Health economic evaluation of digital technologies in nursing care: a review on methodological recommendations

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Abstract

Background

Health economic evaluation of digital technologies in nursing is important to provide information that help avoid undesirable developments and implementations as well as increasing the chances of success of developed applications. At the same time, studies and evidence on cost-effectiveness are still very rare in this area. Review studies in related technology areas, such as telemedicine, continuously criticize the quality and comparability of the health economic evaluations that have been conducted in this field. Based on a content analysis of methodological literature on the economic evaluation of innovative (digital) technologies in health and nursing this article aims to identify specific challenges in this research area and the given recommendations on how to address these challenges to promote more sound health economic evaluations in the future.

Methods

A rapid review was conducted, consisting of a systematic search in the Pubmed database as well as Google Scholar. In addition, the literature lists of the analysed texts were searched for additional texts to be included. Methodological literature, single studies, and reviews were included. A total of 536 studies were screened, of which 29 were included in the full text analysis.

Results

Based on the systematic content analysis of the studies under consideration, 10 special methodological challenges are identified, and it was worked out which methodological recommendations could be considered. A particular focus aimed on whether special methodological approaches might be needed in the context of evaluating the efficiency of digital care technologies.

Conclusion

Many of the challenges identified for the health economic evaluations of digital nursing technologies are comparable to those of other complex healthcare interventions. The discussed recommendations can help to alleviate those challenges. Future research should focus on alternative approaches to assess causality in different phases of technology development while maintaining high evidence standards. High evidence economic assessment of technologies in nursing care should be carried out in routine use especially if they target to be reimbursed by the social insurance.

Background

Digital innovations are expected to change the way both healthcare and nursing care are provided in the future. Although a wide range of technologies have been developed and tested in nursing care in recent years, valid evidence on the effectiveness of digital technologies in nursing practice is still scarce [1]. Evidence on cost-effectiveness or efficiency is also rare [2]. Review studies in related technology areas,

such as telemedicine – a field that has been under research for 30 years now – continuously criticise the low methodological quality and comparability of the health economic evaluations or economic analyses that have been conducted in this field [3–7].

Research on digital technologies aiming at nursing care is funded based on the expectation that the use of digital technologies may increase independency of otherwise care-dependent people, improve the quality of care, increase efficiency, and/or reduce the burden or workload of formal and informal caregivers [8, 9] However, this cannot be taken for granted. Decision-makers who decide on funding or the implementation of digital technologies in health or nursing care need reliable information on which to base their decisions on.

Against the background that there are only very few economic evaluation studies in this field so far, and that research in related fields indicates that the economic evaluation of innovative technologies or new ways of providing health or nursing care may be challenging this review aims to elaborate, what these particular challenges are – and what approaches or options there are to deal with them.

The well-established methods of health economic evaluation have been developed in the field of clinical interventions. This raises the question of how well these methods are suited for evaluating technological innovations in nursing care – or if they can be adapted for this purpose. We could not identify any prior research on the methodological challenges of the economic evaluation of digital innovations in nursing care, but it can be assumed that challenges in closely related research fields are similarly applicable here. For this reason, we conducted a review on methodological guidelines for the economic evaluations of digital technologies in nursing care or closely related areas such as telemedicine, telecare, eHealth, digital health, and mobile health to identify prior research and methodological recommendations in this area.

Terms used to describe or categorise specific technological applications in this area – like eHealth, digital health or mHealth – are often not very clearly defined, they are used incoherently, or categories overlap. Still, the main focus is the application of digital technologies to support health care, nursing care or care dependent people. Our analysis will focus on methodological challenges that are similar for different fields of application – rather than providing distinctive definitions for different areas of technology supported care. We assume that whether certain challenges apply will depend more on the specific application and setting than on a particular category of technology.

The aim of this review is to identify specific challenges of economic evaluations that apply into the field of digital nursing technologies [10, 11] and the recommendations that were developed to date to address these issues.

This article is thus guided by the following research questions:

- RQ1: What specific challenges for the economic evaluation of innovative (digital) technologies in health and nursing are identified in the included studies?

- RQ2: How can these challenges be addressed and what recommendations are provided in the studies?

Economic Evaluation – Basic Concepts

Following the common definition by Drummond et al. economic evaluation is defined as the comparative analysis of alternative courses of action in terms of both costs and consequences. Thus the core tasks of an economic evaluation are the identification, measurement, valuation and comparison of the costs and consequences of the alternatives under consideration [12]. When comparing two alternative health care options the concept of opportunity costs is applied. Opportunity costs are the benefits foregone when opting for a specific intervention compared to another [13]. This is an important concept to understand because many publications on costs of digital interventions are just cost analyses and no full economic evaluations [11]. While a simple cost analysis usually focuses only on the financial costs of a given intervention, a full economic evaluation measures the value of an intervention by the value of benefits that were not achieved because resources were not spent on another option. This may include costs whose financial value cannot be determined directly.

As a basis for this article, the most common methods of economic evaluation used in health care are briefly summarized in the following. These methods are differentiated according to how they measure the benefits of an intervention. Cost-effectiveness analysis (CEA) uses single natural parameters to indicate effects of a health intervention, such as for example weight loss, or number of strokes prevented. Cost-utility analysis (CUA) aggregates different aspects in a virtual parameter. The most commonly used parameter is the quality adjusted life year (QALY) that combines a quantitative effect (life extension) and qualitative effects (health related quality of life) of an intervention. Another option to aggregate different effects of an intervention is a monetary valuation of effects as it is done by cost-benefit analyses (CBA). CBA values effects based on the assessment of the individual's willingness-to-pay (WTP) for it. This allows to capture the individual's preferences as part of the analysis which is in line with the welfarist economic paradigm. Results, however, are strongly dependent on whose willingness-to-pay is assessed. There is the option to avoid subjective elements by just determining the avoided cost for health and/or nursing care – but this would imply that the health gain or gain in quality of life itself would be attributed no value. The presentation of a range of different effects of an intervention without aggregating them in a single measure is called-cost consequence analysis (CCA). This allows to draw a more comprehensive picture of the effects, but it is left to the decision maker to decide on the relative importance of the different aspects. If it can be reliably assumed that the effects of the two compared interventions are the same, cost-minimisation analyses (CMA) are another option [12].

Applying these standard methods to the economic evaluation of digital technologies in nursing may be challenging in several ways. To determine more precisely what those challenges are, this study was conducted.

Methods

Search Process

To identify prior research that discusses methodological aspects of the economic evaluation of digital technologies (including information and communication technologies) applied in health or nursing care we performed a rapid review that consisted in a systematic literature search in PubMed and an extensive search in Google Scholar. In addition, the reference lists of the included texts were searched for additional studies.

Eligibility Criteria for systematic search

Included were scientific papers that provided guidance and/or discussed in detail methodological challenges or specific methodological aspects of the economic evaluation of the application of digital technologies in health or nursing care – or closely related fields. Included were papers in English or German language, there was no restriction on the publication period. The PubMed-Search was performed on March 8th 2021, the Google Scholar Search was performed on March 9th 2021.

Exclusion criteria:

- 1. Studies or text that only commented on single methodological issues in the context of the discussion of study results.
- 2. Reviews or texts that did not make recommendations or provided explicit guidance on methodological issues that are related to the application of digital technologies in health or nursing care.
- 3. Macro-economic concepts or concepts that aim at a rather rough or generalised estimation of the efficiency of technologies.
- 4. Studies that only provide an exemplary evaluation as a framework for future evaluations.
- 5. Single clinical trials or RCTs.
- 6. Modelling studies without clear references to empirical data/studies.

Search Terms

The search consisted of a fairly specific search in PubMed to keep the number of hits manageable and a more general search in Google Scholar aimed at finding relevant studies not covered by the PubMed search. The search terms can be found in Table 1.

Table 1: PubMed Search Strategy

	A "Telemedicine/economics"[Mesh] OR "Mobile Applications/economics"[Mesh] OR "Digital Technology"[Mesh] OR "Independent Living/economics"[Mesh] OR "Ambient Intelligence"[Mesh] OR "Information Technology/economics"[Mesh] OR health-it[Title/Abstract] OR gerontechnology[Title/Abstract] OR ehealth[Title] OR e-health[Title] OR digital health[Title] OR telecare[Title] OR mobile health[Title] OR medical device[Title]
B	((Digital[Title/Abstract]) OR (Technolog*[Title/Abstract])) AND Nurs*[Title/Abstract]
C	("Cost-Benefit Analysis"[Mesh] OR "Efficiency"[Mesh] OR cost*[Title] OR economic*[Title] OR finance*[Title] OR "Costs and Cost Analysis"[MeSH] OR early assessment[Title/Abstract])
D	("Research Design" [Mesh] OR "Research/economics"[Mesh] OR "Models, Theoretical" [Mesh] OR guideline*[Title/Abstract] OR framework*[Title/Abstract] OR recommendation *[Title/Abstract] OR method*[Title])

The search was defined as "(#A OR #B) AND #C AND #D NOT clinical trial NOT RCT".

Google Scholar Search

The Google Scholar Search was inspired by Böhler [14] and consisted in 14 different variations of technology related search terms and economic evaluation related search terms. Examples are:

- "(Ehealth or mhealth or telemedicine or telehealth or information technology) AND economic evaluation)"
- „Digital-health AND (cost-effectiveness OR cost-utility OR cost-benefit)"
- (technology AND nursing) AND economic evaluation AND (guideline or framework or methodological)"

For each search, the first 50 hits (sorted by relevance) were screened for relevant publications. As most of the later searches generated no further hits besides duplicates, the search was considered saturated after the 14 variations. A documentation of the search process is provided as additional file 1.

Search Results

The PubMed search resulted in 520 studies. The Google Scholar search added 26 studies. After removing duplicates 536 studies remained for title/abstract screening, which resulted in 47 papers that were screened based on their full texts. Based on the screening of the full texts 21 studies were included for the final analysis. The screening of the reference lists of the included studies added another 8 studies, resulting in a final total of 29 studies that were included in the analysis. The search and screening

process was performed by one author, if in doubt exclusions were discussed and agreed upon with a second author. The prisma flow chart of the search process is provided in figure 1.

Data Extraction

Data of the included studies was extracted according to the following categories: author, year, country (first author), technology field, main hypotheses/statements, specific challenges, recommended methods, recommended perspective, recommendations on clinical effectiveness data, multidimensionality, timing, included costs, specific aspects concerning costs, specific aspects concerning outcomes, recommendations on modelling, transferability, additional decision criteria, main future research questions. Based on the extracted information, main contents were summarised in a qualitative content analysis.

Results

Twenty-nine texts that provided guidelines, frameworks, or recommendations on the economic evaluation of health care related digital technologies or discussed their specific methodological challenges were included in this review. More than half of the texts refer explicitly to telemedicine or telehealth (16 studies), three texts reach refer to eHealth and digital health technologies in general, individual studies refer to mhealth, health information technology, digital health apps, assisted living technologies.

Research that was reflecting on the health economic evaluation of telemedicine started to appear in the mid 1990ies. Up until 2014 most studies in this field focussed on telemedicine applications. Studies on a wider spectrum of digital technologies started to appear after 2015 – so 13 of the included studies were published between 2015 and 2020. These cover a wider range of digital technologies and reflect the emergence and broader research on digital technologies in healthcare in recent years. Table 2 depicts the years of publication and the technology fields of the included papers.

Table 2 Years of publication and technology fields

Year of publication	Studies	Technology fields
1992-1998	6	5 telemedicine, 1 digital radiology systems (1992)
2000-2009	7	6 telemedicine, 1 assistive technology
2010-2014	3	2 telemedicine, 1 telemental health
2015-2017	9	telemedicine, telehealth, eHealth, health information systems, health information technology, digital health, assisted living technologies
2018-2020	4	digital health (focus: mhealth, telemedicine), digital health technologies in general, eHealth

The first authors of most papers come from only a few countries. Nine of the studies were authored by US-American researchers, seven studies come from the United Kingdom. Other European countries are represented by eight studies (Austria, Finland, France, Italy, Norway, Poland), three papers are authored by Australian, two by Canadian authors.

Ten challenges for the economic evaluation of digital nursing technologies (RQ 1)

Overall, there is a wide range of challenges that is addressed in the included papers. Main challenges – that have been addressed by many authors – relate to the **rapidly evolving technologies** [3, 14-21] and a **limited generalizability** (external validity) of results [3, 17, 21-24], which is due to a **large heterogeneity in the field** [20, 24, 25] on the one hand, and a **strong context dependency** of the interventions on the other hand [15, 18-20, 25-27].

Unlike most medical or pharmaceutical applications, digital technologies in health and nursing care do not only target health objectives but imply organisational changes as well. Alternatively, they may target mainly organisational processes, but will have effects on health outcomes as well. In this sense many digital health applications can be categorised as **complex interventions** or are situated in **complex systems** (as e.g. hospitals) [14, 28].

The identified challenges relate to the following key aspects of the economic evaluation that will be described in more detail below.

1. Challenges in performing effectiveness studies
2. Timing of the economic evaluation (iterative approaches)
3. Choice of comparator
4. Choice of perspective
5. Cost Assessment
6. Outcome Assessment
7. Choice of method
8. Transferability
9. Poor quality of economic evaluations – missing guidelines
10. Additional decision criteria

A more detailed description of these aspects, as well as the recommendations discussed in the included texts, is provided below. An extensive overview on the different perspectives is given in Additional File 2.

1. Challenges in performing effectiveness studies

A key precondition for assessing the cost-effectiveness or efficiency of an intervention is the availability of valid data on the effects or effectiveness of an intervention. Randomised controlled trials (RCTs) are usually regarded as gold standard to provide effectiveness data – this is supported by many of the included authors [14, 15, 22, 27, 29-31]. The lack of RCTs or the general lack of reliable evidence on effectiveness is considered a challenge by several of them [4, 22, 32], often small or inadequate sample sizes limit the validity [3, 16, 22]. In many areas, the development and introduction of a technology may be incremental, i.e. the application or system may change regularly, e.g. due to updates or extensions of functionalities [27]. As RCTs are difficult to perform in this context, a significant number of authors question this standard [17, 18, 20, 25, 27, 28, 33]. On the one hand time frames of RCTs are often considered too long, regarding the rapid or continuous development of technologies, and on the other hand usage patterns and thus effectiveness may be different from those under study conditions. Bergmo calls for pragmatic or naturalistic trials as gold standard for telemedicine studies [20, 25], McNamee et al. recommend natural experiments or Cluster-RCTs as data base for studies on digital health interventions [28], others rather demand more flexible or additional approaches [18, 27, 34].

2. Timing of the economic evaluation - iterative approaches

The challenging task of performing RCTs – or other types of effectiveness studies on digital health technologies – leads to the question of the right timing for economic evaluations.

As reliable RCTs and especially long-term evaluation studies are often lacking [22], technologies evolve, and it has to be assumed that short term effects may differ significantly from long-term effects [16]. Several authors recommend an iterative approach: Ohinmaa et al. recommend the performance of a series of rapid, less detailed evaluations to provide decision makers with timely interim advice [17]. Luzzi et al. and Sisk & Sanders refer to the necessity of an on-going continuous assessment [27, 35]. McIntosh and Cairns recommend to incorporate the economic evaluation into the clinical study at the beginning of the trial, collect relevant costs, and then carry out a sensitivity analysis with updated costs at the end of the study [16]. LeFevre et al. present a stage-based model that advises the use of different economic methods depending on the maturity of the technology. (Pre-)prototype phases should be accompanied by model based economic evaluations. During pilot- and effectiveness studies economic evaluations should be based on primary data. In order to predict long-term effects modelling techniques can be used again [33]. This approach is recommended by Böhler as well [14].

3. Choice of Comparator

The choice of comparator may be challenging [26, 36]. If no obvious alternative course of action exists, the usual comparator will be 'standard care', but data on conventional (administrative) services may be difficult to assess [19]. For some technological innovations the alternative may only be inaction.

Especially in a social perspective the social costs of inaction may be difficult to determine, as for example the social cost of no health care in a region where – without telemedicine or telecare – medical care would not be available at all, or a care dependent person had no other option of support [23, 37].

Another recommendation refers to the adaptability/customisability of some technological intervention: If the implementation of the technological intervention may be adapted to specific situations, e.g., with different configurations of the technology, different options had to be included in the analysis [3, 14, 27, 38].

4. Choice of perspective

The choice of perspective is decisive for determining which costs and effects are considered in an economic evaluation. The decision on the perspective may be challenging as there may be a range of different stakeholders involved in the implementation of an innovative digital intervention and the recommendations in the included texts differ considerably. While a range of text just point out that the perspective has to be stated clearly [15, 25, 38] or depends on the research question [19, 27, 33] or decision-maker [18, 29], some authors – mainly in recommendations on the economic evaluation of telemedicine – definitely recommend to apply a societal perspective [24, 35, 39]. Another range of studies recommends considering the fact that there may be different parties involved. These recommend a multistakeholder perspective [3, 14, 17, 23, 31], or to complement a societal perspective by an analysis of costs and benefits that is differentiated by different stakeholder groups [16, 22].

5. Cost Assessment

There is a range of challenges that concern the assessment of costs. The main challenges specific to digital technologies are outlined/listed below:[\[1\]](#)

- Continuing changes in the price-performance ratio of equipment and related software due to rapidly changing prices of technology, thus costs are difficult to estimate [16, 20, 24, 40].
- Costs may be dependent on the uptake or usage rates, which are difficult to foresee, so, costs per unit of service would be high at low caseloads but decline with volume of use [4, 16, 23, 27, 41].
- Lacking evidence on costs or especially on costs that are difficult to measure [3, 4, 17, 19, 27].
- There may be a variety of budgets of different stakeholders affected, these should all be considered [3, 14, 22], especially as costs and cost-savings may fall in different budgets [23].
- Divergent opinions on the classification of costs [27, 40] and the inclusion of research and development costs [21].
- Some of the equipment may be used by other applications as well, thus boundaries of the intervention may be ambiguous, or due to multiple use of the technology it can be difficult to

determine whether costs should be attributed to the intervention or not, e.g. the implementation of a WLAN-network [14, 15, 18, 24, 35].

- Depreciation periods may be short, life-cycle of technologies have to be considered, as well as costs for regular updates [21, 23, 28].
- There may be large differences between costs for pilot projects versus costs of mature real-life applications, thus costs should be assessed rather in pragmatic trials [14, 25, 40].
- Some authors highlight that the costs of supporting the health care providers in using eHealth interventions, e.g. costs of training, helpdesks, change management [3, 20] and the costs of assessing what type of technical support the client needs [37] should be included as well. As the implementation of technology may change organisational processes or changes in clinical pathways there may also be indirect or intangible costs (e.g. changes in staff morale, new types of staff) that have to be considered [26, 31].

Recommendations to address these challenges are that costs be reported in a very transparent way; quantities of resources and cost weights should be reported separately to facilitate transferability in other context [14, 20]. In addition, several authors recommend an iterative approach that regularly updates the cost-assessment throughout the different stages of a technologies life cycle [14, 17, 27, 35, 41] - and the use of micro-costing methods if no pricing information is available [21]. A more general recommendation is the performance of sensitivity analyses for the (many) areas of uncertainty that will remain, e.g. anticipated changes in equipment and transmission costs [4, 15, 16, 24, 35].

6. Outcome Assessment

A main challenge that refers to the outcome assessment are the already mentioned difficulties in assessing effectiveness data, respectively the lack of (good quality) evidence on effectiveness outcomes [3, 17, 19, 24, 31, 41]. Another challenge that is mentioned by many authors relates to the fact that digital health or nursing interventions may have diverse or multidimensional impacts, while the most widely used health economic evaluation methods – especially CEA and CUA – are rather inadequate to capture multiple impacts or impacts beyond health [3, 18, 20, 26, 29, 34, 36].

This involves different difficulties: Digital technological interventions in health and nursing care do not only address health outcomes, but also imply or explicitly address organisational change processes or individual behavioural change processes that may not lead to immediate health effects. Kolasa & Kozinski – as one example – suggest to differentiate clinical, organizational, behavioural and technical impacts [26]; Bongiovanni-Delarozière et al. recommend to assess four categories of outcomes indicators for telemedicine interventions: accessibility, professional practice/care organisation; care quality; and costs [3]. On the one hand this implies the problem of measurement and valuation of non-health outcomes that may be difficult [14, 20, 29, 36, 39]: standardised measures are often missing [15], some outcomes may be intangible or difficult to quantify [18, 23, 31, 34], or sometimes only intermediate

(surrogate) outcomes may be accessible, while the relationship to health related measures is not well established [17, 24, 28].

On the other hand, these effects may accrue to different stakeholders [20, 22, 31], this may pose the challenge of how to weight outcomes for different stakeholders or how to decide between divergent preferences of different stakeholder groups [36].

Overall, 17 of the included texts explicitly indicate the need for a multidimensional outcome assessment, but recommendations on how to do this differ. Two studies recommend the use of CBA [22, 39], another one the combination of CUA and CBA [36] to deal with these challenges. This implies a monetary valuation of different outcomes to enable the comparison of diverse or aggregated outcomes. This is rejected by other authors, who consider a monetary valuation of health outcomes or QALYs as difficult or even ethically inappropriate [14, 16, 20, 37]. Luxton concludes that there is a need for standardised effectiveness outcomes for telemedicine that include clinical outcomes as well as other factors such as patient compliance and treatment satisfaction [15]; the British National Institute for Health Care Excellence (NICE) advises the use of CCA if applicable [42], so do McIntosh & Cairns who suggest the use of a balance sheet with disaggregated costs and benefits and the use of conjoint analysis for the valuation of non-health benefits [16].

Four authors recommend the use of an outcome matrix differentiated by stakeholders and different outcome categories to assess the multidimensional outcomes [3, 17, 31, 43]. Böhler advises the use of CEA and CUA as a reference case – and to consider additional methods such as multi-criteria decision analysis (MCDA) or choice-based methods if there is a significant non-medical benefit, similarly Kolasa & Kozinski propose a weighting of the different value attributes based on the preferences of chosen stakeholder groups [26].

7. Choice of method

Regarding the general choice of method and the applicability of the established methods of health economic evaluation, many authors recommend the use of the established methods (CEA, CUA, CBA, sometimes CCA) without any further adjustments, mainly indicating that the choice of method depends on the research question [4, 15, 20, 24, 27, 29, 35, 38, 42]. Another large group rather focusses on the need of an extension of the established methods to cover multidimensional outcomes that accrue to different stakeholders [3, 14, 17, 19, 26, 31, 41]. Explicit use of CBA to cover multiple outcomes is only recommended by very few authors. [22, 36, 39].

Additional methods that are recommended mainly by individual authors are:

- Extended CEA and Net benefit regression CEA for subgroup analyses [33],
- Social audit analysis [17, 31, 41],
- Multi-criteria decision analysis [14, 26],

- Economic production functions, decision making frameworks, functional economic analysis [18],
- Decision theoretic approaches, social network analysis [28],
- Q-methodology to elicit group views on relevant attributes [36],
- Conjoint analysis for the valuation of non-health benefits [16],
- Budget Impact analysis [29, 39, 42],
- SCAI – an instrument for cost assessment that is presented in the text [44],
- Multivariate statistical techniques to improve efficiency of estimation and adjustment of selection bias [43].

8. Transferability of results

A large challenge is the question of the external validity or transferability of the results of the evaluations performed. A strong context dependency or sensitivity of the results of economic studies is stated in several of the included texts [15, 18-20, 25, 26]. This may be caused for example by differences of the specific technologies or equipment used [20, 24, 25], local adjustments in the implementation of specific technologies [27], or differences in the willingness-to-use by end users [26]. As many technological applications may change organisational routines or working patterns, the effects may differ greatly depending on previous work patterns and organisational structures [23, 25], or organisational competence [25]. Structural aspects of the national healthcare system or regulatory changes may influence the use and possible effects as well [26-28].

Recommendations for dealing with these questions are:

- the thorough reflection on generalizability, in case of minor differences between settings and interventions a transferability of results is possible [20],
- reflection on transferability of study results to different settings should be considered early in the design of the evaluation study, this includes theoretical considerations on the relevance of potential variability factors and their exploration e.g. by subgroup, sensitivity and scenario analyses [14],
- replication of studies in different countries to assess differences in organisational and funding aspects [31],
- Discussion of results of economic evaluations should focus on their generalizability [3],
- Conduct evaluations based on pragmatic trials, estimation of different variations of relevant context variables by decision modelling [25].

9. Poor quality of economic evaluations - missing guidelines

Many of the included texts criticise that there are only few economic evaluations on telemedicine or other digital innovations in healthcare – and that the quality of published evaluations is rather poor, and that existing guidelines and methodological recommendations are disregarded [3, 4, 15, 18, 19, 22, 33, 36]. Thus, conducting studies – and especially high-quality studies that follow the general established guidelines for health economic evaluations – seems to be a challenge in itself. On top of that, several authors consider it a challenge – or a reason for the lacking quality – that guidelines for this specific field of research were lacking so far [15, 21, 26, 33]. Thus, several of the included texts try to fill this gap and develop frameworks or present tutorials to guide future evaluations.

In order to improve this situation, many recommendations revolve around guidelines: general guideline compliance should be increased, and the specific recommendations that are presented in the different publications could be followed. Some authors indicate a further need for the development of common guidelines or frameworks [14, 15, 21, 26, 28] or complementary the development of standard parameters for the valuation of certain costs or benefits [36, 37].

Reardon specifically highlights that research on necessary consensus guidelines is unlikely to be financed by individual research or provider groups [18], this points to the need of adequate funding of corresponding research.

10. Additional decision criteria

Some of the texts highlight additional decision criteria that should be taken into account, these are in particular equity and/or distributional consequences [16, 29, 31, 33, 36, 41], accessibility [3, 16], ethical and legal aspects [3], priorities/values of policy-makers [17], or “clinical experience, common sense and professional ethics” [37].

[1] Challenges that were mentioned by more than one text.

Discussion

This review reveals a wide range of challenges of the economic evaluation of digital interventions in health care that are also applicable to digital technologies in nursing care (RQ1). Reflection on some of these problems date back to 1992. There is a huge debate since the 1990ies focussing on telemedicine – and many of the early stated challenges persist today. The related field of telenursing has become particularly relevant in recent years as the COVID crisis has necessitated new methods of remote care [45]. This makes challenges and recommendations on the health economic evaluation of telemedicine applications equally relevant for the field of nursing. Most of the findings from the included articles are also very generic and can therefore be reflected in the context of nursing.

At the same time, recommendations on how to tackle or approach these challenges differ widely as well (RQ2). While there are authors that conclude that conventional techniques of economic evaluation are inappropriate to assess i.e. telemedicine applications [16], or only partially applicable [3] – other authors rather detect a problem of missing guidance on which analytical approaches are most appropriate [15, 33], or recommend the further development of the methodology [26, 36].

Several of the included texts present or develop frameworks and tutorials to guide future evaluations. Some of them mainly present general guidelines or recommendations on health economic evaluation and do not or hardly account for specific challenges of digital technological interventions [4, 27, 35, 38]. But there are several frameworks or recommendations that go beyond this and provide guidance on the specific reported challenges of digital interventions [3, 14, 16, 22, 29, 33, 42].

In the diverse included papers, the authors' opinions of whether and which health economic methods can and should be used - or whether they should be developed further - differ.

A total of 10 challenges were identified, four of which can be described as the most important ones in the context of digital nursing technologies:

1. the strong context dependency of the interventions
2. the multidimensional effects on different stakeholders
3. the incomplete assessment of economic costs, different approaches on the measurement and valuation of cost
4. the rapid and often incremental development of the technologies, that may result in the need to repeatedly adapt evaluation results

Not all of these challenges are specific for the evaluation of technological applications. The economic evaluation of technological interventions in health and nursing care shares many methodological problems that are discussed in the context of the economic evaluation of complex interventions or public health interventions that are similar in this respect [46–50]. This refers especially to **the strong context dependency of the interventions** and the possibility of **multidimensional outcomes** beyond health. Different stakeholder groups may be involved as well.

There is an extensive methodological debate on the **evaluation of complex interventions** – which could be referred to more intensively. Still, this debate refers especially to the general evaluation of complex interventions [51–53] the inclusion of respective results or approaches in (health) economic evaluations is not yet so far advanced. There is critical debate about the use of MCDA combined with economic evaluations that is very applicable here [54–58]. Baltussen et al conclude that MCDA is often used inadequately in economic evaluations because opportunity costs are not considered [55], Marsh et al. recommend for this reason to complement MCDA by an economic evaluation, but not to substitute the economic evaluation by MCDA [58]. Still there seem to be interesting approaches to integrate multidimensional outcomes that should be further developed.

Challenges referring to the **incomplete assessment of economic cost**, or different approaches on the measurement and valuation of cost are not specific to the evaluation of digital technologies in nursing, but rather a common problem of economic evaluations in other areas as well [59, 60]. Still, the critique on the poor methodological quality of economic evaluations in the field of telemedicine or digital health technologies is very persisting. Conducting economic evaluations according to the existing methodological standards of the discipline – including a comprehensive assessment of all relevant cost categories – seems to be a challenge in itself. The adequate identification of relevant cost categories should be achievable by complying with general economic evaluation guidelines. The actual assessment may be more challenging. Adequate funding of economic evaluations is necessary to ensure the conduct of high-quality evaluation studies. The planning of economic evaluations should be included early in the study design to ensure that all relevant data may be collected. The development of guidelines for specific fields of application of technologies could be helpful to align evaluations and thus obtain more comparable studies.

The most specific challenge of the economic evaluation of digital technologies in nursing, that could call for adapted procedures, is their **rapid and often incremental development**. An extreme example are artificial intelligence technologies. These technologies are rapidly evolving and self-learning, which makes it difficult to determine their effectiveness at a given point in time. Especially in the context of regulatory and reimbursement requirements, this challenge is currently particularly critical because the effectiveness measurement is tied to a certain state of the technology and does not allow for further development.

An iterative approach as it is proposed by LeFevre et al. [33] and Böhler [14] seems recommendable and could be useful here. The economic methods used should then be adapted to the stage of development of the technology.

Early stages of development can be accompanied by model-based evaluations, which allow for a first cost effectiveness assessment and the strategic development of a business case. Pilot studies can be used to further explore possible costs and consequences of the technological innovation. Full economic evaluations are complex and costly, they should be based on high-quality effectiveness studies to ensure that valid data on the effects of the intervention is obtained. This will only be worthwhile once the technology has reached a certain level of maturity. Technological changes that affect the prices of the technological component of the interventions may be included in sensitivity analyses, these are unproblematic to integrate retrospectively. Technological changes that significantly change the performance of a technology should rather be tested in pilot studies first. If they can be expected to significantly affect the outcomes, these changes may be assessed by sensitivity analyses as well. Smaller and more efficient study designs are entirely appropriate in early stages of digital technology evaluation [61]. However, the authors of this paper particularly advocate for high evidence standards, when it comes to adoption into standard care by social insurance providers. Methodological evidence standards should not be lowered just to facilitate reimbursement. Added value and measurable

effectiveness, as well as e.g., cost-effectiveness should be demonstratable. Appropriate funding should be made available to support studies with high standards of evidence.

Limitations

The search process and analysis process were carried out very thoroughly, but there is always the possibility that single texts were not found. However, we assume that the main challenges and recommendations in the included texts have all been identified and that no problems have arisen as a result. It was also noticeable that none of the included texts described their own limitations, which is not uncommon in methodological texts, but certainly is important to mention for critical reflection.

Conclusion

Conducting an economic evaluation in the context of digital nursing technologies is complex, but important. Many of the described challenges are comparable to the challenges in similar technological fields and other complex healthcare interventions. The recommendations discussed from the literature can help mitigate these challenges and should encourage early economic evaluation of digital care technologies.

The information obtained from health economic evaluation is very important and could help to avoid undesirable developments in research and development and increase the chances of success of the applications developed for nursing care.

Performing such economic evaluations can be costly, but the availability of important information at an early stage of development provides many opportunities to initiate appropriate further development steps. The costs associated with missteps at a later stage can be much higher than conducting a good preliminary economic evaluation at an earlier stage.

Future research should focus on the advancement of alternative approaches to assess causality [18], to keep up with the pace of technology development, while still maintaining a high quality evidence standard in different phases of development. A rolling evidence procedure over time with a high standard of evidence, as in the German Fast Track Process for Digital Health Applications (DiGA) [62], with simultaneous collection of economic parameters could be a future option for economic evaluations.

As part of a stage based approach economic evaluations of technologies should also be carried out in routine use [37, 41], and not only in laboratory or experimental study settings. It is essential to thoroughly discuss and reflect on the contextual conditions of the results to enable assessments on the transferability in other settings or countries. [31].

Overall, the information in this article can be used as a basis for methodological discussion and further development of health economic evaluations in the area of nursing technologies.

Abbreviations

BIA	
Budget Impact Analysis	
CBA	
Cost-Benefit Analysis	
CCA	
Cost-Consequence Analysis	
CEA	
Cost-Effectiveness Analysis	
CMA	
Cost-Minimisation Analysis	
CUA	
Cost-Utility Analysis	
IT	
Information technology	
DiGA	
Digital Health Applications	
RCT	
Randomised Controlled Trial	
QALY	
Quality-adjusted life year	
US	
United States	
WTP	
Willingness-to-pay	

Declarations

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Authors' Contributions

All authors conceptualized the study. KH handled the screening in all stages, interpreted the results and wrote the first draft of the manuscript. KH and TK conceptualised the data abstraction form. HR obtained funding for the study. KH, TK and HR read and provided substantial edits on the manuscript. All authors authorized the final version of the manuscript that was submitted. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

There are no competing interests to declare.

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Figures

Figure 1

Flowchart

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