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Citation: Mikkonen, Kristina, Yamakawa, Miyae, Tomietto, Marco, Tuomikoski, Anna-Maria, Utsumi, Momoe, Jarva, Erika, Kääriäinen, Maria and Oikarinen, Anne (2022) Randomised controlled trials addressing how the clinical application of information and communication technology impacts the quality of patient care—A systematic review and meta-analysis. *Journal of Clinical Nursing*. ISSN 0962-1067 (In Press)

Published by: Wiley-Blackwell

URL: <https://doi.org/10.1111/jocn.16448> <<https://doi.org/10.1111/jocn.16448>>

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REVIEW

Randomised controlled trials addressing how the clinical application of information and communication technology impacts the quality of patient care—A systematic review and meta-analysis

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Abstract

Background: The number of people with chronic and long-term conditions has increased during recent decades; this has been addressed by leveraging information and communication technology (ICT) to develop new self-care solutions. However, many of the developed technological solutions have not been tested in terms of impact(s) on patients' quality of care.

Objectives: This systematic review aimed to identify the current best evidence on the types of interventions that have been developed to improve the quality of patient care through the clinical application of ICT in primary, tertiary or home care.

Design: A systematic review, including a meta-analysis, was conducted according to the JBI Manual for Evidence Synthesis guidelines.

Data sources: Relevant data were identified from four electronic databases: CINAHL, PUBMED, SCOPUS and MEDIC.

Review methods: The eligibility criteria were formatted according to PICOS inclusion and exclusion criteria. At least two researchers performed the screening process separately, after which they agreed upon the results. The Cochrane Risk of Bias Assessment and JBI Critical Appraisal tool for randomised controlled studies (RCTs) were used to assess research quality. Data were extracted, and a meta-analysis was performed if the research met quantitative requirements.

Results: Of the 528 initially identified studies, 11 studies were chosen for final data synthesis. All of the interventions integrated ICT solutions into patient care to improve the quality of care. Patients across all of the RCTs were educated through direct training, the provision of information relevant to their disease or one-to-one

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educational coaching. The interventions included various interactions, e.g. nurse expert visits and support, and support provided by peers, groups or family members. These interactions occurred through face-to-face coaching, virtual human coaching or virtual coaching that relied on an algorithm. The performed meta-analysis included 6 of the 11 identified studies. The overall effect was nonsignificant, with three studies demonstrating a significant postintervention effect on patients' quality of care and quality of life and three studies a nonsignificant effect.

Conclusions: The presented results suggest that ICT-based care should be developed in collaboration with nurses and other health care professionals, involve patients in decision-making and combine ICT solutions with human interaction and coaching. ICT education was found to be essential to the success of an intervention.

KEYWORDS

ICT, information and communication technology, meta-analysis, nurse, quality of patient care, randomised controlled trials, systematic review

1 | INTRODUCTION

In recent years, patients with long-term/chronic illnesses have become more common and diverse (World Health Organization & United Nations Children's Fund, 2020). This can be explained by advances in medicine, which have enabled people with chronic and long-term conditions to live longer, and better cope with their ailment(s).

Furthermore, the digital age—which involves the rapid shift from 3G and 4G to 5G networks—has enriched various dimensions of health care services (Ting et al., 2020). For example, patients' daily lives have been improved by numerous technologies, e.g. monitoring devices to help patients understand their own physical condition, learning tools, solutions for communicating with health care professionals, and assisted living and robotics to expand patient's self-care capacities. New technological solutions can also substantially improve the way nurses work because it avoids consuming a lot of time that nurses would have spent collecting patient information (Day & Beard, 2019). Electronic health records are being developed to manage workloads and to facilitate the efficient sharing of medical information between nurses, other health care providers and stakeholders; these types of solutions will improve care by enabling the capture of detailed patient information and allowing nurses to deepen their assessment of the patient (Roehrs et al., 2017; Symons et al., 2019).

In this way, information communication technology (ICT) is highly relevant to the health care sector. ICT technology has developed rapidly due to the dedication of innovative engineers and companies, yet there is little evidence on how well these technologies improve patients' self-care and self-management skills and how effective they are on the quality of patient care. Adherence to self-care is a crucial factor in preventing the progression of chronic conditions or the consequences of an unhealthy lifestyle. Adherence

What is already known about the topic?

- The increasing prevalence of chronic diseases, when considered together with decreasing numbers of health care staff, will challenge health care systems in the future.
- The WHO has stated that digitalised health care can improve patients' access to health services, reduce the burden of travel and potentially reduce inequalities in health care.
- Versatile ICT solutions have been developed for patient-centred care, but the effectiveness of these solutions has not been adequately measured in the health care domain.

What this paper adds

- The integration of ICT into patient-centred care requires human interactions and educational coaching.
- Educating both patients and nurses is essential to the success of ICT solutions.
- Any developed intervention should include measurements related to nurses and other stakeholders in addition to patient-centric outcomes.
- Digital literacy measurements could be integrated into future studies to avoid bias in measurements and the reporting of results.

to self-care can be defined as goal-oriented, patient's active self-management of one's own health in close collaboration with health care personnel (Kähkönen et al., 2020; Oikarinen et al., 2018). Adherence to self-care is often challenging, even though the effects

of long-term outcomes are undeniable, e.g. smoking cessation halves the mortality risk (Booth et al., 2014) and a healthy diet (Estruch et al., 2013) and increased physical activity (Graham et al., 2007) may reduce mortality risk by 33%. That is, it's essential to investigate digital, web-based environments more for patients who are chronically ill since they may have the potential to increase the quality of life while empowering patients in self-care (Neame et al., 2019). Some studies suggest that digital environments could complement standard counselling in supporting self-care adherence to self-care (Paalimäki-Paakki et al., 2022).

In the context of the application of ICTs to health care practice, two relevant literature reviews exist. First, Koivunen and Saranto (2018) published a qualitative review that integrates the experiences of nursing professionals on which factors are facilitators and barriers to patients' use of ICT in the use of online telehealth services. This systematic review scrutinised 25 articles and found that nurses' skills and attitudes are barriers to the implementation of telemedicine. Moreover, the analysed literature revealed that the shift from face-to-face nursing to the use of telemedicine will require local consensus and further professional discussions on how the change will be accepted and implemented. Koivunen and Saranto (2018) further support the active adoption of ICT tools by patients and the use of telemedicine by concluding that attention needs to be paid to the role of patients. However, the review fails to examine how ICTs have impacted on the quality of patient care and patient quality of life (Koivunen & Saranto, 2018).

The field of digital technologies for care has already been explored in terms of acceptability, effectiveness and efficiency, with a recent scoping review clarifying how different solutions have been used in various target settings, target groups and areas of support (Krick et al., 2019). This scoping review—which included more than 700 references published up until 2018—comprehensively presented the extant evidence. However, the current evidence base is not sufficiently detailed about how specific innovations can improve the quality of care and/or nurses' clinical work. This again is limited to a discussion of the use of ICT for nursing tasks and does not adequately address the impact of ICT on the quality of patient care. In addition, because the field of ICT is progressing at an incredibly rapid rate, many studies have reported results that are no longer relevant based on the technological developments that occurred between the research process and the publication of the findings. Therefore, there is a need for another systematic review on the topic that includes the most recent evidence.

Despite these wide varieties of ICTs being developed, there is a lack of clear evidence on the extent to which they directly contribute to patient care and what impact they have on patient quality of life. For this reason, the current review has found that in all health care sectors, from home care to highly specialised care in hospitals, and preventive care in the community, the use of ICTs has led to self-care solutions that enhance patient self-care and self-management, from the perspective of preventing disease onset to early detection and improving patient behaviour and improve the quality of patient care will be explored.

2 | METHODS

2.1 | Study aim and research questions

The aim of this systematic review was to identify the current best evidence on the types of interventions that have been developed to improve the quality of patient care by the clinical application of ICT solutions in specialised, primary or home care. The research was guided by the following study questions:

1. What types of interventions have been designed to improve the quality of primary, tertiary or home care via the use of ICT solutions?
2. How have these interventions, i.e. the clinical implementation of ICT solutions, affected the quality of primary, tertiary or home care?

2.2 | Search strategy

The systematic review was conducted according to JBI Manual for Evidence Synthesis guidelines (Aromataris & Munn, 2020), and the protocol was registered in PROSPERO 2020 (ID227645). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA statement was followed to ensure that the findings were reported in a rigorous and transparent manner (Page et al., 2021; Supplementary File 3). The eligibility criteria were formatted according to PICOS inclusion and exclusion criteria (see Table 1). The population (P) included patients involved in primary, tertiary or home care, interventions (I) of interest included the clinical application of ICT with the underlying goal of enhancing patient-centred care, comparison (C) mandated that the research had to include a control group that had not received the tested ICT intervention and outcome (O) represented the quality of patient-centred care through at least one of the following outcomes: maintaining patient autonomy, empowering self-care/self-management/self-efficacy, individualised and relationship-based care, and shared decision-making. In addition, study type (S) included randomised controlled trials (RCTs) that were peer-reviewed and published between 2010 and 2020 in English, Finnish or Japanese. Hence, non-peer-reviewed publications, studies that did not follow an RCT study design and/or were published prior to 2010 were excluded. The combination of keywords included 'patient or client or user or consumer or customer' AND 'specialized care or primary care or home care' AND 'Information and communication technology or ICT' AND 'Quality of patient-centred care' AND 'Intervention or randomized/randomised controlled trial or experimental or trial study'. MESH terms and the required acronyms were applied to develop the most inclusive search strategy. A library specialist from the University of Oulu, Mrs. Sirpa Grekula, was consulted during the development and pilot testing of the search process. The precise searches developed for each database are shown in Supplementary File 1. A total of four electronic databases were screened for relevant data: CINAHL

TABLE 1 Inclusion criteria by PICOS review

Inclusion criteria for chosen studies (PICOS)		Exclusion criteria	Keywords
Population	Patient at specialised or primary or home care	User or customer not involved in specialised and/or primary and/or home care	Patient or client or user or consumer or customer and specialised care or primary care or home care
Interventions	Intervention of clinical applications of information and communication technology (ICT) to enhance the quality of patient care	Noninterventional study Intervention protocol Clinical applications of noninformation and communication technology	Information and communication technology or ICT
Comparative	Control group (no intervention or no intervention of clinical applications of ICT)	No control group	
Outcome	Quality of patient-centered care (including maintaining patient autonomy, empowering self-care, individualised and relationship-based care, shared decision-making and creating a homelike environment). Measured with validated instruments.	Other than quality of patient-centered care Measurements without validated instruments	Quality of patient-centered care (including maintaining patient autonomy, empowering self-care, individualised and relationship-based care, shared decision-making and creating a homelike environment)
Study types	Peer-reviewed, RCT, published during years 2010–2020; languages English, Finnish, Japanese	Non-peer-reviewed, other than RCT, published before 2010 other languages than English, Finnish or Japanese	Intervention or randomised controlled trial or experimental or trial study

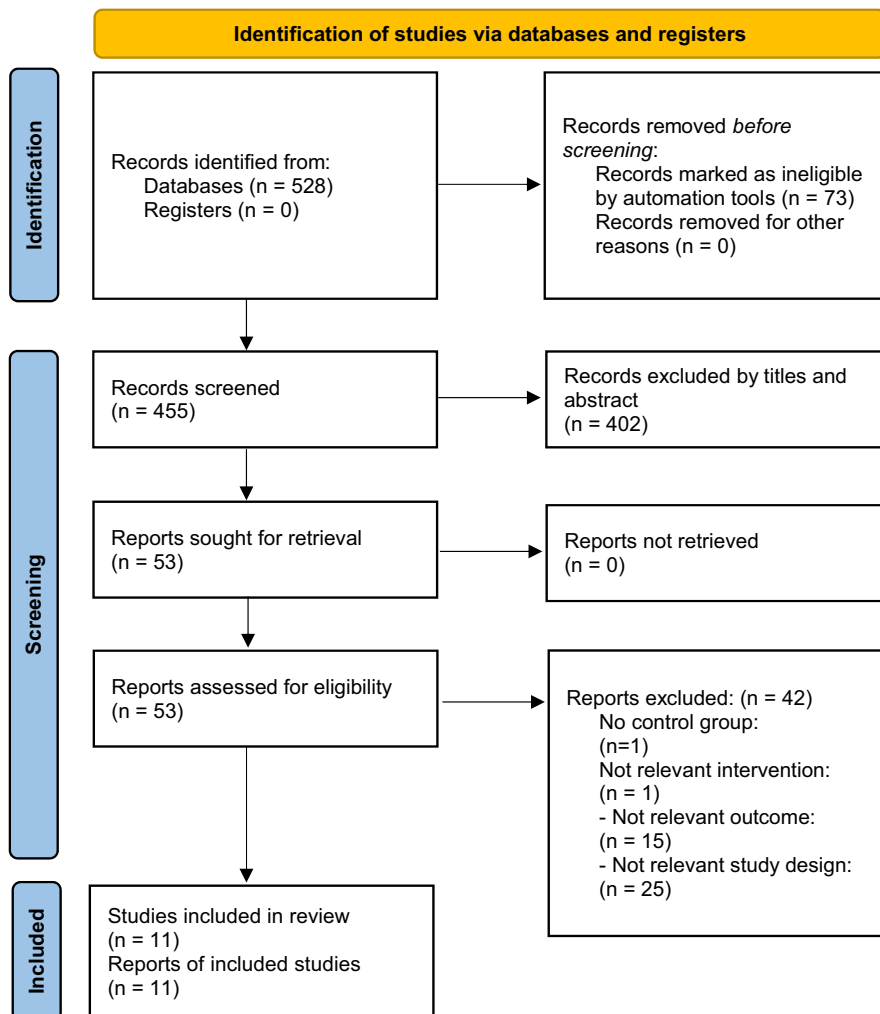


FIGURE 1 PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases and registers only

(EBSCO), PUBMED (Medline), SCOPUS and MEDIC. Any instances of grey literature were not included in the review.

2.3 | Study selection

The selection of relevant research was conducted by four researchers (KM, MY, AMT and AO), who individually screened the identified studies by title, abstract and full text, after which they discussed—and agreed upon—the results together. The researchers used Covidence 2020 (Veritas Health Innovation, Melbourne, Australia) when importing and screening data. A total of 528 studies were identified during the literature search, with 455 remaining after duplicate removal ($n = 73$). The studies were then assessed based on title and abstract ($n = 455$), with 402 studies excluded. The remaining studies ($n = 53$) were assessed based on the full-text article ($n = 53$), after which 41 studies were excluded for the following reasons: no control group ($n = 1$); intervention was not relevant ($n = 1$); outcomes were not relevant ($n = 15$); study design was not relevant ($n = 24$). Eventually, 11 eligible studies were chosen for the risk of bias assessment and final synthesis. The flow chart of the study selection process, which was conducted according to PRISMA guidance, is presented in Figure 1.

2.4 | Assessment of risk of bias and study quality

During the next phase of the study progress, four researchers (KM, MY, AMT and AO) assessed the risk of bias and study quality. This was first done separately, after which all of the researchers discussed, and agreed upon, the results. The quality of the 11 chosen studies was assessed with seven criteria of the Cochrane Risk of Bias Assessment (Higgins et al., 2011): random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors; incomplete outcome data, selective outcome reporting and other sources of bias (see Figures 2 and 3). For each of these criteria, a study could receive a high, low or unclear score. Out of the 11 identified studies, only one study (Chan et al., 2014) demonstrated low scores across all seven criteria. The article by Zhu et al. (2018) demonstrated a high or unclear risk of bias scores for most criteria. On the other hand, most studies had an unclear risk of bias concerning incomplete outcome data and selective outcome reporting (Chan et al., 2014; Jansen et al., 2017; Khanna et al., 2019; Kravitz et al., 2018; Tung et al., 2019; Tutino et al., 2017; Waki et al., 2015; Wigg et al., 2013). The criteria 'blinding of participants and personnel' and 'blinding of outcome assessors' most commonly showed a high risk of bias. Only Chan et al. (2014), Hanberger et al. (2013) and Zhu et al. (2018) reported the blinding procedures in the RCT methodologies. Additionally, a checklist for randomised controlled trials in a Critical Appraisal tool (JBI Systematic Reviews) was used to assess the quality of the identified studies (Tufanaru et al., 2020). Each study was assessed according to 13 critical statements related to RCT quality, validity and reliability, with the researchers selecting 'Yes', 'No' or 'Unclear' as the answer (see Supplementary File 2). In this assessment,

Chan et al. (2014) scored 100%, Kravitz et al. (2018) scored 92%, Wigg et al. (2013) scored 85%, while the articles by Hanberger et al. (2013), Khanna et al. (2019), Tutino et al. (2017) and Zhu et al. (2018) all had scores of 77%. The remaining studies scored between 54% and 70%. All studies have been included in the final data synthesis.

2.5 | Data extraction and meta-analysis

The following data were extracted from the 11 chosen RCT studies: study identification, study objective, population, intervention, comparison, outcome, measurements and key findings (see Table 2). During the meta-analysis, the overall effect and heterogeneity indexes were calculated in the 'metaan' package in Stata v12 (Kontopantelis & Reeves, 2010; StataCorp., 2011). The random-effects models incorporated the heterogeneity estimation in the weighting (Harris et al., 2008) as recommended by Veroniki et al. (2019) and Kontopantelis and Reeves (2010). The overall effect was calculated with the profile likelihood (PL) random-effects model (Kontopantelis & Reeves, 2010).

Heterogeneity was represented by three indices: the Q-statistic in the χ^2 distribution and the corresponding p -value (Hoaglin, 2016); the I^2 statistic; and the τ^2 statistic (Higgins et al., 2019). A significant p -value for the Q-statistic indicated heterogeneity bias. However, heterogeneity was further assessed by calculating the I^2 statistic because the Q-statistic should be interpreted with caution when the p -value does not show statistical significance (Higgins et al., 2019). According to the Cochrane standards, heterogeneity is not important if I^2 is between 0% and 40%, moderate if I^2 is between 30% and 60%, substantial if I^2 is between 50% and 90% and considerable if I^2 is between 75% and 100% (Higgins et al., 2019). The τ^2 statistic was also determined to estimate the amount of variation between the included studies. Studies characterised by a high degree of heterogeneity in the measurement of primary outcomes, i.e. to the extent that the results could not be pooled for the meta-analysis, were summarised narratively.

The funnel plot graphic was adopted to assess publication bias. A funnel plot provides a visual representation of the treatment effects reported in a set of studies; in cases in which the funnel plot has an asymmetrical shape, the meta-analysis may overestimate the effect of a studied treatment; and therefore, publication bias exists (Sterne & Harbord, 2004). The 'metafunnel' package was used to generate the funnel plot in Stata v12 (StataCorp., 2011; Sterne & Harbord, 2004).

3 | RESULTS

3.1 | Study characteristics

Most of the 11 identified studies were conducted in Asia, e.g. in Hong Kong (Chan et al., 2014), China (Tutino et al., 2017; Zhu et al., 2018) and Japan (Waki et al., 2015). The other RCT studies

Study

Study	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinded of outcome assessors	Incomplete outcome data	Selective outcome reporting	Other sources of bias
Chan et al. (2014)	+	+	+	+	+	+	+
Hanberger et al. (2013)	+	?	+	+	-	+	+
Hermanns et al. (2012)	-	+	-	-	+	-	+
Jansen et al. (2017)	+	?	-	?	+	+	+
Khanna et al. (2019)	+	+	?	?	+	+	+
Kravitz et al. (2018)	+	+	+	-	+	+	?
Tung et al. (2019)	+	-	-	-	+	+	?
Tutino et al. (2017)	+	+	-	-	+	+	?
Waki et al. (2015)	+	+	-	-	+	+	+
Wigg et al. (2013)	+	+	+	?	+	+	?
Zhu et al. (2018)	?	?	+	+	-	-	?

Legend: ■ high, ■ low, ■ unclear

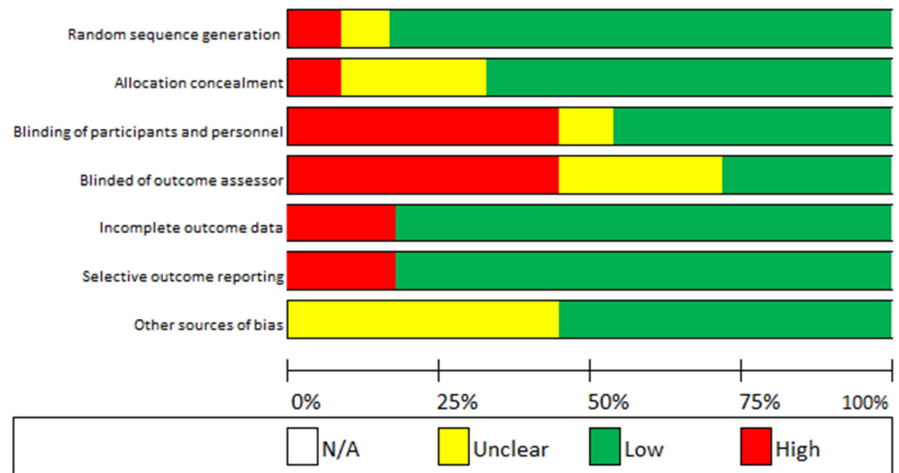
FIGURE 2 Assessment of risk of bias using the Cochrane Risk of Bias Tool

were conducted in the United States (Khanna et al., 2019; Kravitz et al., 2018; Tung et al., 2019), Australia (Wigg et al., 2013) and Europe, e.g. Sweden (Hanberger et al., 2013), Germany (Hermanns et al., 2012) and the Netherlands (Jansen et al., 2017). All the studies included were published in the English language. The identified RCTs included a total of 6128 participants (a minimum of 30 and a maximum of 3586), of which 3149 participants were in interventional groups and 2979 were in control groups. The participants represented patients with type 2 diabetes mellitus (Chan et al., 2014; Hermanns et al., 2012; Tutino et al., 2017; Waki et al., 2015), type 1 diabetes mellitus (Hanberger et al., 2013), cancer of the head and neck (Jansen et al., 2017), systemic sclerosis (Khanna et al., 2019), chronic musculoskeletal pain (Kravitz et al., 2018), chronic liver failure (Wigg et al., 2013) and hypertension (Zhu et al., 2018), along with general primary care attendees (Tung et al., 2019).

3.2 | Types of interventions

All of the interventions included ICT utilisation to improve the quality of patient-centred care (see Table 3). The clinical application of ICT included the telephone (Chan et al., 2014; Khanna et al., 2019; Kravitz et al., 2018; Tung et al., 2019; Tutino et al., 2017; Wigg et al., 2013; Zhu et al., 2018), a web portal (Chan et al., 2014; Hanberger et al., 2013; Hermanns et al., 2012; Jansen et al., 2017; Khanna et al., 2019; Tutino et al., 2017), interactive online educational resources (e.g. games and simulations) (Hanberger et al., 2013; Hermanns et al., 2012), mobile health applications (Kravitz et al., 2018; Waki et al., 2015), the utilisation of electronic health records (Tung et al., 2019) and delivery system design (e.g. algorithms) (Tung et al., 2019; Tutino et al., 2017; Waki et al., 2015; Wigg et al., 2013; Zhu et al., 2018). All of the studies, with the exception of one (Tung et al., 2019), reported that the patient ICT support system involved various interactions during the

FIGURE 3 Overall risk of bias using the Cochrane Risk of Bias Tool (Higgins et al., 2019)



intervention. These interactions included visits and support from health care experts (e.g. nurse, interprofessional team, doctor), along with support from peers, groups or family members. These interactions occurred via face-to-face coaching, virtual human coaching or virtual coaching based on an algorithm. Patients in all of the RCT studies were educated through direct training, information and educational resources relevant to their disease, or one-to-one educational coaching. The research presented by Hermanns et al. (2012) and Khanna et al. (2019) combined all three of these methods in the described intervention.

3.3 | Outcome measures

All of the studies collected baseline measurements, with the length of the investigated intervention varying; the shortest duration was 3 months (Tung et al., 2019; Waki et al., 2015), while the longest duration was 24 months (Hanberger et al., 2013), with the other studies describing interventions, which lasted six (Hermanns et al., 2012), eight (Khanna et al., 2019; Zhu et al., 2018) or 12 months (Chan et al., 2014; Jansen et al., 2017; Kravitz et al., 2018; Tutino et al., 2017; Wigg et al., 2013). Of the 11 identified studies, six included measurements of clinical variables, e.g. haemoglobin, blood glucose, cholesterol, body weight and blood pressure (Chan et al., 2014; Hanberger et al., 2013; Hermanns et al., 2012; Tutino et al., 2017; Waki et al., 2015; Zhu et al., 2018). In terms of the quality of patient-centred care, the described interventions measured the quality of life or care, self-efficacy or self-management. Quality of life was measured using the following instruments: EQ-5D EuroQol for Quality of Life (Chan et al., 2014; Jansen et al., 2017; Khanna et al., 2019); SF-36 Health-Related Quality of Life (Hermanns et al., 2012); DISABKIDS Quality of Life for Children (Hanberger et al., 2013); and Quality of Life Chronic Liver Disease Questionnaire (Wigg et al., 2013). Quality of care was measured using the following instruments: Quality of Care (Wigg et al., 2013); and Quality of Care from the Patient's Perspective (QPP) questionnaire (Hanberger et al., 2013). Self-efficacy was measured using the following instruments: DES-20

Diabetes Empowerment Scale for Self-efficacy (Chan et al., 2014), Chinese version of the Short-Form Chronic Disease Self-Efficacy Scale (Zhu et al., 2018) and PROMISE Self-efficacy scale (Khanna et al., 2019; Kravitz et al., 2018). Self-care or self-management was measured using the following instruments: SDSCA-14 Self-care Activities (Chan et al., 2014), SWE-DES-SF-10 Swedish Diabetes Empowerment Scale (Hanberger et al., 2013), Self-Care Activities scale (Hermanns et al., 2012), Patient Activation Measure (PAM) (Khanna et al., 2019), self-made items measuring self-management (Tung et al., 2019) and Compliance to Self-care (Waki et al., 2015).

3.4 | Effects of interventions based on a meta-analysis

Of the 11 studies included in this systematic review, six were eligible for quantitative synthesis in the meta-analysis (Chan et al., 2014; Hermanns et al., 2012; Jansen et al., 2017; Khanna et al., 2019; Kravitz et al., 2018; Wigg et al., 2013). The other studies did not include the information required to perform a quantitative synthesis (e.g. summative mean scores, standard deviation or confidence intervals). The overall effect calculated in the meta-analysis supports that the tested interventions had a positive effect on the quality of care (PL = 0.33); however, the confidence interval of this result (95% CI = -0.07-0.80) does not allow us to exclude a null effect. The forest plot (see Figure 4) illustrates the effects reported in each study and the overall effect calculated in the meta-analysis with the associated 95% CIs (see Figure 4). According to the meta-analysis of six studies, three studies significantly influenced patients' quality of care and quality of life. The intervention described by Wigg et al. (2013) reported rather large effect size, 1.50 (CI = 0.90-2.10). The intervention described by Wigg et al. (2013) focused on the efficacy of a chronic disease management approach for patients with chronic liver failure, which integrated a telephone and delivery system, interaction with health care experts, family involvement and face-to-face coaching, patient training and educational coaching. The intervention described by Jansen et al. (2017) included four

TABLE 2 Data extraction of the 11 chosen RCT studies

Authors	Study objective	Population	Intervention
Chan et al. (2014) Hong Kong ^a	To investigate whether frequent contacts through a telephone-based peer support programme (Peer Support, Empowerment, and Remote Communication Linked by Information Technology [PEARL]) would improve cardiometabolic risk and health outcomes by enhancing psychological well-being and self-care in patients receiving integrated care implemented through a web-based, multicomponent quality improvement programme (JADE [Joint Asia Diabetes Evaluation]).	628 Chinese patients with T2DM were randomised to the intervention JADE + PEARL ($n = 312$) or the control JADE ($n = 316$) groups.	Thirty-three motivated patients with well-controlled T2DM received 32 hours of training (four 8-hour workshops) to become peer supporters, with 10 patients assigned to each. Peer supporters called their peers at least 12 times in the JADE + PEARL group; these calls were guided by a checklist.
Hanberger et al. (2013) Sweden	To develop a Web portal designed to facilitate self-management, including diabetes-related information and social networking functions, and to study its use and effects in paediatric patients with diabetes.	474 children and adolescents with diabetes in a geographic population of two paediatric clinics in Sweden were randomised to the intervention group ($n = 244$), with access to the portal, or a control group ($n = 230$) with no access.	The Diabiet Web portal was developed and offered to the intervention group with services of self-directed communication with health professionals, interaction with peers and access to information.
Hermanns et al. (2012) Germany ^a	To evaluate the effect of an education programme (MEDIAS 2 ICT) involving intensive insulin treatment for people with type 2 diabetes when compared to an established education programme as an active comparator condition (ACC).	186 Type 2 diabetes patients were randomised to the intervention MEDIAS 2 ICT ($n = 94$) or control ACC-established education programme without ICT ($n = 92$) groups.	MEDIAS 2 ICT was designed to help patients perform multiple-injection insulin therapy and adjust their insulin doses depending on carbohydrate consumption, physical exercise and preprandial glucose levels. In addition, MEDIAS 2 ICT focused on controlling metabolic risk factors such as elevated lipids and blood pressure. It was conducted as a group interactive programme comprising 10 lessons of 90 min each.
Jansen et al. (2017) Netherlands ^a	To assess the cost-utility of the stepped care (SC) programme compared with care-as-usual (CAU) in patients with head and neck cancer or lung cancer who have psychological distress.	156 patients with head and neck cancer or lung cancer were randomised to intervention SC ($n = 75$) or control CAU ($n = 81$) groups.	The SC programme consisted of four steps: (1) watchful waiting, (2) guided self-help via the Internet or a booklet, (3) face-to-face problem-solving therapy and (4) specialised psychological interventions and/or psychotropic medication.

Comparison	Outcomes	Measurements	Key findings
No peer PEARL programme, only JADE portal.	Primary outcomes: physiological measures (haemoglobin). Secondary outcomes: quality of life, patient health for depression, diabetes, empowerment for self-efficacy and distress	Measurement at 0 and 12 months. Instruments: EQ-5D (Euroqol for quality of life), PHQ-9 (Patient Health Questionnaire for depression), SDSCA-14 (self-care activities), DASS-21 (Depression Anxiety Stress Scale for psychological distress), DES-20 (Diabetes Empowerment Scale for self-efficacy) and CDDS-15 (Chinese Diabetes Distress Scale).	Both groups showed similar, and significant, improvements in most psychological behavioural parameters, including medication, adherence and self-efficacy. In the JADE+PEARL group, 90% of patients maintained contacts with their peer supporters, with a median of 20 calls per patient. Most of the discussion items were related to self-management.
No access to the Diabit Web.	Primary outcomes: quality of life, empowerment and perception of quality of care. Clinical variables: HbA1c, hypoglycaemia and blood glucose.	Measurements at 0, 1 and 2 years. Instruments: DISABKIDS (Quality of Life for children), Quality from the Patients' Perspective (QPP) Questionnaire and Swedish Diabetes Empowerment Scale.	The outcome variables did not differ between the intervention and control groups. No adverse treatment or self-care effects were identified. Peer interaction was a valued aspect.
ACC-established education programme without ICT.	Primary outcomes: HbA1c, lipids and weight. Secondary outcomes: emotional distress, diabetes knowledge, self-care activity and health-related quality of life	Measurements at baseline, 5 weeks and 6 months. Instruments: PAID diabetes-related distress, diabetes knowledge test, Summary of Self-Care Activities Scale and SF-36 Health Survey	Diabetes education led to a significant improvement in glycaemic control in both education groups. The MEDIAS 2 ICT group showed a statistically significant reduction in diabetes-related distress. After the 6-month follow-up, participants in MEDIAS 2 ICT showed a significant improvement in the Physical Composite Score of the SF-12, indicating a significant improvement in health-related quality of life. Neither group showed a statistically significant change in the Mental Composite Score of the SF-12 during the study period. Both groups showed a significant improvement in diabetes knowledge. Self-reported self-care behaviour was significantly increased in MEDIAS 2 ICT.
Care-as-usual (CAU).	Primary outcomes: Intervention costs, direct medical costs, direct nonmedical costs, productivity losses and health-related quality-of-life data.	Measurements at baseline, 12 months. Instruments: Trimbos and Institute of Medical Technology Assessment Cost Questionnaire for Psychiatry, Productivity and Disease Questionnaire, and EuroQol-5 Dimension measures and data from the hospital information system.	In the baseline case analysis, the intervention group had a significantly higher number of QALYs and significantly lower cumulative costs than the control group. The probability that cumulative QALYs were higher and costs were lower was 96%, indicating that SC is highly likely to be cost-effective when compared to CAU.

TABLE 2 (Continued)

Authors	Study objective	Population	Intervention
Khanna et al. (2019) USA ^a	To compare an internet-based self-management programme to a patient-focused educational book developed to assess measures of self-efficacy and other patient-reported outcomes in patients with systemic sclerosis (SSc).	267 patients with SSc were randomised to internet-based self-management programme intervention ($n = 134$) and a patient-focused educational book control ($n = 133$) groups.	Internet programme with a self-management website included 15 modules with a basic overview, coping and body image, exercise, self-advocacy, pain management, activities of daily living, fatigue and energy conservation, tips for families and caregivers, muscle and lung disease. The programme included interactive discussions with moderators.
Kravitz et al. (2018) USA ^a	To determine whether patients randomised to participate in an n-of-1 trial supported by a mobile health (mHealth) app would experience less pain and improved global health, adherence, satisfaction and shared decision-making compared with patients assigned to usual care.	215 patients with chronic musculoskeletal pain were randomised to intervention ($n = 108$) and control ($n = 107$) groups.	Intervention patients met with their clinicians and used a desktop interface to select treatments and trial parameters for an n-of-1 trial comparing two pain-management regimens. The mHealth app provided reminders to take designated treatments on assigned days and to upload responses to daily questions on pain and treatment-associated adverse effects.
Tung et al. (2019) USA	To evaluate the impact of CommunityRx, an automated, low-intensity resource referral intervention, on patients' knowledge, beliefs and use of community resources.	374 participants were randomised to intervention (HealthRx) ($n = 190$) and control ($n = 184$) groups.	CommunityRx generated an automated, personalised list of resources, known as HealtheRx, near each participant's home using condition-specific, evidence-based algorithms. Algorithms used patient demographic and health characteristics documented in the electronic health record to identify relevant resources from a comprehensive, regularly updated database of health-related resources in the study area.
Tutino et al., 2017 China	To test the hypothesis that delivery of integrated care augmented by a web-based disease management programme and nurse coordinator would improve treatment target attainment and health-related behaviour.	3586 diabetes mellitus participants were randomised to interventional (JADE) ($n = 1858$) and control (DIAMOND) ($n = 1728$) groups.	The web-based Joint Asia Diabetes Evaluation (JADE) and Diabetes Monitoring Database (DIAMOND) portals contain identical built-in protocols to integrate structured assessment, risk stratification, personalised reporting and decision support. The JADE portal contains an additional module to facilitate structured follow-up visits.

Comparison	Outcomes	Measurements	Key findings
An educational book.	Primary outcomes: self-efficacy. Secondary outcomes: quality of life, self-management.	Measurements at baseline, 16 weeks. Instruments: PROMIS Self-Efficacy for Managing Chronic Conditions instrument, the PROMIS-29 Profile instrument, the Patient Health Questionnaire, the Patient Activation Measure (PAM), the EuroQol 5-domain instrument (EQ-5D) and quality-adjusted life years (QALYs).	There were no statistical differences between the two groups in self-efficacy for managing symptoms. The quality of life was visually higher in the intervention group. Internet group participants agreed that the self-management modules were of importance to them, the information was presented clearly, and the website was easy to use and at an appropriate reading level.
Care-as-usual.	Primary outcomes: pain management. Secondary outcomes: patient-reported pain intensity, overall health, analgesic adherence, trust in clinician, satisfaction with care, medication-related shared decision-making and for the n-of-1 group only, participant engagement and experience.	Measurement at baseline, 6 months, 12 months. Instruments: PROMIS (Patient-Reported Outcomes Measurement Information System) scale, Pain Medication in Primary Care Patient questionnaire; Trust in Physician scale; Consumer Assessment of Health care Providers and Systems survey.	At the 6-month follow-up, pain interference was reduced in both groups, although the difference between the intervention and control groups was insignificant. The intervention patients did not outperform the control patients in any secondary outcomes, with the exception of medication-related shared decision-making at six months. Among patients assigned to the intervention group, 88% affirmed that the mHealth app could help people like them manage their pain.
Care-as-usual.	Primary outcomes: patient self-care including healthy eating classes, individual counselling, mortgage assistance, smoking cessation, stress management and weight loss classes or groups. Secondary outcomes: beliefs about having resources in the community to manage health.	Measurement at baseline, 1 month and 3 months. Instruments: self-made items for the study.	Intervention recipients showed improved knowledge and beliefs about common resources in the community to manage health relative to control subjects. More specifically, they gained knowledge relevant to smoking cessation and weight loss. Positive changes in both knowledge and beliefs about community resources were associated with higher resource use.
Diabetes Monitoring Database (DIAMOND) and no nurse visit in follow-up.	Primary outcomes: patients' clinical samples (incl. HbA _{1c} , blood pressure, cholesterol). Secondary outcomes: default rates, change in quality-of-life measures, frequency of hypoglycaemia, adherence to lifestyle modification/self-care activities, and new onset of physician-documented diabetes-related endpoints.	Measurements at baseline, 12 months. Instruments: metabolic control, insulin, drugs, quality-of-life instrument.	The proportion of participants attaining treatment targets increased in both groups and there were similar absolute reductions in HbA _{1c} and LDL cholesterol. The JADE group was more likely to self-monitor blood glucose and had fewer defaulters. There was no significant difference among the groups in the quality-of-life measurements.

TABLE 2 (Continued)

Authors	Study objective	Population	Intervention
Waki et al. (2015) Japan	To test a more patient-friendly version of DialBetics, the development of which was based on the original participants' feedback about the previous version of DialBetics.	54 type 2 diabetes patients were randomised to interventional (DialBetics) ($n = 27$) and control (non-DialBetics) ($n = 27$) groups.	DialBetics as a smartphone-based application that supports improved self-management among diabetics was implemented into patient self-care. DialBetics included components of data transmission, evaluation, exercise input and food recording and dietary evaluation.
Wigg et al. (2013) Australia ^a	To investigate the effect of a chronic disease management (CDM) intervention on hospital use in a cohort of chronic liver failure (CLF) patients.	60 patients with cirrhosis and complications from CLF were randomised to intervention ($n = 40$) or usual care control ($n = 20$) groups.	The intervention comprised four CDM components: delivery system redesign, self-management support, decision support and clinical information systems. Delivery was coordinated through case management by hepatology nurses involving multidisciplinary team care (gastroenterologist, nurse, general practitioner, dietician, alcohol counsellors), home visit by nurse within a week after discharge, initial weekly nurse telephone reviews of patients, rapid access to care pathway using a mobile telephone service for patients concerned about deterioration, and written and telephone patient reminders before appointments.
Zhu et al. (2018) China	To establish a nurse-led hypertension management model and to test its effectiveness at the community level.	134 hypertensive patients with uncontrolled blood pressure were randomised to intervention ($n = 67$) or control ($n = 67$) groups.	The nurse-led hypertension management model included four components (delivery system design, decision support, clinical information system and self-management support). Patients in the intervention group received a 12-week period of hypertension management.

^aIncluded in meta-analysis.

Comparison	Outcomes	Measurements	Key findings
Non-DialBetics general care.	Primary outcomes: blood glucose, blood pressure, weight. Secondary outcomes: compliance, diet input, participants' experiences.	Measurements at baseline, 3 months. Instruments: a smartphone (Samsung Galaxy Note 1, Seoul, Korea), NFC-enabled glucometer (Terumo MS-FR201B, Tokyo, Japan) and Bluetooth enabled BP monitor (Omron HEM-7081-IT, Kyoto, Japan), pedometer (Omron HJ-720IT, Kyoto, Japan) with adapter (Omron HHX-IT1) and weight scale (Omron HBF-206IT), all able to transmit measurement readings by wireless network to the DialBetics server.	Diet evaluations of the DialBetics group showed a significant decline in HbA1c. DialBetics with FoodLog was shown to be an effective and convenient tool, its new meal-photo input function helping provide patients with real-time support for diet modification.
Care-as-usual.	Primary outcomes: number of days spent in a hospital bed for liver-related reasons. Secondary outcomes: rates of other hospital use measures, rate of attendance at planned outpatient care, disease severity, quality of life and quality of care.	Measurements at baseline, 6 months, 12 months. Instruments: liver-related OBDs expressed as a rate per person per year, hospitalisation reasons and length, monitoring of outpatient care, changes in disease severity, quality-of-life disease-specific Chronic Liver Disease Questionnaire and quality of care.	The intervention did not reduce the number of days patients spent in hospital beds for liver-related reasons, compared with usual care, or affect other measures of hospitalisation. Patients given the intervention had a 30% higher rate of attendance at outpatient care and significant increases in quality of care, based on adherence to hepatoma screening, osteoporosis and vaccination guidelines and referral to transplant centers.
Care-as-usual.	Primary outcomes: blood pressure, self-care behaviours, self-efficacy, quality of life and satisfaction.	Measurements at baseline, after intervention (12 weeks), 16 weeks after the intervention. Instruments: calibrated sphygmomanometer and stethoscope, patients' adherence to anti-hypertensive drugs, nonpharmacological behaviours, Chinese version of the Short-Form Chronic Disease Self-Efficacy Scale, Chinese version of the Short-Form Health Survey, satisfaction assessment.	Blood pressure among intervention group members decreased significantly. In addition, the group's self-care behaviour and satisfaction improved significantly. No statistically significant difference in self-efficacy and quality of life was detected between the two groups after the intervention.

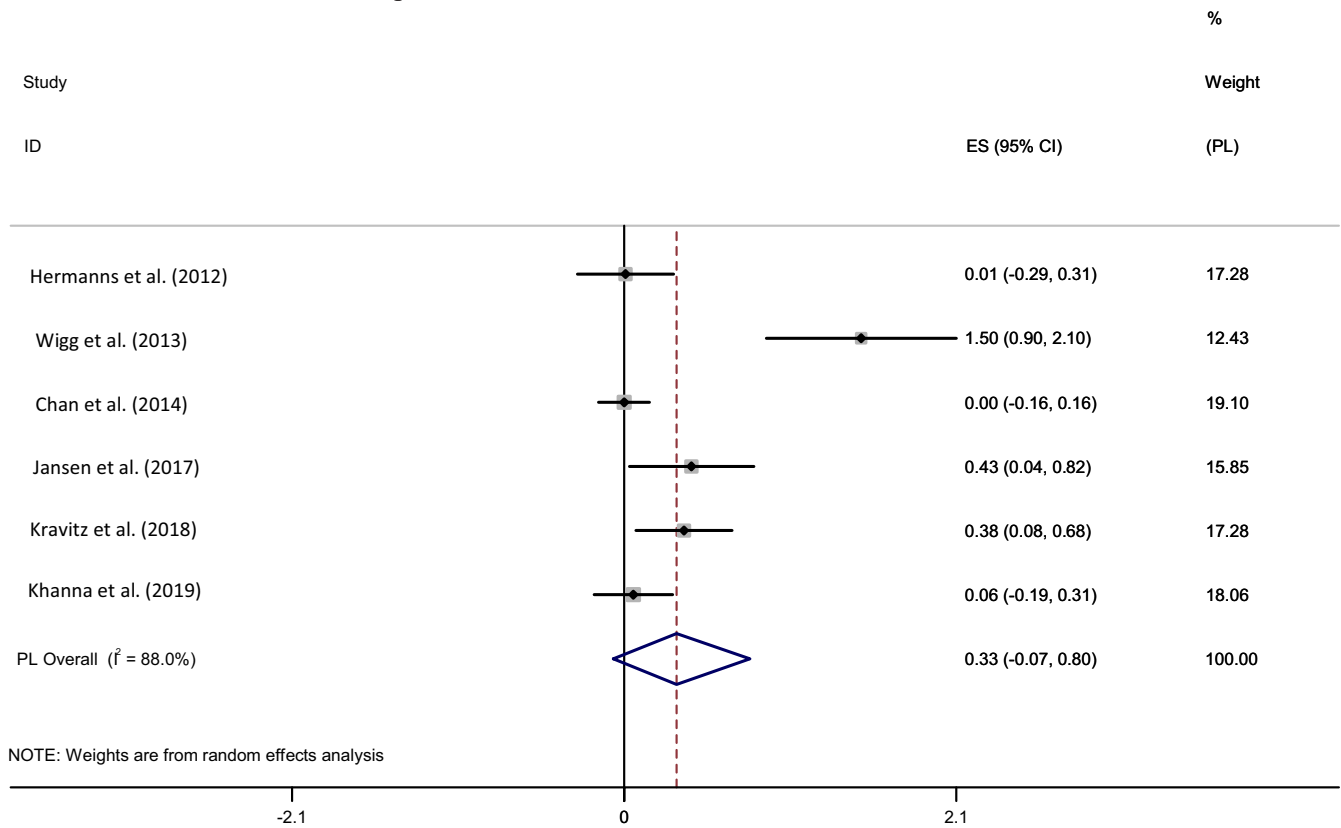


FIGURE 4 Meta-analysis: Forest plot (positive values represent a favourable effect compared with the standard)

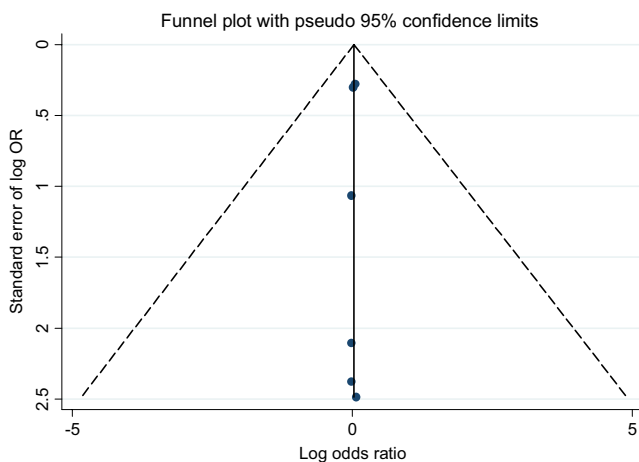


FIGURE 5 Publication bias assessment: Funnel plot

steps with an ICT intervention of guided self-help for patients with head, neck or lung cancer. The effect size was 0.43 (CI = 0.04–0.82). Kravitz et al. (2018) tested an app designed to support patients with chronic and musculoskeletal pain. The intervention was effective in improving pain management with an effect size of 0.38 (CI = 0.08–0.68).

The results of the meta-analysis revealed that the included studies included a certain degree of heterogeneity. More specifically, the

Q-statistic was statistically significant ($Q = 28.17$; $df = 5$, $p < .001$) while I^2 was 88.04% (95% CI = 76.44–93.92); these results indicate a considerable level of heterogeneity. The τ^2 statistic was 0.155 (95% CI = 0.00–0.85). The funnel plot showed a symmetrical pattern; hence, the meta-analysis was not affected by publication bias, and the results do not overestimate the effects of the described treatments (see Figure 5).

4 | DISCUSSION

This review aimed to identify the current best evidence concerning which types of interventions have been developed to improve the quality of patient care by the application of ICT solutions in primary, tertiary or home care. Numerous earlier studies have reported how long-term digital care paths impact the quality of life among patients with long-term illnesses (Chan et al., 2007; Cullington et al., 2018; Ryhänen et al., 2013; Wagenaar et al., 2019). The interventional study by Wigg et al. (2013) focused on integrated, multidimensional care in which ICT systems were complemented with human interactions (including nurses, other health care experts and family involvement) along with patient training and education.

This systematic review provided mixed findings regarding whether the clinical application of ICT solutions improves the quality

of life among patients in empowering self-care. The identified studies demonstrated that the clinical application of ICT solutions was effective in terms of behavioural parameters, including medication adherence (Hermanns et al., 2012), along with glycaemic control (Chan et al., 2014; Tutino et al., 2017; Waki et al., 2015), self-care behaviour (Chan et al., 2014; Waki et al., 2015; Zhu et al., 2018), LDL cholesterol levels (Tutino et al., 2017) and blood pressure management (Zhu et al., 2018). Earlier studies have suggested that digitalised care pathways do not necessarily result in better self-care among patients with long-term illnesses (e.g. Mata et al., 2020). The current systematic review does not provide clear and consistent evidence that ICT interventions positively affect a patient's quality of life in empowering self-care (Ammenwerth et al., 2012).

Earlier reviews have also reported mixed results on the impact of digital patient portals (Carini et al., 2021), digitalised care pathways (Neame et al., 2019; O'Connor et al., 2016) and telemedicine interventions (Eze et al., 2020) on the utilisation of health services, and the quality and effectiveness of care. However, there is a lack of research into the quality of digitalised health care (Carini et al., 2021). For example, there is previous evidence that patients are accepting of, and satisfied with, digitalised health care interventions, yet there are still notable barriers to the wider use of innovative solutions (Eze et al., 2020). The digitalisation of health care can help strengthen relationships and communication between patients, nurses and other health care professionals, empower the patient's well-being and help health care professionals and patients make better decisions (El Kefi & Asan, 2021); however, the presented results indicate that—at this point—human interaction cannot be replaced by digital technology.

It is important to recognise that a patient's quality of life was measured using multiple instruments in this systematic review; furthermore, the impact on quality of life may differ depending on the characteristics of a specific disease, such as diabetes mellitus or chronic liver dysfunction. The subjects in this study did not noticeably vary in terms of age and, as such, their acceptance of ICT solutions did not strongly vary. However, it is possible that there are individual differences in ICT literacy among patients. The technology acceptance model is commonly used to gauge technology adoption in patients, and a systematic review of 134 studies found that the concepts of subjective norms and self-efficacy, and compatibility, experience, training, anxiety, habit and facilitators, promote acceptance (Rahimi et al., 2018). However, none of the studies included in the present review mentioned these factors. The results of the meta-analysis could be expected to change if these potential clinical heterogeneities could be minimised.

It is also necessary to consider whether the level of ICT literacy and the use of ICT can improve a patient's quality of life, since the quality of life of patients who do not use ICT has not been taken into account. In other words, how compatible the applied ICT solution is with users' ICT literacy will determine the strength of the impact on quality of life.

Based on the results of the included interventional studies, nurse's and health care professional's competence in ICT use and delivery may have a large impact on how the patient experiences the

potential benefits of the solution. According to a previous systematic review, sufficient digital health competence among staff members can ensure that patients receive patient-centred quality care when ICT solutions are used during care delivery (Konttila et al., 2018). However, other studies have noted that nurses and other health care professionals might lack the competence to motivate and advise patients in self-management (Kujala et al., 2018) or communicate through patient portals (Laukka et al., 2020). Moreover, previous research has concluded that the development of health care professionals' digital health competence requires systematic and individually-designed education (Nazea et al., 2020). Additionally, organisational and collegial support (Jimenez et al., 2020; Konttila et al., 2018), and patient-friendly designs, are a starting point for the efficient use of ICT solutions by health care professionals (Lusigan et al., 2013).

The increasing prevalence of chronic diseases has led to considerable growth in health care costs (Boersma et al., 2020). This problem is not only restricted to high-income countries but has been noticed on a global scale (Bommer et al., 2017; Hajat & Stein, 2018). The long progression of many chronic diseases means that the prevention of severe illness and early detection of comorbidities are necessary. To achieve this, health care systems need solutions that adequately support self-management by patients and their families (Reynolds et al., 2018). The care for patients with chronic diseases needs to shift from the traditional focus on inpatient and outpatient care to community-based care interventions that are more in tune with patients' lifestyles (Stellefson et al., 2013). The performed meta-analysis, which consisted of six studies, revealed that only one study achieved a significant postintervention effect on the quality of patient care and the patient's quality of life (Wigg et al., 2013). Clearly, the impact of s-based care on a patient's quality of life is an area that warrants more research attention.

4.1 | Strengths and limitations

This paper provides an update to previous systematic reviews on the same topic and widens the evidence based on the rapidly changing topic that is digital health. The findings of this systematic review are further supported by the results of a meta-analysis to enhance the strength of evidence on the topic. Nevertheless, the presented research was undoubtedly affected by certain limitations. First, our systematic review did not include some databases, such as PsycInfo, and even if we had included every relevant database, it is still possible that some evidence would be overlooked. Second, the meta-analytic approach could only be applied to six of the 11 identified studies due to partial quantitative reporting in five studies. As such, the presented findings suggest that the methodological quality of future studies on the topic could be improved; this would allow a more complete meta-analysis to be conducted. It should be noted that two studies included in the meta-analysis demonstrated a risk of bias scores between 54% and 70%, even if they met the quantitative criteria for inclusion (Hermanns et al., 2012; Jansen et al., 2017);

the risk of bias scores for the other studies was between 77% and 100%. Although most of the studies included in the meta-analysis reported a low risk of bias, the two studies with a higher risk of bias could have affected the overall effect size. Third, our systematic review and meta-analysis focussed on the effectiveness of clinical ICT applications in improving patient-centred care across various clinical settings; focussing on a specific field of patient care could contribute to more targeted results. In this way, future studies could consider specific conditions (e.g. diabetes or oncological conditions) to enhance the evidence of how effective ICT interventions are at improving the patients' quality of life. When considered from a methodological perspective, this approach could also decrease the heterogeneity that was present in the meta-analytical synthesis.

5 | CONCLUSION

The increasing prevalence of chronic diseases and the decreasing number of health care staff will challenge health care systems in the future. According to the World Health Organisation (WHO, 2019), digitalised health care can improve patient access to health services, reduce travel costs and potentially reduce inequalities in health care. However, digital solutions, e.g. ICT-based care interventions, have shown mixed results on patient-centred care and quality of life. According to the presented results, we suggest that ICT-based care should be developed in collaboration with nurses and other health care professionals, involve patients in decision-making and combine technological solutions with human interaction and coaching. ICT solutions are potentially beneficial, as our meta-analysis results found a benefit in patients' outcomes when ICT interventions are integrated into patient care. However, as only three of the six studies included in the meta-analysis showed that the ICT interventions exerted a significantly positive effect, more research into how ICT-based care can improve a patient's quality of life is needed. Future ICT-based interventions should also not only measure patients' outcomes but also determine how the intervention impacts the interaction between patients and nurses, other health care staff and stakeholders. Additionally, the digital literacy of patients and nurses' measurements should be integrated into future studies to avoid bias in measurements and reported results.

AUTHOR CONTRIBUTIONS

All authors have contributed equally to this work.

ACKNOWLEDGEMENTS

We would like to thank and acknowledge library specialist Mrs. Sirpa Grekula for her involvement in this review to ensure the quality of the search strategy. Additionally, we would like to acknowledge Sees-Editing Ltd (<http://www.seesediting.co.uk>) service for improving the language and helping us to communicate our findings to readers of the journal.

FUNDING INFORMATION

No funding.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

All data generated during this study are included in this published article.

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How to cite this article: Mikkonen, K., Yamakawa, M., Tomietto, M., Tuomikoski, A-M, Utsumi, M., Jarva, E., Kääriäinen, M., & Oikarinen, A. (2022). Randomised controlled trials addressing how the clinical application of information and communication technology impacts the quality of patient care—A systematic review and meta-analysis. *Journal of Clinical Nursing*, 00, 1–20. <https://doi.org/10.1111/jocn.16448>