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Health technology assessment for digital technologies that manage chronic disease: a systematic review

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Abstract

Objective. A growing number of evaluation frameworks have emerged over recent years addressing the unique benefits and risk profiles of new classes of digital health technologies (DHTs). This systematic review aims to identify relevant frameworks and synthesize their recommendations into DHT-specific content to be considered when performing Health Technology Assessments (HTAs) for DHTs that manage chronic noncommunicable disease at home.

Methods. Searches were undertaken of Medline, Embase, Econlit, CINAHL, and The Cochrane Library (January 2015 to March 2020), and relevant gray literature (January 2015 to August 2020) using keywords related to HTA, evaluation frameworks, and DHTs. Included framework reference lists were searched from 2010 until 2015. The EUNetHTA HTA Core Model version 3.0 was selected as a scaffold for content evaluation.

Results. Forty-four frameworks were identified, mainly covering clinical effectiveness ($n = 30$) and safety ($n = 23$) issues. DHT-specific content recommended by framework authors fell within 28 of the 145 HTA Core Model issues. A further twenty-two DHT-specific issues not currently in the HTA Core Model were recommended.

Conclusions. Current HTA frameworks are unlikely to be sufficient for assessing DHTs. The development of DHT-specific content for HTA frameworks is hampered by DHTs having varied benefit and risk profiles. By focusing on DHTs that actively monitor/treat chronic noncommunicable diseases at home, we have extended DHT-specific content to all nine HTA Core Model domains. We plan to develop a supplementary evaluation framework for designing research studies, undertaking HTAs, and appraising the completeness of HTAs for DHTs.

Introduction

Digital health technologies (DHTs) have the potential to overcome the barrier of geographical location to widen access to health care and improve connectivity between patients and their healthcare team. A DHT's ability to continuously monitor a patient's physiological indicators with preset alert thresholds can expedite treatment compared with traditional office visits.

Chronic diseases are long-lasting conditions with persistent effects, often affecting a patient's social and economic circumstances (1). DHTs that help patients self-manage a long-lasting condition at home and escalate treatment only when required may be particularly suited to these patients. With increasing personal investment in electronic devices, the growing burden of chronic disease, and a limited health budget and workforce, there is potential for DHTs to offer a comparatively safe, effective, and cost-effective treatment pathway for chronic disease.

Terms describing DHT classes (digital devices, mhealth, and ehealth) are numerous, not consistently defined, and rapidly changing (see Table 1 footnote d for DHT class terms and definitions). The DHTs that are the focus of this review are those specifically designed for patients with diagnosed chronic noncommunicable diseases to use at home for active monitoring or treatment; for example, remote monitoring *via* implants/wearables and web-based cognitive behavioral therapy treatment programs. These DHTs with a functional classification of "Active monitoring" or "Treat" are classified into the highest risk evidence tier, Evidence Tier 3b, under the United Kingdom's (UK) National Institute for Health and Care Excellence (NICE) Evidence Standards (37), and are regulated as Medical Device Software (MDSW) under the new European Union (EU) Medical Devices Regulation (MDR) (48).

Despite the unique benefits of these DHTs, there are many risks/challenges associated with their use: technical reliability/stability of electronic sensors and data transmissions; transparency of algorithms for autonomous decisions; access and usability; reorganization of workflows/infrastructure; and security threats in data transmissions and storage. Given that patients with chronic disease may already be socially isolated and economically vulnerable, the use of DHTs in this population deserves careful consideration. A tailored approach to

Assessment

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Table 1. Summary of coverage and DHT-specific content by the HTA domain for each framework

HTA Domains[a]	1. Health problem and current use of technology (CUR)		2. Description and technical character of technology (TEC)		3. Safety (SAF)		4. Clinical effectiveness (EFF)		5. Costs and economic evaluation (ECO)		6. Ethical analysis (ETH)		7. Organization aspects (ORG)		8. Patients and Social aspects (SOC)		9. Legal aspects (LEG)		DHT class[d] covered by framework
Frameworks	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	
Eysenbach 2011 (2)	◗		✓	D	◗	D	◗	D	✗		◗	D	✗		✗		✗		eHealth
Andalusian Health Quality Agency (AHQA) 2012 (3)	◗		◗	D	◗	D	◗	D	✗		◗	D	✗		✗		◗	D	mHealth Apps
Kidholm et al. 2012 (4)	✓		✓	D	✓	D	◗	D	◗	D	◗		✓		◗	D	✓	D	eHealth
Haute Autorité de Santé (HAS) 2013 (5)	✗		✗		✗		◗		✗		✗		✗		✗		✗		MDSW
Khoja 2013 (6)	✗		✗		✗		◗	D	◗		◗		◗		✗		✗		eHealth
Lewis and Wyatt 2014 (7)	✗		✗		◗	D	✗		✗		✗		✗		✗		✗		mHealth
Bergmo 2015 (8)	✗		✗		✗		✗		✓	D	✗		✗		✗		✗		eHealth
Mohr et al. 2015 (9)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		digital health
Mookherji et al. 2015 (10)	✗		✗		✗		◗		✗		✗		✗		✗		✗		mHealth
Steventon et al. 2015 (11)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		digital health
EU Draft Consard Ltd 2016 (12)	◗		✓	D	◗	D	◗	D	◗		◗	D	✗		✗		◗	D	mHealth Apps
Gorski 2016 (13)	◗		✗		✗		✗		◗	D	✗		✗		✗		✗		mHealth
McMillan et al. 2016 (14)	✗		✗		◗	D	◗	D	✗		✗		✗		✗		✗		mHealth (behavior intervention)
McNamee et al. 2016 (15)	✗		✗		✗		✗		◗	D	✗		✗		✗		✗		digital health
Murray et al. 2016 (16)	◗		◗	D	◗	D	◗	D	◗	D	✗		✗		✗		✗		digital health
Rojahn et al. 2016 (17)	✗		✗		✗		✗		◗		✗		◗	D	✗		✗		MDSW
IRB Advisor 2017 (18)	✗		✗		✗		✗		✗		◗	D	✗		✗		✗		mHealth
Lennon et al. 2017 (19)	✗		✗		✗		✗		✗		✗		◗	D	✗		✗		digital health
Maar et al. 2017 (20)	✗		✗		✗		◗		✗		✗		✗		✗		✗		mHealth
Michie et al. 2017 (21)	✗		✗		◗	D	◗	D	◗	D	✗		✗		✗		✗		digital health

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Philpott et al. 2017 (22)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		mHealth Apps
Drury et al. 2018 (23)	◗	D	◗	D	✗		✗		✓	D	✗		◗	D	✗		✗		digital health
European Commission (EC) 2018 (24)	✗		◗	D	◗	D	✗		◗	D	✓	D	◗	D	◗		◗	D	digital health
Hogaboam 2018 (25)	✗		✓	D	◗	D	◗	D	◗	D	✗		◗	D	◗	D	✗		digital devices
Jurkeviciute 2018 (26)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		eHealth
Nielsen and Rimpiläinen/ The Digital Health & Care Institute 2018 (27)	✗		◗	D	◗	D	◗	D	✗		✗		✗		✗		◗	D	mHealth Apps
Sax et al. 2018 (28)	✗		✗		✗		✗		✗		◗	D	✗		✗		◗	D	mHealth
UK Academy of Medical Sciences 2018 (29)	✗		✗		◗	D	✗		✗		◗	D	✗		✗		✗		digital health
Wyatt 2018 (30)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		mHealth Apps
Beintner et al. 2019 (31)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		eHealth
Caulfield et al. 2019 (32)	◗		✓	D	◗	D	◗	D	◗	D	✗		✗		✗		◗	D	digital devices
UK Dept Health & Social Care 2019 (33)	◗		◗	D	◗	D	◗		◗		✗		✗		◗		◗	D	digital health
HAS 2019 (34)	✓		◗	D	◗	D	◗		◗		✗		◗	D	✗		✗		MDSW
Draft HAS 2019 (35)	◗		◗	D	◗	D	◗	D	✗		✗		✗		✗		✗		AI-based MDSW
Huckvale et al. 2019[b] (36)	✗		✗		◗	D	✗		✗		◗	D	✗		✗		✗		mHealth Apps
NICE 2019 (37)	◗	D	◗	D	◗	D	✓	D	✓		◗		✓	D	◗		◗	D	digital health
NHS Digital 2019 (38)	✓		◗	D	◗	D	◗		✗		✗		✗		✗		✗		digital health
Rajan et al. 2019 (39)	✗		✗		✗		✗		◗	D	✗		◗	D	✗		✗		eHealth
Draft Australian commission on safety and quality in health care (CSQHC) 2020 (40)	✗		◗	D	✓	D	◗	D	✗		◗	D	◗		◗	D	◗	D	digital mental health services
Dick et al. 2020 (41)	✗		✗		✗		◗	D	✗		✗		✗		✗		✗		mHealth
Draft Federal Ministry of Health Germany 2020 (42)	◗		◗		◗	D	◗	D	✗		✗		◗		✗		◗	D	digital health

(*Continued*)

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Table 1. (*Continued.*)

HTA Domains[a]	1. Health problem and current use of technology (CUR)		2. Description and technical character of technology (TEC)		3. Safety (SAF)		4. Clinical effectiveness (EFF)		5. Costs and economic evaluation (ECO)		6. Ethical analysis (ETH)		7. Organization aspects (ORG)		8. Patients and Social aspects (SOC)		9. Legal aspects (LEG)		DHT class[d] covered by framework
Frameworks	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	Coverage	DHT specific	
Health Information and Quality Authority (HIQA) Ireland 2020 (43)	✗		✗		✗		✗		✗		✗		✗		✗		◗	D	digital health
Draft Aust. Medical Services Advisory Committee MSAC 2020[c] (44)	✓		◗		◗	D	✓		✓		✓		✓		◗		✓		digital health
Moshi et al. 2020 (45)	◗	D	✓	D	✓	D	◗	D	◗	D	◗	D	◗	D	◗	D	◗	D	mHealth

✓ Majority coverage; ◗ Partial coverage (less than two-thirds of topics covered); ✗ No coverage of HTA domain; D DHT-specific content; DHT, digital health technology; HTA, health technology assessment.

[a] From HTA Core Model version 3.0 (46).

[b] Although this paper does not strictly meet the evaluation framework inclusion criteria, it provides DHT-specific content on data privacy relevant to the Safety and Ethical Analysis domains.

[c] Note this is a draft version of the technical guidelines for MSAC applications that includes DHT-specific content. There exist two in-force technical guidelines: One for investigative and one for therapeutic technologies that do not include digital specific content.

[d] Terms and definitions for DHT classes.

Term	Definition	Source
digital devices	Human performance and behavior measurement devices, for example, sensors and wearables	Caulfield et al. (32)
mHealth	The use of mobile wireless technologies for health. This includes digital devices defined above and either mobile or web-based applications "Apps"	WHO (47)
mHealth Apps	The subset of mHealth technologies that are mobile or web-based applications ("Apps")	Study defined
eHealth	The use of information and communications technology in support of health and health-related fields. This includes mHealth as defined above	WHO (47)
digital health	A broad umbrella term encompassing eHealth (which includes mHealth), as well as emerging areas, such as the use of advanced computing sciences in "big data," genomics and artificial intelligence	WHO (47)
medical device software (MDSW)	Software that is intended to be used, alone or in combination, for a purpose as specified in the definition of a "medical device" in the medical devices regulation or *in vitro* diagnostic medical devices regulation	MDCG (48)
AI-based MDSW	MDSW with embedded self-learning algorithms	HAS (35)
digital mental health services	Mental health, suicide prevention, or alcohol and other drug services…in the form of information; digital counseling; treatment (including assessment, triage, and referral); or peer-to-peer service that is delivered to a service user *via* a digital means	ACSQHC (40)

WHO, World Health Organization; MDCG, Medical Device Co-ordinating Group; HAS, Haute Autorité de Santé; ACSQHC, Australian Commission on Safety and Quality in Health Care.

conducting health technology assessments (HTAs) of DHTs could assist such considerations by explicitly examining the unique benefits and risks of DHTs for these vulnerable patients.

Although HTA has multiple definitions, for this paper, we define HTA as a multidisciplinary process (49) to assess and prioritize new technologies against existing health care interventions based on comparative safety, clinical, and cost-effectiveness (50) at the lifecycle stage of public funding assessment.

Given that the topics and issues within established HTA frameworks have evolved to guide the assessment of pharmaceuticals, medical devices, and medical services, it is not clear if such frameworks are fit for purpose in assessing DHTs. The last decade has seen an increase in DHT-specific evaluation frameworks, HTA agency guidance, and improved clarity in DHT regulation (EU MDR (48;51) and EU General Data Protection Regulation [GDPR] (52)); all important considerations for a DHT-specific HTA framework.

An exponential rise in clinical applications for DHTs has driven an increase in clinical trials of these technologies. Recent systematic reviews (53–56) of HTAs and economic evaluations for DHTs identify a wide variation in the scope and methods used, limiting the quality and consistency of evidence available to inform funding decisions. Identifying and defining DHT-specific content within generally accepted HTA frameworks may help researchers collect consistent and robust evidence for decision makers.

The aim of the current systematic review is twofold: first, to identify and synthesize the recommendations of DHT-specific HTA and evaluation frameworks using an established HTA model with a broad scope of content and applicability to multiple jurisdictions as a scaffold, and second, to develop a comprehensive list of DHT-specific content to be considered when undertaking an HTA to inform funding decisions for DHTs that manage chronic noncommunicable disease at home.

Methods

This systematic review was registered with PROSPERO (#CRD42020186888) and is reported in accordance with the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines (57).

Inclusion Criteria

This review focuses on HTA frameworks for evaluating comparative effectiveness, cost-effectiveness, and safety for public funding purposes, not on the evaluation of effectiveness or safety for individual interventions. The review is limited to recently published frameworks because of the rapid development of DHTs. Frameworks also have to be suitable for MDSW. For these reasons, peer-reviewed journal articles, dissertations and theses, HTA agency, and health economic institute publications that discuss methods for performing an HTA, or an assessment of comparative effectiveness, safety, or cost-effectiveness, appropriate for MDSW and published between 2015 and 2020, were eligible for inclusion.

Exclusion Criteria

The following types of frameworks were excluded: Guidelines or regulations from medical device regulators; frameworks for evaluating DHTs used in clinical trials of nondigital interventions; and frameworks targeted solely at DHTs that are not MDSW. Frameworks for implementing digital technology for health systems, such as clinical decision support, electronic health record systems, and establishing telemedicine businesses, were also excluded.

Information Sources and Search Strategy

Medline, Embase, Econlit, CINAHL, and The Cochrane Library were searched from 1 January 2015 to 20 March 2020 using keywords related to HTA, evaluation frameworks, and DHT. The full search strategy is presented in Supplementary Table 1. The start date of January 2015 was selected given the rapid development of DHTs and the focus on up-to-date HTA frameworks.

Gray literature was searched using the Canadian Agency for Drugs and Technologies in Health (CADTH)'s *Grey Matters* (58). Agencies listed under HTA and Health Economics (see Supplementary Table 2) were searched for evaluation frameworks published between 1 January 2015 and 31 March 2020 using the keyword searches: "electronic health" or eHealth or "mobile health" or mHealth or telehealth or telemedicine or "digital health" or "digital medicine." The ProQuest Dissertations and Theses Global (PQDT) database was searched using these same keywords. The gray literature search was updated on 31 August 2020 for releases post 31 March 2020.

To reduce the risk of missing DHT-specific content from evaluation frameworks published before 2015 but not subsequently updated, pearling of included frameworks was conducted. The start date of 2010 for pearling was chosen because, prior to 2010, DHT evaluation frameworks had focused mainly on telecommunications as a replacement for face-to-face consultations (59–63), and these DHTs are out of scope for our review.

Study Selection

All authors participated in the title and abstract screening. Full-text screening was undertaken by AvH, with 10 percent of full texts reviewed independently by JC and conflicts resolved by SN.

Data Extraction

Data extracted for each framework included: First author/institution, the year of publication, the country/region that the framework is intended for, the Web site or journal citation, the author's affiliation (e.g., university, HTA agency, and government agency), the intended audience, the purpose of the framework (and if relevant, the name of the framework), and the DHT classes covered.

Data extraction was conducted by AvH and checked by JC.

Content Evaluation

The aspects covered by the included frameworks were analyzed using the European Network for Health Technology Assessment (EUNetHTA) HTA Core Model version 3.0 (HTA Core Model) (46). The HTA Core Model was selected as our analytic scaffold, because it is used across multiple countries to assess a range of health technologies, it includes a wide range of issues for content mapping, and it uses internationally accepted HTA terminology. The model has nine domains, with 51 topics and 145 issues (see Supplementary Table 3). Each of the 145 issues has a unique assessment element identifier (issue identifier) and a card that clarifies which content is common to all applications or is specific to applications within a technology class.

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Content from the included frameworks was mapped to the 145 issues of the HTA Core Model in a two-stage process. Initially, DHT-specific topics and issues raised by the frameworks but not already included in the model were included to ensure a comprehensive collation of DHT content. For new DHT-specific topics, new topic names were proposed (indicated as *NEW* in tables), and for new DHT-specific issues, new issue identifiers were assigned using a *DHT* prefix. Subsequently, all content recommended by each framework was mapped to the extended set of issues. Decisions regarding whether to map content from the included frameworks to new DHT-specific issues or existing HTA Core Model issues were made by AvH and reviewed by SN.

For each included framework, we recorded whether it partially or (near) completely covered each HTA domain and whether it recommended any DHT-specific content in each HTA domain.

Synthesis of Results

We calculated the number and proportion of frameworks covering, and recommending DHT-specific content in, each HTA domain.

We summarized the content mapping results into two lists: The first comprised DHT-specific content to be considered when undertaking an HTA; the second comprised existing HTA content (i.e., content common across digital and nondigital technologies) but recommended by the frameworks as essential for undertaking HTAs on DHTs. For both lists, each item of content was reported by HTA domain, topic, issue identifier, and the reference(s) of the framework(s) that recommended it for ease of use and traceability.

Risk of bias and completeness of reporting assessments (beyond comparison with the HTA Core Model) were not relevant for this systematic review.

Results

Study Selection and Characteristics

The peer-reviewed literature and gray literature searches resulted in 9,236 unique records (Supplementary Figure 1). After applying our inclusion and exclusion criteria, forty-four frameworks were included (Table 1 and Supplementary Table 4). These frameworks were published between 2011 and 2020, with twenty-three dating from 2018 to 2020. Twenty-two frameworks were indicated as being international, eleven were intended for EU countries, seven for the UK, and four for the Asia Pacific region. Fifteen frameworks covered digital health, seven were limited to eHealth, fifteen further refined their scope to mHealth, five were strictly intended for MDSW, and two targeted sensors and wearables (digital devices). Twenty-six first authors were affiliated with universities, seven with HTA agencies, and seven with government bodies.

HTA Domain Coverage and Recommended HTA Content From Included Frameworks

Table 1 presents a summary of coverage and DHT-specific content by HTA domain for each framework, and Table 2 reports

Table 2. Summary of EUNetHTA HTA core model version 3.0 (46) domain coverage and digital health technology (DHT)-specific content of frameworks in review

			Frameworks ($N = 44$)			
			Frameworks covering the domain	Full or near-full coverage	Partial coverage	Discusses DHT-specific content
Domains within the HTA Core Model (46)			*n* (%)	*n* (%)	*n* (%)	*n* (%)
1	CUR	Health problem and current use of technology	16 (36%)	4 (9%)	12 (27%)	3 (7%)
2	TEC	Description and technical characteristics of technology	19 (43%)	6 (14%)	13 (29%)	17 (39%)
3	SAF	Safety	23 (52%)	3 (7%)	20 (45%)	23 (52%)
4	EFF	Clinical effectiveness	30 (68%)	2 (5%)	28 (63%)	23 (52%)
5	ECO	Costs and economic evaluation	19 (43%)	4 (9%)	15 (34%)	12 (27%)
6	ETH	Ethical analysis	14 (32%)	2 (5%)	12 (27%)	10 (23%)
7	ORG	Organizational aspects	14 (32%)	3 (7%)	11 (25%)	9 (20%)
8	SOC	Patient and social aspects	8 (18%)	0 (0%)	8 (18%)	4 (9%)
9	LEG	Legal aspects	14 (32%)	2 (5%)	12 (27%)	13 (30%)

HTA, health technology assessment; DHT, digital health technology.
Frameworks covering the domain: Framework provides any coverage of the domain.
Full or near-full coverage: Framework covers more than two-thirds of topics in the domain.
Partial coverage: Framework covers less than two-thirds of topics in the domain.
Rows of the table are the domains of the EUNetHTA HTA Core Model version 3.0 (46):
CUR: Describes the new technology's target population, target condition and current management, current and expected utilization, and regulatory status.
TEC: Describes the new technology's features in enough detail to differentiate it from comparators, and the investments, tools, and training required to use it.
SAF: Identifies unwanted or harmful effects of the new technology important to patients or the decisions of healthcare providers and policy makers.
EFF: Provides evidence of comparative effectiveness of the new technology in producing health benefits in the relevant healthcare setting.
ECO: Provides information on the new technology's costs, health-related outcomes, and economic efficiency to inform value for money judgments.
ETH: Considers potential harms to autonomy, respect for persons, justice, and equity from the use of the new technology or from performing the HTA.
ORG: Identifies resources to mobilized or organized to implement the new technology and the consequences (Intra/interorganizational and health system).
SOC: Considers issues related to the new technology relevant to patients, carers, and social groups.
LEG: Identifies rules and regulations protecting patient's rights and societal interests for consideration when evaluating the new technology.

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the number and proportion of frameworks covering, and recommending DHT-specific content for, each HTA domain.

As stated in Methods, we created two lists of HTA content recommended by the frameworks. Table 3 presents the list of DHT-specific content to be considered when undertaking an HTA. Table 4 presents the list of existing HTA content common across digital and nondigital technologies but recommended as essential for undertaking HTAs on DHTs. A more detailed listing of the recommended content can be found in Supplementary Table 5.

The included frameworks recommended DHT-specific content in 28 of 145 issues (18 of the 51 topics) and all nine domains of the HTA Core Model (see Table 3). Another twenty-two issues (eight topics) not included in the HTA Core Model are recommended in six HTA domains; predominantly Domain 3: Safety (SAF) and Domain 4: Clinical effectiveness (EFF).

The frameworks' coverage of HTA domains, DHT-specific content, and HTA content recommendations are summarized below by HTA domain.

Domain 1: Health Problem and Current Use of the Technology (CUR)

More than one-third of frameworks covered CUR, but only three frameworks (7 percent) recommended DHT-specific content, the least out of all domains (see Table 2). The topics and issues raised by the frameworks for CUR were the same as the HTA Core Model. DHT-specific content was confined to issues of the new technology's current and expected utilization (see Table 3).

Domain 2: Description and Technical Characteristics of the Technology (TEC)

TEC was covered by nineteen frameworks (43 percent), with seventeen discussing DHT-specific content (see Table 2). The topics raised by the frameworks for TEC were the same as the HTA Core Model. However, thirteen frameworks suggested a new issue addressing how well the features of DHTs and their comparator (s) overcome technical barriers. DHT-specific content was recommended for HTA Core Model issues of material investments, training, and information required to use the technology (see Table 3).

Domain 3: Safety (SAF)

SAF had the most DHT-specific content, with all twenty-three frameworks covering this domain recommending DHT-specific content (see Table 2). The frameworks recommended three DHT topics (covering a total of ten issues) not in the HTA Core Model for SAF: Quality and safeguarding (data security and privacy, interoperability, usability and accessibility, transparency, and adequate disclosures for algorithms); technical safety (technical reliability and stability, continuity and updates); and communicating for safety (see Table 3).

Domain 4: Clinical Effectiveness (EFF)

EFF was the most commonly covered domain, with thirty frameworks (68 percent) making recommendations in this domain. The frameworks suggested four additional topics (and eight issues) for EFF: Demonstrating effectiveness (DHT-appropriate study design, comparators, outcome measures, and transparent reporting of effectiveness studies); ensuring reliable information content; the use of appropriate and best practice behavior change; and measures for assessing the external validity/generalisability of DHT effectiveness studies. DHT-specific content was also recommended for the HTA Core Model issue of patient satisfaction.

Domain 5: Costs and Economic Evaluation (ECO)

Nineteen frameworks covered ECO, with twelve making DHT-specific recommendations. Cost-effectiveness and budget impact frameworks comprise this domain. The topics raised by the frameworks for ECO were the same as the HTA Core Model. However, a new issue within the validity of the model(s) topic was recommended to ensure that the changes in fixed costs for scaling up DHTs from the trial to the health-system level have been investigated. DHT-specific content was recommended for estimating resource utilization, costs, and health outcomes.

Domain 6: Ethical Analysis (ETH)

Fourteen frameworks covered ETH, with ten making DHT-specific recommendations. The topics and issues raised by the frameworks for ETH were the same as the HTA Core Model. However, DHT-specific content was recommended for four HTA Core Model topics (seven issues): Benefit-harm balance (benefits and harms for stakeholders other than the patient, and hidden unintended consequences of the technology), autonomy (vulnerable persons, threats to autonomy, and supports required); respect for persons (privacy); and justice and equity (accessibility).

Domain 7: Organizational Aspects (ORG)

Fourteen frameworks covered ORG, with nine making DHT-specific recommendations. A new topic not in the HTA Core Model for ORG, namely, contextual issues for barriers and enablers to DHT implementation, was recommended. DHT-specific content was also recommended for two HTA Core Model topics (five issues): Health delivery process (changes to current work processes, resources, training, co-operation, and communication) and the structure of the health system (processes to ensure access to the new technology).

Domain 8: Patients and Social Aspects (SOC)

SOC was the least covered with only eight frameworks making recommendations, and only four making DHT-specific recommendations. The topics and issues raised by the frameworks for SOC were the same as the HTA Core Model. DHT-specific content was limited to two issues: Improving access to health care and upfront communication of direct and data usage costs of DHTs to improve treatment adherence.

Domain 9: Legal Aspects (LEG)

Fourteen frameworks covered LEG, with almost all, thirteen, making DHT-specific recommendations. A new issue of professional liability was recommended for the HTA Core Model topic of ownership and liability. DHT-specific content was also recommended for the HTA Core Model topic of patient privacy, that is, designing DHTs to comply with laws/binding rules for data security and privacy.

Discussion

To our knowledge, we have conducted the most extensive systematic search of international peer-reviewed and gray literature for HTA and evaluation frameworks for DHTs designed to actively monitor or treat a diagnosed chronic noncommunicable disease

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Table 3. Digital specific content to be considered when undertaking health technology assessments (HTAs) of DHTs

HTA domain[a]	Topic *(EUN)*[a]/*(NEW)*[b]	Issue content	Issue ID[a,c] (Reference)
CUR	Utilization (*EUN*)	Describe inputs, algorithms, and outputs of DHTs	F0001 (45)
		Do/will health workers/patients invest in the personal digital technologies required to use DHTs? Costly/difficult to support?	A0011/2 (23;37)
		Are DHTs limited in terms of platforms, languages, network connectivity, or users' digital literacy?	
		Are (will) data on DHT usage (be) collected and accessible ongoing?	
TEC	Features of Technology (*EUN*)	How well do DHTs and comparator(s) perform in overcoming technical barriers: Interoperability, data extraction, visualization, *etc.*?	DHT01 (3;4;12;23–25;27;32–34;38;40;45)
	Investments/tools required (*EUN*)	Consider device size, battery life/charging method, operating system, connectivity, data access and storage, data security, technical support	B0007 (2;4;12;25;32;38;45)
	Training/information needed (*EUN*)	Personnel/caregivers/patient/family: Training required/provided on personal data handling, digital skills, and digital health literacy? Also consider these requirements in ORG, Topic: Health delivery process, G0002/3	B0013/4 (23–25;45)
SAF	Quality and safeguarding (*NEW*)	How well are data security and privacy managed? Do they comply with the GDPR principles of data minimization/protection by default/design? Also consider laws/binding rules in LEG, Topic: Privacy of the Patient, I0007/9	DHT02 (2–4;12;14;24;25;27;29;32;33;36–38;40;42;45)
		How well is interoperability designed and data quality managed?	DHT03 (12;24;33;38;40)
		How transparent are DHT risks (e.g., data sharing, conflicts of interest) to a user?	DHT04 (2;3;12;24;33;38;40;45)
		How well is a DHT designed for usability and accessibility? Also consider ensuring access in ORG, Topic: Structure of the health system, G0101	DHT05 (3;38;40)
		Is adequate information disclosed on DHT algorithms to evaluate their risk?	DHT06 (33;35)
	Technical safety (Reliability and stability) (*NEW*)	How technically reliable and stable are DHTs and comparator(s)?	DHT07 (4;7;12;27;35;37;38;40;42;45)
		How well are updates/continuity of DHTs managed?	DHT08 (40;45)
	Communicating for safety (*NEW*)	Can a user send critical risk information to a DHT provider?	DHT09 (3;40)
		Processes for correct identification of users in DHTs?	DHT10 (40)
		Processes to communicate changes to or transfer of a patient's care?	DHT11 (40)
EFF	Demonstrating effectiveness (*NEW*)	Are accepted methods used to overcome common methodological problems in RCTs for DHTs, for example, achieving blinding, biases from informed consent?	DHT12 (2;5;9;34)
		Is it clear whether a DHT was changed (bug fixes, content) during the trial?	
		Was digital literacy an implicit eligibility criterion?	
		Was the comparator group restricted in the DHT to which they had access?	DHT13 (16;21)
		Have DHT-specific and validated outcome measures been collected: that is, the intensity of use (dose, exposure), online adherence, engagement	DHT14 (2;26;31;37)
		Has data collection been embedded in the DHT-created systematic bias?	
		Is reporting of the RCT in accordance with CONSORT E-HEALTH?	DHT15 (20;26)
	Reliable information content (*NEW*)	Is the health information provided by a DHT accurate, valid, up to date, comprehensive, clear, and tailored to a users' diversity?	DHT16 (2–4;12;27;37;40;42;45)
	Use of appropriate behavior change techniques (*NEW*)	Do DHTs use appropriate and best practice behavior change techniques? Is the mechanism credible?	DHT17 (2;9;12;14;16;21;27;37)

(*Continued*)

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Table 3. (*Continued.*)

HTA domain[a]	Topic *(EUN)*[a]/*(NEW)*[b]	Issue content	Issue ID[a,c] (Reference)
		Is the targeted behavior change apparent to the user, and are the appropriate supports in place? Are they relevant for the target population?	
	External validity/ generalizability (*NEW*)	Have patient identity validation and obtaining off-line contact details to improve follow-up rates jeopardized external validity?	DHT18 (16;21)
		Are results generalizable to settings where telecommunication infrastructure is poor, or is there low network connectivity?	DHT19 (4;41)
	Patient satisfaction (*EUN*)	Is there evidence that DHTs are usable and accessible for a diverse range of users, including those with disabilities or limited technical ability? Are there obvious design issues hindering usability, for example, washable, durable, cause skin allergies?	D0017 (4;12;16;25;27;32;38;41)
ECO	Resource utilization (*EUN*)	Consider costs of supporting health care providers in using DHTs and costs to use DHTs in the health system (licensing, platforms, hardware, etc.)	E0001/2/9 (4;8;45)
	Validity of the model(s) (*EUN*)	Are changes in fixed costs for scaling up DHTs known? Is the cost function per patient smooth or stepped?	DHT20 (4)
	Measurement and estimation of outcomes (*EUN*)	Have DHT-specific outcomes been considered and measured where possible; for example, self-management benefits, better-connected healthcare professionals?	E0005 (8;23;24)
		Given that all the functionalities of DHTs may not be used, and many people may not use DHTs from the outset, are the estimated benefits of DHTs realistic?	
ETH	Benefit-harm balance (*EUN*)	Are DHTs designed and used for clearly defined purposes that uphold the health system's social values or the society's?	F0011 (29)
		Is the value of patient data realized but protected from commercial use?	
		Do DHTs preserve and enhance direct contact between patients and healthcare professionals while supporting them to manage their health?	
		Where are alerts about a patient's health reported? Are real-time data securely transmitted? How does a DHT affect a participant's safety and welfare?	F0003 (2;18)
		Can DHTs promote a false sense of security or create harm from patients having access to their data without someone to interpret them?	
	Autonomy (*EUN*)	Do DHTs use simple and understandable language?	F0005 (12)
		For DHTs targeting behavior change, what controls limit DHTs influencing a person's behavior for purposes other than those stated?	F0004 (28)
		Is a user always able to make independent and authentic decisions based on an adequate range of options given by a DHT?	
		Are any potential conflicts of interest (funding, promotion) clearly disclosed?	F0006 (12;18;45)
		Is there concise information on how a DHT's contents were selected?	
		Are the data collected by DHTs, their use, and availability clearly disclosed?	
	Respect for persons (*EUN*)	Does a DHT clearly identify who holds any personal data?	F0101 (12;24;36;40)
		Are DHTs regularly audited for transmissions with third parties that include linkable identifiers? Are users informed of this risk?	
	Justice and Equity (*EUN*)	How do DHTs overcome access barriers, for example, patients/ with a lack of economic resources, poor IT skills/digital health literacy?	H0012 (33;40;45)

(*Continued*)

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Table 3. (*Continued.*)

HTA domain[a]	Topic *(EUN)*[a]/*(NEW)*[b]	Issue content	Issue ID[a,c] (Reference)
		Are DHTs compatible with common assistive technologies and available in a wide number of languages?	
ORG	Health delivery process (*EUN*)	How does removing the constraints of distance and sharing patient data impact staff work methods and the interactions between medical staff, patients, and their carers?	G0100 (34)
		Consider changes to electronic communication, information/reporting systems, face-to-face consultations, and staff communication	G0004 (4)
	Contextual issues (*NEW*)	Consider all contextual barriers and enablers to DHT uptake: Infrastructure, clinical endorsement, champions of DHTs, supplementary payments, etc.	DHT21 (17;19;23)
SOC	Social group aspects (*EUN*)	How much does a DHT improve the connectivity between the healthcare team and the patient? Is access improved for remote patients?	H0201 (25)
	Communication aspects (*EUN*)	Are expected direct and data usage costs made clear to users to improve adherence rates?	H0203 (17;19;23;40)
LEG	Ownership and liability (*EUN*)	Professional liability: Clarify responsible parties, litigation risks, and insurance implications of DHT recommendation or use	DHT22 (45)

[a]From EUNetHTA HTA Core Model version 3.0 (46).
[b]New topic.
[c]A DHT prefixed denotes a new issue (i.e., *DHTXX*).

at home. These DHTs, such as remote monitoring *via* digital devices or web-based treatment programs, are classified into the highest risk evidence tier under the NICE Evidence Standards (37) and are strictly regulated under medical device regulation (48). Deliberately focusing on a high-risk DHT class has allowed us to identify a fuller range of DHT-specific content, with the expectation that not all of this content will apply to lower-risk DHT classes.

The findings from this systematic review demonstrate that there is no single framework that is used uniformly across jurisdictions to assess the comparative safety, effectiveness, and cost-effectiveness of DHTs. The NICE's Evidence Standards for DHTs (37), although DHT-specific, focus primarily on the EFF and ECO domains. Our review highlights the need for more comprehensive technology-specific questions for undertaking HTAs of DHTs across all HTA domains.

Our analysis shows that HTA Core Model topics are relevant for funding assessment of DHTs, covering all topics raised by the frameworks in six domains. However, the included frameworks recommend adding DHT-specific content in 28 of 145 issues (18 of the 51 topics) and all nine domains of the HTA Core Model (see Table 3). They also recommend another twenty-two issues (eight topics) that are not currently included in the HTA Core Model (see Table 3). Collectively, this suggests that the HTA Core Model is not sufficiently comprehensive for undertaking HTAs of DHTs that manage chronic noncommunicable disease at home.

We also highlight the existing HTA content common to digital and nondigital technologies but essential for DHTs, as shown in Table 4. Given the rapid growth in DHTs over recent years, identifying current alternative DHTs available for patients with the targeted condition (22) assists in estimating the expected utilization of DHTs and understanding the DHTs available to comparator groups. Rapid growth in DHT development also makes identifying a DHT's stage in the product lifecycle crucial. The NICE (37) requires evidence that a DHT is relevant and has been piloted successfully in the healthcare system and also evidence that a DHT can perform for an expected number of users, for example, adequate server size. Kidholm et al. (4) also stipulate that the technology is in a steady state to enable a robust economic analysis to be performed. The lack of face-to-face contact in remote monitoring/self-management interventions may also require heightened risk management controls. For example, defined parameters to identify and respond to a patient's acute deteriorating condition and controls for vulnerable users (40) may reduce patient risk. Remote-monitoring DHTs require a consideration of the management of incidental findings. All DHTs require evidence of improved access to health care.

Because the DHTs of interest to this study are used directly by patients for self-management, existing HTA content examining patient satisfaction is crucial. Identifying changes to infrastructure, services, and systems for existing and new care pathways associated with DHTs is also critical when changing health-care delivery from in-person consultations to remote. An organizational enabler to the successful implementation of DHTs is its credibility with healthcare professionals; the NICE (37) requires published or publicly available evidence documenting the relevant healthcare experts' role in the development of DHTs.

There was much discussion in the included frameworks about innovative trial designs for assessing the clinical effectiveness of DHTs in EFF and the complexity of economic evaluation in ECO. However, no evidence was provided that these alternate trial designs are appropriate when DHTs have reached a steady state. The framework authors concluded that a high-quality randomized controlled trial (RCT) conducted in people with the target condition in a setting relevant to the health system (37) remains the most unbiased evidence of clinical effectiveness for DHTs (5;10;22;30;34;37). Advice for overcoming common methodological problems for RCTs of DHTs, such as blinding and informed consent, was given by the Haute Autorité de Santé (5). Little

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Table 4. Existing health technology assessment (HTA) content that is common across DHTs and non-DHTs

HTA domain[a]	Topic[a]	Issue content	Issue ID[a] (Reference)
CUR	Current management of the condition	What DHTs do those with the condition already have available to them?	A0018 (33)
TEC	Features of the technology	Is there evidence that DHTs are relevant to the health system and can perform to the expected number of users (e.g., is the server size adequate)?	B0003 (4;37)
		As DHTs often develop rapidly, are they in a steady state to enable a robust economic analysis to be performed?	
SAF	Risk management	Are there defined parameters to identify and respond to a patient's acute deterioration?	C0062 (40)
EFF	Patient satisfaction	Is there evidence to show that relevant stakeholders were involved in the design and satisfied with a DHT?	D0017 (2–4;12;14;16;25;27;32;37;38;40;41;44)
		Are ongoing data collected on user satisfaction that will be acted upon and available to decision makers?	
		Have qualitative data been collected and analyzed to evaluate the mode of action and the differences between recipients and sites, and to identify barriers to uptake or implementation?	
		Does a DHT create additional burden on the patient or caregiver that may affect uptake or adherence?	
ECO	None noted		
ETH	Benefit-harm balance	What will be done with any incidental findings?	F0003 (18)
	Autonomy	Does a DHT provider: • Identify the diversity of service users/groups of users at a higher risk of harm and adapt the DHT accordingly? • Have systems to minimize the risk for children and young people to be harmed?	F0005 (40)
	Justice and Equity	Show evidence of a DHT being used in hard-to-reach populations	H0012 (37)
ORG	Health delivery process	Describe the steps in the proposed new care pathway or pathways incorporating a DHT intervention for the relevant population and setting	G0100 (37;44)
		Detail any infrastructure and service-level changes needed to existing pathways and associated systems to implement, operate, and maintain the new pathway	
	Culture	Do DHTs have credibility with healthcare professionals?	G0010 (37;40;42)
		Is there published or publicly available evidence documenting the relevant healthcare experts' role in the design, development, testing, or sign-off of DHTs?	
SOC	None noted		
LEG	None noted		

[a]From EUNetHTA HTA Core Model version 3.0 (46).

justification was provided for using a pre-test/post-test design for DHTs that are an adjunct to standard care (relevant to many DHTs that manage chronic noncommunicable disease at home), because the ideal comparator group, people having standard care (37), should not generally create ethical issues (5). For economic evaluation methods in ECO, frameworks state that DHTs are complex interventions implemented in a complex health system (8;15;62;64). This complexity presents challenges for economic evaluation, such as instability in preference values (8). However, McNamee et al. (15) consider that it is valid to use standard economic methods for DHTs, and where there are interactions, nonlinearity in changes, or multiplier effects, these can be dealt with by sensitivity analyses (8;15) and data from cluster trials (8).

Twenty of the twenty-eight existing HTA Core Model issues recommended for DHT-specific content are concentrated in four domains. The identification of DHT-specific content for the technical characteristics in TEC, the estimation of DHT-specific resource utilization and costs in ECO, and the DHT-specific changes to work processes in ORG were expected. The large amount of DHT-specific content identified in ETH is warranted when we consider the description by Sax et al. (28) of the unique risks of DHTs that collect a large amount of personal data to develop predictive algorithms of behavior. Consequently, there are ethical issues in terms of the potential for DHTs to influence the behavior of susceptible persons at critical times for commercial purposes.

A weakness of the included frameworks is the lack of discussion and recommendations on patients' perspectives in the domain of SOC. We acknowledge that the ability of a DHT to engage and motivate a patient is implicit in any demonstration

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of DHT effectiveness, and we are not suggesting that effectiveness from a patient perspective should be re-evaluated during an HTA. Rather, we suggest that information regarding patient preferences and experience with a DHT will be informative to judgments regarding the transferability of effectiveness from one population setting to another.

The eight new topics (and nineteen of the twenty-two new issues) are concentrated in the three domains of SAF, EFF, and ORG. The new SAF topics address issues of technical reliability and stability, data security and privacy, accessibility, and communications that promote the safety of users and the autonomy of stakeholders. Although examples of data privacy breaches/threats (e.g., Australia's HealthEngine, UK NHS ransomware attacks) are plentiful, it is the less overt data privacy breaches that occur when DHTs operate on personal devices that patients use for social media and the internet (i.e., not purpose-built medical devices) that are a unique threat for DHTs. Huckvale et al. (36) showed evidence of the prevalence of data transmissions with linkable identifiers from depression and smoking cessation apps to technology companies for marketing and analytics purposes without disclosures in privacy policies. The authors recommend regular audits of data transmissions rather than reliance on privacy disclosures.

The new EFF topics focus on high-quality evidence generation, transparent and standardized reporting of effectiveness studies, ensuring the reliability of health information content, and the use of appropriate and best practice behavior change techniques. Contextual issues for barriers and enablers to DHT implementation in ORG are comprehensively addressed by Drury et al. (23), Lennon et al. (19), and Rojahn et al. (17).

A strength of our analysis is the use of many sources, including gray literature. Additionally, focusing on a particular class of DHT with its specific risk/benefit profile has allowed us to identify and extend DHT-specific content to all HTA Core Model domains. Identifying content specific to the chronic noncommunicable disease target population and the active monitoring/treatment MDSW DHT class may limit the applicability of our analysis to other clinical circumstances, but many of the issues are sufficiently generic to be broadly applicable across other health areas and DHT classes. We also aimed to identify content broadly applicable across jurisdictions. However, some tailoring to meet local HTA needs may be required. Although a focus on the most recent 5 years in our search strategy was appropriate given the rapid development of DHTs, we have managed the risk of missing DHT-specific content in earlier evaluation frameworks by pearling included frameworks.

As DHT development continues apace, greater clarity is required regarding the evidence needed to inform policy makers and payers of the value of DHTs. By specifying additional DHT-specific content, we hope researchers can better plan to gather standardized and robust evidence that meets decision makers' needs.

Future research is recommended on the applicability of the new topics and issues to lower-risk DHT classes and their relative importance to specific chronic diseases.

Conclusion

The development of DHT-specific content for HTA frameworks is hampered by DHTs having varied benefits and risk profiles. By focusing on a particular DHT class, we demonstrate that relevant evaluation frameworks from peer-reviewed and gray literature can be used to extend DHT-specific content to all HTA Core Model domains. We plan to develop companion resources for designing research studies and undertaking HTAs of DHTs that manage chronic noncommunicable disease at home.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0266462321000362.

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References

1. **Australian Institute of Health and Welfare**. Chronic disease overview. 2020 [cited 2021 Feb 10]. Available from: https://www.aihw.gov.au/reports-data/health-conditions-disability-deaths/chronic-disease/overview.
2. **Eysenbach G**. Consort-ehealth: Improving and standardizing evaluation reports of web-based and mobile health interventions. *J Med Internet Res*. 2011;**13**:e126.
3. **Andalusian Health Quality Agency (ES)** [Internet] Complete list of recommendations on design, use and assessment of health apps. Seville (ES). 2012 [cited 2020 Aug 16]. Available from: www.calidadappsalud.com/en/listado-completo-recomendaciones-app-salud/.
4. **Kidholm K, Ekeland AG, Jensen LK, Rasmussen J, Pedersen CD, Bowes A, et al.** A model for assessment of telemedicine applications: MAST. *Int J Technol Assess Health Care*. 2012;**28**:44.
5. **Haute Autorité de Santé [French National Authority for Health]**. Methodological choices for the clinical development of medical devices. Paris (FR): The Authority; 2013.
6. **Khoja S, Durrani H, Scott RE, Sajwani A, Piryani U**. Conceptual framework for development of comprehensive e-health evaluation tool. *Telemed e-Health*. 2013;**19**:48–53.
7. **Lewis TL, Wyatt JC**. Mhealth and mobile medical apps: A framework to assess risk and promote safer use. *J Med Internet Res*. 2014;**16**:e210.
8. **Bergmo TS**. How to measure costs and benefits of ehealth interventions: An overview of methods and frameworks. *J Med Internet Res*. 2015;**17**:e254.
9. **Mohr DC, Schueller SM, Riley WT, Brown CH, Cuijpers P, Duan N, et al.** Trials of intervention principles: Evaluation methods for evolving behavioral intervention technologies. *J Med Internet Res*. 2015;**17**:e166.
10. **Mookherji S, Mehl G, Kaonga N, Mechael P**. Unmet need: Improving mhealth evaluation rigor to build the evidence base. *J Health Commun*. 2015;**20**:1224–9.
11. **Steventon A, Grieve R, Bardsley M**. An approach to assess generalizability in comparative effectiveness research: A case study of the whole systems demonstrator cluster randomized trial comparing telehealth with usual care for patients with chronic health conditions. *Med Decis Making*. 2015;**35**:1023–36.
12. **Ruck A, Wagner Bondorf S, Lowe C** (Consard Limited). Second draft of guidelines, EU guidelines on assessment of the reliability of mobile health applications. European Commission, Directorate-General of Communications Networks, Content & Technology; 2016.
13. **Gorski I, Bram JT, Sutermaster S, Eckman M, Mehta K**. Value propositions of mhealth projects. *J Med Eng Technol*. 2016;**40**:400–21.
14. **McMillan B, Hickey E, Patel MG, Mitchell C**. Quality assessment of a sample of mobile app-based health behavior change interventions using

a tool based on the national institute of health and care excellence behavior change guidance. *Patient Educ Couns*. 2016;**99**:429–35.
15. **McNamee P, Murray E, Kelly MP, Bojke L, Chilcott J, Fischer A, et al.** Designing and undertaking a health economics study of digital health interventions. *Am J Prev Med*. 2016;**51**:852–60.
16. **Murray E, Hekler EB, Andersson G, Collins LM, Doherty A, Hollis C, et al.** Evaluating digital health interventions: Key questions and approaches. *Am J Prev Med*. 2016;**51**:843–51.
17. **Rojahn K, Laplante S, Sloand J, Main C, Ibrahim A, Wild J, et al.** Remote monitoring of chronic diseases: A landscape assessment of policies in four European countries. *PLoS ONE*. 2016;**11**:e0155738.
18. **Young M**. IRBs could address ethical issues related to tracking devices: Mobile devices raise new concerns. *IRB Advisor*. 2017;**17**:8–9.
19. **Lennon MR, Bouamrane MM, Devlin AM, O'Connor S, O'Donnell C, Chetty U, et al.** Readiness for delivering digital health at scale: Lessons from a longitudinal qualitative evaluation of a national digital health innovation program in the United Kingdom. *J Med Internet Res*. 2017;**19**:e42.
20. **Maar MA, Yeates K, Perkins N, Boesch L, Hua-Stewart D, Liu P, et al.** A framework for the study of complex mhealth interventions in diverse cultural settings. *JMIR MHealth UHealth*. 2017;**5**:e47.
21. **Michie S, Yardley L, West R, Patrick K, Greaves F**. Developing and evaluating digital interventions to promote behavior change in health and health care: Recommendations resulting from an international workshop. *J Med Internet Res*. 2017;**19**:e232.
22. **Philpott D, Guergachi A, Keshavjee K**. Design and validation of a platform to evaluate mhealth apps. *Stud Health Technol Inform*. 2017;**235**:3–7.
23. **Drury P, Roth S, Jones T, Stahl M, Medeiros D**. Guidance for investing in digital health. Manila (PH): Asian Development Bank (ADB); 2018.
24. **European Commission**. Synopsis report, consultation: Transformation health and care in the digital single market. Luxembourg: The Commission; 2018.
25. **Hogaboam LS**. Assessment of technology adoption potential of medical devices: Case of wearable sensor products for pervasive care in neurosurgery and orthopedics [PhD]. Ann Arbor: Portland State University; 2018.
26. **Jurkeviciute M**. Planning of a holistic summative ehealth evaluation: The interplay between standards and reality [Licentiate]. Ann Arbor: Chalmers Tekniska Hogskola (Sweden); 2018.
27. **Nielsen S, Rimpiläinen S**. Report on international practice on digital apps. Glasgow (UK): Digital Health and Care Institute; 2018.
28. **Sax M, Helberger N, Bol N**. Health as a means towards profitable ends: Mhealth apps, user autonomy, and unfair commercial practices. *J Consumer Policy*. 2018;**41**:103–34.
29. **Academy of Medical Sciences (UK)**. Our data-driven future in healthcare: People and partnerships at the heart of health related technologies. London (UK): The Academy; 2018.
30. **Wyatt JC**. How can clinicians, specialty societies and others evaluate and improve the quality of apps for patient use? *BMC Med*. 2018;**16**:225.
31. **Beintner I, Vollert B, Zarski AC, Bolinski F, Musiat P, Gorlich D, et al.** Adherence reporting in randomized controlled trials examining manualized multisession online interventions: Systematic review of practices and proposal for reporting standards. *J Med Internet Res*. 2019;**21**:e14181.
32. **Caulfield B, Reginatto B, Slevin P**. Not all sensors are created equal: A framework for evaluating human performance measurement technologies. *npj Digital Med*. 2019;**2**:7.
33. **Department of Health & Social Care (UK)** [Internet] Code of conduct for data-driven health and care technology. London (UK): The Department; 2019 [updated 2019 Jul 18; cited 2020 Aug 18]. Available from: https://www.gov.uk/government/publications/code-of-conduct-for-data-driven-health-and-care-technology/initial-code-of-conduct-for-data-driven-health-and-care-technology.
34. **Haute Autorité de Santé [French National Authority for Health]**. Guide to the specific features of clinical evaluation of a connected medical device (CMD) in view of its application for reimbursement. Paris (FR): The Authority; 2019.
35. **Haute Autorité de Santé [French National Authority for Health]**. Public consultation on the draft analysis grid intended for use by CNEDiMTS to contribute to its evaluation of medical devices embedding decision systems based on automatic learning processes ("artificial intelligence"). Paris (FR): The Authority; 2019.
36. **Huckvale K, Torous J, Larsen ME**. Assessment of the data sharing and privacy practices of smartphone apps for depression and smoking cessation. *JAMA Network Open*. 2019;**2**:e192542.
37. **National Institute for Health and Care Excellence (UK)**. Evidence standards framework for digital health technologies. London (UK): The Institute; 2019.
38. **NHS Digital (UK)** [Internet] How we assess health apps and digital tools. London (UK): NHS Digital; 2019 [updated 2019 May 17; cited 2020 Apr 13]. Available from: https://digital.nhs.uk/services/nhs-apps-library/guidance-for-health-app-developers-commissioners-and-assessors/how-we-assess-health-apps-and-digital-tools.
39. **Rajan B, Tezcan T, Seidmann A**. Service systems with heterogeneous customers: Investigating the effect of telemedicine on chronic care. *Manag Sci*. 2019;**65**:1236–67.
40. **Australian Commission on Safety and Quality in Health Care**. National safety and quality digital mental health standards - Consultation draft. Sydney (AU): The Commission; 2020.
41. **Dick S, O'Connor Y, Thompson MJ, O'Donoghue J, Hardy V, Wu TJ, et al.** Considerations for improved mobile health evaluation: Retrospective qualitative investigation. *JMIR MHealth UHealth*. 2020;**8**:e12424.
42. **Federal Ministry of Health (DE)**. Regulation on the procedure and requirements for testing the eligibility for reimbursement of digital health applications in the statutory public health insurance (Digital Health Applications Ordinance - DiGAV) (Draft bill). Bonn (DE): The Ministry; 2020.
43. **Health Information and Quality Authority (IE)**. International review of consent models for the collection, use and sharing of health information. Cork (IE): The Authority; 2020.
44. **Medical Services Advisory Committee (AU)**. Draft guidelines for preparing assessment reports for the medical services advisory committee. Canberra (AU): The Committee; 2020.
45. **Moshi MR, Tooher R, Merlin T**. Development of a health technology assessment module for evaluating mobile medical applications. *Int J Technol Assess Health Care*. 2020;**36**:252–61.
46. **EUnetHTA Joint Action 2, Work Package 8**. HTA Core Model® version 3.0. [Pdf]; 2016. Available from: www.htacoremodel.info/BrowseModel.aspx.
47. **World Health Organization**. *WHO guideline: Recommendations on digital interventions for health system strengthening*. Geneva (CH): The Organization; 2019.
48. **Medical Device Coordination Group**. Guidance on qualification and classification of software in regulation (EU) 2017/745 – MDR and Regulation (EU) 2017/746 – IVDR. European Commission; 2019.
49. **O'Rourke B, Oortwijn W, Schuller T**. The new definition of health technology assessment: A milestone in international collaboration. *Int J Technol Assess Health Care*. 2020;**36**:187–90.
50. **Australian Government Department of Health and Ageing**. Review of health technology assessment in Australia. Canberra (AU): Commonwealth of Australia; 2009.
51. **Regulation (EU) 2017/745 of the European Parliament and of the Council**. *Official Journal*. 2017;L117:1–175.
52. **Regulation (EU) 2016/679 of the European Parliament and of the Council**. *Official Journal*. 2016;L119:1–88.
53. **Moshi MR, Tooher R, Merlin T**. Suitability of current evaluation frameworks for use in the health technology assessment of mobile medical applications: A systematic review. *Int J Technol Assess Health Care*. 2018;**34**:464–75.
54. **Iribarren SJ, Cato K, Falzon L, Stone PW**. What is the economic evidence for mhealth? A systematic review of economic evaluations of mhealth solutions. *PLoS ONE*. 2017;**12**:e0170581.
55. **Kidholm K, Kristensen MBD**. A scoping review of economic evaluations alongside randomized controlled trials of home monitoring in chronic disease management. *Appl Health Econ Health Policy*. 2018;**16**:167–76.
56. **Vukovic V, Favaretti C, Ricciardi W, de Waure C**. Health technology assessment evidence on e-health/m-health technologies: Evaluating the

https://doi.org/10.1017/S0266462321000362 Published online by Cambridge University Press

transparency and thoroughness. *Int J Technol Assess Health Care*. 2018;**34**:87–96.
57. **Moher D, Liberati A, Tetzlaff J, Altman DG**. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med*. 2009;**6**:e1000097.
58. **Grey matters: A practical tool for searching health-related grey literature [Internet]**. Ottawa (CA): CADTH; 2018 [updated 2019 Apr; cited 2020 Apr 4]. Available from: https://www.cadth.ca/resources/finding-evidence.
59. **Hailey D, Ohinmaa A, Roine R**. *Study quality and evidence of benefit in recent assessments of telemedicine*. London (UK): SAGE Publications; 2004. p. 318–24.
60. **Gagnon M-P, Scott R**. Striving for evidence in e-health evaluation: Lessons from health technology assessment. *J Telemed Telecare*. 2005;**11**: S34–6.
61. **Reardon T**. Research findings and strategies for assessing telemedicine costs. *Telemed e-Health*. 2005;**11**:348–69.
62. **Shiell A, Hawe P, Gold L**. Complex interventions or complex systems? Implications for health economic evaluation. *BMJ*. 2008;**336**:1281–3.
63. **Dávalos ME, French MT, Burdick AE, Simmons SC**. Economic evaluation of telemedicine: Review of the literature and research guidelines for benefit-cost analysis. *Telemed e-Health*. 2009;**15**:933–48.
64. **Rickles D, Hawe P, Shiell A**. A simple guide to chaos and complexity. *J Epidemiol Community Health*. 2007;**61**:933–7.

https://doi.org/10.1017/S0266462321000362 Published online by Cambridge University Press