Applications of digital health approaches for cardiometabolic diseases prevention and management in the Western Pacific region

Fengchao Liang,[a,i] Xueli Yang,[b,c,i] Wen Peng,[d,e] Shihan Zhen,[a] Wenzhe Cao,[a] Qian Li,[a] Zhiyi Xiao,[a] Mengchun Gong,[f] Youfa Wang,[g,*] and Dongfeng Gu[a,h,**]

[a]School of Public Health and Emergency Management, Southern University of Science and Technology, 1088 Xueyuan Avenue, Shenzhen 518055, People's Republic of China
[b]Tianjin Key Laboratory of Environment, Nutrition and Public Health, Tianjin Medical University, 22 Qixiangtai Rd, Tianjin 300070, People's Republic of China
[c]Department of Occupational and Environmental Health, School of Public Health, Tianjin Medical University, 22 Qixiangtai Rd, Tianjin 300070, People's Republic of China
[d]Nutrition and Health Promotion Center, Department of Public Health, Medical College, Qinghai University, 251 Ningda Road, Xining City 810016, People's Republic of China
[e]Qinghai Provincial Key Laboratory of Prevention and Control of Glucolipid Metabolic Diseases with Traditional Chinese Medicine, Xining 810008, People's Republic of China
[f]Institute of Health Management, Southern Medical University, No. 1023-1063, Shatai South Road, Guangzhou 510515, People's Republic of China
[g]The First Affiliated Hospital of Xi'an Jiaotong University Public Health Institute, Global Health Institute, School of Public Health, International Obesity and Metabolic Disease Research Center, Xi'an Jiaotong University, Xi'an 710061, People's Republic of China
[h]School of Medicine, Southern University of Science and Technology, 1088 Xueyuan Avenue, Shenzhen 518055, People's Republic of China

The Lancet Regional Health - Western Pacific 2024;43: 100817

Published Online 1 December 2023

https://doi.org/10.1016/j.lanwpc.2023.100817

Summary

Cardiometabolic diseases (CMDs) are the major types of non-communicable diseases, contributing to huge disease burdens in the Western Pacific region (WPR). The use of digital health (dHealth) technologies, such as wearable gadgets, mobile apps, and artificial intelligence (AI), facilitates interventions for CMDs prevention and treatment. Currently, most studies on dHealth and CMDs in WPR were conducted in a few high- and middle-income countries like Australia, China, Japan, the Republic of Korea, and New Zealand. Evidence indicated that dHealth services promoted early prevention by behavior interventions, and AI-based innovation brought automated diagnosis and clinical decision-support. dHealth brought facilitators for the doctor-patient interplay in the effectiveness, experience, and communication skills during healthcare services, with rapidly development during the pandemic of coronavirus disease 2019. In the future, the improvement of dHealth services in WPR needs to gain more policy support, enhance technology innovation and privacy protection, and perform cost-effectiveness research.

Keywords: **Digital health; Cardiometabolic disease; Western Pacific region; Prevention; Health management**

Introduction

The use of information and communications technology (ICT) to support health services is known as eHealth or digital health (dHealth, which is used next). Its related technologies and applications have been developing rapidly in the past two decades, and drawing increasing attention worldwide.[1] It has been viewed as a very useful and promising development for supporting future health care services, especially for the prevention and management of non-communicable diseases (NCDs). The development and applications in dHealth varied greatly among countries in the world, while some countries in the Western Pacific region (WPR) have invested heavily in this field, including counties like Japan and China.

Cardiometabolic diseases (CMDs) are the most common type of NCDs, and usually comprise cardiovascular diseases (CVDs) such as ischemic heart disease (IHD), stroke, hypertension, and metabolic disorders

*Corresponding author. The First Affiliated Hospital of Xi'an Jiaotong University Public Health Institute, Global Health Institute, School of Public Health, International Obesity and Metabolic Disease Research Center, Xi'an Jiaotong University, Room 3104, No. 21 Hongren Building, West China Science and Technology Innovation Harbour (iHarbour), Xi'an, People's Republic of China.
**Corresponding author. School of Public Health and Emergency Management, Southern University of Science and Technology, Room 117, Taizhou Building, 1088 Xueyuan Avenue, Shenzhen, 518055, People's Republic of China.
E-mail addresses: youfawang@gmail.com (Y. Wang), gudf@sustech.edu.cn (D. Gu).
[i]Equal contribution.

Key messages

- Cardiometabolic diseases (CMDs) are the major types of non-communicable diseases, contributing to a huge disease burden in the Western Pacific region (WPR). The use of digital health (dHealth) technologies, such as wearable gadgets, mobile apps, and artificial intelligence (AI), facilitates interventions for CMDs prevention and treatment.
- Most studies on dHealth and CMDs in WPR were conducted in Australia, China, Japan, the Republic of Korea, and New Zealand, while those in low-income countries were limited. Some studies indicated the effectiveness of dHealth approaches.
- dHealth services promoted early prevention and rehabilitation by behavior interventions and self-management. AI-based innovation brought automated diagnosis and clinical decision-support.
- dHealth technologies help patients to facilitate their interactions with healthcare providers, family members, and other patients; facilitators and barriers from both patient- and doctor-sides may affect the efficiency, quality, and experiences using dHealth services.
- More investigations are required to evaluate the cost-effectiveness of dHealth-related interventions and policies in WPR. Future cooperation and technology sharing among countries will help reduce disparities in healthcare resources and improve health equity worldwide.

characterized by central obesity and diabetes.[2] The Global Burden of Diseases, Injuries, and Risk Factors Study indicated that disability-adjusted life years (DALYs) of CVD had a decades-long steady rise in WPR, from 75.4 million DALYs in 1990 to 114.9 million DALYs in 2019.[3] International Diabetes Federation estimated that there were 205.6 million adults aged 20–79 years with diabetes in WPR in 2021, accounting for 46% of the world's patients with diabetes, and this number was predicted to be 260.2 million by 2045.[4] Although CMDs share common etiology and predisposing factors,[5] people with CMDs may have various presentations ranging from no symptoms to diabetes, from silent coronary ischemia to acute myocardial infarction or sudden death. The diversity in clinical presentation challenges early prevention and precision management for CMDs, especially in most WPR countries where healthcare resources are limited and unequally distributed. There is a great need to develop technologies with lower cost and higher efficiency for the prevention and management of NCDs including CMDs; and dHealth has the potential to transform the monitoring, diagnosis, and management of such conditions.

For future healthcare systems and services, dHealth has a lot of promises. According to the World Health Organization (WHO), dHealth covers a broader scope, encompassing eHealth and emerging areas such as computing science and artificial intelligence (AI).[1] The applications of dHealth technologies are getting fast ground in biosignal acquisition, risk factor control, integration of electronic medical records, and healthcare services that facilitate the prevention, diagnostics and management of CMDs. Mobile apps and wireless devices provide tools for early prevention by behavior interventions (eg, weight loss, exercise monitoring), especially among populations with obesity and/or diabetes.[6] Advances in AI are also moving from research to clinical practice, such as the interpretation of results to coronary image analysis, electrocardiogram (ECG) interpretation, and cardiovascular risk assessment.[7] The pandemic of coronavirus disease 2019 (COVID-19) and associated shifts of care to the home and community further accelerated the integration of dHealth technologies into healthcare for CMDs. Although some progress in dHealth has been achieved, challenges to dHealth usage in WPR still existed such as the applicability of ICT, data safety, and effectiveness of new digital techniques. WHO has developed a global strategy on dHealth and emphasized that countries must be guided by evidence to establish sustainable harmonized dHealth systems.[8]

This study described the latest evidence on the applications including effectiveness of dHealth technologies for CMDs prevention, diagnosis, treatment, and rehabilitation, with a particular emphasis on applications in WPR. We also summarized facilitators and barriers in using dHealth services from both patient- and doctor-sides, and further discussed the future efforts to support dHealth, which may facilitate efficient integration of dHealth technologies into cardiometabolic healthcare in WPR (Fig. 1).

Applications of dHealth approaches in CMDs

This section mainly described evidence from global systematic reviews and key literature in WPR, using defined search strategies and selection criteria presented in Panel 1. The main findings focus on the effectiveness of dHealth technologies in the prevention, diagnosis, and treatment of CMDs (Tables 1–3 and Tables S1–S6). Further, the advantages and limitations of dHealth in WPR were illustrated based on evidence summaries.

Applications in prevention of CMDs

Healthy behavior interventions are vital to the prevention and management of CMDs. We summarized evidence on dHealth focusing on five behaviors (ie, weight loss, smoking cessation, healthy diet, exercise, and sleep) of eight cardiovascular health metrics based on the statement of "the Life Essential 8" released by the American Heart Association (AHA).[37] Evidence of primary or secondary prevention derived from systematic reviews on dHealth intervention to change unhealthy behaviors was presented in Table 1, involving the general population, high-risk individuals, and patients with CMDs. In general, most studies reported overall positive effects of digital technology interventions in the prevention of CMDs. Various ICTs

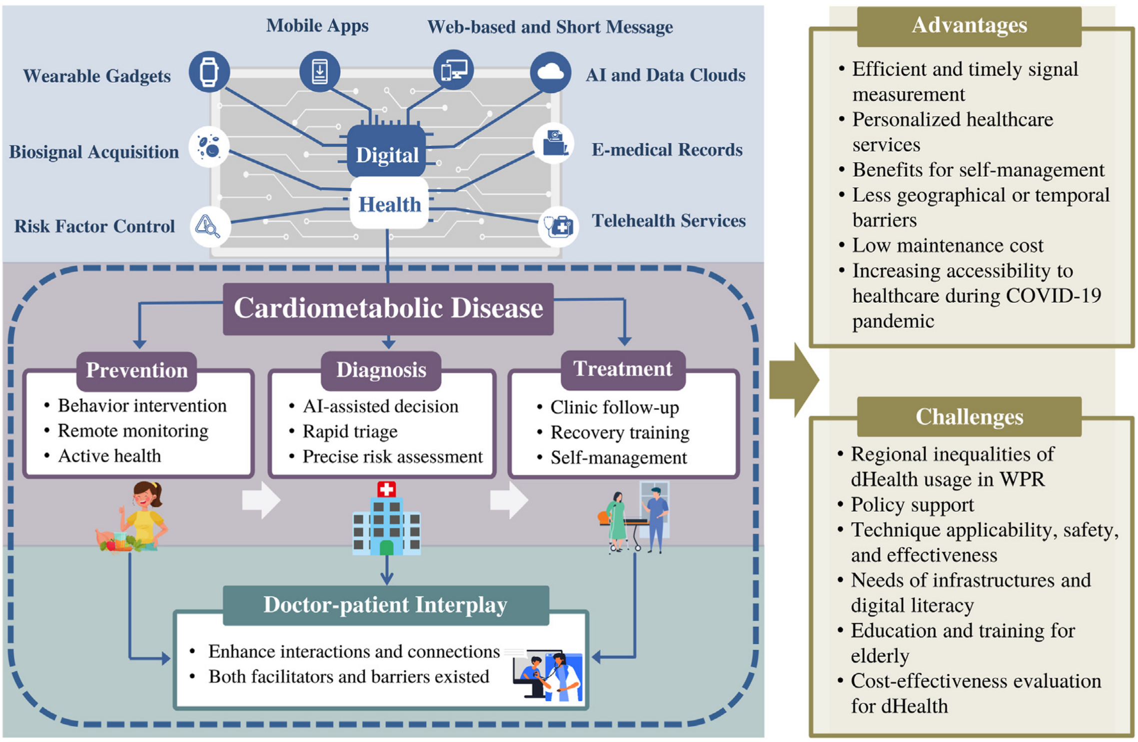

Fig. 1: **Core conceptions and fields of digital health approaches for cardiometabolic diseases**. AI, artificial intelligence. COVID-19, coronavirus disease 2019. WPR, the Western Pacific region. dHealth, digital health.

were used for daily tasks and schedule management in behavior intervention.[9–11,13,17] Wearable devices and/or videoconferencing for exercise, and mobile apps used for recording diet, were also effective for behavior interventions.[15,16,18]

However, these studies usually failed to clarify the mechanism of the intervention and failed to explain what component of the apps lead to what kind of behavior change. Future studies should focus on identifying the specific components of dHealth interventions that are most effective in promoting behavioral change and improving metabolic and physical parameters. This may involve conducting randomized controlled trials that systematically manipulate different app components (such as feedback, goal-setting, and social support) and assess their impact on various outcomes. Such studies would provide valuable insights into the mechanisms through which dHealth apps produce their effects and could inform the development of more effective interventions.

In WPR, most original studies on behavioral interventions using ICTs were conducted in some high- and middle-income countries (HMICs), such as Australia, China, the Republic of Korea, Japan, and New Zealand. Most studies in WPR provided simple and convenient interventions to cope with the problems of accessibility to health services, cost-effective delivery, and scalability to large populations.[10,11,38] Behavior intervention and remote monitoring could be tailored to personalized preferences and functional abilities. For example, a 3-month randomized trial in Japan reported that a remote health-data monitoring system is a feasible and effective tool for modifying the lifestyles of patients with type 2 diabetes mellitus (T2DM).[39] A study in China reported a higher probability of success in quitting smoke among participants using a mobile-phone-based text messaging intervention (Happy Quit), compared to the control group who received messages unrelated to quitting.[40] These approaches were relatively safe and usable, especially for those aimed to improve clinical outcomes by modifying lifestyles and enhancing self-management.

Nonetheless, compared to the regions where health promotion programs are well established and medications are widely available (eg, North America), studies on dHealth in the prevention and management of CMDs are still limited in WPR. With the rapid growth of smartphone usage and self-monitoring devices ownership in WPR, substantial research works are needed to promote health behavior interventions by digital technologies.

Applications in diagnosis and decision-support of CMDs

AI is getting fast ground and has made expert-level and automated diagnosis a reality for some CMD cases. At

Panel 1: Search strategies and selection criteria.

We searched key research databases (PubMed and Web of Science) for relevant research articles including systematic reviews published in English between January 1, 2010 and November 30, 2022, and retrieved the most recent agency reports from their official websites (eg, World Health Organization, World Bank, and National Health Commission of the People's Republic of China) in English and Chinese. We conducted the search using various combinations of key terms for dHealth intervention (eg, "wearable gadget", "mobile app", "web-based message service", "short message service", "artificial intelligence", "data cloud", "mHealth", and "eHealth"), scenarios of applications (eg, "biosignal acquisition", "risk factor control", "e-medical records", "clinical services", "behavior intervention", "diagnosis", "decision-support", "treatment", and "rehabilitation"), cardiometabolic factors and conditions (eg, "weight loss", "smoking cessation", "healthy diet", "exercise", "sleep", "hypertension", "diabetes", "dyslipidemia", "obesity", "ischemic heart disease", "stroke", "cardiovascular disease", and "cardiometabolic disease"). Relevant literature and reports were screened, reviewed, and selected by reviewing their titles, abstracts, and full text. The publications and other data sources were included if they were timely contributions to the topic of dHealth approaches in the prevention, diagnosis, and treatment of CMDs.

present, dHealth approaches used for CMDs diagnosis and decision-support mainly included natural language processing (NLP), AI-assisted identification, risk assessment and prediction (Table 2). Current evidence from systematic reviews indicated that most dHealth approaches fulfilled their goals to improve diagnostic efficacy, and provided decision support for optimizing treatment plans, as well as identifying high risk populations with specific cardiometabolic events. For CVD diagnosis and decision-support, typical cases were the application of NLP to deal with unstructured data in electronic medical records. NLP could be used for making a specific diagnosis, identifying disease severity, or predicting the clinical outcomes for CVD patients.[23] In addition, radiomics and radiogenomics combined with AI techniques have been used in the decision-support for treatment plans of CVD. For example, Infante et al. found that radiomic features extracted by cardiac computed tomography angiography (Area Under Curve: 0.7–0.9) and cardiac magnetic resonance (Area Under Curve: 0.6–0.9) showed high diagnostic accuracy in identifying coronary plaques and myocardium structure, respectively.[24] For ischemic stroke and large vessel occlusions, AI-assisted classification improved disease detection, and rapid triage is necessary for expedited treatment.[26]

Applications of dHealth were also involved in screening and predicting CVD risks accurately.[28,41,42] For adults without symptoms or a diagnosis of CVD, the addition of resting ECG into traditional risk factors was able to help doctors accurately reclassify CVD patients.[28] Risk prediction models were validated to identify 10-year CVD risk with total net reclassification index ranging 3.6%–30.0%.[41,42] However, the performance of the clinical risk prediction scores varied in diverse racial/ethnic groups, given the heterogeneous nature of the populations, differences in lifestyles, and distinct prevalence of risk factors.[43] WHO has endorsed and facilitated screening for high CVD risk in low- and middle-income countries (LMICs) by providing risk prediction charts, including those designed for WPR, but they were developed from data collected two decades ago.[44]

Most countries in WPR have experienced rapid transitions of CMD epidemic. Locally validated risk prediction instruments were more preferable when predicting CMD risks for either healthy population or patients. As a successful example in China, the project of Prediction for Atherosclerotic CVD Risk in China (China-PAR) published a model to predict the 10-year risk of atherosclerotic CVD, using cohorts among over 106,000 individuals.[45] The China-PAR model demonstrated that the US-data based Pooled Cohort Equations for Americans substantially overestimated risk for the population in China. These practices and findings should serve as a wake-up call for many other highly populated LMICs in WPR where the CMD risk factor profile is worsening rapidly in recent years. Digital technique-assisted tools for prediction and diagnosis may help populations in these nations to get local and specific solutions.

Applications in treatment and rehabilitation of CMDs

We summarized evidence from systematic reviews about the effectiveness of digital interventions on treatment and rehabilitation among patients with CMDs. Current studies in WPR focus on prognostic management among patients underlying supports of mobile apps,[29–33,35,36,46] internet-based services,[29–33,35,36] short messaging service,[29–33] gadgets,[31,33,36] and home ICT[30,36,46] as the main interventions. Most studies have proved that dHealth interventions significantly improved CMDs outcomes (Table 3).

In WPR, several randomized controlled trials have confirmed the positive effects of dHealth intervention on the management of diabetes and CVDs. For glycemic control, a randomized controlled study in New Zealand using customized short messages as the primary intervention found better glycemic control in the intervention group, indicating a reduced glycosylated hemoglobin type A1c (HbA1c) with a mean level of 8.9 (SD = 14.8) mmol/mol, compared with that in the control group.[47] In China, a community-based cluster randomized trial was conducted among 19,601 participants residing in 864 communities of 25 provinces, which found that mobile apps significantly improved HbA1c control in primary care, indicating a relative improvement of 18.6% in the intervention group compared to the control group.[48] The WHO Global Diabetes Compact has set a series of targets for diabetes management. dHealth technologies would benefit

ID	Scenarios/target outcomes	Author, year	No. of studies	Population	Digital intervention	Control	Countries/ regions	No. of studies in WPR[a]	Combined effects[b]
1	Smoking cessation	Sha L, 2022[9]	19	High risk (smoker)	Short messaging service Mobile Apps	None Self-help guideline	Asia (nWPR) (n = 2) Europe (n = 7) South America (n = 1) North America (n = 5) WPR (n = 3) Multi-center (the US, UK, Australia, and Singapore) (n = 1)	Australia (n = 1) China (n = 2) New Zealand (n = 1) Singapore (n = 1)	Benefits for smoking cessation, pooled RR = 1.6 (95% CI: 1.3, 1.9)
2	Smoking cessation	Kock L, 2019[10]	42	High risk (smoker)	Short messaging service Mobile Apps	Usual care Mixed	Asia (nWPR) (n = 1) Europe (n = 8) North America (n = 30) WPR (n = 3)	Australia (n = 2) China (n = 1)	Benefits for smoking cessation, pooled RR = 1.6 (95% CI: 1.4, 1.8)
3	Smoking cessation	Whittaker R, 2019[11]	26	High risk (smoker)	Short messaging service Mobile Apps	None Self-help guideline	Europe (n = 7) North America (n = 9) WPR (n = 9) Multi-center (the US, UK, Australia, and Singapore) (n = 1)	Australia (n = 4) China (n = 4) New Zealand (n = 2) Singapore (n = 1)	Benefits for smoking cessation, pooled RR = 1·5 (95% CI: 1.2, 2.0)
4	Healthy diet	Beck Silva KB, 2022[12]	13	General	Internet-based services	Usual care	Asia (nWPR) (n = 1) Europe (n = 5) North America (n = 7)	NA	Benefits for reducing consumption of fats, pooled SMD = −0.1 (95% CI: −0.2, −0.1)
5	Healthy diet, Exercise, Weight loss	Robert C, 2021[13]	70	General High risk (obesity) Patients (diabetes, CVD, pre-diabetes, etc)	Short messaging service Mobile Apps	Usual care	Asia (nWPR) (n = 3) Europe (n = 18) North America (n = 35) South America (n = 1) WPR (n = 13)	Australia (n = 3) China (n = 2) Hong Kong, China (n = 1) Republic of Korea (n = 2) Japan (n = 1) Malaysia (n = 1) New Zealand (n = 2) Singapore (n = 1)	Benefits for consumption of fruit and vegetable, pooled MD = 0.4 (95% CI: 0.1, 0.7); Reduced weight, pooled MD = −2.3 (95% CI: −2.8, −1.8); Reduced BMI, pooled MD = −0.7 (95% CI: −1.0, −0.4); Reduced WC, pooled MD = −2.0 (95% CI: −3.2, −0.8)
6	Exercise	Vetrovsky T, 2022[14]	85	General High risk (obesity) Patients (diabetes, CVD, pre-diabetes, etc)	Gadgets (wearable activity trackers) Internet-based services	Usual care	Asia (nWPR) (n = 2) Europe (n = 19) North America (n = 55) WPR (n = 9)	Australia (n = 2) China (n = 1) Republic of Korea (n = 1) Japan (n = 2) Malaysia (n = 1) Singapore (n = 2)	Benefits for increasing daily step count, pooled MD = 926 (95% CI: 651, 1201)
7	Exercise	Brown RC, 2021[15]	32	High risk (obesity) Patients (diabetes, CVD, heart failure, etc)	Internet-based services (telemedicine)	None Usual care	Asia (nWPR) (n = 1) Europe (n = 13) North America (n = 12) WPR (n = 6)	Australia (n = 4) China (n = 2)	Benefits for exercise capacity, pooled SMD = 0.6 (95% CI: 0.3, 1.0)
8	Exercise	Ferguson T, 2022[16]	39[c]	General Patients (CMD, CVD, diabetes, etc)	Gadgets (wearable activity trackers)	None	NA	NA	Benefits for improved physical activity (a systematic review of systematic reviews and meta-analyses)

(Table 1 continues on next page)

ID	Scenarios/target outcomes	Author, year	No. of studies	Population	Digital intervention	Control	Countries/ regions	No. of studies in WPR[a]	Combined effects[b]
(Continued from previous page)									
9	Exercise, Healthy diet, Weight loss	Oh YJ, 2021[17]	9	General High risk (obesity)	Short messaging service Internet-based services Mobile apps (food diaries)	Usual care	Europe (n = 5) North America (n = 2) WPR (n = 2)	Australia (n = 1) Republic of Korea (n = 1)	Benefits for physical activity, diet adherence and weight loss (a qualitative systematic review)
10	Sleep	Aji M, 2021[18]	15	General High risk (sleep disturbance)	Gadgets (wearable activity trackers) Internet-based services Internet-based services	Usual care	Europe (n = 2) North America (n = 10) WPR (n = 3)	Australia (n = 2) Republic of Korea (n = 1)	Limited evidence shown benefits for sleep disturbance (a qualitative systematic review)
11	Sleep	Arroyo AC, 2022[19]	12	General	Mobile apps (mHealth) Internet-based services	None	Europe (n = 3) North America (n = 5) WPR (n = 4)	Australia (n = 2) China (n = 1) Republic of Korea (n = 1)	Mobile health apps are effective in improving sleep (a qualitative systematic review)
12	Weight loss	Chew HSJ, 2022[20]	16	High risk (overweight or obesity)	Mobile Apps	Not report	Europe (n = 1) North America (n = 12) WPR (n = 3)	Australia (n = 1) China (n = 1) Japan (n = 1)	Benefits for reducing weight, pooled MD = −2.2 (95% CI: −3.6, −0.8) for 3 months; pooled MD = −2.2 (95% CI: −3.3, −1.1) for 6 months; pooled MD = −1.6 (95% CI: −3.0, −0.3) for 9–12 months
13	Weight loss	Patel ML, 2021[21]	53[d]	High risk (overweight or obesity)	Internet-based services Mobile Apps Gadgets (website, apps, wearable devices, e-scales, SMS, personal digital assistants, and IVR technology)	Not report	Europe (n = 3) North America (n = 31) WPR (n = 5)	Australia (n = 3) China (n = 1) New Zealand (n = 1)	Benefits for reducing weight (a qualitative systematic review)
14	Weight loss	Triantafyllidis A, 2020[22]	17	High risk (overweight or obesity)	Internet-based services Mobile Apps Gadgets (Electronic health records, wearable devices)	Not report	Asia (nWPR) (n = 1) Europe (n = 1) North America (n = 14) WPR (n = 1)	Australia (n = 1)	Benefits for predict and diagnose childhood obesity (a qualitative systematic review)

Abbreviations: BMI, Body mass index; CMD, Cardiometabolic disease; CVD, Cardiovascular disease; IVR, Interactive voice response; MD, Mean difference; NA, Not available; RCT, Randomized controlled trial; RR, Risk ratio; SMD, Standardized mean difference; SMS, Short messaging service; SR, Systematic review; WC, Waist circumference; WPR, the Western Pacific region; nWPR, non-WPR. [a]The sum number of studies in WPR is allowed more than the corresponding number shown in the column "Countries/regions" for WPR, due to multi-center studies involved. [b]Combined effect from each systematic review was shown, unless a summarized description maintained for the qualitative systematic review. [c]Evidence from SR. [d]39 of the 53 studies were unique RCTs.

Table 1: **Characteristics and main findings of selected reviews on digital health applications in prevention of cardiometabolic diseases.**

ID	Scenarios	Author, year	No. of studies	Population	Digital intervention	Control	Countries/regions	No. of studies in WPR[a]	Combined effects[b]
1	NLP-assisted identification of CVD	Reading Turchioe M, 2022[23]	37	High risk	NLP	None	Europe (n = 7) South America (n = 1) North America (n = 27) WPR (n = 2)	China (n = 2)	Success on identifying/classifying disease phenotypes, events, medications, and symptoms (a qualitative systematic review)
2	AI-assisted identification of CVD	Infante T, 2021[24]	60	High risk	Radiogenomics and AI: Radiogenomics integrate a huge amount of features extracted from medical images with genomic phenotypes AI describes the use of computational techniques such as ML	None	Europe (n = 29) North America (n = 15) WPR (n = 15) Multi-center (Netherlands, the UK, China) (n = 1)	China (n = 10) Japan (n = 3) Republic of Korea (n = 3)	Success on CHD diagnosis, classification, and prognostic assessment (a qualitative systematic review)
3	AI-assisted identification of CVD	Banerjee A, 2021[25]	97	High risk	ML methods included hierarchical, non-hierarchical, K-means, K-medoids, mixture model-based, weighted average clustering, self-organizing map, support vector machine, multiple Kernel learning, random forest, principal component analysis, latent class analysis	None	Asia (nWPR) (n = 2) Europe (n = 9) North America (n = 76) WPR (n = 9) Multi-center (Canada, Germany, Italy, Republic of Korea, Switzerland, and the US) (n = 1)	Australia (n = 1) China (n = 6) Republic of Korea (n = 3)	Benefits for a simple checklist to foster standardized reporting and validation (a qualitative systematic review)
4	AI-assisted identification of stroke	Murray NM, 2020[26]	20	High risk	AI method and software	None	Europe (n = 16) North America (n = 2) WPR (n = 2)	Japan (n = 1) Republic of Korea (n = 1)	Success on improving LVO stroke detection and rapid triage. In ischemic stroke studies compared to humans, the AUC results using AI for acute diagnosis, triage, or complication prediction ranged from 0.74 to 0.96. (a qualitative systematic review)
5	Risk assessment of complications in diabetes	Slieker RC, 2021[27]	41	Patients with diabetes	All prognostic models from discovery studies to predict risk of nephropathy	None	Asia (nWPR) (n = 5) Europe (n = 12) North America (n = 11) WPR (n = 13)	Australia (n = 2) China (n = 5) Hong Kong, China (n = 2) Japan (n = 3) Singapore (n = 1)	Success on predicting nephropathy in people with diabetes. AUC >0.80 for the three investigated outcomes of albuminuria, chronic kidney disease, and diabetic kidney disease. (a qualitative systematic review)
6	Evaluation for CVD risk	Jonas DE, 2018[28]	16	General Patients with CVD	Screening for cardiovascular disease risk with resting or exercise electrocardiography	Usual care	Europe (n = 6) North America (n = 9) WPR (n = 1)	Japan (n = 1)	Benefits for screening for CVD risk with resting or exercise electrocardiography, total NRI ranged from 3.6% to 30% (a qualitative systematic review)

Abbreviations: AI, Artificial intelligence; AUC, Area under curve; CHD, Coronary heart disease; CVD, Cardiovascular disease; LVO, Large vessel occlusion; ML, Machine learning; NA, Not available; NLP, Natural language processing; NRI, Net reclassification improvement; WPR, the Western Pacific region; nWPR, non-WPR. [a]The sum number of studies in WPR is allowed more than the corresponding number shown in the column "Countries/regions" for WPR, due to multi-center studies involved. [b]Combined effect from each systematic review was shown, unless a summarized description maintained for the qualitative systematic review.

Table 2: **Characteristics and main findings of selected reviews on digital health applications in diagnosis and decision-support of cardiometabolic diseases.**

ID	Scenarios/target outcomes	Author, year	No. of studies	Population	Digital intervention	Control	Countries/regions	No. of studies in WPR[a]	Combined effects[b]
1	Diabetes control	Eberle C, 2021[29]	10	Patient with diabetes	Real-time video/audio intervention Asynchronous intervention (email, SMS, etc)	Not report	Asia (nWPR) (n = 1) Europe (n = 3) North America (n = 4) WPR (n = 2)	Taiwan, China (n = 1) Australia (n = 1)	Benefits for diabetes control with declined HbA1c levels ranged from −0.6% to −0.2%
2	Diabetes control	Shan R, 2019[30]	14	Patients with diabetes	Blood sugar meters Education Food and exercise diaries SMS Mobile games supporting protective factors	Usual care	Europe (n = 4) North America (n = 6) WPR (n = 1) Multi-center (n = 3)	New Zealand (n = 1)	8 out of 13 studies support diabetes control (a qualitative systematic review)
3	Diabetes and obesity control	Wang Y, 2017[31]	24	Patients with diabetes or obesity	Mobile Apps SMS Gadgets	Not report	Asia (nWPR) (n = 2) Europe (n = 5) North America (n = 15) WPR (n = 2)	Republic of Korea (n = 1) Australia (n = 1)	An average decrease of glycated hemoglobin ranged from −0.4% in 10 months to −1.9% in 12 months; An average weight loss ranged from −2.0 kg in 16 weeks to −7.1 kg in 5 weeks
4	Hypertension control	Cavero-Redondo I, 2021[32]	51	Patients with hypertension	Mobile Apps Internet-based Service SMS	Usual care	Africa (n = 1) Asia (nWPR) (n = 6) Europe (n = 12) North America (n = 25) WPR (n = 9)	China (n = 4) Republic of Korea (n = 4) Taiwan, China (n = 1)	The benefits of using three types of intervention to control blood pressure: mutilple dHealth interventions (SBP/DBP: −0.5/−0.3), phone calls (SBP/DBP: −0.4/−0.3) and smartphone application (SBP/DBP: −0.3/−0.4)
5	Hypertension control	Xu H, 2021[33]	8	Patients with hypertension	Gadgets	Usual care	Asia (nWPR) (n = 1) Europe (n = 2) North America (n = 4) WPR (n = 1)	China (n = 1)	Benefits for hypertension control: blood pressure (weighted mean difference: −2.3)
6	CHD management	Yue X, 2021[34]	15	Patients with CVD	Home ICT Mobile Apps	Mixed	Europe (n = 3) WPR (n = 12)	China (n = 10) Australia (n = 2)	Benefits for CHD management: reduce BMI (−1.2), waist circumference (−4.4), TC (−0.4), LDL-C (−0.3), diastolic blood pressure (−2.0), depression (−8.3), increase high-density lipoprotein cholesterol level (0.1)
7	Cardiac rehabilitation	Wongvibulsin S, 2021[35]	31	Patients with CVD	Home ICT Internet-based Service Education	Usual care	Europe (n = 11) North America (n = 8) WPR (n = 11) Multi-center (n = 1)	China (n = 3) Australia (n = 4) New Zealand (n = 4)	Benefits for cardiac rehabilitation (a qualitative systematic review)
8	Cardiac rehabilitation	Santo K, 2020[36]	4	Patients with CHD	Gadgets SMS Mobile Apps	Usual care	North America (n = 1) WPR (n = 3)	Australia (n = 3)	Benefits for Cardiac Rehabilitation (a qualitative systematic review)

Abbreviations: BMI, Body mass index; CHD, Coronary heart disease; CVD, Cardiovascular disease; DBP, Diastolic blood pressure; ICT, Information and communications technology; LDL-C, Low-density lipoprotein cholesterol; SBP, Systolic blood pressure; SMS, Short messaging service; TC, Total cholesterol; WPR, the Western Pacific region; nWPR, non-WPR. [a]The sum number of studies in WPR is allowed more than the corresponding number shown in the column "Countries/regions" for WPR, due to multi-center studies involved. [b]Combined effect from each systematic review was shown, unless a summarized description maintained for the qualitative systematic review.

Table 3: **Characteristics and main findings of selected reviews on digital health applications in treatment and rehabilitation of cardiometabolic diseases.**

achieving these global targets during the process of monitoring, treatment, and management of diabetes population.[49] For CVD rehabilitation, a randomized controlled trial showed that the dHealth intervention based on WeChat, a popular mobile app of social network in China with 1.2 billion active users,[50] significantly improved self-management and controlled blood pressure (BP) levels in middle-aged and elderly hypertensive patients.[51] A systematic review by Cavero-Redondo I et al. found that compared to conventional care, the joint use of two or more digital interventions improved adherence on medication and physical activity, and significantly reduced systolic BP (–0.46 mmHg) and diastolic BP (–0.29 mmHg) in hypertensive patients and improved their living quality.[32] Compared to conventional care that relies on patients' self-discipline, digital interventions can improve CMD outcomes by changing patients' lifestyles, promoting medication, and improving patients' self-management and adherence. In addition, the use of smartphones and telemonitoring makes healthcare more accessible by facilitating communication between patients and healthcare providers, allowing remote monitoring and stratification of the patients. However, considering the limitations of existing studies, such as uneven geographical distribution, selection bias,[32] and the impact uncertainty of interventions,[32,33] studies with long-term interventions and rigorous study designs are still needed to provide further evidence.

Advantages and limitations of dHealth studies in WPR

dHealth technologies have their unique advantages in the prevention and management of CMDs. It could overcome geographical or temporal barriers by sending messages efficiently and timely, and facilitate professionals to provide personalized health services by tailoring health information, AI-assisted diagnosis, and treatment.[11,13] dHealth has shown great potential to change unhealthy behavior, improve medication adherence, and reduce emergency department visits and hospitalizations.[52] dHealth also offers feasibility for the monitoring of BP,[32] atrial fibrillation,[53] and unexplained syncope.[54] It also can be used in physician diagnostics such as predicting the occurrence of hypertension,[55] as well as deep learning to measure plaque volume and stenosis severity.[56] In addition, dHealth has been shown to play a role in the prognosis for CVD, including significant BP reduction after stroke/transient ischemic attack[57] and improve secondary prevention after acute myocardial infarction.[58] The use of dHealth technologies also has tremendous positive implications in developing clinical guidelines, facilitating daily clinical workflow, enabling new models of virtual trials, and reducing the duration and cost of research.[32,33]

At present, dHealth approaches for CMDs interventions are mostly applied in HMICs in WPR like Australia, China, Japan, the Republic of Korea, and New Zealand. These countries have better economic environments and advanced technology levels, which facilitate telemedicine and e-health implementation. However, fewer studies were reported in countries with lower levels of internet accessibility, limited availability of hardware devices, and backward development of digital technology. Despite the rapid development of technologies, applicability and effectiveness should also be a concern when using dHealth services. An important barrier is the lack of generally implemented data standards, which is essential for the migration of dHealth solutions across countries and languages in WPR.[59] As an example, AI analysis relies heavily on a standardized digital acquisition; however, this is not universal in current clinical environments, even in high-resource settings.[60] The cost-effectiveness of digital-based intervention programs for CMDs should be also concerned with caution before broad adoption. Previous studies have provided a practical framework for assessing the validity and clinical utility of machine learning studies for CVDs.[25] These clinical and technical factors would challenge the applications of dHealth not only in WPR but also the worldwide, unless they were addressed by comprehensive and feasible solutions.

Applications of dHealth regarding CMDs in the context of COVID-19

COVID-19 has spread all over the world since the end of 2019, and its pandemic has affected both global and regional economies, society, and healthcare systems. The COVID-19 pandemic followed by lockdown measurements and mitigation strategies, has brought great pressure on CMDs prevention and control. Personal behavior and lifestyle have changed significantly, such as office mode, home-based leisure and entertainment, and outdoor exercise times.[61] More discussion on COVID-19 and NCDs was shown in the paper entitled "The impact of COVID-19 on risks and deaths of non-communicable diseases in the Western Pacific region" of this series.

Effectively managing the high-risk groups and patients with CMDs during the COVID-19 pandemic or potential public health emergencies is of great significance for slowing down the epidemic of CMDs, especially for the regions or populations with lower medical accessibility. The COVID-19 pandemic provides a good application scenario for dHealth technologies. For example, the use of dHealth was an integral part to China's early response to COVID-19 and it was greatly promoted by national policy directives in emergency preparedness, public health response, and clinical services.[62] A telemedicine network, including 5G service, smartphone apps, and telemedicine systems, was activated during the COVID-19 pandemic in Western China and proved to be an effective way of health care for patients with chronic diseases.[63] Using telemedicine was also effective in improving the thrombolysis administration during the COVID-19 pandemic among Chinese patients who had limited access to hospitals.[64] Current studies worldwide and in WPR during the COVID-19 pandemic showed that the screening and management of CMDs based on dHealth techniques would be efficient ways to guide the high-risk population to carry out lifestyle self-management, non-drug treatments, or medication measurements through remote approaches. By using these techniques, the frequency and duration of hospital visits for CMDs management were largely decreased, and the exposure risk of COVID-19 was also substantially reduced.[65]

With the spread and application, dHealth approaches, such as E-consult and telemedicine support, were rapidly developed and enhanced during the COVID-19 pandemic.[66] The change in medical treatment mode has prompted people to have a better sense of using dHealth services, to realize their important role in medical care, and to gradually accept such technologies and services.[67] Although the management of COVID-19 has entered a normalization stage in WPR, successful dHealth practices and telehealth modes will benefit future management of CMDs as well as other NCDs under a potential social isolation status due to other infectious pandemics or public health emergencies.

Impact of dHealth on the interaction between doctors and patients

The usage of dHealth services may both positively and negatively affect the interaction and communications between doctors and patients. Some key facilitators and barriers of the doctor-patient interaction were outlined, including those related to efficiency and quality, attitude and experience, and communication during telehealth services (Fig. 2).

The direct efficiency and quality gains for both doctors and patients are the provision of in-time and helpful information,[68–72] increased efficiency in consultations such as scheduling capabilities,[68,70,71,73] and reduced time and costs.[68,70,73,74] A scoping review demonstrated that the cost savings for dHealth ranged from 32 to 3523 US dollars in different scenarios and regions, compared to face-to-face consultancy.[75] Patient training to use the dHealth tools may enable independent access to the information and resources required for disease management without the guidance of doctors.[68–70,74]

However, some barriers emerged during the telehealth service, such as the excessive workload for doctors due to handling electronic medical materials and more frequent access to patients.[70,76] Incorrect information input or output from doctors and patients during teleconsultation may lead to incorrect decisions made by doctors.[70,71] In addition, older patients or those who live alone may find it difficult to use some of the dHealth services independently.[68,72] A study in China showed that willingness to use internet hospital services was lower in patients aged 56 years or older than those aged 18–29 years.[77] Therefore, it is recommended to increase the training of dHealth tools and to improve the ease of system usage for the older adults.[68]

Doctors and patients had various attitudes and experiences with dHealth services. Many physicians and patients were satisfied with the accessibility of dHealth and had positive attitudes toward professional information delivery,[68,69,72] but they were also fear of new technologies,[68,69] internet speed issues,[68–70] and difficulties in operational complexities.[68–70,72] A cross-sectional study in Australia investigated patient satisfaction with telehealth services during the COVID-19 pandemic and showed that 61.9% of respondents felt satisfied, compared to face-to-face consultations.[78] dHealth allowed patients to receive consultations or treatment at home, which brought a sense of ease and tranquility, but family members may interfere or interrupt the consultation process and may overhear private conversations that patients did not want to disclose.[68] Additionally, some users believed that dHealth services can safely protect their private information so they talked about their privacy and difficult issues over the Internet or smartphones safely and easily,[68,71,72] while other users still feared the loss of privacy and stigmatization.[68–70,73,76]

For the doctor-patient communication, digital medical tools provided emotional and technical support for patients.[69–73,79,80] On the contrary, conflicts and bad experiences may occur when anyone has low communication skills.[68,80] In addition, factors such as lack of body language can cause some patients to become frustrated or prefer to communicate in person.[68,76] A systematic review highlighted that of the 53 papers reviewed on the impact of online health information searches on the doctor–patient relationship in China, 58.5% supported a positive impact while 11.3% concluded a negative impact and emphasized the damage to doctor-patient trust resulting from online misinformation and reports of malignant events on the doctor–patient relationship.[81] Although more evidence shows the overall positive effects of dHealth on the doctor–patient relationship, the barriers involved may cause more negative effects and therefore need to be noted and addressed.

Pay attention to those who might not benefit from dHealth applications

Although dHealth is demonstrated to be useful for people in need, there are still lots of people who have limited benefit from it. Aging is an accelerating thread in Asia, and the number of people older than 65 years old will increase from 440.7 million to 661.6 million from 2021 to 2100.[82] Nearly two-thirds of older adults

	Facilitators			Barriers		
Domains			Items			Items
Efficiency and quality		●	Patients training for better disease management		●	Assistance requirement
	●	●	In-time information and efficient consultancy	●		Extra workload for medical personnel
	●	●	Travel time and cost reduction	●		Loss of competencies by over-dependence
	●	●	Higher patients' compliance	●	●	Erroneous information input
	●		Personalized care for patients			
	●	●	Helpful information in medical records			
Attitude and experience	●	●	Service availability and simplicity	●	●	Refusal of usage
	●	●	Security and privacy for data transfer	●	●	Difficulty in using
		●	Family members involvement and support	●		Non-reimbursable expenses
		●	Accessibility to medical personnel	●	●	Privacy unsafety concern
	●	●	Professional information present		●	Interruption of consultation process
Communications between patients and medical personnel	●	●	Comfortable communication	●	●	Poor communication expression
		●	Emotional support in consultancy	●	●	Prefer face-to-face consultancy
	●	●	Clear allocation of responsibilities by e-records		●	Misunderstand due to information differences

***Fig. 2:* Facilitators and barriers of doctors-patients interplay in application of digital health approaches**. Facilitators and barriers during digital healthcare services were summarized in three domains including efficiency and quality, attitude and experience, and communications between patients and medical personnel. The bulletin points indicated these facilitators (or barriers) would primarily benefit (or affect) the doctor-side (dark blue dots), the patient-side (light blue dots), or both during the delivery of digital healthcare services.

aged ≥65 years suffer from multimorbidity, and two out of five have three or more chronic conditions.[83] The high prevalence of multimorbidity will put considerable pressure on the healthcare system. With the steady increase in smartphone and tablet use, the popularity of dHealth also increased, especially among older adults.[84,85] The dHealth applications may play a role in the prevention, early detection, and management of chronic diseases and long-term conditions among older adults.[86] Incorporating dHealth into the aging society may offer a potential solution to unburden the healthcare system.

However, the amount of older internet users is still insufficient. For example, only 11.2% of all web users were over 60 years old in China.[84] Due to their cognitive decline, low literacy rates, and physical impairments, older people may have difficulty using dHealth apps.[87] Physical decline due to aging and related diseases makes older people difficult in pressing smaller buttons, or feel uncomfortable when holding the device with one hand, which is prone to increase learning time and error rates.[88–90] The perception impairment of the elderly such as the decline of hearing and vision is also an important aging problem worthy of attention, which leads to the difficulty of watching and reading from dHealth applications and software interaction.[88] Besides, older people's preference is an important factor, and they expect that dHealth apps are easy to use and could bring benefits quickly.[91]

Apart from physical and cognitive impairments, internet usage rates are also deficient among rural residents and low-income groups, who may have a higher marginal effect of internet usage.[92] The barriers for these groups of people include those without smartphones[69] and lack of knowledge in technology.[68] Few applications took into account the complexities associated with people's co-morbidities or disabilities, making them prone to mistakes, and even leading to negative health impacts.[93] The barrier is even more commonly found among ethnic minorities and low socioeconomic status groups,[94] which may lead to the low involvement and the digital divide.

To improve intervention effectiveness for those with barriers related to aging, limited capabilities or digital divide, different strategies may be necessary. Research showed that training older adults with basic knowledge of digital tools could increase their interests and skills in dHealth.[95,96] Family members and health professionals are important to help them and reduce the burden of care.[96] Thus countries in WPR started to emphasize the value of helping old people's usage of dHealth.[97] There are also technologies involving elderly people in the design and development of dHealth programs, and paying attention to low social status, low technology comfort, and disabled people.[98,99] For example, clear interface elements and concise navigation structures should be considered in the design and development of dHealth apps to accommodate the usage preferences.[87] To improve long-term retention rate and intervention effectiveness, future developers of dHealth interventions should focus on finding persuasive design techniques, including the addition of instructional videos, gamified design and combing mobile health with face-to-face support, and providing the most supportive combination of behavior-change techniques to improve long-term retention rate.[100]

Future challenges, opportunities and recommendations

Enhance government and policy support for developing dHealth

Governments in some WPR countries have attached great importance to the development of dHealth industry, and relevant policies are blooming everywhere. For example, China has issued a series of policies or guidelines at the national and industry levels that are conducive to the development of the dHealth industry (Table 4 and Table S7 in Chinese). In 2016, China announced the blueprint of Healthy China 2030, a declaration that made public health a key prerequisite for all future socio-economic development.[101] One action plan in the Healthy China 2030 is to build a unified, authoritative, and interconnected population health information platform, and to promote "Internet Plus Healthcare" services.[102] The 14th Five-Year Plan for Comprehensive Medical Security, issued by the State Council in 2021, emphasized the supports for the orderly development of new modes of healthcare services such as Internet-based services (eg, diagnosis, treatment, and drug delivery), and the use of new technologies (eg, AI).[103] In 2008, the Vietnamese Minister of Health released the policy "Intelligent Health Scheme during 2018–2025".[104] In addition, Australia,[105,106] Japan,[107,108] Singapore[109] and other countries have formulated relevant policies for dHealth development. These policies mainly focused on encouraging and supporting technological innovation of dHealth, reforming the telehealth service management mode, and improving the medical insurance reimbursement system for dHealth services.

It is paramount for governments to provide continuous policies to support the dHealth industry in WPR, although it had rapid growth over the past decade. The policies implemented in developed countries might provide references to encourage the development of digital healthcare for other countries in WPR, especially for LMICs. Countries with different levels of development need to introduce policies tailored to their situation. Understanding the prevalence of CMDs and common cardiometabolic multimorbidity at the local and national levels is also important, which helps policymakers and relevant stakeholders to design and improve policies and programs for the dHealth industry by targeting highly prevalent diseases, risk factors and their projected future trends. In addition, the technology-assisted care is a promising way for CMDs prevention and management, but not the sole solution. The development of CMDs depends on multiple determinants, including environmental, behavioral, and socioeconomic factors. The multifaceted nature of these risk factors calls for an integrated strategy with socio-population-community domains, including the assistance of dHealth, to comprehensively prevent and control the epidemic of CMDs.[110]

Enrich technology support by industrial enterprises

Strength in digital technology innovation is essential in creating and developing dHealth ecosystem in WPR. Several agency reports and academic studies have documented that ICT development is capable to contribute to the healthcare and health sectors of developing countries in East Asia and Southeast Asia.[111] For instance, WeChat is the most popular social network platform (like Facebook and Twitter) in China, covering approximately 78% of adults aged 16–64 years.[50] WeChat-based self-management intervention showed a reduction in BP and better BP monitoring, resulting in improved disease knowledge and self-efficacy.[51] Beyond significant improvements in digital-economy infrastructure and favorable business landscape, WPR has a large number of industrial enterprises with global influence in the fields of medical and healthcare (eg, Toshiba Medical, Japan), electronic technology (eg, Samsung Electronics, the Republic of Korea), and ICT (eg, Huawei, China). Such will benefit the future development and applications of dHealth in WPR.

Digital technologies and their applications in healthcare services will promote to build a global community of health for all. Findings indicated that dHealth applications may offer the potential as a suitable tool for the promotion of health behaviors, self-management of chronic diseases, and medication adherence.[88] However, unbalanced economic and technological development remained one of the key challenges in WPR. For example, there are substantial gaps between countries in Southeast Asia in basic access to the Internet, along with issues of speed and cost, as well as similar gaps in large countries with remote regions.[112] These gaps must be addressed when people embrace the digital industrial revolution, otherwise the unbalance tends may bring a problem of unequal development in the dHealth industry, leading to further uneven usage of dHealth in WPR. Experiences and technologies from the advanced digitalized regions, like China and Japan, would help to benefit the dHealth development in LMICs and reduce health disparity in WPR. LMICs and less developed regions in WPR may accelerate learning from successful programmes and experiences in the countries with advanced digital-economy and dHealth industries, and implement dHealth development initiatives tailored to their populations and healthcare resources to promote NCDs prevention and control. In addition, a low retention rate of dHealth applications may have impacts on the effectiveness of dHealth interventions. This must be taken into account in future app design and related research. It is also possible to combine other intervention methods and improve human–computer

ID	Year	Name of policies or guidelines	Main contents
1	2016	State Council, "Guiding Opinions on Promoting and Regulating the Application and Development of Big Data in Health and Medical Care"	Promote the interconnection and integration of government medical health and public health information systems, openness and sharing, elimination of isolated islands of information, and active creation of big data security norms to promote health and medical care. Through "Internet Plus Healthcare", explore new service models, cultivate and develop new formats.
2	2016	State Council, "Outline of 'Healthy China 2030' Plan"	Comprehensively build a unified authoritative, interconnected population health information platform, standardize and promote "Internet Plus Healthcare" services, innovate Internet health care service models; continue to promote the national health information services, intergrating prevention, treatment, rehabilitation and independent health management covering the entire life cycle.
3	2017	State Council, "Guiding Opinions on Promoting the Construction and Development of Medical Consortium"	Vigorously develop the telemedicine collaboration network for grassroots, remote and underdeveloped areas, encourage public hospitals to provide telemedicine, distance education, distance training and other services to grassroots medical and health institutions, use information technology to promote the vertical flow of resources, improve the availability of high-quality medical resources, and the accessibility and efficiency of health services.
4	2017	State Council, "Notice on Issuing the Development Plan on the New Generation of Artificial Intelligence"	Promote the application of new models and new methods of artificial intelligence treatment, and establish a fast and accurate intelligent medical system. Explore the construction of smart hospitals, develop man-machine collaborative surgical robots and intelligent diagnosis and treatment assistants, develop flexible wearable, biocompatible physiological monitoring systems, develop human-machine collaborative clinical intelligent diagnosis and treatment solutions, and realize intelligent image recognition, pathological typing and intelligent multidisciplinary consultation.
5	2018	State Council, "Opinions on Promoting the Development of 'Internet Plus Healthcare'"	Improve the "Internet Plus Healthcare" service system. Encourage higher-level medical institutions in medical associations to use artificial intelligence and other technical means to provide basic services such as remote consultation, remote ECG diagnosis, and remote imaging diagnosis. Focus on hypertension, diabetes, etc., and strengthen the online service management of chronic diseases in the elderly; develop an artificial intelligence-based clinical diagnosis and treatment decision support system; carry out intelligent medical image recognition, pathological typing, multidisciplinary consultation, intelligent voice technology application in various medical and health scenarios to improve the efficiency of medical services.
6	2018	National Health Commission, State Administration of Traditional Chinese Medicine, "Administration of Internet Diagnosis and Treatment (for Trial Implementation)"	Further promote the sustainable and healthy development of telemedicine services, optimize the allocation of medical resources, promote the sinking of high-quality medical resources, promote the integration and sharing of regional medical resources, and improve the ability and level of medical services.
7	2018	National Health Commission, State Administration of Traditional Chinese Medicine, "Notice Regarding In-depth Development of Civilian-friendly and Civilian-benefiting 'Internet Plus Healthcare' Activities"	Combined with the regional national health information platform, realize the integration of the existing public health information system and residents' electronic health records, improve the management network of chronic diseases such as hypertension and diabetes and foodborne diseases, and focus on online health status assessment, monitoring and early warning, medication guidance, follow-up, health management and other services; comprehensively promote the construction of telemedicine private network, implement the testing equipment guarantee project of telemedicine regional central hospitals; promote the "primary check-up and higher-level diagnosis" model to improve the ability and efficiency of primary medical services.
8	2019	National Health Care Security Administration, "Guiding Opinions on Improving the Policies of 'Internet Plus' Medical Service Prices and Medical Insurance" Payment	"Internet Plus" medical services refer to medical institutions of all levels and types that carry out and extend offline medical services online under the premise of law and compliance. "Internet Plus" medical service prices have been integrated into the current medical service price policy system for unified management.
9	2020	State Council, "Opinions on Deepening the Reform of Medical Insurance System"	To meet the needs of direct settlement of medical services in different places, "Internet Plus Healthcare" and the development of service models for medical institutions, explore and carry out trials of budgeting for trans-regional funds. Promote the application of big data vigorously, and introduce a multi-tiered medical insurance payment system that focuses on payment by disease type.
10	2020	National Health Commission, National Health Care Security Administration, "Guidance on Advancement of 'Internet Plus' Medical Insurance Services During the Period of Prevention and Control of COVID-19"	The "Internet Plus" medical services that meet the requirements will be covered by medical insurance; consistently improve the level of informatization; strengthen the supervision of medical insurance funds; ensure smooth and orderly work.
11	2020	National Health Commission, "Notice on Improving the Appointment Diagnosis and Treatment System and Strengthening the Construction of Smart Hospitals"	Further play the important role of information technology in the construction and management of modern hospitals, continuously improve the modernization level of hospital governance, and form a modern hospital service and management model that integrates online and offline. Speed up the access to Internet diagnosis and treatment and Internet hospitals under the law and regulations. It is necessary to further improve the construction of the telemedicine system, improve the utilization rate of telemedicine services, and promote the normalization of telemedicine services.

(Table 4 continues on next page)

ID	Year	Name of policies or guidelines	Main contents
(Continued from previous page)			
12	2020	National Development and Reform Commission, “Guiding Opinions on Supporting Sound Development of New Business Forms and New Modes, and Activating the Consumer Market to Drive and Increase Employment”	Actively develop Internet medical care; further strengthen the construction of smart hospitals; include eligible “Internet Plus” medical service fees into the scope of medical insurance payment; standardize and promote the modes of chronic disease Internet follow-up consultation, telemedicine, and Internet health consultation, and support coordinated development of the platform in areas such as medical treatment, health management, elderly care and health care to cultivate healthy consumption habits.
13	2021	State Council, “Guiding Opinions on Promoting the High-Quality Development of Public Hospitals”	Promote the deep integration of next-generation information technologies such as cloud computing, big data, the Internet of Things, blockchain, and fifth-generation mobile communications (5G) with medical services. Promote the “trinity” of electronic medical records, smart services, and smart management in the construction of smart hospitals and the construction of hospital information standardization. Vigorously develop telemedicine and Internet diagnosis and treatment. Promote the development and application of intelligent medical equipment such as surgical robots and intelligent auxiliary diagnosis and treatment systems.
14	2021	State Council, “National Medical Insurance Plan in the 14th Five-year Plan”	Support the orderly development of new models and formats of medical and health services such as telemedicine services, Internet diagnosis and treatment services, Internet drug distribution, and door-to-door nursing services, and promote the rational use of new technologies such as artificial intelligence; improve the “Internet Plus Healthcare” medical insurance service designated agreement management, and improve “Internet Plus Healthcare” medical service prices and medical insurance payment policies.
15	2022	National Health Commission, “Guiding Principles for the Planning of Setting up Medical Institutions (2021–2025)”	Strengthen the supporting role of informatization, effectively implement the informatization construction standards and norms of hospitals and grassroots medical and health institutions; promote the deep integration of artificial intelligence, big data, cloud computing, 5G, Internet of Things and other emerging information technologies and medical services; promote the construction of smart hospitals and hospital information standardization, and vigorously develop and standardize telemedicine and Internet medical care.
16	2022	National Development and Reform Commission, National Health Commission, “‘14th Five-Year’ Medical Equipment Industry Development Plan”	Promote the simultaneous development of open-source external devices, medical and health software, and basic medical facilities; establish and improve the whole-process management system for automatic perception, storage and transmission, intelligent computing, and evaluation and early warning of health information for key populations; carry out pilot projects for the combination of elderly health, medical care and elderly care with remote collaborative services, and promote harmonious combination of medical care and health care.
17	2022	State Council, “14th Five-Year Plan for National Health Program”	Carry out original technological research, and launch a batch of high-quality medical equipment that incorporates new technologies such as artificial intelligence. Encourage qualified places to build medical equipment application and promotion bases, and to create medical equipment industrial clusters with complete chains and distinctive features. Focus on the needs of health promotion, chronic disease management, and elderly care services. Focus on the development of new health products such as health management, intelligent rehabilitation aids, scientific fitness, and traditional Chinese medicine health care, and promote qualified artificial intelligence products to enter clinical trials.
18	2022	National Development and Reform Commission, “‘14th Five-Year Plan’ Bio-Economy Development Plan”	Artificial intelligence assists diagnosis and treatment. Research and development of medical image-aided diagnosis system. Support the application development of artificial intelligence-based medical image-aided diagnosis, pathological classification, and physiological signal analysis; carry out image recognition technology research and development for common injuries and diseases such as brain, lung, eye, bone, cardiovascular and cerebrovascular, and skin diseases; and accelerate medical image-aided diagnosis system productization and clinical auxiliary application; with the help of natural language processing, knowledge graph and other technical means, realize intelligent guidance to collect and distinguish medical record information, covering the whole process of physical examination, triage, decision-making, postoperative review.
19	2022	State Council, “Outline of the Strategic Plan for Expanding Domestic Consumption (2022–2035)”	Actively develop “Internet Plus Healthcare” services, improve the charging policies of Internet diagnosis and treatment; incorporated the qualified Internet medical services into the scope of medical insurance payment according to procedures.

Table 4: **Government policies and guidelines on digital health development in China released during 2016–2022 (see Supplemental Table 7 for the information in Chinese, the original language).**

interaction to enhance the effectiveness of interventions on CMDs prevention and management.

Develop dHealth applications based on behavioral theories

Behavioral theories are usually used to design messages for interventions and strategies of implementation. Recently, studies try to develop dHealth applications based on behavioral theories.[9,113,114] For example, Carr et al.[113] used social cognitive theory to develop a physical activity intervention that could be delivered via the Internet. The result showed that the internet-delivered theory-based intervention increased physical activity (an average of 1384 steps/day vs 816 steps/day) and positively influenced cardiometabolic risk factors (decreased waist circumference and coronary risk ratio) in sedentary overweight adults. Spittaels et al.[114] directed participants to a website that presented a tailored message based on the theory of planned behavior. They found that the tailored message was more read, printed, and discussed than the standard message. The transtheoretical model posits that individuals progress toward adopting a healthy behavior or toward cessation of unhealthy behavior.[115] Future studies should focus on identifying digital health applications based on theories in promoting behavioral change and improving metabolic and physical parameters.

Concern in privacy

The importance and concerns of users about data privacy have been raised in many studies.[69,73] While the use of dHealth tools provides patients with a sense of privacy and offers protocols and/or means for privacy protection.[116] Some health-related mobile apps did not follow the restrictions by data protection laws, which endangered the privacy of millions of users,[117,118] and one estimation reported even 95.6% of health-related applications represented potential harm through privacy infringements.[119]

Studies have pointed out the importance of privacy.[120,121] Blockchain and pseudonymization techniques may provide solutions to the low effectiveness and low-security issues in electronic health records.[121] Cloud-, biometric-, and password-based authentication, machine learning, and network-traffic-based security solutions have been used to improve privacy security.[120] Some countries in WPR have issued successive acts on data security protection.[122,123] Health apps in Singapore are required to be approved by the Health Sciences Authority before they can be released, strictly protecting data privacy and security.[116] Legal regulation and user supervision are needed to overcome the roadblock of dHealth data ownership and confidentiality in the long run.

Need more scientific research and innovation

Reliable research on new technologies related to dHealth is not yet sufficient. According to the rank of contributable risk to CMDs, the control of BP, lipids, and blood glucose is extremely important.[50] Measuring and managing these three core risk factors accurately, rapidly, and noninvasively through biosensors is what dHealth technologies should continue to focus on. Also, for newly recognized risk factors of CMDs such as environmental pollution,[124] technologies of corresponding monitoring, tracking and management need to be further developed to impede the epidemic of cardiometabolic risk factors and to achieve early prevention. In addition, verification studies are also needed to validate the innovative technological tools so that they can be applied to personalized healthcare. Further performance evaluations of digital interventions in effectiveness and equity are needed.

Moreover, WHO Member States in WPR need to capture the transformations in technologies, finance, and society, which are shaping population health. The WHO Regional Office for the Western Pacific reported that stimulating health innovation at a regional level is the initiative goal of Innovation for the Future of Public Health.[125] As one pivotal field in health innovation, dHealth technologies are advancing at unimaginable rates, but it is still a long journey to scale the dHealth innovation to population level in WPR.

Conclusions

dHealth technologies have developed rapidly over the past two decades. A growing number of studies conducted globally and in WPR have confirmed that dHealth is effective in the prevention and management of CMDs and related risk factors. However, it will still take some time for dHealth to be deeply involved in clinical guidelines and practices of CMDs and other NCDs. dHealth will promote to build a global community of health for all. Opportunities and challenges come from the regional policy environment, economic development, technological innovation, etc. In the future, there is a need to promote greater cooperation and technology sharing across WPR in the field of dHealth to compensate for the disparities in healthcare resources and improve health equity in WPR.

Contributors

FL, XY, DG and YW formulated the major concepts. YW and DG provided overall supervision. FL and XY drafted the manuscript and led data collection and analysis. DG, YW, WP, and MG reviewed and made critical revision for the manuscript. SZ, WC, QL, and ZX collected and interpreted the data. All authors approved the authorship and the final manuscript.

Declaration of interests

Mengchun Gong is an employee of Digital Health China, Co, Ltd. All other authors have no conflicts to declare.

Acknowledgements

We thank Yanhui Zhang, Haolong Pei and Wenjing Zhao of Southern University of Science and Technology for their work in data collection, figure improvement, and policy searching. We thank Profs. Yaogang Wang, Zumin Shi, Ling Zhang, Liang Sun, Xiaomin Sun, and Ruiyue Yang for their comments to help improve the manuscript, thank Dr. Yue Ma for her assistance in collecting some information and editing.

Funding: This work was supported in part by National Natural Science Foundation of China, China (Grant Numbers 82030102, 12126602) and the Shenzhen Science and Technology Innovation Committee, Shenzhen, China (Grant Number ZDSYS20200810171403013). The funders had no role in the design of this study, analyses, interpretation of the data, writing of the paper, or decision to publish.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2023.100817.

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