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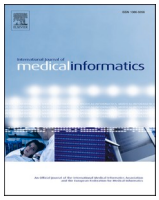

Healthcare professionals' digital health competence and its core factors; development and psychometric testing of two instruments

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ABSTRACT

Background: Healthcare professionals' digital health competence is an important phenomenon to study as healthcare practices are changing globally. Recent research aimed to define this complex phenomenon and identify the current state of healthcare professionals' competence in digitalisation but did not include an overarching outlook when measuring digital health competence of healthcare professionals.
Objectives: The purpose of this study was to develop and psychometrically validate two self-assessed instruments measuring digital health competence and factors associating with it.
Methods: The study followed three phases of instrument development and validation: 1) conceptualisation and item pool generation; 2) content validity testing and pilot study; and 3) construct validity and reliability testing. The conceptual background of the instruments was based on individual interviews conducted with healthcare professionals ($n = 20$) and previous systematic reviews. A total of 17 experts assessed the instrument's content validity. Face validity was evaluated by a group of healthcare professionals ($n = 20$). Data collection from 817 professionals took place in spring-summer 2022 in nine organisations. Construct validity was confirmed with exploratory factor analysis. Cronbach's alpha was used to assess the internal consistency of the instruments.
Results: The instrument development and validation process resulted in two instruments: DigiHealthCom and DigiComInf. DigiHealthCom included 42 items in 5 factors related to digital health competence, and DigiComInf included 15 items in 3 factors related to educational and organisational factors associated with digital health competence. The DigiHealthCom instrument explained 68.9 % of the total variance and the factors' Cronbach alpha values varied between 0.91 and 0.97. The DigiComInf instrument explained 59.6 % of the total variance and the factors' Cronbach alpha values varied between 0.76 and 0.88.
Conclusions: The two instruments gave valid and reliable results in psychometric testing. The instruments could be used to evaluate healthcare professionals' digital health competence and associated factors.

1. Introduction

Competence has been identified as including knowledge, skills, attitudes, values and performance which can be improved through education, training and professional development [1,2]. Like the definition of competence, digital competence is a broad concept that includes technical skills, ability to use and apply digital technologies as part of everyday life in a meaningful way, understanding of the phenomena of digital technologies and motivation to participate in digital culture [3]. In the context of healthcare, digital competence comprises digital knowledge and skills of digital technology to provide patient-centric care of good quality, digital interaction skills with patients and an interprofessional team, knowledge of ethical perspectives of digitalisation, and motivation and attitude to adopt and gain experience of digital technologies in a professional context [4–6].

According to the World Health Organisation (WHO), digital health is defined as "the field of knowledge and practice associated with the development and use of digital technologies to improve health" and includes a variety of digital solutions such as the Internet of Things, big data analytics, advanced computing and artificial intelligence used in

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the context of healthcare [7]. Digital solutions in healthcare enable personalised care, enhance information flow and facilitate accessibility of services [7,8] but also need careful and constant evaluation to ensure equal and cost-effective service provision for all and prevent digital exclusion of patients and professionals [9,10]. For example, the Electronic Health Records (EHRs) are effective in improving patient safety, in providing integrated decision-making tools and a more complete patients' documentation, and in decreasing organizational costs. However, three main barriers have been identified: upfront costs in implementing and adopting the digital solutions, privacy and security concerns, and lack of confidence and trained healthcare professionals to maintain the system [11]. The digital revolution of service provision and working methods across the healthcare sector has forced healthcare professionals to acquire new competences to stay up-to-date with requirements for high quality patient care and adjust to changes of increasingly automated societies [12].

Healthcare professionals' competence in digitalisation has been examined in various studies and reviews in recent years. However, a comprehensive definition is difficult due to the evolving nature of the phenomenon [13]. The roots for defining healthcare professionals' competence in digitalisation can be found in nursing informatics competence, which has been used to describe nurses' computer skills, informatics knowledge and informatics skills at four levels of practice (beginner nurse, experienced nurse, informatics specialist and informatics innovator) [14]. More recent research has broadened this definition to include other aspects related to the delivery of healthcare remotely (telehealth), where coaching skills, clinical expertise, communication and a supportive attitude are especially prominent [15]. Simultaneously, the use of artificial intelligence, e.g. in clinical decision making and patient monitoring, is increasing [2]. However, most studies have focused on the perspectives of a specific professional group, such as nurses [16] or doctors [17], on digital health competence.

Moreover, reviews of recent research have synthesised digital health competence frameworks and concluded the versatility and broadness of digital health competence definition. For example, Nazeha et al. [13] identified 30 competence frameworks, for which the majority were aimed at nurses. These frameworks included 28 digital health competency domains connected to, e.g. digital communication, basic information technology literacy, and data privacy and security. Another review explored competence frameworks and identified 59 capabilities connected to digital health competence categorised into change management, user application and data, information and knowledge [18]. Still, more research is needed on healthcare professionals' competencies to ensure patient-centric care [18], and these frameworks should be updated regularly as digital technologies are rapidly evolving [13].

Various instruments have been developed to measure healthcare professionals' core competences but included only single items related to the use of health information technologies [19–21]. In the early 2000 s, instruments developed to measure healthcare professionals' computer competency (knowledge, skills, attitudes) were reviewed, but competences focused solely on the use of computer programmes and software [22]. Instruments measuring healthcare professionals' wider competence in digitalisation were developed more recently but again included only limited dimensions of healthcare digitalisation, such as EHR documentation, basic IT skills and patient support in health information tool use [23,24], acceptance of electronic patient records [25], perceptions of artificial intelligence [26] and the ability to use robots in healthcare [27]. It is important to measure healthcare professionals' digital health competence on a wider scale to plan appropriate educational initiatives to improve the digital health competence of various healthcare professionals at different stages of their professional careers [5,13]. Additionally, professionals' evaluation of the organisational and educational factors associated with digital health competence adds to the understanding of the supporting and hindering aspects of competence development [5]. Hence, in the present study, two instruments were developed to identify and include several dimensions of digital health competence and associated factors of healthcare professionals with different professional backgrounds.

The purpose of this study was to develop and psychometrically validate self-assessed instruments measuring healthcare professionals' digital health competence (DigiHealthCom) and associating educational and organisational factors (DigiComInf). The aim of the instrument validation process was to produce instruments that could be used to measure healthcare professionals' digital health competence in versatile healthcare contexts. The specific research questions were as follows:

1. What is the face and content validity of the new DigiHealthCom and DigiComInf instruments?
2. What is the construct validity and reliability of the new DigiHealthCom and DigiComInf instruments in assessing the digital health competence of healthcare professionals and associated factors?

2. Materials and methods

This study comprised three phases: 1) conceptualisation and item pool generation, 2) content validity testing and pilot study, and 3) construct validity and reliability testing (internal consistency) [28,29] (Table 1). The COSMIN guidelines were followed to guide the process and enhance the methodological quality of the study [30].

Phase I: The phenomenon of healthcare professionals' digital competence and associated factors were operationalised and the item pool was created. This phase was executed inductively by constructing a conceptual framework based on systematic reviews [6,13,17], reports [31,32] and results from previous content analysis on healthcare professionals' perceptions of digital health competence and competence development [4,5]. The inductive approach was selected with the intention to test the chosen concepts empirically [29] as the definition of digital health competence and factors relating to it are broad. The conceptual framework was tested in phases II (content validity) and III (construct validity and reliability), which resulted in the final version of variables to be measured in two separate instruments [29].

Phase II: Content validity evaluation was conducted with the content validity index (CVI) method to determine whether the included items represented the phenomenon or proposed domains sufficiently [33]. For this step, one round of expert evaluation was conducted to evaluate the instruments' relevance and clarity at both scale and item levels. The experts were chosen from different organisations based on purposeful sampling and voluntary response according to criteria to attain a versatile and representative group of healthcare and social service professionals, digital healthcare service experts, instrument development experts and higher education teachers and researchers from different fields. Prior to giving their evaluation, the experts were provided with an explanation of the purpose of the study and the definition of digital health competence to ensure a common basis to build their evaluation on. Additionally, the experts were provided with the possibility to contact the researcher (author blinded) if any questions or concerns related to the topic arise. The cut-off for an acceptable item level content validity index (I-CVI) value was set at 0.78 and scale level content validity index (S-CVI) at 0.90 [33]. A pilot study was conducted to assess the feasibility and face validity of the instruments and gather feedback about the technical functionality, such as readability, completion time and clarity of the questionnaire [34].

Phase III: The instruments' construct validity and internal consistency reliability were analysed after finalisation of the data collection in the main study. Explorative factor analysis (EFA) with principal axis factoring and promax rotation was performed to determine the construct validity of the developed instruments by identifying correlations among the variables and assessing the extent to which the instruments correlated with the construct [34,35]. Factor estimation was conducted with measured eigenvalues using a cut-off of 1. The Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity (BTS) were implemented to

Table 1
Phases of instrument development and validation.

Phase 1. Conceptualisation and item pool generation		
Conceptual framework from – interviews with healthcare professionals (n = 20) – systematic reviews – reports	May 2019-October 2021	**Digital health competence** – *Usage of information and communication technology (7 items)* – *Patient-centric digital communication (21 items)* – *Evaluation of the usage of digital solutions (9 items)* – *Applying digital solutions (5 items)* – *Ethical competence related to digital solutions (6 items)* – *Accepting digital solutions (16 items)* **Factors associated with digital health competence** – *Influence of colleagues and the work community (11 items)* – *Influence of managers and leaders (8 items)* – *Influence of education and orientation (20 items).*
Phase 2. Content validity testing and pilot study		
Expert panel (n = 17)	November 2021-January 2022	**DigiHealthCom (53 items)** – *Usage of information technology (5 items)* – *Human-centred digital communication (17 items)* – *Evaluation of the usage of digital solutions (5 items)* – *Applying digital solutions (6 items)* – *Ethical competence related to digital solutions (7 items)* – *Accepting digital solutions (13 items)* Content validity index (S-CVI/Ave): 0.94 (relevancy) and 0.96 (clarity) **DigiComInf (30 items)** – *Influence of colleagues and the work community (11 items)* – *Influence of managers and leaders (8 items)* – *Influence of education and orientation (11 items).* Content validity index (S-CVI/Ave): 0.95 (relevancy) and 0.96 (clarity)
Pilot study with healthcare professionals (n = 20)	February 2022	**DigiHealthCom (50 items)** – *2 items deleted from sub-dimension 'human-centred digital communication'* – *1 item deleted from sub-dimension 'evaluation of the usage of digital solutions'* **DigiComInf (30 items)**
Phase 3. Construct validity and reliability testing		
Main study with healthcare professionals (n = 817, after multivariate outlier deletion n = 747)	March-August 2022	**DigiHealthCom (5 factors, 42 items), total variance 68.9 %** – *Human-centred remote counselling competence (16 items)* – *Digital solutions as part of work (9 items)* – *ICT competence (5 items)* – *Competence in utilising and evaluating digital solutions (8 items)* – *Ethical competence related to digital solutions (4 items)* Reliability: Cronbach's alpha: 0.91–0.97. **DigiComInf (3 factors, 15 items), total variance 59.6 %** – *Support from management (6 items)* – *Organisational practices as part of digital competence development (4 items)* – *Colleagues' adoption and influence (5 items)* Reliability: Cronbach's alpha: 0.74–0.88.

ensure sampling adequacy. Cronbach's alpha was used to assess the reliability of the instruments' items using a cut-off set at 0.70 for newly developed instruments [36].

2.1. Participants and data collection

The target population in the cross-sectional main study [37] consisted of Finnish healthcare professionals working in tertiary, primary and private healthcare organisations (N = 23 100, n = 817). The main inclusion criterion was the attainment of a license to practice the profession according to the guidelines of the National Supervisory Authority for Welfare and Health in Finland [38] and professional qualification from a university of applied sciences. Other healthcare professionals, such as physicians were excluded from the study since their degree programme is conducted at university level and is significantly longer compared to studies in a university of applied sciences. Data were collected from three primary healthcare organisations, one private organisation and five university hospitals in Finland using a voluntary response sampling design [39]. The organisations were chosen to cover different healthcare contexts in the Finnish healthcare system and reach a sufficiently large sample. The aim was to achieve more than five respondents per item (n = 400) to enable construct validity testing and verify the reliability of the instruments [36]. Information about the study and informed consent was distributed to the potential respondents according to the organisations' research practices. Data were collected between March and July 2022.

2.2. Ethical considerations

The study was conducted according to the responsible conduct of research (RCR) guidelines set by the Finnish National Board on Research Integrity [40] and Declaration of Helsinki [41]. The effects of the study on society and people's wellbeing were evaluated before initiating the data collection for content and construct validity testing [42]. Research permissions were requested and obtained from ten organisations to

conduct the pilot study and gather data for instrument validation. In the main study, contact persons forwarded the information about the study to each organisation. The eligibility criteria were informed separately to the contact persons and in the study's information letter to ensure participants met the inclusion criteria. Hence, the researchers did not have access or information about the participants' email addresses at any stage of the research to maintain anonymity and reduce bias [43]. Consent to participate in the study was requested at the beginning of the questionnaire and participants provided their responses to the questions anonymously according to general data protection regulations (GDPR) [44]. Data were stored in password secured files as stipulated by the GDPR.

3. Results

Phase I: In the conceptual framework, defined concepts were generated as sub-dimensions and items to be measured. The framework included 64 items in six sub-dimensions covering digital health competence and 39 items in three sub-dimensions covering educational and organisational aspects associated with digital health competence. Digital health competence included usage of information and communication technology (7 items), patient-centric digital communication (21 items), evaluation of the usage of digital solutions (9 items), applying digital solutions (5 items), ethical competence related to digital solutions (6 items) and accepting digital solutions (16 items) sub-dimensions. Associated factors to digital health competence included influence of colleagues and the work community (11 items), influence of managers and leaders (8 items) and influence of education and orientation (20 items) sub-dimensions.

Phase II: Seventeen experts participated in evaluating the face and content validity of the instrument. The majority of the experts provided additional comments to specific items as well as the scale. According to the results of the content validity testing, the research team decided to continue the instrument development process with two separate instruments: DigiHealthCom and DigiComInf. I-CVI of the items varied between 0.77 to 1 (DigiHealthCom) and 0.75 to 1 (DigiComInf) when measuring relevance and 0.71 to 1 (DigiHealthCom) and 0.86 to 1 (DigiComInf) when measuring clarity. S-CVI was calculated with S-CVI/Ave and had a value of 0.94 in DigiHealthCom and 0.95 in DigiComInf for relevance and 0.96 in both DigiHealthCom and DigiComInf for clarity, indicating very high content validity. According to the evaluation and written feedback provided by the expert panel, specific focus was put on revision or deletion of items with <0.78 I-CVI value [33]. As a result, the wording of 26 items was modified (DigiHealthCom 17 items, DigiComInf 9 items), 17 items were deleted (DigiHealthCom 12 items, DigiComInf 5 items) and 6 items were translated as background questions or transferred to other sub-dimensions (DigiHealthCom 2 items, DigiComInf 4 items). Additionally, the names of two sub-dimensions in DigiHealthCom were slightly modified to *usage of information technology* and *human-centred digital communication.*

Twenty healthcare professionals took part in the pilot study. Feedback from the pilot test resulted in minor modifications to the wording of 10 items (DigiHealthCom 8 items, DigiComInf 2 items), deletion of 3 items in DigiHealthCom and inclusion of 6 background questions. Responses from the pilot study were not included as part of the dataset for instrument validation.

Phase III: Data collected in the main study were used to conduct construct validity and reliability testing. In total, 817 healthcare professionals from the participating organisations answered the electronic questionnaire, representing a response rate of 3.5 %. Most of the respondents were female (86.7 %) and slightly over half (52.8 %) were reported to be registered nurses. The mean age among the respondents was 43.7 years (SD 11.4). 51.8 % of respondents worked in an inpatient unit and 89.2 % performed clinical work at least weekly. 17.4 % worked in a management position (Table 2). A four-point Likert scale (1 – completely disagree; 2 – partially disagree; 3 – partially agree; 4 – completely agree) was used for item scoring in the respondents' evaluation of their competence [45].

Table 2
Respondent characteristics.

Characteristics	Respondents (N = 817)
Gender	*n*, %
Female	708 (86.7 %)
Male	96 (11.8 %)
Other	5 (0.6 %)
Prefer not to say	8 (1.0 %)
Age	
Mean	43.7 years
Min	19 years
Max	67 years
SD	11.4
Profession	*n*, %
Registered nurse	431 (52.8 %)
Practical nurse	51 (6.2 %)
Physical therapist	45 (5.5 %)
Midwife	40 (4.9 %)
Occupational therapist	32 (3.9 %)
Public health nurse	19 (2.3 %)
Laboratory nurse/bio-analyst	14 (1.7 %)
Radiographer	12 (1.5 %
Social worker	10 (1.2 %)
Paramedic	9 (1.1 %)
Social advisor	8 (1.0 %)
Other (rehabilitation advisor, podiatrist, prosthetist/orthotist)	5 (0.6 %)
Assistant head nurse	58 (7.1 %)
Head nurse	56 (6.9 %)
Service manager/supervisor	16 (2.0 %)
Specialist/project coordinator	11 (1.4 %)
Clinical working environment/unit	*n*, %
Inpatient (including hospital ward, emergency ward, intensive care unit, operating theatre, delivery room)	423 (51.8 %)
Outpatient	245 (30.0 %)
Home care and assisted living	27 (3.3 %)
Emergency care	12 (1.5 %)
Administration and research	53 (6.5 %)
Other	57 (6.9 %)
Patient work	*n*, %
Daily (at least 5 days/week)	565 (69.2 %)
Weekly (1–4 days/week)	163 (20.0 %)
Monthly (a few times/month)	29 (3.5 %)
Rarely (a few times during several months)	21 (2.6 %)
I do not do patient work currently	39 (4.8 %)

Prior to explorative factor analysis and further data analysis, the quality and factorability of the data were assessed. No missing data management was required since the survey included only mandatory items. Multivariate normality has been tested by calculating the mean value of the Mahalanobis squared distances in the data distribution against the critical value (number of items multiplied by the number of items plus 2) [29]. As multivariate normality was not achieved, the distribution has been tested for multivariate outliers by considering the Mahalanobis distances and Mardia's kurtosis coefficient. A total of 70 multivariate outliers were detected and deleted, in order to achieve multivariate normality and to properly perform psychometric validation [29]. After outlier deletion, an inter-item correlation matrix was analysed and EFA was conducted. According to key concepts in the conceptual framework and examination of the eigenvalue (>1) [46], suitable factor models were achieved for two instruments. 8 low and cross-loading (<0.400) items were removed from DigiHealthCom and

15 items were removed from DigiComInf (<0.350). KMO tests (0.96 and 0.89) confirmed that the sample size was adequate for both instruments and BTS (DigiHealthCom: 28681.515, d.f = 861, $p < 0.001$; DigiComInf: 4853.812, d.f = 105, $p < 0.0001$) in both factor models revealed that correlations between the items existed. The final factor models in the instruments represented 5 factors with 42 items (DigiHealthCom) and 3 factors with 15 items (DigiComInf).

In DigiHealthCom, the total variance explained by the five-factor model was 68.9 % (Table 3). Of the factor specific percentages, the first factor *human-centred remote counselling competence* (16 items) explained 41.79 %, the second factor *digital solutions as part of work* (9 items) 10.08 %, the third factor *information and communication technology (ICT) competence* (5 items) 8.63 %, the fourth factor *competence in utilising and evaluating digital solutions* (8 items) 4.90 %, and the fifth factor *ethical competence related to digital solutions* (4 items) 3.45 %. In DigiComInf, the total variance explained by the three-factor model was 59.6 % (Table 4). The first factor *support from management* (6 items) explained 39.18 %, the second factor *organisational practices as part of digital competence development* (4 items) 12.76 %, and the third factor *colleagues' adoption and influence* (5 items) 7.67 %. Cronbach's alpha was used for internal consistency assessment. In DigiHealthCom, Cronbach's alpha ranged from 0.91 to 0.97 in the factors, whereas in DigiComInf, alpha ranged from 0.74 to 0.88.

4. Discussion

The purpose of this study was to develop and psychometrically validate instruments for healthcare professionals to conduct self-evaluation of their competence in digital health and factors associating with it. Measuring healthcare professionals' self-assessed competence in digitalisation is important as healthcare practices are becoming increasingly digitalised and digital health competence is slowly being recognised as one of healthcare professionals' core competences [47]. The current state of professionals' digital competence and competence needs should be acknowledged to plan comprehensive, individualised and quickly adoptable interventions that can assist professional development and provision of evidence-based, patient-centric care in a digitalised world [7,12]. Information about professionals' digital health competence development needs is especially important from managerial and organisational perspectives to target necessary competence development actions cost-effectively and timely.

The developed DigiHealthCom and DigiComInf instruments measure not only healthcare professionals' competence in digital health but also the educational and organisational factors that associate with healthcare professionals' digital health competence. Although different instruments have previously been developed to measure healthcare professionals' competence in digitalisation, the DigiHealthCom instrument covers the phenomenon in a broader sense. The instrument includes competence areas related to human-centred remote counselling, attitudes towards digital solutions as part of everyday work, skills in using information and communication technology, knowledge to utilise and evaluate different digital solutions, and ethical perspectives when using digital solutions. Some of these aspects, such as IT skills [22], data protection and patient support [23], have previously been included in separate instruments. However, compared to other instruments, the DigiHealthCom instrument addresses competence areas related to ICT competence and ethical competence more broadly.

Moreover, the DigiHealthCom instrument includes competence areas in human-centred remote counselling, digital solutions as part of work and utilisation and evaluation competences, which have not been explored in prior instrument development studies. Competence in remote counselling is a poorly studied area but is of increasing importance, not only because of the COVID-19 pandemic but also global interest in delivering healthcare more remotely using different digital platforms [7,13]. It is important to study attitudes towards the constant and increasing usage of digital solutions as part of everyday work as

Table 3
DigiHealthCom exploratory factor analysis.

DigiHealthCom items	Factor loading				
Factor 1: Human-centred remote counselling competence	1	2	3	4	5
I can act in reciprocal (aiming towards respect and equality) interaction with the customer in remote counselling	0.980				
I can set goals together with the customer in remote counselling	0.947				
I can form a confidential relationship with the customer in remote counselling	0.943				
I can recognise the customer's need for support and guidance in remote counselling	0.918				
I can motivate the customer into action/self-care in remote counselling	0.875				
I can take into consideration the special characteristics of online interaction (e.g. wording, addressing empathy) in remote counselling	0.851				
I can recognise when the customer's service (e.g. care or guidance) can be delivered remotely	0.851				
I can guide the customer verbally in remote counselling (e.g. on the phone without video)	0.752				
I can guide the customer by utilising a video connection in remote counselling	0.752				
I can evaluate the customer's situation (need for care or service) in remote counselling	0.736				
I can guide the customer in writing (e.g. chat service) in remote counselling	0.680				
I can evaluate whether customers receive equal service in remote counselling	0.679				
I can recognise the customer's willingness to use digital solutions	0.669				
I can act professionally in remote counselling	0.634				
I can evaluate the customer's digital readiness	0.606				
I can guide the customer to find reliable information (e.g. from the Finnish Institute for Health and Welfare, Social Insurance Institution of Finland, Health Village, Health Library, Nursing Research Foundation)	0.425				
Factor 2: Digital solutions as part of work					
The transfer to digital services is a positive change		0.879			
Digital solutions should be used more in social and health services		0.821			
I am motivated to use digital solutions in my work		0.815			
I consider digital solutions as useful		0.802			
I am interested in learning about digital solutions in my work		0.798			
Digital solutions support my work		0.788			
Digital services are a good way to deliver social and health		0.655			

(*continued on next page*)

Table 3 (*continued*)

DigiHealthCom items	Factor loading				
Factor 1: Human-centred remote counselling competence	1	2	3	4	5
services (e.g. customer work, care, rehabilitation)					
Digital solutions are a natural part of my work		0.548			
Digital solutions do not slow down my work		0.535			
Factor 3: Information and communication technology (ICT) competence					
I can use the most common computer programs and services (e.g. email, intranet) in my work			0.988		
I can use equipment based on information technology (e.g. computer) in my work			0.965		
I can ask for help in information technology issues (e.g. ICT support)			0.868		
I can use the patient/client information system in my work			0.821		
I can solve most common information technology challenges (e.g. login problems, display settings, printer settings) in my work			0.689		
Factor 4: Competence in utilising and evaluating digital solutions					
I can recognise what digital solutions are in social and health services				0.892	
I can recognise factors (e.g. resources, motivation) that influence the utilisation of digital solutions				0.774	
I can utilise digital solutions (e.g. smart devices, applications) in customer care/guidance				0.702	
I can utilise digital solutions creatively (e.g. usage according to different customer needs) in my work				0.697	
I can boldly experiment and implement digital solutions in my work				0.618	
I can explain digital social and health services (e.g. Health Village, Omaolo) to customers				0.579	
I can use my professional skills when using digital solutions				0.551	
I can critically evaluate new digital solutions				0.468	
Factor 5: Ethical competence related to digital solutions					
I can secure the customer's privacy when using digital solutions					0.857
I can ensure the secure processing of customer data					0.842
I can acknowledge the customer's autonomy when using digital solutions					0.815
I can recognise the ethical aspects of digital solutions (e.g. freedom of choice, privacy, fairness)					0.644
Eigenvalue	17.553	4.235	3.625	2.057	1.450
Percentage of variance	41.792	10.083	8.632	4.898	3.453
Total percentage of factor model	68.9				
Cronbach's alpha	0.97	0.91	0.93	0.92	0.91
Cronbach's alpha on total scale	0.80				

Table 4
DigiComInf exploratory factor analysis.

DigiComInf items	Factor loading		
Factor 1: Support from management	1	2	3
My manager's example supports the development of my digital competence	0.935		
My manager supports the implementation of digital solutions	0.856		
My manager gives feedback about the development of my digital competence	0.673		
My manager can lead the development of my digital competence (e.g. prediction of competence development, communication, clear guidance, support for renewal and participation)	0.647		
My manager supports my participation in continuing education to strengthen my digital competence	0.597		
Top management supports the uptake of digital solutions	0.526		
Factor 2: Organisational practices as part of digital competence development			
Education about the digital solutions used at my work has been sufficient		0.799	
Digital competence development is planned in my unit according to individual needs		0.694	
The orientation for digital solutions is conducted systematically at my work unit		0.668	
My organisation's practices support opportunities to develop my digital competence		0.565	
Factor 3: Colleagues' adoption and influence			
Colleagues are not reluctant to start using digital solutions at work			0.796
The implementation of digital solutions has been perceived positively in my work community			0.630
Colleagues are eager to develop their own work on digital solutions			0.573
Colleagues do not have a negative influence on the development of my digital competence			0.528
Colleagues in my work community have mainly a good level of digital competence			0.430
Eigenvalue	5.877	1.913	1.150
Percentage of variance	39.177	12.756	7.669
Total percentage of factor model	59.6		
Cronbach's alpha	0.88	0.79	0.74
Cronbach's alpha on total scale	0.72		

healthcare professionals' adoption and acceptance is highly reliant on a positive and experimental attitude and satisfactory user experiences [48]. Competence to utilise and evaluate digital solutions includes knowledge of the possibilities and content of different digital solutions and capability to modify the use of digital solutions depending on the situation and patient needs. This also includes competence to critically evaluate digital solutions. According to a recent OECD report [12], crucial competence requirements for future healthcare professionals include adaptive problem-solving skills, which entail the effective use and exploitation of digital tools. Thus, the DigiHealthCom instrument could be used to evaluate healthcare professionals' digital health competence to meet future needs.

Previous research has focused on determining the content of healthcare professionals' competence in digitalisation and developing instruments that measure specific elements of the entire phenomenon. In addition to defining the phenomenon of digital health competence among healthcare professionals, it has been recognised that aspects such as managerial support as well as amount and content of education or training have an influence on healthcare professionals' competence and competence development [6,23]. However, no other study has validated an instrument that includes factors that influence healthcare professionals' digital health competence. The new DigiComInf instrument covers this phenomenon by including the perspectives of managerial

support, organisational practices and social influence from colleagues. It is important to evaluate the influence of different stakeholders, such as leaders and colleagues, on healthcare professionals' digital health competence development. The roles of a leader as a resource allocator, decision-maker and facilitator provide the basis for healthcare professionals' continuous competence development [49], and a leader's example or stance as a role model may have a negative or positive influence on healthcare professionals' digital health competence development [5]. On the other hand, the social influence of colleagues and their technology acceptance or level of competence can play a significant role in acceptance and digital competence development [5,50]. It is important to have an instrument that can evaluate these factors when assessing what aspects need to be taken into account when new digital solutions are implemented into work practices and educational or training initiatives are planned to increase digital health competence. Thus, the use of DigiComInf may assist in developing other methods of competence evaluation that are not based on self-evaluation.

The definition of healthcare professionals' competence in digitalisation is constantly evolving as not only are the digital possibilities expanding but also understanding of the phenomenon is increasing. Reviews of previous literature and competence frameworks have synthesised that digital health competence includes basic information technology skills, communication and interaction skills when using digital tools and environments, motivation and willingness to use digital solutions at work, and knowledge of data security and ethical aspects of digitalisation in patient work [6,13]. This definition based on two systematic reviews was used as a foundation in the conceptual framework of the newly developed instruments with supporting literature, especially from qualitative studies [4,5]. It has been noted that there is a shortage of validated instruments on digital health competence [51]. Moreover, previous instruments that have been validated lack a generic definition of digital health competence concerning different healthcare professionals. In psychometric testing, both the DigiHealthCom and DigiComInf instruments provided acceptable results in the internal consistency assessment (>0.70) [36] at both the factor and scale levels.

4.1. Study limitations and strengths

The study has several limitations. The low response rate (3.5 %) may inhibit the generalisability of the results, whereas including several different healthcare organisations nationally in Finland increases the generalisability of the results to the Finnish healthcare system. The fact that most of the respondents were nurses could be viewed as a limitation even though nurses form the vast majority of healthcare professionals in Finland and worldwide. External factors (industrial action among healthcare organisations, major organisational changes and COVID-19 restrictions) may have had a negative influence on data collection during spring 2022. Hence, where possible, data collection continued for two months instead of the planned 4–6 weeks to obtain a sufficient sample size. Data collection reached more than ten responses per item, which increases the reliability of the instruments [36]. Additionally, respondents were requested to answer all questions, including items relating to guiding patients in digital environments or remotely, even though the use of such digital solutions were not part of their current work responsibilities. However, respondents were guided to evaluate their digital competence at a general level. As the instruments are based on self-evaluation, the subjective nature of competence evaluation can compromise the validity of the results.

4.2. Conclusions

The newly developed DigiHealthCom and DigiComInf instruments were shown to be valid and reliable instruments for measuring healthcare professionals' digital health competence and the associating educational and organisational factors in different healthcare settings. The instruments are suitable to be used among a variety of healthcare and social services professionals. The instruments need to be further tested with medical professionals, since this group has not been included in the instruments' validation testing.

The instruments are currently only validated in Finland, but they could be implemented after validation in other countries and for cultures in different languages to measure healthcare professionals' digital health competence internationally and conduct comparative analysis to evaluate competence levels and needs of various healthcare professionals in different healthcare systems. The instruments may provide insights into different needs of digital health competence development not only in various healthcare settings but also in low- versus high-income countries.

Summary table

What was already known on the topic?

- The digital revolution has changed healthcare professionals' competence requirements.
- Healthcare professionals' competence in digitalisation is a constantly evolving concept that is difficult to define comprehensively.
- Although some instruments measuring healthcare professionals' digital competence have been developed, they only partially cover the digital competence phenomenon.

What this study added to our knowledge?

- According to the instrument development process, healthcare professionals' competence in digitalisation consists of issues related to human-centred remote counselling competence, digital solutions as part of work, ICT competence, competence in utilising and evaluating digital solutions, and ethical competence related to digital solutions.
- Factors associated with healthcare professionals' digital competence include support from management, organisational practices as part of digital competence development, and colleagues' adoption and influence.
- The new validated instruments can be used to assess healthcare professionals self-evaluated digital health competence and associating factors in versatile healthcare settings.
- The results of instrument development may be used to design and target educational and training activities to increase healthcare professionals' competence in digitalisation according to individual needs.

CRediT authorship contribution statement

Erika Jarva: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Anne Oikarinen:** Conceptualization, Formal analysis, Methodology, Supervision, Validation, Visualization, Writing – review and editing. **Janicke Andersson:** Conceptualization, Supervision, Validation, Writing – review and editing. **Marco Tomietto:** Formal analysis, Software, Validation, Visualization, Writing – review and editing. **Maria Kääriäinen:** Funding acquisition, Project administration, Resources, Supervision, Validation, Writing – review and editing. **Kristina Mikkonen:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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