

ANNA-LEENA VUORINEN

The Effect of Telemonitoring Interventions on Health Outcomes in Individuals with Type 2 Diabetes, Heart Failure and Coronary Artery Disease

Results from three randomized controlled trials

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ACADEMIC DISSERTATION

To be presented, with the permission of
the Faculty Council of the Faculty of Social Sciences
of the University of Tampere,
for public discussion in the auditorium F115
of the Arvo building, Arvo Ylpön katu 34, Tampere,
on 8 February 2019, at 13 o'clock.

ACADEMIC DISSERTATION
Tampere University, Faculty of Social Sciences
Finland
VTT Technical Research Centre of Finland

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Cover design: Roihu Inc.

Layout: Sirpa Randell

ISBN 978-952-03-0996-1 (print)
ISBN 978-952-03-0997-8 (pdf)
ISSN 2489-9860 (print)
ISSN 2490-0028 (pdf)
<http://urn.fi/URN:ISBN:978-952-03-0997-8>

PunaMusta Oy – Yliopistopaino
Tampere 2019

Abstract

The increasing burden of chronic conditions creates a need to develop more effective approaches to improve management and health outcomes of chronic conditions. Information- and communication technologies provide tools to promote the management of chronic conditions.

This thesis presents three randomized controlled trials that assessed the effect of telemonitoring interventions on health outcomes in individuals with type 2 diabetes (T2D), heart failure (HF) and coronary artery diseases (CAD). In all studies, telemonitoring involved self-monitoring of chronic condition related health parameters on a weekly basis, and sharing these data with healthcare professionals using a mobile phone. In addition, each study had a specific patient decision support component linked to the telemonitoring data. Study I, the Mobile Sipoo study, was conducted at the healthcare center of Sipoo, and included 51 patients with T2D who were followed for 10 months. The participants in the intervention arm recorded their weight, blood pressure, steps and/or blood glucose. These data were further linked with an automatic feedback system that provided patients with real-time, behavioral theory-based feedback messages that summarized the telemonitoring data, and motivated patients and provided them with behavioral skills to strengthen their self-management practices. The primary aim of Study I was to improve glycemic control, measured as HbA_{1c}, and decrease blood pressure. Study II, the Heart at Home study, was conducted at the Cardiology Outpatient Clinic of Helsinki University Central Hospital and included 94 patients with systolic heart failure. The intervention participants were instructed to monitor their weight, blood pressure, heart rate and symptoms, and the data were linked with real-time, short feedback messages that summarized the data in relation to pre-specified individual target values. The primary aim of Study II was to reduce HF-related hospitalizations during the 6-month follow-up. Study III, the Renewing Health study, was conducted at healthcare centers in South Karelia and included 519 patients with T2D (n=250), CAD (n=227) or HF (n=42). Participants monitored their weight, blood pressure, steps and/or blood glucose. In addition, each participant received individual

health coaching calls every 4 to 6 weeks to empower the patients and to teach them appropriate self-management skills tailored for each condition. The primary aim of Study III was to improve the health-related quality of life in all patients, and to reduce HbA_{1c} in patients with T₂D. In all studies the control group consisted of patients receiving standard care. As adherence is a prerequisite for achieving the intervention effects, adherence to the telemonitoring interventions was investigated in detail using the log files, and was defined as a percentage of weeks including at least one health parameter recorded. Analyses were performed according to the intention-to-treat principle.

In all studies, adherence to the weekly telemonitoring was moderate (Study III) to high (Study I and II) with the median percentage of adherent weeks being 93%, 90% and 66% in Study I, II and III, respectively, without major attrition in time. The telemonitoring intervention in Study I demonstrated a statistically significant improvement in glycemic control by reducing HbA_{1c} by 0.44 percentage points. However, the blood pressure levels did not differ between the treatment arms. In study II, the telemonitoring intervention did not significantly reduce HF-related hospital admissions but, in fact, the utilization of the healthcare resources increased with the number of appointments and calls to the HF-nurse being 2–5 times higher in the telemonitoring arm, and more unplanned visits to the cardiology clinic. A combination of telemonitoring and health coaching in Study III did not improve the health-related quality of life in patients with T₂D, HF or CAD. Neither did it reduce HbA_{1c} in patients with T₂D.

Sustained, fairly high adherence seen in all studies suggests that weekly telemonitoring of health-related parameters is feasible. Nevertheless, high adherence does not guarantee positive health effects. Two of the studies showed no improvement in health outcomes although participants were actively involved with telemonitoring. This indicates that telemonitoring as such might not be effective in improving chronic disease outcomes. Positive health effects were seen only in study I, where the individuals received real-time, behavioral-theory based feedback messages that summarized the TM data, and motivated and guided patients to take actions to promote self-management. Putting the results together, the findings of this work support earlier research findings on the importance of grounding interventions on behavioral theory and providing timely feedback with enriched content to promote self-management and further improve the health outcomes of individuals with chronic conditions. However, telemonitoring interventions might increase the use of healthcare resources, especially personnel resources by requiring more time of the responsible nurse. Thus, sufficient resources should be ensured and the benefits gained evaluated in the light of other findings. Telemonitoring interventions should be carefully designed to target patients who are likely to adhere to them and likely to benefit from such interventions.

Tiivistelmä

Kroonisten sairauksien hoitoon vaaditaan tehokkaampia ratkaisuja. Informaatio- ja kommunikaatioteknologiat tarjoavat mahdollisuuksia pitkäaikaissairaiden potilaiden hoidon kehittämiseksi ja paremman hoitotasapainon saavuttamiseksi.

Tässä väitöskirjassa esitellään kolme satunnaistettua kontrolloitua tutkimusta, joissa arvioitiin etämittausinterventioiden vaikuttavuutta terveyteen liittyviin muuttujiin tyyppin 2 diabeetikoilla, sydämen vajaatoimintapotilailla sekä sepelvaltimotautipotilailla. Kaikissa tutkimuksissa etämittausinterventio käsitti pitkäaikaissairauteen liittyvien terveysparametrien viikoittaista seurantaa sekä mittausarvojen välittämisen terveydenhuollon ammattilaisten käyttöön matkapuhelimen avulla. Etämittausten tueksi jokaisessa tutkimuksessa interventioon sisältyi erilainen potilaan päätöksentukikomponentti. Tutkimus I, Mobile Sipoo -tutkimus, toteutettiin Sipoon terveyskeskuksessa. Tutkimuksessa oli mukana 51 tyyppin 2 diabeetikkoa, joita seurattiin 10 kuukauden ajan. Etämittausryhmässä potilaat ohjeistettiin mittaamaan painoa, verenpainetta, askelia ja/tai verensokeria. Mittaustuloksiin perustuen potilaat saivat reaaliaikaisia palauteviestejä omahoidon tukemiseksi. Käyttäytymisteoriaan pohjautuvat palauteviestit sisälsivät tiivistettyä tietoa potilaan pitkäaikaismittauksista, motivoivat muutokseen ja tarjosivat käytännön keinoja muutoksen saavuttamiseksi. Tutkimus I:n primääritavoite oli potilaiden glykohemoglobiinin ja verenpaineen alentaminen. Tutkimus II, Heart at Home -tutkimus, toteutettiin sydän- ja keuhkokeskuksen poliklinikalla Helsingin yliopistollisessa sairaalassa. Tutkimukseen osallistui 94 sydämen vajaatoimintapotilasta. Etämittausryhmän potilaat ohjeistettiin viikoittain mittaamaan painoa, verenpainetta, sykettä sekä sydämen vajaatoimintaan liittyviä oireita. Etämittauksiin perustuen potilaat saivat reaaliaikaisen palauteviestin, joka sisälsi lyhyen palautteen suhteessa asetettuihin tavoitearvoihin sekä kuvaajan mittaushistoriasta. Tutkimuksen II primääritavoite oli sydämen vajaatoimintaan liittyvien sairaalakäyntien määrän vähentäminen. Tutkimuksen kesto oli kuusi kuukautta. Tutkimus III, Renewing Health -tutkimus, toteutettiin Etelä-Karjalan sairaanhoitopiirin terveyskeskuksissa. Tutkimukseen osallistui 519 potilasta; 250 tyyppin 2 diabeetikkoa, 227 sepelvaltimotautipo-

tilasta ja 42 sydämen vajaatoimintapotilasta. Potilaat ohjeistettiin mittamaan painoa, verenpainetta, askelia ja/tai verensokeria viikoittain. Etämittausten lisäksi osallistujat saivat henkilökohtaisen terveystalmentajan, joka oli heihin puhelimitse yhteydessä 4–6 viikon välein. Terveystalmentuksen avulla pyrittiin voimaannuttamaan potilasta sekä tarjoamaan keinoja pitkäaikaissairauden paremman hoitotasapainon saavuttamiseksi. Primääritavoite tutkimus III:ssa oli parantaa potilaiden elämänlaatua sekä tyyppin 2 diabeetikoiden osalta madaltaa veren glykohemoglobiinia, jota mitattiin HbA_{1c}:n avulla. Kaikissa kolmessa tutkimuksessa kontrolliryhmä sai tavanomaista hoitoa. Koska terveystalmentusten saavuttaminen edellyttää potilaiden sitoutumista interventioon, potilaiden sitoutumista etämittaustalmentioihin tutkittiin yksityiskohtaisesti lokitietojen avulla. Sitoutuminen määriteltiin niiden viikkojen prosentuaalisena osuutena, jotka sisälsivät vähintään yhden etämittaustalmentuksen. Tilastolliset analyysit toteutettiin intention-to-treat periaatteiden mukaisesti.

Sitoutuminen viikoittaisiin etämittaustalmentioihin vaihteli tutkimusten välillä kohtuullisesta (III) korkeaan (I ja II). Potilaat toteuttivat etämittaustalmentioita keskimäärin 93 % (I), 90 % (II) ja 66 % (III) viikoista. Sitoutumisen aste ei huomattavasti laskenut seuranta-ajan kuluessa. Etämittaustalmentio tutkimuksessa I johti glykohemoglobiinin tilastollisesti merkitsevään vähenemiseen. HbA_{1c} oli 0,44 prosenttiyksikköä matalampi etämittaustalmentiossa. Verenpaineessa ei ollut eroa ryhmien välillä. Tutkimuksessa II etämittaustalmentio ei vähentänyt sydämen vajaatoimintaan liittyvien sairaalapäivien määrää. Itse asiassa terveydenhuollon resurssien käyttö lisääntyi; sydänhoitajan vastaanottoaikoja ja puhelinkontakteja oli 2–5 kertaa enemmän etämittaustalmentiossa. Etämittaustalmentiossa oli myös enemmän ennakoimattomia poliklinikkakäyntejä. Etämittaustalmentio tutkimuksessa III, jossa yhdistettiin etämittaustalmentio sekä henkilökohtainen terveystalmentus, ei johtanut elämänlaadun parantamiseen. Myöskään glykohemoglobiini ei vähentynyt tyyppin 2 diabeetikotilalla.

Kaikissa kolmessa tutkimuksessa potilaiden sitoutuminen viikoittaisten etämittaustalmentien tekemiseen oli suhteellisen korkea eikä se vähentynyt ajan kuluessa. Nämä havainnot viittaavat siihen, että viikoittainen etämittaaminen on toteutettavissa. Korkea sitoutuminen ei kuitenkaan johtanut positiivisiin terveystalmentioihin; kahdessa tutkimuksesta ei havaittu positiivisia terveystalmentioita, vaikka potilaat tekivät aktiivisesti etämittaustalmentioita. Etämittaaminen itsessään ei välttämättä ole riittävää kroonisten sairauksien hoitotulosten parantamiseksi. Positiivisia terveystalmentioita saavutettiin ainoastaan tutkimus I:ssä, jossa osallistujat saivat etämittaustalmentionsa pohjalta käyttäytymisteoriaan perustuvia palaustalmentioita. Palaustalmentioit sisälsivät tiivistettyä tietoa potilaan pitkäaikaissalmentioista sekä motivoivat muutokseen ja tarjosivat keinoja muutoksen saavuttamiseksi. Tämän työn tulokset ovat linjassa aiempien tutkimustalmentosten kanssa, jotka korostavat käyttäytymisteorioihin perustuvien talmentioiden tärkeyttä. Väitöskirjan yhteenvetona todetaan, että etämittaustalmentioista saatavalla palaustalmentiolla on keskeinen rooli. On tärkeää antaa reaaliaikaissalmentiota ja sisältörikasta palaustalmentiota, jotta voidaan tukea pitkäaikaissalmentioitien omahoitoa ja

saavuttaa positiivisia terveysvaikutuksia. Etämittausinterventiot saattavat kasvattaa terveydenhuollon resurssien käyttöä, erityisesti sairaanhoitajien työkuormaa, joten tarvittavat resurssit tulisi varmistaa ja etämittausintervention mahdolliset hyödyt punnita muiden tulosten valossa. Lisäksi on tärkeää suunnitella etämittausinterventiot huolellisesti ja kohdistaa ne potilaille, jotka sitoutuvat käyttöön ja todennäköisesti hyötyvät interventiosta.

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List of Original Publications

- I **Orsama A-L**, Lähteenmäki J, Harno K, Kulju M, Wintergerst E, Schachner H, Stenger P, Leppänen J, Kaijanranta H, Salaspuro V, Fisher W. (2013). Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: results of a theory-based randomized trial. *Diabetes Technology and Therapeutics*, 15(8), 662–669.
- II **Vuorinen A-L**, Leppänen, J, Kaijanranta H, Kulju, M, Heliö T, van Gils M, Lähteenmäki J. (2014). Use of Home Telemonitoring to Support Multidisciplinary Care of Heart Failure Patients in Finland: Randomized Controlled Trial. *Journal of Medical Internet Research*, 16(12), e282.
- III Karhula T, **Vuorinen A-L**, Rääpysjärvi K, Pakanen M, Itkonen P, Tepponen M, Junno UM, Jokinen T, van Gils M, Lähteenmäki J, Kohtamäki K, Saranummi N. (2015). Telemonitoring and Mobile Phone-Based Health Coaching Among Finnish Diabetic and Heart Disease Patients: Randomized Controlled Trial. *Journal of Medical Internet Research*, 17(6), e153.
- IV **Vuorinen A-L**, Ermes M, Karhula T, Rääpysjärvi K, Lähteenmäki J. (2016). Is Home Telemonitoring Feasible in the Care of Chronic Diseases - Insights into Adherence to a Self-management Intervention in Renewing Health Finland Trial. In: Li H., Nykänen P., Suomi R., Wickramasinghe N., Widén G., Zhan M. (eds) *Building Sustainable Health Ecosystems*. WIS 2016. Communications in Computer and Information Science, vol. 636. Springer, Cham

Author's Contributions

Author's contributions to the original publications were as follows:

- I The author was responsible for designing the algorithms and content for the automatic feedback system together with W. Fisher, J. Lähteenmäki, K. Harno and J. Leppänen. The author was also responsible for the statistical analyses and wrote the publication together with W. Fisher and J. Lähteenmäki.
- II The author conducted the statistical analyses and was the main responsible for writing the publication.
- III The author was responsible for the statistical study design, data monitoring and data analyses, and was responsible for writing the Methods and Results sections for the publication.
- IV The author had the main responsibility for defining the research question, outlining the paper, conducting statistical analyses and writing the publication.

Abbreviations

BMI	Body Mass Index
CAD	Coronary artery disease
CI	Confidence interval
EHR	Electronic health records
EHFSBS	European Heart Failure Self-Care Behavior Scale
ECG	Electrocardiogram
GP	General practitioner
ICT	Information and communication technologies
HbA1c	Glycosylated hemoglobin
HF	Heart failure
HRQoL	Health-related quality of life
IMB	Information-Motivation-Behavioral skills
IRR	Incidence rate ratio
LDL	Low-density lipoprotein
LVEF	Left ventricular ejection fraction
HFrEF	Reduced ejection fraction
MCS	Mental component score in SF-36
NNB	Number needed to benefit
NNH	Number needed to harm
NNT	Number needed to treat
NYHA	New York Heart Association
OR	Odds ratio

PCS	Physical component score in SF-36
PHR	Personal Health Records
RCT	Randomized controlled trial
RR	Risk Ratio
SMBG	Self-monitoring of blood glucose
TM	Telemonitoring
T2D	Type 2 diabetes
ZIP	Zero-inflated Poisson

1 Introduction

Chronic conditions—diseases of long duration and generally slow progression—have become a major health threat globally as the leading cause of mortality and morbidity and adversely affecting health-related quality of life (HRQoL), especially when poorly managed (Bauer, Briss, Goodman, & Bowman, 2014; World Health Organization, 2014). As of 2012, 68% of deaths globally, of which more than 40% were premature, were attributable to chronic conditions (World Health Organization, 2014). In Finland, 93% of deaths were due to chronic conditions in 2017 (World Health Organization, 2017). Besides increasing premature mortality and morbidity, chronic conditions are highly prevalent and pose a significant strain on individual health and well-being and healthcare resources. In the US, more than 50% of adults have at least one chronic condition (Ward, Schiller, & Goodman, 2014), and in 2012 chronic conditions were the primary reason for adults seeking healthcare services and accounted for 86% of total healthcare costs in the United States (Gerteis et al., 2014). In Finland, 52% of women and 56% of men had at least one chronic condition in 2017, and the prevalence increased up to 64% and 65%, respectively, among adults over 60 years old (Koponen, Borodulin, Lundqvist, Sääksjärvi, & Koskinen, 2018).

The chronic disease burden can, however, be reduced. Many share common risk factors, behavioral and genetic, that account for a substantial amount of the chronic disease burden, and play a major role in managing chronic conditions (World Health Organization, 2002; 2009). Managing long-term conditions requires maintained lifestyle changes, adherence to treatments and care seeking behaviors, posing self-management as the key element in managing chronic conditions. However, as few as 50% of individuals with a chronic condition adhere to long-term treatment guidelines (World Health Organization, 2003). Insufficient adherence exposes individuals to poor health outcomes and complications, and is further associated with reduced quality of life and excess healthcare costs (Donkin et al., 2011; World Health Organization, 2003).

There is considerable interest in developing effective approaches to improve self-management and chronic disease outcomes. Information and communication technologies

(ICT) have the potential to overcome some of these challenges. Leveraging ICT provides possibilities to intensify the delivery of healthcare through remote collection and transmission of health-related data, and to connect individuals with healthcare providers outside of healthcare facilities. Moreover, technology-assisted interventions have great potential to support individuals' self-management efforts (Hanlon et al., 2017). The interventions have increasingly included education and information provision components, and mechanisms for providing feedback for patients. Typically, the feedback has involved healthcare providers who review the patient's data and provide feedback accordingly (Kitsiou, Paré, & Jaana, 2015). More recently, there has been considerable interest in the potential of automatic feedback systems to improve self-management through personalized feedback and recommendations.

Telemonitoring (TM) interventions involve individuals measuring and reporting their health-related information remotely and transferring these data to healthcare providers in order to tailor care to individual needs (Pare, Jaana, & Sicotte, 2007). TM interventions have been widely studied with positive results among a variety of chronic conditions including diabetes, hypertension, chronic obstructive pulmonary disease and heart failure, and have been shown to reduce mortality and hospitalizations, improve glycemic control, lower blood pressure, and increase HRQoL and individuals' knowledge of their condition (Hanlon et al., 2017; Inglis, Clark, Dierckx, Prieto-Merino, & Cleland, 2015; Jaana & Paré, 2007). However, a growing number of studies show that TM interventions are not effective, specifically those involving heart failure (HF) patients (Chaudhry et al., 2010; Koehler et al., 2011; Ong et al., 2016). Moreover, the quality of evidence of TM studies and related systematic reviews has been criticized, and several authors have called for high-quality RCTs to make further conclusions including rigorous study designs, detailed description of adherence, and bigger sample sizes (Eysenbach, 2005; Inglis et al., 2015; Kitsiou et al., 2015).

The objective of this thesis was to investigate TM interventions in individuals with chronic conditions focusing on secondary prevention. As a part of this work, three randomized controlled trials were conducted across Finland to assess the effect of the TM interventions on health-related outcomes in individuals with type 2 diabetes (T2D), heart failure (HF) and coronary artery disease (CAD). Each study included a differential feedback component linked to TM which contributes to the understanding of their role in TM interventions. This thesis is based on four original articles from the three separate clinical trials.

2 Concept Definitions

Chronic conditions have an impact on patients' physical, mental and social well-being. Chronic disease management is multifaceted and involves multiple components at both the patient and provider level, and requires system-level involvement for organizing care in a way that is it proactive rather than reactive. The following sections define the concepts central to the TM interventions developed and assessed in this work.

2.1 Self-management

Living with a chronic condition requires ongoing efforts by the individuals to adjust their behavior and to develop skills to cope with the illness. Typically, individuals meet with a healthcare provider only a few times a year, thus placing the responsibility for managing chronic conditions mainly on the patient. Self-management is therefore essential (Barlow, Wright, Sheasby, Turner, & Hainsworth, 2002; Martz, 2018).

Self-management has been conceptualized and defined in many ways. According to Corbin and Strauss, self-management involves three components: (i) medical management, such as adhering to medication regimes, (ii) behavioral management, such as maintaining or adopting new life roles after the onset of a condition, (iii) emotional management, such as dealing with emotional reactions to the onset of a chronic condition (Corbin & Strauss, 1988). Clark et al. (1991) refers to self-management as “day to day tasks an individual must undertake to control or reduce the impact of disease on physical health status”. In addition, self-management requires psychosocial coping to react to problems generated or exacerbated by the condition (Clark et al., 1991.) Parsons et al. defined self-management as “actions individuals and others take to mitigate the effect of a long-term condition and to maintain the best possible quality of life” (Parsons et al., 2010). Richard and Shea refer to self-management as “the ability of the individual, in conjunction with family, community, and healthcare professionals, to manage symptoms, treatment, lifestyle changes, and

psychosocial, cultural, and spiritual consequences of health conditions” (Richard & Shea, 2011).

Self-management differs from self-care, although the concepts are sometimes used interchangeably (Richard & Shea, 2011). Self-management encompasses the ability to take actions to cope with a chronic condition, whereas self-care refers to the ability to care for oneself and perform activities to achieve, maintain or promote optimal health rather than managing a condition (Grady & Gough, 2014; Richard & Shea, 2011). Self-care is a broad concept subsuming self-management (Richard & Shea, 2011).

The ability to decide which actions to take to manage one’s condition involves specific skills (Martz, 2018). There are five core self-management skills: problem solving, decision making, resource utilization, forming a collaborative partnership between individuals and the healthcare providers, and taking action (Bodenheimer, 2005; Lorig & Holman, 2003). Other skills needed are more disease-specific; for example, individuals with heart failure should restrict their fluid intake. The collaboration between the patient and the healthcare providers is important. Although individuals with a chronic condition have the main responsibility for the daily management of their condition, they need information and education from healthcare professionals on how to perform evidence-based care in order to avoid complications (Martz, 2018).

To summarize, self-management involves individuals taking an active role in managing their condition; they should not be viewed, nor see themselves, as passive recipients of healthcare but actively participate in managing their condition while collaborating with healthcare personnel. Self-management encompasses the skills needed to choose appropriate health promoting behaviors and adhere to them, as well as collaboration with the healthcare professionals who provide the information and education needed for successful self-management.

Self-management interventions are complex and multifaceted involving both the patient and the healthcare providers and need to be tailored according to individual and condition-specific needs (Hanlon et al., 2017). Pearce et al. developed a taxonomy that identified 14 components to be used to support self-management (Pearce et al., 2016). Hanlon et al. further defined six categories of self-management support components that could be specifically targeted through telehealth interventions. These include: patient education and information provision, remote monitoring with feedback and action plans, telehealth-facilitated clinical review, adherence support, psychological support, and lifestyle intervention (Hanlon et al., 2017).

2.2 Self-monitoring

Self-monitoring is an aspect of self-management (Richard & Shea, 2011) that involves systematic self-observation, periodic measurement and recording of target behaviors (Burke, Wang, & Sevick, 2011; Kanfer, 1970). Conscious attention to certain behaviors

increases self-awareness, which is an essential step in promoting behavior change (Burke, Swigart, Warziski Turk, Derro, & Ewing, 2009). Self-monitoring originates from Kanfer's self-regulation model, which includes three stages of promoting behavior change; self-monitoring, self-assessment and self-reinforcement (Kanfer, 1970). Self-monitoring is expected to improve self-management.

In the context of chronic conditions, self-monitoring involves the individual undertaking the following: self-measurement of vital signs, symptoms, or behaviors, ii) self-interpretation of data, and iii) self-adjustment of medication, lifestyle or care-seeking behaviors as a result of increased awareness (McBain, Shipley, & Newman, 2015; Wilde & Garvin, 2007). The optimal intensity of self-monitoring is not defined, but self-monitoring patterns, including the intensity, timing and method of self-monitoring and the target behaviors, are subject to the chronic condition and to individual care plans. Regardless of the intensity of self-monitoring, most important are the actions taken in response to self-monitoring efforts rather than intensively gathering comprehensive data (Inglis et al., 2015; Mattila, 2010).

2.3 Telehealth and telemonitoring

Telemonitoring (TM) is a particular form of self-monitoring and a particular form of telehealth. Telehealth refers to the use of ICT to provide healthcare to individuals at a distant location (World Health Organization, 2010). It is often used interchangeably with telemedicine. eHealth in turn refers to organizing and delivering of health services and information using the Internet and related technologies (Eysenbach, 2001). Telehealth may be synchronous or asynchronous. Asynchronous telehealth involves a store-and-forward approach that allows data to be recorded at one point in time and viewed by a healthcare provider at another time and location (Whitten, Holtz, & Laplante, 2010; World Health Organization, 2010). In contrast, synchronous approaches refer to more conventional telehealth involving delivery of information in real-time where all individuals are present simultaneously for immediate exchange of information (Whitten et al., 2010). A typical example of synchronous services is videoconferencing.

TM is, as defined by Pare et al. (2007), an automated process for the transmission of data on an individual's health status from a distant location to the healthcare provider where the individual is responsible for uploading and transmitting the data without the help of the healthcare provider. TM moves patients' care out of a clinical setting into the patient's home. TM is thus sometimes referred to as home TM. However, in this work, TM is used without reference to the patient's home. TM involves remote monitoring of physiological data specific to a chronic condition, such as blood glucose monitoring in diabetes patients or blood pressure monitoring in individuals with hypertension, and using monitoring devices for transferring the data for use by the healthcare providers. Sharing the monitored data with the healthcare professionals has potential to intensify the collaboration and influence

professionals' decision making. In addition, TM is assumed to improve self-management by increasing awareness and knowledge of one's health condition through self-monitoring (Inglis et al., 2015).

TM has been typically referred to as asynchronous telehealth; patients monitor their vital signs and store the data in a database that can be accessed by the healthcare providers. As such technology is used as a passive medium that enables remote access and delivery of care. Yet, TM interventions have increasingly included mechanisms that involve interaction between the patient and technology. Such interventions include both synchronous and asynchronous components. Patients upload their data, which is further processed, and algorithms generate responses based on specific parameter values. Interactive systems tailor the content of the responses based on the data provided by the patient. However, such systems do not involve information processing, which is a specific feature of active assistance technology. Active assistance technology takes a step further, serving as an active tool for automated processing of health information in an ongoing manner as the user interacts with the technology (Kennedy et al., 2012). The active information processing affects semantic content of the responses provided, which is a distinctive feature of interactive systems (Kennedy et al., 2012).

2.4 Adherence

Interventions can be effective only if participants adhere to them. According to WHO, adherence defines "the extent to which a person's behavior corresponds with agreed recommendations from a healthcare provider" (World Health Organization, 2003). Adherence, contrary to compliance, emphasizes the collaborative relationship between the individual and the healthcare provider in which treatment goals have been jointly agreed. Compliance refers more to the authority of healthcare professionals who set up treatment regimens that individuals are required to follow (World Health Organization, 2003). Attrition is closely related to adherence and refers to discontinuation of an intervention (Eysenbach, 2005). While adherence is measured throughout the intervention, attrition refers to a specific time point when the participant stops using the intervention (Eysenbach, 2005).

Adherence is always context-specific depending on the components and specific requirements of an intervention and the technology used. Unlike medication, self-management is not uniform treatment but encompasses multiple components and typically targets multiple behaviors such as following a diet, executing lifestyle changes, or taking medications. While in pharmacology sufficient adherence is typically defined as taking 80% or more of prescribed doses (Nieuwlaat et al., 2014), in self-management interventions sufficient exposure is multifaceted and should be defined study-wise or even on a patient level depending on individual needs.

Studies exploiting ICT produce log data that allow accurate and objective description of adherence to interventions (Sieverink, Kelders, Poel, & van Gemert-Pijnen, 2017). The log data provides possibilities to investigate participants' exposure to the intervention from different perspectives by using metrics such as number of logins, duration of sessions, intensity of use, uploaded self-measurements, and page visited (Couper et al., 2010). Thorough description of adherence combined with feedback from users helps determine the efficacy of different components, which would not necessarily be possible with more conventional interventions.

The consort statement for eHealth interventions recommends detailed description of usage data including an attrition diagram showing the proportion of adherent participants over time (Eysenbach & CONSORT-EHEALTH Group, 2011). As an individual's involvement with an intervention typically decreases over time, single aggregated measures may provide misleading information on adherence (Nelson, Coston, Cherrington, & Osborn, 2016). Thus, a time varying description of adherence has been recommended. Nonetheless, adherence remains poorly reported in the eHealth interventions. One possible reason might be high attrition, which is a typical feature of eHealth interventions, especially those without human involvement (Eysenbach, 2005). As high attrition and low adherence rate are linked to intervention failure, this might contribute to such interventions being underreported, thus posing a bias in the literature. However, it is important to measure adherence, not only to shed light on non-usage, but also to ensure that possible health benefits achieved can be attributed to the intervention used (World Health Organization, 2003).

Currently, adherence is an improperly used concept in eHealth interventions in particular. It is frequently insufficiently defined or completely undefined, and is interchangeably used with actual use (Sieverink, Kelders, & van Gemert-Pijnen, 2017). It has been recognized that sufficient exposure to an intervention is challenging to determine for behavioral interventions in particular because effective usage patterns might differ across individuals, and individuals do not necessarily have to be exposed to all of the elements of an intervention to achieve positive health outcomes (Donkin et al., 2011). Therefore, higher engagement with an intervention does not necessarily constitute improved outcomes, and discontinuation with an intervention does not mean failure, but may also reflect sufficient mastery and thus continued exposure to the intervention is no longer needed. Yardly et al. have proposed effective engagement as meaning sufficient engagement with the intervention to achieve intended outcomes. Effective engagement is based on the purpose of a particular intervention and based on individual needs. (Yardley et al., 2016.) Nevertheless, it is recommended that adherence and associated measures are clearly defined in the design phase, and should preferably be justified by using theory, evidence or rationale (Sieverink, Kelders, & van Gemert-Pijnen, 2017).

3 Background on the Chronic Conditions Studied

This work focuses on three chronic conditions: type 2 diabetes (T2D), heart failure (HF) and coronary artery disease (CAD). Each condition is described in the following sections followed by a summary of the self-management guidelines for each disease. This short overview provides a background for the TM interventions developed and assessed in this work.

3.1 Heart failure

Heart failure (HF) results from cardiac dysfunction that impairs the ability of the ventricle to fill with or eject blood. As a result, too little blood is delivered, and the organs and other tissues do not receive enough oxygen to meet their needs (Ponikowski et al., 2016; Yancy et al., 2013). Ejection fraction determines how well the ventricle pumps out blood on each contraction. Left ventricular ejection fraction (LVEF) is used in the classification of individuals with HF. Systolic heart failure refers to reduced ejection fraction (HFrEF) when the LVEF < 40%. A normal LVEF is 50–75%. (Ponikowski et al., 2016.) HF decreases individuals' functional status and impairs HRQoL with typical symptoms including breathlessness, ankle swelling, fatigue with limited exercise tolerance, and fluid retention (Nieminen et al., 2015; Yancy et al., 2013). The New York Heart Association (NYHA) functional classification is frequently used to describe the functional severity of HF; the NYHA assigns individuals to one of four classes based on exercise capacity and symptoms: I=no limitation of physical activity, II=slight limitation of physical activity, III=marked limitation of physical activity, IV=unable to carry on any physical activity without symptoms of HF (Yancy et al., 2013).

HF is associated with high mortality and high hospitalization rates, which makes it a serious and costly disease. One-year mortality is approximately 30% varying according to the severity of the condition; among recently hospitalized HF patients mortality rates can increase up to 43%, whereas for stable HF 1-year mortality is 7% (Blackledge,

Tomlinson, & Squire, 2003; Chen, Normand, Wang, & Krumholz, 2011; Maggioni et al., 2013). Without appropriate treatment, HF has a poorer survival rate than many forms of cancer (Stewart, MacIntyre, Hole, Capewell, & McMurray, 2001). HF is characterized by periodic acute decompensations that require treatment intensification. Frequent hospital admissions are typical for individuals with HF; after initial hospital admission 19–25% are readmitted within 30 days, and the 1-year hospitalization rate is 32–44% (Maggioni et al., 2013; Ross et al., 2010). These hospitalizations pose a heavy economic burden on society, accounting for 60–70% of the total cost of HF care (Stewart, 2005). Approximately half of the hospitalizations are preventable (Braunstein et al., 2003; Vinson, Rich, Sperry, Shah, & McNamara, 1990). Factors contributing to preventable admissions include nonadherence to medications and diet, inadequate discharge planning or follow up, and failure to seek medical care promptly when symptoms occur (Vinson et al., 1990).

The prevalence of HF is approximately 1–2% rising to $\geq 10\%$ among people >70 years of age (Ponikowski et al., 2016). In Finland, approximately 3% of adults under 70 years have HF, and the prevalence increases up to 27% among people >80 years of age (Koponen et al., 2018).

The management of HF requires a multidisciplinary approach that encompasses structured follow-up, education, optimized medical treatment, psychosocial support and improved access to care where HF practitioners and other experts collaborate (Lainscak et al., 2011; Yancy et al., 2013). Self-management in HF involves regular monitoring of HF-related disease parameters and acting on early symptoms to decrease the risk of hospital admission (Lainscak et al., 2011; Yancy et al., 2013). Specific self-management behaviors include medication taking, weight and symptom monitoring, dietary adherence, fluid and alcohol restriction, weight management, exercise, smoking cessation, and engaging in preventative behaviors such as travel safety and immunization (Lainscak et al., 2011). Self-monitoring of weight is recommended as body weight is an indicator of fluid retention that often predicts decompensated HF (Chaudhry, Wang, Concato, Gill, & Krumholz, 2007). Daily information on body weight may help in detecting high-risk periods where appropriate intervention (such as medication adjustment) could be provided. A sudden unexpected weight gain of >2 kg in 3 days is an indicator of a need for an increased diuretic dose, which requires alerting the healthcare provider (Ponikowski et al., 2016). Other recommended self-monitoring parameters include blood pressure and heart rate (Lainscak et al., 2011) to allow the detection of episodes of arrhythmias and hypotension which also might precede decompensation (Zile et al., 2008). Regular symptom monitoring may shorten the delay for seeking care for worsening symptoms (Evangelista, Dracup, & Doering, 2000). Restriction of fluids and sodium are recommended for maintaining euvoemia because volume overload can worsen the symptoms of HF and lead to hospitalization (Lainscak et al., 2011).

Unfortunately, adherence to self-management recommendations is frequently suboptimal; adherence to a low sodium diet, weight monitoring, fluid restriction and exercise recommendations has been as low as 5–10% (Jaarsma et al., 2013; van der Wal &

Jaarsma, 2008). HF is associated with old age, presence of multiple chronic conditions, and an increased prevalence of anxiety, depression and impaired cognition that may contribute to poor adherence rates (Braunstein et al., 2003; Freedland et al., 2016; Riegel et al., 2009; Yancy et al., 2013).

3.2 Type 2 diabetes

Diabetes is a chronic condition that occurs when the human body does not produce enough insulin, or the body is unable to use insulin effectively to regulate blood glucose. As a result, blood sugar builds up in the blood leading to high levels of blood glucose, hyperglycemia (International Diabetes Federation, 2017a). Chronic hyperglycemia strains blood vessels and reduces blood flow, which can further damage several body organs over time. Diabetes complications include cardiovascular complications, foot ulcers, retinopathy and kidney failure, amongst others (International Diabetes Federation, 2017a; World Health Organization, 2016). In addition, abnormally low blood glucose, hypoglycemia, can occur in diabetes patients and may result in seizures or loss of consciousness (World Health Organization, 2016).

Type 2 diabetes (T2D) is the most common form of diabetes and accounts for over 90% of all diabetes cases globally (Rydén et al., 2013). Although T2D and type 1 diabetes are heterogeneous diseases, the global estimated of diabetes are often combined for both types (World Health Organization, 2016). In 2014, the prevalence of diabetes was 8.5% (World Health Organization, 2016). Approximately 420 million adults had diabetes in 2014 and this figure is estimated to increase to 552 million by 2030 (Rydén et al., 2013; World Health Organization, 2016). In Finland, 300,000 people have T2D, and further 150,000 are estimated have the condition but remain undiagnosed (Diabetesliitto, 2018).

Glycosylated hemoglobin (HbA_{1c}) is an indirect measure of long-term blood glucose concentration, referring to the process by which hemoglobin, a protein within red blood cells, combines with glucose in the blood stream to form the glycosylated hemoglobin. The more glucose in the blood, the more HbA_{1c} is present. As red cells survive for 8–12 weeks, the amount of HbA_{1c} present reflects the blood glucose concentration over that duration (World Health Organization, 2011.) HbA_{1c} is a commonly used outcome variable in diabetes studies because it provides a useful biomarker for average long-term blood glucose concentration and does not require fasting (Quinn et al., 2009). Although low HbA_{1c} does not necessarily mean that diabetes is being well-managed, well-controlled blood glucose levels are characterized by normal or close to normal HbA_{1c} levels (Quinn et al., 2009).

Healthy individuals have HbA_{1c} typically below 6% (47mmol/mol) (American Diabetes Association, 2018a). Individuals with T2D should maintain a glycemic level as close to normal as possible to prevent complications. The recommended target for HbA_{1c} is <7.0% (53mmol/mol) (American Diabetes Association, 2018a; Montalescot et al., 2013; Suomalaisen Lääkäriseuran Duodecimin Suomen Sisätautilääkäreiden yhdistyksen ja

Diabetesliitos Lääkärineuvoston asettama työryhmä, 2018). For T2D individuals with short disease duration and no significant cardiovascular disease, an HbA_{1c} target of <6.5% can be used if it can be achieved without significant hypoglycemia (American Diabetes Association, 2018a).

Lifestyle changes are recommended in the first instance for newly diagnosed T2D individuals. Even a modest weight reduction of 5–10% improves glycemic control and reduces cardiovascular risk factors (Inzucchi et al., 2012). If the HbA_{1c} target is not achieved with lifestyle changes, Metformin is added as the first-line drug. For individuals with hyperglycemic symptoms and/or HbA_{1c} >10.0%, insulin therapy should be considered (American Diabetes Association, 2018b). In addition, hypertension should be treated and all individuals should have a blood pressure target of <140/90 mmHg unless individually defined (American Diabetes Association, 2018c). Individuals with high risk and very high risk of cardiovascular events should have a low-density-lipoprotein (LDL) cholesterol level below 2.5mmol/L and 1.8mmol/L, respectively (Rydén et al., 2013).

Self-monitoring of blood glucose (SMBG) is a central component of self-management for individuals with diabetes. SMBG involves collecting detailed information on glucose levels at different times during the day. The SMBG data guides individuals in adjusting medication, insulin doses in particular, and preventing or confirming hypoglycemia, thus improving the patient's own recognition of severe events (Malanda, 2013). SMBG also helps understand the impact of lifestyle on blood glucose variation, thus helping to guide nutrition therapy and physical activity (American Diabetes Association, 2018a). While SMBG is especially important for insulin-treated individuals to prevent hypoglycemia and hyperglycemia, there has been controversy about the value of SMBG among non-insulin T2D individuals (Farmer et al., 2012; Malanda et al., 2012). Promoting SMBG alone does not improve glycemic control, instead SMBG should be combined with individual and provider education to ensure patients have the appropriate skills to do SMBG and that the data is correctly interpreted and effectively used in decision making (Polonsky & Fisher, 2013). In addition, structured SMBG profiles that include a pre-specified frequency and timing of SMBG in accordance with individual SMBG goals are recommended (American Diabetes Association, 2018a). In Finland, the SMBG for non-insulin dependent patients is recommended on an individual basis depending on the patient's needs, skills, glycemic control and individual risk of hypoglycemia (Suomalaisen Lääkäriseuran Duodecimin Suomen Sisätautilääkäreiden yhdistyksen ja Diabetesliitos Lääkärineuvoston asettama työryhmä, 2018).

3.3 Coronary artery disease

Coronary artery disease (CAD) refers to a heart disease in which the blood flow is restricted or reduced due to narrowing of the coronary arteries that supply oxygen-rich blood to the heart muscle. CAD develops when plaque, cholesterol-containing deposits, builds up inside

the coronary arteries (Montalescot et al., 2013). Typical symptoms of CAD include chest pain or shortness of breath, or heart attack if the supply of blood is completely blocked by a sudden rupture of plaque and formation of a blood clot (Montalescot et al., 2013). Over time, CAD can weaken the heart muscle and lead to HF and arrhythmias.

CAD is estimated to affect 4–7% of 45–64-year-olds and 10–14% 65–84-year-olds (Montalescot et al., 2013). In Finland, 9% of men and 7% of women >50 years of age had CAD in 2017 (Koponen et al., 2018). Ischemic heart disease is the single largest cause of death and illness in the world (World Health Organization, 2018). In 2016, ischemic heart disease caused 9 million deaths globally accounting for 17% of all deaths. In Finland the condition was attributable to 20% of all deaths and was the most common cause of death in 2016 (Official Statistics of Finland, 2016). In high-risk individuals one-year mortality is 3.8%, whereas in individuals with non-obstructive plaques within the coronary arteries, the annual mortality rate is 0.6% (Montalescot et al., 2013).

The management of CAD encompasses lifestyle modification, controlling the risk factors, pharmacological therapy and patient education (Fihn et al., 2012; Montalescot et al., 2013). The goal is to reduce plaque buildup and lower the risk of blood clots forming, and relieve symptoms. Medical procedures including laser surgery, coronary bypass surgery and stent placement are considered if the arteries are very narrow (Montalescot et al., 2013).

Management of the risk factors for damage to the coronary arteries is essential to avoiding cardiovascular complications. These risk factors include smoking, high levels of sugar and certain fats and cholesterol in the blood, high blood pressure, and blood vessel inflammation (Montalescot et al., 2013; National Heart Lung and Blood Institute, 2018). The target levels for blood pressure are <140/90 mmHg, or within 130–139/80–85 mmHg as suggested recently (Montalescot et al., 2013). The goal for LDL cholesterol is below 1.8 mmol/L or a 50% reduction when the target level cannot be reached. As diabetes increases the progression of CAD, target for HbA_{1c} is <7.0%, or <6.5–6.9% on an individual basis (Montalescot et al., 2013).

Lifestyle recommendations include heart-healthy eating, maintaining a healthy weight (BMI 18.5–24.9 kg/m²), regular physical activity and smoking cessation (Montalescot et al., 2013). In addition, individuals with CAD are encouraged to take up regular physical activity, including both moderate-intensity aerobic exercise and muscle training (Fihn et al., 2012; Montalescot et al., 2013). Cardiac rehabilitation, which encompasses structured exercise counselling and training is a class I recommendation for all individuals with CAD (Anderson et al., 2016; Anderson & Taylor, 2014; Montalescot et al., 2013). In addition, introducing and educating self-monitoring skills and encouraging patients towards regular self-monitoring of blood pressure and glucose, tracking daily calories and physical activity, are recommended to support lifestyle changes (Fihn et al., 2012).

4 Review of Literature on Telemonitoring Interventions in Heart Failure, Type 2 Diabetes and Coronary Artery Disease

The underlying idea of TM interventions is to promote the management of chronic conditions by encouraging individuals to monitor their health parameters remotely and to share the data with healthcare professionals, thus providing them with accurate and up-to-date patient information (Pare et al., 2007). The self-monitoring data is recorded in a natural setting and constitutes longitudinal information that cannot be obtained during brief clinic visits. Exploiting this data, healthcare providers can remotely detect indicators of poor or worsening health and modify the patient's management plan accordingly in a timely manner to avoid complications, for example through medication or lifestyle adjustments (Greenwood, Young, & Quinn, 2014).

Besides informing the healthcare providers with the patient's health data, TM interventions also have potential to support individuals' self-management efforts and aid their decision making based on the TM data. There are a variety of self-management support components that could be targeted through telehealth interventions (Hanlon et al., 2017). One of the components, specifically relevant for TM interventions, is the remote monitoring with feedback and action plans (Hanlon et al., 2017). In fact, a complete feedback loop is considered essential to produce positive health outcomes (Jimison et al., 2008). The complete feedback loop encompasses a combination of five stages: (i) monitoring and transmission of data about the current status of the patient; (ii) interpretation of these data in light of established treatment goals; (iii) adjusting the management plan as needed; (iv) timely communication back to the patient with tailored recommendations or advice, and (v) regular repetition of this cycle (Jimison et al., 2008).

Feedback in TM interventions has typically involved healthcare providers who review the TM data and provide feedback accordingly (Kitsiou et al., 2015). Consequently, the feedback is frequently provided intermittently rather than in real time. However, in

response to the growing demand for healthcare services TM interventions have increasingly included mechanisms for providing automatic feedback. Such automatic feedback systems involve reminders and feedback messages automatically delivered to the patients based on their data and individual treatment targets. Processing TM data in real time enables timely responses to the data, which is one of the elements in a complete feedback loop (Jimison et al., 2008).

To achieve optimal outcomes, interventions promoting self-management and health behavior changes should be grounded on behavioral theories and use specific behavior change techniques. Theories can help identify key determinants of the target behaviors and associated behavior change strategies needed to achieve the desired health outcomes (van Vugt, de Wit, Cleijne, & Snoek, 2013; Winter, Sheats, & King, 2016). These principles apply to telehealth interventions. Providing feedback on performance is consistently found to be important in promoting behavior change (van Vugt et al., 2013). It has been shown that interventions that used behavioral theory achieved better health outcomes (Sharon, Esser, & Hofmann, 2018; Webb, Joseph, Yardley, & Michie, 2010). Accordingly, extensive use of behavior change techniques produces larger effects than interventions with fewer techniques (van Vugt et al., 2013; Webb et al., 2010).

Chronic disease management requires organizing the delivery of care in a way that is proactive and supports long-term management rather reacting to acute episodes. The Chronic Care Model is a widely accepted and validated framework for developing the care of chronic diseases in a such way (Bodenheimer, Wagner, & Grumbach, 2002; Coleman, Austin, Brach, & Wagner, 2009; Davy et al., 2015). The model identifies six components to be included in efficient management of chronic diseases: self-management support, health system support, clinical information systems, delivery system design, decision support, and community resources. More recently, the eHealth enhanced Chronic Care Model, framework has been published to guide the organization of care when integrating eHealth technologies (Gee, Greenwood, Paterniti, Ward, & Miller, 2015). This, in particular, is applicable to TM interventions. According to this model, eHealth education, eHealth support and a complete feedback loop are critical to assure efficient patient-provider collaboration.

The next three chapters review RCTs investigating TM interventions in individuals with T2D, HF and CAD. Studies published mainly after 2008 are included summarizing the evidence from the past ten years to avoid major technological differences that may influence the results. The interventions are summarized by separately describing the TM component and feedback provided in response to TM. The effectiveness of the TM interventions is summarized using the primary outcomes and HRQoL to link the findings of this thesis to the existing literature.

4.1 Telemonitoring interventions in individuals with heart failure

In individuals with HF, TM interventions have involved remote patient monitoring of HF-specific symptoms and vital signs typically including weight, symptoms and blood pressure, and sharing the data with healthcare professionals to provide them with increased information about the individuals' clinical status. Besides increasing the individual's own awareness and thus improving their self-management, the TM interventions focus on predicting decompensation episodes that usually correlate with fluid retention and require treatment intensification. Gathering longitudinal data on weight and blood pressure is expected to enable early recognition of such deterioration. (Gyllensten et al., 2016.)

TM interventions in individuals with HF have been extensively studied during the last two decades, and the results have been summarized in multiple reviews (Inglis et al., 2015; Kitsiou et al., 2015; Pandor et al., 2013; Paré, Moqadem, Pineau, & St-Hilaire, 2010), and a meta-analysis summarizing evidence from 15 reviews by Kitsiou et al. (2015). Both reviews concluded that TM reduces mortality and HF-related hospitalization and improves HRQoL. However, many of the studies included in the meta-analyses were criticized for poor to moderate quality, and the authors called for additional, well-designed, randomized controlled trials to confirm the results (Inglis et al., 2015; Kitsiou et al., 2015; Pandor et al., 2013).

Table 1 summarizes 13 RCTs published after 2008 that investigated TM interventions with HF patients. One important study from 2005 is also included in this review as it is one of the first well-designed RCTs to assess the effectiveness of TM interventions and is frequently cited in the literature (Cleland et al., 2005). TM interventions and the feedback provided in response to TM data are summarized. The effectiveness of the studies is presented by including adherence, mortality, hospitalizations and HRQoL outcomes.

Participants of TM studies were typically recently hospitalized patients with HF with mean ages varying from 54 to 76 years, and the majority being men. Participants frequently had HFrEF with LVEF varying from 25% to 40%, and a NYHA class of II–IV indicating at least a marked limitation of physical activity. The length of the studies varied from 6 to 26 months. The largest studies included 1653 and 1437 participants, whereas the smallest study had 80 participants.

The TM interventions typically involved daily TM of weight, blood pressure, heart rate and symptoms. Some studies included additional monitoring parameters such as ECG (Cleland et al., 2005; Koehler et al., 2011; Mortara et al., 2009; Seto et al., 2012), psychological assessment (Bekelman et al., 2015; Chaudhry et al., 2010; Villani et al., 2014) or medication adherence (Cleland et al., 2005; Villani et al., 2014). In one study (Mortara et al., 2009), participants self-monitored their health parameters on a weekly basis. The monitoring data were reviewed by the study personnel on a daily or weekly basis but no less frequently. Seven studies relied on alerts; the healthcare providers received an alert if patients' recordings exceeded the predefined thresholds (Cleland et al., 2005; Dar et al.,

2009; Dendale et al., 2012; Lyngå et al., 2012; Olivari et al., 2018; Ong et al., 2016; Seto et al., 2012).

Patient feedback components varied substantially, if provided at all. In one study, participants received automatic feedback messages coupled with instructions; after each measurement participants received instructions on what to do after taking the measurement (Seto et al., 2012). In another study TM was combined with monthly health coaching (Ong et al., 2016). Other studies did not provide feedback or health counselling. Instead, the healthcare providers were typically informed if the TM data exceeded the predefined target values and they took appropriate actions. Only in two studies it was specifically clarified that the HF-nurse called the patient and provided self-management support if the target values were exceeded (Dar et al., 2009; Dendale et al., 2012). In four studies participants were also contacted if they did not adhere to the TM plan (Chaudhry et al., 2010; Lyngå et al., 2012; Ong et al., 2016; Seto et al., 2012). Three TM interventions included collaboration with the research team and the patients' local physicians (Cleland et al., 2005; Dendale et al., 2012; Koehler et al., 2011).

Adherence to the daily TM was relatively high with adherence rates of approximately 80% or higher across the studies. However, the definitions of adherence were heterogeneous. For example, in two studies the researchers reported the percentage of participants who adhered to making daily recordings, whereas another study reported the percentage of participants who used the system but without detailing the intensity of use (Cleland et al., 2005; Olivari et al., 2018; Seto et al., 2012). Particularly low adherence rates were seen in the studies by Chaudhry et al. and Ong et al. In the former study, 14% of participants never used the system, and 55% were adherent at the end of the study although participants received automatic reminder calls if they did not submit data. In the latter study, adherence was 52%. Both of these studies had large sample sizes, 1653 and 1437, respectively (S. Chaudhry et al., 2010; Ong et al., 2016).

It seems that TM interventions were not effective in reducing mortality. Of the twelve studies that reported mortality outcomes, only two studies showed a statistically significant decrease in mortality rates (Bekelman et al., 2015; Dendale et al., 2012). In addition, in the study by Cleland et al. participants receiving either TM or structured telephone support showed significantly lower mortality than participants receiving standard care, although no statistical test was reported comparing the TM group only with the standard care group (Cleland et al., 2005). Although only two studies reached statistical significance in mortality outcomes, the overall trend was that TM improved survival, as the majority of the studies reported lower mortality rates in the TM arm. However, those reductions were not statistically significant. The HF-related hospitalization admissions were lower in the TM arms in two studies (Dendale et al., 2012; Villani et al., 2014) with 0.24 vs 0.42 admissions per patient, and 58% vs. 30% of patients hospitalized, respectively. Similarly, the general tendency was that hospitalization rates were slightly lower in the TM arms; however, the differences between the treatment arms were small and not statistically significant.

HRQoL in individuals with HF has been assessed using different instruments, including the Minnesota Living with Heart Failure questionnaire (Riegel et al., 2002), the SF-12/36 (McHorney, Ware, & Anastasia, 1993) or the Kansas City Cardiomyopathy questionnaire (Green, Porter, Bresnahan, & Spertus, 2000). In five studies (in total nine studies investigated HRQoL), participants in the TM group reported significantly improved HRQoL (Jayaram et al., 2017; Olivari et al., 2018; Ong et al., 2016; Seto et al., 2012; Villani et al., 2014). HRQoL was the primary outcome in only one study (Seto et al., 2012). Thus, studies that did not reach statistical significance may have been unpowered to detect differences between the groups. The HRQoL results suggest that TM interventions may have potential for treating psychological aspects and improving HRQoL rather than reducing hospitalization and mortality.

The reviewed TM interventions were heterogeneous with differential outcomes and patient populations, making it difficult to identify effective components. However, some were identified. TM intervention components that were associated with positive health outcomes included providing feedback that included advice in response to TM data, monitoring psychological parameters, and intense collaboration between clinic and general practitioner (GP) (Bekelman et al., 2015; Dendale et al., 2012; Jayaram et al., 2017; Seto et al., 2012; Villani et al., 2014). In one study where participants experienced improved HRQoL, the TM system provided immediate automatic instructions on how to act in response to the recorded data (Seto et al., 2012). Intense collaboration between the HF clinic and the patient's GP was included in one TM intervention where TM data were shared with patients' GPs to support their decision making, and the GPs also received back-up support for their decisions from the HF clinic. This intervention significantly reduced mortality and HF-related hospitalizations (Dendale et al., 2012). Focusing on psychological aspects as a part of the TM intervention was associated with improved HRQoL in particular (Jayaram et al., 2017; Villani et al., 2014), and with reduced mortality (Bekelman et al., 2015) and hospitalization (Villani et al., 2014).

Researchers have sought to identify subgroups of patients who are most likely to benefit from TM interventions. Dendale and colleagues found that neither LVEF nor N-terminal pro brain natriuretic peptide correlated with study outcomes (Dendale et al., 2012). Similarly Ong et al. (Ong et al., 2016) and Villani et al. (Villani et al., 2014) found no interaction between demographical and clinical variables, and the TM intervention. Koehler et al. reported that depression scores correlated with mortality and days lost to death or hospitalization (Koehler et al., 2012). Overall, the patients' characteristics seem to have small effect on outcomes in TM interventions. Factors related to the etiology of the HF, healthcare system -related components, TM intervention components, and perceived benefit from the patient's perspective may prove more informative for improving the health outcomes of TM interventions with individuals with HF (Krumholz et al., 2016; Webb et al., 2010).

Table 1. Telemonitoring interventions, adherence to them, and their effects on mortality, hospitalization and health-related quality of life in individuals with heart failure assessed in randomized controlled trials

Reference and country	Number of participants, inclusion criteria and duration	Content of telemonitoring intervention	Feedback on telemonitoring	Standard care	Characteristics	Adherence	Mortality	Hospitalization	Health-related quality of life
Cleland et al. (2005) Germany Netherlands UK	<ul style="list-style-type: none"> n = 426 Hospitalized for HF within 6 weeks LVEF<40% Duration: 240 days 	<ul style="list-style-type: none"> TM of W, BP, HR, ECG twice daily + monthly calls to assess symptoms and medication Study personnel made a patient management plan that was sent to the patient's primary care physician to implement it. 	<ul style="list-style-type: none"> Study nurse was notified if data exceeded the target values, and the nurse or primary care physician took appropriate action. 	<ul style="list-style-type: none"> Clinics without comprehensive HF management 	<ul style="list-style-type: none"> 81% male Mean age 67 years 34% had NYHA \geq III LVEF 25% 	81% were 80% adherent to daily recordings	17% in TM group vs. 24% in SC group, p-value NA ^a	Hospitalized for HF: 25% in TM group vs. 28% in SC group, p-value NA ^a	
Mortara et al. (2009) UK	<ul style="list-style-type: none"> n=451 Hospitalized for HF within 12 months NYHA class II-IV LVEF \leq 40% Duration: 12 months 	<ul style="list-style-type: none"> Group 1: monthly telephone contacts with study nurse to check clinical status Group 2: as Group 1 + weekly TM of W, HR, BP, S using interactive voice response + monthly ECG and PA available for the research team Group 3: as Group 2 + ECG and PA data made available for clinical management 	<ul style="list-style-type: none"> 24-h answering machine available If parameters exceeded target values, investigators chose the best action following the guidelines 	<ul style="list-style-type: none"> Outpatient clinics experienced in HF management 	<ul style="list-style-type: none"> 85% male Mean age 60 years 39% had NYHA \geq III LVEF 29% 	<ul style="list-style-type: none"> 81% of all measurements were transmitted 		Hospitalized for HF: 17% in Group 1, 18% in Group 2, 18% in Group 3, 18% in SC group, p-value NA	

Dar et al. (2009) UK	<ul style="list-style-type: none"> n=182 Recently hospitalized for HF NYHA class II-IV Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of W, BP, HR, S, oxygen saturation 	<ul style="list-style-type: none"> Nurse reviewed data daily If data exceeded the target values, an alert was triggered and the HF nurse called to provide advice for self-management 	<ul style="list-style-type: none"> Multidisciplinary care team Telephone support available 	<ul style="list-style-type: none"> 66% male Mean age 72 years 61% had LVEF < 40% 	<ul style="list-style-type: none"> 95% of participants used the system daily for >90 % of time 	<ul style="list-style-type: none"> 15% in TM group vs. 4% in SC group, p-values not reported 	<ul style="list-style-type: none"> Hospitalized for HF: 19% in TM group vs. 11% in SC group, p=0.11 	<ul style="list-style-type: none"> No change in MLHFQ, p=0.6
Chaudhry et al. (2010) US	<ul style="list-style-type: none"> n=1653 Hospitalized for HF within 30 days Duration: 6 months 	<ul style="list-style-type: none"> Interactive voice-response system to assess general health and symptoms of depression monthly Data reviewed daily by site coordinators 	<ul style="list-style-type: none"> Data reviewed on weekdays System-generated reminder calls if the patient did not use the system for 2 consecutive days Clinicians received alerts if data exceeded target values, and took appropriate actions 	<ul style="list-style-type: none"> Educational materials 	<ul style="list-style-type: none"> 58% male Mean age 61 years 57% had NYHA class \geq III 71% had LVEF < 40% 	<ul style="list-style-type: none"> 55% used system on week 26 14% never used the system 21 alerts per patient sent to clinician 21% drop-out rate 	<ul style="list-style-type: none"> 11% TM vs. 11% in SC, p=0.88 	<ul style="list-style-type: none"> Hospitalized for HF: 28% in TM group vs. 27% in SC group, p=0.81 	<ul style="list-style-type: none"> KCCG: 72 in TM group vs. 69 in SC group, p=0.01 (Jayaram et al., 2017)
Koehler et al. (2011) Germany	<ul style="list-style-type: none"> n=710 Hospitalized within 2 years LVEF \leq 35% NYHA II-III OR LVEF \leq 25% Duration: 26 months 	<ul style="list-style-type: none"> Daily TM of W, BP, ECG, HR with personal digital assistant Telemedical center informed patients' local physicians every 3 months 	<ul style="list-style-type: none"> Participants were contacted by the study physician if needed or requested 	<ul style="list-style-type: none"> Treatment in accordance with current guidelines 	<ul style="list-style-type: none"> 81% male Mean age 67 years 50% had NYHA III or IV LVEF 27% 	<ul style="list-style-type: none"> 81% were at least 70% adherent 	<ul style="list-style-type: none"> 8% in TM group vs. 9% in SC group, p=0.87 	<ul style="list-style-type: none"> Hospitalized for HF: 11% in TM group vs. 13% in SC group, p=0.32 	<ul style="list-style-type: none"> SF-36 physical functioning: 54 in TM group vs. 52 in SC group, p=0.30

Seto et al. (2012) Canada	<ul style="list-style-type: none"> n=100 LVEF < 40% Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of W, BP, S and weekly ECG Secure website to view data 	<ul style="list-style-type: none"> Instructions were sent to participants on what to do after taking each measurement Reminder calls if data not recorded If data exceeded target values or patient reported symptoms, alerts were emailed to the cardiologist 	<ul style="list-style-type: none"> Clinic visits 1 in 2 weeks – 1 in 6 months 	<ul style="list-style-type: none"> 79% male Mean age 54 years 46% had NYHA \geq III LVEF 27% 	66% were 80% adherent	3 died in TM group vs. no deaths in SC group, p-value not reported	0.5 admissions per patient in TM group vs. 0.3 admissions per patients in SC group, p=0.1	MLHFQ: 41.4 in TM group vs. 47.3 in SC group, p=0.05
Dendale et al. (2012) Belgium	<ul style="list-style-type: none"> n=160 Hospitalized for fluid overload Diuretic treatment Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of W, BP, HR Intense collaboration between HF clinic and GP Scheduled follow-up at 3 and 6 months GPs were asked to enter the medication changes into online website 	<ul style="list-style-type: none"> Email alerts were sent to the GP and HF clinic when target values were exceeded GP contacted patients + a follow-up call from the HF nurse 	<ul style="list-style-type: none"> Education for patients and their relatives Follow-up by GPs 	<ul style="list-style-type: none"> 65% males Mean age 76 years NYHA (mean) 3 LVEF 35% 	<ul style="list-style-type: none"> 83% 76% of the GP's logged into the website at least once 	5% in TM group vs. 18% in SC group, p=0.01	HF admissions per patient: 0.24 in TM group vs. 0.42 in SC group, p=0.056	

<p>Lyngå et al. (2012) Sweden</p>	<ul style="list-style-type: none"> n=344 Hospitalized for HF within 8 weeks NYHA III-IV Treatment with diuretics LVEF < 50% Duration: 12 months 	<ul style="list-style-type: none"> Daily TM of W with an electronic scale 	<ul style="list-style-type: none"> Alarm is generated if weight gain of > 2kg or upward trend Data were reviewed by the nurse within 4 days In case of weight gain, patients were contacted If data were not transmitted, patients were contacted after 4 days 	<ul style="list-style-type: none"> Recommended for daily weight monitoring Instructed to contact the HF clinic in case of weight gain 	<ul style="list-style-type: none"> 75% males Mean age 73 years 57% LVEF < 30% 	<p>75%</p>	<p>3.0% in TM group vs. 5.2% in SC group, p=0.32</p>	<p>Hospitalized for any cause: 48% in TM group vs. 55% in SC group, p=0.24</p>	
<p>Villani et al. (2014) Italy</p>	<ul style="list-style-type: none"> n=80 NYHA ≥ III LVEF < 40% Hospitalized for HF Duration: 12 months 	<ul style="list-style-type: none"> Daily TM of W, BP, HR, compliance with medication + weekly ECG + psychological assessment monthly GPs not involved The cardiologist could modify treatment 	<ul style="list-style-type: none"> The nurse checked data daily A toll-free number available on weekdays 	<ul style="list-style-type: none"> Follow-up every three months at HF clinic HF education 	<ul style="list-style-type: none"> 73% males Mean age 72 years NYHA class (mean) 3 LVEF 32% 		<p>13% in TM vs. 23% in SC group, p > 0.05 (exact p-value not reported)</p>	<p>Hospitalized for HF: 30% in TM group vs. 58% in SC group, p < 0.03</p>	<p>PGWBI: 68.3 in TM group vs. 56.2 in SC group, p < 0.01</p>

<p>Bekelman et al. (2015) US</p>	<ul style="list-style-type: none"> n=392 KCCQ < 60 Duration: 12 months 	<ul style="list-style-type: none"> Daily TM of W, BP, HR, S + mood and behavior for individuals with depression Depression intervention for depressed individuals 	<ul style="list-style-type: none"> Collaborative care team reviewed data weekly and recommended care changes that were approved by the primary care physician Nurse reviewed high or medium risk patients and took actions if needed Medication reminders 	<ul style="list-style-type: none"> Scales provided Primary care physicians were notified of depressive symptoms 	<ul style="list-style-type: none"> 97% male Mean age 68 years 38% had LVEF < 40% 		<p>4.3% in TM group vs. 9.6% in SC group, p=0.04</p>	<p>Hospitalized for any cause: 29.4% in TM group vs. 29.9% in SC group, p=0.87</p>	<p>KCCQ: 54.2 in TM vs. 54.6 in SC, p=0.97</p>
<p>Ong et al. (2016) US</p>	<ul style="list-style-type: none"> n=1437 Hospitalized for HF 50 years or older Receiving active treatment Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of W, BP, HR, S Telephone health coaching weekly at month 1, then once per month Discharge education 	<ul style="list-style-type: none"> If data exceeded threshold, health coaches contacted the participants The nurse called participants who were not transmitting data Pre-discharge education for self-care 	<ul style="list-style-type: none"> Robust discharge education A follow-up call 	<ul style="list-style-type: none"> 54% male Mean age 73 years 61% had NYHA III or IV LVEF 43% 	<ul style="list-style-type: none"> 52% for TM 68% for health coaching calls 	<p>14% in TM group vs. 15.8% SC group, p=0.34</p>	<p>Hospitalized for any cause: 51% in TM group vs. 49% of SC group p=0.42</p>	<p>MLHFQ: 28.5 in TM group vs. 32.6 SC group p=0.02</p>

<p>Kotooka et al. (2018) Japan</p>	<ul style="list-style-type: none"> n=183 NYHA II–III Hospitalized for HF within 30 days Duration: 15 months 	<ul style="list-style-type: none"> Daily TM of W, BP, HR, body composition 	<ul style="list-style-type: none"> Telecentre nurses reviewed data If data exceeded the predefined thresholds, the nurse notified patient's physician 	<ul style="list-style-type: none"> Discharge education 	<ul style="list-style-type: none"> 59% male Mean age 66 years NYHA III 22% LVEF 40% 	<p>Adherence at 12 months 91%</p>	<p>11% in TM group vs. 14% in SC group, p=0.614</p>	<p>Hospitalized for HF: 21% in TM group vs. 22% in SC group, p=0.983</p>	<p>MLHFQ: 18.5 in TM group vs. 20.4 in SC group, p=0.943</p>
<p>Oliveri et al. (2018) Italy</p>	<ul style="list-style-type: none"> n=299 Hospitalized within 3 months > 65 years Duration: 23 months 	<ul style="list-style-type: none"> TM of HR, BP, W, ECG and pulse oximetry 5 days/week A wearable wrist clinic device + digital weight scale 	<ul style="list-style-type: none"> Data processed automatically to detect alarm values. Clinicians were informed and reviewed the data and took appropriate actions. 	<ul style="list-style-type: none"> Routine outpatients visits after the first month from discharge Subsequent visits after 3–12 months. Telecare service for detecting home emergencies 	<ul style="list-style-type: none"> 63% male Mean age 80 years NYHA ≥III 52% LVEF 39% 	<ul style="list-style-type: none"> 83% used TM 58 403 alarms were managed by the regional center 	<ul style="list-style-type: none"> 24% in the TM group vs. 22% in the SC group, p=0.097 	<p>Hospitalized for HF: 35% in the TM group vs. 39% in the SC group, p=0.48</p>	<p>SF-36: PCS was 2.6 points higher in the TM group, p<0.001 MCS was 1.7 points higher in the TM group, p=0.04</p>

BP=blood pressure, ECG=electrocardiograph, GP=general practitioner, HR=heart rate, KCCQ=Kansas City Cardiomyopathy Questionnaire, LVEF= left ventricular ejection fraction, MLHFQ=Minnesota Living with Heart Failure Questionnaire, MCS= Mental component score in SF-36, NYHA, New York Heart Association classification, PCS= Physical component score in SF-36, PGWBI= Perception of General Well-Being Inventory, S=symptoms, SC=standard care, TM=telemonitoring, W=Weight

^a The study did not report p-values for comparison of the telemonitoring arm with the standard care arm. However, it was shown that patients in the standard care arm had higher mortality than patients assigned to receive telemonitoring or nurse telephone support, p=0.032

4.2 Telemonitoring interventions in individuals with type 2 diabetes

In individuals with T2D, TM interventions have typically involved self-monitoring of blood glucose (SMBG) and lifestyle related behaviors such as weight, diet and physical activity. The promise of TM interventions lies in increasing awareness of the effect that lifestyle behaviors have on blood glucose, thus further encouraging patients to make behavioral changes to control the risk factors. In addition, TM has potential to increase purposeful exploitation of SMBG data. SMBG provides detailed information about blood glucose variation, including events of hypoglycemia and hyperglycemia, especially when monitored in a structured manner at regular times and frequencies. With the TM technology healthcare providers can use the data obtained to inform decisions regarding the adjustment of insulin dosage, use of other drugs, or lifestyle behaviors that may need to be modified, such as meals and physical activity, to achieve better glycemic outcomes (American Diabetes Association, 2018a; Farmer et al., 2012).

TM interventions in diabetes patients have been summarized in three reviews, all covering studies published before 2010 (Health Quality Ontario, 2009; Paré et al., 2010; Polisen et al., 2009). The first two reviews covered individuals with both type 1 diabetes and T2D, and the latter T2D only. The reviews concluded that TM resulted in a small to moderate reduction in HbA_{1c} varying from 0.2 to 0.5 percentage points. A more recent review by Greenwood et al. summarized telehealth interventions with a specific focus on the elements of structured SMBG. The review concluded that telehealth interventions that incorporated at least five elements of structured SMBG improved glycemic control more in individuals with T2D (Greenwood et al., 2014).

Table 2 summarizes 15 RCTs that investigated TM interventions in individuals with T2D published after 2008. TM interventions and feedback components provided in response to TM data are summarized. The effectiveness of the TM interventions is presented by including the following outcomes: HbA_{1c}, body weight, blood pressure, cholesterol, and HRQoL.

TM studies in individuals with T2D mainly used HbA_{1c} for inclusion by recruiting participants if their HbA_{1c} was above a certain threshold. The threshold values varied from 6.5% to 9% across studies. Patients were frequently included regardless of poor glycemic control; only four studies excluded participants if their HbA_{1c} was above a certain threshold, typically > 10.0% or > 11.0%, whereas other studies did not define the upper thresholds for HbA_{1c}. Most TM studies did not distinguish between insulin-requiring and non-insulin requiring individuals, with participants recruited regardless of their medication regimen.

Participants were typically 50–60 years old with a BMI above 30 kg/m², with the exception of studies conducted in Japan and South Korea where participants' BMI was above 25 kg/m². The baseline levels of HbA_{1c} varied from 7% to 9%. The proportion of participants who were using insulin was between 9–53%, if reported. Information on insulin use was available only in nine studies. The duration of the studies varied from 6 to 12 months, and the sample sizes were typically between 100 to 300 participants. The

largest study was conducted by Tang et al. in the US in 2013 with 415 participants who were followed for 12 months (Tang et al., 2013).

All interventions involved TM of blood glucose. Blood glucose was typically measured daily or several times a week. However, six studies did not specify the monitoring frequency or the intensity was subject to the individual care plans (Dario et al., 2017; Holmen et al., 2014; Lindberg, Torbjørnsen, Söderberg, & Ribu, 2017; Quinn et al., 2011; Tang et al., 2013; Wakefield et al., 2011). In four studies, structured SMBG was applied indicating that participants were instructed to measure their pre- and postprandial glucose levels at certain times a day, such as in the morning and/or at bedtime (Crowley et al., 2016; Greenwood, Blozis, Young, Nesbitt, & Quinn, 2015; Lim et al., 2011; Wild et al., 2016). In seven studies, participants were advised to monitor and report their blood pressure and/or weight in conjunction with blood glucose (Lindberg et al., 2017; Nicolucci, Cercone, Chiriatti, Muscas, & Gensini, 2015; Stone et al., 2010; Tang et al., 2013; Wakefield et al., 2011; Waki et al., 2014; Wild et al., 2016). Other TM parameters used in the studies included physical activity, insulin dose, and diet-related parameters.

The TM data were reviewed regularly, typically on a weekly basis by the healthcare providers. In five studies, regular times for the data review were not described, or automatic alerts were used to notify if the recordings exceeded the pre-defined thresholds (Bujnowska-Fedak, Puchała, & Steciwko, 2011; Dario et al., 2017; Holmen et al., 2014; Lim et al., 2011; Waki et al., 2014). In seven studies medication adjustments were done on the basis of SMBG data (Crowley et al., 2016; Greenwood et al., 2015; Jeong et al., 2018; Lim et al., 2011; Stone et al., 2010; Tang et al., 2013; Wild et al., 2016). In a study by Lim et al. (2011) participants were taught how to interpret their glucose data and they received recommendations for adjusting their medication doses themselves. In the other studies, the SMBG data were reviewed by the healthcare providers who further made changes to the medications if needed. In six studies the responsible care providers were informed about medication changes and/or the TM data were shared with them (Bujnowska-Fedak et al., 2011; Greenwood et al., 2015; Jeong et al., 2018; Nicolucci et al., 2015; Stone et al., 2010; Tang et al., 2013).

In almost all TM interventions, participants received feedback in response to their TM measurements. Typically, the healthcare providers were involved in providing feedback. In ten studies, the feedback and/or recommendations were tailored to patients' TM data (Bujnowska-Fedak et al., 2011; Greenwood et al., 2015; Lim et al., 2011; Lindberg et al., 2017; Nicolucci et al., 2015; Quinn et al., 2011; Stone et al., 2010; Tang et al., 2013; Waki et al., 2014; Wild et al., 2016), whereas in another two studies participants received counselling that did not specifically exploit the TM data (Crowley et al., 2016; Holmen et al., 2014). In one study participants did not receive any feedback but clinicians were contacted if the TM data exceeded the thresholds, and they took appropriate actions (Dario et al., 2017). Automatic feedback messages were used in nine studies (Bujnowska-Fedak et al., 2011; Greenwood et al., 2015; Holmen et al., 2014; Jeong et al., 2018; Lim et al., 2011; Quinn

et al., 2011; Tang et al., 2013; Wakefield et al., 2011; Waki et al., 2014), and two of these studies relied on automatic feedback messages solely (Bujnowska-Fedak et al., 2011; Lim et al., 2011).

The automatic feedback messages were typically information-oriented messages summarizing the TM data. In four studies participants were provided with more enhanced feedback. In a study by Quinn et al. participants received real-time educational, behavioral and motivational messages specific to their submitted data (Quinn et al., 2011). Tang et al. provided diabetes status collating reports that included all important elements for self-managing T2D based on TM data (Tang et al., 2013). In the study by Lim et al. (2011) feedback was generated by combining information from TM data, electronic health records, and diet and exercise records. A feedback loop was implemented in the study of Greenwood et al. where participants were taught how to interpret their blood glucose data and received a computer-assisted pattern analysis of their glucose data (Greenwood et al., 2015). However, in that study the feedback was not provided in real time, whereas in the other former three studies the participants received feedback messages immediately after each data submission.

Adherence to TM varied typically between 60–80% in studies that reported TM adherence. Two studies showed lower adherence rates with approximately 40% of participants being adherent to the TM plans (Holmen et al., 2014; Jeong et al., 2018). Five studies did not report adherence-related measures at all (Dario et al., 2017; Greenwood et al., 2015; Lindberg et al., 2017; Quinn et al., 2011; Wild et al., 2016). In some studies the TM frequency was not determined, and thus adherence to TM intervention was not possible to measure (Dario et al., 2017; Holmen et al., 2014; Lindberg et al., 2017; Quinn et al., 2011; Tang et al., 2013). Moreover, some studies reported usage-related measures rather than adherence (Bujnowska-Fedak et al., 2011; Crowley et al., 2016; Holmen et al., 2014; Nicolucci et al., 2015). Definitions of adherence also varied considerably across studies. For example, Tang et al. reported the percentage of participants uploading glucose data, whereas Jeong et al. reported the percentage of participants who were 90% adherent to weekly TM of blood glucose and weight (Jeong et al., 2018; Tang et al., 2013). Interestingly, in one study 41% of participants were unable to use the system alone (Bujnowska-Fedak et al., 2011). The heterogeneous definitions of adherence and the high rate of missing adherence measures thus make it difficult to compare patients exposure to the TM interventions across studies.

The results of the studies reviewed indicate that TM interventions improve glyemic control in individuals with T2D. In eight studies, HbA_{1c} levels were statistically significantly lower in the TM arm with reductions varying from 0.4 to 0.6 percentage points (Crowley et al., 2016; Greenwood et al., 2015; Lim et al., 2011; Nicolucci et al., 2015; Quinn et al., 2011; Stone et al., 2010; Waki et al., 2014; Wild et al., 2016). The magnitude is similar, or somewhat higher, to those reported in the systematic reviews (Health Quality Ontario, 2009; Paré et al., 2010; Polisena et al., 2009).

Evidence of TM interventions improving HRQoL is weaker; HRQoL was investigated in six studies, of which two showed small but statistically significant improvement (Dario et al., 2017; Nicolucci et al., 2015). Other clinical outcomes were not as frequently improved in the TM studies; three studies showed decreased blood pressure levels in the TM arm (Crowley et al., 2016; Wakefield et al., 2011; Wild et al., 2016), and one study showed a significant reduction in weight (Lim et al., 2011). All of these results except one (Wakefield et al., 2011) were found in conjunction with reductions in HbA_{1c}.

Of the six TM interventions that did not improve glycemic control, in two studies participants did not receive feedback on their TM data at all, and the patients were contacted rarely or only if data was above the pre-defined thresholds (Dario et al., 2017; Lindberg et al., 2017). In the other four studies, participants received brief information-oriented feedback consisting of a numerical and/or graphical summary of the TM data (Bujnowska-Fedak et al., 2011; Holmen et al., 2014; Jeong et al., 2018; Wakefield et al., 2011). These findings indicate that a lack of support and feedback or provision of solely information-oriented feedback may be associated with failure to improve glycemic control in TM studies.

Providing feedback that contains tailored advice and recommendations for the patient might contribute to positive health outcomes in TM interventions in patients with T₂D. Studies that included educational components and/or lifestyle advice showed significant improvements in glycemic control (Greenwood et al., 2014; Lim et al., 2011; Quinn et al., 2011; Waki et al., 2014). However, in the study by Tang et al. (2013) where participants received tailored diabetes status reports, regular advice from study personnel, educational tips, and intensified medication management, the TM group did not show improvements in any of the clinical outcomes except LDL cholesterol. One relevant component missing in that study was structured SMBG; the TM frequency for blood glucose or for any other health parameters used in the study was not determined. Consequently, the researchers did not report adherence to the TM intervention but described that 88% of the participants uploaded blood glucose data. All interventions (except Tang et al. and Jeong et al.) that included medication adjustment based on the TM data showed improved glycemic control (Crowley et al., 2016; Greenwood et al., 2015; Lim et al., 2011; Shea et al., 2009; Stone et al., 2010; Wild et al., 2016).

It seems that patients' clinical characteristics were not associated with study outcomes. Wild et al. conducted a subgroup analysis and showed that age, sex, socio-economic status, BMI, baseline HbA_{1c}, and baseline blood pressure did not modify the change in HbA_{1c} in their intervention (Wild et al., 2016). The study by Crowley et al., which showed the biggest reduction in HbA_{1c} of 1 percentage point (and reduced blood pressure levels) included insulin-requiring individuals only and the baseline level for HbA_{1c} was 10.5% (Crowley et al., 2016). These results suggest that TM might be most beneficial for those whose blood glucose levels are poorly managed and use insulin. However, in contrast, Bujnowska-Fedak et al. reported that glycemic control improved only among non-insulin-requiring T₂D

individuals (Bujnowska-Fedak et al., 2011). Regarding the baseline level of HbA_{1c}, the studies included in this review showed no correlation between the baseline HbA_{1c} and study outcomes. However, a recent review recommended that telehealth interventions for T₂D patients should recruit individuals whose HbA_{1c} \geq 7,5% (Greenwood et al., 2014), and a similar recommendation was earlier made regarding SMBG for non-insulin treated T₂D patients (Klonoff et al., 2011).

Table 2. Telemonitoring interventions, adherence to them, and their effects on HbA1c, body weight, blood pressure, cholesterol and health-related quality of life in individuals with type 2 diabetes assessed in randomized controlled trials

Reference and country	Number of participants, inclusion criteria and duration	Content of telemonitoring intervention	Feedback on telemonitoring	Standard care	Characteristics	Adherence	HbA1c	Blood pressure, body weight, cholesterol	Health-related quality of life
Stone et al. (2010) US	<ul style="list-style-type: none"> n=150 HbA1c \geq 7.5% Taking oral hypoglycemic agents and/or insulin Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of BG, BP and W 	<ul style="list-style-type: none"> Nurse reviewed data on weekdays and made medication changes together with endocrinologist based on data Primary care providers were informed retrospectively about the medication changes Timely telephone follow-up with self-management education if BG or BP were unacceptably high or low Monthly self-management counselling based on the TM data 	<ul style="list-style-type: none"> Monthly calls for education and self-management review 	<ul style="list-style-type: none"> 90% male 33% were \geq 66 years HbA1c 9.5%, Mean weight 103 kg 53% insulin-requiring 	<ul style="list-style-type: none"> 11% never submitted data 75% performed SMBG daily 	<p>7.9% in TM group vs. 8.6% in SC group, p<0.001</p>	<ul style="list-style-type: none"> Systolic BP (mmHg): 132 in TM group vs. 133 in SC group, p=0.79 Diastolic BP (mmHg): 72 in TM group vs. 76 in SC group, p=0.13. Weight (kg): 95 in TM group vs. 101 in SC group, p=0.49 LDL cholesterol (mg/dL): 82 in TM group vs. 91 in SC group, p=0.10 	

Wakefield et al. (2011) US	<ul style="list-style-type: none"> n=302 Coexisting T2D and hypertension Duration: 12 months 	<ul style="list-style-type: none"> Group 1: TM of BG as directed by physician, daily BP, and a large set of questions + automatic education component Group 2: TM of BG as directed by physician, daily BP, a small set of questions + automatic education component Intervention lasted for the first 6 months 	<ul style="list-style-type: none"> Automatic feedback on the set of questions Nurse reviewed data on weekdays and contacted if needed Nurse had access to electronic health records 	<ul style="list-style-type: none"> Follow-up appointments as usual 	<ul style="list-style-type: none"> 98% male 68 years BMI 33.3 kg/m² HbA1c 7.1% Insulin-requiring NA 	<ul style="list-style-type: none"> Group 1: Data entered on 69% of days Group 2: Data entered on 70% of days 	<ul style="list-style-type: none"> Change in HbA1c: -0.19 in Group 1 vs. -0.17% in Group 2 vs. -0.33% in SC group, p=0.665 	<p>Change in systolic BP (mmHg): -4.9 in Group 1 vs. 0.8 in Group 2 vs. 3.3 in SC group, p=0.02</p>	<ul style="list-style-type: none"> 3.7 in TM group vs. 3.4 in SC group, p-value not statistically significant. HRQoL questionnaire designed for the study.
(Bujnowska-Fedak et al., 2011) Poland	<ul style="list-style-type: none"> n=100 18-75 years old Insulin and noninsulin requiring T2D patients Duration: 6 months 	<ul style="list-style-type: none"> Weekly TM of BG and insulin dose TM of specific events such as PA, food intake, stress. Intensity not specified Data shared with GPs 	<ul style="list-style-type: none"> Numerical summary and longitudinal trends sent to patients If data exceeded predefined thresholds, audio video alarm was triggered at the clinic and a text-message sent to the patient's GP 	<ul style="list-style-type: none"> Scheduled visits every 2 months Participants encouraged towards SMBG 	<ul style="list-style-type: none"> 54% male 65 years BMI 25.8 kg/m² HbA1c 7.6% 50% insulin-requiring 	<ul style="list-style-type: none"> 41% were unable to use the system 1.6 transmissions per patient per week 	<ul style="list-style-type: none"> 7.4% in TM group vs. 7.4% in SC group, p=0.720 <p>Among noninsulin requiring individuals: 6.7% in TM group vs. 7.2% in SC, p=0.02</p>	<ul style="list-style-type: none"> Systolic (mmHg): 127 in TM group vs. 129 in SC, p=0.320 Diastolic (mmHg): 81 in TM group vs. 82 in SC group, p=0.320 BMI (kg/m²): 24.8 in TM group vs 26.4 in SC group, p=0.380 Total cholesterol (mg/dL): 192 in TM group vs. 208 in SC group, p=0.31 	<ul style="list-style-type: none"> 3.7 in TM group vs. 3.4 in SC group, p-value not statistically significant. HRQoL questionnaire designed for the study.

<p>Quinn et al. (2011) US</p>	<ul style="list-style-type: none"> n=163 HbA1c \geq 7.5% Duration: 12 months 	<ul style="list-style-type: none"> TM of BG, CI, M Web-portal for secure messaging, PHR, learning library, logbook Communication preferably via portal Action plan every 2.5 months Providers received ADA guidelines, a quarterly report, and had access to view the data TM frequency not determined 	<ul style="list-style-type: none"> Diabetes educators intermittently reviewed data Automatic, real-time educational, behavioral and motivational messages specific to entered data sent to the patients Messages from diabetes educators concerning longitudinal trends and education 	<ul style="list-style-type: none"> Treatment according to ADA guidelines 	<ul style="list-style-type: none"> 50% male 63 years HbA1c 9.4% 76% had BMI \geq 30 kg/m² Insulin-requiring NA 	<p>7.9% in TM group vs. 8.5% in SC group, p <0.001</p>	<ul style="list-style-type: none"> Systolic (mmHg): 128 in TM group vs. 133 in SC group, p>0.05 Diastolic (mmHg): 78 in TM group vs. 79 in SC group, p>0.05 LDL-cholesterol (mg/dL): 102 in TM group vs. 91 in SC, p>0.05 	<p>PHQ-9: 4.8 in TM group vs. 3.6 in SC, p>0.05</p>
<p>Lim et al. (2011) South Korea</p>	<ul style="list-style-type: none"> n=144 \geq 60 years HbA1c 6.5–10.5% Duration 6 months 	<ul style="list-style-type: none"> Group 1: TM of BG 8 times per week (\geq 3 at fasting, \geq 3 postprandial, \geq 2 bedtimes) Group 2: as Group 1 + information on diet and exercise collected + automatic messages from rule engine server 	<ul style="list-style-type: none"> Group 2: Automatic real-time guideline- based feedback including lifestyle changes and medication adjustment recommendations on TM data combined with electronic health records and diet+ exercise information Weekly reminders to boost adherence 	<ul style="list-style-type: none"> Education session Visit to outpatient clinic every 3 months 	<ul style="list-style-type: none"> 42% male 67 years BMI 25kg/m² HbA1c 7.9% 28% were insulin users 	<p>Group 1: 69% reaching target frequency \geq times per week Group 2: 81% reaching target frequency \geq times per week</p>	<p>Group 2 had significantly lower HbA1c at 6 months (p < 0.05)</p>	<ul style="list-style-type: none"> BMI (kg/m²): 25.0 in Group 1 vs. 24.4 in Group 2 vs. 25.5 in SC, p=0.005 LDL cholesterol (mg/dL): 101 in Group 1 vs. 115 in Group 2 vs. 93 in SC, p=0.099

<p>Tang et al. (2013) US</p>	<ul style="list-style-type: none"> n=415 HbA1c \geq 7.5% Duration: 12 months 	<ul style="list-style-type: none"> TM of BG Possibility to log diet, PA, BP, insulin dose, W online Online messaging with healthcare team Primary care physicians were kept up to date TM frequency not determined 	<ul style="list-style-type: none"> Graphical feedback on glucose measurements Diabetes status report collating all important elements to manage T2D Regular in-person advice Medication adjustment Educational tips in response to the recorded data 	<p>Annual check-ups + laboratory tests for screening</p>	<ul style="list-style-type: none"> 60% male 54 years HbA1c 9.2% Weight 98kg Insulin-requiring NA 	<p>88% uploaded glucose data</p>	<p>8.1% in TM group vs. 8.3% in SC group, p=0.133</p>	<ul style="list-style-type: none"> Weight (kg): 99.2 in TM group vs. 97.8 in SC group, p=0.232 Systolic (mmHg): 120 in TM group vs. 121 in SC group, p=0.306 Diastolic (mmHg): 72 in TM group vs. 73 in SC group, p=0.374 LDL (mg/dL): 89 vs. 98, p=0.001
<p>Waki et al. (2014) Japan</p>	<ul style="list-style-type: none"> n=54 Able to exercise Duration: 3 months 	<ul style="list-style-type: none"> TM of BG, BP, W, PA twice a day TM of meals and exercise using voice input + photos of meals 	<ul style="list-style-type: none"> Immediate feedback in relation to pre-defined thresholds Reminders sent to personnel if data were not recorded If data exceeded predefined thresholds, study physician was informed Lifestyle advice based on food and exercise data 	<p>Self-management regimen without any device</p>	<ul style="list-style-type: none"> 66% male 57 years HbA1c 7.4% BMI 26.7 kg/m² Insulin requiring NA 	<p>Adherence to morning glucose in the first 2 weeks 84%</p> <p>Adherence to morning glucose in the last 2 weeks 71%</p>	<p>6.7% in TM group vs. 7.1% in SC group, p=0.015</p>	<ul style="list-style-type: none"> Systolic BP (mmHg): 130 in TM group vs. 122 in SC group, p=0.40 Diastolic BP (mmHg): 76 in TM vs. 71 in SC, p=0.35 BMI (kg/m²): 25.9 in TM group vs. 27.1 in SC group, p=0.062 LDL (mg/dL) 114 in TM group vs. 105 in SC group, p=0.43

<p>Holmen et al. (2014) Norway</p>	<ul style="list-style-type: none"> n=151 HbA1C \geq 7.1% Duration: 12 months 	<ul style="list-style-type: none"> Group 1: TM of BG, PA, food intake + personal goals Group 2: as Group 1 + monthly theory-based health counselling for the first 4 months TM frequency not determined 	<ul style="list-style-type: none"> Feedback through graphs, symbols and color codes Data visualization + trend reports 	<ul style="list-style-type: none"> Annual visit to GP Laboratory test SMBG recommended 	<ul style="list-style-type: none"> 59% male 57 years HbA1c 8.2% BMI 31.7 kg/m² Insulin-requiring NA 	<ul style="list-style-type: none"> 39% (Group 1) and 35% (Group 2) performed \geq 5 BG measurement monthly and had \geq 50 interactions with mobile diary All participants (group 2) attended \geq 4 health counselling sessions 	<p>7.8% in Group 1 vs. 8.0% in Group 2 vs. 8.2% in SC group. P=0.42 for Group 1 vs. SC. P=0.97 for Group 2 vs. SC p=0.97</p>	<p>Weight (kg): 95 in Group 1 vs. 89 in Group 2 vs. 93 in SC group, p-values NA</p>	<p>No statistically significant differences in SF-36 (data not shown)</p>
<p>Greenwood et al. (2015) US</p>	<ul style="list-style-type: none"> n=90 Not using insulin HbA1c 7.5–10.9% Participant in the diabetes management program Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of paired BG for 3 months Daily educational health sessions as a text document or slides Calls at 4, 8, 12, weeks shared decision making. Behavior change action plan Participants taught to analyze paired glucose data Active intervention ended at 3 months 	<ul style="list-style-type: none"> A complete feedback loop Computer-assisted pattern analyses shared with participants CDE reviewed data on weekdays and called patient if data indicated concern Medication changes recommended for primary care providers 	<ul style="list-style-type: none"> Diabetes management program 	<ul style="list-style-type: none"> 54% male 58 years BMI 34.1 kg/m² HbA1c 8.3% Insulin-requiring 0% 	<p>Change in HbA1c (%): -1.1% in TM group vs. -0.7% in SC group, p=0.005</p>			

<p>Nicolucci et al. (2015) Italy</p>	<ul style="list-style-type: none"> n=302 HbA1c 7.5%–10% BP > 130/80 mmHg Exclusion criteria: Diabetes treated only with lifestyle intervention, or with monotherapy with metformin Duration: 12 months 	<ul style="list-style-type: none"> Daily TM of W, BG, BP Participants sent the data to the telehealth center twice a month Data available for GP Feedback to the GP GP responsible for medication changes 	<ul style="list-style-type: none"> Research nurses called once per month to discuss data and provide support for self-management: <ul style="list-style-type: none"> Educational support Participants can access online system that generates numerical and graphical summaries of TM data Reminders, notifications and warning messages for patient and/or physician if agreed at baseline 	<p>No information</p>	<ul style="list-style-type: none"> 61% males 58 years HbA1c 7.9% Insulin-requiring 8.6% 	<p>2.2 contacts per patient-month</p>	<p>7.4% in TM group vs. 7.8% in SC group, p = 0.001</p>	<ul style="list-style-type: none"> Systolic BP (mmHg): 136 in TM group vs. 136 in SC group, p=0.58 Diastolic BP (mmHg): 80 in TM group vs. 79 in SC group, p=0.62 Weight (kg): 82 in TM group vs. 81 in SC group, p=0.66 Total cholesterol (mg/dL): 184 in TM group vs. 170 in SC group, p=0.94 	<p>SF-36 PCS: 47 in TM group vs. 45 in SC group, p=0.66</p> <p>SF-36 MCS: 50 in TM group vs. 47 in SC group, p=0.03</p>
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<p>Crowley et al. (2016) US</p>	<ul style="list-style-type: none"> n=50 HbA1c > 9% Insulin-requiring Duration: 6 months 	<ul style="list-style-type: none"> Daily TM of BG before meals and bedtime Meeting with psychiatrist if depressive symptoms 	<ul style="list-style-type: none"> Reminder calls if data not submitted for 3 days Nurse called at 2-week intervals to review data and medications, and to provide self-management support (not tailored) At 2-week intervals physicians received a summary report on TM data and medications and made further adjustments if needed. Recommendations were delivered to the patients by the nurses. 	<p>No information</p>	<ul style="list-style-type: none"> 96% male 60 years HbA1c 10.5% Insulin-requiring 100% 	<p>8.7/12 telephone calls completed</p>	<p>9.2% in TM group vs. 10.2% in SC group, p=0.05</p>	<p>Systolic BP (mmHg): 122 in TM group vs. 130 in SC group, p=0.035 Diastolic BP (mmHg): 68 in TM group vs. 73 in SC group, p=0.013</p>	
<p>Wild et al. (2016) UK</p>	<ul style="list-style-type: none"> n=231 HbA1c > 7.5% Duration: 9 months 	<ul style="list-style-type: none"> TM of pre- and postprandial BG twice weekly, and BP and W weekly Advice for lifestyle modification 	<ul style="list-style-type: none"> Primary care nurse checked data weekly and adjusted medication or reinforced lifestyle if needed 	<p>Annual check-ups, or more frequently if needed</p>	<ul style="list-style-type: none"> 67% male 61 years BMI 32.9 kg/m² HbA1c 8.8% Insulin-requiring 16% 		<p>7.9% in TM group vs. 8.4% in SC group, p=0.007</p>	<ul style="list-style-type: none"> Systolic BP (mmHg): 131 in TM group vs. 134 in SC, p=0.017 Diastolic BP (mmHg): 76 in TM group vs. 78 in SC group, p=0.006 Weight (kg): 97 in TM group vs. 92 in SC group, p=0.557 	

Dario et al. (2017) Italy	<ul style="list-style-type: none"> n=299 HbA1c > 7.0% Duration: 12 months 	<ul style="list-style-type: none"> TM of BG TM frequency not determined 	<ul style="list-style-type: none"> If data exceeded pre-defined thresholds, clinicians were informed and they took an appropriate action. Participant's relatives and/or ED were contacted in case of critical values 	<ul style="list-style-type: none"> Paper log book of BG shared with GP 	<ul style="list-style-type: none"> 56% male 73 years HbA1c 7.9 Insulin-requiring 52% 	<ul style="list-style-type: none"> Change in HbA1c (%): -0.2 in TM group vs. -0.25 in SC group, p=0.76 	<ul style="list-style-type: none"> SF-36: PCS: 45 in TM group vs. 43 in SC group, p=0.07 MCS: 48 in TM group vs. 48 in SC group, p <0.001 	
Lindberg et al. (2017) Sweden	<ul style="list-style-type: none"> n=166 HbA1c > 6.5% Duration: 19 months 	<ul style="list-style-type: none"> TM of BG, BP, PA Health counselling Group sessions for TZD self-management at baseline TM frequency not determined 	<ul style="list-style-type: none"> GP/nurse reviewed data every second month, revised care plan and provided feedback via email or video. If data exceeded pre-defined thresholds, a healthcare professional was notified. 	<ul style="list-style-type: none"> Participants were given glucose meters, strips, and lancets SMBG recommended and reported to the diabetes nurse. 	<ul style="list-style-type: none"> 71% male 68 years HbA1c 8.1% BMI=30.7 kg/m² Insulin-requiring NA 	<ul style="list-style-type: none"> 8.0% in TM group vs. 8.2% in SC group, p=0.33 	<ul style="list-style-type: none"> Systolic BP (mmHg): 143 in TM group vs. 144 in SC group Diastolic BP (mmHg): 85 in TM group vs. 82 in SC group Weight (kg): 93 in TM group vs. 89 in SC group Cholesterol (mmol/l) 3.0 in TM group vs. 3.0 in SC group P-values not reported 	<ul style="list-style-type: none"> SF-36 did not differ between the groups (data not shown)

<p>Jeong et al. (2018) South Korea</p> <ul style="list-style-type: none"> n=338 HbA1c 7–11% Duration: 6 months 	<ul style="list-style-type: none"> Group 1: TM of BG (3–6 week) and W + appointment with endocrinologist who made medication changes Group 2: TM of BG (3–6 per week) and W + remote contact with physician who made medication changes 	<p>Group 1: automated short feedback message</p>	<p>Not described</p>	<ul style="list-style-type: none"> 68% male 63 years BMI 25.2 kg/m² HbA1c 8.3% Insulin-requiring 15% 	<ul style="list-style-type: none"> Group 1: 39% were 90% adherent Group 2: 41% were 90% adherent 	<ul style="list-style-type: none"> 7.6% in Group 1 vs. 7.4% in Group 2 vs. 7.7% in SC group. P-value for Group 1 vs. SC is 0.61 P-value for Group 2 vs SC is 0.16 	<ul style="list-style-type: none"> Change in systolic BP (mmHg): -2.1 in Group 1 vs. 0.2 in Group 2 vs. 0.4 in SC group. Change in diastolic BP (mmHg): -0.7 in Group 1 vs. -0.6 in Group 2 vs. -0.03 in SC group. Change in weight (kg): -0.5 in Group 1 vs. -0.5 in Group 2 vs. -0.1 in SC group. Change in cholesterol (mg/dL): -1.5 in group 1 vs. -4.8 in group 1 vs. -0.9 in SC group Differences were not statistically significant
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ADA =American Diabetes Association, BG= blood glucose, BP= blood pressure, CDE = certified diabetes educator, CI=carbohydrate intake, GP=general practitioner, M=meals, PA=physical activity, PHR=personal health records, SC=standard care, TM=telemonitoring, T2D=type 2 diabetes, W=weight

4.3 Telemonitoring interventions in individuals with coronary artery disease

Interventions promoting self-management in individuals with CAD typically involve cardiac rehabilitation programs that focus on structured exercise training. The programs may be center-based or home-based, both of which have been shown to be equally effective (Anderson et al., 2017). However, cardiac rehabilitation programs suffer from low uptake and poor adherence (Kotseva et al., 2016). Recently, telehealth technologies have also been introduced to cardiac rehabilitation to further increase the uptake of the programs and adherence to them while enabling more individualized counselling. These programs have been shown to be at least equally effective with center-based and home-based programs (Rawstorn, Gant, Direito, Beckmann, & Maddison, 2016). Typically the telehealth rehabilitation interventions involve telephone counselling (Rawstorn et al., 2016). To the best knowledge of the author, there are only few studies that have investigated TM interventions in CAD patients, or the interventions have focused on TM of physical activity only. Moreover, such interventions are rarely evaluated in randomized controlled settings.

Frederix et al. (2012) evaluated the effect of a physical activity TM program in a RCT including eighty CAD patients. Participants in the TM arm wore a motion sensor, and each week they received personalized feedback and a renewed step count goal. Patients in the control group wore a modified motion sensor for one week during the first, sixth and 18th week of the study. However, the motion sensors were modified to hide all information from the control patients. After 18 weeks, the TM program demonstrated increased oxygen uptake capacity but no improvements in other cardiovascular risk related outcomes. Re-hospitalization rates also remained unchanged.

In another RCT, individuals with acute coronary syndrome received a TM intervention which consisted of patients monitoring their weight, heart rate and blood pressure weekly, and capillary plasma lipid profile and glucose monthly. A cardiologist reviewed the data and sent recommendations. Patients in the TM group experienced improvement in cardiovascular risk factors and achieved their treatment goals for blood pressure and HbA_{1c} more frequently. In addition, they had significantly lower BMIs. The TM intervention had no effect on smoking cessation or LDL cholesterol (Blasco et al., 2012).

A study by Kraal et al. evaluated a home-based cardiac rehabilitation with TM guidance to improve lifestyle behaviors and long-term health effects (Kraal et al., 2017). Fifty individuals participated in the study and were allocated to the TM and control groups. The intervention group was provided with supervised training sessions and a heart rate monitor and received individual telephone coaching based on the training data. The results showed no differences in adherence, physical fitness, physical activity or HRQoL after 12 weeks between the study arms.

Another RCT by Skobel et al. introduced a smartphone-guided training system that involved TM of breathing rate and an ECG that transmitted information on training intensity, arrhythmias and adherence to the training prescriptions (Skobel et al., 2017).

Based on the data, participants received feedback from a medical team who further adjusted the training sessions. The study included 118 participants and followed them for six months. The intervention faced technical problems; almost 30% of participants in the TM group withdrew from the study, and technical problems prevented a further 38% from participating. For those who completed the study, their exercise capacity improved more.

In addition, one study, which used a pre-post design, evaluated a TM surveillance system involving 25 individuals with CAD to improve adherence to medication and lifestyle recommendations (Ammenwerth et al., 2015). The intervention included education, self-monitoring with goal-setting, feedback, and regular clinical visits. Participants monitored their blood pressure and steps daily, and provided information on their medication intake. In addition, individuals with T2D were provided with glucose meters and obese participants with scales. Based on the data provided, participants received automatic, individualized feedback messages once a week. The results showed high adherence with 77% of daily measurement completed, high self-reported adherence to medication intake, and the pre-defined goals for physical activity were reached.

TM interventions in individuals with CAD typically involve promoting physical activity. Yet, the potential of TM interventions concentrating on risk factor management was demonstrated in the studies by Blasco et al. (2012) and Ammenwerth et al. (2015). Similarly, studies in other patient populations have shown that such interventions have potential to promote weight loss and decrease blood pressure and cholesterol, which are known risk factors for CAD (Lim et al., 2011; Luley et al., 2014; Tanget al., 2013; Wakefield et al., 2011). However, not all CAD patients suffer from such comorbidities, which might be one reason why such TM interventions have not been applied to CAD patients. Therefore, the TM interventions should be tailored according to individual risk profiles.

4.4 Summary of the literature

TM interventions are heterogeneous across chronic conditions and across individual studies of conditions. In HF patients, TM interventions typically involved measuring weight, blood pressure and vital signs, and the TM data were shared with the healthcare professionals who reviewed the data frequently. The emphasis of these interventions was on exploiting the data in clinical work to predict decompensation and further avoid hospitalizations. Although HF studies consistently reported high adherence rates, the majority of the studies did not statistically significantly reduce hospital admissions or mortality in patients with HF. However, TM interventions frequently improved HRQoL. In individuals with T2D, the TM interventions focused on TM of blood glucose and other lifestyle behaviors that are known risk factors of T2D and its complications. These interventions frequently included feedback and instructions for patients provided in response to the TM data to promote self-management, whereas in HF studies patients rarely received feedback on their TM data. In patients with T2D, TM interventions improved glycemic control by reducing

HbA_{1c} by 0.4–0.6 percentage points. Specifically, those interventions that provided versatile feedback to their participants achieved positive outcomes.

TM interventions were heterogeneous and included different components, which makes it difficult to compare them and to identify factors that constitute an effective TM intervention. However, some were found. TM intervention components that were associated with positive health outcomes included providing feedback in response to TM data, providing lifestyle counselling and recommendations, education, monitoring psychological parameters, intense collaboration with the patient's GP, and using TM data to adjust medication in T₂D patients.

TM studies in individuals with CAD were scarce and focused more on telehealth rehabilitation, which typically involved TM of physical activity only.

5 Aims of the Study

The aim of the current study was to assess the effect of TM interventions on health-related outcomes in individuals with type 2 diabetes (T2D), heart failure (HF) and coronary artery disease (CAD). This work adds knowledge on the role of patient decision support provided in response to TM as each of the three TM interventions studied included a differential feedback component linked to TM.

The specific objectives were as follows:

- ♦ to assess whether a TM intervention that combined automatic, real-time, behavioral theory based feedback messages improved glycemic control and reduced blood pressure among individuals with T2D (I, the Mobile Sipoo study),
- ♦ to assess whether a TM intervention that combined automatic, real-time, information-oriented feedback messages reduced HF-related hospitalizations in individuals with HF (II, the Heart at Home study),
- ♦ to assess whether a TM intervention that combined monthly telephone-based health coaching improved HRQoL in individuals with T2D, CAD and HF, and improved glycemic control in individuals with T2D (III, the Renewing Health study),
- ♦ to investigate participants' long-term adherence to the TM interventions as sustained adherence is a prerequisite for achieving the intervention effects (IV).

6 Methods

The objectives of this thesis were addressed with three experimental studies. Three randomized controlled trials were conducted to assess the effectiveness of TM interventions among individuals with T₂D, HF or CAD. The aim of the TM interventions was to promote self-management by encouraging participants to actively self-monitor their disease-specific health parameters and share their self-monitoring data remotely with health care professionals in order to enable care to be tailored to the individual needs of the patient. All three studies were two-arm randomized controlled trials where the comparison groups consisted of individuals receiving standard care. The studies were conducted across Finland; the Mobile Sipoo and Renewing Health studies were conducted at the health care centers of Sipoo and South Karelia, respectively, and the Heart at Home study was conducted at the cardiology outpatient clinic of Helsinki University Central Hospital. The design of each study is described in detail in the following chapters and summarized in Table 3.

Table 3. Summary of study designs, participants, telemonitoring interventions and primary outcomes of the three studies

	Mobile Sipoo (I)	Heart at Home (II)	Renewing Health (III, IV)
Design	2-arm randomized controlled trial	2-arm randomized controlled trial	2-arm randomized controlled trial separately for two disease groups; T2D and heart disease
Setting	Healthcare center	Cardiology outpatient clinic	Healthcare center
Follow-up	10 months	6 months	12 months
Participants	53 patients with T2D	94 patients with HF	250 patients with T2D 42 patients with HF 227 patients with CAD
Intervention	Weekly TM of blood pressure, body weight, steps and blood glucose. Access to online PHR account for reviewing TM data and health related information.	Weekly TM of blood pressure, body weight, heart rate and symptoms.	Weekly TM of blood pressure, body weight, steps and blood glucose. Access to online PHR account for reviewing TM data.
Feedback component	Individualized, behavioral theory-based feedback messages.	Short, information-oriented, feedback messages.	Telephone-based health coaching every 4–6 weeks.
Standard care	Diabetes education at the time of diagnosis, annual check-ups and laboratory tests.	Multidisciplinary care, self-monitoring of signs and symptoms with pen and paper recommended.	Disease management booklet at the time of diagnosis, annual appointment or a phone call and laboratory tests, CAD patients offered group intervention sessions to promote physical activity and self-management.
Primary outcome	HbA1c Systolic and diastolic blood pressure	HF-related hospitalizations	Health-related quality of life (HRQoL) HbA1c in patients with T2D

CAD=coronary artery disease, HbA1c=glycosylated hemoglobin, HF=heart failure, HRQoL=health-related quality of life, PHR=personal health records, TM=telemonitoring, T2D=type 2 diabetes

6.1 Study design

6.1.1 Mobile Sipoo (I)

The Mobile Sipoo study was a two-arm randomized controlled pilot trial designed to test the feasibility of an automatic feedback system, and to assess the clinical effectiveness of a TM intervention that incorporated the feedback system in patients with T2D. The trial was conducted at the healthcare center of Sipoo. The follow-up time was 10 months. The municipality of Sipoo is located in Southern Finland and has 18,000 (in 2010) inhabitants, of whom approximately 30% are Swedish-speaking.

The Mobile Sipoo intervention was designed to be tested separately in two groups: patients with T2D and hypertension. Sample size calculations were done separately for both groups assuming a power of 90% and an alpha level of 0.05. In the T2D group, the TM

intervention was assumed to reduce HbA_{1c} by 1% with a standard deviation of 1%. For hypertensive patients, systolic blood pressure was assumed to decrease by 5 mmHg with a standard deviation of 6.5 mmHg. In total, 120 patients (46+74) needed to be recruited. However, patient recruitment entailed practical challenges. Potential participants were difficult to contact and patients declined to participate for reasons that were not systematically collected. Eventually only one group of patients with T2D were recruited.

Stratified randomization was used to allocate participants to the TM and standard care arms with an allocation ratio of 1:1. Participants were stratified by sex and dichotomized age (< 65 years and ≥ 65 years).

6.1.2 Heart at Home (II)

Heart at Home was a matched-pair randomized trial that took place at the cardiology outpatient clinic of Helsinki University Central Hospital. The clinic examines and treats patients who require demanding cardiological clarifications or treatment. It deals with approximately 600 individuals with cardiological complications, of whom 150–200 require regular follow-up. The study population consisted of HF patients with HFrEF who were followed for six months.

The TM intervention was expected to decrease the number of HF-related hospitalizations by 3 days with a standard deviation of 6. Using a power of 90% and a two-sided α -level of 0.05, 44 participants per treatment arm needed to be recruited.

Eligible patients were matched in pairs according to their sex, age, LVEF and NYHA classification. The study nurse called potential participants, informed them about the study and asked about their initial willingness to participate. Patients who agreed to participate were further randomized by the study nurse assigning one of the pair to the TM group and one of the pair to the standard care group. On a subsequent baseline visit participants were assessed on the remaining inclusion criteria (such as not attending other clinical trials) and eligible participants were recruited for the study.

6.1.3 Renewing Health (III)

The Renewing Health study was a two-arm randomized controlled trial designed to assess the effectiveness of a TM intervention combined with health coaching in two separate disease groups: T2D and heart disease. The study was conducted in the South Karelia Social and Health Care District in Finland, which provides primary and secondary healthcare for approximately 100,000 inhabitants living in the region. The study population consisted of individuals with T2D or a heart disease, with the latter specifically defined as being diagnosed with either HF or ischemic heart disease. Both disease groups were separately recruited, and both had a TM arm and a standard care arm. Potential participants were

screened using electronic health records using their diagnosis codes. Patients recruited with a diagnosis of ischemic heart disease had a CAD. The follow-up time was 12 months.

The TM intervention was expected to improve HRQoL by increasing the SF-36 scores by 3 points (with a standard deviation of 8). With a statistical power of 80%, a two-sided α -level of 0.05, and an allocation ratio of 2:1, 163 TM participants and 61 control participants were required. Predicting a dropout rate of up to 20%, at least 200 intervention participants and 75 control participants needed to be randomized. The numbers were applied to the T2D and heart disease groups separately resulting in 550 participants in total.

Stratified randomization was used to assign patients to the TM and standard care arms with an allocation ratio of 2:1, respectively. Participants were stratified by sex and dichotomized age (< 65 years and \geq 65 years). The allocation sequence was concealed in an opaque and sealed envelope until the baseline visit. The randomization procedure was done separately for the T2D and heart disease groups.

The Finnish Renewing Health study was a part of a large European research project, Renewing Health, including nine regions across Europe to implement and evaluate the effectiveness of telehealth services for treating chronic conditions including diabetes, chronic obstructive pulmonary and cardiovascular diseases. Approximately 7,000 patients were recruited in randomized controlled trials in the nine regions to assess the effect of telehealth interventions (Kidholm et al., 2014).

6.2 Ethical considerations and trial registrations

The Heart at Home and Mobile Sipoo studies were reviewed and approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa. Renewing Health was approved by the Ethics Committee of the Social and Health Care District of South Karelia. All participants provided informed written consent.

Each of the studies is registered at clinicaltrials.gov: Mobile Sipoo NCT01547156, Heart at Home NCT01759368, Renewing Health NCT01310491.

6.3 Participants

The study population consisted of patients with at least one chronic condition. Participants had a diagnosis of either T2D or HF or CAD. Secondary diagnoses were not investigated. The study-specific inclusion and exclusion criteria are presented in Table 4.

Table 4. Inclusion and exclusion criteria of the three studies

	Mobile Sipoo (I)	Heart at Home (II)	Renewing Health (III)
Inclusion criteria	<ul style="list-style-type: none"> • Diagnosis of T2D at least 6 months prior • HbA1c > 6.5% <p>OR</p> <ul style="list-style-type: none"> • Diabetes medication combined with elevated blood pressure (systolic > 130mmHg or diastolic >80 mmHg) • Age 30–70 years 	<ul style="list-style-type: none"> • Systolic heart failure • NYHA class ≥ 2 • LVEF ≤ 35% • Age 18–90 years • Need for regular check-up visits • Time from last visit less than six months 	<ul style="list-style-type: none"> • Diagnosis of T2D at least three months prior AND • HbA1c > 6.5% (test taken within 1 year before screening) <p>OR</p> <ul style="list-style-type: none"> • Diagnosis of ischemic heart disease or heart failure • Age 18 years or older • Being able to walk
Exclusion criteria	<ul style="list-style-type: none"> • Poor technology literacy or reluctant to do self-monitoring • Pregnancy • Life expectancy of less than one year • Major elective surgery planned within six months or having had major surgery within the previous two months • Psychiatric disorder e.g. depression • Alcohol or narcotics misuse • Excluded by the healthcare physician 	<ul style="list-style-type: none"> • Planned major medical operation/surgery • Severe comorbidity such as cancer • Participation in another clinical trial during the last three months • Expected poor compliance due to inability to use technical devices 	<ul style="list-style-type: none"> • Incapable of filling out the questionnaires in Finnish • Incapable of using the remote patient monitoring system devices • Inadequate cognitive capacity to participate

6.4 Telemonitoring interventions and standard care

In all studies, the intervention was aimed at improving management of a chronic condition by introducing TM as a part of patient’s care (Table 3). The TM intervention consisted of making an individual self-management plan in agreement with the patient and the healthcare provider, the patient measuring condition-specific health parameters at home, and reporting the measurements to the healthcare professionals using a mobile phone. The general architecture of the TM interventions is described in Figure 1. Blood pressure and body weight were used as self-monitored health parameters in all studies. Additionally, participants were instructed to monitor their blood glucose, steps, heart rate, health status and/or symptoms. Measuring and reporting of health parameters was done on a weekly basis. Participants received a TM toolbox that included measurement devices and a mobile phone with a pre-installed application for reporting purposes.

In all studies, the TM data were stored on a secure remote monitoring server. Study personnel were able to access the data through a web-based browser. They were instructed to review the data on a regular basis and exploit the data in their work. With the help of the self-monitoring data, the personnel were expected to be able to tailor the care to individual needs and intervene if the measurements indicated a need for an additional appointment. Details of each TM intervention are described in the following sections.

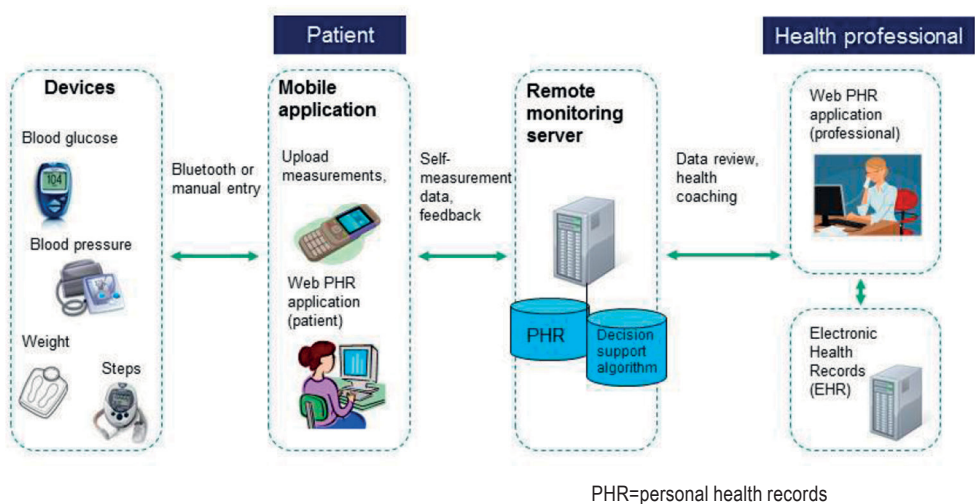


Figure 1. Architecture for the telemonitoring interventions

6.4.1 Mobile Sipoo (I)

The Mobile Sipoo intervention consisted of weekly TM of weight, blood pressure, blood glucose and steps linked with automated feedback messages, Table 3. All study participants received standard care, which included diabetes education at the time of diagnosis, annual check-ups and laboratory tests, and diabetes guidance and education given by a physician or nurse during patient-initiated appointments to the healthcare center. In addition, patients were able to contact healthcare providers any time they needed.

At the baseline visit, participants agreed together with the study nurse on a self-management plan that included selecting relevant health parameters to be monitored and setting target values for those parameters. Participants were given a mobile phone with a pre-installed self-monitoring application and measurement devices (blood pressure meter, scale, pedometer and blood glucose meter, if needed). They were instructed to measure their weight and blood pressure at least once a week. The pedometer was advised to be used on a regular basis, but the intensity of optimal use was not specified. In addition, blood glucose meters were given to six participants who were instructed to measure their blood glucose three times a week including pre- and postprandial measurements—before and 1–2 hours after a meal. However, one of these patients proved not to have T2D and was thus excluded from the analyses. After each measurement, the patients uploaded their data to the mobile application and sent it to the server. After each reported measurement, the patient received a personalized feedback message. Participants also received access to an online personal health records (PHR) account where they could enter and view their self-monitoring data, view their data graphically, review the feedback messages sent as a

response to their measurements, review their self-management plan, and review individual clinical information including prescriptions and laboratory tests.

The feedback messages were short, text-message like messages, the content of which was based on the self-monitoring data, Finnish Current Care Guidelines (www.kaypahoito.fi), and the Information-Motivation-Behavior Skills (IMB) model (Fisher & Fisher, 1992; Fisher, Fisher, & Harman, 2003). The Finnish Current Care Guidelines are evidence-based clinical practice guidelines developed by the Finnish Medical Society Duodecim in association with medical specialist societies. They are published to support management of different diseases and to benefit both professionals and citizens. The IMB model is a behavioral theory that specifies determinants of behavior that are potentially amenable to change. The IMB model states that an individual needs to be informed about his or her health situation, motivated to make a change, and behaviorally skilled to adjust their behavior towards healthier habits (Fisher & Fisher, 1992. Fisher et al., 2003). Information is a prerequisite for changing behavior, but in itself is insufficient to achieve the change. Motivation and behavioral skills are critical for behavior change (Fisher & Fisher, 1992; Fisher et al., 2003; World Health Organization, 2003). The IMB model guided the structure of the feedback messages. The feedback messages were built accordingly to include all three dimensions: information, motivation, and behavioral skills. The information part was based on the Finnish Current Care Guidelines or individual guideline-based target values that provided thresholds for normal or elevated parameter values to be combined with TM data. The motivation part provided positively-oriented feedback about the measurement whenever possible. If not possible, neutral feedback content was provided. Negative feedback was never given. The behavioral skills part provided detailed low-threshold instructions on how to achieve better outcomes. The objective of the feedback messages was to encourage individuals to initiate and maintain lifestyle changes (see Table 5). The feedback messages were available in Finnish and Swedish depending on the patient's preferences.

The pool of feedback messages included 265 messages on body weight, blood pressure, pre- and postprandial blood glucose, steps, a combination of these health parameters. Each message had a set of rules that defined a condition under which they were to be delivered to an individual. The content of a feedback message was tailored according to its conditions (e.g. whether the reported parameter was within or outside target levels, or how many times it had exceeded the target levels). Whenever a new measurement was reported, as a first step the algorithm scanned through all messages and selected those that fulfilled their rules. Messages that were found to be eligible in the current context were scored based on their importance (high priority for those with suspected measurement error or alert), history (how frequently they had been sent), and positivity (messages with positive, reinforcing nature had higher scores). In addition, for each summary score the algorithm added random variation to add unpredictability. The message with the highest score was sent to the user. Certain messages had a high priority—these messages were always delivered in the first instance. Such messages included extremely high/low blood glucose and blood pressure

values. In these cases, the user was instructed to repeat the measurement and if it was still alarmingly low or high, immediate contact with a healthcare professional was instructed. All high priority messages delivered to the study participants were also shared with the healthcare professionals involved, who were instructed to review the data on a weekly basis. At the beginning of the study it was agreed that the participants themselves had the responsibility to seek help if the feedback messages indicated that this was necessary.

Table 5. Examples of automatic feedback messages in the Mobile Sipoo study

<i>You have managed to keep your blood pressure at your target level of below 130/80 mmHg for 2 months. Well done! Please remember to continue monitoring your blood pressure.</i>	<i>Your blood sugar levels were above the target levels of 8 mmol/L seven times out of the 12 after-lunch measurements made during the past 2 months. Please keep your meal times regular and manage the content of your lunches to avoid excessive variation in your blood sugar levels.</i>	<i>You have lost 4% of your weight. That's great, keep up the good work! A 5–10% weight loss is beneficial in preventing weight-related illnesses and in treating them. Please remember to maintain a balanced diet and regular exercise.</i>	<i>Your blood pressure has risen 5/3 mmHg in the past month. Please pay attention to healthy lifestyle choices; increased endurance exercise, for example, will help lower your blood pressure.</i>
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6.4.2 Heart at Home (II)

The intervention of the Heart at Home study involved weekly TM of weight, blood pressure, heart rate and symptoms that were further sent to the HF nurse to be reviewed and exploited to optimize the patients' care. In response to the TM data, participants received individualized short, information-oriented feedback messages (Table 3). In addition, all participants received standard care at the cardiology clinic. Standard care encompassed multidisciplinary care including a cardiac team comprising two physicians and a specialized HF nurse as well as a physiotherapist who assisted after hospitalization periods. The cardiac team was responsible for the care and bi-annual check-ups at the cardiology clinic. In addition, participants were able to contact the HF nurse at any time. As part of the standard care, individuals capable of carrying out self-monitoring were encouraged to regularly measure their blood pressure, heart rate and weight at home. These monitoring data were further reviewed during the appointments or with scheduled calls. However, systematic collection and exploitation of this data was challenging as it was recorded with pen and paper and patients often forgot to bring their records or lost their notes between appointments.

At the baseline visit, the participants were given a TM toolbox which included a blood pressure meter, a scale and a mobile phone with a pre-installed application for reporting purposes. They received instructions on how to use the devices and the mobile phone application and practiced their use together with the nurse. The duration of the baseline visit was approximately 10–20 minutes per patient. Individual target values for blood pressure and weight were agreed together with the patient and the nurse during the baseline

visit. Participants were instructed to measure their blood pressure, body weight, heart rate, experienced health status (deteriorated/same/improved) and symptoms (dizziness, dyspnea, palpitation, weakness and edema) at least once a week. The self-monitoring data were reported via the touch-based mobile phone. After sending the data, the user received feedback on whether the measured value was within their individual target values, and a graphic showing their measurement history (Figure 2). One nurse oversaw all of the study participants. If the patient experienced technical problems, (s)he was instructed to contact the nurse. Six contacts were made due to technical problems.

TM data were stored on a secure remote patient monitoring server where the information could be accessed by the study personnel. The patient’s whole measurement history was made available each time the data were reviewed. The study nurse reviewed the data of each participant on a weekly basis. The nurse was instructed to call the participant and assess whether (s)he needed an appointment at the clinic for the following reasons: 1) the reported value was beyond the target values, 2) the reported value was clearly different from previous values, or 3) the patient reported any of the symptoms. During the first months of the study participants were contacted if the reported measurement exceeded the target values. Later, the measurement history played a bigger role, and the participant was not necessarily contacted on the basis of a single measurement. If the participant did not adhere to the weekly reporting plan, the nurse called and encouraged him or her to continue with the monitoring.

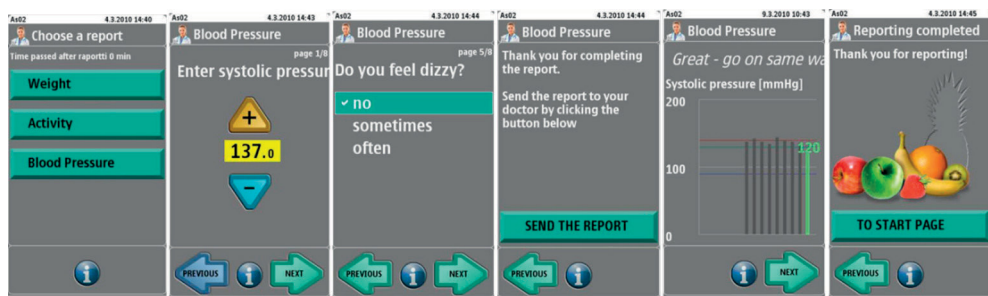


Figure 2. Screenshots of the reporting process with the mobile application in the Heart At Home study

6.4.3 Renewing Health (III)

The Renewing Health intervention consisted of two components: weekly TM of weight, blood pressure, and blood glucose or steps, and structured telephone-based health coaching (Table 3). All study participants received standard care. As a part of standard care, patients with T2D, HF and CAD received a disease management booklet at the time of diagnosis. Laboratory tests were taken once a year and patients were scheduled with one appointment

or a phone call with a nurse or physician. In addition, individuals were able to contact healthcare providers any time they need. Individuals with CAD were encouraged to take part in the group intervention sessions that provided information about CAD and encouraged regular exercise.

Intervention participants received a TM toolbox that consisted of a touch screen mobile phone with a pre-installed application for monitoring purposes, an account for a PHR application and a set of measurement devices connected to the PHR account. An expert evaluation by one usability expert as well as usability evaluations with five participants of the pilot study were done prior to the main study to ensure the ease of use of the technology. Participants were instructed to measure their weight and blood pressure at least once a week. Additionally, patients with T2D measured their blood glucose, and patients with heart disease measured their steps on at least a weekly basis. However, the individual self-management plan altered the monitored health parameters in some cases (e.g. TM of blood glucose was recommended only for those who were already advised for SMBG). The reporting of the health parameters was done with the mobile application which transferred the data to the participant's PHR account. Using the PHR account, the participants were able to review their data and the self-management plan entered by the health coach. The TM system was provided by Medixine Ltd.

The health coaching program was designed to increase patients' abilities to self-manage their condition while empowering the patients and increasing their self-efficacy for active self-management. The health coaching program had been previously used in the TERVA study, which provides a detailed description of the program (Patja et al., 2012). Briefly, the health coaching program was a solution-oriented model that integrated behavior change techniques. The program consisted of eight topics, each of which provided tools essential for managing chronic conditions. Each topic was introduced to participants using a five-stage care process (Figure 3). The health coaching calls covered one topic at a time, and the content of each call was modified for a specific condition and further tailored to the individual's needs. Six nurses who previously worked in outpatient care or in a hospital were hired to provide the health coaching. The recruited health coaches received specific training, after which they continued working as a health coach one day per week throughout the study. For quality control and educational purposes, each health coach recorded some of the coaching calls and the calls were assessed together with a behavioral professional once every three months. The health coaching framework was provided by Pfizer Health Solutions Oy.

Each intervention participant was assigned to a personal health coach. During the first call the health coach and the participant agreed on a self-management plan according to the individual's needs, and they set low-effort goals to improve the patient's lifestyle. The health coach and the participant also agreed on a self-monitoring plan depending on the condition and skills of the patient. The health coach called on a monthly basis, approximately every 4-6 weeks. During each call, the health coach and the participant

reviewed the previous goals and set a new goal related to the topic of the call, and the health coach provided information and support to aid adherence to the self-management plan. Health coaches had access to the participants' PHR accounts; before each call the coach reviewed the participant's self-monitoring data. The health coach and the patient discussed the data, and the coach advised the patient to take appropriate actions to balance their health outcomes if the data indicated a change in the patient's condition. If needed, participants were advised to make an appointment with their physician. The duration of each health coaching call was approximately 30 minutes.

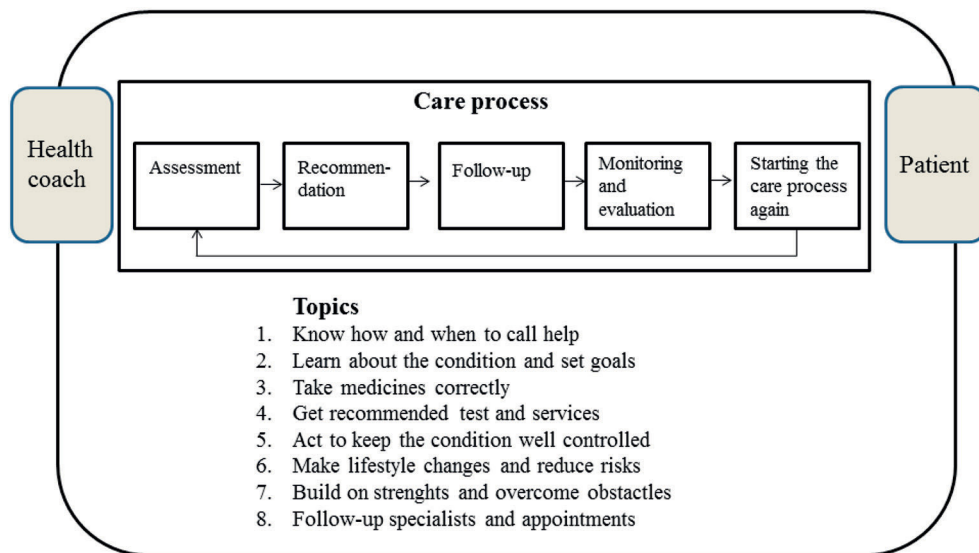


Figure 3. Framework for the health coaching program in the Renewing Health study. Figure modified from Patja et al. (2012)

6.5 Adherence and outcomes

Table 6 summarizes the primary outcomes, selected secondary outcomes and adherence metrics used in the three studies. The next paragraphs describe the outcome measures in detail.

Adherence In all studies, the TM system stored time-stamped self-monitoring data from participants' measurement devices. Adherence to the TM intervention was measured using the log files. Adherence was defined as the percentage of weeks that included at least one recorded measurement. Each week was analyzed separately and was relative to the individual follow-up time. Adherence to glucose TM in the Mobile Sipoo study (I) was defined as the percentage of weeks with at least three preprandial and at least three postprandial glucose measurements. In the Renewing Health study (III) adherence to health coaching was defined as the total number of answered health coaching calls. As the

coaching calls were made at 4–6 week intervals, each participant was to receive a total of 7 to 11 calls excluding the baseline and end-point calls. The baseline and end-point calls were excluded from the calculations because all study participants received those calls and thus they did not reflect adherence to the intervention.

Primary outcomes The primary aim of the Mobile Sipoo study (I) was to improve glycemic control and reduce the blood pressure of individuals with T2D measured with HbA_{1c} and systolic and diastolic blood pressure, respectively. The HbA_{1c} was obtained from EHR if the test was no more than one month old. Otherwise, patients were scheduled with a new laboratory test. The Heart at Home study (II) aimed primarily at reducing HF-related hospital admissions during the 6-month follow-up. Information on hospitalizations was obtained from EHR, and supplemented by interviewing the patient. The primary aim in the Renewing Health study (III) was to improve HRQoL and to improve glycemic control in individuals with T2D by reducing HbA_{1c}. HRQoL was assessed using SF-36 version 2 translated into Finnish. SF-36v2 is a 36-item questionnaire including statements on physical and mental health that are assessed on a 5-level response scale (Ware & Sherbourne, 1992). The responses are summarized in eight dimensions and two summary scores scaled 0 to 100 with a high score corresponding to more favorable health status. A 3–5 point difference is considered a minimum clinically important difference (Hays & Morales, 2001). The two component scores: the physical component score (PCS) and mental component score (MCS) were compared between the study arms.

Secondary outcomes In the Mobile Sipoo study (I), all clinical outcomes were measured by the study nurse and subsequently recorded in an online lifestyle survey by the participants in the intervention arm. Patients in the standard care arm filled out the same survey using pen and paper. In the Heart at Home study (II), clinical outcomes were measured by the nurse. LVEF was measured by echocardiography. Adherence to HF-specific lifestyle behaviors was assessed using the European Heart Failure Self-Care Behavior Scale (EHFSBS) questionnaire (Jaarsma, Strömberg, Mårtensson, & Dracup, 2003). EHFSBS is a 12-item self-administered questionnaire specifically designed and tested for individuals with HF. The questionnaire included statements regarding self-management behaviors essential to the care of HF, such as ‘If I experience increased fatigue, I contact my doctor and nurse’, ‘I exercise regularly’, and ‘I take my medication as prescribed’. The statements were scored from 1 to 5; the lower the score, the better the self-management performance. A summary score was used in the analysis. The number of appointments with nurse and physician, and the number of unplanned visits to the cardiology clinic were retrieved from EHR. The number of patient-initiated and nurse-initiated calls were recorded by the study nurse and the calls were analyzed separately. In the Renewing Health study (III), the secondary outcomes were measured during the baseline and follow-up visits and recorded in the TM database by the health coaches who conducted the baseline and end-point visits for the patients in the standard care arm.

Table 6. Adherence, primary outcomes and selected secondary outcomes

	Mobile Sipoo (I)		Heart At Home (II)		Renewing Health (III)	
	Measure	Source	Measure	Source	Measure	Source
Adherence	% of weeks with at least one measurement	log data	% of weeks with at least one measurement	log data	% of weeks with at least one measurement Number of health coaching calls	log data log data
Primary outcomes						
HbA1c	EHR - laboratory tests within 1 month from the beginning and study completion	EHR and supplemented by interviewing the patient	HRQoL	Self-administered questionnaire SF-36 at baseline and 12 months		
Systolic and diastolic blood pressure	Measured at baseline and 10 months	HbA1c for individuals with T2D		EHR- laboratory tests within 2 months from the beginning and study completion		
Secondary outcomes						
Clinical outcomes	Weight Waist circumference	Measured at baseline and at 10 months	Blood pressure Weight LVEF	Measured at baseline and at 6 months	Weight Blood pressure Waist circumference LDL-cholesterol	Measured at baseline and at 12 months
Self-management behaviors			EHFBSBS score	Self-administered questionnaire at baseline and at 6 months		
Use of health care resources			Appointments with HF nurse. Appointments with HF physician. Unscheduled visits to HF clinic. Number of phone calls to nurse and to patient.	EHR EHR EHR Recorded by HF nurse		
Death			Death from any cause.	EHR		

EHR=electronic health records, EHFBSBS= European Heart Failure Self-Care Behavior Scale, HbA1c= glycosylated hemoglobin, HF=heart failure, HRQoL=health-related quality of life, LDL=low-density lipoprotein, LVEF=left ventricular ejection fraction, T2D=type 2 diabetes

6.6 Statistical methods

All analyses were performed according to the Intention-To-Treat principle. Imputations were not done for missing outcome data, but participants whose outcome was available at baseline and at follow-up were included in the analyses. An α -level of 0.05 was considered statistically significant.

Participants' baseline characteristics were presented according to the treatment groups. Adherence was described with a line chart where the x-axis represents time in weeks. In addition, the median number of adherent weeks with an interquartile range was calculated individually. The adherence data in the Renewing Health study (III and IV) were further analyzed to investigate the association between adherence and primary outcomes by calculating either Pearson's or Spearman's correlation between adherence and the change score in PCS, MCS and HbA_{1c}.

The differences in the clinical and behavioral outcome variables between the study arms were analyzed using the analysis of covariance. The follow-up measures were compared between the study arms by adjusting for the outcome baseline level. The results were presented as the mean difference between groups with 95% confidence intervals (CIs) and p-values. The p-values for the model coefficients were obtained from Wald's test. The outcome variables in the Renewing Health study (II) were presented separately for each chronic condition (T₂D, CAD and HF) to make the results comparable with the Mobile Sipoo and Heart at Home studies. The differences between the treatment arms were compared by combining all disease groups in the Renewing Health study. An additional analysis was done by adding an interaction term *condition x treatment arm* to the model to investigate whether the treatment effect differed across individuals with T₂D, HF and CAD.

Data related to the use of healthcare resources were analyzed using Poisson regression and Zero Inflated Poisson (ZIP) regression models. The models were adjusted for individual follow-up times by adding them to the model as an offset variable. The distributions of the resource-related variables were skewed to the right with a significant proportion of participants having zero values. The data was therefore presented as a percentage of participants who had zero values combined with the mean (standard deviation) number of events. The excess proportion of zero values led to an assumption that ZIP regression models may better fit the distribution. The superiority between the Poisson regression model and the ZIP regression model was assessed using Vuong's test (Vuong, 1989). Finally, the following variables were analyzed using ZIP regression: number of HF-related hospital days, number of unplanned visits to the clinic, and number of phone calls initiated by the patients. The incidence rate ratios (IRR) with 95% CIs and p-values were reported for the Poisson regression models, and odds ratios (ORs) with 95% CIs for analyzing the proportion of participants with zero counts. The other resource-related variables were analyzed using Poisson regression; the IRRs, their 95% CIs and p-values were reported to describe the differences between treatment arms. It should be noted that the ORs differ from risk

ratios (RR), especially when the initial risk is high. In such cases the OR overestimates the RR and, thus, the interpretation of OR should not be confused with RR (Schmidt & Kohlmann, 2008).

In the Heart at Home study, where the primary outcome was proportional, the number needed to treat (NNT) and its 95% CI were calculated for the HF-related hospitalization rate. NNT refers to the number of patients that need to be treated to achieve the outcome in one patient who would not have benefited otherwise (Schechtman, 2002). The NNT was calculated according to the following formula: $1 / (r_{\text{standard care}} - r_{\text{telemonitoring}})$ where r was the risk of hospitalization, i.e. the percentage of patients being hospitalized.

7 Results

7.1 Enrollment, withdrawal and completion

7.1.1 Mobile Sipoo (I)

One hundred individuals confirmed an initial agreement to participate in the Mobile Sipoo study (Figure 4a). Of those, 35 did not meet the inclusion criteria and nine subsequently declined to participate. Fifty-six individuals were randomized, and scheduled with a baseline visit. Fifty participants completed the study, of whom two were further excluded from the analyses because they proved not to have T2D. Recruitment started in December 2010 and ended in April 2011. The study was completed in April 2012.

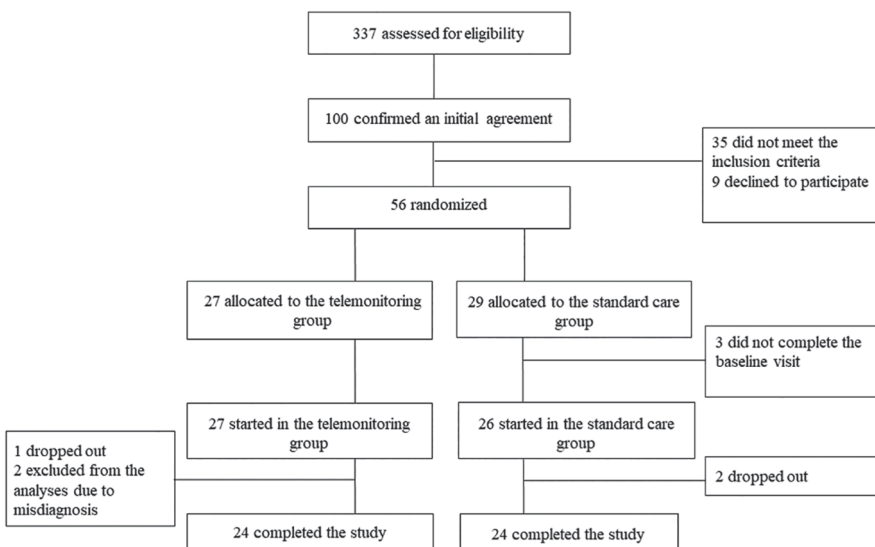


Figure 4a. Eligibility, randomization and follow-up in the Mobile Sipoo study

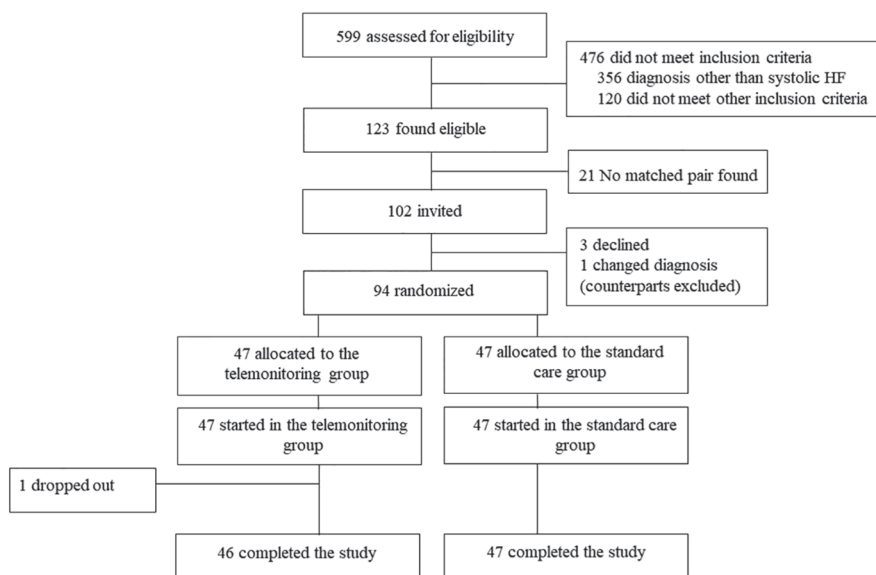


Figure 4b. Eligibility, randomization and follow-up in the Heart at Home study

7.1.2 Heart at Home (II)

A total of 123 HF patients were found eligible for the Heart at Home study; these were further matched in pairs according to their sex, age, LVEF and NYHA classification (Figure 4b). Fifty-one pairs were formed, and 21 patients were excluded as a matched pair was not found. Invitation letters were sent to 102 individuals, of whom three declined to participate and one had a changed diagnosis. Respectively, their matched counterparts were excluded from the study. Finally, 94 HF individuals were randomized and included in the study. The baseline visits were conducted between November 2010 and August 2011, and the study was completed in February 2012 with 93 participants.

7.1.3 Renewing Health (III)

Invitation letters were sent to 2,084 individuals, of whom 595 (29%) agreed to participate and were further randomized to the TM and the standard care groups with an allocation ratio of 2:1 (Figure 4c). Of those, 519 completed the baseline visit and were included in the study. The drop-out rate was 8% in the TM group and 9% in the standard care group. Eventually, 337 and 134 participants in the TM and standard care groups, respectively, completed the study. Recruitment started in August 2010 and ended in December 2011. The study was completed in December 2012.

The drop-out analysis showed that not being familiar with mobile phones increased the risk of withdrawal; 86% of drop-outs vs. 98% of study completers reported being familiar with mobile phones (p -value obtained from Fisher's exact test was < 0.001). No other baseline characteristic was associated with withdrawal. Moreover, the drop-out rates did not differ between the three conditions ($p=0.918$).

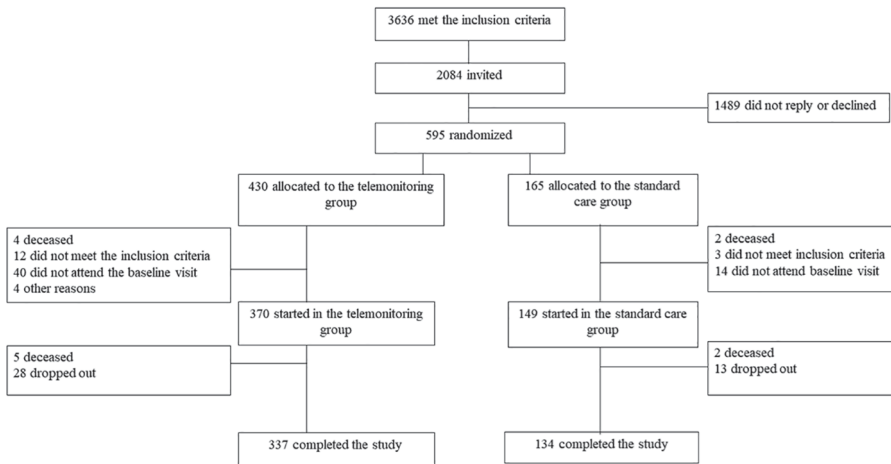


Figure 4c. Eligibility, randomization and follow-up in the Renewing Health study

7.2 Baseline characteristics

Table 7 shows the baseline characteristics of the participants in the three studies, and the findings are summarized below.

7.2.1 Mobile Sipoo (I)

The mean age was 62 years, 53% of participants were male and the mean BMI was 32.1 kg/m². The mean level of HbA_{1c} was 7.0%. Participants in the TM group had a lower BMI (30.5 kg/m²) than those in the standard care group (33.7 kg/m²) and also higher blood pressure, 157/89 mmHg vs. 146/85 mmHg, respectively (see Table 9 for blood pressure and HbA_{1c}). In addition, there were fewer patients on insulin medication in the TM group. Almost all participants (98%) had either elevated blood pressure or blood pressure medication. Sixty-four percent of the participants in the TM group used mobile phones and the internet at least on a weekly basis.

7.2.2 Heart at Home (II)

In the Heart at Home study, 83% of participants were male with a mean age of 58 years and a BMI of 28.1 kg/m². The mean LVEF was 28.0%, and 62% of participants had a NYHA classification of III or IV indicating at least marked limitation of physical activity (see Table 9 for LVEF). Eighty-one percent of participants in the TM group reported using mobile phones at least on a weekly basis, and 75% used the internet at least on a weekly basis. There were more smokers in the TM group; in the TM and SC groups, 24% and 11% smoked, respectively.

7.2.3 Renewing Health (III)

Of the 519 individuals who started in the study, 250 participants were T2D patients, and 269 individuals had a heart disease. Of the heart disease patients, 227 (84%) had CAD and 42 (16%) had HF. The mean age of the whole study group was 68 years, the mean BMI was 29.7 kg/m², and the majority (61%) were male. Eighty-nine percent of the participants were familiar with a mobile phone, and 55% were familiar with a computer.

Table 7. Baseline characteristics in the three studies

	Mobile Sipoo (I)		Heart at Home (II)		Renewing Health (III)					
	TM n=25	SC n=26	TM n=47	SC n=47	TM n=180	SC n=70	TM n=159	SC n=68	TM n=31	SC n=11
Sex, male, %	52	54	83	83	55	57	66	69	62	64
Age, years, mean (SD)	62.6 (6.6)	62.1 (9.0)	58.3 (11.6)	57.9 (11.9)	66.6 (8.2)	65.5 (9.6)	69.3 (8.9)	68.1 (9.1)	70.7 (10.0)	67.6 (11.7)
BMI, kg/m ² , mean (SD)	30.5 (4.6)	33.7 (7.7)	28.4 (6.0)	27.9 (4.7)	31.1 (5.4)	30.9 (5.7)	28.3 (4.1)	27.9 (4.2)	28.1 [24.5;33.9] ^a	29.0 [24.9;32.1] ^a
Smoking, %	8	12	24	11	9	9	9	6	0	18
Education, years, mean (SD)	11.4 (3.4)	12.0 (3.7)	1		22	14	27	17	7	
Primary school or less					42	43	51	32	55	64
Secondary or high school					36	34	31	40	29	36
College/university or higher					15	17	14	13	7	
Mobile phone use, %	64 ^b		81 ^b		89 ^c	87 ^c	92 ^c	87 ^c	87 ^c	91 ^c
Computer/internet use, %	64 ^b		1		14	9	10	8	4	
Hypertension, %			1	13	57 ^c	59 ^c	54 ^c	53 ^c	52 ^c	46 ^c
Hypertension or hypertensive medication, %	100	96	17		4	8	14	10	4	
Insulin medication, %	20	50								
NYHA classification, %										
			Class II: 40	Class II: 36						
			Class III: 58	Class III: 60						
			Class IV: 2	Class IV: 4						

^a Median [25th percentile; 75th percentile]

^b Using a mobile phone/internet at least on a weekly basis

^c Familiar with mobile phone / computer

BMI=body mass index, CAD=coronary artery disease, HF=heart failure, LVEF=left ventricular ejection fraction, NYHA=New York Heart Association, SC=standard care, SD=standard deviation, TM=telemonitoring, T2D=type 2 diabetes

7.3 Adherence

Figure 5 shows the percentage of adherent participants, that is, those reporting at least one recorded measurement on a given study week. Adherence was highest in the Mobile Sipoo (I) and Heart at Home (II) studies with adherence rates of approximately 80% or higher. In the Renewing Health study (III) the percentage of adhering participants varied between 50–60%. There was no major attrition towards the end of the follow-up in either of the studies.

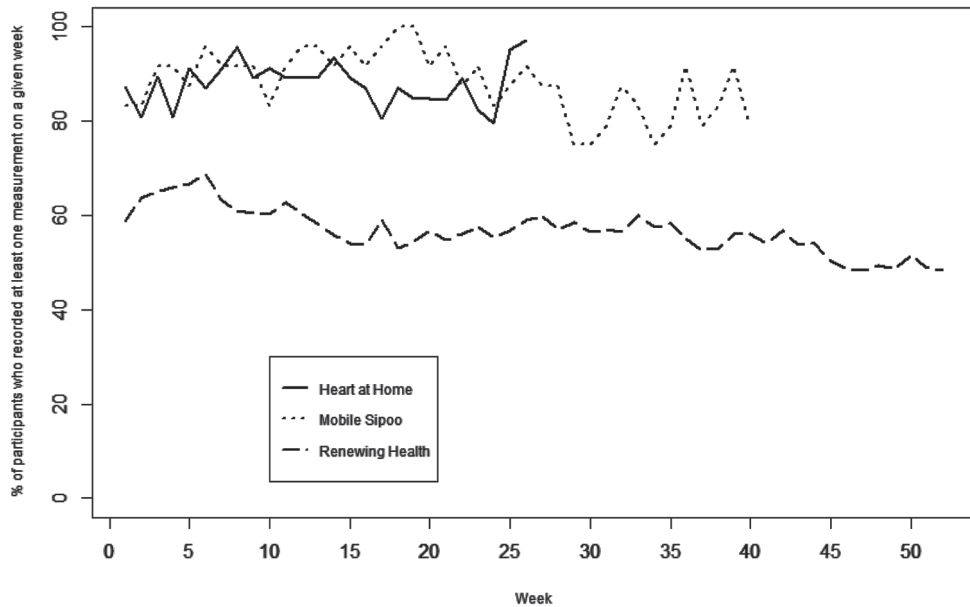


Figure 5. Adherence to weekly telemonitoring in the three studies over time; from the baseline (week 0) to the end of the study. Adherence is presented as the percentage of participants in the intervention group who recorded at least one measurement on a given week.

7.3.1 Mobile Sipoo (I)

The percentage of adherent participants varied from 75% (week 29, 30 and 34) to 100% (week 18 and 19). The median percentage of weeks with at least one recorded measurement was 93%; the 25th and 75th percentiles were 79% and 98%, respectively.

For the five participants who were instructed to monitor their blood glucose, the percentage of weeks in which at least three pre- and postprandial glucose measurements recorded were 4%, 62%, 60%, 57%, and 63%. The participant whose adherence was 4% did not report three pre- and postprandial measurements weekly, however, the participant monitored his/her blood glucose on a regular basis until the follow-up visit. The median number of recorded blood glucose measurements per participant was 49.

7.3.2 Heart at Home (II)

The percentage of adherent participants varied from 80% (week 17 and 23) to 96% (week 8) (Figure 5). The median percentage of weeks with at least one recorded measurement was 90% with 25th and 75th percentiles of 79% and 100% (Figure 6).

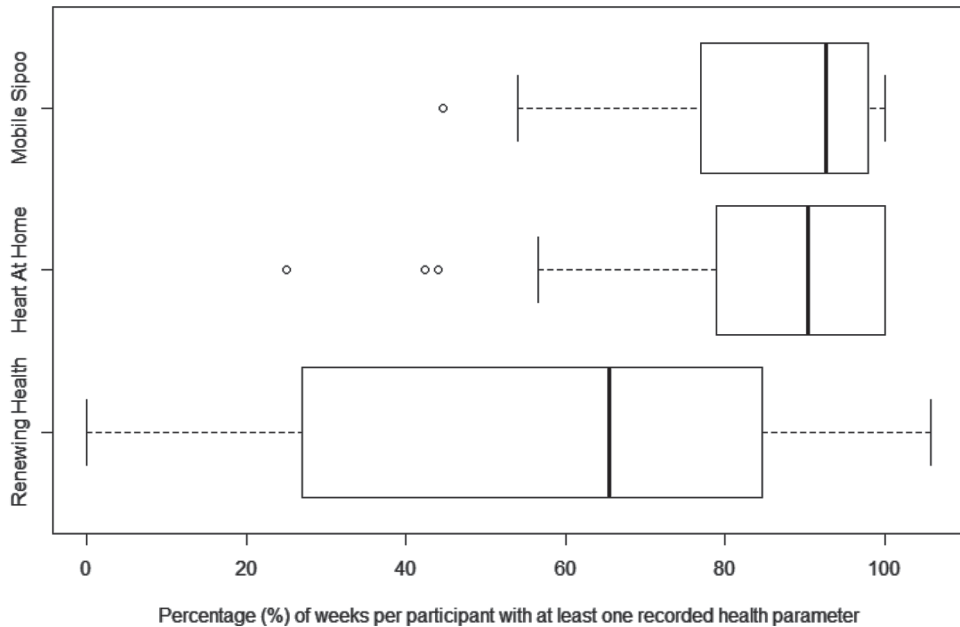


Figure 6. Patient-level adherence to weekly telemonitoring in the three studies, showing the median (thick black line) and interquartile ranges (left and right sides of the boxes) for the percentage of weeks with at least one recorded health parameter. White circles denote single data points defined as outliers.

7.3.3 Renewing Health (III and IV)

The percentage of adherent participants varied from 51% (week 37) to 68% (week 6). The median percentage of adherent weeks per individual was 65%; the 25th and 75th percentiles were 27% and 85%, respectively.

The mean number of health coaching calls was 7.5 when baseline and end-point calls were excluded. Sixty-six percent of participants received 7–11 calls, which corresponds to the predefined coaching schedule. Eighty-nine percent received at least 6 calls. The mean duration of calls was 27 minutes.

Figure 7 illustrates the relationship between adherence to TM and change in HbA_{1c} and HRQoL, measured as PCS and MCS. Adherence to TM did not correlate with change

in PCS ($\rho=0.02$, $p=.67$) or MCS ($\rho=0.08$, $p=0.17$), or with change in HbA1c in individuals with T2D ($\rho=0.08$, $p=0.34$). Correspondingly, the number of answered health coaching calls did not correlate with any of the primary outcomes: $r=0.06$ ($p=0.32$) for PCS; $r=0.03$ ($p=0.58$) for MCS; and $r=0.003$ ($p=0.97$) for HbA1c in T2D patients.

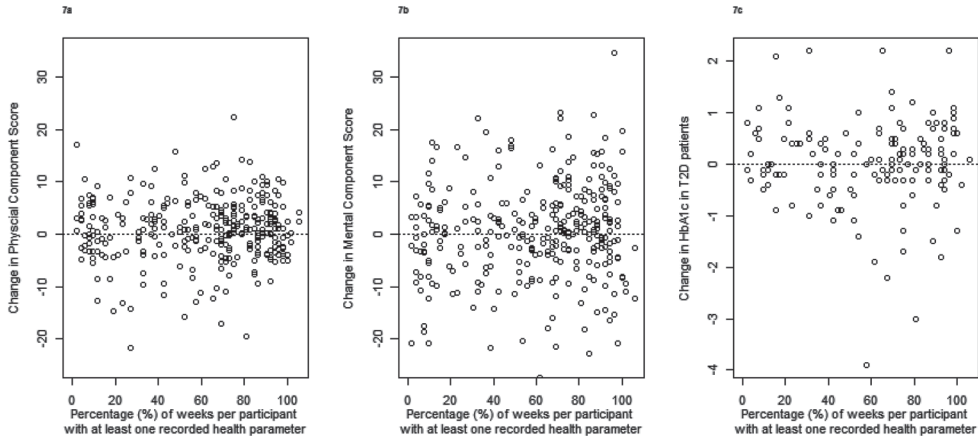


Figure 7. Scatter plots illustrating the relationship between adherence to telemonitoring, defined as a percentage of weeks per patients with at least one recorded health measurement, and the change in health-related quality of life, measured as Physical Component Score of SF-36 (7a) and Mental Component Score of SF-36 (7b), and change in HbA1c in type 2 diabetes patients (7c) in the Renewing Health study. Participants in the telemonitoring group only are included in the figures.

7.4 Outcomes

Table 8 shows the baseline and follow-up measures, and the study-wise differences between the treatment arms in the selected clinical and behavioral outcomes, and in HRQoL. Table 9 presents the utilization of healthcare resources in the Heart at Home study. The results are summarized below.

7.4.1 Primary outcomes

7.4.1.1 Mobile Sipoo (I)

At 10 months, the baseline adjusted difference in HbA1c was 0.44 percentage points lower in the TM arm (95% CI: -0.81; -0.07), $p=0.02$. The difference remained statistically significant after further adjusting for the baseline BMI and insulin medication with a difference of 0.44 percentage points (95% CI: -0.83; -0.05), $p=0.03$.

Reductions in blood pressure levels did not differ between the study arms at 10 months; the baseline adjusted difference in systolic blood pressure was 3.6 mmHg lower in the TM arm (95% CI: -14.5; 7.3), $p=0.51$, and 2.2 mmHg lower (95% CI: -7.1; 2.8), $p=0.38$, in diastolic blood pressure (Table 8).

7.4.1.2 *Heart at Home (II)*

HF-related hospitalizations did not differ between the study arms, Table 9. Eight (17%) and 13 (28%) participants in the TM and standard care groups, respectively, were hospitalized due to HF. The likelihood of not being hospitalized was 1.9 measured with OR (95% CI for OR: 0.7; 5.1), and the difference between groups was not statistically significant ($p=0.22$). Moreover, the number of hospital days among those who were hospitalized did not differ between the treatment arms (IRR=0.8, 95% CI: 0.5-1.3, $p=0.35$).

The absolute risk difference for HF-related hospitalization was 10.3% with a 95% CI from -0.067 to 0.271. The NNT to prevent one HF-related hospitalization was 10, with a 95% CI of -15 to 4.0. The NNT should be interpreted with caution, because the confidence interval for the absolute risk difference included zero, which, in theory, increased the NNT to infinity, and the lower threshold for the interval was negative. Such CIs are challenging to interpret, and it has been recommended that in such cases the confidence intervals is separated into two parts; number needed to harm (NNH) and number needed to benefit (NNB). (Altman, 1998; Schechtman, 2002; Uhari, 2001.) For HF-related hospitalizations, the NNH is 15-∞ and the NNB is 4-∞. The NNH result indicates that when 15 patients receive TM intervention, one patient may benefit from the standard care more, and the NNB result indicates that at least 4 patients need to be treated with TM intervention to avoid one HF-related hospitalization.

The risk of HF-related hospitalization was assessed using ORs obtained from the ZIP regression models. The ORs should be interpreted with caution when the initial risk is high and in such cases ORs tend to overestimate the actual risk (Schmidt & Kohlmann, 2008). In this study 83% of TM patients and 72% of standard care patients were not hospitalized at all during the follow-up. These numbers constitute a RR of 1.2, whereas the OR for not being hospitalized was 1.9. One can see that there is a discrepancy between the RR and OR; however, neither the interpretation nor conclusions regarding HF-related hospitalization are affected by this discrepancy. Similar comparisons between the ORs and RRs were done for the other resource-related variables that were analyzed using ZIP regression models and no major differences were observed between the measures. The RR results are not specifically presented in this work, although their figures can be obtained from Table 9.

Table 8 Clinical and behavioral outcomes and the health-related quality of life at baseline and study completion, and study-wise differences between the treatment arms in the three studies.

	Renewing Health, n=471																			
	Heart at Home, n=93				T2D				HF,											
	Mobile Sipoo, n=48		TM n=46		SC n=47		TM n=162		SC n=62		TM n=147		SC n=62		TM n=28		SC n=9			
HbA1c, %	Baseline mean (sd)	6.6 (1.2)	7.1 (1.5)	7.1 (1.1)	7.1 (1.1)	7.3 (1.0)	7.3 (1.0)	7.3 (1.0)	7.2 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)	7.4 (0.9)		
	Difference at 10 mo ^a (95%CI) P-value			-0.44 (-0.8; -0.1) p=0.02															-0.11 (-0.3; 0.1) p=0.34	
Systolic pressure, mmHg	Baseline mean (sd)	157 (16)	137 (15)	147 (16)	137 (16)	112 (13)	117 (13)	116 (16)	122 (17)	122 (17)	148 (16)	148 (16)	148 (16)	148 (16)	148 (16)	148 (16)	148 (16)	148 (16)	148 (16)	
	Difference at 6 mo ^b (95%CI) P-value			-3.6 (-4.5; -2.7) p=0.51																-2.1 (-7.0; 2.9) p=0.41
Diastolic pressure, mmHg	Baseline mean (sd)	89 (10)	85 (9)	78 (7)	78 (7)	74 (9)	74 (9)	72 (11)	73 (9)	73 (9)	87 (11)	87 (11)	87 (11)	87 (11)	87 (11)	87 (11)	87 (11)	87 (11)	87 (11)	
	Difference at 6 mo ^b (95%CI) P-value			-2.2 (-7.1; 2.8) p=0.38																1.1 (-2.4; 4.6) p=0.53
Weight, kg	Baseline mean (sd)	89.3 (15.8)	87.7 (15.1)	99.2 (25.6)	99.1 (22.9)	89.0 (19.6)	89.7 (20.3)	86.3 (16.4)	87.7 (17.8)	87.7 (17.8)	88.7 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)	88.9 (16.6)
	Difference at 10 mo ^a (95%CI) P-value			-2.5 (-4.7; -0.4) p=0.02																-0.7 (-1.6; 3.0) p=0.56
Waist, cm	Baseline mean (sd)	107.6 (9.1)	105.3 (8.0)	104.5 (19.5)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)	107.8 (16.1)
	Difference at 10 mo ^a (95%CI) P-value			-4.8 (-8.9; -0.8) p=0.02																-1.6 (-2.9; -0.4) p=0.01
LDL, (mmol/L)	Baseline mean (sd)	181 (18)	181 (18)	161 (16)	161 (16)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)	156 (15)
	Difference at 12 mo ^c (95%CI) P-value																			0.8 (-2.3; 3.8) p=0.62

LVEF, %	27.3 (4.9) 46	32.4 (9.8) 46	28.6 (5.0) 47	32.8 (8.2) 47	-0.04 (-3.7; 3.7) p=0.98	42.6 (10.2) 146	43.2 (11.1) 146	41.5 (11.3) 55	42.0 (10.3) 55	41.3 (10.0) 135	40.6 (9.9) 59	41.7 (9.9) 59	30.5 (9.7) 27	34.5 (10.1) 27	38.1 (6.1) 9	37.9 (7.0) 9	0.5 (-0.7;1.7) p=0.40
EHFSBS	27.6 (6.8) 46	22.6 (6.9) 46	27.9 (6.5) 47	24.1 (8.3) 47	-1.3 (-3.8; 1.2) p=0.30	50.2 (11.1) 148	51.2 (10.9) 148	50.1 (12.6) 56	52.0 (10.9) 56	51.0 (11.3) 135	50.1 (12.6) 59	52.0 (10.9) 59	47.6 (7.7) 27	47.6 (12.5) 27	47.9 (9.4) 9	50.2 (9.8) 9	-0.7 (-2.4;1.0) p=0.44
PCS																	
MCS																	

CI=Confidence interval, EHFSBS= European Heart Failure Self-Care Behavior Scale, LDL=low-density-lipoprotein, MCS=mental component score of SF-36 for HRQoL, mo=months, PCS=physical component score of SF-36 for HRQoL, SC=standard care, sd=standard deviation, TM=telemonitoring

^a Difference between the treatment arms in the Mobile Sipoo study at 10 months when adjusted for the outcome baseline level

^b Difference between the treatment arms in the Heart at Home study at 6 months when adjusted for the outcome baseline level

^c Difference between the treatment arms in the Renewing Health study at 12 months when adjusted for the outcome baseline level. Data from all three conditions are combined for the comparisons.

7.4.1.3 *Renewing Health (III)*

At 12 months, there were no statistically significant differences in either of the summary scores of SF-36; the PCS differed by 0.5 points (95% CI: -0.7; 1.6, $p=0.40$), and the MCS by -0.7 points (95% CI: -2.4; 1.0, $p=0.52$) between the study arms when adjusted for the corresponding baseline levels. Adding the interaction term *condition x treatment group* to the model did not change the results in either of the summary scores, indicating that the intervention effect on HRQoL was not different across the three chronic conditions, as demonstrated by the absolute values in Table 9. Neither was there a difference in HbA1c in participants with T2D. At 12 months the baseline adjusted difference was -0.1 percentage points with a 95% CI of -0.3 to 0.1 and a p-value of 0.3.

According to the study protocol, individuals with T2D were eligible if their HbA1c was > 6.5% within 12 months from screening. However, there were 81 T2D patients whose HbA1c at baseline was lower or equal to 6.5% because their HbA1c had changed since screening. To further investigate the effect of low baseline values on glycemic outcomes, the analyses regarding HbA1c were repeated by excluding participants whose HbA1c at baseline was < 6.5%. The results remained similar, with a difference of 0.1 percentage points between arms ($p=0.49$), and a 95% CI of -0.4 to 0.2.

7.4.2 Secondary outcomes

In the *Mobile Sipoo* study (I), the TM group had significantly lower weight and waist circumference at 10 months. The difference in weight was -2.5 kg (95% CI: -4.7; -0.4), with a p-value of 0.02, and in waist circumference -4.8 cm (95% CI: -8.9; -0.8) with a p-value of 0.02.

In the *Heart at Home* study (II), none of the clinical and behavioral outcomes including weight, blood pressure, LVEF, and EHFSBS scores differed between the TM and standard care groups at 6 months (Table 8). In addition, none of the participants died during the 6-month follow-up. However, the TM intervention resulted in increased use of healthcare resources (Table 9). Use of nurse resources increased, with the number of appointments being 1.7 (95% CI: 1.4; 2.2, $p < 0.001$) times higher in the TM group, and the number of nurse-initiated and patient-initiated calls being 5.6 (95% CI 3.4; 7.6, $p < 0.001$) and 1.6 (95% CI: 1.0; 2.7, $p=0.05$) times higher, respectively. Moreover, the number of unplanned visits to the cardiology clinic was 3.3 (95% CI: 2.2; 5.1, $p<0.001$) times higher in the TM group among those who had at least one visit. Use of physician's time did not increase in the TM group (IRR=0.95, 95% CI: 0.7; 1.3, $p=0.74$).

Table 9. Use of health care resources in the Heart at Home study (II)

	TM n=46	SC n=47	Mean difference between groups (95% CI)	IRR (95%CI)	p-value for IRR	OR (95%CI)	p-value for OR
HF-related hospital days ^a	0.7 (2.4)	1.4 (3.5)	-0.6 (-1.9; 0.6)	0.8 (0.5; 1.3) ^b	0.35		
% of patients with zero counts	83	72				1.9 (0.7; 5.1) ^c	0.22
Number of appointments with nurse ^a	4.5 (2.2)	2.7 (1.0)	1.8 (1.0; 2.5)	1.7 (1.4; 2.2)	< 0.001		
Number of appointments with physician ^a	1.9 (0.9)	2.0 (0.8)	-0.2 (-0.5; 0.2)	0.95 (0.7; 1.3)	0.74		
Number of calls initiated by the nurse ^a	3.0 (2.4)	0.6 (0.9)	2.3 (1.6; 3.1)	5.6 (3.4; 7.6)	0.001		
% of patients with zero counts	15	57					
Number of calls initiated by the patient ^a	2.3 (2.1)	0.6 (1.5)	1.6 (0.9; 2.4)	1.6 (1.0; 2.7) ^b	0.05		
% of patients with zero counts	30	72				0.2 (0.1; 0.5) ^c	< 0.001
Number of unscheduled visits to the clinic ^a	3.7 (2.6)	1.0 (1.5)	2.7 (1.8; 3.6)	3.3 (2.2; 5.1) ^b	0.001		
% of patients with zero counts	13	47				0.4 (0.1; 2.2) ^c	0.31

CI=confidence interval, IRR=incident rate ratio, OR=odds ratio, SC=standard care, TM=telemonitoring

^a mean (standard deviation)

^b IRR is calculated for those who had at least one call/visit

^c OR for having no calls/visits

In the *Renewing Health* study (III), the TM intervention did not reduce weight, systolic pressure, diastolic pressure or LDL cholesterol. Waist circumference was significantly lower in the TM group differing by -1.7 cm (95% CI; -2.9; -0.4), and the p-value was 0.01. There were no statistically significant interactions between the chronic condition (T₂D/CAD/HF) and the treatment group in any of the clinical outcomes.

8 Discussion

8.1 Summary of main findings

The purpose of this thesis was to investigate the effect of TM interventions, which combined TM with differential patient decision support components, on health-related outcomes in individuals with T₂D, HF or CAD. The three RCTs, conducted as a part of this work, demonstrated the following results:

- ♦ Adherence to the TM interventions was moderate to high. In the Mobile Sipoo (I) and Heart at Home (II) studies 80–90% of participants adhered to weekly TM throughout the follow-up. In the Renewing Health study (III, IV) participants monitored their health parameters on 65% of the weeks, and 66% of participants received health coaching calls as scheduled.
- ♦ TM combined with automatic, real-time, behavioral theory based feedback messages improved the glycemic control of individuals with T₂D with a reduction of 0.44 percentage points in HbA_{1c}. However, there was no significant difference in blood pressure levels between the TM and the standard care arms (I).
- ♦ TM combined with automatic, real-time, information-oriented feedback messages did not reduce HF-related hospital admissions in individuals with HF. Instead, the TM arm demonstrated increased use of healthcare resources reflected as a higher number of appointments and phone calls with the HF nurse and more unscheduled visits to the cardiology clinic (II).
- ♦ TM combined with monthly telephone-based health coaching did not improve the HRQoL of individuals with T₂D, HF or CAD or glycemic control of individuals with T₂D (III).

8.2 Methodological considerations

8.2.1 Study design

Randomization is the gold standard design for clinical trials, and one of the strengths of the present study. When properly conducted, it eliminates selection bias, and balances the groups with respect to many known and unknown confounding factors (Schulz & Grimes, 2002). Designing studies as RCTs also helps to avoid bias caused by the Hawthorne effect, that is, the control arm showing improvements in their health outcomes because the patients know they are being followed. In this work, the use of a pre-post study design would have resulted in biased conclusions about the superiority of TM intervention, underlining the importance of controlled designs.

It has been estimated that studies with inadequate or unclear randomization procedures tend to overestimate treatment effects up to 40% compared with those that use proper randomization (Schulz, Chalmers, Hayes, & Altman, 1995). To reduce the selection bias and the likelihood of such biased positive results, the generation of random sequence and concealing the allocation should be ensured and described transparently (Schulz & Grimes, 2002). In all three studies of the present work, the randomization was done after the initial agreement from potential participants was obtained. In the Renewing Health (III) and Mobile Sipoo (II) studies, the study personnel created a list of eligible participants that was further sent to the statistician for randomization. The statistician was not involved in clinical work or recruitment. Thus, there was no chance that clinical staff could have intervened in the allocation based on their prior knowledge about the individuals. The concealment procedure was conducted only in the Renewing Health study (III), where the allocation information was concealed in a closed envelop and opened at the baseline visit. In the Heart at Home study (II), the HF nurse identified potential participants using the database and formed matched pairs according to the most important prognostic factors. The nurse further conducted the randomization of each pair. To minimize the theoretical risk that the nurse could have interfered with the allocation and thus biased the selection, structured instructions were given and the process was made as transparent as possible.

8.2.2 Baseline characteristics

To avoid baseline differences that may be sources of confounding in small studies in particular (Senn, 1994), stratified randomization was used in the Mobile Sipoo (I) and Renewing Health (III), and a matched pair design in the Heart at Home study (II). Despite the randomization, the baseline characteristics slightly differed between the treatment arms in the Mobile Sipoo study (I). In the TM group there were fewer individuals with insulin medication and they had lower BMIs and higher levels of blood pressure. All analyses were done by adjusting for the baseline level of the outcome variable to control for confounding.

Further adjustments for baseline imbalances did not change the results. The baseline level of HbA_{1c}, which was the primary outcome, was similar between the TM and standard care groups

In the Heart at Home study (II), the HF nurse screened eligible participants using the database and formed matched pairs according to prognostic factors including sex, age, LVEF and NYHA classification. This approach resulted in balanced groups with respect to the important prognostic factors. However, there was a considerable reduction in the sample size; approximately 10% of patients were excluded because no matched pair was found.

In the Renewing Health study (III) no imbalances were observed between the treatment arms in any of the prognostic variables in the three conditions (T₂D, HF, CAD). Patients with T₂D had higher BMIs and a lower proportion of them were male compared to the patients with HF and CAD. However, these differences did not affect the outcome variables.

The ceiling effect, which refers to a point at which the health status of a patient is already so good at baseline that any further improvement becomes hard to detect (Frost et al., 2005), might be a factor that contributed to the neutral findings in the Heart at Home (II) and Renewing Health (III) studies. In the Heart at Home (II) participants received multidisciplinary care at the university hospital and they were residents of the capital area. Given the high quality of the standard care and availability of the healthcare services, there was little room for improvement. Moreover, the HF patients were relatively stable, which was reflected in low hospitalization rates and no deaths during the 6-month follow-up. The results showed that the weekly monitoring of vital signs did not provide benefits over the standard care at the cardiology clinic. TM could be more beneficial for patients whose health condition is poorly managed. For example, newly diagnosed patients who are starting to learn to monitor and interpret their health parameters may benefit from such TM intervention. It has also been suggested that TM might be more effective among high risk patients with poor prognosis (Cleland et al., 2005; Dendale et al., 2012). In the Renewing Health study, as well as in the Mobile Sipoo study, the inclusion criteria for all individuals with T₂D was HbA_{1c} > 6.5%, and the baseline levels of HbA_{1c} were 7.3% and 7.1%, respectively. According to the guideline recommendations, the target level for HbA_{1c} in T₂D patients is < 7.0%, or < 6.5% for individuals without additional risk factors (American Diabetes Association, 2018a; International Diabetes Federation, 2017b). Thus, both the Renewing Health study and the Mobile Sipoo study likely included participants whose HbA_{1c} was already so low that they had little room to improve their glycemic control. In fact, it has been recommended that remote patient monitoring interventions in T₂D patients should target individuals whose HbA_{1c} is above 7.5% (Greenwood et al., 2014). Nevertheless, significant improvements have been seen in other TM studies where the baseline level of HbA_{1c} has been close to 7% (Waki et al., 2014), and the results of the Mobile Sipoo (I) study are in line with these findings; despite the relatively well-balanced

glycemic control of the Mobile Sipoo participants, the TM group showed an improvement in HbA1c and in weight and waist circumference (I).

8.2.3 Validity of outcomes

The use of SF-36 in assessing HRQoL in the Renewing Health study (III) requires further discussion. The motivation for the use of SF-36 was to include a generic outcome in the European Renewing Health project to simultaneously assess heterogeneous patient populations that do not share common targets for optimal management or a common measure to reflect positive health status. However, SF-36 might have been too generic to reflect changes in HRQoL in individuals with different chronic conditions. Instead, disease-specific instruments that include aspects closely related to a specific condition, such as the Minnesota Living with Heart Failure questionnaire (Riegel et al., 2002), the Kansas City Cardiomyopathy Questionnaire (Green et al., 2000), and the Diabetes Distress Scale (Polonsky et al., 2005), could have provided more robust outcomes by being more sensitive to changes in patients' health. Of the five HF studies that reported significant improvements in HRQoL, four used instruments other than SF-36 (Jayaram et al., 2017; Ong et al., 2016; Seto et al., 2012; Villani et al., 2014).

8.2.4 Generalizability

All studies were pragmatic trials conducted parallel with routine clinical practice, which is one of the strengths of this work. Incorporating the intervention components into the standard care provision increases the external validity of the studies, the lack of which is a frequent criticism of highly controlled clinical trials conducted in specialized research settings with a carefully selected patient population (Rothwell, 2006). The implementation of the TM intervention required additional efforts to educate healthcare providers to use the technology and to incorporate it as part of their care routines. Sufficient resources should be ensured when designing pragmatic trials.

The generalizability of the findings in the Renewing Health study (III) is limited by the low participation rate and the majority of participants in the heart disease group being CAD patients. The low number of HF patients indicates selective participation. Potential participants were screened using individuals' diagnosis codes and individuals with CAD and HF were invited accordingly. Nonetheless, 84% of the participants in the heart disease group were CAD patients. Individuals with HF are typically older with poorer prognosis, which might have affected their willingness and ability to partake in the study. In addition, TM required experience in using a mobile phone, which is less common among older individuals. The importance of having appropriate IT skills is also supported by the findings of the drop-out analysis, which showed that individuals who were not familiar with mobile

phones were more likely to drop out. The overall response rate in the recruitment phase of the Renewing Health study was 29%, which is lower than seen in some TM studies (Bekelman et al., 2015) but not in all (Stone et al., 2010). These findings imply that the results of the Renewing Health study may not be generalized to all patients with T2D or CAD but to a subgroup of those who are able to conduct self-monitoring and have the ability to use mobile phones to report their measurement data. These individuals are presumably more motivated to improve their self-management. Furthermore, the results for individuals with HF represent a specific subgroup of individuals who are presumably healthier with a better prognosis. The low response rate in the Renewing Health study and the difficulties with patient recruitment in the Mobile Sipoo study demonstrate the challenges in recruiting participants to clinical trials. This is not always anticipated by researchers, who tend to assume that their new treatment/technology will appeal to potential participants. Sufficient resources and time for recruitment should be therefore ensured and carefully-defined inclusion criteria used to maximize participation rates.

In the Heart at Home study (II) participants were customers at the cardiology clinic at the Helsinki University Central Hospital where each patient received multidisciplinary care. They were all residents of the Helsinki metropolitan area and thus had better access to healthcare services than individuals living in remote areas. Generalization of the findings of the Heart at Home study is therefore limited to exclude other parts of Finland where access to such high quality healthcare is generally not as readily available. Typically, individuals with HF are customers at the healthcare centers where resources and the possibility to provide multidisciplinary are relatively limited, as was the case in Renewing Health study, the participants of which likely had a lower standard of care compared to Heart at Home study participants.

In the Mobile Sipoo (I) and Heart at Home (II) studies, no information was available concerning the number and characteristics of patients who were screened but not enrolled in the studies. In the Heart at Home study, all participants who were contacted agreed to participate in the study (compare to the response rate of 29% in the Renewing Health study). In addition, the lack of information on the reasons for exclusions prevents further assessment of potential selection bias.

An important consideration in the Mobile Sipoo study (I) is the small sample size of 51 participants. Although the findings on the positive effect of the automatic feedback system are appealing, the results need to be confirmed with a larger sample to ensure the feasibility of such a system when applied large scale and in different sites.

8.3 Results in relation to other studies

The Mobile Sipoo intervention that linked TM data with automatic, real-time, behavioral theory based feedback messages improved glycemic control of individuals with T2D by reducing HbA_{1c} by 0.44 percentage points (I). The observed difference is comparable with

glycemic outcomes in other TM studies in T2D patients where the reductions typically varied from 0.4 to 0.6 percentage points (Greenwood et al., 2015; Lim et al., 2011; Nicolucci et al., 2015; Stone et al., 2010; Waki et al., 2014; Wild et al., 2016). Effect of similar magnitude has also been found in a systematic review by Marcolino et al. (2013) that demonstrated a decrease 0.44 percentage points. The improvement in the present study was higher than 0.3 percentage points, which is accepted to be of clinical importance (Klonoff et al., 2008). However, some guidelines consider 0.5 percentage points to be of clinical relevance (Little, Rohlfing, Sacks, & National Glycohemoglobin Standardization Program (NGSP) Steering Committee, 2011).

The Mobile Sipoo intervention (I) was similar to the intervention by Quinn et al. where participants received real-time educational, behavioral and motivational messaging and consistently demonstrated a decreased HbA_{1c} of 1.2 percentage points (Quinn et al., 2011). Furthermore, neither of these studies improved blood pressure, although individuals in the Mobile Sipoo study were specifically instructed to monitor their blood pressure. Similarly, some other studies of T2D patients that have included TM of blood pressure have shown improved glycemic control without decreasing blood pressure levels (Nicolucci et al., 2015; Stone et al., 2010; Waki et al., 2014). In the Mobile Sipoo study (I), the reduction in systolic blood pressure was 3.6 mmHg that is comparable to the effects typically observed with lifestyle changes (Whelton et al., 2018). However, the variability across individuals was high. The reductions in weight and waist circumference, in conjunction with HbA_{1c}, imply that the improved glycemic control was attributable to lifestyle changes rather than adjustments in diabetes medication. This is also supported by the fact that only five patients telemonitored their blood glucose, and thus only these patients provided healthcare providers with additional data to adjust their diabetes medication.

The TM intervention in the Heart at Home study (II) did not result in a statistically significant reduction in hospital admissions, which is in line with results seen in the majority of TM studies in individuals with HF (Bekelman et al., 2015; Chaudhry et al., 2010; Dar et al., 2009; Koehler et al., 2011; Kotooka et al., 2018; Lyngå et al., 2012; Mortara et al., 2009; Ong et al., 2016; Seto et al., 2012). Although the reduction was not statistically significant, the magnitude of the effect imply that the TM intervention had a protective effect on HF-related hospitalization with an IRR of 0.8. The effect was of similar magnitude to the pooled effect reported in a systematic review where the risk reduction for HF-related hospitalizations was 0.71 (95% CI: 0.60 to 0.93) (Inglis et al., 2015). Moreover, none of the participants died during the 6-month follow-up in the Heart at Home study. This was contrary to expectations given that one third of individuals with HF die within one year (Chen et al., 2011) and even 1-month mortality can be as high as 7% (Savarese & Lund, 2017). The participants in the Heart at Home study (II) were not recruited from hospital but invited to the study regardless of the time since their last hospital admission. Thus, the participants may have had better prognosis when compared to the recently admitted patients. Their clinical characteristics nevertheless indicated poor prognosis; mean LVEF

was 28% and 60% of participants had NYHA class III or IV. In one study, patients whose LVEF was below 40% had a 1-month mortality of approximately 4%, with the risk of death increasing linearly with decreasing LVEF (Toma et al., 2014).

The number needed to treat with the TM intervention to prevent one HF-related hospitalization was 10 in the Heart at Home study (II). Given the non-invasive nature of the TM intervention, ease of delivery and the potential for increased availability of healthcare services through TM, the NNT number seems to be appealing. However, the substantial increase in the use of nurse resources outweighs the potential benefits. The intervention almost doubled appointments with the HF nurse, tripled the number of unscheduled visits to the clinic, and initiated more phone contacts with the patient. Treating ten patients with such intervention would result in 18 additional nurse appointments, 40 additional phone calls, and 27 more unscheduled visits to the clinic. These figures suggest that such an investment of resources is not cost-effective, especially as the reduction in HF-related hospitalization could be due to chance, as the p-value of 0.22 indicates. Moreover, the confidence interval of the NNT showed that if 15 patients were treated with TM, one patient is likely to benefit more from the current care.

The increased use of healthcare resources found in the Heart at Home study (II) has also been seen in other TM studies regardless of the chronic condition studied (Cleland et al., 2005; Wakefield et al., 2011; Wild et al., 2016). These results suggest that additional resource investment is required if TM is implemented as part of standard care. Whereas nurse-initiated calls were mainly attributable in the present study to promoting adherence and assessing the need for an additional appointment, the reasons for patient-initiated calls are likely to be multifaceted. Patients called the nurse to ask for help with interpreting their TM data (II). However, TM may in some cases increase dependence on the healthcare professionals, reinforcing the sick role and creating dependence on TM rather than promoting self-management (Fairbrother et al., 2013). The increased number of contacts might also reflect patients' loneliness and need for social contact. It has been proposed that patients find the presence of TM comforting and that it reduces anxiety and depression, which are common in HF patients in particular (Inglis et al., 2015; Ponikowski et al., 2016). These aspects are important considerations and should be investigated more detailed in the future TM studies. Although increasing the burden of the HF nurse, increased contacts might improve HRQoL, which was not measured in the Heart at Home study (II).

The intervention that combined TM with health coaching did not improve HRQoL or glycemic control in patients with T2D (III). This result is in line with other studies, in particular those conducted under the European Renewing Health project (Kidholm et al., 2014). The TM interventions by Holmen et al. and Lindberg et al. involved blood glucose TM and health counselling, and neither of these studies showed improved HRQoL outcomes or glycemic control (Holmen et al., 2014; Lindberg et al., 2017). Both authors discussed whether the ceiling effect regarding HbA_{1c} (the inclusion criteria for Holmen et al. and Lindberg et al. was HbA_{1c} > 6.5% and ≥ 7.1%, respectively) had contributed

to their results. On the other hand, some TM interventions have enhanced HRQoL (Dario et al., 2017; Nicolucci et al., 2015; Olivari et al., 2018; Ong et al., 2016; Seto et al., 2012). One study showed a statistically significant improvement in the MCS of SF-36 but not in the PCS of SF-36 in patients with T2D (Nicolucci et al., 2015). Dario et al. and Olivari et al. demonstrated increased HRQoL. However, both of these findings lacked clinical significance as the SF-36 scores differed by less than the three points needed to be considered of clinical relevance (Dario et al., 2017; Olivari et al., 2018). The study by Ong et al. combining TM with health counselling improved HRQoL in individuals with HF. However, in that study the authors reported that the survey non-respondents differed from the survey respondents in their baseline characteristics, which may have affected the outcomes (Ong et al., 2016). One possible factor contributing to the positive HRQoL effects in the study by Seto et al. could be the automatic instructions sent immediately after each data submission (Seto et al., 2012). The timely instructions likely improved patients' self-management which further improved the HRQoL as discussed by the authors (Seto et al., 2012). In the present study (II), two common reasons for patient-initiated calls to the HF nurse included asking for help interpreting measurements and asking for help making changes to diuretic medication (II). To minimize confusion, the provision of instructions, such as those provided by Seto et al., might result in improved HRQoL.

The health coaching component in the Renewing Health study (III) was similar to the TERVA trial that was conducted four years earlier, and which showed no difference in any clinical outcomes except diastolic blood pressure, which more frequently improved in the intervention arm (Patja et al., 2012). In the present study (III), the only statistically significant difference was observed in waist circumference. However, the difference of -1.7cm in waist circumference lacked clinical significance, and could be attributable to measurement error (Verweij, Terwee, Proper, Hulshof, & van Mechelen, 2013). Moreover, the finding may have come about due to multiple testing rather than reflecting a true positive effect of the intervention.

8.4 Adherence to the telemonitoring interventions

Adherence to an intervention is a key determinant of its efficacy (World Health Organization, 2003). Adherence to the TM intervention was high in the Mobile Sipoo (I) and Heart at Home (II) studies with 80–90% of participants recording their health parameters on a weekly basis. In both of these studies, and in line with several other TM studies, adherence was specifically promoted (Chaudhry et al., 2010; Lim et al., 2011; Lyngå et al., 2012; Nicolucci et al., 2015; Ong et al., 2016; Seto et al., 2012; Waki et al., 2014). In the Heart at Home study (II), the HF nurse was responsible for all participants and for all practicalities, and was thus actively involved with the intervention. The HF nurse contacted the patients if they did not submit data, whereas in the Mobile Sipoo study the feedback messages encouraged patients to continue with TM. In both of these

studies, the number of participants was rather small. When applied large-scale, as in the Renewing Health study (III), the possibility of the healthcare professionals to intervene and actively promote self-management is limited and resource-intensive. In the Renewing Health study (III), efforts to improve patients' adherence to the TM intervention were made through monthly health coaching calls rather than promptly reacting to missing data. Consequently, adherence rates were lower than in the other two studies (I and II), varying from 51% to 68% during the 12-month intervention (IV). Typically, TM studies have shown adherence rates of approximately 80% in patients with HF, and from 40–80% in individuals with T2D. In the Renewing Health study, adherence to health coaching was 66%, i.e. two thirds responded to the calls as scheduled. Adherence to health coaching was similar to the study by Ong et al. (2016), but clearly lower than the adherence to monthly health counselling in the study by Holmen et al. in which all participants received health counselling as scheduled (Holmen et al., 2014).

High attrition rates that increase towards the end of the follow-up are typical of eHealth interventions in particular (Eysenbach, 2005). Interestingly, there was no major attrition in any of the three studies of this work (I–IV), and the percentage of adherent participants remained at approximately the same level until study completion. Adherence measures in TM studies frequently rely on aggregated parameters, as reported for instance in (Koehler et al., 2011; Seto et al., 2012; Waki et al., 2015), or on reporting the proportion of patients who never used the system (Chaudhry et al., 2010) or used the system at least once (Tang et al., 2013). Often, adherence is not reported at all, which is more common in TM studies in T2D (Holmen et al., 2014; Lindberg et al., 2017; Quinn et al., 2011). The aggregated adherence rates do not necessarily reflect sustained use which has been linked with improved outcomes (Bradway et al., 2018; Mattila et al., 2013). One of the strengths of the current work is its time-varying description of adherence as recommended in the eHealth consort statement (Eysenbach, 2011).

The adherence analysis of the Renewing Health data (IV) showed that adherence to TM was not associated with changes in HRQoL or HbA1c. In other words, the health outcomes remained similar regardless of whether the participants were actively involved with the weekly TM or did not record their health parameters at all, or with low intensity. These findings are in line with many TM studies of individuals with HF that have shown high adherence rates without improved survival or reduced hospitalization (Kotooka et al., 2018; Lyngå et al., 2012; Mortara et al., 2009; Olivari et al., 2018). Similarly, in a study by Stone et al. (2010) the intensity of TM of blood glucose was not associated with changes in HbA1c. These results suggest that TM per se might not be effective in improving clinical outcomes.

A notable difference between the studies of this work and the majority of other TM interventions is the intensity of TM. In this work, participants were instructed to measure and report their health parameters on a weekly basis (except glucose monitoring in the Mobile Sipoo study, which was done three days per week), whereas other TM studies have

typically used daily TM. While adherence rates were high in the Mobile Sipoo and Heart at Home studies (I, II), the absolute intensity of self-monitoring remained lower than in other TM studies. It is open to further investigation whether more intense TM would have resulted in improved outcomes. An optimal frequency for self-monitoring is rarely defined and depends on the condition and exploitation of the self-monitored data. For example, weight monitoring for patients with HF is assumed to provide signs of fluid retention and enable early intervention if needed. Therefore, daily weight monitoring is recommended to provide sufficient data to distinguish fluid retention from normal weight variation (Ponikowski et al., 2016). The weight monitoring intensity in the Heart at Home study (II) deviated from the guideline recommendations, which might be a reason for the lack of change in hospitalization rates. It is possible that weekly weight recordings did not provide accurate information to further prevent hospitalizations in the TM arm. Regarding other health parameters, there are no guideline recommendations for optimal monitoring frequency. For example, regular self-weighing at a specified intensity is recommended to support weight loss, and frequent (weekly or more often) self-weighing is recommended to support weight loss maintenance (Jensen et al., 2014). Regarding T2D, individual skills, treatment recommendations and the exploitation of the TM data in clinical decision making are emphasized rather than intensity as such (American Diabetes Association, 2018a). Moreover, rather than focusing on the intensity of TM, other aspects such as educational components, long-term adherence, or efforts made in response to the self-monitored data might be more relevant in promoting health outcomes in TM interventions (Bradway et al., 2018; Donkin et al., 2011).

It is important to note that adherence measures used in this study likely underestimated the true exposure to the TM interventions. In all three studies, the TM intervention involved measuring 3–5 health parameters once a week. However, the monitored health parameters were individually defined in each patient’s self-management plan based on their needs and treatment targets. Patients did not necessarily monitor all health parameters if they were not expected to gain benefit from TM. The individual self-management plans were not available for the analysis, and, thus, adherence was defined as monitoring and reporting at least one health parameter once in a week. The intensity of TM was likely to be higher when multiple health parameters were monitored.

8.5 Patient decision support in telemonitoring interventions

It seems that TM studies in individuals with HF have focused on collecting data and transmitting the data to the providers’ use rather than supporting individuals’ self-management efforts along TM. Only one study included automatic feedback messages sent to the participants (Seto et al., 2012). Instead, the feedback involved healthcare professionals who contacted the patient if the data exceeded the target values (Dar et al., 2009; Lyngå et al., 2012), or, more frequently, only the healthcare professionals were informed about the

data and took appropriate actions (Chaudhry et al., 2010; Cleland et al., 2005; Dendale et al., 2012; Kotooka et al., 2018; Mortara et al., 2009; Olivari et al., 2018; Seto et al., 2012). The lack of feedback and specific recommendations to patients might be reflected in the results as the majority of the TM interventions in HF patients did not achieve positive health outcomes. On the contrary, the TM interventions in individuals with T2D included differential feedback components, delivered either automatically or by involving healthcare professionals, and these TM interventions achieved improved health outcomes more frequently (Crowley et al., 2016; Greenwood et al., 2015; Lim et al., 2011; Nicolucci et al., 2015; Quinn et al., 2011; Waki et al., 2014).

In the Heart at Home study (II), TM invoked patients' interest in their condition and raised questions that resulted in an increase in the use of healthcare resources: the number of appointments and phone calls with the HF nurse were two to five times higher in the TM group. Each time the patient submitted data, (s)he was provided with a short feedback message illustrating longitudinal trends and guiding the patient as to whether their measurements were within the predefined target values. It seems however that these feedback messages did not provide sufficient decision support and that patients needed more detailed advice in order to understand their data and manage their condition.

More intense exploitation of the TM technology could have lessened, at least to some extent, the increased workload of the HF nurse seen in the Heart at Home study (II). In that study, the HF nurse called the patient if TM data was missing, indicating that the high number of nurse-initiated phone calls were partly attributable to efforts to promote adherence. To lessen this workload, automatic reminders could be used to remind patients of the importance of the TM and encourage them to continue with it. Yet, only one TM study has used automatic reminder messages to advance adherence (Lim et al., 2011). Instead, low adherence or missing TM data have generated calls to the patients and/or healthcare providers (Chaudhry et al., 2010; Seto et al., 2012). Furthermore, the content of the automatic feedback messages could be enhanced with recommendations and self-management instructions (such as adjustments to diuretics) to overcome possible confusion arising from self-measurements. The results of the Mobile Sipoo study (I) demonstrate the potential of tailored feedback messages with more enhanced content. Each time the patient submitted data, (s)he received a feedback message that included information summarizing the longitudinal trends in their self-monitoring data along with content aimed at motivating the patient to act on this information and helping foster the behavioral skills needed for them to act on their self-management efforts. This TM intervention improved glycemic control and reduced weight and waist circumference in individuals with T2D. However, it is important to note that although positive results in clinical outcomes were achieved in the Mobile Sipoo study (I), it is not known whether healthcare utilization remained similar or lower, or even increased, when automatic decision support was introduced because these data was not analyzed.

The content of the feedback messages in the Mobile Sipoo study were built on the IMB model. Theory-based interventions are known to increase the efficacy of interventions (Webb et al., 2010) and the importance of including a theoretical framework in technology-assisted interventions is emphasized (Burke et al., 2015; Winter et al., 2016). Building an automatic feedback system according to the behavioral principles of the IMB model was a novel approach when the automatic feedback system was developed in 2011. Still in 2018, TM studies rarely describe the behavioral theories behind the feedback components; instead, the theoretical grounds or behavioral techniques of TM studies have been typically reported in the context of health counselling programs (Holmen et al., 2014; Lindberg et al., 2017).

Besides building the content of the feedback messages on the IMB model, another aspect that likely contributed to the positive health outcomes in the Mobile Sipoo study was the timely delivery of the feedback messages (I). An immediate feedback response to self-monitored data is important (Gee et al., 2015; Jimison et al., 2008). In the Mobile Sipoo study, each time the patient submitted data, they received a feedback message guiding and motivating them to take action in response to their TM data (I). In the Heart at Home and Renewing Health studies participants received either an information-oriented feedback message sent immediately in response to their recorded data, or did not receive immediate feedback at all; neither of the studies improved health outcomes. In those studies, support and instructions to take action in response to the TM were subject to the patient's own activity or were provided with a delay. In the Heart at Home study (II), the participants contacted the HF nurse themselves if they had a question or needed advice, which was reflected in a two times higher number of patient-initiated calls in the TM arm. In the Renewing Health study (III), the participants received health coaching calls every 4–6 weeks, which is a considerably long response delay to possible questions arising from weekly TM. These findings emphasize the importance of delivering feedback in a timely manner rather than reacting to data when there is a need for an intervention, or delivering delayed feedback, thus, increasing the risk of losing so-called teachable moments, when feedback would be most relevant and beneficial.

8.6 Integrating telemonitoring as a part of standard care

The importance of the interoperability of different components in organizing chronic care is highlighted in the Chronic Care Model (Bodenheimer et al., 2002). Integrating TM as a part of current care and enabling efficient use of the TM data is one of the pre-requisites of efficient chronic care management.

In the Mobile Sipoo study, the TM data and the feedback messages sent to the patients were shared with the healthcare professionals who were instructed to review the data on a weekly basis (I). High priority feedback messages typically triggered in response to alarming values were specifically highlighted. However, the responsibility to seek care remained with

the patient. In the Heart at Home study (II), the HF nurse was responsible for managing all study participants and worked full-time at the cardiology clinic. The HF nurse reviewed the patients' TM data and contacted them if needed. The nurse was able to react to the TM data and advise individuals on, for example, adjusting diuretics or making an appointment with an HF physician.

In the Renewing Health study (III), the TM data was underutilized. Access to the TM data was available only to the patients and their health coaches and not to the clinicians who remained responsible for the patients' care. The health coaches reviewed the TM data prior to each coaching call and discussed them with the patient during the call. If the data indicated problems with self-management or a need to intensify treatment, the health coach advised the patient to make an appointment with their clinician for further assessment. Changes in medication, for example, were not suggested or approved by the health coach even if the self-monitoring data indicated such a need. The patients' own clinicians did not, however, have access to this TM data, and were therefore unable to directly assess the need for changes in treatment regimens. This lack of integration and subsequent underutilization of the TM data might have influenced the neutral health effects seen in the Renewing Health study (III). Many studies have shown that TM interventions are effective when TM data are exploited for adjusting medications for glycemic control (Crowley et al., 2016; Greenwood et al., 2015; Lim et al., 2011; Shea et al., 2009; Stone et al., 2010; Wild et al., 2016). As the clinicians have better pre-existing knowledge about their patients, sharing the TM data with them could have led to more efficient use of the data.

Nevertheless, it should be noted that despite the fact that the TM data was integrated with clinical work in the Heart at Home study, neither self-care behaviors nor clinical outcomes were improved and hospital admissions were not reduced. However, more medication changes were made in the TM arms (II), which might reflect effective exploitation of the TM data.

8.7 Future research

Based on this work, the use of automatic feedback systems in combination with TM interventions has the potential to promote the management of chronic conditions. More research is needed to develop TM interventions with automatic feedback systems that retain high adherence and deliver meaningful support and recommendations beyond 12 months. It should be studied whether automatic feedback messages with enhanced content could lessen the workload of healthcare professionals rather than increasing the use of healthcare resources, as was seen in the Heart at Home study (II), and what kind of content the feedback messages should have. Investigating the reasons for the increased contacts would guide the development of the feedback messages so that they contain tailored support for individual needs and concerns.

Achieving sustained adherence through technology without human involvement is not a simple task. In one study almost 30% of participants withdrew from the study and technological problems related to algorithm safety prevented a further 38% from participating (Skobel et al., 2017). In another study, 40% of participants requested receiving feedback messages before the end of the study (Arambepola et al., 2016). Novel aspects are needed to provide patients with relevant, appealing and helpful feedback and recommendations in a way that the messages do not repeat themselves but support individuals' self-management efforts long-term. To enrich the content of the feedback messages, one possibility is to identify individual patterns in the TM data that correlate with changes in the patient's health status. One such approach is the analysis of missing data. Major declines in adherence or non-usage attrition might indicate a change in patient health status (Sperrin et al., 2016) which, in fact, would call for patient support or review, rather than a boost in adherence. Feedback messages may also target aspects other than physical health and related behaviors, which were the focus in the Mobile Sipoo study. For example, assessing and enhancing self-efficacy and confidence with self-management behaviors, both of which mediate behavior change, could be a valuable feature of automatic feedback messages.

Future studies should also consider adaptive study designs. As technology evolves rapidly over time, the use of adaptive designs that include pre-specified modifications of the design or statistical procedures of an on-going trial based on the data generated (Chow, Chang, & Pong, 2005) would be beneficial for telehealth studies. The use of multi-arm trials with pre-defined interim analyses to modify or stop treatment would be an efficient approach to assess intensity trials with different telehealth components. Based on pre-defined rules, components that do not work would be accordingly dropped while the others are retained and possibly developed further (Law & Wason, 2014). In addition, it is important to acknowledge the complex nature of telehealth interventions, which typically include and target multiple behaviors and multiple parties. The pharmacological analogy should be avoided in such interventions; instead, for example, sample size calculations and expected outcomes should be based on similar multifaceted interventions to ensure sufficient power for the studies. Also, effective engagement (Yardley et al., 2016) should be thoroughly studied and defined accordingly. Adherence could be an outcome in telehealth studies rather than a process variable, as used in this work.

Many studies conduct per-protocol analyses post hoc to assess the efficacy of the intervention by investigating the effect among those participants who were adherent and completed the study. This is common in telehealth studies where detailed information on adherence is available through log data. While such per-protocol analyses are important and guide the development of effective treatment components, they have weaknesses. Per-protocol analyses might overestimate the effect of optimal use as there is no randomized control group, and thus the comparison may be biased towards factors that contribute to attrition in the first phase, such as low motivation or poor health status. An appealing

approach for investigating efficacy is the use of the Run-in and Withdrawal Design originally proposed by Eysenbach in 2005 (Eysenbach, 2005). Briefly, Run-in and Withdrawal Design involves two randomization phases where the first phase refers to the conventional approach in which effectiveness is assessed by comparing participants assigned to the intervention arm to those assigned to the control arms. After the follow-up, individuals who continue to adhere to the intervention are further randomized into two groups: those who continue to receive the intervention and those from whom the intervention is withdrawn. The second randomization phase provides information on efficacy that is not biased towards unmeasured factors related to attrition. Moreover, using the Run-in and Withdrawal design, the health effects would not be limited to a single group but compared with control patients who are willing and capable of continuing with the intervention. The challenge for such designs is to achieve a sample size that retains sufficient power for the second-phase analyses. Well-designed pilot studies are clearly needed to obtain sensitive estimates of the proportion of participants who are likely to adhere to the intervention and continue to the second phase.

9 Conclusions

- Combining TM with real-time, behavioral theory based feedback messages enriched with tailored self-management information as well as motivational and behavioral skills enhancing content improved glycemic control of individuals with T2D with a reduction of 0.44 percentage points in HbA1c, and decreased body weight and waist circumference. However, blood pressure levels were not affected by the TM intervention.
- Combining TM with real-time, information-oriented feedback messages did not reduce HF-related hospital admissions in individuals with HF. Instead, the TM intervention demonstrated increased use of healthcare resources reflected in a higher number of appointments and phone calls with the HF nurse and more unplanned visits to the cardiology clinic.
- A combination of TM and individualized monthly health coaching did not improve the HRQoL of individuals with T2D, HF and CAD. Neither did it improve glycemic control of individuals with T2D.
- Adherence to weekly TM was moderate to high in all of the studies, and there were no major declines in adherence rates over time. These results imply that weekly TM of chronic condition related health parameters is feasible.
- Nevertheless, high adherence does not guarantee positive health effects. Two of the studies showed no improvement in health outcomes despite the participants' active engagement in weekly TM. Moreover, adherence to TM did not correlate with improved health outcomes, i.e. health outcomes remained similar regardless of the intensity of TM.
- Putting the results together, the findings suggest that the positive health effects in TM studies may be related to differential patient decision support components provided in response to the TM data. Improvements in health outcomes were seen only in one of the studies where individuals received real-time tailored feedback messages that motivated and guided them to take actions in response to their

self-monitoring data. These findings suggest that delivering timely feedback with enriched content is important.

- ◆ Moreover, the positive findings of the Mobile Sipoo study (I) emphasize the importance of building TM interventions on a theoretical basis, even to be applied when developing automatic feedback systems. However, the sample size in the Mobile Sipoo study was small, and thus the results need to be confirmed in larger RCTs.
- ◆ TM might increase the use of healthcare resources, particularly nurse contacts. Therefore, sufficient resources should be ensured when implementing TM as a part the care chain. Moreover, the benefits gained through TM should be carefully evaluated in the light of other findings and the requirement for investment in additional resources. In the Heart at Home study (II) the increase in the use of healthcare resources was substantial and was unlikely to be compensated by reduced hospitalization rates.
- ◆ More intense exploitation of TM technology has the potential to lessen, at least to some extent, the increased workload of healthcare professionals. By enhancing the content of the automatic feedback messages with tailored recommendations for individual needs and concerns, and preferably building on behavioral theory, individuals' self-management efforts could be further supported and their knowledge and skills enhanced, and the workload of healthcare providers thus also potentially minimized.
- ◆ It is important to target TM interventions at patients who are likely to adhere to them and likely to benefit from them. If the quality of the care is high and the chronic condition well managed, TM interventions are however unlikely to be superior to standard care.

10 Acknowledgements

This study was conducted at the VTT Technical Research Centre of Finland Ltd and at the Faculty of Social Sciences at Tampere University. I am grateful to the directors and team leaders of both institutions for providing me with excellent facilities and a nurturing research environment. I would like to express my gratitude to everyone who I had a chance to work with, and to learn from, during these years.

My sincerest gratitude to my supervisors Docent Susanna Lehtinen-Jacks, Dr. Miikka Ermes and Research Director Tapio Nummi. Susanna, I am deeply grateful for the mentorship you provided through our many discussions, and all the encouragement and motivation that I received from you. I admire your thoroughness and immense knowledge of epidemiology. I could not have imagined a better supervisor for my PhD project. Miikka, this work would have never seen daylight without your help. As my team leader you directed me towards projects that eventually led to this dissertation. I am grateful for all your help with the practicalities and for the discussions. Tapio, my first steps towards a PhD were taken with your help, thank you for enlightening my thoughts and encouraging me to start this project and for all your comments along the way.

I was privileged to do most of this work as part of the Care4me project led by Jaakko Lähteenmäki, Lic.Sc (Tech), co-author of all four papers. Thank you for all your support and advice through these years. You allowed me to focus on research which made it possible to do this PhD study. I particularly want to thank you for your timely and generous guidance throughout this process. I was privileged to have a mentor like you.

Heartfelt gratitude to Elina Mattila, D.Sc (Tech). Without your expertise, insightful comments and constructive feedback, this dissertation would have looked quite different. I enjoyed our invaluable discussions that were never too serious but left me full of ideas and with so many suggestions for improving my work.

I would like to extend my warmest gratitude also to Docent Ilkka Korhonen. I am deeply grateful for your encouraging comments and ideas when I started writing my second

publication. Most importantly, your advice on both my research and my career has been priceless.

I also owe my sincere thanks to Research Professor Mark van Gils. You have always been a go-to person, easy to approach with any problem, especially those concerning statistics which often led me to your door. You always had time to listen to my questions and share your wise thoughts. I admire your warm-hearted attitude, which makes any work with you so smooth and easy.

I was pleased to work with Juha Leppänen, MSc, Hannu Kaijanranta, MSc, Minna Kulju, MSc, Docent Kari Harno and Professor William Fisher when developing the feedback system in the Mobile Sipoo study. Thank you for sharing your expertise and providing me with many ‘teachable moments’ during the process.

My warm thanks to principal investigator of the Finnish Renewing Health project Tuula Karhula, MD, PhD and the core team Katja Rääpysjärvi, BEng, and Mira Viden, MSc, and Kari Kohtamäki, MSc, for providing me the opportunity to be involved in your project and for giving me so much responsibility.

I also wish to thank Holly Jimison and Misha Pavel for their constructive feedback and helpful comments for my work.

I wish to express my appreciation to the official reviewers of this thesis, Docent Kristiina Patja and Docent Jari Haukka. Thank you for your many helpful and enlightening comments and suggestions. Kristiina, I am also deeply grateful for the valuable opportunity to discuss my work with you.

None of the studies would have been possible without the huge efforts of the personnel working in the field and the funding received. I also wish to thank the personnel of the Cardiology Outpatient Clinic at Helsinki University Hospital, at the Sipoo healthcare center and at the healthcare centers of Eksote. I deeply appreciate the time and effort you all gave to the studies. I acknowledge the funding received from the Finnish Funding Agency for Technology and Innovation and from the European Commission Information and Communication Technologies Policy Support Programme (ICT PSP) 2009 of the Competitiveness and Innovation framework Programme (CIP). This work was also financially supported by personal grants from Doctoral Programs of Public Health, Kariston säätiö, Linnamon säätiö, Tampereen kaupungin tiederahasto and Tekniikan edistämissäätiö. All are gratefully acknowledged.

I am deeply grateful to my parents, Pirjo and Pertti, and my two brothers, Antti and Olli, for all your support throughout my life. Thank you, mum, for always being there for me. Throughout this journey, too, your help has been priceless. Dad, thank you for sharing your enthusiasm in my research—and also for the bountiful emails that definitely kept me up-to-date on this topic. I am also grateful to my parents-in-law, Maritta and Seppo, and to my aunt Minna for all the help you have provided me and my family during these years.

Without my friends, this journey would have been quite different. Thank you Jemina, Nina, Riikka and Tytti for being so supportive and sharing the ups and downs of work and

of life. I am also grateful to my friends from Orivesi. Thank you Anna, Kaisa, Mari, Minna and Tintti for your friendship ever since pre-school and for the so many happy, silly and funny memories over the years.

Most of all, I am grateful to my husband, Toni, for being so patient and understanding during this project. You were my greatest support. Thank you for all the laughs you brought, especially when the work was most intense. This project would not have been so much of schedules and arrangements with our two kids Aaron and Inka. Thank you for reminding me what is most important in my life. And thank you—all three—for bringing so much joy and laughter to my days.

11 References

- Altman, D. G. (1998). Confidence intervals for the number needed to treat. *BMJ*, *317*(7168), 1309–12.
- American Diabetes Association. (2018a). 6. Glycemic Targets: Standards of Medical Care in Diabetes—2018. *Diabetes Care*, *41*(Supplement 1), 55–64. <http://doi.org/10.2337/dc18-S006>.
- American Diabetes Association. (2018b). 8. Pharmacologic Approaches to Glycemic Treatment: Standards of Medical Care in Diabetes—2018. *Diabetes Care*, *41*(Supplement 1), 73–85. <http://doi.org/10.2337/dc18-S008>.
- American Diabetes Association. (2018c). 9. Cardiovascular Disease and Risk Management: Standards of Medical Care in Diabetes—2018. *Diabetes Care*, *41*(Supplement 1), 86–104. <http://doi.org/10.2337/dc18-S009>.
- Ammenwerth, E., Woess, S., Baumgartner, C., Fetz, B., van der Heide, A., Kastner, P., ... Poelzl, G. (2015). Evaluation of an Integrated Telemonitoring Surveillance System in Patients with Coronary Heart Disease. *Methods of Information in Medicine*, *54*(05), 388–397. <http://doi.org/10.3414/ME15-02-0002>.
- Anderson, L., Sharp, G. A., Norton, R. J., Dalal, H., Dean, S. G., Jolly, K., ... Taylor, R. S. (2017). Home-based versus centre-based cardiac rehabilitation. *Cochrane Database of Systematic Reviews*, *6*, CD007130. <http://doi.org/10.1002/14651858.CD007130.pub4>.
- Anderson, L., & Taylor, R. S. (2014). Cardiac rehabilitation for people with heart disease: an overview of Cochrane systematic reviews. In R. S. Taylor (Ed.), *Cochrane Database of Systematic Reviews*. Chichester, UK: John Wiley & Sons, Ltd. <http://doi.org/10.1002/14651858.CD011273.pub2>.
- Anderson, L., Thompson, D. R., Oldridge, N., Zwisler, A.-D., Rees, K., Martin, N., & Taylor, R. S. (2016). Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database of Systematic Reviews*. <http://doi.org/10.1002/14651858.CD001800.pub3>.
- Arambepola, C., Ricci-Cabello, I., Manikavasagam, P., Roberts, N., French, D. P., & Farmer, A. (2016). The Impact of Automated Brief Messages Promoting Lifestyle Changes Delivered Via Mobile Devices to People with Type 2 Diabetes: A Systematic Literature Review and Meta-Analysis of Controlled Trials. *Journal of Medical Internet Research*, *18*(4), e86. <http://doi.org/10.2196/jmir.5425>.
- Barlow, J., Wright, C., Sheasby, J., Turner, A., & Hainsworth, J. (2002). Self-management approaches for people with chronic conditions: a review. *Patient Education and Counseling*, *48*(2), 177–87. [http://doi.org/10.1016/S0738-3991\(02\)00032-0](http://doi.org/10.1016/S0738-3991(02)00032-0).

- Bauer, U. E., Briss, P. A., Goodman, R. A., & Bowman, B. A. (2014). Prevention of chronic disease in the 21st century: elimination of the leading preventable causes of premature death and disability in the USA. *The Lancet*, *384*(9937), 45–52. [http://doi.org/10.1016/S0140-6736\(14\)60648-6](http://doi.org/10.1016/S0140-6736(14)60648-6).
- Bekelman, D. B., Plomondon, M. E., Carey, E. P., Sullivan, M. D., Nelson, K. M., Hattler, B., ... Rumsfeld, J. S. (2015). Primary Results of the Patient-Centered Disease Management (PCDM) for Heart Failure Study. *JAMA Internal Medicine*, *175*(5), 725. <http://doi.org/10.1001/jamainternmed.2015.0315>.
- Blackledge, H. M., Tomlinson, J., & Squire, I. B. (2003). Prognosis for patients newly admitted to hospital with heart failure: survival trends in 12 220 index admissions in Leicestershire 1993–2001. *Heart (British Cardiac Society)*, *89*(6), 615–20.
- Blasco, A., Carmona, M., Fernández-Lozano, I., Salvador, C. H., Pascual, M., Sagredo, P. G., ... Alonso-Pulpón, L. (2012). Evaluation of a Telemedicine Service for the Secondary Prevention of Coronary Artery Disease. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *32*(1), 25–31. <http://doi.org/10.1097/HCR.0b013e3182343aa7>.
- Bodenheimer, T. (2005). Helping Patients Improve Their Health-Related Behaviors: What System Changes Do We Need? *Disease Management*, *8*(5), 319–330. <http://doi.org/10.1089/dis.2005.8.319>.
- Bodenheimer, T., Wagner, E. H., & Grumbach, K. (2002). Improving primary care for patients with chronic illness: the chronic care model, Part 2. *JAMA*, *288*(15), 1909–14.
- Bradway, M., Pfuhl, G., Joakimsen, R., Ribu, L., Grøttland, A., & Årsand, E. (2018). Analysing mHealth usage logs in RCTs: Explaining participants' interactions with type 2 diabetes self-management tools. *PLOS ONE*, *13*(8), e0203202. <http://doi.org/10.1371/journal.pone.0203202>.
- Braunstein, J. B., Anderson, G. F., Gerstenblith, G., Weller, W., Niefeld, M., Herbert, R., & Wu, A. W. (2003). Noncardiac comorbidity increases preventable hospitalizations and mortality among Medicare beneficiaries with chronic heart failure. *Journal of the American College of Cardiology*, *42*(7), 1226–33.
- Bujnowska-Fedak, M. M., Puchała, E., & Steciwko, A. (2011). The Impact of Telehome Care on Health Status and Quality of Life Among Patients with Diabetes in a Primary Care Setting in Poland. *Telemedicine and E-Health*, *17*(3), 153–163. <http://doi.org/10.1089/tmj.2010.0113>.
- Burke, L. E., Ma, J., Azar, K. M. J., Bennett, G. G., Peterson, E. D., Zheng, Y., ... Quinn, C. C. (2015). Current Science on Consumer Use of Mobile Health for Cardiovascular Disease Prevention. *Circulation*, *132*(12), 1157–1213.
- Burke, L. E., Swigart, V., Warziski Turk, M., Derro, N., & Ewing, L. J. (2009). Experiences of self-monitoring: successes and struggles during treatment for weight loss. *Qualitative Health Research*, *19*(6), 815–28. <http://doi.org/10.1177/1049732309335395>.
- Burke, L. E., Wang, J., & Sevick, M. A. (2011). Self-monitoring in weight loss: a systematic review of the literature. *Journal of the American Dietetic Association*, *111*(1), 92–102. <http://doi.org/10.1016/j.jada.2010.10.008>.
- Chaudhry, S., Matterna, J., Curtis, J., Spertus, J., Herrin, J., Lin, Z., ... Krumholz, H. (2010). Telemonitoring in Patients with Heart Failure. *New England Journal of Medicine*, *363*(24), 2301–2309. <http://doi.org/10.1056/NEJMoa1010029>.
- Chaudhry, S., Wang, Y., Concato, J., Gill, T. M., & Krumholz, H. M. (2007). Patterns of Weight Change Preceding Hospitalization for Heart Failure. *Circulation*, *116*(14), 1549–1554. <http://doi.org/10.1161/CIRCULATIONAHA.107.690768>.

- Chen, J., Normand, S.-L. T., Wang, Y., & Krumholz, H. M. (2011). National and Regional Trends in Heart Failure Hospitalization and Mortality Rates for Medicare Beneficiaries, 1998-2008. *JAMA*, *306*(15), 1669. <http://doi.org/10.1001/jama.2011.1474>.
- Chow, S.-C., Chang, M., & Pong, A. (2005). Statistical Consideration of Adaptive Methods in Clinical Development. *Journal of Biopharmaceutical Statistics*, *15*(4), 575-591. <http://doi.org/10.1081/BIP-200062277>.
- Clark, N. M., Becker, M. H., Janz, N. K., Lorig, K., Rakowski, W., & Anderson, L. (1991). Self-Management of Chronic Disease by Older Adults. *Journal of Aging and Health*, *3*(1), 3-27. <http://doi.org/10.1177/089826439100300101>.
- Cleland, J., Louis, A., Rigby, A., Janssens, U., Balk, A. H. M. M., & TEN-HMS Investigators. (2005). Noninvasive Home Telemonitoring for Patients With Heart Failure at High Risk of Recurrent Admission and Death. *Journal of the American College of Cardiology*, *45*(10), 1654-1664. <http://doi.org/10.1016/j.jacc.2005.01.050>.
- Coleman, K., Austin, B. T., Brach, C., & Wagner, E. H. (2009). Evidence on the Chronic Care Model in the new millennium. *Health Affairs (Project Hope)*, *28*(1), 75-85. <http://doi.org/10.1377/hlthaff.28.1.75>.
- Corbin, J., & Strauss, A. (1988). *Unending work and care: Managing chronic illness at home*. San Francisco, CA: Jossey-Bass.
- Couper, M. P., Alexander, G. L., Zhang, N., Little, R. J., Maddy, N., Nowak, M. A., ... Cole Johnson, C. (2010). Engagement and Retention: Measuring Breadth and Depth of Participant Use of an Online Intervention. *Journal of Medical Internet Research*, *12*(4), e52. <http://doi.org/10.2196/jmir.1430>.
- Crowley, M. J., Edelman, D., McAndrew, A. T., Kistler, S., Danus, S., Webb, J. A., ... Bosworth, H. B. (2016). Practical Telemedicine for Veterans with Persistently Poor Diabetes Control: A Randomized Pilot Trial. *Telemedicine and E-Health*, *22*(5), 376-384. <http://doi.org/10.1089/tmj.2015.0145>.
- Dar, O., Riley, J., Chapman, C., Dubrey, S. W., Morris, S., Rosen, S. D., ... Cowie, M. R. (2009). A randomized trial of home telemonitoring in a typical elderly heart failure population in North West London: results of the Home-HF study. *European Journal of Heart Failure*, *11*(3), 319-25. <http://doi.org/10.1093/eurjhf/hfn050>.
- Dario, C., Toffanin, R., Calcaterra, F., Saccavini, C., Stafylas, P., Mancin, S., & Vio, E. (2017). Telemonitoring of Type 2 Diabetes Mellitus in Italy. *Telemedicine and E-Health*, *23*(2), 143-152. <http://doi.org/10.1089/tmj.2015.0224>.
- Davy, C., Bleasel, J., Liu, H., Tchan, M., Ponniah, S., & Brown, A. (2015). Effectiveness of chronic care models: opportunities for improving healthcare practice and health outcomes: a systematic review. *BMC Health Services Research*, *15*(1), 194. <http://doi.org/10.1186/s12913-015-0854-8>.
- Dendale, P., De Keulenaer, G., Troisfontaines, P., Weytjens, C., Mullens, W., Elegeert, I., ... Hansen, D. (2012). Effect of a telemonitoring-facilitated collaboration between general practitioner and heart failure clinic on mortality and rehospitalization rates in severe heart failure: the TEMA-HF 1 (Telemonitoring in the Management of Heart Failure) study. *European Journal of Heart Failure*, *14*(3), 333-340. <http://doi.org/10.1093/eurjhf/hfr144>.
- Diabetesliitto (2018) (Finnish Diabetes Association). Retrieved November 25, 2018, from www.diabetes.fi.
- Donkin, L., Christensen, H., Naismith, S. L., Neal, B., Hickie, I. B., & Glozier, N. (2011). A Systematic Review of the Impact of Adherence on the Effectiveness of e-Therapies. *Journal of Medical Internet Research*, *13*(3), e52. <http://doi.org/10.2196/jmir.1772>.

- Evangelista, L. S., Dracup, K., & Doering, L. V. (2000). Treatment-seeking delays in heart failure patients. *The Journal of Heart and Lung Transplantation: The Official Publication of the International Society for Heart Transplantation*, 19(10), 932–8.
- Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, 3(2), E20. <http://doi.org/10.2196/jmir.3.2.e20>.
- Eysenbach, G. (2005). The law of attrition. *Journal of Medical Internet Research*, 7(1), e11. <http://doi.org/10.2196/jmir.7.1.e11>.
- Eysenbach, G. (2011). CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *Journal of Medical Internet Research*, 13(4), e126. <http://doi.org/10.2196/jmir.1923>.
- Eysenbach, G., & CONSORT-EHEALTH Group. (2011). CONSORT-EHEALTH: Improving and Standardizing Evaluation Reports of Web-based and Mobile Health Interventions. *Journal of Medical Internet Research*, 13(4), e126. <http://doi.org/10.2196/jmir.1923>.
- Fairbrother, P., Pinnock, H., Hanley, J., McCloughan, L., Sheikh, A., Pagliari, C., & McKinstry, B. (2013). Exploring telemonitoring and self-management by patients with chronic obstructive pulmonary disease: A qualitative study embedded in a randomized controlled trial. *Patient Education and Counseling*, 93(3), 403–410. <http://doi.org/10.1016/j.pec.2013.04.003>.
- Farmer, A. J., Perera, R., Ward, A., Heneghan, C., Oke, J., Barnett, A. H., ... O'Malley, S. (2012). Meta-analysis of individual patient data in randomised trials of self monitoring of blood glucose in people with non-insulin treated type 2 diabetes. *BMJ (Clinical Research Ed.)*, 344, e486. <http://doi.org/10.1136/BMJ.E486>.
- Fihn, S. D., Gardin, J. M., Abrams, J., Berra, K., Blankenship, J. C., Dallas, A. P., ... American College of Cardiology Foundation. (2012). 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the Diagnosis and Management of Patients With Stable Ischemic Heart Disease: Executive Summary: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. *Circulation*, 126(25), 3097–3137. <http://doi.org/10.1161/CIR.0b013e3182776f83>.
- Fisher, J. D., & Fisher, W. A. (1992). Changing AIDS-risk behavior. *Psychological Bulletin*, 111(3), 455–74.
- Fisher, W. A., Fisher, J. D., & Harman, J. (2003). The Information-Motivation-Behavioral Skills Model: A General Social Psychological Approach to Understanding and Promoting Health Behavior. In *Social Psychological Foundations of Health and Illness* (pp. 82–106). Malden, MA, USA: Blackwell Publishing Ltd. <http://doi.org/10.1002/9780470753552.ch4>.
- Freedland, K. E., Hesseler, M. J., Carney, R. M., Steinmeyer, B. C., Skala, J. A., Dávila-Román, V. G., & Rich, M. W. (2016). Major Depression and Long-Term Survival of Patients With Heart Failure. *Psychosomatic Medicine*, 78(8), 896–903. <http://doi.org/10.1097/PSY.0000000000000346>.
- Frost, A. E., Langleben, D., Oudiz, R., Hill, N., Horn, E., McLaughlin, V., ... Barst, R. J. (2005). The 6-min walk test (6MW) as an efficacy endpoint in pulmonary arterial hypertension clinical trials: Demonstration of a ceiling effect. *Vascular Pharmacology*, 43(1), 36–39. <http://doi.org/10.1016/J.VPH.2005.03.003>.
- Gee, P. M., Greenwood, D. A., Paterniti, D. A., Ward, D., & Miller, L. M. S. (2015). The eHealth Enhanced Chronic Care Model: A Theory Derivation Approach. *Journal of Medical Internet Research*, 17(4), e86. <http://doi.org/10.2196/jmir.4067>.

- Gerteis, J., David, I., Deborah, D., Lisa, L., Richard, R., Therese, M., & Jayasree, B. (2014). *Multiple Chronic Conditions Chartbook*. (A. P. N. Q14-0038, Ed.). Rockville, MD: Agency for Healthcare Research and Quality.
- Grady, P. A., & Gough, L. L. (2014). Self-management: a comprehensive approach to management of chronic conditions. *American Journal of Public Health, 104*(8), e25-31. <http://doi.org/10.2105/AJPH.2014.302041>.
- Green, C. P., Porter, C. B., Bresnahan, D. R., & Spertus, J. A. (2000). Development and evaluation of the Kansas City Cardiomyopathy Questionnaire: a new health status measure for heart failure. *Journal of the American College of Cardiology, 35*(5), 1245-55.
- Greenwood, D. A., Blozis, S. A., Young, H. M., Nesbitt, T. S., & Quinn, C. C. (2015). Overcoming Clinical Inertia: A Randomized Clinical Trial of a Telehealth Remote Monitoring Intervention Using Paired Glucose Testing in Adults With Type 2 Diabetes. *Journal of Medical Internet Research, 17*(7), e178. <http://doi.org/10.2196/jmir.4112>.
- Greenwood, D. A., Young, H. M., & Quinn, C. C. (2014). Telehealth Remote Monitoring Systematic Review: Structured Self-monitoring of Blood Glucose and Impact on A1C. *Journal of Diabetes Science and Technology, 8*(2), 378-389. <http://doi.org/10.1177/1932296813519311>.
- Gyllensten, C. ., Bonomi, A., Goode, K., Reiter, H., Habetha, J., Amft, O., & Cleland, J. (2016). Early Indication of Decompensated Heart Failure in Patients on Home-Telemonitoring: A Comparison of Prediction Algorithms Based on Daily Weight and Noninvasive Transthoracic Bio-impedance. *JMIR Medical Informatics, 4*(1), e3. <http://doi.org/10.2196/medinform.4842>.
- Hanlon, P., Daines, L., Campbell, C., Mckinstry, B., Weller, D., & Pinnock, H. (2017). Telehealth interventions to support self-management of long-term conditions: A systematic metareview of diabetes, heart failure, asthma, chronic obstructive pulmonary disease, and cancer. *Journal of Medical Internet Research*. <http://doi.org/10.2196/jmir.6688>.
- Hays, R. D., & Morales, L. S. (2001). The RAND-36 measure of health-related quality of life. *Annals of Medicine, 33*(5), 350-7.
- Health Quality Ontario, H. Q. (2009). Home telemonitoring for type 2 diabetes: an evidence-based analysis. *Ontario Health Technology Assessment Series, 9*(24), 1-38.
- Holmen, H., Torbjørnsen, A., Wahl, A. K., Jenum, A. K., Småstuen, M. C., Arsand, E., & Ribu, L. (2014). A Mobile Health Intervention for Self-Management and Lifestyle Change for Persons With Type 2 Diabetes, Part 2: One-Year Results From the Norwegian Randomized Controlled Trial RENEWING HEALTH. *JMIR MHealth and UHealth, 2*(4), e57. <http://doi.org/10.2196/mhealth.3882>.
- Inglis, S. C., Clark, R. A., Dierckx, R., Prieto-Merino, D., & Cleland, J. G. (2015). Structured telephone support or non-invasive telemonitoring for patients with heart failure. *Cochrane Database of Systematic Reviews, (10)*, CD007228. <http://doi.org/10.1002/14651858.CD007228.pub3>.
- International Diabetes Federation. (2017a). *IDF Diabetes Atlas*, 8th edition (8th editio). Brussels, Belgium: International Diabetes Federation.
- International Diabetes Federation. (2017b). *Recommendations for Managing Type 2 Diabetes in Primary Care, 2017*. Brussels, Belgium.
- Inzucchi, S. E., Bergenstal, R. M., Buse, J. B., Diamant, M., Ferrannini, E., Nauck, M., ... European Association for the Study of Diabetes (EASD). (2012). Management of Hyperglycemia in Type 2 Diabetes: A Patient-Centered Approach: Position Statement of the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). *Diabetes Care, 35*(6), 1364-1379. <http://doi.org/10.2337/dc12-0413>.

- Jaana, M., & Paré, G. (2007). Home telemonitoring of patients with diabetes: a systematic assessment of observed effects. *Journal of Evaluation in Clinical Practice*, 13(2), 242–53. <http://doi.org/10.1111/j.1365-2753.2006.00686.x>.
- Jaarsma, T., Strömberg, A., Ben Gal, T., Cameron, J., Driscoll, A., Duengen, H.-D., ... Riegel, B. (2013). Comparison of self-care behaviors of heart failure patients in 15 countries worldwide. *Patient Education and Counseling*, 92(1), 114–120. <http://doi.org/10.1016/j.pec.2013.02.017>
- Jaarsma, T., Strömberg, A., Mårtensson, J., & Dracup, K. (2003). Development and testing of the European Heart Failure Self-Care Behaviour Scale. *European Journal of Heart Failure*, 5(3), 363–70.
- Jayaram, N. M., Khariton, Y., Krumholz, H. M., Chaudhry, S. I., Mattera, J., Tang, F., ... Spertus, J. A. (2017). Impact of Telemonitoring on Health Status. *Circulation: Cardiovascular Quality and Outcomes*, 10(12), e004148. <http://doi.org/10.1161/CIRCOUTCOMES.117.004148>.
- Jensen, M. D., Ryan, D. H., Apovian, C. M., Ard, J. D., Comuzzie, A. G., Donato, K. A., ... Obesity Society. (2014). 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation*, 129(25 Suppl 2), 102–38. <http://doi.org/10.1161/01.cir.0000437739.71477.ee>.
- Jeong, J. Y., Jeon, J.-H., Bae, K.-H., Choi, Y.-K., Park, K.-G., Kim, J.-G., ... Lee, I.-K. (2018). Smart Care Based on Telemonitoring and Telemedicine for Type 2 Diabetes Care: Multi-center Randomized Controlled Trial. *Telemedicine and E-Health*, tmj.2017.0203. <http://doi.org/10.1089/tmj.2017.0203>.
- Jimison, H., Gorman, P., Woods, S., Nygren, P., Walker, M., Norris, S., & Hersh, W. (2008). Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved. *Evidence Report/Technology Assessment*, (175), 1–1422.
- Kanfer, F. . (1970). Self-regulation: Research, issues, and speculations. In C. Neuringer & J. . Michael (Eds.), *Behavior modification in clinical psychology* (pp. 178–220). New York, NY: Appleton-Century-Crofts.
- Kennedy, C. M., Powell, J., Payne, T. H., Ainsworth, J., Boyd, A., & Buchan, I. (2012). Active Assistance Technology for Health-Related Behavior Change: An Interdisciplinary Review. *Journal of Medical Internet Research*, 14(3), e80. <http://doi.org/10.2196/jmir.1893>.
- Kidholm, K., Stafylas, P., Kotzeva, A., Duedal Pedersen, C., Dafoulas, G., Scharf, I., ... Wanscher, C. E. (2014). *Regions of Europe Working together for Health—Final report*.
- Kitsiou, S., Paré, G., & Jaana, M. (2015). Effects of Home Telemonitoring Interventions on Patients With Chronic Heart Failure: An Overview of Systematic Reviews. *Journal of Medical Internet Research*, 17(3), e63. <http://doi.org/10.2196/jmir.4174>.
- Klonoff, D. C., Bergenstal, R., Blonde, L., Boren, S. A., Church, T. S., Gaffaney, J., ... Wollitzer, A. O. (2008). Consensus report of the coalition for clinical research-self-monitoring of blood glucose. *Journal of Diabetes Science and Technology*, 2(6), 1030–53. <http://doi.org/10.1177/193229680800200612>.
- Klonoff, D. C., Blonde, L., Cembrowski, G., Chacra, A. R., Charpentier, G., Colagiuri, S., ... Coalition for Clinical Research-Self-Monitoring of Blood Glucose Scientific Board. (2011). Consensus Report: The Current Role of Self-Monitoring of Blood Glucose in Non-Insulin-Treated Type 2 Diabetes. *Journal of Diabetes Science and Technology*, 5(6), 1529–1548. <http://doi.org/10.1177/193229681100500630>.

- Koehler, F., Winkler, S., Schieber, M., Sechtem, U., Stangl, K., Böhm, M., ... Anker, S. D. (2012). Telemedicine in heart failure: Pre-specified and exploratory subgroup analyses from the TIM-HF trial. *International Journal of Cardiology*, 161(3), 143–150. <http://doi.org/10.1016/j.ijcard.2011.09.007>.
- Koehler, F., Winkler, S., Schieber, M., Sechtem, U., Stangl, K., Bohm, M., ... Telemedical Interventional Monitoring in Heart Failure Investigators. (2011). Impact of Remote Telemedical Management on Mortality and Hospitalizations in Ambulatory Patients With Chronic Heart Failure: The Telemedical Interventional Monitoring in Heart Failure Study. *Circulation*, 123(17), 1873–1880. <http://doi.org/10.1161/CIRCULATIONAHA.111.018473>.
- Koponen, P., Borodulin, K., Lundqvist, A., Sääksjärvi, K., & Koskinen, S. (2018). *Terveys, toimintakyky ja hyvinvointi Suomessa FinTerveys 2017 -tutkimus*. Helsinki.
- Kotooka, N., Kitakaze, M., Nagashima, K., Asaka, M., Kinugasa, Y., Nochioka, K., ... HOMES-HF study investigators. (2018). The first multicenter, randomized, controlled trial of home telemonitoring for Japanese patients with heart failure: home telemonitoring study for patients with heart failure (HOMES-HF). *Heart and Vessels*. <http://doi.org/10.1007/s00380-018-1133-5>.
- Kotseva, K., Wood, D., De Bacquer, D., De Backer, G., Rydén, L., Jennings, C., ... EUROASPIRE Investigators. (2016). EUROASPIRE IV: A European Society of Cardiology survey on the lifestyle, risk factor and therapeutic management of coronary patients from 24 European countries. *European Journal of Preventive Cardiology*, 23(6), 636–648. <http://doi.org/10.1177/2047487315569401>.
- Kraal, J. J., Van den Akker-Van Marle, M. E., Abu-Hanna, A., Stut, W., Peek, N., & Kemps, H. M. (2017). Clinical and cost-effectiveness of home-based cardiac rehabilitation compared to conventional, centre-based cardiac rehabilitation: Results of the FIT@Home study. *European Journal of Preventive Cardiology*, 24(12), 1260–1273. <http://doi.org/10.1177/2047487317710803>.
- Krumholz, H. M., Chaudhry, S. I., Spertus, J. A., Mattera, J. A., Hodshon, B., & Herrin, J. (2016). Do Non-Clinical Factors Improve Prediction of Readmission Risk? *JACC: Heart Failure*, 4(1), 12–20. <http://doi.org/10.1016/j.jchf.2015.07.017>.
- Lainscak, M., Blue, L., Clark, A. L., Dahlström, U., Dickstein, K., Ekman, I., ... Jaarsma, T. (2011). Self-care management of heart failure: practical recommendations from the Patient Care Committee of the Heart Failure Association of the European Society of Cardiology. *European Journal of Heart Failure*, 13(2), 115–126. <http://doi.org/10.1093/eurjhf/hfq219>.
- Law, L. M., & Wason, J. M. S. (2014). Design of telehealth trials – Introducing adaptive approaches. *International Journal of Medical Informatics*, 83(12), 870–880. <http://doi.org/10.1016/j.ijmedinf.2014.09.002>.
- Lim, S., Kang, S. M., Shin, H., Lee, H. J., Won Yoon, J., Yu, S. H., ... Jang, H. C. (2011). Improved Glycemic Control Without Hypoglycemia in Elderly Diabetic Patients Using the Ubiquitous Healthcare Service, a New Medical Information System. *Diabetes Care*, 34(2), 308–313. <http://doi.org/10.2337/dc10-1447>.
- Lindberg, I., Torbjørnsen, A., Söderberg, S., & Ribu, L. (2017). Telemonitoring and Health Counseling for Self-Management Support of Patients With Type 2 Diabetes: A Randomized Controlled Trial. *JMIR Diabetes*, 2(1), e10. <http://doi.org/10.2196/diabetes.6884>.
- Little, R. R., Rohlfing, C. L., Sacks, D. B., & National Glycohemoglobin Standardization Program (NGSP) Steering Committee. (2011). Status of Hemoglobin A1c Measurement and Goals

- for Improvement: From Chaos to Order for Improving Diabetes Care. *Clinical Chemistry*, 57(2), 205–214. <http://doi.org/10.1373/clinchem.2010.148841>.
- Lorig, K. R., & Holman, H. (2003). Self-management education: history, definition, outcomes, and mechanisms. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, 26(1), 1–7.
- Luley, C., Blaik, A., Götz, A., Kicherer, F., Kropf, S., Isermann, B., ... Westphal, S. (2014). Weight Loss by Telemonitoring of Nutrition and Physical Activity in Patients with Metabolic Syndrome for 1 Year. *Journal of the American College of Nutrition*, 33(5), 363–374. <http://doi.org/10.1080/07315724.2013.875437>.
- Lyngå, P., Persson, H., Hägg-Martinell, A., Hägglund, E., Hagerman, I., Langius-Eklöf, A., & Rosenqvist, M. (2012). Weight monitoring in patients with severe heart failure (WISH). A randomized controlled trial. *European Journal of Heart Failure*, 14(4), 438–444. <http://doi.org/10.1093/eurjhf/hfs023>.
- Maggioni, A. P., Dahlström, U., Filippatos, G., Chioncel, O., Leiro, M. C., Drozd, J., ... Heart Failure Association of the European Society of Cardiology (HFA). (2013). EUR Observational Research Programme: regional differences and 1-year follow-up results of the Heart Failure Pilot Survey (ESC-HF Pilot). *European Journal of Heart Failure*, 15(7), 808–817. <http://doi.org/10.1093/eurjhf/hft050>.
- Malanda, U. L., Welschen, L. M. C., Riphagen, I. I., Dekker, J. M., Nijpels, G., & Bot, S. D. M. (2012). Self-monitoring of blood glucose in patients with type 2 diabetes mellitus who are not using insulin. *The Cochrane Database of Systematic Reviews*, 1, CD005060. <http://doi.org/10.1002/14651858.CD005060.pub3>.
- Marcolino, M. S., Maia, J. X., Alkmim, M. B. M., Boersma, E., & Ribeiro, A. L. (2013). Telemedicine Application in the Care of Diabetes Patients: Systematic Review and Meta-Analysis. *PLoS ONE*, 8(11), e79246. <http://doi.org/10.1371/journal.pone.0079246>.
- Martz, E. (2018). Defining self-management on the individual level. In E. Martz (Ed.), *Promoting self-management of chronic conditions: theories and practice*. New York, NY: Oxford University Press. Available online at <https://lccn.loc.gov/2017022826>
- Mattila, E. (2010). *Design and evaluation of a mobile phone diary for personal health management*. Helsinki: VTT Technical Research Centre of Finland.
- Mattila, E., Orsama, A.-L., Ahtinen, A., Hopsu, L., Leino, T., & Korhonen, I. (2013). Personal health technologies in employee health promotion: usage activity, usefulness, and health-related outcomes in a 1-year randomized controlled trial. *JMIR MHealth and UHealth*, 1(2), e16. <http://doi.org/10.2196/mhealth.2557>.
- McBain, H., Shipley, M., & Newman, S. (2015). The impact of self-monitoring in chronic illness on healthcare utilisation: a systematic review of reviews. *BMC Health Services Research*, 15, 565. <http://doi.org/10.1186/s12913-015-1221-5>.
- McHorney, J. E., Ware, J., & Anastasia. (1993). The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and Clinical Tests of Validity in Measuring Physical and Mental Health Constructs. *Raczek Source: Medical Care*, 31(3), 247–263.
- Montalescot, G., Sechtem, U., Achenbach, S., Andreotti, F., Arden, C., Budaj, A., ... Zamorano, J. L. (2013). 2013 ESC guidelines on the management of stable coronary artery disease. *European Heart Journal*, 34(38), 2949–3003. <http://doi.org/10.1093/eurheartj/eht296>.
- Mortara, A., Pinna, G. D., Johnson, P., Maestri, R., Capomolla, S., La Rovere, M. T., ... HHH Investigators. (2009). Home telemonitoring in heart failure patients: the HHH study

- (Home or Hospital in Heart Failure). *European Journal of Heart Failure*, 11(3), 312–318. <http://doi.org/10.1093/eurjhf/hfp022>.
- National Heart Lung and Blood Institute. (2018). Coronary heart disease. Retrieved May 30, 2018, from <https://www.nhlbi.nih.gov/health-topics/coronary-heart-disease>.
- Nelson, L. A., Coston, T. D., Cherrington, A. L., & Osborn, C. Y. (2016). Patterns of User Engagement with Mobile- and Web-Delivered Self-Care Interventions for Adults with T2DM: A Review of the Literature. *Current Diabetes Reports*, 16(7), 66. <http://doi.org/10.1007/s11892-016-0755-1>.
- Nicolucci, A., Cercone, S., Chiriatti, A., Muscas, F., & Gensini, G. (2015). A Randomized Trial on Home Telemonitoring for the Management of Metabolic and Cardiovascular Risk in Patients with Type 2 Diabetes. *Diabetes Technology & Therapeutics*, 17(8), 563–570. <http://doi.org/10.1089/dia.2014.0355>.
- Nieminen, M. S., Dickstein, K., Fonseca, C., Serrano, J. M., Parissis, J., Fedele, F., ... Zymliński, R. (2015). The patient perspective: Quality of life in advanced heart failure with frequent hospitalisations. *International Journal of Cardiology*, 191, 256–264. <http://doi.org/10.1016/j.ijcard.2015.04.235>.
- Nieuwlaat, R., Wilczynski, N., Navarro, T., Hobson, N., Jeffery, R., Keepanasseril, A., ... Haynes, R. B. (2014). Interventions for enhancing medication adherence. In R. Nieuwlaat (Ed.), *Cochrane Database of Systematic Reviews*. Chichester, UK: John Wiley & Sons, Ltd. <http://doi.org/10.1002/14651858.CD000011.pub4>.
- Official Statistics of Finland. (2016). *Causes of death in 2016* (e-publication). Helsinki: Official Statistics of Finland [referred 2.4.2018]. Available online at: http://www.stat.fi/til/ksyyt/index_en.html.
- Olivari, Z., Giacomelli, S., Gubian, L., Mancin, S., Visentin, E., Di Francesco, V., ... Stafylas, P. (2018). The effectiveness of remote monitoring of elderly patients after hospitalisation for heart failure: The renewing health European project. *International Journal of Cardiology*, 257, 137–142. <http://doi.org/10.1016/j.ijcard.2017.10.099>.
- Ong, M. K., Romano, P. S., Edgington, S., Aronow, H. U., Auerbach, A. D., Black, J. T., ... Better Effectiveness After Transition—Heart Failure (BEAT-HF) Research Group. (2016). Effectiveness of Remote Patient Monitoring After Discharge of Hospitalized Patients With Heart Failure: The Better Effectiveness After Transition—Heart Failure (BEAT-HF) Randomized Clinical Trial. *JAMA Internal Medicine*, 176(3), 310–8. <http://doi.org/10.1001/jamainternmed.2015.7712>.
- Pandor, A., Thokala, P., Gomersall, T., Baalbaki, H., Stevens, J., Wang, J., ... Fitzgerald, P. (2013). Home telemonitoring or structured telephone support programmes after recent discharge in patients with heart failure: systematic review and economic evaluation. *Health Technol Assess*, 17(32), 1–207, v–vi. <http://doi.org/10.3310/hta17320>.
- Pare, G., Jaana, M., & Sicotte, C. (2007). Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base. *Journal of the American Medical Informatics Association*, 14(3), 269–277. <http://doi.org/10.1197/jamia.M2270>.
- Paré, G., Moqadem, K., Pineau, G., & St-Hilaire, C. (2010). Clinical effects of home telemonitoring in the context of diabetes, asthma, heart failure and hypertension: a systematic review. *Journal of Medical Internet Research*, 12(2), e21. <http://doi.org/10.2196/jmir.1357>.
- Parsons, S., Bury, M., Carter, S., Hurst, P., Magee, H., & Taylor, D. (2010). *Self management support amongst older adults: The availability, impact and potential of locally based services and resources. Report for the National Institute for Health Research Service Delivery and Organisation programme.*

- Patja, K., Absetz, P., Auvinen, A., Tokola, K., Kytö, J., Oksman, E., ... Talja, M. (2012). Health coaching by telephony to support self-care in chronic diseases: clinical outcomes from The TERVA randomized controlled trial. *BMC Health Services Research*, *12*(1), 147. <http://doi.org/10.1186/1472-6963-12-147>.
- Pearce, G., Parke, H. L., Pinnock, H., Epiphaniou, E., Bourne, C. LA, Sheikh, A., & Taylor, S. J. (2016). The PRISMS taxonomy of self-management support: derivation of a novel taxonomy and initial testing of its utility. *Journal of Health Services Research & Policy*, *21*(2), 73–82. <http://doi.org/10.1177/1355819615602725>.
- Polisena, J., Tran, K., Cimon, K., Hutton, B., McGill, S., & Palmer, K. (2009). Home telehealth for diabetes management: a systematic review and meta-analysis. *Diabetes, Obesity and Metabolism*, *11*(10), 913–930. <http://doi.org/10.1111/j.1463-1326.2009.01057.x>.
- Polonsky, W. H., & Fisher, L. (2013). Self-monitoring of blood glucose in noninsulin-using type 2 diabetic patients: right answer, but wrong question: self-monitoring of blood glucose can be clinically valuable for noninsulin users. *Diabetes Care*, *36*(1), 179–82. <http://doi.org/10.2337/dc12-0731>.
- Polonsky, W. H., Fisher, L., Earles, J., Dudl, R. J., Lees, J., Mullan, J., & Jackson, R. A. (2005). Assessing psychosocial distress in diabetes: development of the diabetes distress scale. *Diabetes Care*, *28*(3), 626–31.
- Ponikowski, P., Voors, A. A., Anker, S. D., Bueno, H., Cleland, J. G. F., Coats, A. J. S., ... ESC Scientific Document Group. (2016). 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. *European Heart Journal*, *37*(27), 2129–2200. <http://doi.org/10.1093/eurheartj/ehw128>.
- Quinn, C., Gruber-Baldini, A., Shardell, M., Weed, K., Clough, S., Peeples, M., ... Lender, D. (2009). Mobile diabetes intervention study: Testing a personalized treatment/behavioral communication intervention for blood glucose control. *Contemporary Clinical Trials*, *30*(4), 334–346. <http://doi.org/10.1016/j.cct.2009.02.004>.
- Quinn, C., Shardell, M., Terrin, M., Barr, E., Ballew, S., & Gruber-Baldini, A. (2011). Cluster-Randomized Trial of a Mobile Phone Personalized Behavioral Intervention for Blood Glucose Control. *Diabetes Care*, *34*(9), 1934–1942. <http://doi.org/10.2337/dc11-0366>.
- Rawstorn, J. C., Gant, N., Direito, A., Beckmann, C., & Maddison, R. (2016). Telehealth exercise-based cardiac rehabilitation: a systematic review and meta-analysis. *Heart (British Cardiac Society)*, *102*(15), 1183–92. <http://doi.org/10.1136/heartjnl-2015-308966>.
- Richard, A. A., & Shea, K. (2011). Delineation of Self-Care and Associated Concepts. *Journal of Nursing Scholarship*, *43*(3), no-no. <http://doi.org/10.1111/j.1547-5069.2011.01404.x>.
- Riegel, B., Moser, D. K., Anker, S. D., Appel, L. J., Dunbar, S. B., Grady, K. L., ... American Heart Association Interdisciplinary Council on Quality of Care and Outcomes Research. (2009). State of the Science: Promoting Self-Care in Persons With Heart Failure: A Scientific Statement From the American Heart Association. *Circulation*, *120*(12), 1141–1163. <http://doi.org/10.1161/CIRCULATIONAHA.109.192628>.
- Riegel, B., Moser, D. K., Glaser, D., Carlson, B., Deaton, C., Armola, R., ... Albert, N. (2002). The Minnesota Living With Heart Failure Questionnaire: sensitivity to differences and responsiveness to intervention intensity in a clinical population. *Nursing Research*, *51*(4), 209–18.
- Ross, J. S., Chen, J., Lin, Z., Bueno, H., Curtis, J. P., Keenan, P. S., ... Krumholz, H. M. (2010). Recent National Trends in Readmission Rates After Heart Failure Hospitalization. *Circulation: Heart Failure*, *3*(1), 97–103. <http://doi.org/10.1161/CIRCHEARTFAILURE.109.885210>

- Rothwell, P. M. (2006). Factors that can affect the external validity of randomised controlled trials. *PLoS Clinical Trials*, 1(1), e9. <http://doi.org/10.1371/journal.pctr.0010009>.
- Rydén, L., Grant, P. J., Anker, S. D., Berne, C., Cosentino, F., Danchin, N., ... Xuereb, R. G. (2013). ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD. *European Heart Journal*, 34(39), 3035–3087. <http://doi.org/10.1093/eurheartj/ehs108>.
- Savarese, G., & Lund, L. H. (2017). Global Public Health Burden of Heart Failure. *Cardiac Failure Review*, 03(01), 7. <http://doi.org/10.15420/cfr.2016:25:2>.
- Schechtman, E. (2002). Odds Ratio, Relative Risk, Absolute Risk Reduction, and the Number Needed to Treat—Which of These Should We Use? *Value in Health*, 5(5), 431–436. <http://doi.org/10.1046/J.1524-4733.2002.55150.x>.
- Schmidt, C. O., & Kohlmann, T. (2008). When to use the odds ratio or the relative risk? *International Journal of Public Health*, 53(3), 165–7.
- Schulz, K. F., Chalmers, I., Hayes, R. J., & Altman, D. G. (1995). Empirical evidence of bias. Dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA*, 273(5), 408–12.
- Schulz, K. F., & Grimes, D. A. (2002). Allocation concealment in randomised trials: defending against deciphering. *Lancet (London, England)*, 359(9306), 614–8. [http://doi.org/10.1016/S0140-6736\(02\)07750-4](http://doi.org/10.1016/S0140-6736(02)07750-4).
- Senn, S. (1994). Testing for baseline balance in clinical trials. *Statistics in Medicine*, 13(17), 1715–26.
- Seto, E., Leonard, K. J., Cafazzo, J. A., Barnsley, J., Masino, C., & Ross, H. J. (2012). Mobile Phone-Based Telemonitoring for Heart Failure Management: A Randomized Controlled Trial. *Journal of Medical Internet Research*, 14(1), e31. <http://doi.org/10.2196/jmir.1909>.
- Sharon, E., Esser, N. M., & Hofmann, S. G. (2018). Cognitive-Behavioral Therapy to Promote Self-Management. In E. Martz (Ed.), *Promoting Self-Management of Chronic Health Conditions: theories and practice*. New York, NY: Oxford University Press.
- Shea, S., Weinstock, R. S., Teresi, J. A., Palmas, W., Starren, J., Cimino, J. J., ... Eimicke, J. P. (2009). A Randomized Trial Comparing Telemedicine Case Management with Usual Care in Older, Ethnically Diverse, Medically Underserved Patients with Diabetes Mellitus: 5 Year Results of the IDEATel Study. *Journal of the American Medical Informatics Association*, 16(4), 446–456. <http://doi.org/10.1197/jamia.M3157>.
- Sieverink, F., Kelders, S. M., & van Gemert-Pijnen, J. E. (2017). Clarifying the Concept of Adherence to eHealth Technology: Systematic Review on When Usage Becomes Adherence. *Journal of Medical Internet Research*, 19(12), e402. <http://doi.org/10.2196/jmir.8578>.
- Sieverink, F., Kelders, S., Poel, M., & van Gemert-Pijnen, L. (2017). Opening the Black Box of Electronic Health: Collecting, Analyzing, and Interpreting Log Data. *JMIR Research Protocols*, 6(8), e156. <http://doi.org/10.2196/resprot.6452>.
- Skobel, E., Knackstedt, C., Martinez-Romero, A., Salvi, D., Vera-Munoz, C., Napp, A., ... Cleland, J. (2017). Internet-based training of coronary artery patients: the Heart Cycle Trial. *Heart and Vessels*, 32(4), 408–418. <http://doi.org/10.1007/s00380-016-0897-8>.
- Sperrin, M., Rushton, H., Dixon, W. G., Normand, A., Villard, J., Chieh, A., & Buchan, I. (2016). Who Self-Weighs and What Do They Gain From It? A Retrospective Comparison Between Smart Scale Users and the General Population in England. *Journal of Medical Internet Research*, 18(1), e17. <http://doi.org/10.2196/jmir.4767>.
- Stewart, S. (2005). Financial aspects of heart failure programs of care. *European Journal of Heart Failure*, 7(3), 423–428. <http://doi.org/10.1016/j.ejheart.2005.01.001>.

- Stewart, S., MacIntyre, K., Hole, D. J., Capewell, S., & McMurray, J. J. (2001). More “malignant” than cancer? Five-year survival following a first admission for heart failure. *European Journal of Heart Failure*, 3(3), 315–22.
- Stone, R. A., Rao, R. H., Sevick, M. A., Cheng, C., Hough, L. J., Macpherson, D. S., ... Derubertis, F. R. (2010). Active care management supported by home telemonitoring in veterans with type 2 diabetes: the DiaTel randomized controlled trial. *Diabetes Care*, 33(3), 478–84. <http://doi.org/10.2337/dco9-1012>.
- Suomalaisen Lääkäriseuran Duodecimin Suomen Sisätautilääkäreiden yhdistyksen ja Diabetesliitos Lääkärineuvoston asettama työryhmä. (2018). *Tyyppin 2 diabetes. Käypä hoito -suositus*. Suomalainen Lääkäriseura Duodecim. Helsinki.
- Tang, P. C., Overhage, J. M., Chan, A. S., Brown, N. L., Aghighi, B., Entwistle, M. P., ... Young, C. Y. (2013). Online disease management of diabetes: Engaging and Motivating Patients Online With Enhanced Resources-Diabetes (EMPOWER-D), a randomized controlled trial. *Journal of the American Medical Informatics Association*, 20(3), 526–534. <http://doi.org/10.1136/amiajnl-2012-001263>.
- Toma, M., Ezekowitz, J. A., Bakal, J. A., O'Connor, C. M., Hernandez, A. F., Sardar, M. R., ... Starling, R. C. (2014). The relationship between left ventricular ejection fraction and mortality in patients with acute heart failure: insights from the ASCEND-HF Trial. *European Journal of Heart Failure*, 16(3), 334–341. <http://doi.org/10.1002/ejhf.19>.
- Uhari, M. (2001). NNT-luku ja sen luottamusvälit. *Suomen Lääkärilehti*, 6(56), 702–703.
- van der Wal, M. H. L., & Jaarsma, T. (2008). Adherence in heart failure in the elderly: problem and possible solutions. *International Journal of Cardiology*, 125(2), 203–8. <http://doi.org/10.1016/j.ijcard.2007.10.011>.
- van Vugt, M., de Wit, M., Cleijne, W. H. J. J., & Snoek, F. J. (2013). Use of behavioral change techniques in web-based self-management programs for type 2 diabetes patients: systematic review. *Journal of Medical Internet Research*, 15(12), e279. <http://doi.org/10.2196/jmir.2800>
- Verweij, L. M., Terwee, C. B., Proper, K. I., Hulshof, C. T., & van Mechelen, W. (2013). Measurement error of waist circumference: gaps in knowledge. *Public Health Nutrition*, 16(02), 281–288. <http://doi.org/10.1017/S1368980012002741>.
- Villani, A., Malfatto, G., Compare, A., Rosa, F. Della, Bellardita, L., Branzi, G., ... Parati, G. (2014). Clinical and psychological telemonitoring and telecare of high risk heart failure patients. *Journal of Telemedicine and Telecare*, 20(8), 468–475. <http://doi.org/10.1177/1357633X14555644>.
- Vinson, J. M., Rich, M. W., Sperry, J. C., Shah, A. S., & McNamara, T. (1990). Early Readmission of Elderly Patients With Congestive Heart Failure. *Journal of the American Geriatrics Society*, 38(12), 1290–1295. <http://doi.org/10.1111/j.1532-5415.1990.tb03450.x>.
- Vuong, Q. H. (1989). Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses. *Econometrica*, 57(2), 307. <http://doi.org/10.2307/1912557>.
- Wakefield, B. J., Holman, J. E., Ray, A., Scherubel, M., Adams, M. R., Hillis, S. L., & Rosenthal, G. E. (2011). Effectiveness of Home Telehealth in Comorbid Diabetes and Hypertension: A Randomized, Controlled Trial. *Telemedicine and E-Health*, 17(4), 254–261. <http://doi.org/10.1089/tmj.2010.0176>.

- Waki, K., Aizawa, K., Kato, S., Fujita, H., Lee, H., Kobayashi, H., ... Ohe, K. (2015). DialBetics With a Multimedia Food Recording Tool, FoodLog. *Journal of Diabetes Science and Technology*, 9(3), 534–540. <http://doi.org/10.1177/1932296815579690>.
- Waki, K., Fujita, H., Uchimura, Y., Omae, K., Aramaki, E., Kato, S., ... Ohe, K. (2014). DialBetics. A Novel Smartphone-based Self-management Support System for Type 2 Diabetes Patients. *Journal of Diabetes Science and Technology*, 8(2), 209–215. <http://doi.org/10.1177/1932296814526495>.
- Ward, B. W., Schiller, J. S., & Goodman, R. A. (2014). Multiple Chronic Conditions Among US Adults: A 2012 Update. *Preventing Chronic Disease*, 11, 130389. <http://doi.org/10.5888/pcd11.130389>.
- Ware, J. E., & Sherbourne, C. D. (1992). The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Medical Care*, 30(6), 473–83.
- Webb, T. L., Joseph, J., Yardley, L., & Michie, S. (2010). Using the internet to promote health behavior change: a systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. *Journal of Medical Internet Research*, 12(1), e4. <http://doi.org/10.2196/jmir.1376>.
- Whelton, P. K., Carey, R. M., Aronow, W. S., Casey, D. E., Collins, K. J., Dennison Himmelfarb, C., ... Wright, J. T. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task F. *Hypertension*, 71(6), 1269–1324. <http://doi.org/10.1161/HYP.0000000000000666>.
- Whitten, P., Holtz, B., & Laplante, C. (2010). Telemedicine: What have we learned? *Applied Clinical Informatics*, 1(2), 132–41. <http://doi.org/10.4338/ACI-2009-12-R-0020>.
- Wild, S. H., Hanley, J., Lewis, S. C., McKnight, J. A., McCloughan, L. B., Padfield, P. L., ... McKinstry, B. (2016). Supported Telemonitoring and Glycemic Control in People with Type 2 Diabetes: The Telescot Diabetes Pragmatic Multicenter Randomized Controlled Trial. *PLoS Medicine*, 13(7). <http://doi.org/10.1371/journal.pmed.1002098>.
- Wilde, M. H., & Garvin, S. (2007). A concept analysis of self-monitoring. *Journal of Advanced Nursing*, 57(3), 339–350. <http://doi.org/10.1111/j.1365-2648.2006.04089.x>.
- Winter, S. J., Sheats, J. L., & King, A. C. (2016). The Use of Behavior Change Techniques and Theory in Technologies for Cardiovascular Disease Prevention and Treatment in Adults: A Comprehensive Review. *Progress in Cardiovascular Diseases*, 58(6), 605–612. <http://doi.org/10.1016/J.PCAD.2016.02.005>.
- World Health Organization. (2002). *Innovative care for chronic conditions: Building blocks for action: global report*. Geneva. <http://www.who.int/iris/handle/10665/42500>.
- World Health Organization. (2003). *Adherence to long-term therapies: Evidence for action*. Geneva. <http://www.who.int/iris/handle/10665/42682>.
- World Health Organization. (2009). *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva. <http://www.who.int/iris/handle/10665/44203>.
- World Health Organization. (2010). *Telemedicine: Opportunities and developments in Member States: report on the second global survey on eHealth 2009*. Global Observatory for eHealth. Geneva. http://www.who.int/goe/publications/goe_telemedicine_2010.pdf.
- World Health Organization. (2011). *Use of glycated haemoglobin (HbA1c) in diagnosis of diabetes mellitus: abbreviated report of a WHO consultation*. Geneva. <http://www.who.int/iris/handle/10665/70523>.

- World Health Organization. (2014). *Global status report on non-communicable diseases 2014*. Geneva. <http://www.who.int/iris/handle/10665/148114>.
- World Health Organization. (2016). *Global report on diabetes*. Geneva. <http://www.who.int/iris/handle/10665/204871>.
- World Health Organization. (2017). *Noncommunicable Diseases Progress Monitor*. Geneva. <http://apps.who.int/iris/handle/10665/258940>.
- World Health Organization. (2018). *Global Health Estimates 2016: Deaths by Cause, Age, Sex by Country and by Region, 2000–2016*. Geneva. Available online at http://www.who.int/healthinfo/global_burden_disease/estimates/en/.
- Yancy, C. W., Jessup, M., Bozkurt, B., Butler, J., Casey, D. E., Drazner, M. H., ... American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. (2013). 2013 ACCF/AHA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*, 128(16), e240–e327. <http://doi.org/10.1161/CIR.0b013e31829e8776>.
- Yardley, L., Spring, B. J., Riper, H., Morrison, L. G., Crane, D. H., Curtis, K., ... Blandford, A. (2016). Understanding and Promoting Effective Engagement With Digital Behavior Change Interventions. *American Journal of Preventive Medicine*, 51(5). <http://doi.org/10.1016/j.amepre.2016.06.015>.
- Zile, M. R., Bennett, T. D., St. John Sutton, M., Cho, Y. K., Adamson, P. B., Aaron, M. F., ... Bourge, R. C. (2008). Transition From Chronic Compensated to Acute Decompensated Heart Failure: Pathophysiological Insights Obtained From Continuous Monitoring of Intracardiac Pressures. *Circulation*, 118(14), 1433–1441. <http://doi.org/10.1161/CIRCULATIONAHA.108.783910>.

Original Publications

PUBLICATION

I

Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: results of a theory-based randomized trial

Orsama A-L, Lähteenmäki J, Harno K, Kulju M, Wintergerst E, Schachner H, Stenger P, Leppänen J, Kaijanranta H, Salaspuro V, Fisher W.

Diabetes Technology and Therapeutics, 2013, 15(8), 662–669.

<https://www.liebertpub.com/doi/abs/10.1089/dia.2013.0056>

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ORIGINAL ARTICLE

Active Assistance Technology Reduces Glycosylated Hemoglobin and Weight in Individuals With Type 2 Diabetes: Results of a Theory-Based Randomized Trial

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Abstract

Background: Type 2 diabetes is an individual health challenge requiring ongoing self-management. Remote patient reporting of relevant health parameters and linked automated feedback via mobile telephone have potential to strengthen self-management and improve outcomes. This research involved development and evaluation of a mobile telephone-based remote patient reporting and automated telephone feedback system, guided by health behavior change theory, aimed at improving self-management and health status in individuals with type 2 diabetes.

Subjects and Methods: This research comprised a randomized controlled trial. Inclusion criteria were diagnosis of type 2 diabetes, elevated glycosylated hemoglobin (HbA1c) levels (range, 6.5–11%) or use of oral diabetes medication, and 30–70 years of age. Intervention subjects ($n=24$) participated in remote patient reporting of health status parameters and linked health behavior change feedback. Control participants ($n=24$) received standard of care including diabetes education and healthcare provider counseling. Patients were followed for approximately 10 months.

Results: Intervention participants achieved, compared with controls and controlling for baseline, a significantly greater mean reduction in HbA1c of -0.40% (95% confidence interval [CI] -0.67% to -0.14%) versus 0.036% (95% CI -0.23% to 0.30%) ($P<0.03$) and significantly greater weight reduction of -2.1 kg (95% CI -3.6 to -0.6 kg) versus 0.4 kg (95% CI -1.1 to 1.9 kg). Nonsignificant trends for greater intervention compared with control improvement in systolic and diastolic blood pressure were observed.

Conclusions: Sophisticated information technology platforms for remote patient reporting linked with theory-based health behavior change automated feedback have potential to improve patient outcomes in type 2 diabetes and merit scaled-up research efforts.

Introduction

DIABETES IS AN INDIVIDUAL and public health challenge that has significant medical^{1,2} and financial^{1,2} consequences and rapidly expanding prevalence worldwide.^{2–4} Importantly, type 1 and type 2 diabetes are chronic conditions that require ongoing healthcare professional and self-management efforts, which are crucial to reducing disease-related morbidity and mortality.^{5–8} Because healthcare professional and self-management of diabetes are essential,

but time-, effort-, and cost-intensive,⁹ management of diabetes is often suboptimal.^{6,10} For this reason, the search for efficient and effective means to improve management of diabetes has been a focus of research efforts.^{11–16} The rapid evolution of sophisticated information technologies and mobile communication devices in the past decade has made it possible to exploit technology to facilitate healthcare professional and self-management of diabetes.^{17,18}

Information technology and mobile communication devices can be used to support diabetes management in several

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ways. Remote patient reporting of relevant health parameters such as blood glucose levels, blood pressure, weight, physical activity, and nutrition can be linked, via mobile telephone, intermittently or in real time, with human healthcare personnel or with automated feedback. Such remote reporting supported with feedback systems may prove to be efficient and effective means to improve medical and self-management of diabetes and to improve patient outcomes in this chronic disease state.

Tatara et al.¹⁷ have reviewed 28 studies of mobile communication device interventions to support diabetes management. Most of the studies reviewed reported on mobile communication applications developed by investigators (as opposed to commercially available applications), and most of the studies involved individuals with type 1 diabetes compared with type 2 diabetes (when diabetes type was specified). In addition, most of the studies involved direct healthcare provider involvement: healthcare providers themselves gave feedback to patients (on an asynchronous basis), reviewed patient data, or were notified by research teams if deemed medically necessary on the basis of patient data. In half of the studies Tatara et al.¹⁷ reviewed, patients' blood glucose data were automatically transmitted from their blood glucose meter via wireless technology, and in half of the research reports patients manually entered their blood glucose values. Across studies, activity data (pedometer measurements), weight, blood pressure, and food intake information were reported via mobile telephones as well. A significant decrease in glycosylated hemoglobin (HbA1c) was observed in about half of the mobile device intervention studies reviewed, and findings for acceptability of this technology by patients participating in the studies were generally positive. (See also systematic reviews by Fjeldsoe et al.¹⁹ and Wei et al.²⁰ for discussion of additional mobile telephone device intervention research focused on improving management of diabetes and other conditions.)

Individual studies in the active assistance literature include work by Quinn et al.,²¹ who used WellDoc® (Baltimore, MD) software. WellDoc was designed by endocrinologists and diabetes educators, and it provided real-time feedback, based on remote patient reports, which were responded to on the basis of proprietary algorithms. In this mobile technology-based study of individuals with type 2 diabetes, a significant decrease in HbA1c in intervention compared with control participants was observed across a 3-month trial. Additional studies using mobile phone technology for remote reporting of patient data and feedback with recommendations for self-management have also shown positive impact. Kim²² conducted a 12-week study involving mobile telephone reporting of blood glucose and receipt of feedback with individuals with type 1 diabetes, and Yoon and Kim²³ reported a similar 12-month study with individuals with type 2 diabetes. Both studies reported significant reductions in HbA1c. The recent DIABEO study provided automated feedback concerning medication adjustment, based on carbohydrate intake, pre-meal blood glucose, and anticipated physical activity, to individuals with type 1 diabetes and reported significantly lowered HbA1c levels compared with controls.²⁴ In related work concerning individuals with type 2 diabetes and uncontrolled hypertension,²⁵ mobile telephone-based remote patient reporting of blood pressure resulted in a significant decrease in ambulatory blood pressure across the study pe-

riod. We note that not all individual studies of mobile telephone and information technology report significant change in HbA1c or other clinical end points (see studies by Franklin et al.²⁶ and studies reviewed by Fjeldsoe et al.,¹⁹ Wei et al.,²⁰ and Tatara et al.¹⁷ for examples of studies that did not achieve clinical end points.)

Intervention research using mobile telephone technology to support healthcare provider and patient management of diabetes has thus employed both healthcare provider (most often) or automatic (less often) feedback to patients who use mobile telephones for remote reporting of relevant diabetes parameters (e.g., blood glucose, blood pressure, weight, and activity). Feedback is more often provided in asynchronous and intermittent format than in real time, and research samples have generally been small. Recent studies of mobile telephone-mediated interventions to improve diabetes management reviewed by Fjeldsoe et al.¹⁹ and Wei et al.²⁰ had a median sample size of 51. It is notable that mobile telephone-based diabetes management interventions appearing in the scientific literature have rarely been formally based on relevant health behavior theory and research, despite the fact that information technology interventions based on health behavior models have considerable potential to support health behavior change. The current study, in contrast, involved development and evaluation of a mobile telephone-based remote patient reporting and automated feedback system that is based on the Information-Motivation-Behavioral Skills Model,^{11,27-31} a well-researched and well-validated model of health behavior change and adherence.

According to the Information-Motivation-Behavioral Skills Model,^{11,27-29,31} *diabetes self-management information* that is easy for the individual to translate into appropriate self-management action is a necessary prerequisite of optimal self-management. In addition, *diabetes self-management motivation*, including positive attitudes toward personally enacting diabetes self-management actions and perceptions of social support for undertaking self-management actions, is essential to incline even well-informed individuals to initiate and maintain diabetes self-management practices. Finally, *diabetes self-management behavioral skills*, including objective skills for carrying out complex patterns of diabetes self-management action (e.g., selecting appropriate foods and reminding oneself to be active, to monitor weight, to test blood glucose, etc.), and perceived self-efficacy for doing so, are essential so that even well-informed and well-motivated individuals will be capable of acting effectively in diabetes self-management efforts.

The current research involved development and evaluation of a mobile telephone-based remote patient reporting system, linked to automated feedback and guided by the Information-Motivation-Behavioral Skills Model^{11,27-29,31} and evidence-based patient care guidelines.¹⁸ In this study, knowledge-based reasoning based on the user's health data was linked in a dynamic process to the delivery of self-management information, motivation, and behavioral skills messages. Assessment of HbA1c, weight, and blood pressure at baseline and follow-up of a 10-month study period, in intervention and control patients, was used to gauge intervention impact on diabetes health-related end points.

A conference presentation that was based on the findings reported in this article has been published previously in abstract form.³²

Subjects and Methods

Participants

The current research comprised an initial randomized controlled trial to establish proof of concept for theory based active assistance technology to promote diabetes self-management and improve HbA1c, body weight, and blood pressure. General inclusion criteria for this research program included the following: age range of 30–70 years combined with HbA1c >6.5%, systolic blood pressure >140 mm Hg, or diastolic blood pressure >90 mm Hg. Specific inclusion criteria for the current study of the impact of active assistance technology on HbA1c, body weight, and blood pressure in individuals with type 2 diabetes were as follows: known diagnosis of type 2 diabetes, elevated HbA1c (>6.5%) or currently using oral diabetes medication, and age range of 30–70 years. Exclusion criteria were expected poor study compliance (e.g., information technology illiteracy or reluctance to perform self-monitoring), pregnancy, patients with life expectancy of less than 1 year, patients with major elective surgery within the past 6 months or planned for the next 6 months, patients with psychiatric disorders (e.g., depression), or alcohol or narcotics abuse.

Research design

Stratified randomization was used to allocate patients to control and intervention study arms. Patients were stratified by sex and dichotomized age (<65 years and ≥65 years). Using Microsoft® (Redmond, WA) Excel-generated random numbers, patients were then assigned to either the control ($n=29$) or intervention study arms ($n=27$). The intervention group participated in a diabetes lifestyle self-management promotion program involving remote patient reporting and automated theory-based health behavior feedback. The control group received standard medical care, including diabetes education, annual checkups, and diabetes guidance and education given by a doctor or nurse during patient-initiated visits to their health center.

Intervention and control arm patients underwent baseline laboratory tests for HbA1c and blood pressure and related assessments. If patients had laboratory tests on record that were no more than 2 months old, these were used. Baseline visits for intervention patients included appointments with a physician and a nurse. At the physician visit, a personal care plan was developed and provided to the patient. In addition, individual target values concerning blood pressure, weight, and activity (steps), as well as blood glucose for selected patients, were established. At the nurse's visit, all intervention patients received measurement devices for self-monitoring of blood pressure, body weight, and physical activity (pedometer). Blood glucose meters were given to six intervention patients with type 2 diabetes who had particularly high HbA1c values. A mobile phone with an application ("Monica") was provided to intervention patients for reporting their health parameters (blood pressure, weight, physical activity, and, in specific cases, blood glucose values). The nurse provided instructions for using the Monica application and measurement devices. Intervention arm patients were also given a personal health record account ("Medinet") that enabled them to view their medical records and remote data reports that were uploaded using their mobile phone appli-

cation. Intervention subjects were asked to complete an electronic health questionnaire through the personal health record at baseline and then again post-intervention. Control arm patients completed the same questionnaires at baseline and post-intervention with pen and paper. The personal health record questionnaire assessed body weight at these points in time. Following study participation of approximately 10 months in duration, all patients returned for follow-up laboratory and clinical assessment. Intervention patients were asked to complete a questionnaire about the usability, user experience and usefulness of the Monica and Medinet applications. The study was approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa.

Intervention

The intervention under study consisted of providing patients with technology (mobile telephone, software application, and assessment devices) for monitoring and remote reporting of diabetes health-related parameters from home. Intervention patients were provided with automatically generated, theory-based, health promotion-rich information, motivation, and behavioral skills feedback messages, linked to patients' remote reports of their health parameters and aimed at strengthening their self-care practices.

The intervention group was instructed to carry out a blood pressure measurement in the morning and evening of 1 day each week. They were also instructed to measure their weight once a week, in the morning. Blood glucose was measured on 3 days each week, for those for whom this was indicated, with the blood glucose meter provided. Selected intervention patients were instructed to take paired (pre- and postprandial) blood glucose measurements—before and 1–2h after a meal—on blood glucose testing days. Patients were permitted to choose if and how they wanted to use the pedometer to measure activity. Patients were instructed to upload their health parameter data using the Monica application directly after making each measurement. For each reported measurement, the patient received a feedback message based on the reported data and data reported earlier during the trial, on the basis of a decision support algorithm. Intervention patients could also access their personal health record (Medinet) through a browser-based user interface offering the opportunity for patients to view their personal health information, including prescriptions, laboratory data, and their personal care plan.

The information technology architecture used for remote uploading of patient data to the automated feedback response system and personal health record is depicted in Figure 1. The Monica application in the mobile phone supports uploading of patients' health parameter measurements. After each upload, the application displays graphs reflecting the uploaded data in relation to individual target values and an information, motivation, and/or behavioral skills feedback message to support patient self-care. Study nurses scanned through the status of all intervention patients each week and contacted patients if warranted by their remote data reports. All patients were encouraged to call their healthcare provider if needed.

Automated feedback

Automated feedback messages for patients were generated by a decision support system directly integrated with

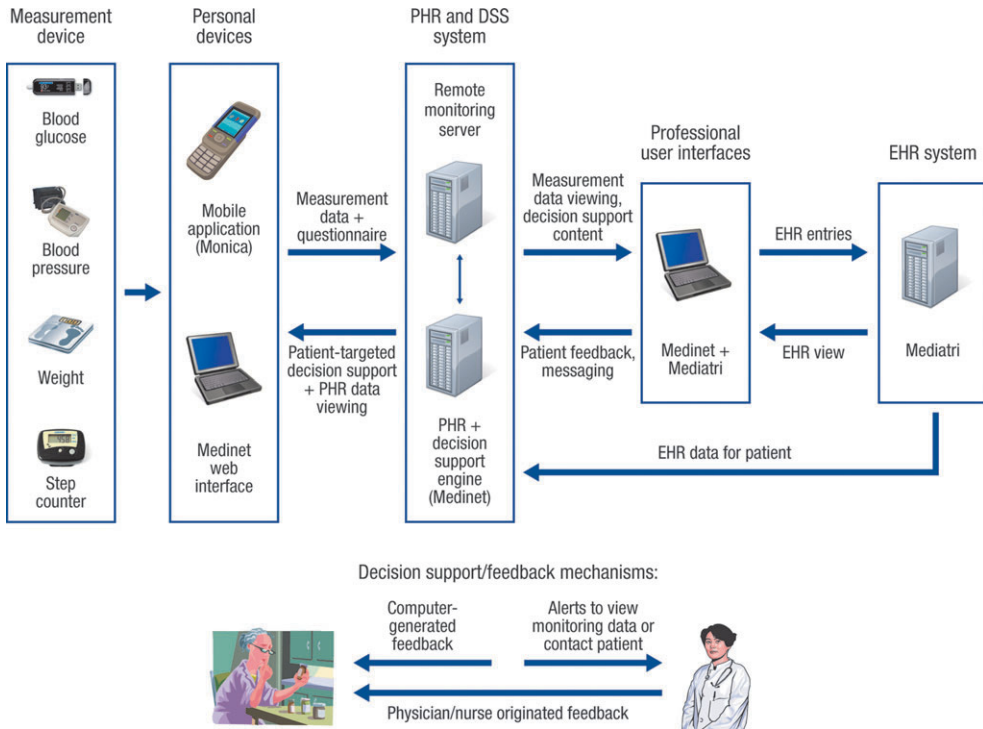


FIG. 1. Architecture of the remote patient monitoring system. DSS, decision support system; PHR, personal health records; EHR, electronic health record.

participants' personal health records. The objective was to encourage patients to initiate and maintain lifestyle changes appropriate to self-care of diabetes and hypertension by providing personalized, information-, motivation-, and behavioral skills-rich feedback, based on patients' self-measured remote reported health parameters.

Patients' personal health record database stored all patient-reported remote measurements. A rule-based decision support algorithm scans the data and provides a patient-specific feedback message for each measurement value reported by the patient. For this purpose, we developed 265 separate feedback messages concerning blood glucose, blood pressure, weight, and activity (steps). Rules were set defining conditions under which each message was to be delivered to a patient. These conditions were based on the value of the monitored parameter (whether it was within or beyond a target interval) and on the basis of long-term trends of remote reported measurements. The decision support system is activated when a new measurement is remotely reported by the patient. It scans all feedback messages and messages that fulfill the preset conditions that are identified as eligible for delivery in the current patient context. An inference engine then selects the most appropriate feedback message to be delivered to the patient. The inference engine scores the messages based on a pre-assigned priority (highest for sus-

pected measurement error and alerts), history of previous messages, and positive, reinforcing nature of the message. The engine also includes a random component introducing natural variability to avoid unnecessary repetition of the same or similar messages. Randomness is introduced, however, only when possible without compromising the delivery of high-priority alerts. A high-priority message results, for example, in a situation in which immediate contact with the patient's health center is recommended. High-priority messages are also delivered, via the patient record system, to the attention of the health personnel who are in charge of patient follow-up. The medical content of feedback messages that are linked to patient remote reporting of health parameter data is provided in accord with evidence-based patient care guidelines (Duodecim¹⁸).

A core concept of the decision support system, as noted, is to inform patients with easy-to-act-on self-management information, to motivate them to act on such self-management information, and to provide behavioral skills coaching to enhance the patient's ability to act effectively in self-management efforts. For this purpose the Information-Motivation-Behavioral Skills Model was used as a basis for the formulation of feedback message contents. An example of a feedback message concerning an out-of-range trend for blood glucose levels follows: "Your blood sugar levels were above the target

levels of 8 mmol/L seven times out of the 12 after-lunch measurements made during the past 2 months. Please, pay attention to regular meal times and the contents of your lunch to avoid excessive variation in your blood sugar levels."

Study end points

Primary end points of the study were the change in HbA1c (% units) and systolic and diastolic blood pressure (mm Hg) from baseline to post-intervention. A secondary end point involved reduction in body weight (kg) from baseline to post-intervention. Patient acceptance and usability and usefulness of the feedback system were described as the proportion of patients with a positive experience.

Statistical analysis

Analysis of covariance was used to assess effects of the intervention on HbA1c, blood pressure, and weight, adjusting for baseline levels. The 95% confidence intervals and unadjusted change scores are reported as well. As sex and age were used in stratification, analyses were repeated adjusting for these variables. No imputations were made to replace missing values, and patients with missing values were excluded from the corresponding analysis. Significance tests were conducted with $\alpha=0.05$.

Results

Recruitment started in December 2010 and ended in April 2011. Invitation letters were sent to 337 patients who were screened from the electronic health record system at the Sipoo,

Finland, Community Health Centre. In total, 237 patients did not respond to the invitation letter or declined to participate. Of the 100 respondents who indicated an interest in the study, 35 were excluded as ineligible, and nine patients subsequently declined to participate. From the 56 randomized patients, 27 were allocated to the intervention group, and 29 were allocated to receive usual care (control). Of 29 control patients, three did not complete the baseline visit, and consequently 26 control patients were included in the control arm. Six intervention patients were selected for glucose monitoring on the basis of high HbA1c level, and an equivalent subgroup of five patients with highest HbA1c levels was identified within the control group. One patient was lost to follow-up in the intervention group, whereas two patients were lost to follow-up in the control group. Two intervention patients were excluded from our final analysis because they proved not to have type 2 diabetes. The study was thus completed with 24 intervention patients and 24 control patients.

Baseline characteristics of intervention and control participants appear in Table 1. The study arms were similar except for systolic blood pressure (significantly higher in the intervention arm) and body mass index (somewhat lower in the intervention arm). The unadjusted and baseline-adjusted changes in clinical health end-point variables (HbA1c, blood pressure, and weight) in the control and intervention groups are presented in Table 2. Probability values denote the level of significance of the difference between the study groups. As can be seen in Table 2, the intervention group achieved a significantly greater decline in HbA1c and in weight compared with controls, when values are adjusted for the corresponding

TABLE 1. BASELINE PATIENT CHARACTERISTICS

	Control group (n=24)	Intervention group (n=24)	P value
Sex (% male)	13 (54%)	13 (54%)	1.0
Age (years)	61.5 (9.1)	62.3 (6.5)	0.745
BMI (kg/m ²)	33.5 (8.0)	30.7 (4.5)	0.151
Blood pressure (systolic/diastolic) (mm Hg)	146.5/84.7 (15.3/9.1)	157.0/88.5 (15.6/10.3)	0.029/0.204
Missing	3	0	
HbA1c (%)	7.09 (1.51)	6.86 (1.56)	0.609
Education (years)	11.9 (3.9)	11.5 (3.5)	0.718
Exercise			0.730
No regular exercise	6 (25%)	4 (17%)	
Regular health-enhancing physical activity	11 (46%)	14 (58%)	
Regular fitness-related exercise	6 (25%)	5 (21%)	
Practice of competitive sports several times a week	0	0	
Missing	1 (4%)	1 (4%)	
Stress			0.373
My life situation is almost intolerable	0	1 (4%)	
Considerably more than most people	3 (12%)	5 (21%)	
To some degree, not more than people usually	11 (46%)	12 (50%)	
Not at all	10 (42%)	5 (21%)	
Missing	1 (4%)	1 (4%)	
Alcohol (standard drinks/week)	7.8 (9.4)	9.3 (12.5)	
Missing	8	1	0.676
Smoking			1.0
Not at all	18 (75%)	19 (80%)	
Occasionally	2 (8%)	1 (4%)	
Yes, daily	3 (13%)	2 (8%)	
Missing	1 (4%)	2 (8%)	

Data are means (SD) or frequency (percentile). The number of missing values is reported where relevant. BMI, body mass index; HbA1c, glycosylated hemoglobin.

TABLE 2. CHANGE IN GLYCOSYLATED HEMOGLOBIN, BLOOD PRESSURE, AND WEIGHT AS A FUNCTION OF STUDY ARM

	Control group	Intervention group	P value
Change in HbA1c (% units)			
Adjusted	0.036 (−0.23 to 0.30)	−0.40 (−0.67 to −0.14)	0.022
Unadjusted	0.004 (−0.35 to 0.36)	−0.37 (−0.73 to −0.01)	0.141
Missing	0	1	
Change in weight (kg)			
Adjusted	0.4 (−1.1 to 1.9)	−2.1 (−3.6 to −0.6)	0.021
Unadjusted	−0.07 (−1.8 to 1.6)	−1.6 (−3.3 to 0.1)	0.205
Missing	0	0	
Change in systolic blood pressure (mm Hg)			
Adjusted	−13.5 (−21.3 to −5.8)	−17.1 (−24.3 to −9.9)	0.508
Unadjusted	−9.8 (−18.5 to −1.0)	−20.5 (−28.6 to −12.3)	0.078
Missing	3	0	
Change in diastolic blood pressure (mm Hg)			
Adjusted	−7.3 (−10.9 to −3.8)	−9.5 (−12.9 to −6.2)	0.377
Unadjusted	−6.3 (−10.5 to −2.1)	−10.5 (−14.4 to −6.6)	0.148
Missing	3	0	

Data are means (95% confidence intervals).
HbA1c, glycosylated hemoglobin.

baseline level. HbA1c reduction within the intervention arm was significant ($P=0.025$), and weight reduction within the intervention arm was marginally significant ($P=0.058$). HbA1c and weight change were nonsignificant within the control group ($P=0.985$ and $P=0.941$, respectively). We also observed a significant within-group decrease in systolic and diastolic pressure in both the control ($P=0.018$ and $P=0.004$, respectively) and the intervention groups ($P<0.001$ and $P<0.001$, respectively) with no difference in magnitude of change between the study arms. We note that there were no significant differences in medication adjustments among participants in the two study arms. Adjusting for participant age, sex, and body mass index did not have any meaningful effect on results.

Post-intervention reports indicated that 100% of intervention participants (24 of 24 who responded to this question) regarded Monica, the mobile telephone application, as “very easy” or “quite easy” to use. More than 90% of respondents (21 of 23 who responded to this question) reported that making health parameter measurements and reporting them was “very useful” or “quite useful,” and approximately 82% (18 of 22 who responded to this question) of intervention participants regarded the automatic feedback they received as “very useful” or “quite useful.”

Discussion

The current research was structured as an initial randomized controlled trial to examine the impact of an active assistance intervention, guided by health behavior theory, on self-management and health status in individuals with type 2 diabetes. The intervention consisted of mobile telephone-based remote reporting of blood pressure, weight, and, for individuals with particularly high HbA1c, blood glucose levels, linked with synchronous, automatic, theory-based feedback. Patient feedback was enriched with self-management information, motivation, and behavioral skills content. Results showed that the automated feedback intervention had significant effects on HbA1c and on weight, which declined reliably in intervention compared with control participants

with type 2 diabetes or type 2 diabetes and hypertension. Blood pressure trends were more positive for the intervention group compared with the control group, but this effect was not significant. We note that these effects were present at the 10-month intervention follow-up and indicate sustained intervention impact across a greater interval of time than is the case in several other studies in this area.^{21,22}

Seen as a proof-of-concept study, current results are supportive of further research with mobile telephone remote reporting and automated Information-Motivation-Behavioral Skills Model-based feedback linked to patient-reported health parameters. Given the prevalence and consequences of diabetes and the fact that healthcare professional management and self-management of diabetes are time-, effort-, and cost-intensive, the potential efficiency and effectiveness of automated feedback, articulated to remote patient reports and guided by health behavior change theory, would seem to be considerable. In the clinical diabetes reality, ongoing healthcare provider support for diabetes self-management is not uniformly available. At the same time, however, many, if not most, individuals with diabetes have mobile communication devices that provide potential access to information technology-based interventions, guided by health behavior models, from which they may benefit at minimum cost.

Interactive technology support has been shown to improve glycemic control in individuals with type 2 diabetes,³³ but success in this respect is determined primarily by frequent contact between intervention patients and healthcare personnel.³⁴ This increases use of healthcare resources and may not be an option for all patients. On the other hand, extensive use of behavioral change techniques via the Internet produces larger effects than interventions with fewer techniques.³⁵ Our study applied active assistance technology for automated processing of health information from patients in an ongoing interaction with technology. This was achieved with semantic information processing of patient-reported data and delegation of decision-making to the automated system, which frees up healthcare personnel resources.

There are several limitations of the current research. It is notable that our sample size, like many similar published

interventions, was modest, but despite modest sample size and statistical power to detect differences between groups, significant intervention impact was observed in relation to HbA1c and weight declines across a clinically meaningful time span. We note that inclusion criteria enabled participation of patients with type 2 diabetes who had controlled or uncontrolled HbA1c levels, reducing, to an extent, room available for significant HbA1c reductions. Nonetheless, significant HbA1c reductions were observed over a sustained intervention interval. In addition, we note that our patient population self-selected to participate in a technology-based self-management intervention. Although it is not known to what proportion of patients with diabetes such interventions would appeal, we found considerable evidence of user experience satisfaction both with the mobile telephone application and with the value of the feedback that was provided. In published Web-based interventions with adults with type 2 diabetes, participation rates have varied between 32% and 83%.³³ Thus, it may be anticipated that active assistance technology would be an option for roughly half of adults with diabetes. Sophisticated information technology platforms for remote patient reporting linked with health behavior change theory-based automated feedback appear to have potential to improve patient outcomes in type 2 diabetes and merit scaled-up research efforts.

Acknowledgments

We wish to thank the personnel of Sipoo Health Centre, Sipoo, Finland, for their important contribution in carrying out the clinical aspects of this study. Development of this article was supported by Bayer HealthCare LLC, Diabetes Care. The Finnish Funding Agency for Technology and Innovation, Technical Research Centre of Finland, and Bayer HealthCare are acknowledged for funding the study. Meters were supplied by Bayer HealthCare. Technical editorial assistance was provided by Nancy Bella, PharmD, of MedErgy and was funded by Bayer HealthCare LLC, Diabetes Care.

Author Disclosure Statement

E.W. and H.S. are full-time employees of Bayer HealthCare LLC, Diabetes Care. P.S. was a full-time employee of Bayer HealthCare LLC, Diabetes Care at the time of the study. A.-L.O., J.L., K.H., M.K., J.L., H.K., V.S., and W.A.F. have received research support from Bayer HealthCare LLC, Diabetes Care.

References

- Centers for Disease Control and Prevention: National diabetes fact sheet, 2011. Data sources, methods, and references for estimates of diabetes and prediabetes. www.cdc.gov/diabetes/pubs/pdf/methods11.pdf (accessed November 17, 2012).
- International Diabetes Federation: Global diabetes plan. 2011–2021. www.idf.org/sites/default/files/Global_Diabetes_Plan_Final.pdf (accessed November 12, 2012).
- Centers for Disease Control and Prevention: Increasing prevalence of diagnosed diabetes—United States and Puerto Rico, 1995–2010. *MMWR Morbid Mortal Wkly Rep* 2012; 61:918–921.
- Wild S, Roglic G, Green A, Sicree R, King H: Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004;27:1047–1053.
- The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial Research Group. *N Engl J Med* 1993;329:977–986.
- Hirsch IB, Bode BW, Childs BP, Close KL, Fisher WA, Gavin JR, Ginsberg BH, Raine CH, Verderese CA: Self-monitoring of blood glucose (SMBG) in insulin- and non-insulin-using adults with diabetes: consensus recommendations for improving SMBG accuracy, utilization, and research. *Diabetes Technol Ther* 2008;10:419–439.
- Gregg EW, Gu Q, Cheng YJ, Narayan KM, Cowie CC: Mortality trends in men and women with diabetes, 1971 to 2000. *Ann Intern Med* 2007;147:149–155.
- Reichard P, Nilsson BY, Rosenqvist U: The effect of long-term intensified insulin treatment on the development of microvascular complications of diabetes mellitus. *N Engl J Med* 1993;329:304–309.
- American Diabetes Association: Executive summary: standards of medical care in diabetes—2012. *Diabetes Care* 2012;35(Suppl 1):S4–S10.
- American Diabetes Association: Standards of medical care in diabetes—2012. *Diabetes Care* 2012;35(Suppl 1):S11–S63.
- Fisher WA, Kohut T, Schachner H, Stenger P: Understanding self-monitoring of blood glucose among individuals with type 1 and type 2 diabetes: an information-motivation-behavioral skills analysis. *Diabetes Educ* 2011;37:85–94.
- Fisher WA, Cornman DH, Kohut T, Schachner H, Stenger P: What primary care providers can do to address barriers to self-monitoring of blood glucose. *Clin Diabetes* 2013;31:34–42.
- Jones H, Edwards L, Vallis TM, Ruggiero L, Rossi SR, Rossi JS, Greene G, Prochaska JO, Zinman B: Changes in diabetes self-care behaviors make a difference in glycemic control: the Diabetes Stages of Change (DiSC) study. *Diabetes Care* 2003;26:732–737.
- Moreland EC, Volkening LK, Lawlor MT, Chalmers KA, Anderson BJ, Laffel LM: Use of a blood glucose monitoring manual to enhance monitoring adherence in adults with diabetes: a randomized controlled trial. *Arch Intern Med* 2006;166:689–695.
- Norris SL, Engelgau MM, Narayan KM: Effectiveness of self-management training in type 2 diabetes: a systematic review of randomized controlled trials. *Diabetes Care* 2001;24:561–587.
- Smith DE, Heckemeyer CM, Kratt PP, Mason DA: Motivational interviewing to improve adherence to a behavioral weight-control program for older obese women with NIDDM. A pilot study. *Diabetes Care* 1997;20:52–54.
- Tatara N, Arsand E, Nilsen H, Hartvigsen G: A review of mobile terminal-based applications for self-management of patients with diabetes. Presented at the International Conference on eHealth, Telemedicine, and Social Medicine, Cancun, Mexico, 2009.
- Varonen H, Jousimaa J, Helin-Salmivaara A, Kunnamo I: Electronic primary care guidelines with links to Cochrane reviews—EBM guidelines. *Fam Pract* 2005;22:465–469.
- Fjeltdsoe BS, Marshall AL, Miller YD: Behavior change interventions delivered by mobile telephone short-message service. *Am J Prev Med* 2009;36:165–173.

20. Wei J, Hollin I, Kachnowski S: A review of the use of mobile phone text messaging in clinical and healthy behaviour interventions. *J Telemed Telecare* 2011;17:41–48.
21. Quinn CC, Clough SS, Minor JM, Lender D, Okafor MC, Gruber-Baldini A: WellDoc mobile diabetes management randomized controlled trial: change in clinical and behavioral outcomes and patient and physician satisfaction. *Diabetes Technol Ther* 2008;10:160–168.
22. Kim HS: A randomized controlled trial of a nurse short-message service by cellular phone for people with diabetes. *Int J Nurs Stud* 2007;44:687–692.
23. Yoon KH, Kim HS: A short message service by cellular phone in type 2 diabetic patients for 12 months. *Diabetes Res Clin Pract* 2008;79:256–261.
24. Charpentier G, Benhamou PY, Dardari D, Clergeot A, Franc S, Schaepeelynck-Belicar P, Catargi B, Melki V, Chaillous L, Farret A, Bosson JL, Penfornis A: The Diabeo software enabling individualized insulin dose adjustments combined with telemedicine support improves HbA1c in poorly controlled type 1 diabetic patients: a 6-month, randomized, open-label, parallel-group, multicenter trial (TeleDiab 1 Study). *Diabetes Care* 2011;34:533–539.
25. Logan AG, McIsaac WJ, Tisler A, Irvine MJ, Saunders A, Dunai A, Rizo CA, Feig DS, Hamill M, Trudel M, Cafazzo JA: Mobile phone-based remote patient monitoring system for management of hypertension in diabetic patients. *Am J Hypertens* 2007;20:942–948.
26. Franklin VL, Waller A, Pagliari C, Greene SA: A randomized controlled trial of Sweet Talk, a text-messaging system to support young people with diabetes. *Diabet Med* 2006;23:1332–1338.
27. Fisher JD, Fisher WA: Changing AIDS-risk behavior. *Psychol Bull* 1992;111:455–474.
28. Fisher JD, Fisher WA, Amico KR, Harman JJ: An information-motivation-behavioral skills model of adherence to anti-retroviral therapy. *Health Psychol* 2006;25:462–473.
29. Fisher WA, Fisher JD. A general social psychological model for changing AIDS risk behavior. In: Pryor J, Reeder G, eds. *The Social Psychology of HIV Infection*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1993:127–154.
30. Osborn CY, Amico KR, Fisher WA, Egede LE, Fisher JD: An information-motivation-behavioral skills analysis of diet and exercise behavior in Puerto Ricans with diabetes. *J Health Psychol* 2010;15:1201–1213.
31. Fisher WA, Schachner H: Self-monitoring of blood glucose in diabetic children and adolescents—barriers, behaviors, and the search for solutions. *US Endocrinol* 2009;4:2–5.
32. Fisher WA, Orsama A-L, Lähteenmäki J, Harno K, Kulju M, Wintergerst E, Schachner H, Stenger P, Leppänen J, Kaijanranta H, Salaspuro V, Liukko K: Remote patient reporting and automated mobile telephone feedback reduce HbA1C and weight in individuals with type 2 diabetes: results of pilot research [abstract O-21]. *Diabetes Technol Ther* 2013;15(Suppl 1):A-8.
33. Ramadas A, Quek KF, Chan CK, Oldenburg B: Web-based interventions for the management of type 2 diabetes mellitus: a systematic review of recent evidence. *Int J Med Inform* 2011;80:389–405.
34. Fry JP, Neff RA: Periodic prompts and reminders in health promotion and health behavior interventions: systematic review. *J Med Internet Res* 2009;11:e16.
35. Webb TL, Joseph J, Yardley L, Michie S: Using the internet to promote health behavior change: a systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. *J Med Internet Res* 2010;12:e4.

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PUBLICATION

II

Use of Home Telemonitoring to Support Multidisciplinary Care of Heart Failure Patients in Finland: Randomized Controlled Trial

Vuorinen A-L, Leppänen, J, Kaijanranta H, Kulju, M, Heliö T, van Gils M, Lähteenmäki J.

Journal of Medical Internet Research, 2014, 16(12), e282

<http://www.jmir.org/2014/12/e282/>

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Original Paper

Use of Home Telemonitoring to Support Multidisciplinary Care of Heart Failure Patients in Finland: Randomized Controlled Trial

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Abstract

Background: Heart failure (HF) patients suffer from frequent and repeated hospitalizations, causing a substantial economic burden on society. Hospitalizations can be reduced considerably by better compliance with self-care. Home telemonitoring has the potential to boost patients' compliance with self-care, although the results are still contradictory.

Objective: A randomized controlled trial was conducted in order to study whether the multidisciplinary care of heart failure patients promoted with telemonitoring leads to decreased HF-related hospitalization.

Methods: HF patients were eligible whose left ventricular ejection fraction was lower than 35%, NYHA functional class ≥ 2 , and who needed regular follow-up. Patients in the telemonitoring group ($n=47$) measured their body weight, blood pressure, and pulse and answered symptom-related questions on a weekly basis, reporting their values to the heart failure nurse using a mobile phone app. The heart failure nurse followed the status of patients weekly and if necessary contacted the patient. The primary outcome was the number of HF-related hospital days. Control patients ($n=47$) received multidisciplinary treatment according to standard practices. Patients' clinical status, use of health care resources, adherence, and user experience from the patients' and the health care professionals' perspective were studied.

Results: Adherence, calculated as a proportion of weekly submitted self-measurements, was close to 90%. No difference was found in the number of HF-related hospital days (incidence rate ratio [IRR]=0.812, $P=.351$), which was the primary outcome. The intervention group used more health care resources: they paid an increased number of visits to the nurse (IRR=1.73, $P<.001$), spent more time at the nurse reception (mean difference of 48.7 minutes, $P<.001$), and there was a greater number of telephone contacts between the nurse and intervention patients (IRR=3.82, $P<.001$ for nurse-induced contacts and IRR=1.63, $P=.049$ for patient-induced contacts). There were no statistically significant differences in patients' clinical health status or in their self-care behavior. The technology received excellent feedback from the patient and professional side with a high adherence rate throughout the study.

Conclusions: Home telemonitoring did not reduce the number of patients' HF-related hospital days and did not improve the patients' clinical condition. Patients in the telemonitoring group contacted the Cardiology Outpatient Clinic more frequently, and on this way increased the use of health care resources.

Trial Registration: Clinicaltrials.gov NCT01759368; <http://clinicaltrials.gov/show/NCT01759368> (Archived by WebCite at <http://www.webcitation.org/6UFxiCk8Z>).

(*J Med Internet Res* 2014;16(12):e282) doi:[10.2196/jmir.3651](https://doi.org/10.2196/jmir.3651)

KEYWORDS

heart failure; telemonitoring; hospitalization; user experience; clinical outcomes; EHFSBS; health care resources

Introduction

Heart failure (HF) is a serious and costly disease associated with poor quality of life [1], a wide range of comorbidities [2], and a high rate of hospitalization [3]. Nearly 25% of patients are readmitted within 30 days [4], and by 6 months, the proportion increases to 50% [5]. Hospitalizations cause a heavy economic burden since they are responsible for 60-70% of the total costs of HF care [6]. Moreover, the 1-year mortality of HF patients is 30% [3], and the 5-year survival rate is poorer than in most cancers [7].

A multidisciplinary care approach to heart failure is incorporated with European and American guidelines. The multidisciplinary care model includes specially trained HF nurses, the education of patients (and caregivers) regarding precipitating factors and the need for compliance with medication and diet, follow-up monitoring by trained staff, and access to specialized HF clinics [8]. Non-compliance with medication and other lifestyle recommendations is a major problem among HF patients resulting in worsening symptoms that can lead to readmission [9]. Hospitalizations may be preventable by up to 50% mainly by improving compliance with self-care [10].

Care-delivery models that incorporate telemonitoring as a part of HF patients' care have the potential to boost patients' compliance with self-care while at the same time bringing health care services closer to them. Meta-analyses from the years 2009-2011 link telemonitoring with improved survival, decreased hospitalizations, and improved quality of life [11-13]. However, since these meta-analyses were carried out there have been two large randomized controlled trials that have failed to show evidence in favor of telemonitoring in terms of reducing hospitalizations and death [14,15]. Similar findings have been reported in earlier studies [16,17] and more recently in smaller studies [18-20], except in the TEN-HMS trial [16], in which mortality was found to be lower in the telemonitoring group compared to usual care. Furthermore, results from the recent Whole Systems Demonstrator (WSD) study, a multisite trial involving 3230 chronically ill patients shows contradictory evidence. Telehealth was found to reduce mortality and emergency admission rates in the secondary care [21] but failed to improve quality of life or psychological outcomes [22], nor was it cost-effective [23]. Among patients with social care needs in WSD study, telecare did not alter the use of health and social care service or mortality [24]. To summarize, the literature shows conflicting evidence on the effectiveness of telemonitoring dependent on the target population and study environment and the implementation and structure of the intervention itself.

The current literature does not cover the evaluation of telemonitoring as a part of multidisciplinary care. The objective of this study was to investigate whether the multidisciplinary care of HF patients could be improved with telemonitoring at the Cardiology Outpatient Clinic of Helsinki University Central Hospital (HUCH), primarily in terms of reducing HF-related hospitalizations. We hypothesized that telemonitoring improves patients' adherence to self-care—something that will be realized as decreased hospitalizations.

Methods

Study Design

Heart at Home was a two-arm randomized controlled trial conducted at the Cardiology Outpatient Clinic of HUCH in 2010-2012 (NCT01759368). The study protocol was approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa. All the patients provided a written informed consent before they were randomized. (See [Multimedia Appendix 1](#) for the CONSORT EHEALTH checklist [25]).

Matched pair design was used in the randomization. The eligible patients, who were similar in left ventricular ejection fraction, NYHA classification, age, and gender, respectively, were matched in pairs. One was randomized to the control group and the other to the intervention group.

The study was divided into two parts. The first 30 intervention patients and 29 control patients started stepwise from November 2010 to February 2011. After the first 59 patients had finished their follow-up, the second group (17 intervention patients and 18 control patients) started in May to August 2011. The nominal follow-up time was 6 months. The study was completed in February 2012.

Participants

Patients suffering from chronic heart failure were recruited to the study. The inclusion criteria were (1) diagnosis of systolic heart failure, (2) age of 18-90 years, (3) NYHA class ≥ 2 (an interview-based classification by the New York Heart Association concerning limitations to physical activity), (4) left ventricular ejection fraction $\leq 35\%$ as measured during hospital visits, (5) need for a regular check-up visit, and (6) time from the last visit of less than 6 months. Patients were not eligible if they had a planned major medical operation, had severe comorbidity such as cancer, had participated in another clinical trial during the last 3 months, or were suspected of poor compliance. The assessment of compliance was based on patient's technical skills, such as ability to use a mobile phone.

The electronic patient database of HUCH was used for the initial screening of patients with chronic heart failure so as to further assess their eligibility. Eligible patients were informed about the study and were asked whether they were willing to participate (and their formal consent was obtained) when they came for their normal follow-up visit. For willing patients, anthropometric and laboratory measurements were taken and the patients completed the study questionnaires. For each patient, the medication was checked and optimized. The same procedure was repeated at the end-point visit.

Usual Care

At the Cardiology Outpatient Clinic of HUCH, there are about 600 HF patients, of whom 150-200 patients have serious heart failure that requires regular follow-up visits. A multidisciplinary care approach including patient guidance and support for self-care has been adopted at the clinic. In the care of these HF patients, the cardiac team plays a central role in monitoring and interpreting patient symptoms, optimizing medication, and providing education. The cardiac team consists of 2 physicians,

a specialized heart failure nurse, and a physiotherapist who helps after a hospitalization period. As part of the care process, patients capable of carrying out self-care were identified and encouraged to regularly measure their blood pressure, heart rate, and weight at home. The information exchange between HF patients and care personnel took place during patients' visits to the clinic and by telephone. Systematic collection and exploitation of the self-measurement data was difficult since it depended on the patient's own activity. Often a patient had not monitored their health parameters as agreed or had forgotten to bring along the measurement notes. The heart failure nurse contacted patients by telephone if agreed in the care plan to motivate and remind them to comply with the self-care plan.

Intervention: A Telemonitoring-Assisted Self-Care Model

For patients in the intervention arm, a new care process was introduced in which a patient regularly reported their most important health parameters to the nurse using a mobile phone app. At the beginning of the study, the patients were given a home-care package including a weight scale, a blood pressure meter, a mobile phone, and self-care instructions. The patients were advised to carry out and report the measurements together with the assessment of symptoms once a week.

A pre-installed software app on the mobile phone supported the uploading of measurements and the self-assessment of symptoms. In the development of the mobile app, particular care was paid to the simplicity of the user interface and its ease

of use, since most of the patients were elderly. The measurements taken at home to be uploaded were diastolic and systolic blood pressure, pulse, body weight, and an assessment of symptoms. The symptom assessment concerned the patient's feelings of dizziness, dyspnea, palpitation, weakness, and edema. Patients were also asked to evaluate their overall condition, that is, whether their condition had deteriorated, improved, or remained unchanged. In the context of each submission of information, the patient received automatic machine-based feedback of whether the reported parameter was within their personal targets set by the nurse. The overall architecture used in the self-care process and screenshots of the software app are depicted in Figures 1 and 2. The system was developed by VTT Technical Research Centre of Finland.

The measurements were stored on the secured remote patient monitoring server. The cardiac team was able to access the data with a browser-based user interface. The nurse followed the patient's status and the data once a week or more frequently if necessary. In the beginning of the study, the nurse contacted the patient every time the measurement was beyond the target levels or if the patient reported any of the symptoms. Later, the contacts were more dependent on the patient's measurement history. If the latest measurement markedly differed from previous measurements, the nurse called the patient. The nurse could invite the patient for a check-up visit if still necessary after the phone call. If a patient did not comply with the weekly reporting plan, the nurse contacted the patient and encouraged him or her to continue with the monitoring.

Figure 1. Overall architecture for remote patient monitoring.

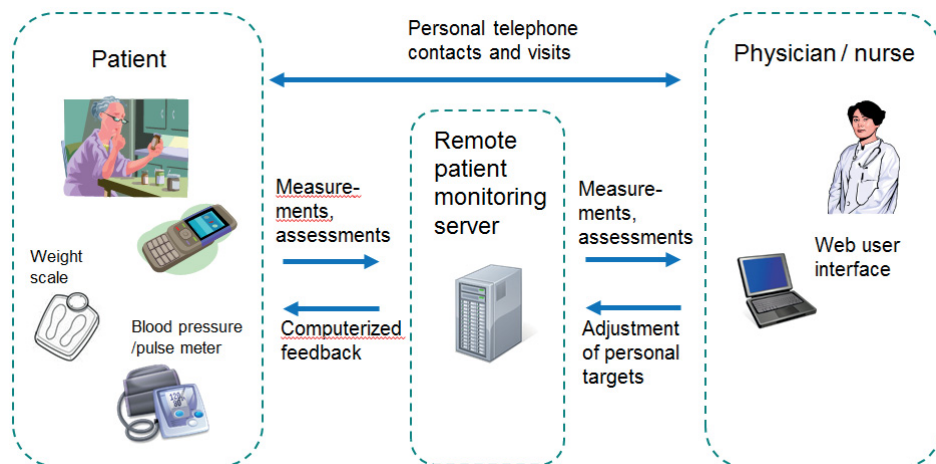
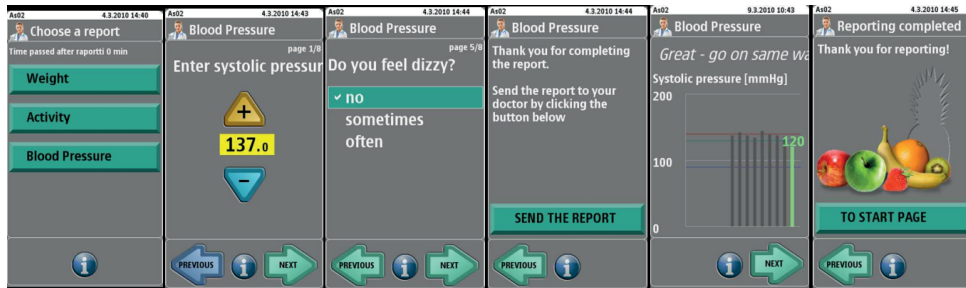


Figure 2. Screenshots of the reporting process with the mobile app.



Outcome Measures

Primary Outcome

The primary outcome was the number of HF-related hospital days during the follow-up. The data were obtained from the electronic health record system of HUCH.

Secondary Outcomes

Secondary outcomes included clinical outcomes, use of health care resources, and user experience. The following variables were analyzed in order to assess clinical effectiveness: death from any cause, heart transplant operation or listing for transplant operation, left ventricular ejection fraction (LVEF, %) measured by echocardiography, plasma concentration of N-terminal of the prohormone brain natriuretic peptide (NT-proBNP, ng/l), creatinine (µmol/l), sodium (mmol/l), and potassium (mmol/l). For the plasma concentrations of sodium, potassium, and creatinine, there is no unambiguous interpretation of the direction of change, but the value should be within the reference range. The reference ranges used at HUCH are sodium 137-145 mmol/l, potassium 3.3-4.9 mmol/l, creatinine among women 50-90 µmol/l and among men 60-100µmol/l. Sodium, potassium, and creatinine were dichotomized indicating whether the observed value was within the reference range.

Self-care behavior was measured using the European Heart Failure Self-Care Behaviour Scale (EHFSBS). EHFSBS is a 12-item self-administered questionnaire specifically designed and tested for HF patients including statements on self-care behavior essential in the care of HF. The statements are scored from 1-5; the lower the score, the better the performance in self-care. The summary score was analyzed, and medication changes were recorded to examine how the telemonitoring intervention affected activity in medication regimen. The nurse collected information regarding changes in patients' medication regimen throughout the study. Changes related to medication optimization during the baseline visit were excluded. Changes made to patients' medication were classified into three categories: increase of medication (a new drug or increase in dosage), decrease of medication (termination of a certain drug or decrease in dosage), and self-imposed medication termination (patient had stopped taking medicine without physician's confirmation). The medications were classified as diuretics, ACE-I, or beta-blockers.

In terms of the use of health care resources, outpatient visits were analyzed: the number of (1) unplanned visits to the Cardiology Outpatient Clinic (nurse or physician), (2) visits to the emergency department, (3) visits to and time spent with the nurse, (4) visits to and time spent with the physicians, and (5) telephone contacts made by the patient and by the nurse. The baseline visits and the end-point visits were included in the calculations. The data were retrieved from the electronic health records and by asking the patient.

Patients' acceptance and experience towards home telemonitoring were evaluated using a questionnaire delivered to patients in the telemonitoring group at the end-point visit. The questionnaire included statements about their experiences with the usability of the mobile phone app, as well as their satisfaction with using the app and the benefits of the telemonitoring-assisted care model. In addition, an in-depth interview was conducted with the nurse responsible in order to assess the user experience from a professional perspective.

Power Calculations

The study was designed to have a power of 90%, an alpha level of .05, and an effect size of 0.5 determined as the expected difference of 3 HF-related hospital days between the study groups (SD 6). A *t* test was used as a calculation framework. With these parameters, we calculated that 44 patients per treatment arm needed to be recruited.

Statistical Analysis

The intention-to-treat principle was applied in statistical analyses. There was one dropout in the intervention group. The patient withdrew from the study shortly after the beginning, and no end-point measurements were available. The patient was excluded in the end-point analyses. All analyses except zero inflated Poisson (ZIP) were carried out using SPSS version 19. ZIP regression models were conducted using R version 2.15.1.

Outcome variables that express counts (eg, HF-related hospital days, visits to the nurse, visits to the physician, number of phone calls, unplanned visits to the clinic) were presented using the mean and a percentage of zero counts. Poisson regression and ZIP regression models were used in order to analyze the difference between the study groups. The Vuong test [26] was used to assess the superiority between Poisson regression and ZIP for each variable. Finally, ZIP regression was used in the analysis of the following variables: number of HF-related hospital days, number of unplanned visits to the clinic, and

telephone contacts initiated by the patient. In all models, the patient’s individual study duration (in days) was set as an offset variable, and the control group was used as a reference group. The incidence rate ratio (IRR) and its 95% confidence interval (CI) were reported.

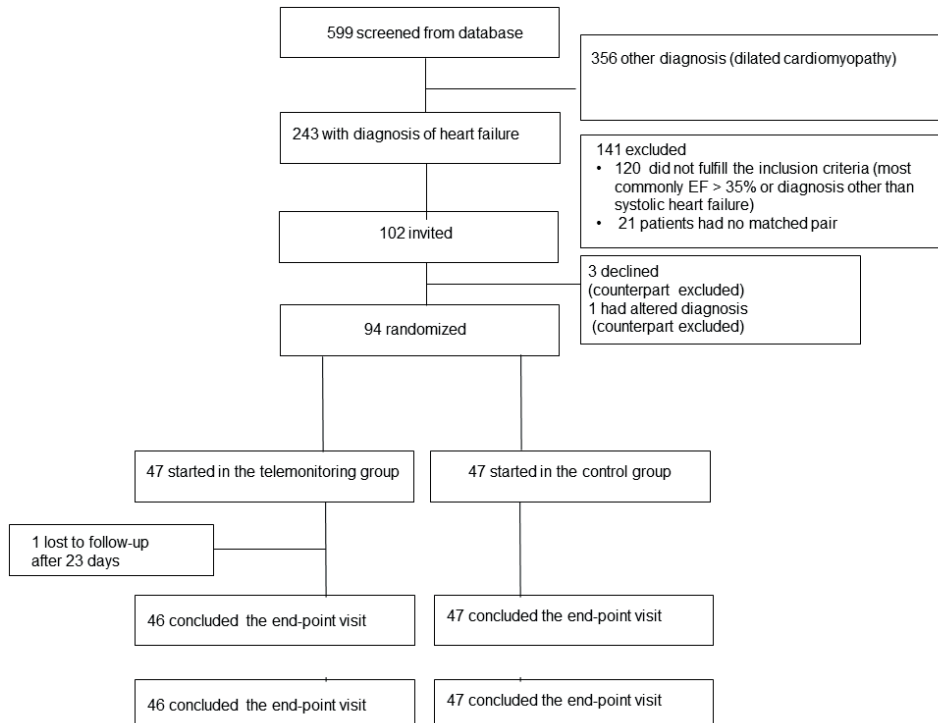
Repeated contiguous variables were analyzed within and between the study groups. The paired *t* test or Wilcoxon matched-pair signed-rank test in the case of non-normality was used for the analyses of within-group changes. Non-normality was confirmed by the Kolmogorov-Smirnov test. Analysis of covariance was used to investigate differences between the control and the intervention groups with adjustment for baseline values. The 95% CI and *P* value for the between-group difference were reported.

Results

Patient Flow

Figure 3 shows the progress of the study. Altogether, 599 patients were screened from the database, of whom 243 were

Figure 3. Screening, randomization, and follow-up of patients.



diagnosed with systolic heart failure. Of these, 123 patients fulfilled the inclusion criteria. Eligible patients who were similar in their left ventricular ejection fraction, NYHA classification, age, and gender were matched; 51 matched pairs were identified. The 102 patients were invited for a baseline visit where baseline measurements were taken and information considering the study was given. Of these, 3 patients declined to participate and another patient had a changed diagnosis. Respectively, their matched counterparts were excluded from the study. Finally, 94 patients were randomized. One from each pair was randomly assigned to receive the usual care, and the other was assigned to the telemonitoring group. There was one dropout in the telemonitoring group. The patient withdrew from the study after 23 days. The patient felt that monitoring his condition made him anxious as it reminded him constantly of the disease.

Baseline Characteristics

Table 1 displays the baseline characteristics of the study subjects in both the control group and the telemonitoring group.

Table 1. Baseline characteristics of the patients: mean (standard deviation) or frequency (percentile).

	Control group (n=47)	Telemonitoring group (n=47)
Sex (male), n (%)	39 (83)	39 (83)
Age in years, mean (SD)	57.9 (11.9)	58.3 (11.6)
BMI (kg/m ²), mean (SD)	27.9 (4.7)	28.4 (6.0)
Systolic blood pressure (mmHg), mean (SD)	116 (16)	112 (13)
Diastolic blood pressure (mmHg), mean (SD)	72 (10)	71 (10)
Heart rate (bpm), mean (SD)	70 (12)	69 (11)
Left ventricular ejection fraction (% units), mean (SD)	28.6 (5.0)	27.3 (4.9)
NYHA, frequency (%)		
Slight limitations in physical activity (Class II)	17 (36)	19 (40)
Marked limitation in physical activity (Class III)	28 (60)	27 (58)
Severe limitations in physical activity (Class IV)	2 (4)	1 (2)
Comorbidities, frequency (%)^a		
Diabetes	2 (4)	2 (4)
Hypertension	6 (13)	8 (17)
Atrial fibrillation	6 (13)	14 (30)
Asthma/COPD	5 (11)	2 (4)
Renal insufficiency	4 (9)	0 (2)
No comorbidities	9 (19)	12 (26)
Smoking (number of non-smokers), n (%) ^a	42 (89)	35 (76)

^aData missing from one patient in the telemonitoring group.

Primary Outcome

On average there were 1.4 (SD 3.5) HF-related hospital days in the control group and 0.7 (SD 2.4) HF-related hospital days in the telemonitoring group. Of the control patients, 72% (34/47), and of the telemonitoring patients, 83% (38/46) had no hospital days during the 6-month follow-up. The difference between the study groups was not statistically significant (IRR=0.812, 95% CI 0.525-1.256, $P=.351$).

Secondary Outcomes

Contrary to expectations, none of the subjects died, underwent a heart transplant operation, or were listed for a transplant

operation. In both study groups, two patients had an emergency episode.

Table 2 shows clinical outcomes at baseline and post intervention. There were no statistically significant differences between the study groups in either of the clinical variables. However, in both study groups, there were significant within-group changes: an increase in LVEF (4.2%, $P=.001$ for control group and 5.0%, $P=.003$ for telemonitoring group) and in EHFSBS (-3.8 points, $P<.001$ in the control group and -5.0, $P<.001$ in the telemonitoring group) and a decrease in NT-proBNP levels in the telemonitoring group (-198ng/l, $P=.01$).

Table 2. Clinical outcomes at the beginning and the end of the study and the within-group change with the corresponding confidence intervals (*P* value refers to the significance level for the between-group difference).

	Control group (n=46)			Telemonitoring group (n=47)			Effect size (95% CI)	<i>P</i> value
	Begin	End	Change (95% CI)	Begin	End	Change (95% CI)		
NT-proBNP (ng/l), median (interquartile range) ^a	1338 (474-2974)	731 (368-2408)	-50 (-831 to 260)	2347 (998-3568)	1014 (609-2631)	-198 (-1921 to 170)	Median difference -148	.256
LVEF (%), mean (SD)	28.6 (5.0)	32.8 (8.2)	4.2 (1.8-6.5)	27.3 (4.9)	32.4 (9.8)	5.0 (1.8-8.1)	β=-.04 (-3.658 to 3.743)	.982
EHFSBS score, mean (SD)	27.9 (6.5)	24.1 (8.3)	-3.8 (-5.4 to -2.1)	27.6 (6.8)	22.6 (6.9)	-5.0 (-7.1 to -3.0)	β=-1.320 (-3.842 to 1.184)	.298
Serum creatinine (μmol/L), median (interquartile range; proportion) ^b ^a	88.0 (78.0-121.0; 0.60)	92.0 (84.0-115.0; 0.57)	2.4 (-2.5 to 6.5)	92.5 (83.8-105.3; 0.67)	95.0 (83.5-112.3; 0.57)	3.5 (-1.0 to 9.0)	Median difference 0.9	.435
Serum potassium (mmol/L), mean (SD; proportion) ^b	4.2 (0.3; 0.98)	4.2 (0.4; 0.98)	-0.06 (-0.18 to 0.05)	4.3 (0.4; 0.94)	4.2 (0.4; 1.0)	-0.1 (-0.3 to 0.01)	β=.008 (-0.141 to 0.156)	.918
Serum sodium (mmol/L), mean (SD; proportion) ^b	140.2 (3.0; 0.96)	140.4 (3.4; 0.85)	0.2 (-0.7 to 1.1)	139.6 (3.0; 0.89)	140.7 (2.5; 0.96)	1.0 (0.2-1.8)	β=-.535 (-1.592 to 0.523)	.318

^aNon-parametric test.

^bProportion of patients whose values were within reference interval.

Changes in medication regimen are presented in [Table 3](#). Significantly more medication changes were done to the patients in the telemonitoring group (*P*=.042 for medication increase and *P*=.026 for medication decrease). All decreases in medication were done to telemonitoring patients, and the decreases were applied to diuretics. The increases in medication

in the telemonitoring group involved the following types of medication: five increases in angiotensin converting enzyme inhibitor (ACE-I) therapy, three increases in beta-blockers, and two increases in diuretics. In the control group, the two increases were applied to diuretics.

Table 3. Categorized medication adjustments and the number of patients to whom the adjustments were applied.

Adjustments	Control group (n=47)	Telemonitoring group (n=46)	<i>P</i> value
Increase in medication, n (%)	2 (4)	8 (17)	.042
Decrease in medication, n (%)	0 (0)	5 (11)	.026
Self-imposed medication termination, n (%)	3 (6)	2 (4)	1.0

[Table 4](#) shows the use of health care resources. The use of the nurse's resources was significantly greater in the telemonitoring group (mean time at the reception was 48.7 minutes longer, and the number of nurse visits was 1.73 times greater, *P*<.001 and *P*<.001 respectively). There were more telephone contacts between the nurse and the telemonitoring patients (IRR=5.6 for nurse initiated contacts and IRR=1.63 for patient initiated contacts, *P*<.001 and *P*=.049 respectively). Typically the patients called the nurse for information to interpret the monitoring results (eg, the safe range for blood pressure) or because they wanted to make changes to their diuretic medication. The most frequent reason for nurse-induced calls was patients' non-adherence to self-monitoring: the nurse called patients to remind them to carry out and report the measurements. The number of unplanned visits to the Cardiology Outpatient Clinic was significantly bigger in the telemonitoring group (IRR=3.31, *P*<.001). The control group had on average one unplanned visit

to the clinic while telemonitoring patients had 3-4 unplanned visits. The most common reason for unplanned visits was patients' concern about their worsening condition and the need to discuss it with the nurse. In some cases, patients visited physician reception if they needed immediate help. The reasons for phone calls and unplanned visits were based on nurse's notes. There was no difference in the use of physician resources: the number of visits and the time used at reception were similar between the study groups.

Depending on the patient's skills, 10-20 minutes was spent at the baseline visit for educating the patient to use the mobile phone app and blood pressure meter. During the follow-up period, only six telephone calls concerning purely technical problems took place. In three cases, the nurse called the patient during the first days to help them get started with the mobile app. The other three calls were initiated by the patient and were

caused due to failed Internet connections. All other contacts took place for medical reasons.

Table 4. The use of health care resources per patient during the study.

	Control group (n=47)	Telemonitoring group (n=46)	Effect size (95% CI)	P value ^a
Nurse time (minutes), mean (SD)	87 (35)	136 (43)	Mean difference 48.7 (32.5-64.8)	<.001
Number of visits to the nurse, mean (SD)	2.7 (1.0)	4.5 (2.2)	IRR=1.73 (1.38-2.15)	<.001
Physician time (minutes), mean (SD)	69 (23)	76 (34)	Mean difference 6.7 (6.0-18.6)	.340
Number of visits to the physician, mean (SD)	2.0 (0.8)	1.9 (0.9)	IRR=0.95 (0.71-1.28)	.738
Number of telephone contacts initiated by nurse, mean (SD)/[% patients with zero-count]	0.6 (0.9)/(57.4%)	3.0 (2.4)/(15.2%)	IRR=5.6 (3.41-7.63)	<.001
Number of telephone contacts initiated by patient, mean (SD)/[% patients with zero-count]	0.6 (1.5)/(72.3%)	2.3 (2.1)/(30.4%)	IRR=1.63 (0.999-2.66)	<.049
Number of unplanned visits to the Cardiology Outpatient Clinic, mean (SD)/[% patients with zero-count]	1.0 (1.5)/(46.8%)	3.7 (2.6)/(13%)	IRR=3.31 (2.15-5.09)	<.001

^aDifference between groups.

Professional Experience

The HF nurse who was involved experienced telemonitoring as a valuable support to the current practice. She reported that the patients of the telemonitoring group took self-measurements more regularly and had internalized the importance of regular self-monitoring. Reception visits were more efficient, since no time was wasted on irrelevant issues. The nurse found that patients had taken their drugs more precisely, although no numerical evidence was collected. The nurse reported that both study groups were more curious about the ongoing study and that patients contacted her more frequently than prior to the study. The benefit that the nurse prioritized was the up-to-date data she received from the patients. The data also provided important support for physicians in their decisions about the patient's treatment, for example, in terms of adjustments to medication. A potential disadvantage that the nurse brought up was that the measurement data were input by the users; there was a possibility that some users sometimes sent false data by mistake or even intentionally. During the study, however, there were no signs of such problems. Automatic data transfer from monitoring devices would reduce the risk of erroneous data. The nurse responsible for the patients did not see any obstacles in adding telemonitoring as a part of their multidisciplinary care model.

Patient Experience

Of 46 patients, 44 (96%) responded to the user experience questionnaire. Almost all patients (95%, 42/44) found that making and reporting measurements with the mobile phone app was "very useful" or "quite useful". The automatic feedback they received after sending the measurements was found to be useful; in fact, 91% (40/44) of patients felt it was "very useful" or "quite useful". However, 9% (4/44) patients responded that they did not derive any benefit from the feedback. Two thirds

(66%, 29/44) responded that the feedback helped them pay more attention to issues essential in the treatment of their disease. In fact, 91% (40/44) of patients responded that the feedback motivated them to take measurements and report them regularly. Just over a quarter of patients (27%, 12/44) reported that the feedback also gave them motivation to change their lifestyle.

Most of the patients accepted the home telemonitoring as part of their care routine. The adherence, calculated as a proportion of weekly submitted self-measurements, was 86% in weight reporting and 89% in blood pressure, heart rate, and symptom reporting. The median number of weight reports was 28 (interquartile range 23-33). The median number of blood pressure and symptom reports was 32 (interquartile range 27-43).

Post-Hoc Power Calculations

The post-hoc power was calculated using the Poisson model framework. Using the following definitions: $\exp(\beta)=.8$, base rate=0.03, total sample=97, mean exposure time=200 days, $\alpha=.05$, $R^2=0$ (since the study group was the only predictor), distribution of group allocation= binomial with $\pi=0.5$, the post-hoc power of 0.81 was obtained.

Discussion

Principal Results

This study evaluated whether a multidisciplinary care model would benefit from telemonitoring as an additional element in the care of heart failure patients, primarily in terms of reducing HF-related hospital days. We found that the telemonitoring-assisted care approach led to increased use of health care resources while showing no quantified improvement in the patients' condition. There was no difference in the number of HF-related hospital days, which was the primary outcome.

However, patients and health care providers reacted positively to telemonitoring. Patients' adherence to the weekly reporting plan was close to 90%, which is high in a population with a severe chronic condition.

The increased use of health care resources was primarily seen in the nurse's workload. The telemonitoring group had an increased number of visits to the nurse reception, a longer time spent at the reception, and more frequent telephone contacts with the nurse. Similarly, in the studies by Cleland et al [16] and Wade et al [19], home telemonitoring was associated with frequent patient contacts including home and office visits, telephone contacts, and emergency visits. However, in our study there was neither increased need for physician consultation nor increased number of visits to the emergency department. Despite the increased workload, the nurse found the increased number of contacts with patients to be a positive change. In her experience, telemonitoring invoked the patients' interest in their condition and raised questions that resulted in contacts. The nurse also felt that the control group patients were more active after their enrollment in the study. Patients' increased curiosity was not reflected in a lower number of HF-related hospitalizations, but we can speculate whether low death rates were associated with this. During the 6-month follow-up, we found no deaths in either of the study groups, which is unexpected since the mortality rate at 30 days after hospital admission is 11% [27], rising to 30% during the first year [3].

When implementing telemonitoring in the care process, the increased workload of care professionals needs to be accounted for. Patients' increased awareness of their disease is likely to increase contacts. Patients need help in interpreting the monitoring results, and they seek individual advice in order to manage their disease and maintain their enthusiasm. This kind of activity may lead to positive health outcomes during a longer follow-up period than was the case in the present study. It should be carefully considered whether the current resources are able to handle the increased demand, or whether additional personnel should be hired. As Chaundry et al [14] concluded, a telemonitoring strategy would be more effective if embedded in cardiology practices with a greater organizational capacity to implement it. To lessen the increased workload of health care professionals, the potential of active assistance technology is worthy of consideration. Such technologies include highly sophisticated automatic messaging systems providing personalized guidance to patients with minimum involvement of health care personnel. Promising results with active assistance technology have been reported in the care of diabetes patients [28].

In this study, telemonitoring was linked to more individualized care in terms of the pharmacological therapy of HF patients. This shows an important aspect, since optimal pharmacological management reduces morbidity and mortality, but it is complex and objective guidelines are lacking [29]. Significantly more changes in medication regimen were made in the telemonitoring group—medication was increased for 17% of these patients whereas in the control group the corresponding percentage was 4%. In addition, all reductions in medication were done for telemonitoring patients. Reductions were applied to Furosemide, which is a diuretic, indicating successful management of fluid

retention. Whether medication changes were the result of self-measurement data that telemonitoring patients provided or through their increased self-care or both cannot be confirmed with these data. The frequency of which the measurements were done may alone not be sufficient to constitute the medication changes, but at least the intervention opened patients' eyes and raised discussion concerning their medication.

Our negative finding regarding the hospitalization rate is in line with findings in studies [14–20]. However, several studies do show evidence in favor of telemonitoring in the care of HF patients. This brings up the challenge in providing telehealth for the right patients in the right context. In the TIM-HF study, a subgroup analysis revealed that patients with lower depression scores had significantly lower hospitalization and mortality [30]. Comorbidities such as chronic obstructive pulmonary disease, chronic kidney disease, and anemia may have a negative effect by blurring the signal from the monitored variables and thus lowering their predictive value [31]. Furthermore, in their review of telemonitoring for chronic diseases, Pare et al [32] concluded that the beneficial effects of telemonitoring are more consistent in pulmonary and cardiac studies than in diabetes and hypertension. In the tele-HF study [14], the authors concluded that none of the participant characteristics including age, sex, race, LVEF, and NYHA class identified a group in which telemonitoring was more effective. A similar conclusion was drawn in [30] in terms of LVEF, gender, age, or NYHA.

We outline four factors that may be associated with unchanged HF-related hospitalizations rates. First, as multidisciplinary care was part of the care practice at the Cardiology Outpatient Clinic of HUCH, all the patients including the control group received high standard interactive care, and some were already used to home self-monitoring. Second, the study was carried out in the Helsinki area where patients live a short distance from health services. Patients were able to visit the clinic easily without great effort. We found that the most common reason for unplanned visits was that the patient wanted to discuss with the nurse face-to-face the signs of deterioration and worsening condition. Home telemonitoring may be more beneficial when applied in rural areas where patients do not have direct access to health care. Third, our study population was relatively young, and medication for all patients was optimized during the baseline visit. Ejection fraction was on average 28%, which is higher than in the TEN-HMS study [16] of high-risk HF-patients. Telemonitoring may be more efficient among patients with poor prognosis. In the TEN-HMS study, which found home telemonitoring associated with improved survival, patients were older, had severe cardiac dysfunction, were recently hospitalized, and had high mortality rates. Finally, the follow-up time was possibly too short. Improved self-care may be realized as a lower number of hospitalizations after a time interval longer than 6 months.

Limitations

Post-hoc calculations were conducted based on the Poisson model framework resulting in a power of 0.81, which was less than was determined in initial power calculations. Considering the fact that the 95% confidence interval for the IRR ranged from 0.525 to 1.256, we do not expect that there was a true

difference in the number of HF-related hospital days between the study groups, although we did not reach the level of 0.1 for the type II error. However, the predicted difference of 3 days was overestimated since the number of hospital days was 1.4 in the control group. In addition, we note that we conducted multiple hypothesis testing, which increases the probability of falsely rejecting the null hypothesis. However, the statistically significant findings that were seen in the use of health care resources were consistent in several variables supporting each other.

The usage of the nurse's time was somewhat biased. The time consumed at the baseline visit for the delivery of telemonitoring technology to the patients was counted as time spent by the nurse. Also, when technical problems emerged, patients contacted the nurse. The time used at baseline visit was 10-20 minutes per patient. During the monitoring period, only six contacts were made with the nurse due to technical problems. Therefore, it can be concluded that the time spent on technical issues was marginal and that the increased use of nurse's resources by telemonitoring patients took place due to medical reasons. Technical issues did not increase the required time to

an extent that would lead to significant overestimation. An additional source of bias is the fact that monitoring took place under control of only one research nurse and the professional experience was based only on her interview. Consequently, it is not possible to draw general conclusions on the attitudes of health care professionals on monitoring.

Conclusions

In the Heart at Home study, we found that home telemonitoring was not efficient to support the multidisciplinary care approach in terms of reducing the number of HF-related hospital days or outpatient visits or improving patients' clinical condition. The telemonitoring increased significantly the nurse's workload by increasing the number of reception visits and the number of telephone contacts. The increased workload should be carefully considered when implementing telemonitoring in the care of HF patients. Extra work is required on top of the multidisciplinary care approach. To lessen the increased workload of health care professionals, the potential of active assistance technology is worthy of further consideration to respond to patients' queries and to keep them motivated.

Acknowledgments

We wish to thank the personnel of the Cardiology Outpatient Clinic of HUCH, and in particular the research nurse Leila Partanen, for carrying out the clinical part of the study. The Finnish Funding Agency for Technology and Innovation and VTT Technical Research Centre of Finland are acknowledged for funding the study.

Conflicts of Interest

None declared.

Multimedia Appendix 1

CONSORT EHEALTH checklist V1.6.2 [25].

[\[PDF File \(Adobe PDF File\), 999KB - jmir_v16i12e282_app1.pdf\]](#)

References

1. McMurray J, Stewart S. The burden of heart failure. *Eur Heart J Suppl* 2002;4(suppleD):307-333.
2. Lang CC, Mancini DM. Non-cardiac comorbidities in chronic heart failure. *Heart* 2007 Jun;93(6):665-671 [FREE Full text] [doi: [10.1136/hrt.2005.068296](https://doi.org/10.1136/hrt.2005.068296)] [Medline: [16488925](https://pubmed.ncbi.nlm.nih.gov/16488925/)]
3. Chen J, Normand SL, Wang Y, Krumholz HM. National and regional trends in heart failure hospitalization and mortality rates for Medicare beneficiaries, 1998-2008. *JAMA* 2011 Oct 19;306(15):1669-1678 [FREE Full text] [doi: [10.1001/jama.2011.1474](https://doi.org/10.1001/jama.2011.1474)] [Medline: [22009099](https://pubmed.ncbi.nlm.nih.gov/22009099/)]
4. Krumholz HM, Merrill AR, Schone EM, Schreiner GC, Chen J, Bradley EH, et al. Patterns of hospital performance in acute myocardial infarction and heart failure 30-day mortality and readmission. *Circ Cardiovasc Qual Outcomes* 2009 Sep;2(5):407-413 [FREE Full text] [doi: [10.1161/CIRCOUTCOMES.109.883256](https://doi.org/10.1161/CIRCOUTCOMES.109.883256)] [Medline: [20031870](https://pubmed.ncbi.nlm.nih.gov/20031870/)]
5. Desai AS, Stevenson LW. Rehospitalization for heart failure: predict or prevent? *Circulation* 2012 Jul 24;126(4):501-506 [FREE Full text] [doi: [10.1161/CIRCULATIONAHA.112.125435](https://doi.org/10.1161/CIRCULATIONAHA.112.125435)] [Medline: [22825412](https://pubmed.ncbi.nlm.nih.gov/22825412/)]
6. Stewart S. Financial aspects of heart failure programs of care. *Eur J Heart Fail* 2005 Mar 16;7(3):423-428. [doi: [10.1016/j.ejheart.2005.01.001](https://doi.org/10.1016/j.ejheart.2005.01.001)] [Medline: [15718184](https://pubmed.ncbi.nlm.nih.gov/15718184/)]
7. Stewart S, MacIntyre K, Hole DJ, Capewell S, McMurray JJ. More 'malignant' than cancer? Five-year survival following a first admission for heart failure. *Eur J Heart Fail* 2001 Jun;3(3):315-322. [Medline: [11378002](https://pubmed.ncbi.nlm.nih.gov/11378002/)]
8. McAlister FA, Stewart S, Ferrua S, McMurray JJ. Multidisciplinary strategies for the management of heart failure patients at high risk for admission: a systematic review of randomized trials. *J Am Coll Cardiol* 2004 Aug 18;44(4):810-819 [FREE Full text] [doi: [10.1016/j.jacc.2004.05.055](https://doi.org/10.1016/j.jacc.2004.05.055)] [Medline: [15312864](https://pubmed.ncbi.nlm.nih.gov/15312864/)]
9. van der Wal MH, Jaarsma T, van Veldhuisen DJ. Non-compliance in patients with heart failure; how can we manage it? *Eur J Heart Fail* 2005 Jan;7(1):5-17. [doi: [10.1016/j.ejheart.2004.04.007](https://doi.org/10.1016/j.ejheart.2004.04.007)] [Medline: [15642526](https://pubmed.ncbi.nlm.nih.gov/15642526/)]

10. Michalsen A, König G, Thimme W. Preventable causative factors leading to hospital admission with decompensated heart failure. *Heart* 1998 Nov;80(5):437-441 [[FREE Full text](#)] [Medline: [9930040](#)]
11. Klersy C, De Silvestri A, Gabutti G, Regoli F, Auricchio A. A meta-analysis of remote monitoring of heart failure patients. *J Am Coll Cardiol* 2009 Oct 27;54(18):1683-1694 [[FREE Full text](#)] [doi: [10.1016/j.jacc.2009.08.017](#)] [Medline: [19850208](#)]
12. Inglis SC, Clark RA, McAlister FA, Stewart S, Cleland JG. Which components of heart failure programmes are effective? A systematic review and meta-analysis of the outcomes of structured telephone support or telemonitoring as the primary component of chronic heart failure management in 8323 patients: Abridged Cochrane Review. *Eur J Heart Fail* 2011 Sep;13(9):1028-1040. [doi: [10.1093/eurjhf/hfr039](#)] [Medline: [21733889](#)]
13. Inglis SC, Clark RA, McAlister FA, Ball J, Lewinter C, Cullington D, et al. Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Cochrane Database Syst Rev* 2010(8):CD007228. [doi: [10.1002/14651858.CD007228.pub2](#)] [Medline: [20687083](#)]
14. Chaudhry SI, Matterna JA, Curtis JP, Spertus JA, Herrin J, Lin Z, et al. Telemonitoring in patients with heart failure. *N Engl J Med* 2010 Dec 9;363(24):2301-2309 [[FREE Full text](#)] [doi: [10.1056/NEJMoa1010029](#)] [Medline: [21080835](#)]
15. Koehler F, Winkler S, Schiebel M, Sechtem U, Stangl K, Böhm M, Telemedical Interventional Monitoring in Heart Failure Investigators. Impact of remote telemedical management on mortality and hospitalizations in ambulatory patients with chronic heart failure: the telemedical interventional monitoring in heart failure study. *Circulation* 2011 May 3;123(17):1873-1880 [[FREE Full text](#)] [doi: [10.1161/CIRCULATIONAHA.111.018473](#)] [Medline: [21444883](#)]
16. Cleland JG, Louis AA, Rigby AS, Janssens U, Balk AH, TEN-HMS Investigators. Noninvasive home telemonitoring for patients with heart failure at high risk of recurrent admission and death: the Trans-European Network-Home-Care Management System (TEN-HMS) study. *J Am Coll Cardiol* 2005 May 17;45(10):1654-1664 [[FREE Full text](#)] [doi: [10.1016/j.jacc.2005.01.050](#)] [Medline: [15893183](#)]
17. Mortara A, Pinna GD, Johnson P, Maestri R, Capomolla S, La Rovere MT, et al. Home telemonitoring in heart failure patients: the HHH study (Home or Hospital in Heart Failure). *Eur J Heart Fail* 2009 Mar;11(3):312-318 [[FREE Full text](#)] [doi: [10.1093/eurjhf/hfp022](#)] [Medline: [19228800](#)]
18. Takahashi PY, Pecina JL, Upatising B, Chaudhry R, Shah ND, Van Houten H, et al. A randomized controlled trial of telemonitoring in older adults with multiple health issues to prevent hospitalizations and emergency department visits. *Arch Intern Med* 2012 May 28;172(10):773-779 [[FREE Full text](#)] [doi: [10.1001/archinternmed.2012.256](#)] [Medline: [22507696](#)]
19. Wade MJ, Desai AS, Spettell CM, Snyder AD, McGowan-Stackewicz V, Kummer PJ, et al. Telemonitoring with case management for seniors with heart failure. *Am J Manag Care* 2011 Mar;17(3):e71-e79 [[FREE Full text](#)] [Medline: [21504262](#)]
20. Seto E, Leonard KJ, Cafazzo JA, Barnsley J, Masino C, Ross HJ. Mobile phone-based telemonitoring for heart failure management: a randomized controlled trial. *J Med Internet Res* 2012;14(1):e31 [[FREE Full text](#)] [doi: [10.2196/jmir.1909](#)] [Medline: [22356799](#)]
21. Steventon A, Bardsley M, Billings J, Dixon J, Doll H, Hirani S, Whole System Demonstrator Evaluation Team. Effect of telehealth on use of secondary care and mortality: findings from the Whole System Demonstrator cluster randomised trial. *BMJ* 2012;344:e3874 [[FREE Full text](#)] [Medline: [22723612](#)]
22. Cartwright M, Hirani SP, Rixon L, Beynon M, Doll H, Bower P, Whole Systems Demonstrator Evaluation Team. Effect of telehealth on quality of life and psychological outcomes over 12 months (Whole Systems Demonstrator telehealth questionnaire study): nested study of patient reported outcomes in a pragmatic, cluster randomised controlled trial. *BMJ* 2013;346:f653 [[FREE Full text](#)] [Medline: [23444424](#)]
23. Henderson C, Knapp M, Fernández JI, Beecham J, Hirani SP, Cartwright M, Whole System Demonstrator evaluation team. Cost effectiveness of telehealth for patients with long term conditions (Whole Systems Demonstrator telehealth questionnaire study): nested economic evaluation in a pragmatic, cluster randomised controlled trial. *BMJ* 2013;346:f1035 [[FREE Full text](#)] [Medline: [23520339](#)]
24. Steventon A, Bardsley M, Billings J, Dixon J, Doll H, Beynon M, et al. Effect of telecare on use of health and social care services: findings from the Whole Systems Demonstrator cluster randomised trial. *Age Ageing* 2013 Jul;42(4):501-508 [[FREE Full text](#)] [doi: [10.1093/ageing/aft008](#)] [Medline: [23443509](#)]
25. Eysenbach G, CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *J Med Internet Res* 2011;13(4):e126 [[FREE Full text](#)] [doi: [10.2196/jmir.1923](#)] [Medline: [22209829](#)]
26. Vuong Q. Likelihood ratio tests for model selection and non-nested hypotheses. *Econometrica* 1989;57:307-333. [doi: [10.2307/191255](#)]
27. Bueno H, Ross JS, Wang Y, Chen J, Vidán MT, Normand SL, et al. Trends in length of stay and short-term outcomes among Medicare patients hospitalized for heart failure, 1993-2006. *JAMA* 2010 Jun 2;303(21):2141-2147 [[FREE Full text](#)] [doi: [10.1001/jama.2010.748](#)] [Medline: [20516414](#)]
28. Orsama AL, Lähteenmäki J, Harno K, Kulju M, Wintergerst E, Schachner H, et al. Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: results of a theory-based randomized trial. *Diabetes Technol Ther* 2013 Aug;15(8):662-669. [doi: [10.1089/dia.2013.0056](#)] [Medline: [23844570](#)]

29. Troughton RW, Frampton CM, Yandle TG, Espiner EA, Nicholls MG, Richards AM. Treatment of heart failure guided by plasma aminoterminal brain natriuretic peptide (N-BNP) concentrations. *Lancet* 2000 Apr 1;355(9210):1126-1130. [Medline: [10791374](#)]
30. Koehler F, Winkler S, Schieber M, Sechtem U, Stangl K, Böhm M, et al. Telemedicine in heart failure: pre-specified and exploratory subgroup analyses from the TIM-HF trial. *Int J Cardiol* 2012 Nov 29;161(3):143-150. [doi: [10.1016/j.ijcard.2011.09.007](#)] [Medline: [21982700](#)]
31. Anker SD, Koehler F, Abraham WT. Telemedicine and remote management of patients with heart failure. *Lancet* 2011 Aug 20;378(9792):731-739. [doi: [10.1016/S0140-6736\(11\)61229-4](#)] [Medline: [21856487](#)]
32. Paré G, Jaana M, Sicotte C. Systematic review of home telemonitoring for chronic diseases: the evidence base. *J Am Med Inform Assoc* 2007;14(3):269-277 [FREE Full text] [doi: [10.1197/jamia.M2270](#)] [Medline: [17329725](#)]

Abbreviations

ACE-I: angiotensin converting enzyme inhibitor
EHFSBS: European Heart Failure Self-Care Behaviour Scale
HF: heart failure
HUCH: Helsinki University Central Hospital
IRR: incidence rate ratio
LVEF: left ventricular ejection fraction
NT-proBNP: N-terminal of the prohormone brain natriuretic peptide
NYHA: New York Heart Association
WSD: Whole Systems Demonstrator

Edited by G Eysenbach; submitted 30.06.14; peer-reviewed by J Cleland, P Kastner, L Ning; comments to author 31.07.14; revised version received 10.09.14; accepted 05.11.14; published 11.12.14

Please cite as:

Vuorinen AL, Leppänen J, Kajjanranta H, Kulju M, Heliö T, van Gils M, Lähteenmäki J

Use of Home Telemonitoring to Support Multidisciplinary Care of Heart Failure Patients in Finland: Randomized Controlled Trial
J Med Internet Res 2014;16(12):e282

URL: <http://www.jmir.org/2014/12/e282/>

doi: [10.2196/jmir.3651](https://doi.org/10.2196/jmir.3651)

PMID:

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PUBLICATION

III

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Journal of Medical Internet Research, 2015, 17(6), e153

<https://www.jmir.org/2015/6/e153/>

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Original Paper

Telemonitoring and Mobile Phone-Based Health Coaching Among Finnish Diabetic and Heart Disease Patients: Randomized Controlled Trial

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Abstract

Background: There is a strong will and need to find alternative models of health care delivery driven by the ever-increasing burden of chronic diseases.

Objective: The purpose of this 1-year trial was to study whether a structured mobile phone-based health coaching program, which was supported by a remote monitoring system, could be used to improve the health-related quality of life (HRQL) and/or the clinical measures of type 2 diabetes and heart disease patients.

Methods: A randomized controlled trial was conducted among type 2 diabetes patients and heart disease patients of the South Karelia Social and Health Care District. Patients were recruited by sending invitations to randomly selected patients using the electronic health records system. Health coaches called patients every 4 to 6 weeks and patients were encouraged to self-monitor their weight, blood pressure, blood glucose (diabetics), and steps (heart disease patients) once per week. The primary outcome was HRQL measured by the Short Form (36) Health Survey (SF-36) and glycosylated hemoglobin (HbA1c) among diabetic patients. The clinical measures assessed were blood pressure, weight, waist circumference, and lipid levels.

Results: A total of 267 heart patients and 250 diabetes patients started in the trial, of which 246 and 225 patients concluded the end-point assessments, respectively. Withdrawal from the study was associated with the patients' unfamiliarity with mobile phones—of the 41 dropouts, 85% (11/13) of the heart disease patients and 88% (14/16) of the diabetes patients were familiar with mobile phones, whereas the corresponding percentages were 97.1% (231/238) and 98.6% (208/211), respectively, among the rest of the patients ($P=.02$ and $P=.004$). Withdrawal was also associated with heart disease patients' comorbidities—40% (8/20) of the dropouts had at least one comorbidity, whereas the corresponding percentage was 18.9% (47/249) among the rest of the patients ($P=.02$). The intervention showed no statistically significant benefits over the current practice with regard to health-related quality of life—heart disease patients: $\beta=0.730$ ($P=.36$) for the physical component score and $\beta=-0.608$ ($P=.62$) for the mental component score; diabetes patients: $\beta=0.875$ ($P=.85$) for the physical component score and $\beta=-0.770$ ($P=.52$) for the mental component score. There was a significant difference in waist circumference in the type 2 diabetes group ($\beta=-1.711$, $P=.01$). There were no differences in any other outcome variables.

Conclusions: A health coaching program supported with telemonitoring did not improve heart disease patients' or diabetes patients' quality of life or their clinical condition. There were indications that the intervention had a differential effect on heart

patients and diabetes patients. Diabetes patients may be more prone to benefit from this kind of intervention. This should not be neglected when developing new ways for self-management of chronic diseases.

Trial Registration: ClinicalTrials.gov NCT01310491; <http://clinicaltrials.gov/ct2/show/NCT01310491> (Archived by WebCite at <http://www.webcitation.org/6Z8I5FwAM>).

(*J Med Internet Res* 2015;17(6):e153) doi:[10.2196/jmir.4059](https://doi.org/10.2196/jmir.4059)

KEYWORDS

health coaching; telemonitoring; type 2 diabetes; heart disease; personal health record; health-related quality of life

Introduction

There is a strong will and need to find alternative models of health care delivery [1], driven by the ever-increasing burden of chronic diseases. To ensure adequate resources for the delivery of health care and to further improve the level of care, care-delivery models need to be changed in a way that patients themselves become more involved in their own care.

Home telemonitoring of chronic diseases seems to be a promising disease management approach with the potential to boost patients' compliance with self-care, while bringing health care services closer to patients and, thus, resulting in improved quality of life. However, the evidence of the effectiveness of telemonitoring is contradictory and is dependent on the nature of the disease [2]. In a systematic review by Pare et al [2], it was found that telemonitoring improved glycemic control of diabetics, decreased blood pressure levels of hypertensive patients, and improved peak expiratory flows of patients with asthma and symptoms associated with the illness. However, the beneficial effect of telemonitoring was not associated with heart failure and the evidence is still contradictory. Meta-analyses conducted among heart failure patients from 2009 and 2011 conclude that there are beneficial effects of telemonitoring with linkage to improved survival and decreased hospitalizations [3,4]. However, since these meta-analyses, there have been two large-scale randomized controlled trials [5,6] failing to show the effectiveness of telemonitoring as concluded by Pare et al [2]. Correspondingly, the evidence of telemonitoring on improved glycemic control is contradictory. Typically, the observed reduction in hemoglobin A1c (HbA1c) has been 0.5% [7,8], raising a question of its clinical significance. Moreover, there have been studies that show nonsignificant changes in glycemic control among diabetics [9].

In chronic diseases the condition of a patient is highly dependent on their engagement of self-care and their ability to adhere to the management recommendations long term. For successful disease management, the education of a patient is important. However, the education-based interventions are by themselves insufficient [10]. Health coaching helps the patient to clarify his motivation to initiate and maintain change, offering a variety of perspectives and recognizing that numerous factors contribute to achieving goals [11]. Promising results have been obtained among type 2 diabetes patients in health coaching conducted by telephone [11]. However, the 1-year long health coaching by telephony to support self-care in chronic diseases (TERVA) trial, in which a health coaching approach was applied, failed to achieve most of the expected improvements in clinical measures [12]. Similar findings were found by Ruggiero et al

[13]. In addition to the importance of self-management, patients and health care professionals need to share complementary knowledge in health care processes, which brings challenges and responsibility from both sides [14]. Telemonitoring provides a possibility for improved interaction. The combination of telemonitoring and remote monitoring has shown promising results among hypertensive patients [15].

The purpose of this study was to assess the benefits of a structured mobile phone-based health coaching program, supported by a remote monitoring system among chronically ill patients. We expected the intervention to improve patients' engagement in self-management and to enrich the interaction between patients and health care professionals that would eventually result in improved quality of life and/or the clinical condition. Primarily, we hypothesized that we would see improved quality of life among patients suffering from heart disease or diabetes.

Methods

Study Design

The study was conducted as a two-armed randomized controlled trial (RCT) between February 2011 and December 2012 in the South Karelia Social and Health Care District (Eksote) in Finland. The trial was registered at ClinicalTrials.gov (NCT01310491). Eksote is responsible for arranging all primary and secondary health care for the inhabitants of eight municipalities, approximately 100,000 inhabitants. Patients with type 2 diabetes and patients suffering from heart disease were recruited to the study and assigned to either the control group or the intervention group. The study was approved by the Ethics Committee of the Social and Health Care District of South Karelia.

Intervention

Overview

The intervention consisted of health coaching over mobile phones and self-monitoring of health parameters with the help of a remote patient monitoring (RPM) system.

Health Coaching

Each patient in the intervention group was assigned a personal health coach who called them at regular intervals—every 4 to 6 weeks. A comprehensive evaluation of the patient's clinical, mental, and social condition was made during the first coaching call and small, achievable health behavior changes were agreed upon with the patient. A self-management plan was created based on the targeted changes. During the mobile phone calls

that were planned to last for approximately 30 minutes, the health coach provided information, assistance, and support to the patients. The health coaching approach was provided by Pfizer Oy. The approach followed Wagner’s Chronic Care Model [16]—one of the key foundational constructs for the approach of chronic care management—and has been developed and tested earlier. The detailed structure of the health coaching program and the behavior change techniques involved are reported elsewhere [12].

Health Coach Recruitment

Health coaches and a health coach supervisor were recruited among the personnel of Eksote. Six coaches were recruited out of 13 applicants. Four of the recruits were working in outpatient care and two in a hospital. The selected coaches continued in their regular positions and worked as health coaches 1 day a week. The health coaches were trained to obtain the needed knowledge about Pfizer’s health coaching model, behavioral management skills, remote monitoring system, and trial procedures. The health coaching model was a solution-oriented working model where all patients received coaching based on their individual needs. For quality control and educational purposes, each health coach recorded some of the coaching calls, which were evaluated together with a behavioral science professional once in every 3 months. The equal quality of all health coaches was assured by continuous education and regular meetings, which all the health coaches and the trainer attended.

Remote Patient Monitoring

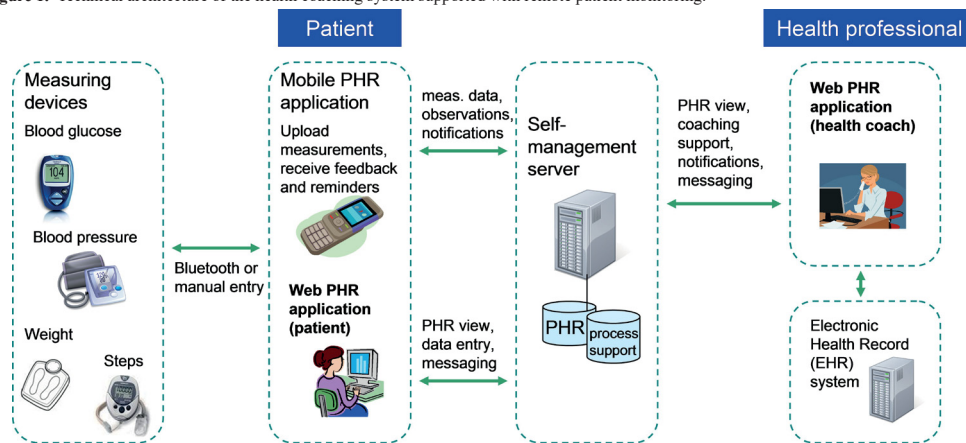
Each patient in the intervention group received a remote monitoring toolbox to be used in the trial. The toolbox consisted of a mobile phone with specific software, a mobile personal

health record (PHR) app, and a set of measurement devices connected to the patient’s PHR account. The mobile PHR app was needed for manual and/or automatic reporting. All patients received a blood pressure meter, which was connectable to the mobile phone via Bluetooth. When the patients measured their blood pressure, the value was automatically transferred to the PHR using a binary short message service (SMS) text message. Other health parameters to be followed were body weight, blood glucose level for diabetics, and step count for heart disease patients. The patients were instructed to measure and send these values manually via the mobile phone to the PHR once a week. The health coaches and patients were able to see the patients’ measurements in the PHR and were advised to utilize them during health coaching phone calls. A self-management guide was given to the patients with the intention to increase their knowledge of their chronic disease.

Remote Patient Monitoring System

The intervention was supported by the RPM system, eClinic, provided by Medixine Ltd (Espoo, Finland) (see Figure 1). The self-management server is the central component of its architecture, providing services for the storing and accessing of information content (ie, RPM data) related to the self-management process. The RPM data included various types of information: health parameters registered by the corresponding measurement devices, personal care plan entered by the health coach in agreement with the patient, and data obtained from the electronic health record (EHR). The HTTPS protocol was used for sending all data from the mobile app to the server. The system underwent no major changes or updates during the trial.

Figure 1. Technical architecture of the health coaching system supported with remote patient monitoring.



Standard Care

Patients assigned to the control group received the care they would have received in the absence of the study. As part of standard care, patients suffering from type 2 diabetes or heart disease receive a disease management information booklet at the time of diagnosis. Standard care includes laboratory tests

taken once a year and 1 appointment or phone call by a nurse or doctor. Patients can contact health care services any time they feel they need to.

Participants and Baseline Assessment

The patients’ eligibility was assessed primarily based on their diagnosis. The diabetic patients were recruited based on a

diagnosis of type 2 diabetes mellitus and their glycosylated hemoglobin (HbA1c) level, which needed to be above 6.5% within 1 year prior to the screening. It was required that the patients had been diagnosed with diabetes at least 3 months earlier. The heart disease group consisted of patients with a diagnosis of ischemic heart disease, heart failure, or both. Other inclusion criteria for all patients were as follows: 18 years of age or older, ability to fill in questionnaires in Finnish, ability to use the RPM system and the devices provided, having adequate cognitive capacities to participate, and being able to walk.

Potential participants were screened using the electronic health record system of Eksote. EHRs cover information about citizens living in the health care district of South Karelia who have contacted health care services at least once. Invitation letters including information about the study were sent to eligible patients. Patients willing to participate signed an informed consent form before randomization. After that, the supervisor contacted each of the patients to schedule an appointment for a baseline visit. Randomization was done after the appointment was settled.

All patients who came in for the baseline visit were asked to fill in a demographic questionnaire and the Short Form (36) Health Survey (SF-36), version 2 [17], which measures health-related quality of life. At the baseline visit, a health coach measured the patient's blood pressure, height (to the nearest 0.1 cm), weight (to the nearest 0.1 kg), and waist circumference (to the nearest 0.1 cm), and calculated their body mass index (BMI). Each patient's medical history was reviewed based on the data in the EHR system. If laboratory tests were older than 2 months, new laboratory tests (ie, HbA1c, cholesterol, triglycerides) were done. At the end of the visit, the health coach checked that the required questionnaires were returned. If not, the patient was asked to fill out the questionnaire at home and send it to a nurse on the following day.

After 1 year following the baseline visit, all patients were invited to an end-point visit. The same procedures were conducted as they were during the baseline visit.

Randomization

A stratified randomization design was used to assign patients to the control and intervention groups. Heart disease and diabetes patients were randomized into separate groups. Patients were further stratified into four subgroups according to their sex and dichotomized age—18 to 65 years versus older than 65 years. Within these subgroups, Excel-generated random numbers were produced. The allocation sequence was concealed from the research nurse by means of an opaque and sealed envelope until the baseline visit. During the baseline visit the envelope was opened and, according to its content, each patient was assigned to either group. The randomization was conducted by the Technical Research Centre of Finland (VTT).

Outcome Variables

Short Form (36) Health Survey

The primary outcome for both disease groups was self-evaluated, health-related quality of life (HRQL) assessed based on the

SF-36 health survey. Eight domains of HRQL and two summary component measures of physical and mental health were analyzed. Additionally, HbA1c level was another primary outcome for the diabetes patients.

Clinical Outcomes

Secondary outcomes were as follows: blood pressure (mmHg), weight (kg), waist circumference (cm), triglycerides (mmol/l), total cholesterol (mmol/l), low-density lipoprotein (LDL) (mmol/l), and high-density lipoprotein (HDL) (mmol/l). The selection of outcome variables was based on the use of a model for assessment of telemedicine applications [18]. However, this paper examines the first three out of the seven domains concentrating on the medical perspectives. Other domains, such as organizational and economic outcomes, will be reported in other articles in the future.

Adherence

Adherence to the health coaching was measured as the number and duration of health coaching calls. The duration of a call consisted of three parts—the time a nurse needed to prepare for a call (eg, familiarize herself with the self-measurement data of a patient), the duration of the actual coaching call, and the time a nurse needed to finalize the call (eg, notes, information delivery). Another perspective of the adherence measure was based on the frequency of home telemonitoring, measured as the total number of measurements made during the study and calculation of the number of weight, blood pressure, blood sugar, and step count reports. Both pre- and postprandial measurements were included in blood glucose reports.

Statistical Analysis

We assumed we would see a difference of three points in the SF-36 scores between the intervention and control groups with a standard deviation of eight. The allocation ratio was unbalanced—approximately 2:1. The number of intervention patients was higher because we wanted to maximize the exposure to, and gain experience about, this new intervention. Defining a power of 80% and a Type I error rate of 5%, 163 intervention patients and 61 control patients were required. Predicting a dropout rate of up to 20%, at least 200 intervention patients and 75 control patients had to be randomized. The numbers were applied to both the heart disease group and diabetes group, resulting in 550 patients to be randomized in total. We used the *t* test as a basis for the power calculations, which is a conservative approach considering that repeated measures were available in the data, and thus more powerful tests could have been used.

The characteristics of dropout patients in terms of their baseline measures were explored using Student's *t* tests and chi-square tests. All analyses were conducted separately for the diabetes and heart disease groups. The analysis of covariance (ANCOVA) was used to study whether the intervention and the control groups differed in terms of their outcome variables. The analyses were done by adjusting for the corresponding baseline level by adding the baseline measure as a covariate in the regression model. The 95% CIs and the corresponding *P* values were reported. Additionally, within-group changes from baseline to postintervention were analyzed using paired *t* tests.

Analyses were conducted following the intention-to-treat principle, meaning that all patients were analyzed in their original allocation group regardless of the extent to which they followed the intervention. No imputations were made to missing values, but missing values were excluded from the analyses. All reported *P* values were two sided. Analyses were conducted using IBM SPSS Statistics version 19.

Results

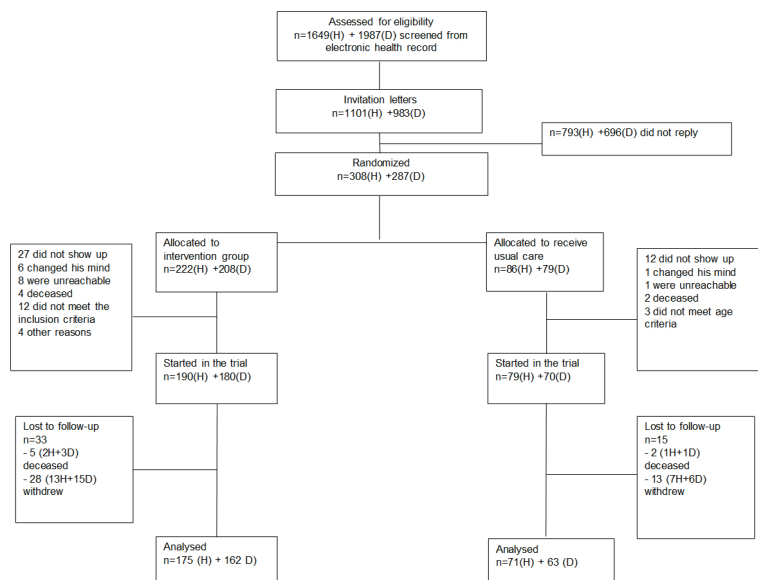
Patient Flow

Figure 2 describes the progress of the trial. The electronic health records were utilized to screen patients with either heart disease or diabetes mellitus type 2. The diagnosis was either type 2 diabetes mellitus with HbA1c >6.5% or one of the following two heart diseases: ischemic heart disease or heart failure. The number of patients fulfilling the criteria was 1649 with heart disease diagnoses, and 1987 patients with diabetes diagnoses. Of these patients, 499 heart disease patients and 500 diabetes patients were randomly selected and received invitation letters in October 2010. The number of patients who refused to participate, changed their mind before the trial began, or did not show up at the baseline visit, was higher than expected. Therefore, the invitation procedure was repeated in November 2010 and August 2011 to achieve the predefined power for the pilot. In total, invitation letters were sent to 2084 patients, of

which 28.02% (584) agreed to participate. Eventually, 595 patients were randomized and, of these, 519 patients (87.2%) attended the baseline visit. All participants filled out the baseline questionnaires before they were told into which group they were randomized.

There were 48 patients out of 519 (9.2%) lost to follow-up: 3 heart patients and 4 diabetes patients died, and 20 and 21 patients, respectively, withdrew from the trial without participating in the concluding visit. The baseline characteristics of the withdrawn patients were analyzed against patients who concluded the trial. Quitting was associated with the patients' unfamiliarity with mobile phones—of the dropouts in the heart disease group, 85% (11/13) were familiar with mobile phones, whereas the corresponding percentage was 97.1% (231/238) among the rest of the patients (*P*=.02). Of the dropouts in the diabetes group, 88% (14/16) were familiar with mobile phones, whereas the corresponding percentage was 98.6% (208/211) among the patients who concluded the trial (*P*=.004). Among heart patients, withdrawal was also often associated with comorbidities—40% (8/20) of the dropouts had at least one comorbidity, whereas the corresponding percentage was 18.9% (47/249) among the rest of the patients (*P*=.04). There was no difference in the dropout rate between intervention and control groups. Eventually, 246 heart disease patients and 225 diabetes patients concluded the trial.

Figure 2. The patient flow within the trial. H: patients with a diagnosis of ischemic heart disease or heart failure, D: patients with a diagnosis of diabetes mellitus type 2 and HbA1c > 6.5%.



Baseline Characteristics

Table 1 displays the baseline characteristic of patients separated according to their primary disease. Overall, patients were similar in the intervention group and in the control group in both disease groups. The mean age among heart patients was 69.1 (SD 9.1)

years, and diabetes patients were slightly younger with a mean age of 66.2 (SD 8.6) years. The majority of patients were men in the heart disease group (178/269, 66.2%) and in the diabetes group (129/250, 51.6%). BMI was higher in the diabetes group than in the heart disease group, but BMI distribution was similar

between the treatment arms. Over two-thirds of the patients (361/519, 69.6%) were retired. Approximately 8.1% (42/519) were smokers. The rate of missing values was clearly higher regarding smoking and alcohol questions compared to the other baseline questions. The high proportion of missing values regarding the alcohol question was explained by the fact that patients did not find a suitable option among the provided choices for answers. They told this to the nurse at the baseline visit, or it was written in the questionnaire that no proper choice was given because they did not use alcohol at all. The majority of the patients were familiar with mobile phones, and approximately half of the patients were familiar with computers. The most common comorbidities were diagnosed connective tissue disease, rheumatic disease, or chronic pulmonary disease. There were only a few patients with dementia or cerebrovascular disease.

Short Form (36) Health Survey

Tables 2 and 3 show the baseline, postintervention, and change scores of HRQL—the eight dimensions of the HRQL assessment and the two summary scores. There were no significant

differences between the control and intervention arms in either of the disease groups for any of the variables.

A total of 45 patients completed the baseline questionnaire at home and later sent it to the nurse. On average, these patients posted their questionnaires 5.3 (range 1 to 7) months after they started in the trial. To exclude the bias that the late responses may have caused, the analyses of HRQL were repeated without the late responses. The level of significance of the difference between the control and intervention groups remained above .1 in all variables. Thus, no change in the interpretation was observed.

The number of respondents varied from question to question. In the diabetes group, the number of respondents varied from 146 to 159 in the intervention group and 55 to 60 in the control group, depending on the questions, which is slightly less than was assumed in the pre hoc power calculations. The lower sample size leads to a post hoc power of .76 when using the *t* test framework. However, the magnitude of .80 was reached when using the ANCOVA framework. The predefined power was reached in the heart disease group.

Table 1. Baseline characteristics of the patients in the two disease groups.

Baseline characteristic	Heart disease patients (n=269), mean (SD) or n (%)		Diabetes patients (n=250), mean (SD) or n (%)	
	Control (n=79)	Intervention (n=190)	Control (n=70)	Intervention (n=180)
	Sex (female), n (%)	25 (32)	66 (34.7)	30 (43)
Age (years), mean (SD)	68.1 (9.4)	69.6 (9.1)	65.5 (9.6)	66.6 (8.2)
BMI ^a (kg/m ²), mean (SD)	28.1 (4.3)	28.6 (4.7)	30.9 (5.7)	31.1 (5.4)
Education, n (%)				
Primary school or less	29 (37)	98 (51.6)	30 (43)	75 (41.7)
Secondary or high school	31 (39)	59 (31.1)	24 (34)	65 (36.1)
College/university or higher	9 (11)	24 (12.6)	12 (17)	27 (15.0)
Missing	10 (13)	9 (4.7)	4 (6)	13 (7.2)
Marital status, n (%)				
Never married	1 (1)	8 (4.2)	4 (6)	10 (5.6)
Married/cohabitating	69 (87)	133 (70)	53 (76)	120 (66.7)
Separated	3 (4)	24 (12.6)	4 (6)	25 (13.9)
Widowed	5 (6)	23 (12.1)	9 (13)	22 (12.2)
Missing	1 (1)	2 (1.1)	0 (0)	3 (1.7)
Work status, n (%)				
Working	12 (15)	34 (17.9)	11 (16)	34 (18.9)
Unemployed (able to work)	4 (5)	6 (3.2)	3 (4)	11 (6.1)
Unemployed (unable to work)	0 (0)	5 (2.6)	0 (0)	5 (2.8)
Retired	53 (67)	138 (72.6)	52 (74)	118 (65.6)
Student	0 (0)	0 (0)	0 (0)	1 (0.6)
Missing	10 (13)	7 (3.7)	4 (6)	11 (6.1)
Smoking, n (%)				
Smoker	6 (8)	14 (7.4)	6 (9)	16 (8.6)
Missing	17 (22)	27 (14.2)	14 (20)	23 (12.8)
Alcohol, n (%)				
5-7 days a week	2 (3)	6 (3.2)	2 (3)	5 (2.8)
1-4 days a week	21 (27)	40 (21.1)	13 (19)	34 (18.9)
Monthly	14 (18)	47 (24.7)	11 (16)	37 (20.6)
Less than monthly	18 (23)	52 (27.4)	23 (33)	65 (36.1)
Missing	24 (30)	45 (23.7)	21 (30)	39 (21.7)
Familiar with PC^b use, n (%)				
Familiar	41 (52)	102 (53.7)	41 (59)	102 (56.7)
Missing	10 (13)	14 (7.4)	8 (11)	14 (7.8)
Familiar with mobile phone use, n (%)				
Familiar	69 (87)	173 (91.1)	61 (87)	161 (89.4)
Missing	8 (10)	10 (5.3)	9 (13)	14 (7.8)
Comorbidities, n (%)				
Heart diseases	79 (100)	190 (100)	15 (21)	47 (26.1)
Cerebrovascular disease	0 (0)	4 (2.1)	3 (4)	9 (5.0)

Baseline characteristic	Heart disease patients (n=269), mean (SD) or n (%)		Diabetes patients (n=250), mean (SD) or n (%)	
	Control (n=79)	Intervention (n=190)	Control (n=70)	Intervention (n=180)
	Chronic pulmonary disease, including COPD ^c	8 (10)	22 (11.6)	12 (17)
Connective tissue disease or rheumatic disease	8 (10)	30 (15.8)	9 (13)	36 (20.0)
Diabetes	18 (23)	46 (24.2)	70 (100)	180 (100)
Cancer	7 (9)	17 (8.9)	4 (6)	12 (6.7)
Other ^d	49 (62)	111 (58.4)	52 (74)	135 (75.0)
No comorbidities	16 (20)	39 (20.5)	14 (9)	23 (6.2)

^aBMI: body mass index

^bPC: personal computer

^cCOPD: chronic obstructive pulmonary disease

^dHypertension is the most common “other” comorbidity.

Table 2. The baseline, postintervention, and change scores in the eight dimensions of the health-related quality-of-life assessments and in the two summary scores for heart disease patients.

Assessment	Control scores				Intervention scores				Between-group difference, beta (95% CI)	P ^a
	n	Base-line	Post ^b	Change (95% CI)	n	Base-line	Post	Change (95% CI)		
Physical component score	68	40.3	40.7	0.39 (-0.72, 1.49)	162	39.5	40.8	1.25 (0.29, 2.22)	0.730 (-3.00, 1.78)	.36
Mental component score	68	50.5	51.0	0.55 (-1.53, 2.58)	162	50.4	50.3	-0.05 (-1.47, 1.37)	-0.608 (-6.19, 6.26)	.62
Physical functioning (PF)	68	64.9	66.1	1.16 (-1.77, 4.09)	170	62.7	64.1	1.42 (-0.82, 3.67)	0.02 (-3.89, 3.93)	.99
Role-physical (RP)	68	60.7	63.5	2.79 (-1.84, 7.42)	168	58.9	62.1	3.16 (-0.58, 6.90)	-1.72 (-6.09, 5.75)	.95
Bodily pain (BP)	68	57.2	57.9	0.70 (-3.27, 4.66)	171	56.4	59.9	3.51 (0.58, 6.44)	2.59 (-2.34, 7.51)	.30
General health (GH)	68	48.7	49.2	0.56 (-2.93, 4.05)	171	47.7	50.3	2.60 (0.36, 4.84)	1.77 (-2.06, 5.61)	.36
Vitality (VT)	68	57.1	56.9	-0.25 (-4.71, 4.22)	165	56.3	56.8	0.48 (-2.03, 3.00)	0.52 (-4.03, 5.06)	.82
Social functioning (SF)	68	80.1	80.0	-0.18 (-4.93, 4.56)	171	78.9	79.8	0.88 (-2.15, 3.90)	0.585 (-4.44, 5.61)	.82
Role-emotional (RE)	67	72.5	75.4	2.86 (-2.63, 8.35)	168	71.2	73.0	1.74 (-1.74, 5.22)	1.54 (-7.42, 4.34)	.61
Mental health (MH)	68	77.3	77.9	0.64 (-2.92, 4.21)	164	77.4	77.2	-0.23 (-1.47, 1.37)	-0.80 (-5.00, 3.36)	.70

^aP values show the level of statistical significance between the treatment arms.

^bPostintervention score.

Table 3. The baseline, postintervention, and change scores in the eight dimensions of the health-related quality-of-life assessments and in the two summary scores for diabetes patients.

Assessment	Control scores				Intervention scores				Between-group difference, beta (95% CI)	P ^a
	n	Base-line	Post ^b	Change (95% CI)	n	Base-line	Post	Change (95% CI)		
Physical component score	55	41.5	42.0	0.51 (-1.19, 2.21)	146	42.6	43.2	0.53 (-0.40, 1.47)	0.875 (0.80 9, 0.95)	.85
Mental component score	56	50.1	52.0	1.84 (0.02, 3.71)	148	50.2	51.2	1.06 (-0.42, 2.53)	-0.77 (-3.15, 1.61)	.52
Physical functioning (PF)	58	64.9	66.0	1.09 (-2.87, 5.06)	157	68.1	68.2	0.17 (-1.83, 2.17)	-0.715 (-4.74, 3.13)	.73
Role-physical (RP)	58	65.2	68.4	3.23 (-2.81, 9.27)	156	65.7	68.8	3.11 (-0.45, 6.68)	-0.036 (-6.19, 6.26)	.99
Bodily pain (BP)	58	55.3	58.8	3.52 (-0.94, 7.98)	159	62.4	62.2	-0.18 (-3.05, 2.68)	-2.02 (-7.20, 3.13)	.44
General health (GH)	60	49.2	50.6	1.34 (-1.48, 4.17)	159	50.1	53.6	3.47 (1.04, 5.89)	2.34 (-1.72, 6.41)	.26
Vitality (VT)	58	52.9	58.1	5.21 (1.29, 9.19)	149	57.6	58.6	0.98 (-1.88, 3.83)	-2.98 (-7.78, 1.83)	.22
Social functioning (SF)	60	79.4	83.3	3.96 (-0.18, 8.10)	157	80.0	81.1	1.19 (-2.05, 4.44)	-2.54 (-7.70, 2.61)	.33
Role-emotional (RE)	59	74.3	78.1	3.81 (-1.72, 9.35)	157	74.7	78.7	3.93 (0.26, 7.60)	0.30 (-5.50, 6.10)	.92
Mental health (MH)	58	76.5	78.5	2.07 (-1.80, 5.93)	149	76.7	77.5	0.87 (-1.75, 3.50)	-1.12 (-5.43, 3.19)	.61

^aP values show the level of statistical significance between the treatment arms.

^bPostintervention score.

Clinical Outcomes

Tables 4 and 5 display the baseline, postintervention, and change scores in the anthropometric and laboratory measures, and the comparison between the treatment arms in both disease groups. In the heart disease group, there was no difference between the treatment arms in any of the variables. However, there was a significant within-group decrease in waist circumference ($P=.02$), systolic blood pressure ($P<.001$), and LDL-cholesterol ($P<.001$) in the intervention group. Also, in the control group, LDL-cholesterol decreased significantly ($P<.001$), as did systolic blood pressure ($P<.001$).

Among diabetics, there was a significant difference between the treatment arms in waist circumference ($P=.01$). In the intervention group, there was a significant decrease in weight ($P=.02$), waist circumference ($P<.001$), systolic blood pressure ($P<.001$), diastolic blood pressure ($P=.007$), and LDL-cholesterol ($P<.001$). In the control group, systolic blood pressure and LDL-cholesterol decreased significantly ($P=.02$ and $P<.001$, respectively).

Adherence

Out of 190 heart disease and 180 diabetes patients, 186 (97.9%) and 177 (98.3%) patients, respectively, received at least one health coach call. The average number of calls per patient was 8.7 (SD 1.6) in the heart disease patient group and 8.5 (SD 1.9) in the diabetes group. The difference between the disease groups was not significant ($P=.40$). The mean duration of a coaching call was 20.1 (SD 8.0) minutes in the heart disease group and 19.2 (SD 8.1) minutes in the diabetes group, with a significant between-group difference ($P=.004$). The mean time consumed by the nurse for the preparation of calls was 3.5 (SD 2.5) minutes in the heart disease group and 4.2 (SD 3.2) minutes in the diabetes group, and the between-group difference was significant ($P<.001$). The time consumed by the nurse after the coaching calls among heart disease and diabetes patients was 3.8 (SD 3.0) and 4.5 (SD 3.6) minutes, respectively, with a significant between-group difference ($P<.001$).

The median number of all self-measurements reported through mobile phones was 209 (interquartile range [IQR] 124-324) among heart patients and 217 (IQR 104-346) among diabetes patients. The median number for heart disease group-specific monitoring parameters per patient were the following: 18 (IQR 2-40) weight reports, 18 (IQR 4-43) step counts, 57 (IQR 36-89)

blood pressure reports, and 42 (IQR 12-67) blood glucose reports—6 patients made blood glucose monitoring reports. The median number for diabetes group-specific monitoring parameters per patient were the following: 15 (IQR 3-39) weight reports, 15 (IQR 5-31) step counts, 56 (IQR 28-80) blood pressure reports, and 47 (IQR 20-89) blood glucose reports, including pre- and postprandial sugar. In the heart disease group and in the diabetes group, 174 out of 190 (91.6%) and 171 out of 180 (95.0%) patients, respectively, adhered to the

self-monitoring intervention to the extent that they sent at least one report of any kind during the follow-up. Among 190 heart disease patients, 136 (71.6%) sent at least one weight measurement, 173 (91.1%) sent at least one blood pressure measurement, 6 (3.2%) sent at least one blood glucose measurement, and 118 (62.1%) sent at least one step count report. Out of 180 diabetes patients, the corresponding numbers were 119 (66.1%) for weight, 170 (94.4%) for blood pressure, 126 (70.0%) for blood glucose, and 13 (7.2%) for step count.

Table 4. Baseline, postintervention, and change scores in clinical outcomes for the heart disease group.

Clinical outcome	Control scores			Change (95% CI)	Intervention scores			Change (95% CI)	Between-group difference, beta (95% CI)	P ^a
	n	Base- line	Post ^b		n	Baseline	Post			
Weight	70	79.9	79.1	-0.84 (-1.85, 0.16)	170	81.4	81.5	0.04 (-0.67, 0.76)	0.934 (-0.34, 2.21)	.15
Waist	65	97.6	98.7	1.10 (-1.65, 3.85)	160	101.5	100.6	-0.88 (-1.61, -0.16)	-1.518 (-3.57, 0.53)	.15
Systolic	68	144.4	138.0	-6.36 (-10.7, -2.01)	161	145.5	140.1	-5.43 (-8.12, -2.75)	1.587 (-2.51, 5.68)	.45
Diastolic	67	81.1	80.9	-0.18 (-2.81, 2.45)	161	82.3	82.1	-0.27 (-1.95, 1.41)	0.468 (-2.24, 3.18)	.73
Total cholesterol	68	4.13	4.05	-0.08 (-0.25, 0.09)	168	4.06	4.01	-0.05 (-0.17, 0.06)	0.009 (-0.168, 0.185)	.92
HDL ^c	68	1.23	1.26	0.03 (-0.02, 0.08)	168	1.29	1.31	0.02 (-0.01, 0.06)	-0.018 (-0.086, 0.05)	.87
LDL ^d	68	2.56	2.21	-0.36 (-0.51, -0.21)	168	2.50	2.16	-0.34 (-0.43, -0.24)	-0.008 (-0.15, 0.13)	.91
Triglycerides	68	1.43	1.32	-0.12 (-0.27, 0.03)	168	1.37	1.35	-0.01 (-0.13, 0.08)	0.071 (-0.08, 0.22)	.36

^aP values show the level of statistical significance between the treatment arms.

^bPostintervention score

^cHDL: high-density lipoprotein

^dLDL: low-density lipoprotein

Table 5. Baseline, postintervention, and change scores in clinical outcomes for the diabetes group.

Clinical outcome	Control scores			Change (95% CI)	Intervention scores			Change (95% CI)	Between-group dif- ference, beta (95% CI)	<i>P</i> ^a
	n	Base- line	Post ^b		n	Baseline	Post			
HbA1c ^c	61	7.20	7.36	0.18 (-0.02, 0.35)	156	7.25	7.29	0.04 (-0.09, 0.17)	-0.106 (-0.33, 0.11)	.34
Weight	60	88.9	88.6	-0.30 (-1.21, 0.60)	153	89.6	88.7	-0.90 (-1.71, -0.22)	-0.566 (-1.86, 0.73)	.39
Waist	57	107.4	107.1	-0.29 (-1.47, 0.90)	143	107.8	105.8	-2.03 (-2.76, -1.29)	-1.711 (-3.042, -0.38)	.01
Systolic	60	151.9	147.8	-4.12 (-7.43, -0.81)	148	155.4	149.3	-6.10 (-9.10, -3.09)	-0.196 (-4.57, 4.18)	.93
Diastolic	60	86.7	84.6	-2.08 (-4.50, 0.34)	148	89.2	86.6	-2.61 (-4.50, -0.72)	0.668 (-2.18, 3.52)	.65
Total cholesterol	60	4.36	4.19	-0.16 (-0.35, 0.03)	153	4.35	4.25	-0.1 (-0.23, 0.04)	0.065 (-0.15, 0.28)	.54
HDL ^d	60	1.26	1.29	0.03 (-0.05, 0.12)	156	1.24	1.26	0.02 (-0.01, 0.05)	0.005 (-0.054, 0.064)	.61
LDL ^e	60	2.66	2.27	-0.39 (-0.55, -0.23)	156	2.74	2.35	-0.40 (-0.51, -0.28)	0.037 (-0.19, 0.20)	.66
Triglycerides	59	1.78	1.89	0.11 (-0.14, 0.36)	154	1.70	1.71	0.01 (-0.10, 0.10)	-1.22 (-0.32, 0.09)	.25

^a*P* values show the level of statistical significance between the treatment arms.

^bPostintervention score

^cHbA1c: hemoglobin A1c

^dHDL: high-density lipoprotein

^eLDL: low-density lipoprotein

Discussion

Principal Findings

This study evaluated whether health coaching, supported with home telemonitoring, improved health-related quality of life and/or the clinical condition of type 2 diabetes patients and heart disease patients after 12 months. The intervention failed to improve patients' quality of life or their clinical condition. Patients received regular health coaching calls throughout the study and the majority of the patients adhered to the home telemonitoring plan and frequently monitored at least one of the required health parameters.

The intervention showed a statistically significant difference only in waist circumference among type 2 diabetics. However, due to the lack of consistency in other variables, this finding is likely a result of multiple tests conducted in this study rather than true a difference between the study groups. Multiple testing increases the likelihood of false positive discoveries and this should be acknowledged when interpreting the findings. In addition, blood pressure and cholesterol levels showed beneficial trends for all patients. Overall, the improvements in clinical variables were more apparent in the type 2 diabetes group than in the heart disease patient group.

There were 48 out of 519 patients (9.2%) that were lost to follow-up. We found that unfamiliarity with mobile phones and poor health status measured as a result of the presence of comorbidities were associated with withdrawal. These findings highlight the importance of offering and targeting interventions to an audience with the appropriate skills. eHealth literacy is a prerequisite for the success of eHealth interventions and should be appropriately accounted for. Electronic health tools provide little value if the intended users lack the skills to effectively engage with them [19]. As suggested by Cruz et al [20], the patient skills and acceptance of the technology should be measured prior to its implementation. Appropriate skills are also required on the professional side. A recent study evaluating the use of email in the communication between the primary health care system and general practitioners showed that the easier the general practitioners thought the email system to be, the more they used it [21]. In our study, six nurses were specifically trained for health coaching and to actively utilize the RPM system as part of the care.

The positive changes in patients' clinical conditions in both study groups emphasize the well-known fact that control patients improve their lifestyles as a consequence of being involved in a trial, even if they are not subjected to the actual intervention.

Some of the control group patients were disappointed for not being randomized into the intervention group and they decided to take better care of themselves. Regarding disease-specific effects, we found that diabetes patients who received the intervention improved their health status among several health parameters. The findings were not verified by testing statistical interaction of group and disease variables, but the results in [Table 5](#) showed significant within-group reductions in patients' weight, waist circumference, blood pressure, and LDL. We can speculate whether diabetes patients are more prone to benefit from this kind of intervention. Similarly, Pare et al reported that telemonitoring was associated with a decline in hemoglobin and better blood glucose control, but clinical effects on the condition of patients suffering from cardiac problems were not as evident [2]. Signals reflecting the state of diabetes are not apparent. Even the symptoms of the worsening condition of a patient may stay unrecognized. Therefore, the importance of self-management as a part of diabetes care should be emphasized. The utilization of self-management in health care is a good direction to take, as it was shown by Rose et al [22] that there is a risk of general practitioners, who are sensitive to patients' low self-efficacy in blood glucose monitoring, taking over the monitoring role, and inadvertently reducing self-management. Furthermore, a recent study showed that the significant improvements in HbA1c achieved during a 6-month trial of home telemonitoring, combined with active medication management, were sustained for at least that same 6 months [23].

Patients adhered to home telemonitoring in terms of measuring their blood pressure. Assuming the duration of the trial was approximately 12 months, 52 parameters were expected to be reported. Heart disease and diabetes patients respectively produced 55 and 57 blood pressure measurements on average. Across other health parameters, the monitoring frequency varied from 15 to 42. Patient groups seemed not to differ from each other in terms of monitoring frequency. Some patients had a lack of skills in using remote monitoring devices or they had technical problems, which reduced the number of remote monitoring measurements. Health coaching was realized as planned. The expected number of health coaching calls was between 9 and 12, with 4 to 6 weeks calling frequency. The number of health coaching calls was 8.7 and 8.6 in the heart disease and diabetes group, respectively. Our health coaching model was solution oriented. All coaching calls were tailored

to the individual needs that affected variation to the call durations. Few patients had lengthy hospital stays, which affected the number of health coaching calls. The number and duration of health coaching calls were significantly different between the disease groups. The low level of significance was likely due to a small standard deviation in the call duration. A 1-minute difference, as seen in the call duration, has no practical relevance.

The low inclusion criteria in terms HbA1c for diabetic patients posed a limitation on this study. For inclusion, a diabetic patient was required to have an HbA1c higher than 6.5%. On average, the HbA1c levels were 7.2%, showing that there was little room for improvement.

A lack of social support was a potential factor that may have influenced the negative findings of this study. Receiving real-time social support may help people to stay engaged and feel supported, which is important in order to initiate and maintain improvements in health-related behaviors [24]. Another appealing approach to keep patients motivated, specifically those involved with self-monitoring of their health parameters, is the utilization of active assistance technology. Active assistance technology involves automatic processing of health or behavior data and delivers automatic tailored messages to users [25]. Results in this field have been promising, including work by Quinn et al [26], Charpentier et al [27], and Orsama et al [28]. As Bock et al [29] have recently shown, in order to produce successful mHealth apps with lasting effects, it is important to obtain user input throughout development. In our study, the patients were contacted every 4 to 6 weeks. An automatic feedback system, based on their self-monitored health parameters, could have kept patients motivated and informed by the delivery of individualized feedback with a coaching perspective.

Conclusions

In conclusion, this study failed to show a beneficial effect of health coaching supported by telemonitoring on patients' quality of life or their clinical status. However, we do not yet know the long-lasting benefits of the intervention. There were indications that the intervention had a differential effect on heart disease patients and diabetes patients. Diabetes patients may be more prone to benefit from this kind of intervention. This should not be neglected when developing new ways for self-management of chronic diseases.

Acknowledgments

A total of 50% of the funding of this study was received from the European Commission Information and Communication Technologies Policy Support Program (ICT PSP) 2009 of the Competitiveness and Innovation framework Programme (CIP), as part of the Renewing Health Project involving nine European countries. The other 50% of the funding was provided by Eksote.

Conflicts of Interest

Tapio Jokinen is the chairman of the board of Medixine Ltd that provided the remote patient monitoring system.

Multimedia Appendix 1

CONSORT-EHEALTH checklist V1.6.2 [30].

[[PDF File \(Adobe PDF File\), 139KB - jmir_v17i6c153_app1.pdf](#)]

References

1. Barr MS. The need to test the patient-centered medical home. *JAMA* 2008 Aug 20;300(7):834-835. [doi: [10.1001/jama.300.7.834](https://doi.org/10.1001/jama.300.7.834)] [Medline: [18714064](#)]
2. Paré G, Jaana M, Sicotte C. Systematic review of home telemonitoring for chronic diseases: the evidence base. *J Am Med Inform Assoc* 2007;14(3):269-277 [FREE Full text] [doi: [10.1197/jamia.M2270](https://doi.org/10.1197/jamia.M2270)] [Medline: [17329725](#)]
3. Klersy C, De Silvestri A, Gabutti G, Regoli F, Auricchio A. A meta-analysis of remote monitoring of heart failure patients. *J Am Coll Cardiol* 2009 Oct 27;54(18):1683-1694 [FREE Full text] [doi: [10.1016/j.jacc.2009.08.017](https://doi.org/10.1016/j.jacc.2009.08.017)] [Medline: [19850208](#)]
4. Inglis SC, Clark RA, McAlister FA, Stewart S, Cleland JG. Which components of heart failure programmes are effective? A systematic review and meta-analysis of the outcomes of structured telephone support or telemonitoring as the primary component of chronic heart failure management in 8323 patients: Abridged Cochrane Review. *Eur J Heart Fail* 2011 Sep;13(9):1028-1040. [doi: [10.1093/eurjhf/hfr039](https://doi.org/10.1093/eurjhf/hfr039)] [Medline: [21733889](#)]
5. Chaudhry SI, Matterna JA, Curtis JP, Spertus JA, Herrin J, Lin Z, et al. Telemonitoring in patients with heart failure. *N Engl J Med* 2010 Dec 9;363(24):2301-2309 [FREE Full text] [doi: [10.1056/NEJMoa1010029](https://doi.org/10.1056/NEJMoa1010029)] [Medline: [21080835](#)]
6. Koehler F, Winkler S, Schieber M, Sechtem U, Stangl K, Böhm M, TIM-HF Investigators. Telemedical Interventional Monitoring in Heart Failure (TIM-HF), a randomized, controlled intervention trial investigating the impact of telemedicine on mortality in ambulatory patients with heart failure: study design. *Eur J Heart Fail* 2010 Dec;12(12):1354-1362. [doi: [10.1093/eurjhf/hfq199](https://doi.org/10.1093/eurjhf/hfq199)] [Medline: [21098580](#)]
7. Health Quality Ontario. Home telemonitoring for type 2 diabetes: an evidence-based analysis. *Ont Health Technol Assess Ser* 2009;9(24):1-38 [FREE Full text] [Medline: [23074529](#)]
8. Montori VM, Helgemo PK, Guyatt GH, Dean DS, Leung TW, Smith SA, et al. Telecare for patients with type 1 diabetes and inadequate glyemic control: a randomized controlled trial and meta-analysis. *Diabetes Care* 2004 May;27(5):1088-1094. [Medline: [15111526](#)]
9. Farmer A, Gibson OJ, Tarassenko L, Neil A. A systematic review of telemedicine interventions to support blood glucose self-monitoring in diabetes. *Diabet Med* 2005 Oct;22(10):1372-1378. [doi: [10.1111/j.1464-5491.2005.01627.x](https://doi.org/10.1111/j.1464-5491.2005.01627.x)] [Medline: [16176199](#)]
10. Bodenheimer T, Lorig K, Holman H, Grumbach K. Patient self-management of chronic disease in primary care. *JAMA* 2002 Nov 20;288(19):2469-2475. [Medline: [12435261](#)]
11. Wolever RQ, Dreusicke M, Fikkan J, Hawkins TV, Yeung S, Wakefield J, et al. Integrative health coaching for patients with type 2 diabetes: a randomized clinical trial. *Diabetes Educ* 2010;36(4):629-639. [doi: [10.1177/0145721710371523](https://doi.org/10.1177/0145721710371523)] [Medline: [20534872](#)]
12. Patja K, Absetz P, Auvinen A, Tokola K, Kytö J, Oksman E, et al. Health coaching by telephony to support self-care in chronic diseases: clinical outcomes from The TERVA randomized controlled trial. *BMC Health Serv Res* 2012;12:147 [FREE Full text] [doi: [10.1186/1472-6963-12-147](https://doi.org/10.1186/1472-6963-12-147)] [Medline: [22682298](#)]
13. Ruggiero L, Moadsiri A, Butler P, Oros SM, Berbaum ML, Whitman S, et al. Supporting diabetes self-care in underserved populations: a randomized pilot study using medical assistant coaches. *Diabetes Educ* 2010;36(1):127-131 [FREE Full text] [doi: [10.1177/0145721709355487](https://doi.org/10.1177/0145721709355487)] [Medline: [20185612](#)]
14. Holman H, Lorig K. Patient self-management: a key to effectiveness and efficiency in care of chronic disease. *Public Health Rep* 2004;119(3):239-243 [FREE Full text] [doi: [10.1016/j.phr.2004.04.002](https://doi.org/10.1016/j.phr.2004.04.002)] [Medline: [15158102](#)]
15. Walsh JM, Sundaram V, McDonald K, Owens DK, Goldstein MK. Implementing effective hypertension quality improvement strategies: barriers and potential solutions. *J Clin Hypertens (Greenwich)* 2008 Apr;10(4):311-316. [Medline: [18401229](#)]
16. Wagner EH. Chronic disease management: what will it take to improve care for chronic illness? *Eff Clin Pract* 1998;1(1):2-4 [FREE Full text] [Medline: [10345255](#)]
17. Contopoulos-Ioannidis DG, Karvouni A, Kouri I, Ioannidis JP. Reporting and interpretation of SF-36 outcomes in randomised trials: systematic review. *BMJ* 2009;338:a3006 [FREE Full text] [Medline: [19139138](#)]
18. Kidholm K, Ekeland AG, Jensen LK, Rasmussen J, Pedersen CD, Bowes A, et al. A model for assessment of telemedicine applications: mast. *Int J Technol Assess Health Care* 2012 Jan;28(1):44-51. [doi: [10.1017/S0266462311000638](https://doi.org/10.1017/S0266462311000638)] [Medline: [22617736](#)]
19. Norman CD, Skinner HA. eHealth literacy: essential skills for consumer health in a networked world. *J Med Internet Res* 2006 Jun;8(2):e9 [FREE Full text] [doi: [10.2196/jmir.8.2.e9](https://doi.org/10.2196/jmir.8.2.e9)] [Medline: [16867972](#)]
20. Cruz J, Brooks D, Marques A. Home telemonitoring in COPD: a systematic review of methodologies and patients' adherence. *Int J Med Inform* 2014 Apr;83(4):249-263. [doi: [10.1016/j.ijmedinf.2014.01.008](https://doi.org/10.1016/j.ijmedinf.2014.01.008)] [Medline: [24529402](#)]
21. Karhula T, Kauppila T, Elonheimo O, Brommels M. Use of email in communication between the Finnish primary healthcare system and general practitioners. *Inform Prim Care* 2011;19(1):25-32. [Medline: [22118333](#)]
22. Rose V, Harris M, Ho MT, Jayasinghe UW. A better model of diabetes self-management? Interactions between GP communication and patient self-efficacy in self-monitoring of blood glucose. *Patient Educ Couns* 2009 Nov;77(2):260-265. [doi: [10.1016/j.pec.2009.03.026](https://doi.org/10.1016/j.pec.2009.03.026)] [Medline: [19720493](#)]

23. Stone RA, Sevick MA, Rao RH, Macpherson DS, Cheng C, Kim S, et al. The Diabetes Telemonitoring Study Extension: an exploratory randomized comparison of alternative interventions to maintain glycemic control after withdrawal of diabetes home telemonitoring. *J Am Med Inform Assoc* 2012;19(6):973-979 [FREE Full text] [doi: [10.1136/amiajn-2012-000815](https://doi.org/10.1136/amiajn-2012-000815)] [Medline: [22610495](https://pubmed.ncbi.nlm.nih.gov/22610495/)]
24. Turner-McGrievy GM, Tate DF. Are we sure that Mobile Health is really mobile? An examination of mobile device use during two remotely-delivered weight loss interventions. *Int J Med Inform* 2014 May;83(5):313-319 [FREE Full text] [doi: [10.1016/j.ijmedinf.2014.01.002](https://doi.org/10.1016/j.ijmedinf.2014.01.002)] [Medline: [24556530](https://pubmed.ncbi.nlm.nih.gov/24556530/)]
25. Kennedy CM, Powell J, Payne TH, Ainsworth J, Boyd A, Buchan I. Active assistance technology for health-related behavior change: an interdisciplinary review. *J Med Internet Res* 2012;14(3):e80 [FREE Full text] [doi: [10.2196/jmir.1893](https://doi.org/10.2196/jmir.1893)] [Medline: [22698679](https://pubmed.ncbi.nlm.nih.gov/22698679/)]
26. Quinn CC, Clough SS, Minor JM, Lender D, Okafor MC, Gruber-Baldini A. WellDoc mobile diabetes management randomized controlled trial: change in clinical and behavioral outcomes and patient and physician satisfaction. *Diabetes Technol Ther* 2008 Jun;10(3):160-168. [doi: [10.1089/dia.2008.0283](https://doi.org/10.1089/dia.2008.0283)] [Medline: [18473689](https://pubmed.ncbi.nlm.nih.gov/18473689/)]
27. Charpentier G, Benhamou P, Dardari D, Clergeot A, Franc S, Schaepeelynck-Belicar P, TeleDiab Study Group. The Diabeo software enabling individualized insulin dose adjustments combined with telemedicine support improves HbA1c in poorly controlled type 1 diabetic patients: a 6-month, randomized, open-label, parallel-group, multicenter trial (TeleDiab 1 Study). *Diabetes Care* 2011 Mar;34(3):533-539 [FREE Full text] [doi: [10.2337/dc10-1259](https://doi.org/10.2337/dc10-1259)] [Medline: [21266648](https://pubmed.ncbi.nlm.nih.gov/21266648/)]
28. Orsama A, Lähteenmäki J, Harno K, Kulju M, Wintergerst E, Schachner H, et al. Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: results of a theory-based randomized trial. *Diabetes Technol Ther* 2013 Aug;15(8):662-669. [doi: [10.1089/dia.2013.0056](https://doi.org/10.1089/dia.2013.0056)] [Medline: [23844570](https://pubmed.ncbi.nlm.nih.gov/23844570/)]
29. Bock BC, Rosen RK, Barnett NP, Thind H, Walaska K, Foster R, et al. Translating behavioral interventions onto mHealth platforms: developing text message interventions for smoking and alcohol. *JMIR Mhealth Uhealth* 2015;3(1):e22 [FREE Full text] [doi: [10.2196/mhealth.3779](https://doi.org/10.2196/mhealth.3779)] [Medline: [25714907](https://pubmed.ncbi.nlm.nih.gov/25714907/)]
30. Eysenbach G, CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *J Med Internet Res* 2011;13(4):e126 [FREE Full text] [doi: [10.2196/jmir.1923](https://doi.org/10.2196/jmir.1923)] [Medline: [22209829](https://pubmed.ncbi.nlm.nih.gov/22209829/)]

Abbreviations

ANCOVA: analysis of covariance
BMI: body mass index
BP: bodily pain
CIP: Competitiveness and Innovation framework Programme
COPD: chronic obstructive pulmonary disease
D: patients with a diagnosis of diabetes mellitus type 2 and HbA1c > 6.5% (in Figure 2)
EHR: electronic health record
Eksote: South Karelia Social and Health Care District
GH: general health
H: patients with a diagnosis of ischemic heart disease or heart failure (in Figure 2)
HbA1c: hemoglobin A1c, glycosylated hemoglobin
HDL: high-density lipoprotein
HRQL: health-related quality of life
ICT PSP: Information and Communication Technologies Policy Support Program
IQR: interquartile range
LDL: low-density lipoprotein
MH: mental health
PC: personal computer
PF: physical functioning
PHR: personal health record
RCT: randomized controlled trial
RE: role-emotional
RP: role-physical
RPM: remote patient monitoring
SF: social functioning
SF-36: Short Form (36) Health Survey
SMS: short message service
TERVA: health coaching by telephony to support self-care in chronic diseases
VT: vitality
VTT: Technical Research Centre of Finland

Edited by G Eysenbach; submitted 24.11.14; peer-reviewed by G Paré, MM Ansari Ramandi; comments to author 22.02.15; revised version received 30.03.15; accepted 17.04.15; published 17.06.15

Please cite as:

Karhula T, Vuorinen AL, Rääpysjärvi K, Pakanen M, Itkonen P, Tepponen M, Junno UM, Jokinen T, van Gils M, Lähteenmäki J, Kohtamäki K, Saranummi N

Telemonitoring and Mobile Phone-Based Health Coaching Among Finnish Diabetic and Heart Disease Patients: Randomized Controlled Trial

J Med Internet Res 2015;17(6):e153

URL: <http://www.jmir.org/2015/6/e153/>

doi:10.2196/jmir.4059

PMID:

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PUBLICATION IV

Is Home Telemonitoring Feasible in the Care of Chronic Diseases—Insights into Adherence to a Self-management Intervention in Renewing Health Finland Trial

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Li H., Nykänen P., Suomi R., Wickramasinghe N., Widén G., Zhan M. (eds) *Building Sustainable Health Ecosystems*. WIS 2016. Communications in Computer and Information Science 2016, vol. 636, 57–66. Springer, Cham

<https://www.springer.com/us/book/9783319446714>

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Is home telemonitoring feasible in the care of chronic diseases - insights into adherence to a self-management intervention in Renewing Health Finland trial

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Abstract.

Background eHealth studies typically suffer from high attrition rates. **Objective** To investigate type 2 diabetes and heart disease patients' adherence to a self-management intervention that combined health coaching and telemonitoring. **Methods** Renewing Health Finland was a 12-month randomized controlled trial to improve quality of life (QoL) and/or HbA1c of 595 patients with chronic conditions. The intervention consisted of 1) weekly measurement of health parameters 2) health coaching every 4-6 weeks. Adherence to telemonitoring was defined as the percentage of weeks with at least one reported health measurement. Adherence to coaching was defined as the number of received calls. **Results** The median percentage of monitored weeks was 65% without time-dependent attrition. 66% of participants received 7-11 calls that corresponds to the predefined coaching schedule. Adherence did not correlate with QoL or HbA1c. **Discussion** Our results indicate that the intervention in the Renewing Health Finland trial was delivered almost with planned intensity.

Keywords: adherence, telemonitoring, health coaching, QoL, HbA1c, type 2 diabetes, heart disease

1 Introduction

Increasing burden of chronic diseases combined with aging population and reductions in health care resources create a need to identify care models that respond to the growing demand while maintaining and/or improving the quality of the care.

Chronic care models that incorporate remote patient monitoring have shown promise in the past decades. Specifically telemonitoring interventions that involve measuring and reporting disease-specific information remotely and transferring the data to

health care providers have been widely studied with positive outcomes among a variety of chronic conditions including diabetes, hypertension, chronic obstructive pulmonary disease and heart failure [1], [2]. Such interventions may improve patient's engagement with self-management while sharing the self-monitoring data with health care professionals provides continuous up-to-date information for care professionals to support their clinical decision making. However, there is a growing bulk of literature including large-scale rigorous randomized controlled trials that have failed to validate the hypothesized benefits of telemonitoring interventions [3]–[7].

Attrition is a common feature for eHealth studies; interventions that are not critical but are based on patients' voluntariness and that are easy to discontinue typically suffer from high nonusage rates [8], [9]. While it has been argued that high drop-out rates might be natural feature for eHealth trials, attrition is underreported and poorly understood and might even cause publication bias as it is often associated with failure of the intervention [8]. Study reports show aggregated statistics on usage, however, they often lack longitudinal aspects. Detailed analyses of uptake and possible discontinuation of the intervention are needed and required [10] to understand and further improve the effectiveness of eHealth interventions.

Between 2010-2013, we conducted a randomized controlled trial that assessed the effect of telemonitoring assisted self-management intervention on the quality of life and glycemic control of patients with chronic conditions [11]. Renewing Health Finland was a part of the European research project Renewing Health where nine collaborating countries assessed the effect of telehealth interventions with RCT settings. In conjunction with the majority of the other trials [5], Renewing Health Finland did not find significant effect on primary health outcomes. In this paper we seek to find potential factors that may have contributed to the nonsignificant findings by analysing patients' engagement with the intervention in the Renewing Health Finland trial and investigating the effect of adherence on the health outcomes.

2 Methods

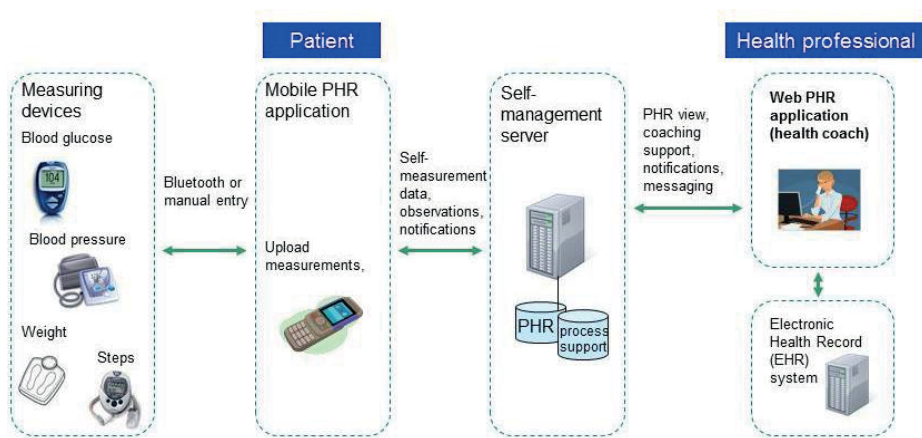
2.1 Renewing Health Finland

Renewing Health Finland (RHF) was a 12-month randomized controlled trial aiming to improve health-related quality of life of type 2 diabetes and heart disease patients and glycemic control of type 2 diabetes patients with an intervention that combined telemonitoring and health coaching. The study population consisted of 308 heart disease patients (ischemic heart disease or heart failure) and 287 type 2 diabetes patients that were recruited from the health care district of South Karelia and further randomized either to the telemonitoring group or to standard care (2:1). Of the 595 participants, 361 (61%) were men, mean age was 67 ± 9 years and mean BMI was 29.7 ± 5.2 kg/m².

The telemonitoring intervention consisted of weekly measurement of weight, blood pressure, blood glucose (for diabetics) and steps (heart disease patients) and reporting the measurements to the back-end systems using a mobile phone. Patients were given a self-monitoring toolbox that consisted of a mobile phone and measurement devices

(incl. blood pressure meter, blood glucose meters, scale and a pedometers). In addition, each patient was assigned a personal health coach. During the first study visit the patient and the health coach created a self-management plan that included small achievable health behaviour changes agreed by the patient. The coach called the patients at a 4-6 week interval. During the calls the coach reviewed the goals and provided the patients with information, assistance and support to achieve them. Before each call, health coaches reviewed patient's self-monitoring data. If the data showed abnormalities, the coach advised patient to contact primary care. If self-measurement data were missing and the patient had received the self-monitoring devices, the coach reminded the patient of the importance of self-monitoring and asked to conduct self-measurements and report them to the system on a regular basis. Detailed description of the intervention and study results is described by Karhula et al. [11]. The telemonitoring system of Renewing Health Finland is depicted in Figure 1.

Fig. 1. Technical architecture of telemonitoring system used in Renewing Health Finland



2.2 Measures

The telemonitoring system stored time-stamped self-monitoring data originating from the patients' measurement devices. The log-data from coaching calls included starting time and ending time and status of the call (failed or answered). The logfiles allow detailed analysis of patients' engagement with the telemonitoring intervention in the course of time and the responsiveness to the health coaching.

Adherence

Adherence to telemonitoring was defined as the percentage of weeks that included at least one measurement (blood glucose, body weight, blood pressure, steps) reported to the system. Each week was analysed separately and was relative to the individual starting time. In addition, adherence to glucose monitoring was analysed separately as HbA1c was the primary outcome. Adherence to glucose monitoring was similarly defined as the percentage of weeks including at least one glucose measurement.

Adherence to health coaching was defined as the total number of answered health coaching calls and the mean duration of the answered calls. As coaching calls were planned to be done with a 4-6 week interval, each patient was supposed to receive 7-11 calls when the baseline and concluding calls were excluded. The first and last calls were excluded because the control group received the corresponding calls. However, the content of the calls was not similar but control patients received only study-related information.

Quality of life

The primary outcomes of the Renewing Health Finland trial were the health-related quality of life (QoL) measured using SF-36 and HbA1c. SF-36 was collected at baseline and at the end of the study after 12 months. Physical component score (PCS) and mental component score (MCS) of SF-36 were used in the analyses.

HbA1c

Among type 2 diabetes patients the other primary outcome was HbA1c. Laboratory tests were done at baseline and at the end of the trial.

2.3 Analysis

Firstly, we calculated descriptive statistics for adherence to the overall telemonitoring, glucose telemonitoring and health coaching and illustrated the adherence trajectories over time. Secondly, the association between adherence and following sociodemographic variables were analysed: sex, age, body mass index (BMI), comorbidities, education, familiarity with mobile phone, familiarity with computer, QoL (PCS and MCS) at baseline, and HbA1c at baseline. The analyses were done separately for telemonitoring and health coaching components by employing a t-test and analysis of variance (ANOVA). Thirdly, the correlations between adherence to the intervention and primary outcomes (SF-36 and Hb1Ac) were analysed using ANCOVA which allowed controlling for potential confounders. QoL models were controlled for sex, age, baseline level of QoL and comorbidities. HbA1c models were controlled for sex, age, and baseline level of HbA1c. For HbA1c and glucose monitoring analyses only the type 2 diabetes group was included.

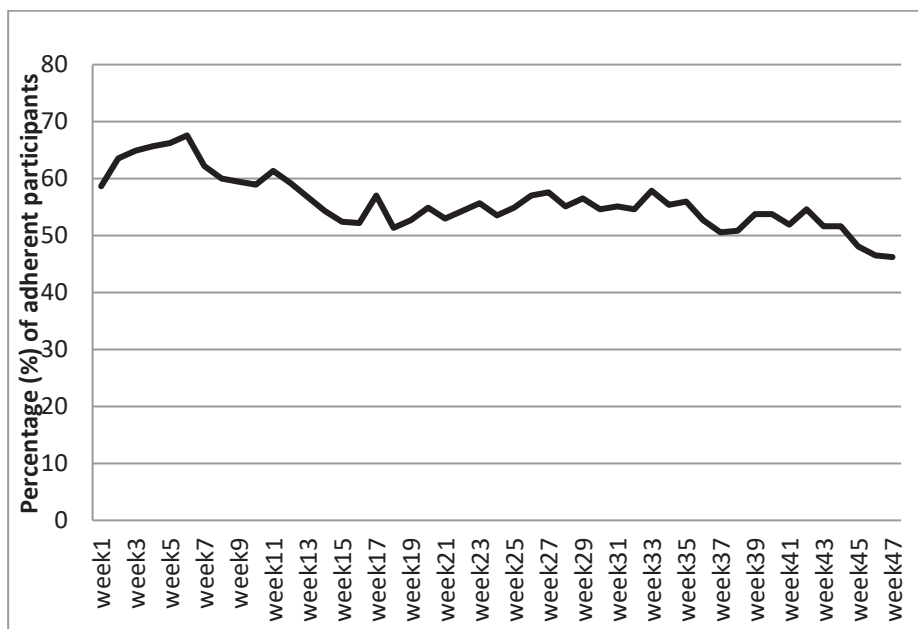
3 Results

3.1 Adherence to telemonitoring

The majority of participants adhered to weekly telemonitoring (Figure 2). The median percentage of adherent weeks was 65%; the 25th and 75th percentiles were 27% and 85%, respectively. When only intervention completers were included, the median adherence increased slightly to 67%. Of the 370 patients, 43% and 29% were 70% and 80% adherent with weekly telemonitoring. No major attrition was observed in the course of the 12-month follow-up. The retention with telemonitoring was fairly good

with the percentage of adherent participants varying from 51% (week 37) to 68% (week 6). However, there was a statistically significant linear decrease over time ($\beta=-0.002$ [-0.003to-0.001]). Adherence did not differ between the disease groups and the median number of monitored weeks was 30 in both groups.

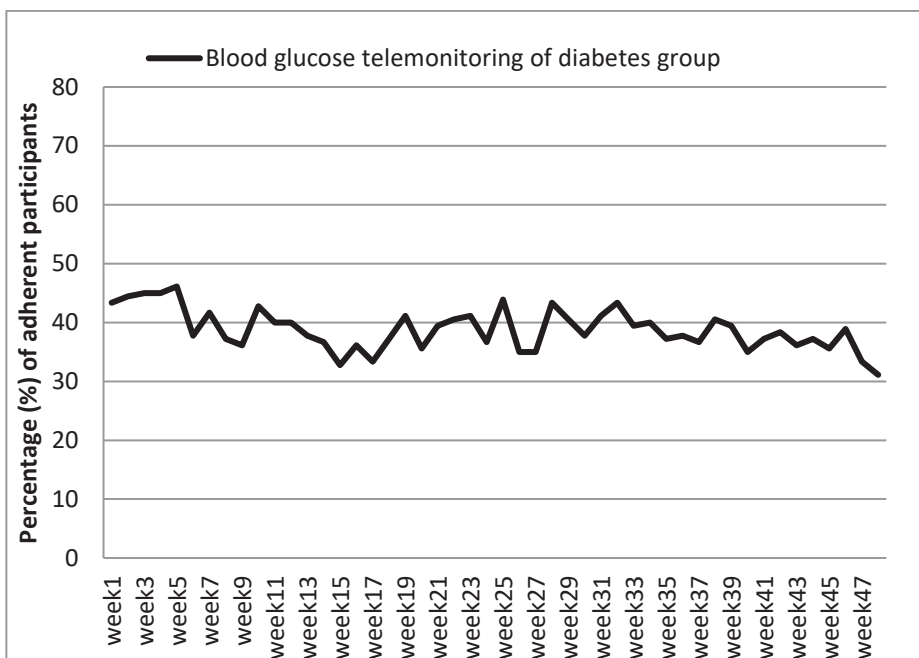
Fig. 2. Adherence to weekly telemonitoring - the percentage of participants who made at least one measurement on a given week ¹



Adherence to glucose monitoring among diabetes patients was investigated separately as HbA1c was the second primary outcome for the diabetes group (Figure 3). Of the 180 diabetes patients, 39 (22%) did not report any glucose measurements via the mobile application. The median number of glucose monitoring weeks was 17 (33%). Twenty-six and eighteen percent of the patients were 70% and 80% compliant, respectively. Among those who started glucose monitoring, the median number of monitored weeks was 52. Similarly to the overall adherence to telemonitoring, adherence to the glucose monitoring remained on a constant level throughout the study; the highest (42%) and lowest (36%) adherence rates were observed at weeks 4 and 14, respectively.

Fig. 3. Adherence to weekly telemonitoring of blood glucose; the percentage of participants who made at least one glucose report on a given week²

¹ The figure is limited to the week 47 because trial's end-point visits were scheduled to start from week 48



3.2 Adherence to the health coaching

The mean number of calls was 7.5 when starting and end-point calls were excluded. Sixty-six percent of participants received 7-11 calls which corresponds to the pre-defined coaching schedule. Eighty-nine percent received at least 6 calls. The mean duration of calls was 26.7 minutes. There were no differences between the disease groups (md=.19, p=.305 for number of calls and md=.007, p=.993 for the mean duration).

3.3 Predictors of Adherence

Of baseline characteristics, male gender (adherence for males and females: 60% vs. 50%, p=.004), younger age (correlation coefficient $r=-0.181$, $p<.001$) and familiarity with mobile phones (adherence for familiar and nonfamiliar participants: 58% vs. 33%, p=.009) and computers (adherence for familiar and nonfamiliar participants: 63% vs. 49%, $p<.001$) were associated with higher adherence. In total, only 12 patients reported they were not familiar with mobile phones. Education level, BMI, baseline level of QoL and number of comorbidities were not associated with adher-

2 The figure is limited to the week 47 because trial's end-point visits were scheduled to start from week 48

ence to telemonitoring. Adherence to glucose telemonitoring was associated with age (correlation coefficient $r=-0.144$, $p=.054$) and familiarity with computer (adherence for familiar and nonfamiliar participants: 47% vs. 28%). There were only 5 diabetes patients who were not familiar with mobile phone; among those the adherence was 7%. The baseline level of HbA1c did not affect adherence.

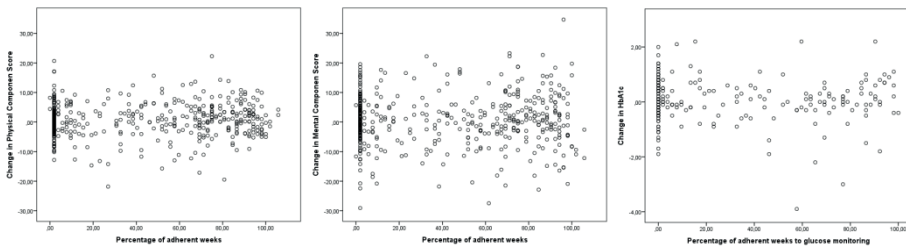
Adherence to health coaching was associated with familiarity with computer measured as a higher number (7.8 vs. 7.4, $p=.027$) and longer duration (27 vs. 26 minutes, $p=.04$) of coaching calls.

3.4 The Impact of Adherence and QoL and HbA1c

Fig 4 illustrates the relationship between adherence to telemonitoring and change in quality of life and HbA1c. Adherence to the telemonitoring was not associated with PCS ($\beta=.012$, $p=.266$) or MCS ($\beta=.029$, $p=.071$). When adjusted for baseline characteristics there was a statistically significant positive association between adherence and MCS: $\beta_{adj}=.033$, $p=.042$. However, the clinical significance is limited as 10% unit increase in adherence increases MCS by only 0.3 points. The association with PCS remained nonsignificant $\beta_{adj}=.011$, $p=.295$ after the adjustments. The effects of adherence to glucose telemonitoring or adherence to overall telemonitoring on HbA1c were negative and statistically nonsignificant $\beta=-0.068$ ($p=.695$) and $\beta=-0.0002$ ($p=.891$), respectively.

Health coaching measured as the number of answered coaching calls ($\beta=.223$, $p=.551$ for PCS, $\beta=-.132$, $p=.808$ for MCS) and mean duration of calls ($\beta=-.049$, $p=.368$ for PCS and $\beta=-.046$, $p=.557$ for MCS) did not correlate with PCS or MCS.

Fig. 4. The relationship between adherence to telemonitoring and change in quality of life



4 Discussion

In this paper we investigated type 2 diabetes and heart disease patients' adherence to a self-management intervention that combined health coaching and telemonitoring, and further assessed the impact of adherence on QoL and HbA1c.

The health coaching component in the Renewing Health Finland (RHF) trial was realized closely as planned. Sixty-six percent (66%) of patients received 7-11 coaching calls which corresponds to the predetermined 4-6week interval for health coaching, and 89% of participants received six or more calls indicating the majority of participants missed one call at maximum.

Participants' adherence to the telemonitoring component was moderate: in the course of 12 months the participants conducted telemonitoring on 65% of the weeks on average. Unlike in many eHealth interventions [8], [12] there was no major attrition towards the end of the trial but the percentage of adherent patients remained 51-68% over time. In telemonitoring studies adherence rates have been shown to vary from 52% to 75% [2], [7], [13], [14]. However, in these studies likewise in a number of other telemonitoring trials, health parameters were monitored on a daily basis that makes the numbers incomparable. Moreover, adherence numbers are typically based on aggregated averages failing to take into account the time effect that was presented in our study.

Glucose telemonitoring was realized with lower adherence rates. Type 2 diabetes patients conducted glucose measurements on 33% of the weeks on average and only 18% of the participants were 80% adherent. The results indicate lower engagement than found in other studies. For example in the DiaTel trial [14], 75% of non-insulin type 2 diabetes patients engaged in daily glucose monitoring. Low adherence might be related to the unchanged HbA1c levels found in RHF study.

Interestingly, telemonitoring activity did not correlate with QoL or HbA1c but the changes in those health parameters were similar regardless whether a patient was high or low adherent to the telemonitoring component. Our results are contradictory to the earlier studies showing improved quality of life in telemonitoring trials [1], [15], and improved HbA1c as a result of self-monitoring of blood glucose [16], though the benefits among type 2 diabetics not using insulin are inconclusive [17]. The analysis of predictors of adherence did not shed light on what could explain the lack of this relationship. Participants' baseline BMI and HbA1c levels and QoL were not associated with adherence to telemonitoring. Adherence was neither affected by the number of comorbidities. Of baseline characteristics, sex, age and familiarity with a mobile phone and a computer predicted higher adherence. The results imply that technology-assisted interventions might have potential to appeal younger men who are typically underrepresented and nonadherent to lifestyle interventions. However, the clinical effectiveness of telemonitoring in this context remains questionable.

While self-monitoring is the cornerstone of effective self-management in chronic diseases, it is only as effective as actions taken in response to the measurements [18]. In RHF health coaching was designed to respond to individual needs and empower patients and educate patients for better self-management. Health coaches reviewed patients' self-monitoring data before each call, however, the medication changes that critically affect patient's condition, were not specifically addressed. We do not have data about whether coaching calls resulted in further actions to intensify pharmacological treatment.

5 Conclusions

Our results on adherence indicate that the intervention in Renewing Health Finland was realized with at least moderate intensity. The vast majority of participants received almost a complete health coaching intervention and the adherence to telemonitoring of health parameters was moderate with 34 monitored weeks on average. However, despite their engagement in the intervention, patients did not show improvement in QoL or glycemic control. In fact, the level of adherence to telemonitoring did not correlate with QoL or HbA1c at all. The results suggest that the self-management intervention components (telemonitoring and health coaching) were not effective in improving the quality of life and glycemic control of patients with chronic conditions even when successfully delivered and adhered to. Further research is needed to identify effective approaches to improve the care of chronic conditions.

6 Acknowledgements

This research received funding from TuTunKo-project which is supported by Tekes, the Finnish Funding Agency for Technology and Innovation and European Regional Development Fund ERDF.

7 References

- [1] G. Pare, M. Jaana, and C. Sicotte, "Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base," *J. Am. Med. Informatics Assoc.*, vol. 14, no. 3, pp. 269–277, May 2007.
- [2] R. A. Clark, S. C. Inglis, F. A. McAlister, J. G. F. Cleland, and S. Stewart, "Telemonitoring or structured telephone support programmes for patients with chronic heart failure: systematic review and meta-analysis.," *BMJ*, vol. 334, no. 7600, p. 942, May 2007.
- [3] A. Steventon, M. Bardsley, J. Billings, J. Dixon, H. Doll, S. Hirani, M. Cartwright, L. Rixon, M. Knapp, C. Henderson, A. Rogers, R. Fitzpatrick, J. Hendy, and S. Newman, "Effect of telehealth on use of secondary care and mortality: findings from the Whole System Demonstrator cluster randomised trial.," *BMJ*, vol. 344, p. e3874, Jan. 2012.
- [4] M. Cartwright, S. P. Hirani, L. Rixon, M. Beynon, H. Doll, P. Bower, M. Bardsley, A. Steventon, M. Knapp, C. Henderson, A. Rogers, C. Sanders, R. Fitzpatrick, J. Barlow, and S. P. Newman, "Effect of telehealth on quality of life and psychological outcomes over 12 months (Whole Systems Demonstrator telehealth questionnaire study): nested study of patient reported outcomes in a pragmatic, cluster randomised controlled trial.," *BMJ*, vol. 346,

p. f653, Jan. 2013.

- [5] Kidholm, K., Stafylas, P., Kotzeva, A., Pedersen, C., Dafoulas, G., Scharf, I., Jensen, L., Lindberg, I., Andersen, A., Lange, M., Aletras, V., Fasterholdt, I., Stübini, M., d'Angelantonio, M., Ribu, L., Grottlund, A., Greuel, M., Giannaokopoulos, Isaksson, L., Orsama, A-L., Karhula, T., Mancin, S., Scavini, C., Dyrvig, A-K., Wanscher, C.: "Regions of Europe working together for health Final Report (2014)". Accessed: 04 Apr 2016. Available online at <http://www.renewinghealth.eu/documents/28946/1008625/D1.12+v1.5>
- [6] Chaudhry, Sarwat I., Jennifer A. Mattera, Jephtha P. Curtis, John A. Spertus, Jeph Herrin, Zhenqiu Lin, Christopher O. Phillips, Beth V. Hodshon, Lawton S. Cooper, and Harlan M. Krumholz. "Telemonitoring in Patients with Heart Failure". *NEJM* 363, 2301-2309, 2010
- [7] M. K. Ong, P. S. Romano, S. Edgington, H. U. Aronow, A. D. Auerbach, J. T. Black, T. De Marco, J. J. Escarce, L. S. Evangelista, B. Hanna, T. G. Ganiats, B. H. Greenberg, S. Greenfield, S. H. Kaplan, A. Kimchi, H. Liu, D. Lombardo, C. M. Mangione, B. Sadeghi, B. Sadeghi, M. Sarrafzadeh, K. Tong, and G. C. Fonarow, "Effectiveness of Remote Patient Monitoring After Discharge of Hospitalized Patients With Heart Failure: The Better Effectiveness After Transition-Heart Failure (BEAT-HF) Randomized Clinical Trial.," *JAMA Intern. Med.*, vol. 176, no. 3, pp. 310–8, Feb. 2016.
- [8] G. Eysenbach, "The law of attrition.," *J. Med. Internet Res.*, vol. 7, no. 1, p. e11, Jan. 2005.
- [9] R. C. Wu, D. Delgado, J. Costigan, J. Maciver, and H. Ross, "Pilot study of an Internet patient-physician communication tool for heart failure disease management.," *J. Med. Internet Res.*, vol. 7, no. 1, p. e8, Jan. 2005.
- [10] G. Eysenbach, "CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions.," *J. Med. Internet Res.*, vol. 13, no. 4, p. e126, Jan. 2011.
- [11] T. Karhula, A.-L. Vuorinen, K. Rääpysjärvi, M. Pakanen, P. Ikonen, M. Tepponen, U.-M. Junno, T. Jokinen, M. van Gils, J. Lähteenmäki, K. Kohtamäki, and N. Saranummi, "Telemonitoring and Mobile Phone-Based Health Coaching Among Finnish Diabetic and Heart Disease Patients: Randomized Controlled Trial.," *J. Med. Internet Res.*, vol. 17, no. 6, p. e153, 2015.
- [12] E. Mattila, A.-L. Orsama, A. Ahtinen, L. Hopsu, T. Leino, and I. Korhonen, "Personal health technologies in employee health promotion: usage activity, usefulness, and health-related outcomes in a 1-year randomized controlled trial.," *JMIR mHealth uHealth*, vol. 1, no. 2, p. e16, Jan. 2013.

- [13] K. Port, K. Palm, and M. Viigimaa, "Daily usage and efficiency of remote home monitoring in hypertensive patients over a one-year period.," *J. Telemed. Telecare*, vol. 11 Suppl 1, pp. 34–6, Jan. 2005.
- [14] R. A. Stone, R. H. Rao, M. A. Sevick, C. Cheng, L. J. Hough, D. S. Macpherson, C. M. Franko, R. A. Anglin, D. S. Obrosky, and F. R. Derubertis, "Active care management supported by home telemonitoring in veterans with type 2 diabetes: the DiaTel randomized controlled trial.," *Diabetes Care*, vol. 33, no. 3, pp. 478–84, Mar. 2010.
- [15] S. C. Inglis, R. A. Clark, F. A. McAlister, J. Ball, C. Lewinter, D. Cullington, S. Stewart, and J. G. Cleland, "Structured telephone support or telemonitoring programmes for patients with chronic heart failure.," *Cochrane database Syst. Rev.*, no. 8, p. CD007228, 2010.
- [16] L. McAndrew, S. H. Schneider, E. Burns, and H. Leventhal, "Does patient blood glucose monitoring improve diabetes control? A systematic review of the literature.," *Diabetes Educ.*, vol. 33, no. 6, pp. 991–1011; discussion 1012–3, Jan. .
- [17] U. L. Malanda, L. M. C. Welschen, I. I. Riphagen, J. M. Dekker, G. Nijpels, and S. D. M. Bot, "Self-monitoring of blood glucose in patients with type 2 diabetes mellitus who are not using insulin.," *Cochrane database Syst. Rev.*, vol. 1, p. CD005060, Jan. 2012.
- [18] H. Kolb, K. Kempf, S. Martin, M. Stumvoll, and R. Landgraf, "On what evidence-base do we recommend self-monitoring of blood glucose?," *Diabetes Res. Clin. Pract.*, vol. 87, no. 2, pp. 150–6, Feb. 2010.

