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Four years upscaling telemonitoring to future-proof health care delivery in Dutch university hospitals: Before and after - where do we stand and what are the results?

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ABSTRACT

Objectives: Upscaling digital solutions is crucial for future-proofing healthcare, yet effective and sustainable methods are underrepresented in literature. In the Netherlands, a University Medical Center (UMC) network collaborated within the Citrien eHealth program to future-proof care using telemonitoring (TM). From 2020–2022, three TM activities were initiated: TM for cardiac rhythm abnormalities/heart failure (TMCardio), TM of blood pressure in high-risk pregnant women (TMAnteNatal), and continuous wireless monitoring of vital functions (TMVitals). This study evaluated the scale-up of these TM programs in seven Dutch UMCs.
Methods: An uncontrolled before-after study design was used.Primary outcome, 'normalization of telemonitoring,' was assessed using the 20-item NoMAD questionnaire. Results were structured according to the non-adoption, abandonment, scale-up, spread and sustainability (NASSS) framework. Secondary outcomes included the number of UMCs offering TM programs and the number of patients using TM.
Results: The NoMAD questionnaire had a 61 % response rate. Respondents were familiar with TM ($N = 85$, mean = 7.27, SD=2.13) and believed it would become more normal in their work ($N = 98$, mean = 8.42, SD=1.64). However, a significant difference between current practice and expected future use of TM was observed ($p \leq 0.001$). All UMCs ran TM programs, but not all implemented all three projects. TMCardio patients increased from 190 to 5185, TMAnteNatal from 41 to 1162, and TMVitals from 2666 to 13630.
Conclusion: Telemonitoring uptake increased across Dutch UMCs, but not uniformly. The complexity of scale-up is highest in NASSS domains 4, 5, and 6, with a focus on management, resources, health care reimbursement, and regulations. Understanding the impact of the Citrien network collaboration on scale requires further qualitative analysis.

Public Interest Summary

Telemonitoring is scaled up in Dutch University Medical Centers

In the Netherlands, scaling up digital solutions in healthcare is a priority. A network of University Hospitals (UMCs) collaborated within the Citrien-2 ehealth program to improve care. They implemented three telemonitoring (TM) projects between 2020 and 2022: TM Cardio for patients with heart rhythm abnormalities, TM AnteNatal for pregnant women at risk of pre-eclampsia, and TM Vitals for continuous monitoring of vital signs. The results

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show an increased uptake of TM in all UMCs. But the increase was not uniform. The complexity of scale-up is highest in NASSS domains 4, 5, and 6, with a focus on management, resources, health care reimbursement, and regulations. Normalizing TM as usual care remains a challenge.

Introduction

Healthcare systems around the world face significant challenges arising from the convergence of inadequate healthcare personnel and an aging population, characterized by multiple chronic conditions [1–3]. To provide resilient and accessible quality care, innovative solutions are necessary to address rising healthcare costs and workforce shortages [1,4,5]. Telemonitoring has often been proposed as one such eHealth solution to reduce hospital admissions [6]. It is a promising tool for effective remote management of care, with the potential to reduce associated travel costs and alleviate patients' difficulties in accessing primary care [7,8]. In this context, TM - also referred to in literature as remote patient monitoring (RPM) - refers to the use of information technology to monitor patient vital signs from a distance [9,10].

Scaling up digital solutions to future-proof healthcare is a priority for many governments and policymakers [11–13]. Enablers and barriers to scaling up exist on different levels (micro, *meso*, macro, and technology/innovation level) and have all been shown to influence adoption and use of digital solutions, such as TM [14–16]. Key recommendations for upscaling TM include: 1) identifying resources for reimbursement, 2) organizing upscaling within a comprehensive change management program, and 3) establishing explicit regulations following care standards and professional guidelines [15].

Despite an increasing social demand from patients to be able to remain at home whilst being monitored for their healthcare condition by their care institutions or providers, the uptake of TM in the Netherlands remains limited. According to healthcare professionals (HCPs), only sixteen percent of patients used TM in 2022 [17,18]. When considering the use of TM in heart failure, based on health insurance claims data from 2017 to 2019, the uptake is 5.8 % [19]. The baseline measurement of the national eHealth program "Upscaling and Implementation" confirms the limited normalization of TM across the eight Dutch University Medical Centres (UMCs) [20].

The Dutch Federation of University hospitals (NFU), a federating organization representing all UMCs in the Netherlands, initiated the "Citrien e-Health program" in 2014 [21]. Following this initial Citrien program (Citrien-1), the sequel CItrien-2 focused on sharing and upscaling best eHealth practices. Citrien-2, titled "Citrien Implementation and Upscaling", specifically aimed to scale up three TM initiatives across all UMCs nationwide:

1. Telemonitoring for patients with cardiac rhythm abnormalities or heart failure, where blood pressure monitoring is indicated (TM Cardio)
2. Telemonitoring of blood pressure in pregnant women with elevated risk of pre-eclampsia at home (TM AnteNatal)
3. Continuous wireless monitoring of vital functions during clinical care pathways on hospital wards (TM Vitals)

The aim of this study was to evaluate the extent to which these three TM programs have been scaled up across all seven Dutch University Medical Centres (UMCs) between 2020 and 2022, helped by the Citrien-2 university network.

Methods

This study employed an uncontrolled before-after study design to evaluate the upscaling of TM within the Citrien-2 program. Uptake numbers were assessed, and a questionnaire was used for evaluation. The detailed study protocol for this Citrien-2 implementation program has been previously published [22].

Settings and intervention

Data were collected from all eight Dutch UMCs (now seven, due to a recent hospital merger of two UMCs). Collectively, these UMCs provide care for 1,2 million patients annually and employ 80.000 health care workers [23]. Among the three selected applications, TM Cardio was adopted by outpatient departments of cardiology, TM AnteNatal was implemented in outpatient obstetric departments, and TM Vitals was adopted by surgical or internal medicine clinical wards. The choice of patient setting was based on the academic profile of each UMC.

Recruitment of respondents

The steering group members of this NFU e-health program were appointed by their UMC Boards. The steering group members appointed Project Leaders (PLs) to govern and help implement the TM projects. PLs recruited the participants for the TM projects in each respective UMC, to participate in an online survey. We aimed for 10 respondents per project, resulting in 30 respondents per UMC. Three monthly reminders were sent by e-mail. A more detailed description of the recruitment can be found in our study protocol [22].

UMCs were asked to provide aggregated telemonitoring uptake data through their Steering Committee member and Projectleader. Data analysts from each UMC were asked to provide this through business reports.

Data collection and procedure

Theoretical framework

The results of this implementation study were structured according to the Non-Adoption, Abandonment, Scale-up, Spread and Sustainability (NASSS) framework [24]. This framework is considered to be a good fit, as it intends to be used to generate ideas about barriers and facilitators. The NASSS framework is intended to evaluate unfolding technology programs in retrospectively or in real time and, in particular, to identify and manage their emergent uncertainties and interdependencies considering multiple domains. The NASSS framework comprises seven domains and aims to recognize activities performed by Citrien-2 within a complex context, from local adoption to sustainable national scale-up. (Fig. 1) [24,25] In each domain, implementation and scale-up can be simple (few components, predictable), complicated (many components but still predictable) or complex (many components interacting in a dynamic and unpredictable way).

Domain 1 is the illness/condition. Complexity can be seen when the condition is e.g. metabolically unstable, inherently unstable, poorly described, poorly understood, associated with comorbidities, or strongly influenced by socio-cultural factors. Domain 2 is technology. Its complexity may relate to its material properties, the knowledge required to use it, the knowledge it brings to practice, the delivery model and intellectual property. Domain 3 is the value proposition, both supply-side and demand-side. Complexity relates to difficulties in formulating a credible business plan. Domain 4 is the adopter system: staff, patients and carers who must use technology, but may not want to or find themselves unable to. This can cause complexity if professional traditions and codes of conduct are threatened by technology's roles and practices. Domain 5 is the organisation. Complexity in this domain may relate to the organisation's capacity to innovate (e.g. leadership, resources, relationships) or its readiness to embrace this technology. Domain 6 is the wider system, including the policy context, support from regulatory or professional bodies, and public perceptions. This domain also includes inter-organisational networking (e.g., quality improvement collaboratives), which can be an effective way of spreading

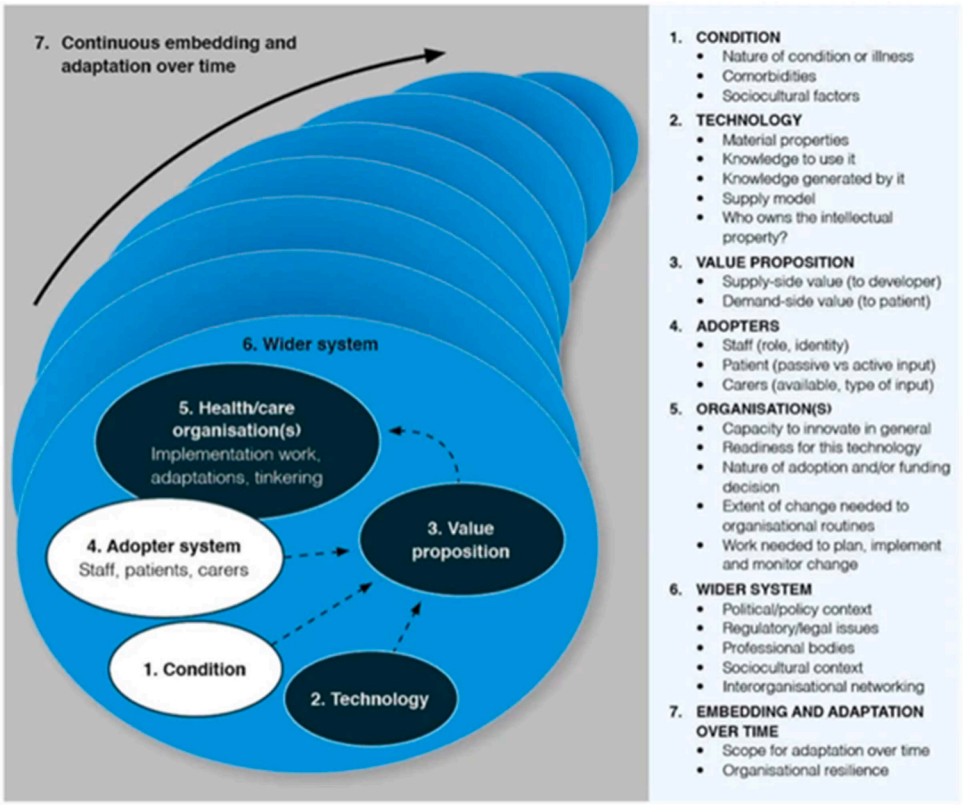

Fig. 1. The NASSS framework for studying non-adoption and abandonment of technologies by individuals and the challenges to scale-up, spread, and sustainability of such technologies in health and care organizations (adapted from Greenhalgh et al. [25]..

innovation at the organisational level. Domain 7 is the embedding and adaptation over time. Complexity can be due to poor technological adaptability to change or poor organisational resilience [25,26]. This study describes the degree of complexity in each domain.

To interpret individual and group behaviour regarding TM implementation in daily care (normalization) is a socio-technical issue. An implementation framework such as the NASSS does not provide sufficient insight. Therefore, we used the Normalisation Process Theory (NPT) and the associated Normalisation MeAsurement Development tool (NoMAD) based on this theory [27,28].

Upscaling is described as the uptake of TM by patients from all Dutch UMCs. This secondary outcome is structured under the seventh domain of the NASSS framework "Embedding over time".

Primary outcome

The degree of standardization – to what extent health care providers consider TM to be a part of their routine practice – was measured using the 20-item Normalization MeAsurement Development tool, NoMAD [27]. The NoMAD is a self-reported questionnaire containing four constructs, as defined by the normalization process theory [29]: coherence (CO), cognitive participation (CP), collective action (CA), and reflexive monitoring (RM). The NoMAD demonstrated high internal consistency and has been validated across heterogeneous examples in different languages and settings [27,28].

Secondary outcomes

Secondary endpoints include the number of UMCs actively using TM and the absolute number of patients using TM, with business reports containing aggregated data.

Procedures

Data were collected between January 2020 and January 2023 by the PLs. Data were provided by business analysts at each UMC and uploaded by PLs in a predefined and structured format. In the case of missing values, project leaders were contacted monthly and reminded by the first author. Every three months, the uptake was reported. Each TM project fell under the responsibility of the PL of the UMC which governed the original TM initiative in the Citrien-1 program. The collective data of all UMCs was uploaded to a research database built for this purpose by the PL responsible for the overall implementation of the TM initiative. This PL was linked to the Chair of the steering group, and managed the database and resulting reports.

Statistics

Data were analysed using SPSS software (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp). The Wilcoxon signed-rank test was used to analyse differences in current and future normalization of TM.

Counts and frequencies were used to describe the sample and summarise NoMAD responses. For the secondary outcomes absolute and cumulative numbers were presented.

Ethical considerations

The primary outcome measure involved a questionnaire administered to health care professionals.

The secondary outcome measure involved management information collected retrospectively. The use of TM was always and only applicable in the context of patient care. The Medical Ethics Review Committee Amsterdam UMC exempted this healthcare professional interview and hospital management result study from ethical review. The study protocol was registered on the Open Science Framework [22,30].

Results

All UMCs actively operated TM. A total of 160 professionals were invited to participate in the NoMAD survey. After three reminders, 98 (61 %) of the invitees completed the online survey.

The characteristics of participants are shown in Table 1.

This result section describes the results of three TM projects and the experienced challenges across the seven domains of the NASSS framework. Since the NoMAD subconstructs engage domains 3, 4, 5 and 7 of the NASSS, the results of the NoMAD questionnaire are presented within the NASSS structure. The secondary outcome, uptake of TM, is described under domain 7 'Embedding over time'.

Further analysis of the 16 sub-constructs of (un)successful implementation is presented with mean scores and frequency distribution of item responses in Figs. 2 and 3. The majority of respondents (81.7 %) of the NoMAD were HCPs such as doctors, nurses or midwifes.

Domain 1. The condition or illness

Each of the three TM projects aimed to support patients with a specific health condition. In case of TM Cardio, mostly patients with cardiac arrhythmias were monitored. This target population was chosen, as outpatient care for patients with non-acute cardiac arrhythmias was considered to be both predictable and consistent. Three UMCs were monitoring patients with heart failure, which was considered complicated due to multiple interacting components. One UMC was monitoring patients with pulmonary hypertension. For TM Antenatal, providing outpatient care for pregnant women with high blood pressure or at risk of high blood pressure using TM was considered simple, straightforward, and predictable. In the case of TM Vitals, measuring vital signs in inpatient care was strongly protocolized and therefore vetted as predictable and classified as easy to implement. For TM Vitals, the underlying clinical condition was often not specified. Monitoring was performed in a variety of clinical wards, such as surgical oncology ward, internal medicine ward or general surgery ward.

Domain 2. The technology

In the three TM projects, a variety of monitoring devices, wearables and software technology was used to measure vital signs, heart rhythm,

Table 1
Characteristics of respondents.

	Telemonitoring cardiac care		Telemonitoring antenatal care		Telemonitoring vital functions		Not involved in telemonitoirng		Total	
n=	*24*	24,5	*22*	22,4	*43*	43,9	*9*	9,2	*98*	100
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Sex										
Female	14	58,3	18	81,8	32	74,4	8	88,9	72	73,5
Male	10	41,7	4	18,2	11	25,6	1	11,1	26	26,5
Age										
<21	0	0	0	0	1	2,3	0	0	1	1
22 < 34 yrs	15	62,5	6	27,3	24	55,8	4	44,4	49	50
35 < 44 yrs	4	16,7	8	36,4	8	18,6	2	22,2	22	22,4
45 < 54 yrs	2	8,3	7	31,8	4	9,3	1	11,1	14	14,3
55 < 64 yrs	3	12,5	1	4,5	6	14,0	2	22,2	12	12,2
>65 yrs	0	0,0	0	0,0	0	0,0	0	0,0	0	0
Job description										
Medical Doctor	11	45,9	13	59,1	9	20,9	1	11,1	34	34,7 %
Physician assistant	0		2	9,1	0	0,0	2	22,2	4	4,1 %
Nurse practitioner	2	8,3	0	0,0	1	2,3	1	11,1	4	4,1 %
Nurse	1	4,2	1	4,5	18	41,9	3	33,3	23	23,5 %
Nursing counselor	0	0	0,0	0,0	0	0	0	0,0	0	0,0 %
Oncology nurse	0	0	0,0	0,0	0	0,0	0	0,0	0	0,0 %
Midwife	0	0	5	22,7	0	0,0	0	0,0	5	5,1 %
Clinical Obstetrician	0	0	1	4,5	0	0	2	22,2	3	3,1 %
Medical Assistant	0	0	0,0	0,0	0	0	0	0,0	0	
Technical Physician	0	0	0,0	0,0	2	4,7	0	0,0	2	2,0 %
Researcher	4	16,6	0,0	0,0	1	2,3	0	0,0	5	5,1 %
PhD student	1	4,2	0,0	0,0	0	0,0	0	0,0	1	1,0 %
Project leader / innovations leader	0	0	0,0	0,0	2	4,7	0	0,0	2	2,0 %
Staff advisor	1	4,2	0,0	0,0	0	0,0	0	0,0	1	1,0 %
Manager	1	4,2	0	0,0	3	7,0	0	0,0	4	4,1 %
Management assistant	1	4,2	0	0,0	0	0,0	0	0,0	1	1,0 %
Operational manager	0	0	0,0	0,0	0	0	0	0,0	0	0,0 %
Strategic advisor	0	0	0	0,0	0	0	0	0,0	0	0,0 %
IT consultant	1	4,2	0	0,0	0	0	0	0,0	1	1,0 %
Information engineer	0	0,0	0	0,0	1	2,3	0	0,0	1	1,0 %
Student	1	4,2	0	0,0	6	14	0	0,0	7	7,1 %
Healthcare purchaser	0	0	0,0	0,0	0	0,0	0	0,0	0	0,0 %
University Medical Center										
Amsterdam UMC	0	0,0	6	27,3	5	11,6	7	77,8	18	18,4
EMC	7	29,2	0	0,0	8	18,6	0	0,0	15	15,3
LUMC	4	16,7	0	0	4	9,3	0	0,0	8	8,2
MUMC+	4	16,7	0	0,0	5	11,6	0	0,0	9	9,2
Radboud UMC	2	8,3	16	72,7	7	16,3	1	11,1	26	26,5
UMCG	1	4,2	0	0,0	0	0,0	0	0,0	1	1,0
UMCU	6	25,0	0	0,0	14	32,6	1	11,1	21	21,4
Work years										
< 1 year	2	8,3	0	0,0	4	9,3	0	0,0	6	6,1
1 to 2 yrs	4	16,7	0	0,0	5	11,6	0	0,0	9	9,2
3 to 5 yrs	10	41,7	1	4,5	14	32,6	5	55,6	30	30,6
6 to 10 yrs	3	12,5	7	31,8	6	14,0	2	22,2	18	18,4
11 to 15 yrs	2	8,3	7	31,8	2	4,7	1	11,1	12	12,2
> 15 yrs	3	12,5	7	31,8	12	27,9	1	11,1	23	23,5

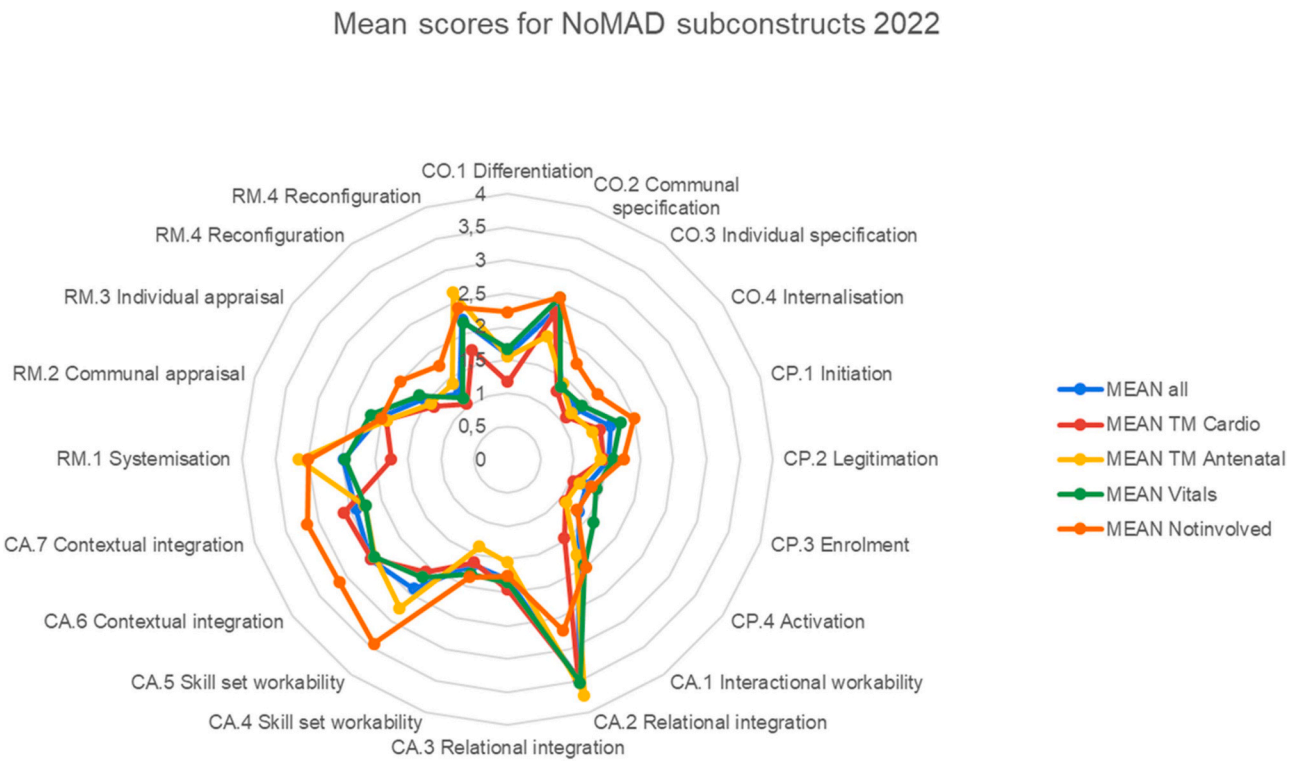

Fig. 2. Spider chart showing mean scores of 1) all responses, 2 TM Cardio, 3) TM AnteNatal, 4) TM Vitals and 5) not involved in TM for the 16 NPT sub constructs. Likert scale of 1 (strongly agree) to 5 (strongly disagree). TM: telemonitoring. CO: coherence, CP: cognitive participation, CA: collective action, RM: reflexive monitoring.

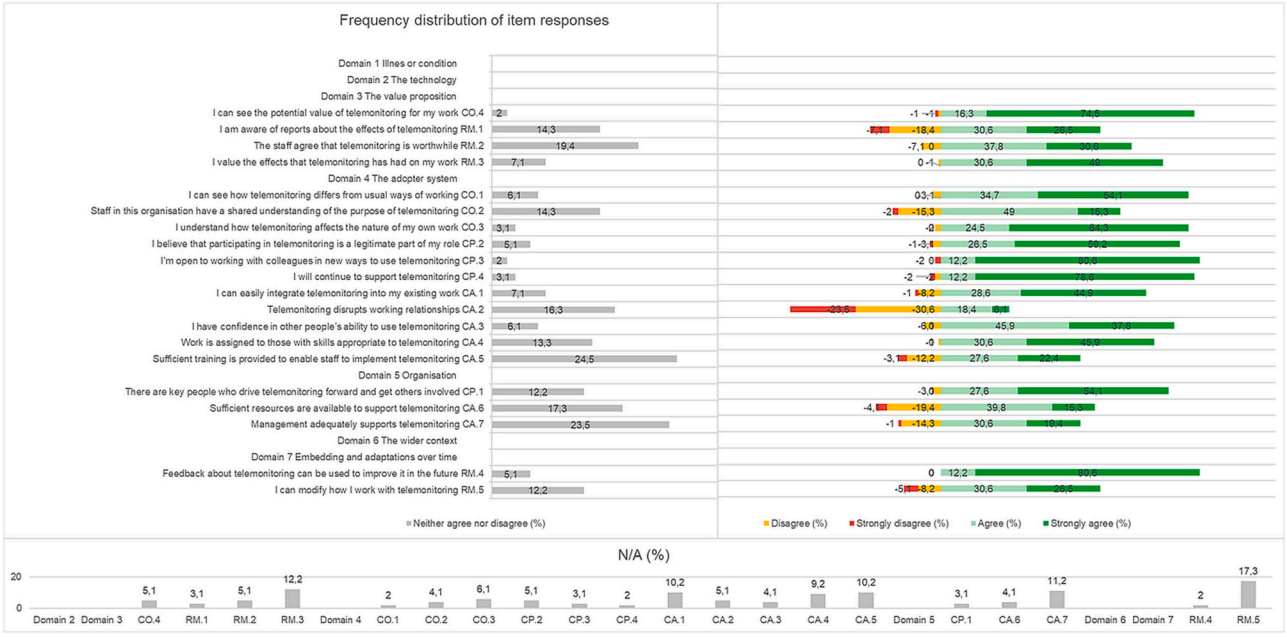

Fig. 3. Frequency distribution of item responses. The NoMAD questionnaire is represented by 4–7 questions per construct of Normalization Process Theory. Constructs are Coherence (CO), Cognitive participation (CP), Collective Action (CA), Reflexive Monitoring (RM). The upper part of the figure shows the percentage of respondents reporting strongly disagree, disagree, agree or strongly agree. The grey bar coupled to the y-axis indicates the percentage of participants rating an item as 'neither agree nor disagree'. The lower part of the figure shows the percentage of respondents who choose not to rate a specific item (not applicable).

blood pressure and body weight. Monitoring was non-acute and non-continuous. The TM devices were largely plug-and-play, but setting up the required connectivity with computer servers and /or the hospital electronic medical record respecting the law and local policies was complex for most organizations. Device logistics, such as patient instructions and distribution of devices, were handled in a variety of ways. It could be decentralised in the outpatient clinic or care unit, centralised in one location in the hospital, or outsourced to a third party. In each situation, instructions were given to the patient so that the devices could be used independently (at home). More technical

information on the devices are described in Supplementary File1. Daily medical and technical support was needed throughout implementation for all TM projects. The technology supply model is mostly classified as either simple or complicated, except for the devices that needed to be integrated with existing hospital standards to enable interoperability and data exchange; which turned out to be complex.

Domain 3. The value proposition

For the three TM projects, the supply-side value is unknown. Developing one clear nationwide business case on the demand-side value is complicated, as every UMC has its own cost prices and reimbursement agreements. Furthermore, there was no disclosure of financial details between UMCs respecting the Dutch Competition Act [31]. From societal perspective, the value of telemonitoring for healthcare in this programme is based on a review of the available literature up to 2020 and is consistent with the findings of the Citrien-1 programme. In general, TM has the potential to reduce hospital readmissions, intensive care readmissions, and regular check-up appointments [32,33]. It can also decrease nursing workload and provide earlier warning of deterioration [34].

The value to clinicians is addressed in the NoMAD, with subconstructs CO4, RM1, RM2 and RM3. Over 90 % of respondents agreed or strongly agreed with the CO4 statement "*I can see the potential value of telemonitoring for my work*".

Domain 4. The adopter system

This domain refers to the altered staff roles, practices, and input – and whether this is achievable and acceptable to them. The NoMAD questionnaire addresses much in this domain with the subconstructs CO1, CO2, CO3, CP2, CP3, CP4, CA1, CA2, CA3, CA4 and CA5.

An important adaptation in the work process of healthcare providers is the new way of assessing health information. In the three TM projects, incoming patient information was assessed by nurses or midwives. In some UMCs, this meant a shift from direct patient-physician measurement to nurses assessing remote patient data.

Incoming data was assessed at different frequencies, for example, based on notifications or at predetermined times, once a day or once a week. If the incoming data was outside the norm, the physician was notified or the treatment plan was adjusted. More than halve of the respondents (53,5 %) agreed that they could "easily integrate telemonitoring into my existing work" in the sub-construct of CA1. They also consider it to be "a legitimate part of my role" according to sub-construct CP.2.

Almost all respondents were open to working with colleagues in new ways using TM, as 92.8 % agreed or strongly agreed on subconstruct CP3 Enrolment. The mean score for "*Do you feel telemonitoring is currently a normal part of your work?"* was 6.53 ($N = 83$, SD = 2.82).

Domain 5. Organization

This domain pertains to organizational enablers and barriers. The NoMAD questionnaire addresses some of these determinants in subconstructs CA6 and CA7. A small majority (55,1 %) of respondents -believe that "*Sufficient resources are available to support telemonitoring*".

In every organization, an innovation program was in place. Six out of the seven UMCs conducted some sort of readiness review. However, this was not based on literature nor models, largely uncoordinated, and executed mostly based on local knowledge.

During this programme, nearly all UMCs updated their vision for e-health and/or digital care [21,35]. The UMCs attempted to widen the scope of digitization in healthcare and explore associated opportunities in the update. Throughout the duration of several UMCs' TM programs, the organization of the service shifted from being largely decentralized and specialty-driven to being more centralized and program-based.

Domain 6. Wider context

This domain refers to the political, economic, regulatory, professional (e.g. medicolegal) and socio-cultural context. In the first year of the Citrien-2 program, it became clear that no structural reimbursement from health care insurers was available for TM. This was an important barrier that was communicated by the steering group and the TM working groups to the Dutch Healthcare Authority. During the program, the Dutch Healthcare Authority developed a performance description in accordance with the Healthcare Market Regulation Act [36].

Since May 26, 2021, the European Medical Device Regulation ((EU) 2017/745 Medical Device Regulation, MDR) [37] has been in effect. The introduction of this legislation was anticipated from the outset of the Citrien-2 program, having a reciprocal impact on the selection and procurement of TM devices in the UMCs. In order to ensure compliance with the aforementioned legislation, existing products and suppliers were subjected to a rigorous assessment process. This entailed a comprehensive examination of the products, a review of the suppliers and technical decisions on the front-end or back-end integration of systems and system compatibility. This, combined with the General Data Protection Regulation (GDPR) [38], which went into force in 2018, made the purchasing process more complicated.

During the Citrien-2 program's tenure, the Integrated Care Agreement (IZA) was initiated by the Ministry of in the Netherlands in September 2022. This act was signed by, among others, umbrella organizations of hospitals, mental health care, and senior care [39]. The IZA emphasises the need for TM, which consequently has a favourable impact on the Citrien-2 program.

Domain 7. Embedding and adaptations over time

This domain refers to the embedding and adaptations over time that lead to and affect the sustainability of TM programs. The NoMAD subconstructs RM4 and RM5 address this domain. For example, only a slight majority thought they could modify how to work with TM in the future.

Respondents of the NoMAD questionnaire reported being familiar with the concept of TM ($N = 85$, mean = 7.27, SD = 2.13) and believed TM would become a more normal part of their work in the near future ($N = 98$, mean = 8.42, SD = 1.64). However, there is still a statistically significant difference between current practice and expected future use (Wilcoxon signed-rank test $z = 5.999$, $p \leq 0.001$).

All UMCs actively operate TM, although not all three TM projects were implemented in each UMC. The number of patients using TM Cardio in all UMCs increased from 190 patients in January 2020 to 5185 patients end of 2022. (Fig. 4) Although UMC#4 initiated the TM Cardio project, there are no uptake numbers available due to the outsourcing of TM in that UMC. In UMC#1, TM was only started at the end of the Citrien-2 programme due to a change of supplier. In UMC#6, the choice of supplier was postponed and coordinated with other hospitals due to policy decisions on collaboration in the region.

The TM Antenatal project was initiated by UMC#1. The number of patients using TM Antenatal has increased from 41 to 1162. (Fig. 5) All seven UMCs were able to operate TM AnteNatal.

The uptake of TM Vitals is mainly explained by its implementation in UMC#1, UMC#5 and UMC#7. An increasing number of patients were remote monitored, from 2666 in January 2020 to 13630 end of 2022. (Fig. 6) The project was initiated by UMC #1, but scientific research on the effectiveness of TM Vitals was also carried out at UMC #5. TM Vitals was piloted at UMC#3 and UMC#4, but implementation was difficult due to technical barriers. Specifically, a lack of IT capacity and an EHR connectivity problem caused delays. In UMC#8, there was no IT infrastructure in place to implement TM Vitals at the end of Citrien-2. In UMC #2, the health care departments felt that the functionality was too limited in comparison to other sensors on the market. As a result, market research was prolonged, which delayed implementation.

Discussion

This study aimed to assess the upscaling and normalization of TM

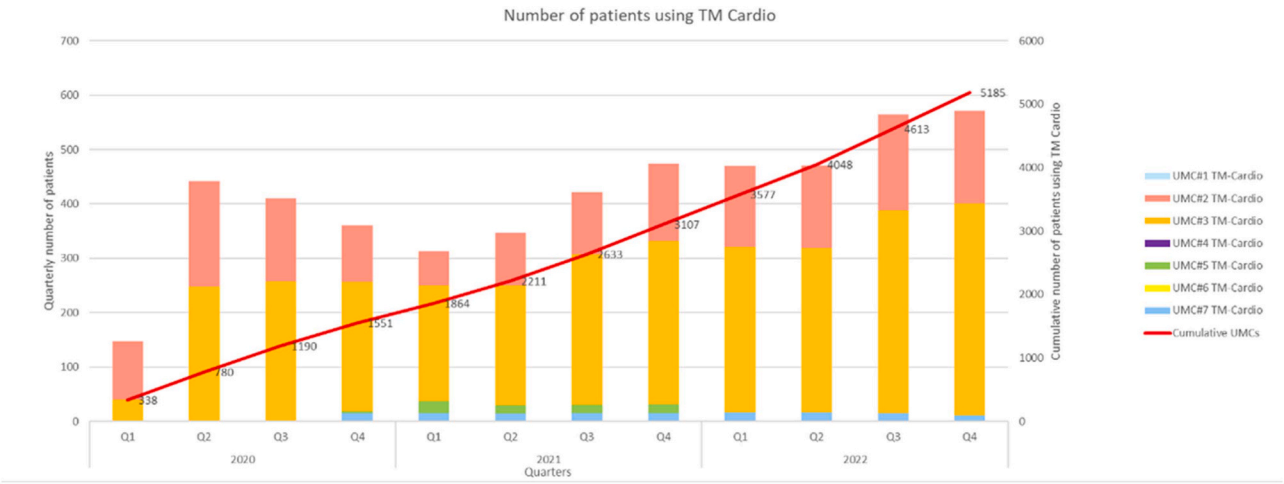

Fig. 4. The number of patients using TM Cardio in all UMCs.

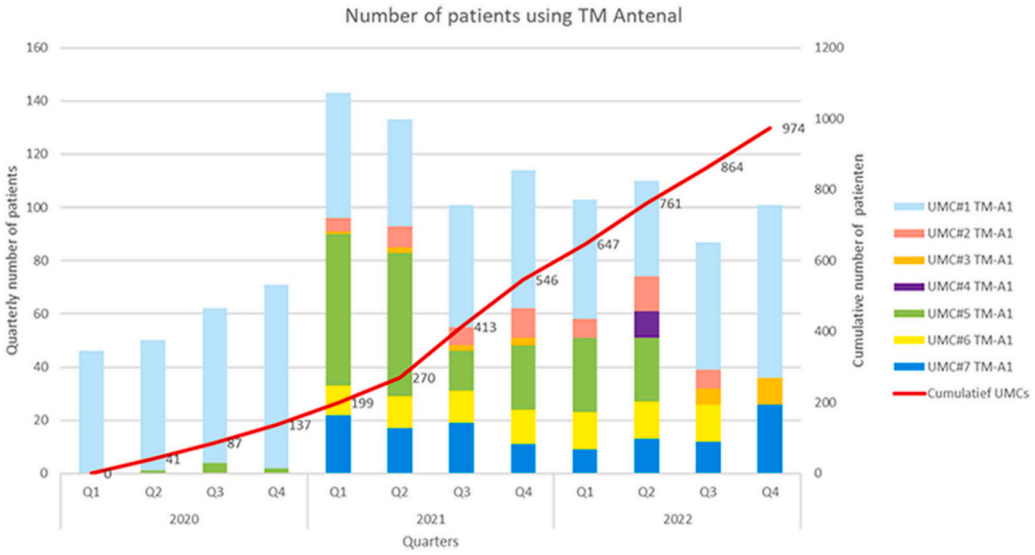

Fig. 5. The number of patients using TM Antenatal in all UMCs.

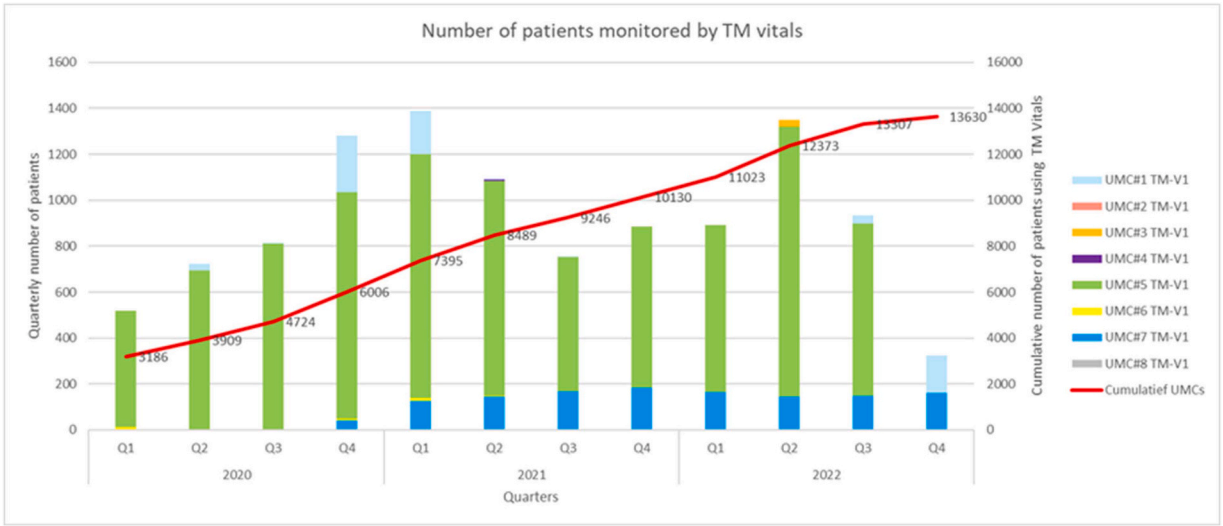

Fig. 6. The number of patients using TM Vitals.

within Dutch UMCs. The uptake numbers reveal a clear upward trend in TM utilization. TM is reported to be normalized among HCPs in this study. There is consensus that TM will play an increasingly prominent role in their work in the near future.

Despite this overall positive trend, variations remain between HCPs actively engaged in TM and those who are not, particularly in the domain of "collective action". Engaged HCPs view TM integration as more favourable expressing less concern about TM disrupting work [40]. HCPs involved in TM have an optimistic outlook regarding the necessary resources, training requirements and managerial support.

The Covid-19 crisis had a dual impact on TM projects and implementation within UMCs. The baseline study in 2020 showed that 68.5 % of the health care providers had not been accelerated to telemonitoring at that time due to the outbreak of the coronavirus [20]. Since then, it accelerated certain TM initiatives, such as cardiac TM [41,42], as well as the use of TM for Covid patients and pregnant women [43–45], however it also caused disruptions. Many project leaders were preoccupied with healthcare provision during the peaks of the COVID-19 outbreak, limiting their ability to focus on TM implementation. So, the impact of Covid-19 resulted in a mixed picture of stagnation and acceleration [46]. Furthermore, there is no observable similarity or trend in the telemonitoring uptake numbers in this study compared to the SARS-CoV-2 infection registry in the Netherlands [47].

During the pandemic, telemonitoring was still under development in many hospitals. A review of TM in patients with COVID-19 shows a lack of RCTs and no statistically significant evidence that TM is effective in preventing ED visits and hospital readmissions, shortening LOS or reducing mortality. However, there is no evidence that TM has unexpected or adverse effects [48].

As compared to two other nationwide studies our study demonstrated better integration and adoption rates. This could be related to the position of the Netherlands in comparison with other countries. The Netherlands consistently ranks among the top EU countries for digital infrastructure and readiness, as measured by the Digital Economy and Society Index (DESI) [49]. The Netherlands is recognised as having high levels of digital health literacy and patient readiness for digital healthcare compared to other European countries. Studies show that Dutch patients are among the most prepared in the EU to use remote healthcare services. They have high levels of internet access and digital skills, and they frequently use digital health tools [50].

An extensive analysis of the TM landscape in Portugal by Miranda et al [51] revealed that the number of TM users in Portugal remained limited. In 2021, only 258 patients across Portugal were using TM, an average of 20 per hospital. By contrast, this study indicated that 3107 Dutch UMC patients were actively using TM for heart diseases by the end of 2021. HCPs in Portugal remain unconvinced about TM, however, our NoMAD results revealed a positive attitude towards TM among HCPs in the Netherlands. Miranda's study highlights the necessity for a coherent national strategy to facilitate TM scaling. In the Netherlands, the government-backed Citrien-2 program was launched specifically to enhance scale-up efforts and foster collaboration among organizations [52].

Despite high levels of digital health literacy and patient readiness in the Netherlands, Auener et al. also reported limited adoption of TM for chronic heart failure in the Netherlands up to 2019 among Dutch hospitals. Their study was based on claim data from a large health care insurance company, making direct comparison with our uptake data challenging due to differences in TM activity registration. Our study, instead, relied on business information reports from hospitals and covered a distinct time period [19].

Unlike Auener et al., who observed slower adoption in UMCs, our study did not encounter the same barriers, possibly due to a more collaborative approach [22].

Reimbursement issues are identified as significant barriers and were successfully addressed in our Citrien-2 implementation program, leading to structural funding adjustments facilitating TM adoption [10,15,53,54]

Strengths and limitations

The present study utilizes the Greenhalgh NASSS methodology, which may appear complex but provides a comprehensive framework, including NPT, to facilitate the understanding of the challenges associated with the implementation of TM [24,25]. Though there is no clear correlation between uptake numbers and NoMad outcomes, the findings of our study indicate a positive attitude among early adopters suggesting a favourable opinion of TM.

Another strength of this study is its multicentre approach. A recently published qualitative study conducted within this Citrien-2 network showed that collaboration between multiple university medical centre's improves the robustness and generalisability of implementation, as well as stimulating knowledge exchange and joint problem solving. The network has facilitated to overcome barriers such as funding issues and regulatory challenges, and has provided a structure for sharing best practices. Therefore, a network approach is recommended for future nationwide scale up projects [55].

This study was subject to several limitations as it may have suffered from selection bias.

The current study focused on scaling up the best practices identified in the Citrien-1 programme [56]. The chosen theoretical frameworks, NASSS and NoMAD, enabled the evaluation of this process. The evaluation of human factors is addressed to a lesser extent by these frameworks. While NoMAD provides insight into the consequences of telemonitoring in terms of change and integration into existing work processes, staff training, and the value of telemonitoring, methods such as qualitative feedback and policy audits would evaluate human factors more extensively.

However, the explicit evaluation of human factors was beyond the scope of the present study. Future studies should include these human factors to support sustainable digital healthcare.

This study did not assess the effects of GDPR compliance and technical interoperability with EHRs, as these aspects were not addressed in the NoMAD questionnaire nor examined through other methods. Future research should explicitly investigate these factors to better understand their impact.

Another possible limitation is the recruitment of participants. Participants were approached by the PL's and were closely involved in TM program adoption. Participants were believed to be the local champions in their UMC. Their participation in the survey may have been influenced by their personal relationship with the PL, who requested their involvement. Additionally, a potential "study effect" bias could influence respondents completing questionnaires during national evaluation.

It was a deliberate choice in this study to focus on scaling up and implementation of telemonitoring without addressing clinical effectiveness and patient-reported outcome measures (PROMs). However, future studies should systematically report PROMs and clinical outcomes alongside implementation outcomes to support Value-Based Health Care (VBHC) and business modelling. This would enable transparent and comparable evaluations between university medical centres. This could also facilitate the development of business models in view of the limited exchange of financial data.

Furthermore, this current evaluation did not specifically assess *how* the Citrien-2 program has contributed to overcoming critical barriers. Future research should focus on the sustainability of scale-up and adoption among late adopters.

Finally, given the uncontrolled before-and after study design, it is important to exercise caution when drawing causal conclusions between the Citrien programme and the described upscaling. Nevertheless, the study provides valuable practical insights for complex large-scale implementation and nationwide scale up.

Conclusion

Overall uptake of TM increased across all three TM projects, although not equally across all UMCs. Our study found a consensus among HCPs regarding its impact. Despite consistent NoMAD results and increased uptake, challenges remain in achieving normalization in day-to-day work and uncertainties persist regarding the association between uptake and outcomes. The findings confirm the complexity of TM implementation.

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CRediT author statement

Harm Gijsbers: Study design, Methodology, Formal analysis, Writing - original draft **Azam Nurmohamed**: Writing – review & editing, Supervision **Linda Dusseljee – Peute**: Writing – review & editing **Tom van de Belt**: Conceptualisation, Methodology, Study design, Data analysis, Writing – review & editing, Supervision **Marlies Schijven**: Funding acquisition, Conceptualisation, Methodology, Study design, Formal analysis, Writing – review & editing, Supervision

All authors have read and approved the final paper and agree to be accountable for all aspects of the work.

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Ethical approval

The Medical Ethics Review Committee Amsterdam UMC exempted this healthcare professional interview and hospital management result study from ethical review. (Number: 2023.0208)

Declaration of competing interest

All authors declare that they have no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.hlpt.2025.101132.

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