	**H**
Mild	5		67.36	344.70	933.60	3693.73
Moderate	5.4	*(3)*	72.74	372.28	1008.29	3989.23
Severe	6.3		84.87	434.32	1176.33	4654.11
Very severe	7.4		99.69	510.15	1381.73	5466.73
Emergency resources for severe exacerbation (hospitalized)						
Services	**Patients using service (%)**	**Reference**	**L**	**LM**	**MU**	**H**
Visit	100		46.56	123.17	177.87	329.55
Ambulance	56	*(2)*	0.00	73.55	106.22	196.80
Medication changes	75		4.57	12.10	17.47	32.37
Emergency resources for moderate exacerbation (outpatient)						
Services	**Patients using service (%)**	**Reference**	**L**	**LM**	**MU**	**H**
Visit	100		46.56	123.17	177.87	329.55
Ambulance	26	*(2)*	0.00	33.52	48.40	89.68
Medication changes	80		3.84	10.17	14.68	27.20

L, low-income; LM, lower–middle income; MU, middle–upper income; H, high income

Appendix table A3.3.
Labour force productivity impairment (percentage of working time lost) by COPD status

Status of COPD	Working time lost (%)	Source
Mild	9.35	*(4)*
Moderate	11.22	
Severe	14.40	
Very severe	14.40	
Mild	0.00	*(5)*
Moderate	15.85	
Severe	15.85	
Very severe	15.85	
Mild	25.16	*(6,7)*
Moderate	25.76	
Severe	36.16	
Very severe	36.16	

Appendix table A3.4.
Annual costs of medical care (inpatient and outpatient visits) by diabetes status and event and by country income level, health state and event, US$ (current, 2023)

Inpatients					
Status	**L**	**LM**	**MU**	**H**	**Reference**
No complications	13.21	67.60	152.62	723.75	*(8)*
Retinopathy, first year	79.26	405.61	869.42	3739.24	*(8)*
Retinopathy, current	26.57	135.98	300.13	1406.57	*(8)*
Blindness, first year	79.26	405.61	869.42	3739.24	*(8)*
Blindness, current	26.57	135.98	300.13	1406.57	*(8)*
Neuropathy, first year	79.26	405.61	869.42	3739.24	*(8)*
Neuropathy, current	26.57	135.98	300.13	1406.57	*(8)*
LEA, amputation	386.62	1978.57	3491.66	10933.45	*(8)*
LEA, current	26.57	135.98	300.13	1406.57	*(8)*
Nephropathy, first year	46.38	237.35	511.24	2301.34	*(8)*
Nephropathy, current	25.48	130.39	287.03	1322.36	*(8)*
ESRD, first year	46.38	237.35	511.24	2301.34	*(8)*
ESRD, current	25.48	130.39	287.03	1322.36	*(8)*
Dialysis, ESRD	8667.83	9990.19	18565.44	41698.01	*(9,10)*
CVD, first year	366.01	1873.10	3375.10	10925.18	*(8)*
CVD, current	23.66	121.09	267.42	1255.31	*(8)*

Annual outpatient care costs					
State	**L**	**LM**	**MU**	**H**	**Reference**
No complications	10.14	30.15	53.69	154.88	*(11)*
Retinopathy, first year	17.26	51.31	91.36	263.57	*(11)*
Retinopathy, current	14.77	43.90	78.18	225.53	*(11)*
Blindness, first year	17.26	51.31	91.36	263.57	*(11)*
Blindness, current	14.77	43.90	78.18	225.53	*(11)*
Neuropathy, first year	17.26	51.31	91.36	263.57	*(11)*
Neuropathy, current	14.77	43.90	78.18	225.53	*(11)*
LEA, amputation	25.89	76.96	137.05	395.36	*(11)*
LEA, current	14.77	43.90	78.18	225.53	*(11)*
Nephropathy, first year	17.26	51.31	91.36	263.57	*(11)*
Nephropathy, current	14.77	43.90	78.18	225.53	*(11)*
ESRD, first year	25.89	76.96	137.05	395.36	*(11)*
ESRD, current	22.16	65.85	117.27	338.29	*(11)*
CVD, first year	20.24	60.17	107.14	309.08	*(11)*
CVD, current	19.13	56.86	101.25	292.10	*(11)*

L, low-income; LM, lower–middle income; MU, middle–upper income; H, high income; LEA, lower extremity amputation; ESRD, end-stage renal disease; CVD, cardiovascular disease

Appendix table A3.5.
Productivity impairment associated with diabetes status and related complications

Status	Working time lost (%)	Reference
Diabetes	11.0	*(12)*
Diabetes and retinopathy	31	*(13)*
Diabetes and blindness	90	Assumption
Diabetes and neuropathy	19.5	*(14)*
Diabetes and LEA	25.0	*(15)*
Diabetes and nephropathy	10	*(16)*
Diabetes and ESRD	38.7	*(17)*
Diabetes and CVD	11.0	*(12)*
Diabetes	1.3	*(18)*
Diabetes and retinopathy	3.2	*(19)*
Diabetes and blindness	24.0	*(20)*
Diabetes and neuropathy	4.3	*(14)*
Diabetes and LEA	32.6	Assumption

Status	Working time lost (%)	Reference
Diabetes and nephropathy	3.4	*(16)*
Diabetes and ESRD	12.2	*(17)*
Diabetes and CVD	2.4	*(21)*
Diabetes	11	*(23)*
Diabetes and retinopathy	10	*(19)*
Diabetes and blindness	10%	*(19)*
Diabetes and neuropathy	19	*(14)*
Diabetes and LEA	23	Assumption
Diabetes and nephropathy	24	*(16)*
Diabetes and ESRD	34.7	*(17)*
Diabetes and CVD	3.7	*(23)*

Appendix table A3.6.
Costs of CVD medical care to the health system perspective by country income, CVD status and event in the CVD model, US$ (current, 2023)

Outpatient care (cost per visit? Per year?)						
Condition	**Annual frequency of visits**	**Reference**	**L**	**LM**	**MU**	**H**
Hypertension	2	*(24)*	8.90	26.45	47.09	135.86
Acute coronary syndrome (first year after acute event)	21	*(25)*	93.43	277.69	494.49	1426.54
Post-stroke (first year after acute event)	6	*(26)*	26.69	79.34	141.28	407.58
Following years after acute events	2.46	*(27)*	10.94	32.53	57.93	167.11
Inpatient care (cost per hospital stay? Per year?)						
Condition	**Length of stay, days**	**Reference**	**L**	**LM**	**MU**	**H**
Myocardial infarction	7.25	*(28)*	91.05	465.95	1262.00	4993.05
Unstable angina	5.30	*(28)*	66.54	340.54	922.32	3649.11
Ischaemic stroke	19.30	*(29)*	174.47	892.87	2418.28	9567.81
Haemorrhagic stroke	37.10	*(29)*	373.11	1909.42	5171.56	20461.00
Transient ischaemic attack	2.70	*(30)*	6.37	32.59	88.28	349.26
Emergency carea						
Condition	**% of patients using care**	**Reference**	**L**	**LM**	**MU**	**H**
Myocardial infarction	0.81	*(24)*	13.11	38.98	69.41	200.24
Unstable angina	0.81	*(24)*	13.11	38.98	69.41	200.24
Ischaemic stroke	0.87	*(31)*	14.19	42.17	75.10	216.66
Haemorrhagic stroke	0.77	*(31)*	12.58	37.39	66.59	192.10
Transient ischaemic attack	0.98	*(31)*	15.91	47.29	84.21	242.92

Rehabilitation						
Condition	**No. of visits**	**Reference**	**L**	**LM**	**MU**	**H**
Myocardial infarction	9	*(32)*	40.04	119.01	211.93	611.37
Proportion of patients who undergo rehabilitation	10%	*(32)*	4.00	11.90	21.19	61.14
Ischaemic or haemorrhagic stroke	12	*(33)*	53.39	158.68	282.57	815.17
Proportion of patients who undergo rehabilitation	10%	Assumption	5.34	15.87	28.26	81.52

L, low-income; LM, lower–middle income; MU, middle–upper income; H, high income
[a] Calculated as ratio of outpatient:emergency care cost (high-income setting).

Appendix table A3.7.
Productivity impairmen tassociated with CVD status and events

Status	Estimate	Working time lost (%)	Reference
Absenteeism			
Hypertension	14.2 days/year	5.6	*(34)*
ACS	36 days/year	14.2	*(35)*
Post-ACS	17 days/year	6.7	*(35)*
IS, HS, TIA	34 days/year	13.4	*(35)*
Post IS, HS, TIA	13 days/year	5.1	*(35)*
Presenteeism			
Hypertension	0 h/day	0	*(36)*
ACS	6 h/day	2	Assumption
Post-ACS	6 days/year	2	*(36)*
IS, HS, TIA	9 days/year	4	Assumption
Post IS, HS, TIA	9 days/year	4	*(36)*
Workforce drop-out (percentage of population)			
Hypertension	5.40%	-	*(34)*
ACS	21.9%	-	*(37)*
Post-ACS	21.9%	-	*(37)*
IS, HS, TIA	24.9%	-	*(38)*
Post-IS, HS, TIA	24.9%	-	*(38)*

ACS, acute coronary syndrome

REFERENCES

1. Wallace AE, Kaila S, Bayer V, Shaikh A, Sinde MU, Willey VJ et al. Health care resource utilization and exacerbation rates in patients with COPD stratified by disease severity in a commercially insured population. J Manag Care Spec Pharm. 2019;25(2):205–17. doi:10.18553/jmcp.2019.25.2.205.
2. Mittmann N, Kuramoto L, Seung SJ, Haddon JM, Bradley-Kennedy C, Ftzgerlad JM. The cost of moderate and severe COPD exacerbations to the Canadian healthcare system. Respir Med. 2008;102(3):413–21. doi:10.1016/j.rmed.2007.10.010.
3. COPD: Who cares when it matters most? National Chronic Obstructive Pulmonary Disease (COPD) Audit Programme: Outcomes from the clinical audit of COPD exacerbations admitted to acute units in England 2014. Mational supplementary report. London: National Chronic Obstructive; 2017 (file:///Users/elisabethheseltine/Downloads/COPD%20-%20Who%20cares%20when%20it%20matters%20most.%20National%20supplementary%20report.pdf).
4. Rai KK, Adab P, Ayres JG, Siebert WS, Sadhra SS, Sitch AJ et al. Factors associated with work productivity among people with COPD: Birmingham COPD Cohort. Occup Environ Med. 2017;74(12):859–67. doi:10.1136/oemed-2016-104014.
5. daCosta DiBonaventura M, Paulose-Ram R, Su J, McDonald M, Zou KH, Wagner JS et al. The burden of chronic obstructive pulmonary disease among employed adults. Int J Chronic Obstruct Pulmon Dis. 2012;7::211–9. doi:10.2147/COPD.S29280.
6. Rai KK, Jordan RE, Siebert WS, Sadhra SS, Fitzmaurice DA, Sitch AJ et al. Birmingham COPD Cohort: a cross-sectional analysis of the factors associated with the likelihood of being in paid employment among people with COPD. Int J Chron Obstruct Pulmon Dis. 2017;12:233–42. doi:10.2147/COPD.S119467.
7. Sin DD, Stafinski T, Ng YC, Bell NR, Jacobs P. The impact of chronic obstructive pulmonary disease on work loss in the United States. Am J Respir Crit Care Med. 2002;165(5):704–7. doi:10.1164/ajrccm.165.5.2104055.
8. Clarke PM, Glasziou P, Patel A, Chalmers J, Woodward M, Harrap SB et al. Event rates, hospital utilization, and costs associated with major complications of diabetes: a multicountry comparative analysis. PLoS Med. 2010;7(2):e1000236. doi:10.1371/journal.pmed.1000236
9. Kerr M, Bray B, Medcalf J, O'Donoghue DJ, Matthews B. Estimating the financial cost of chronic kidney disease to the NHS in England. Nephrol Dialysis Transplantat. 2012;27(Suppl_3):iii73–80. doi:10.1093/ndt/gfs269.
10. Mushi L, Marschall P, Fleßa S. The cost of dialysis in low and middle-income countries: a systematic review. BMC Health Serv Res. 2015;15:506. doi:10.1186/s12913-015-1166-8.
11. Estimation of unit costs for general health services: Updated WHO-CHOICE estimates. Technical background report. Geneva: World Health Organization; 2011 (https://cdn.who.int/media/docs/default-source/health-economics/choice-estimates-updates2011.pdf?sfvrsn=ff4251be_1&download=true).
12. Barnay T, Debrand T. Effects of health on the labour force participation of older persons in Europe. In: Issues in health economics. Paris: Institut de recherche et documentation en économie de la santé, No. 109; 2006 (https://www.academia.edu/25102570/Effects_of_health_on_the_labour_force_participation_of_older_persons_in_Europe).
13. Galvin O, Chi G, Brady L, Hippert C, Del Valle Rubido M, Daly A et al. The impact of inherited retinal diseases in the Republic of Ireland (ROI) and the United Kingdom (UK) from a cost-of-illness perspective. Clin Ophthalmol. 2020;14:707–19. doi:10.2147/OPTH.S241928.
14. DiBonaventura MD, Cappelleri JC, Joshi AV. Association between pain severity and health care resource use, health status, productivity and related costs in painful diabetic peripheral neuropathy patients. Pain Med. 2011;12(5):799–807. doi:10.1111/j.1526-4637.2011.01103.x.
15. Hassan Al Imam M, Alamgir H, Jahan Akhtar N, Hossain Z, Islam R, Sohrab Hossain M. Characterisation of persons with lower limb amputation who attended a tertiary rehabilitation centre in Bangladesh. Disabil Rehabil. 2020;42(14):1995–2001. doi:10.1080/09638288.2018.1544671.
16. Savira F, Ademi Z, Wang BH, Kompa AR, Owen AJ, Liew D et al. The preventable productivity burden of kidney disease in Australia. J Am Soc Nephrol. 2021;32(4):938–49. doi:10.1681/ASN.2020081148.
17. van Haalen H, Jackson J, Spinowitz B, Milligan G, Moon R. Impact of chronic kidney disease and anemia on health-related quality of life and work productivity: analysis of multinational real-world data. BMC Nephrol. 2020;21(1):1–15. doi:10.1186/s12882-020-01746-4.

18. Magliano DJ, Martin VJ, Owen AJ, Zomer E, Liew D. The productivity burden of diabetes at a population level. Diabetes Care. 2018;41(5):979–84. doi:10.2337/dc17-2138.

19. Honda S, Yanagi Y, Koizumi H, Chen Y, Tanaka S, Arimoto M et al. Impact of neovascular age-related macular degeneration: burden of patients receiving therapies in Japan. Sci Rep. 2021;11(1):13152. doi:10.1038/s41598-021-92567-4.

20. Persson S, Johansen P, Andersson E, Lindgren P, Thielke D, Thorsted BL et al. Days absent from work as a result of complications associated with type 2 diabetes: Evidence from 20 years of linked national registry data in Sweden. Diabetes Obes Metab. 2020;22(9):1586–97. doi:10.1111/dom.14070.

21. Non-communicable disease prevention and control: a guidance note for investment cases. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-NMH-NMA-19.95).

22. Holden L, Scuffham PA, Hilton MF, Ware RS, Vecchio N, Whiteford HA. Which health conditions impact on productivity in working Australians? J Occup Environ Med. 2011;53(3):253–7. doi:10.1097/JOM.0b013e31820d1007.

23. Wang PS, Beck A, Berglund P, Leutzinger JA, Pronk N, Richling D, et al. Chronic medical conditions and work performancein the health and work performance questionnaire calibration surveys. J Occup Environ Med. 2003;45(12):1303–11. doi:10.1097/01.jom.0000100200.90573.df.

24. Clement FM, Chen G, Khan N, Tu K, Campbell NR, Smith M et al. Primary care physician visits by patients with incident hypertension. Can J Cardiol. 2014;30(6):653–60. doi:10.1016/j.cjca.2014.03.033.

25. Etemad LR, McCollam PL. Total first-year costs of acute coronary syndrome in a managed care setting. J Manag Care Pharm. 2005;11(4):300–6. doi:10.18553/jmcp.2005.11.4.300.

26. Bravata DM, Daggy J, Brosch J, Sico JJ, Baye F, Myers L et al. Comparison of risk factor control in the year after discharge for ischemic stroke versus acute myocardial infarction. Stroke. 2018;49(2):296–303. doi:10.1161/STROKEAHA.117.017142.

27. Bouchard V, Robitaille A, Perreault S, Cyr MC, Tardif JC, Busseuil D et al. Psychological distress, social support, and use of outpatient care among adult men and women with coronary artery disease or other non-cardiovascular chronic disease. J Psychosom Res. 2023;165:111131. doi:10.1016/j.jpsychores.2022.111131.

28. Toušek P, Bauer D, Neuberg M, Nováčková M, Mašek P, Tu˚ma P et al. Patient characteristics, treatment strategy, outcomes, and hospital costs of acute coronary syndrome: 3 years of data from a large high-volume centre in Central Europe. Eur Heart J Suppl. 2022;24(Suppl_B):B3–9. doi:10.1093/eurheartjsupp/suac001.

29. Kim SM, Hwang SW, Oh EH, Kang JK. Determinants of the length of stay in stroke patients. Osong Public Health Res Perspect. 2013;4(6):329–41. doi:10.1016/j.phrp.2013.10.008.

30. Qureshi AI, Adil MM, Zacharatos H, Suri MFK. Factors associated with length of hospitalization in patients admitted with transient ischemic attack in United States. Stroke. 2013;44(6):1601–5. doi:10.1161/STROKEAHA.111.000590.

31. Holodinsky JK, Lindsay P, Yu AYX, Ganesh A, Joundi RA, Hill MD. Estimating the number of hospital or emergency department presentations for stroke in Canada. Can J Neurol Sci. 2023:50(6):820–5. doi:10.1017/cjn.2022.338.

32. Kanaoka K, Iwanaga Y, Nakai M, Nishioka Y, Myojin T, Kubo S et al. Outpatient cardiac rehabilitation dose after acute coronary syndrome in a nationwide cohort. Heart. 2023;109(1):40–6. doi:10.1136/heartjnl-2021-320434.

33. Abdul Aziz AF, Fairuz Ali M, Fhaisol Yusof M, Che' Man, Z, Sulong S Aljunid SM. Profile and outcome of post stroke patients managed at selected public primary care health centres in Peninsular Malaysia: a retrospective observational study. Sci Rep. 2018;8(1):17965. doi:10.1038/s41598-018-36154-0.

34. MacLeod KE, Ye Z, Donald B, Wang G. A literature review of productivity loss associated with hypertension in the United States. Popul Health Manage. 2022;25(3):297–308. doi:10.1089/pop.2021.0201.

35. Kotseva K, Gerlier L, Sidelnikov E, Kutikova L, Lamotte M, Amarenco P et al. Patient and caregiver productivity loss and indirect costs associated with cardiovascular events in Europe. Eur J Prev Cardiol. 2019;26(11):1150–7. doi:10.1177/2047487319834770.

36. Gordois AL, Toth PP, Quek RG, Proudfoot EM, Paoli CJ, Gandra SR. Productivity losses associated with cardiovascular disease: a systematic review. Exp Rev Pharmacoecon Outcomes Res. 2016;16(6):759–69. doi: 10.1080/14737167.2016.1259571.

37. Mirmohammadi SJ, Sadr-Bafghi SM, Mehrparvar AH, Gharavi M, Davari MH, Bahaloo M et al. Evaluation of the return to work and its duration after myocardial infarction. ARYA Atheroscler. 2014;10(3):137–40. PMC4144381.

38. Han J, Lee HI, Shin YI, Son JH, Kim SY, Kim DY et al. Factors influencing return to work after stroke: the Korean Stroke Cohort for Functioning and Rehabilitation (KOSCO) Study. BMJ Open. 2019;9(7):e028673. doi:10.1136/bmjopen-2018-028673.

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