Nutritional telemonitoring for community-dwelling older adults

Feasibility and effectiveness

Marije N. van Doorn-van Atten

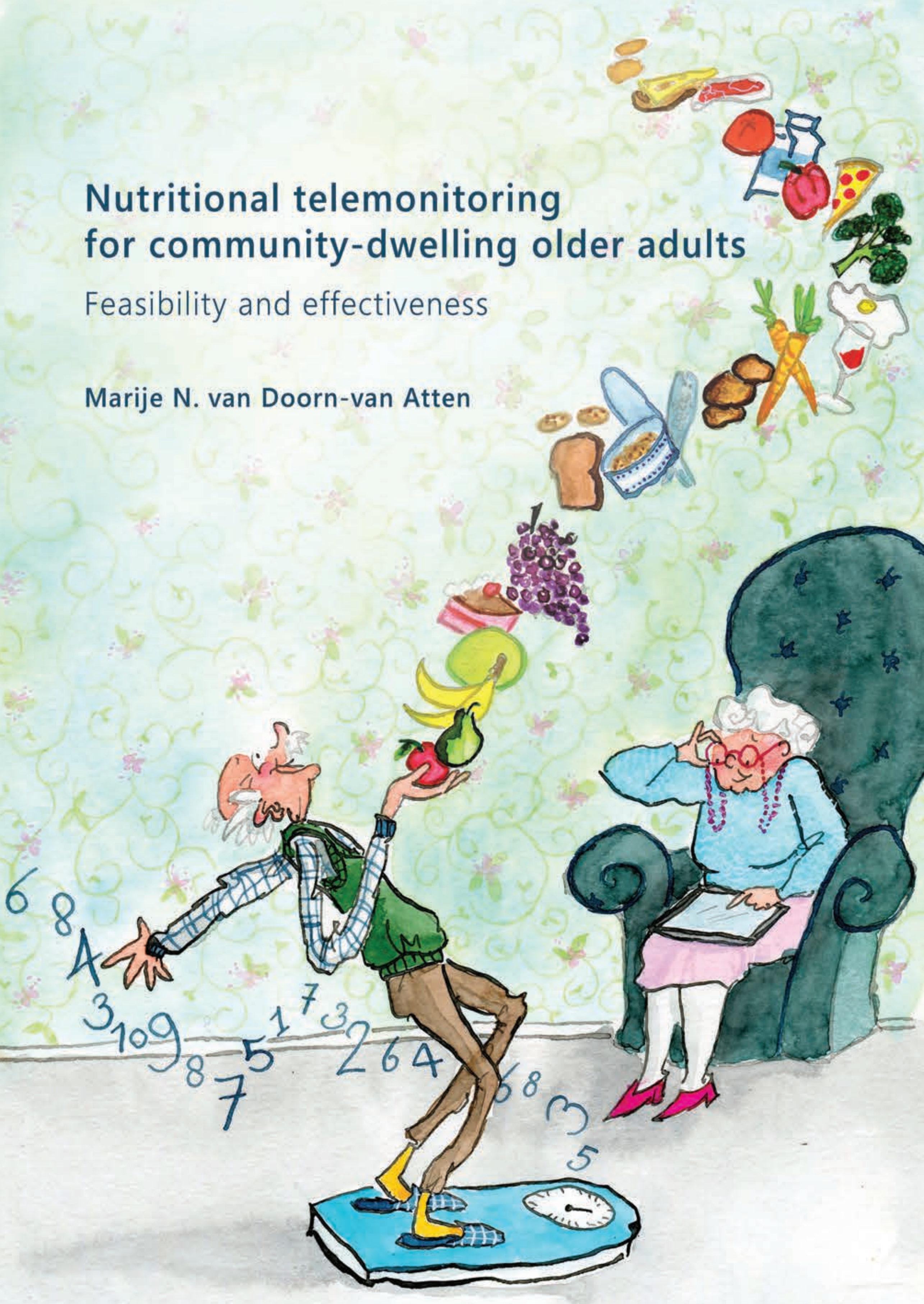

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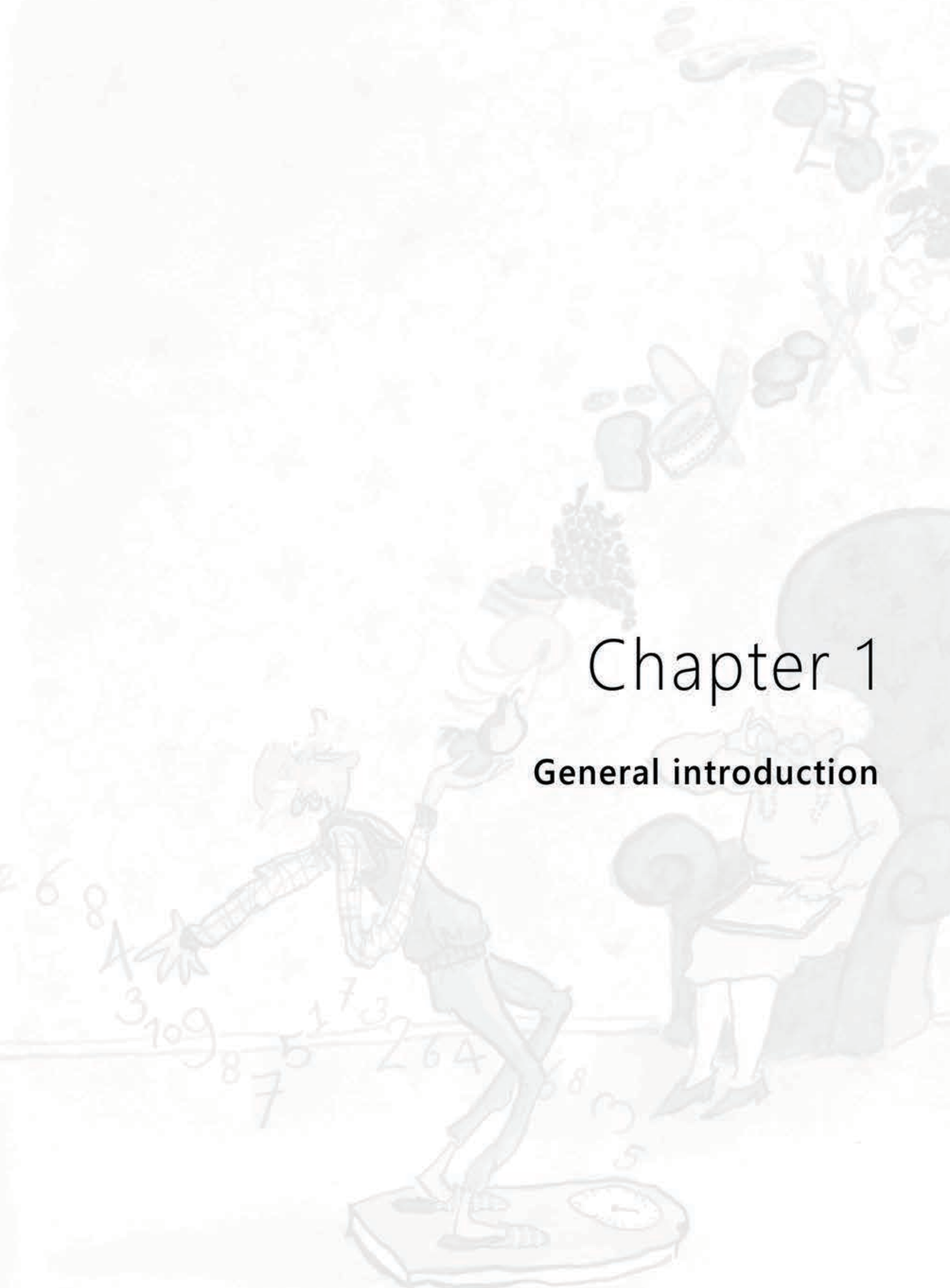
TABLE OF CONTENTS



Chapter 1

General introduction

HEALTHY AGEING

The world's population is in a demographic transition. Increased life expectancy and falling fertility rates result in an expected doubling of the world's population over 60 years from 12% in 2015 to 22% in 2050 [1]. Soon we will have more older adults than children below five years old and more people at extreme old age than ever before [2]. European countries spend on average more than a quarter of their GDP on social protection, mostly on pensions, health, and long-term care for older adults [3]. An ageing population with proportionally less people of working age has profound consequences for public spending on health care and availability of health care services [4]. These concerns have led to the impression that an ageing society is a threat. We should realise, however, that older people contribute to society in many ways. In their family, their local community, and society they are active as family carers, neighbours, volunteers, or through paid labour [3]. From this perspective, longevity is a major opportunity for individuals and society. Good health and functioning contribute to an active role in society and to the ability of older adults to do what they value. Older age, however, is characterised by enormous diversity in health and functioning [5, 6]. Furthermore, it is debatable whether the years that are lived longer are years that are lived in better health and with better functioning [7-9]. Healthy ageing, defined by the WHO as 'the process of developing and maintaining the functional ability that enables wellbeing in older age' [10], is therefore key to maintaining well-being at old age and tackling the challenges of an ageing society.

NUTRITION & HEALTHY AGEING

Healthy ageing can be promoted by healthy behaviours, whether started during the life course or at older age [5]. Healthy behaviours do not only extend lifespan, but also support recovery from illness and reduce morbidity [11, 12]. Physical activity and nutrition are regarded as important predictors of health at old age and survival [10, 13, 14]. However, physical activity levels decline with age. Despite the evident benefits of physical activity, about one third of the 70-79 year-olds and about half of the adults aged 80 years and over fail to meet the WHO guidelines for physical activity [15]. Older age is also associated with increased nutritional risk due to physiological changes, deteriorations in health and functioning, and social circumstances, which in turn affect nutrition behaviour and nutritional status [16, 17]. Ageing may be associated with decreasing intakes of energy, macronutrients, and micronutrients [18-20] and studies show that substantial proportions of older adults have inadequate nutrient intakes [21, 22]. Poor nutrition behaviour can lead to over nutrition and undernutrition. The association of body mass index (BMI) with mortality shows a U-shaped curve with increased risk of mortality at both sides of the BMI spectrum [23]. In old age, however, it is argued that this U-curve is characterised by a large flat bottom with the right-hand side of the curve that is elevated only if BMI values are over 31-32 kg/m^2 [24]. With regard to the left-hand side, mortality risk starts to increase already from BMI values < 23 [25]. Overweight and mild to moderate obesity might thus be protective for older adults [24, 26, 27]. Undernutrition, on the other hand, is associated with increased risk of mortality and negative consequences such as increased length of hospital stay [28], readmission [29], impaired wound healing, immune response, and muscle function [30-32], post-operative complications [28], impaired physical functioning [33], and lower quality of life [34, 35]. Costs of undernutrition, including costs for treatment and costs related to the consequences of undernutrition, are estimated to be 1.8 billion euros per year in the Netherlands [36]. It is difficult to estimate the prevalence of undernutrition, as a golden standard to measure nutritional status is lacking and different instruments are used for diagnosis. In a hospital setting, it is estimated that undernutrition affects 20 to 50% of patients [37]. Nursing home studies found prevalence rates from 1.5 to 66.5% [38]. In the community, undernutrition rates range from 5.8% as estimated by the Mini Nutritional Assessment (in a general elderly population across several countries) to 35% as estimated by the SNAQ^{65+} (in Dutch home care clients) [39, 40]. Risk factors for undernutrition include age, frailty, appetite loss, excessive polypharmacy, functional decline, dementia, and certain psychological factors such as loss of interest in life [41]. In absolute numbers, undernutrition is most prevalent in the community as the majority of older adults live in their own homes. It is in this setting, however, that undernutrition is under-recognised and under-diagnosed, more than in the hospital or nursing home setting. Health care professionals and older adults lack awareness of the risks of undernutrition and in the Netherlands it is unclear, despite guidelines, what the role of health care professionals is in screening for and diagnosing undernutrition [42, 43]. To promote healthy longevity, functioning, and well-being, efforts should be focussed on preventing undernutrition and signalling undernutrition at an early stage to start timely treatment.

NUTRITIONAL INTERVENTIONS

Existing interventions to promote optimal nutritional status focus on early detection, treatment, or prevention. Examples of common interventions include screening [44], oral nutritional supplements (ONS) [45], enriched food products [43, 46], dietary counselling or dietetic care [47], food assistance and meal programs [48], mealtime interventions [49], nutrition education [50], or a combination of these interventions. With regard to early detection of undernutrition, screening is an important first step in identifying risk of undernutrition and improving awareness, regardless of setting. It is argued that more than half of the persons at risk of undernutrition would not be recognised and referred for treatment in absence of formal screening procedures [51]. With regard to treatment, much research has focussed on ONS. ONS have been proven to reduce mortality in undernourished persons [45]. However, prescription of ONS in community-dwelling older adults is less successful as effects on mortality are lacking and functional benefit from ONS varies among studies [45, 52]. Palatability and compliance to ONS remain issues to be addressed [53]. Enriched food products are another way to ensure sufficient intake, with the advantage that these products may better connect to usual eating habits and preferences than ONS [43, 46]. Dietary counselling with or without oral nutritional supplements can result in weight gain, improved energy intake, and improved nutritional status, but effects on mortality have not been proven yet [47, 54, 55]. Meal programs and mealtime interventions are more preventative approaches, from which mealtime interventions are mostly implemented in institutional settings. There may be potential for mealtime interventions in a community setting as well, as social isolation and eating alone may affect meal enjoyment and food intake [49]. Another preventative approach is nutrition education [56, 57].

Nutrition education can result in positive changes in knowledge, but results on behaviour and anthropometrics were variable in one review [56]. Another more recent review, however, presents evidence that nutrition education (sometimes as part of a complex intervention) positively affects diet and physical functioning [57]. The abovementioned types of interventions can co-exist or complement each other as multifactorial interventions might be more effective than single interventions [53]. Which intervention or combination of interventions is most suitable depends on several factors, such as the setting, the target population, the purpose of the intervention, and the nutritional and health status of the intervention recipient. Many interventions also include a physical activity component to enhance effects on health and functioning [57, 58]. Furthermore, approaches to address undernutrition are often multidisciplinary given the multi causal nature of undernutrition, involving for example dentistry and speech therapy. Governments and health care professionals should promote access to nutritional interventions by integrating effective interventions into health care systems and community services [17]. Intervention elements that are associated with effectiveness include personalisation [56, 59], messages that are limited in number and tailored, regular contact with health care professionals, incentives, hands-on activities such as gardening [56], and involvement in goalsetting and action planning [56, 60]. Research gaps exist with respect to establishing effects on functioning and quality of life [52], how and when interventions lead to behavioural change [61], and concerning acceptability of interventions [53]. Therefore, ongoing quantitative and qualitative research is necessary to build evidence for nutrition interventions that contribute to healthy ageing.

EHEALTH

Health care systems need to adapt and extend health care to meet the needs of the growing number of older adults while keeping the financial burden for societies and individuals bearable. Thereby, health care systems should provide security and dignity so that health care meets the quality requirements as seen through the eyes of the health care recipients, health care providers, and the government. Governments present several strategies for this, such as an increased role for informal carers, a shift from long-term institutional care to care at home, an increased emphasis on self-management, and focus on prevention of disease [62]. Advances in health technology are mentioned as another way to accommodate the growing demand for health care [5, 63]. EHealth, defined as "health services and information delivered or enhanced through the Internet and related technologies" [64] is expected to provide numerous advances, such as efficiency, equity, and cost containment [65]. EHealth can be applied for purposes of primary prevention [62, 66] and management of diseases [67-69]. It can take various forms such as apps, websites, devices, and video consulting [66]. Despite its promises, concerns remain with regard to effectiveness, sustainable integration into health care systems, acceptability, equity, and compliance [53, 64-66]. EHealth has been applied in managing undernutrition in community-dwelling older adults. In a review and meta-analysis by Marx et al [70], nine studies were identified that included participants with specific diseases (two studies) or participants with mixed morbidities following hospital or rehabilitation discharge (seven studies). The main mode for intervention delivery was telephone (seven studies), while two studies used internet-based devices. The authors concluded that undernutrition related eHealth interventions can lead to improved protein intake and quality of life, but significant effects on nutritional status, physical functioning, and mortality were not established. More research including larger sample sizes, a more diverse study population, and including measures of acceptability will build to the body of evidence concerning eHealth to address undernutrition in older adults [70].

PUBLIC HEALTH RESEARCH

Building evidence for effective interventions that support healthy ageing entails research ranging from molecular studies to observational studies and public health interventions [71]. The latter are needed to inform governments and public health agencies about effective interventions that can be integrated into health care systems and community services. When designing interventions and evaluation plans for a public health setting, several issues should be taken into account. Firstly, interventions should preferably be evidence-based and/or built on behavioural theory. By building on theory, interventions are more likely to lead to the desired behaviour change, and interventions are more easily compared or replicated. It may also enable identification of efficacious intervention elements, thereby informing future development of interventions [72]. Secondly, the selection of effect and process measures is critical when evaluating public health interventions. These interventions take place in a real-life setting in which conditions are less controlled than in a clinical setting. This potentially influences the delivery of the interventions and its effectiveness. Investigating how an intervention was delivered is crucial to know why effects were or were not achieved [73]. Thirdly, researchers should not only include measures relevant to science, but also measures that are relevant to public health practice and policy [74]. For example, scientists may be focussed on effect measures and mechanisms of impact, while intervention recipients and health care professionals delivering the intervention will likely be interested in acceptability and feasibility of an intervention. All in all, a comprehensive evaluation plan including a process and effect evaluation will ascertain that insight is obtained into effectiveness and mechanisms of impact, and will ascertain that results will be relevant for all stakeholders.

AIM AND OUTLINE OF THE THESIS

This thesis aimed to provide insight into the feasibility and the effectiveness of a multi-component intervention for community-dwelling older adults consisting of nutritional telemonitoring, follow-up by a nurse, and nutrition education. The telemonitoring component aimed at early detection of undernutrition risk. The follow-up component aimed at reversing this risk or at treating undernutrition through nutrition counselling by a nurse or referral to dietetic care. The education component focussed on prevention through promoting a healthy diet and physical activity. This intervention was implemented among community-dwelling older adults in the Netherlands, Spain, and the United Kingdom. Chapter 2 describes the design of the study including the multi-component intervention and its underlying theory, and measures of impact and process. In Chapter 3 we pilot-tested this intervention among 20 Dutch home care clients over a period of twelve weeks. Insights into feasibility and potential impact are presented, as well as suggestions to improve the intervention for more impact during large-scale implementation. Chapter 4 describes the results of an effectiveness study including 204 Dutch community-dwelling older adults who were allocated to the intervention or control group. The intervention group received the multi-component intervention over a period of six months, while the control group received usual care. Effects on the primary outcome nutritional status and secondary outcomes diet quality, appetite, physical functioning, and quality of life are presented. Chapter 5 continues with a process evaluation of this intervention. By using a mixed-methods approach, the process indicators reach, dose, fidelity, and acceptability are studied. In Chapter 6 we aimed to evaluate the effects on behavioural determinants of diet quality and physical activity in older adults. We also assessed the role of several hypothesised mediators in the intervention's effects on diet quality and physical activity, aiming at unravelling the intervention's mechanisms of impact. The last chapter, Chapter 7, summarises the main conclusions of this thesis and discusses the findings, thereby placing the results into a broader perspective, presenting implications for practice and giving suggestions for future research.

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Chapter 2

Telemonitoring to improve nutritional status in community-dwelling elderly: design and methods for process and effect evaluation of a non-randomized controlled trial

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ABSTRACT

Background: A good nutritional status is key for maintaining health and quality of life in older adults. In the Netherlands, 11 to 35% of the community-dwelling elderly are undernourished. Undernutrition or the risk of it should be signalled as soon as possible to be able to intervene at an early stage. However, in the context of an ageing population health care resources are scarce, evoking interest in health enabling technologies such as telemonitoring. This article describes the design of an intervention study focussing at telemonitoring and improving nutritional status of community-dwelling elderly.

Methods: The PhysioDom Home Dietary Intake Monitoring intervention was evaluated using a parallel arm pre-test post-test design including 204 Dutch community-dwelling elderly aged > 65 years. The six-month intervention included nutritional telemonitoring, television messages, and dietary advice by a nurse or a dietician. The control group received usual care. Measurements were performed at baseline, after 4.5 months, and at the end of the study, and included the primary outcome nutritional status and secondary outcomes behavioural determinants, diet quality, appetite, body weight, physical activity, physical functioning, and quality of life. Furthermore, a process evaluation was conducted to provide insight into intervention delivery, feasibility, and acceptability.

Discussion: This study will improve insight into feasibility and effectiveness of telemonitoring of nutritional parameters in community-dwelling elderly. This will provide relevant insights for health care professionals, researchers, and policy makers.

Trial registration: The study was retrospectively registered at Clinical-Trials.gov (identifier NCT03240094) since August 3, 2017.

Keywords: Study protocol, undernutrition, prevention, community-dwelling elderly, telemonitoring, real-life setting.

BACKGROUND

A good nutritional status is key for maintaining health and quality of life in older adults [1, 2]. However, in the Netherlands, 11 to 35 % of community-dwelling elderly is undernourished. Within this group, the highest percentage of undernutrition is seen among the elderly receiving home care [3]. Considering the negative consequences of undernutrition on morbidity and mortality [4], attention should be given to recognizing undernutrition and the risk of it, so that deterioration can be prevented by timely treatment.

Nutritional screening leads to a better recognition of undernutrition and decreased malnutrition rates in long-term care, and seems to be cost-effective [5, 6]. Although figures are not available for other settings, there is a widespread demand for nutritional screening in at-risk populations [7]. The Dutch undernutrition management guidelines advocate for nutritional screening among community-dwelling older adults [8]. However, compliance to these guidelines is poor: only 16 % of home care patients is structurally screened for undernutrition [9]. Furthermore, health care professionals indicate that there is ambiguity concerning screening responsibilities and procedures. They mention that lack of awareness, time, and priority are barriers for nutritional screening among community-dwelling older adults [10].

Concurrently, the increasing burden on health care and focus on self-management of older adults evokes interest in health enabling technologies. eHealth, defined as 'Health services and information delivered or enhanced through the internet and related technologies' [11], is viewed as a possibility to meet the needs for cost-effective health care and to improve the access and quality of care [11]. eHealth may be used for nutritional screening in the form of telemonitoring: 'The use of information technology to monitor patients at a distance' [12]. Studies have shown that telemonitoring is effective in the management of various chronic diseases [13-15]. To our knowledge, there is only one study in which telemonitoring has been used for monitoring of nutritional parameters in community-dwelling elderly. Results showed that this appeared to be feasible, but due to a small sample size no significant effects could be shown [16].

The PhysioDom Home Dietary Intake Monitoring (HDIM) study focused at telemonitoring and improving nutritional status of community-dwelling elderly with the help of a television based platform and a website for health care professionals. The six-month intervention included telemonitoring of nutritional status, appetite, diet quality, and physical activity. Furthermore, participants received television messages and when necessary dietary advice by a nurse or a dietician. The intervention was implemented in a home care setting and involved participation of community-dwelling elderly, nurses, and dieticians.

Evaluating complex interventions in a real-life setting in which circumstances are less controlled requires an extensive evaluation framework that provides insight into intervention effects, but also into the implementation process and mechanisms of impact [17]. Therefore, this study does not only focus on effect evaluation, but also on evaluation of intervention delivery, feasibility, and acceptability.

This paper aims to describe the design of the PhysioDom HDIM study focusing at nutritional telemonitoring in Dutch community-dwelling older adults in a home care setting. The objectives of the study are: a) to assess the effects of the PhysioDom HDIM intervention on the primary outcome nutritional status and the secondary outcomes behavioural determinants, diet quality, appetite, body weight, physical activity, physical functioning, and quality of life; and b) to assess the implementation process of the telemonitoring intervention including its delivery, feasibility, and acceptability.

METHODS

Study design

This study ran from February 2016 until June 2017 and followed a parallel arm pre-test post-test design including 204 Dutch participants. The study was carried out in the Netherlands by Wageningen University and care organizations Zorggroep Noordwest-Veluwe and Opella. The study was part of a European project with study sites in the United Kingdom and Spain as well. Each study site employed the same telemonitoring technology, but the exact intervention and the study design varied between study sites to fit the local health care context. This paper therefore only focuses on the study design in the Netherlands. The duration of the intervention was six months, preceded by a preparation and recruitment phase. Effect measurements were carried out at the beginning, after 4.5 months, and at the end of the study. Process measurements were carried out throughout the study. The study was retrospectively registered at Clinical-Trials.gov (identifier NCT03240094) since August 3, 2017. The ethics committee of Wageningen University approved the study protocol and all participants gave their written informed consent before the start of the study.

Study population

The study population consisted of 204 community-dwelling older adults over 65 years receiving home care, informal care, and/or living in a service flat or sheltered accommodation. Individuals were excluded from participation if they were cognitively impaired (Mini Mental State Examination (MMSE) < 20), received terminal care, had cancer, were not able to watch television, or had a physical impairment that prevented them to use the telemonitoring devices properly. The intervention group was recruited in the municipalities of Nunspeet, Harderwijk, Putten, Ermelo, and Renkum; the control group was recruited in the municipalities of Wageningen, Ede, Rhenen, and Veenendaal. Participants were recruited via invitation letters from the care organizations, invitation letters posted in sheltered housing and service flats, and adverts in newspapers and public spaces. After showing an interest in participation, individuals received an information brochure and researchers visited the interested individual at home to answer questions, sign the informed consent, and screen on eligibility criteria.

Theoretical concept

A logic model is useful for planning and evaluating an intervention and visualizes how intervention activities are linked to the hypothesized outcomes on short-term, medium-term and long-term levels [17]. Figure 2.1 shows the logic model for this study. The logic model guided the selection of the short-term outcomes (intention, knowledge, attitude, self-efficacy, perceived behavioural control, goalsetting, self-monitoring), medium-term outcomes (compliance to guidelines for diet and physical activity), and long-term outcomes (nutritional status, physical functioning, and quality of life). Furthermore, the intervention included several behaviour change techniques such as self-monitoring, goalsetting, providing feedback on performance, [18], belief selection, and persuasive communication [19] (Table 2.1).

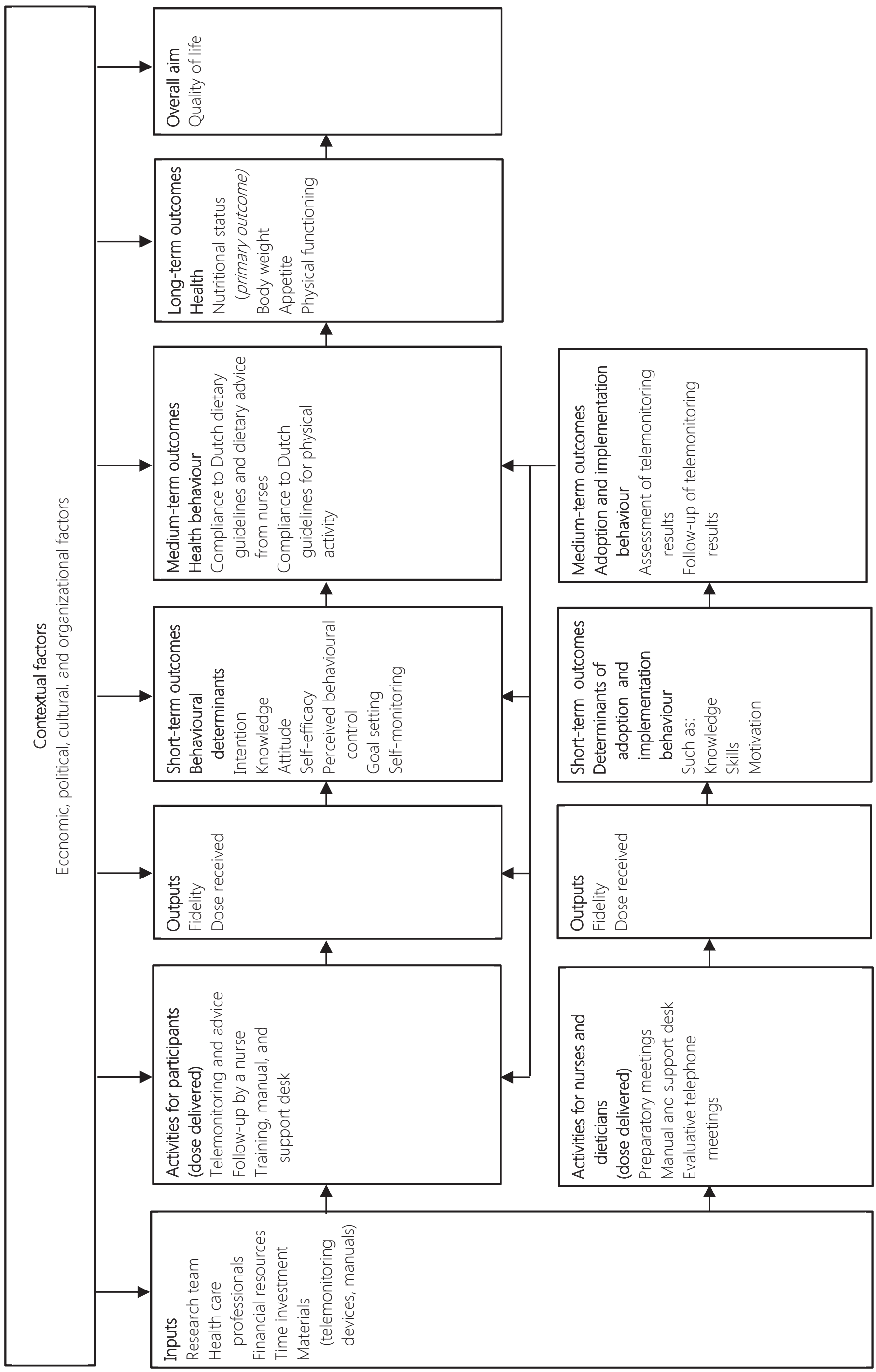

Figure 2.1. Logic model of the PhysioDom HDIM intervention in the Netherlands.

Table 2.1. Behaviour change techniques that underpin the PhysioDom HDIM intervention in the Netherlands.

Intervention activities	Behaviour change techniques	Definition of behaviour change techniques
Telemonitoring and advice		
Telemonitoring of body weight, nutritional status (MNA-SF), appetite (SNAQ), and blood pressure	Self-monitoring of behavioural outcome	"The person is asked to keep a record of specified measures expected to be influenced by the behaviour change, e.g. blood pressure, blood glucose, weight loss, physical fitness" [18]
Telemonitoring of diet quality (DHD-FFQ) and steps	Self-monitoring of behaviour	"The person is asked to keep a record of specified behaviour/s as a method for changing behaviour" [18]
Setting goals for number of steps and which items of diet quality to improve	Goalsetting (behaviour)	"The person is encouraged to make a behavioural resolution (e.g. take more exercise next week). This is directed towards encouraging people to decide to change or maintain change" [18]
Television messages about nutrition and physical activity	Belief selection	"Using messages designed to strengthen positive beliefs, weaken negative beliefs, and introduce new beliefs" [19]
	Consciousness raising	"Providing information, feedback, or confrontation about the causes, consequences, and alternatives for a problem or a problem behaviour" [19]
	Provide information on consequences of behaviour in general	"Information about the relationship between the behaviour and its possible or likely consequences in the general case, usually based on epidemiological data, and not personalised for the individual" [18]
Letters with results of DHD-FFQ and tailored advice on how to improve diet quality and physical activity	Provide feedback on performance	"This involves providing the participant with data about their own recorded behaviour or commenting on a person's behavioural performance" [18]
Follow-up nurse		
Personal follow-up of nurse in case of risk of undernutrition	Verbal persuasion/persuasive communication	"Guiding individuals and environmental agents toward the adoption of an idea, attitude, or action by using arguments or other means" [19]
Implementation and training		
Manual for participants and health care professionals. For participants: also including cartoons with resistance exercises	Provide instruction on how to perform the behaviour	"Involves telling the person how to perform a behaviour or preparatory behaviours, either verbally or in written form" [18]

Table 2.1. Continued.

Intervention activities	Behaviour change techniques	Definition of behaviour change techniques
Preparatory meetings, workshop, and evaluative telephone meetings with health care professionals	Goalsetting (behaviour)	"The person is encouraged to make a behavioural resolution (e.g. take more exercise next week). This is directed towards encouraging people to decide to change or maintain change" [18]
	Action planning	"Involves detailed planning of what the person will do including, as a minimum, when, in which situation and/or where to act" [18]
	Barrier identification/ problem solving	"The person is prompted to think about potential barriers and identify ways of overcoming them" [18]
Training for participants	Guided practice	"Prompting individuals to rehearse and repeat the behavior various times, discuss the experience, and provide feedback" [19]
Support desk for participants and health care professionals	Technical assistance	"Providing technical means to achieve desired behavior" [19]

MNA-SF = Mini Nutritional Assessment-Short Form; SNAQ = Simplified Nutritional Appetite Questionnaire; DHD FFQ = Dutch Healthy Diet Food Frequency Questionnaire

Telemonitoring intervention

Telemonitoring measurements and advice

Participants performed several telemonitoring measurements. These measurements should primarily be regarded as intervention components, measurements for research purposes can be found in the next section. Participants measured their body weight weekly and measured their steps one week per month. Some participants also measured their blood pressure weekly or bi-weekly upon indication of their nurse. For these measurements, participants received a weighing scale (A&D, type UC-411PBT-C), a pedometer (A&D, type UW-101), and a sphygmomanometer (A&D, type UA-767PBT-CI). Participants received instructions to weigh themselves without heavy clothes and shoes and after voiding. Participants had to measure their blood pressure at a fixed time during the day, while being silent and sitting up straight in a chair with their left arm on the table. Furthermore, participants were asked to fill out questionnaires concerning their nutritional status with the Mini Nutritional Assessment Short-Form (MNA-SF) [20], appetite with the Simplified Nutritional Appetite Questionnaire (SNAQ) [21], and diet quality with the Dutch Healthy Diet

Food Frequency Questionnaire (DHD-FFQ) [22]. Participants filled out these questionnaires at the beginning of the study during an interview with the researchers, and three months later a second time. Participants could choose how to fill out the questionnaires this second time: via a tablet that they received from the researchers, via their own PC, or via a phone call with the researchers, dependent on the preferences and capabilities of the participants. The results of the telemonitoring measurements were shown on the television of participants. Results from the body weight and blood pressure measurements were sent to the participants' television by Bluetooth, steps had to be entered manually on the television channel. Furthermore, participants received three short television messages per week with general advice on how to improve nutrition and physical activity. The messages targeted determinants of nutrition and physical activity behaviour such as awareness, knowledge, attitude, and outcome expectations. Participants also received two letters at the beginning and half-way during the study with the results of the DHD-FFQ and customized advice on how to improve diet quality and physical activity.

Follow-up by a nurse

Results of the telemonitoring measurements and questionnaires were sent to the project website. On this website, nurses received alerts in case of undernutrition or the risk of undernutrion, obesity or new blood pressure measurements. Alerts for risk of undernutrition were activated if participants lost five to ten percent of baseline body weight in the past six months, had an MNA-SF score between eight and 11, and/or had a SNAQ score below 15. Alerts for undernutrition were activated if participants lost more than ten percent of baseline body weight, lost more than five percent of body weight in the past month, had a body mass index (BMI) below 20 kg/m^2, and/or had an MNA-SF score of zero to seven. Alerts for obesity were activated if participant had a BMI of 30 kg/m^2 or higher. Additionally, alerts were activated when participants with heart failure gained two or more kilograms of body weight. The thresholds for alerts were based upon current guidelines and protocols in Dutch health care [8, 23, 24]. In case of risk of undernutrition, undernutrition, obesity, or abnormal blood pressure values, the nurse contacted the participant to provide follow-up. If the participant risked undernutrition, the nurse advised on how to improve protein and energy intake and gave a brochure with advice. If the participant was undernourished, the nurse referred to a GP or dietician. Nurses were aided in processing the alerts by decision trees (Appendix 2.1) and could consult dieticians from the care organizations if needed.

Implementation and training of health care professionals and participants

In the months prior to the intervention, the researchers had four preparatory meetings of one to two hours with the nurses and dieticians in which they discussed how implementation could be organized and how the intervention could fit within existing working procedures. During these meetings, nurses and dieticians were trained in using the project website, processing the alerts, and working with the decision trees. Also topics related to change management were covered in the meetings. In the last meeting, a dietician gave a workshop for the nurses with the aim to improve knowledge about nutrition and undernutrition in elderly people. The nurses and dieticians received a manual that covered the information of the preparatory meetings and the workshop. Every one to two months, the researchers and nurses held evaluative meetings via telephone to assess implementation and address questions from nurses. At the beginning of the intervention, participants received a training about the use of the television channel, the weighing scale, pedometer, and, if applicable, sphygmomanometer and/or tablet. This training was based on the theory of guided practice [19], took place at the participant's home and lasted about 45 minutes. Participants also received a step-by-step illustrated manual. A support desk was available for extra assistance via telephone or at the participant's home. Furthermore, compliance to the intervention was stimulated through a paper calendar listing the telemonitoring measurements, illustrated cards with positive cues to use the television channel and to adhere to telemonitoring measurements, and three newsletters.

Participants in the control group receive usual care.

Research measurements

Research measurements were performed during the screening, at baseline (T0), 4.5 months after baseline (T1), and after six months at the end of the intervention (T2). At each time point, trained researchers or research assistants visited the participants at their homes to administer questionnaires in the form of a structured interview or a paper questionnaire and to perform measurements.

During the screening visit, the *background characteristics* age, sex, height, education level, birth country, marital status, living situation (alone or with partner or relatives) and disease history were measured. Items for these characteristics were derived from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS) [25]. Cognitive functioning was assessed with the MMSE [26]. Furthermore, the presence of dental problems, presence of swallowing problems, type and amount of care or informal care, presence of a diet, and wish for weight reduction were recorded.

The primary outcome *nutritional status* was measured during an interview at T0, T1, and T2 with the Mini Nutritional Assessment (MNA). The MNA consists of 18 items and classifies a person as undernourished, at risk for malnutrition, or normal nutritional status. The outcome is a score ranging from zero to 30, with a higher score indicating a better nutritional status. The MNA is a well-validated tool with high sensitivity, specificity, and reliability [27].

Behavioural determinants of healthy eating and sufficient physical activity (defined as eating and being physically active according to Dutch guidelines) were measured at T0, T1, and T2 with a self-developed paper questionnaire. The questionnaire contained 46 statements concerning intention, knowledge, attitude, self-efficacy, perceived behavioural control, goalsetting, and self-monitoring to be answered on a five-point Likert scale, except for the 11 knowledge statements which were answered with true, false, or unsure. Items were derived from validated questionnaires [28-30] or based on previous research [31, 32].

Diet quality and compliance to physical activity guidelines were measured with the DHD-FFQ [22]. The Dutch dietary guidelines form the basis of this screener [33]. The DHD-FFQ contains 25 questions and results in a total score ranging from zero to 80, with a higher score meaning better compliance to the dietary guidelines. Eight sub scores ranging from zero to 10 assess compliance to guidelines for vegetables, fruit, fish, alcohol, saturated fatty acids, trans-fatty acids, sodium and dietary fibre. A ninth score assesses compliance to guidelines for physical activity. For this study, compliance to guidelines for protein and vitamin D were additionally assessed. The DHD-FFQ was administered during an interview at T0 and T2. Additionally, participants in the intervention group filled out the DHD-FFQ half-way during the study as intervention component (see intervention section).

Appetite was assessed with the SNAQ, a reliable and valid tool for identifying elderly people at risk of unintentional weight loss [21]. The outcome is a score ranging from four to 20, with a higher score indicating more appetite. Appetite was measured during an interview at T0 and T2. In addition to that, participants in the intervention group filled out this questionnaire half-way during the study as intervention component (see intervention section).

Body weight was measured with scales from the brand A&D, type UC-411PBT-C at T0, T1, and T2. Participants were weighed without their shoes and heavy clothes.

Physical functioning was measured with the Katz-15 questionnaire [34] and the Short Physical Performance Battery (SPPB) [35]. The SPPB test measures balance (three standing positions), gait speed (three meter course), and lower extremity strength (chair stand). The Katz-15 and SPPB were measured at T0 and T2.

Quality of life was measured with the Short Form 36 questionnaire (SF-36), including eight dimensions of quality of life: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health [36, 37]. This questionnaire was filled out on paper at T0, T1 and T2.

Finally, the process evaluation design was guided by the framework of Saunders et al [38] and included the following process indicators: *recruitment, reach, acceptability, fidelity, dose delivered, dose received, context,* and *applicability* [38-40]. To measure these process indicators, both qualitative and quantitative data were collected using logbooks kept by researchers, questionnaires for participants and health care professionals, and semi-structured interviews with participants and health care professionals. The interviews with participants and health care professionals were guided by a topic list covering questions concerning acceptability of the telemonitoring intervention. Additionally, the participant's involvement with the television channel (e.g. time, duration, frequency of use) and compliance to telemonitoring measurements were logged automatically by software. These log data provide objective information about the use of the television channel.

Data – analysis

Sample size calculation

The sample size calculation was based on the primary outcome nutritional status. We aimed to detect a difference in MNA change of three and assumed a standard deviation of 6.1 [41]. Assuming an alpha of 0.05, power of 80 % and a two-sided test, a sample size of 65 participants per group was required. Taken a drop-out rate of 30 % into account, based on Dutch intervention studies in a real-life setting with a similar study population and duration [42-46], we needed 93 participants in each group.

Quantitative data were analysed using SPSS version 22. Continuous data were presented as mean ± standard deviation or standard error of the mean. Categorical data were presented as percentages. Statistical analysis were carried out according to the intention-to-treat principle. Significance was set at $P < 0.05$. We analysed whether data complied to the assumptions required for the analysis methods. Otherwise, transformation of data or non-parametric tests were carried out. Linear mixed models were used to assess differences in changes between the intervention and control group. If necessary, analyses were adjusted for baseline differences between the groups. Qualitative data analysis was carried out using ATLAS.ti (version 7.0).

DISCUSSION

The aim of this article was to describe the evaluation design of an intervention focusing at improving nutritional status of community-dwelling elderly. To our knowledge, this is the first intervention study that includes telemonitoring of several nutritional outcomes such as diet quality, appetite, and nutritional status including body weight and BMI. Both a process and effect evaluation were included in the study to gain insight into effectiveness, intervention delivery, feasibility, and acceptability.

This study design is expected to provide a thorough evaluation strategy. Firstly, a logic model guided the selection of process indicators and outcome measures at subsequent levels. Secondly, incorporation of behaviour change techniques enables insight into intervention mechanisms [18]. Thirdly, collecting both quantitative and qualitative data provides a complete overview of the process and effects and how these effects could be explained. For example, log data give insight into the participant's interaction with the television channel so that objective records are available of the time, duration, and frequency of the television channel use. Combining these log data with participant characteristics and results on effect outcomes can be of great value for explaining the effects and unravelling the intervention mechanisms. Furthermore, insight into actual use during implementation provided the opportunity to monitor compliance of participants and to offer additional guidance or training when necessary. Finally, this research is expected to provide durable and broadly relevant results. The telemonitoring technology in this study can become dated, but we also focussed on timeless methodology and principles that underpin the telemonitoring intervention [47]. Examples are the behaviour change techniques to promote a healthy diet and physical activity, and decision trees for health care professionals to decide about follow-up of telemonitoring results.

Concluding, this study is expected to provide valuable insight into feasibility and effectiveness of telemonitoring of nutritional parameters in community-dwelling elderly. This will provide important insights for future development of telemonitoring concepts for the elderly, and how these concepts can be integrated within health care with optimal adoption by the elderly and their health care professionals.

LIST OF ABBREVIATIONS

BMI: Body Mass Index; DHD-FFQ: Dutch Healthy Diet Food Frequency Questionnaire; MMSE: Mini Mental State Examination; MNA: Mini Nutritional Assessment; MNA-SF: Mini Nutritional Assessment Short-Form; PhysioDom HDIM: PhysioDom Home Dietary Intake Monitoring; SF-36: Short Form 36; SNAQ: Simplified Nutritional Assessment Questionnaire; SPPB: Short Physical Performance Battery.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The ethics committee of Wageningen University approved the study protocol and all participants gave their written informed consent before the start of the study.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

COMPETING INTEREST

The authors declare that they have no competing interests.

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AUTHORS' CONTRIBUTIONS

MNvD designed the evaluation study and drafted the manuscript. AHN, JHMdV, and CPGMdG participated in the study design, critically read, and revised the manuscript. PP and RR participated in coordination of the study and study design. All authors contributed to the development of the intervention, read and approved the final manuscript.

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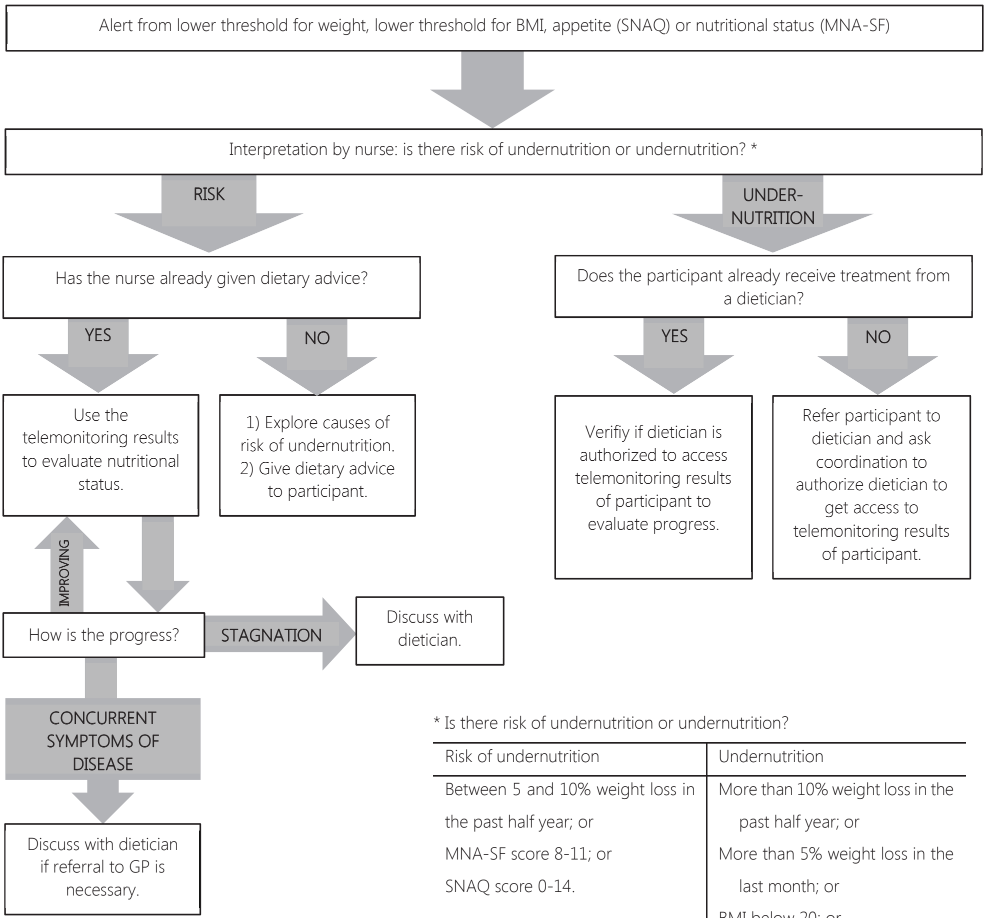
APPENDIX 2.1

Alerts for risk of undernutrition

The decision tree below describes follow-up by a nurse in case of an alert arising from the lower threshold for weight, lower threshold for BMI, appetite (SNAQ) or nutritional status (MNA-SF).

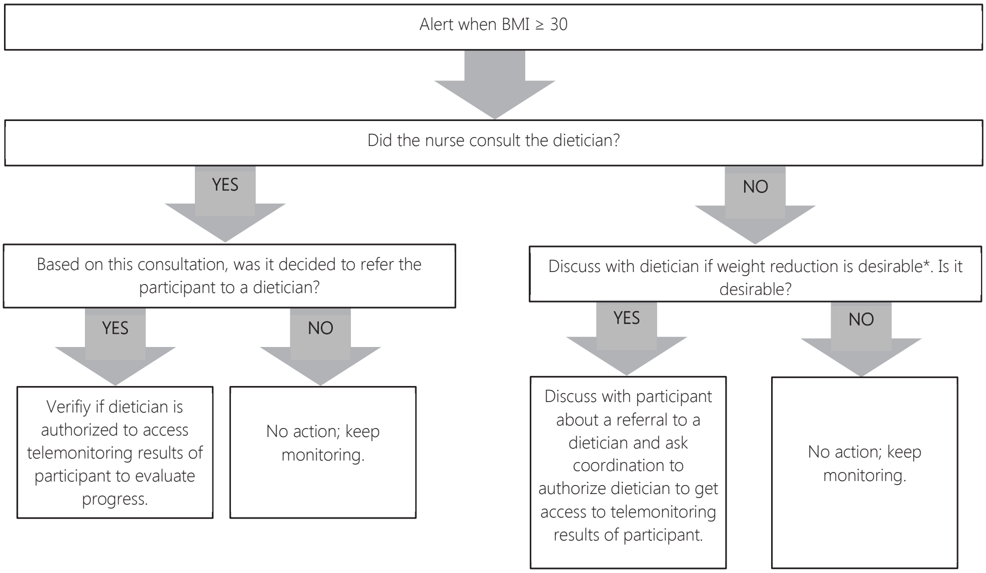


* Is there risk of undernutrition or undernutrition?

Risk of undernutrition	Undernutrition
Between 5 and 10% weight loss in the past half year; or MNA-SF score 8-11; or SNAQ score 0-14.	More than 10% weight loss in the past half year; or More than 5% weight loss in the last month; or BMI below 20; or MNA-SF score 0-7.

Alerts for obesity

The decision tree below describes the follow-up by a nurse in case of obesity (upper threshold of BMI).

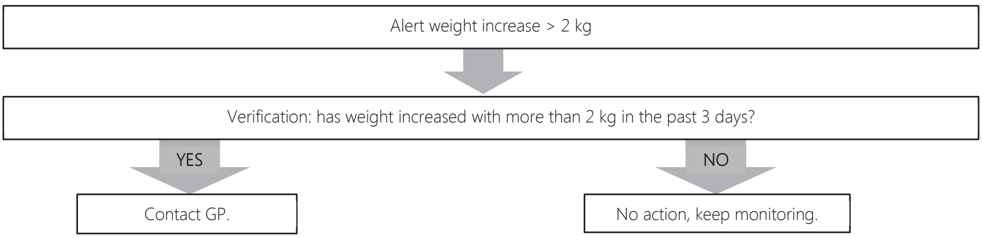


*Is weight reduction desirable in case of a BMI of 30 or higher? Advice from Dutch Nutrition center (https://tinyurl.com/ybhrljek):

"For the elderly , there are no official cut-off points for overweight and obesity as elderly people who are a little heavier have no greater mortality risk. Older people are advised to lose weight only in case of BMI higher than 30 kg/m2, and only if they have complications or diseases that would benefit from a decrease in body weight, such as type 2 diabetes and cardiovascular diseases. It is important that elderly who want to lose weight do this under the guidance of a dietician. Energy-restricted diets need to be nutrient dense, with a large amount of protein combined with regular exercise. Losing weight is not recommended when energy needs of the elderly is below 1,500 kcal. "

Alerts weight increase for heart failure patients

The decision tree below describes the pathway of care in case of an increase in weight in heart failure patients.



Chapter 3

Feasibility and effectiveness of nutritional telemonitoring for home care clients: a pilot study

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ABSTRACT

Background and Objectives: Undernutrition has unfavourable consequences for health and quality of life. This pilot study aimed to evaluate the feasibility of a telemonitoring intervention to improve nutritional status of community-dwelling older adults.

Research Design and Methods: The study involved a one-group pre-test post-test design, complemented by a qualitative study. The three-month intervention included 20 Dutch home care clients aged > 65 years and consisted of nutritional telemonitoring, television messages, and dietary advice. A process evaluation provided insight into intervention delivery, and acceptability. Changes in behavioural determinants, diet quality, appetite, nutritional status, physical functioning, and quality of life were assessed.

Results: Researchers and health care professionals implemented the intervention as intended and health care professionals accepted the intervention well. However, nine participants dropped out and participants' acceptance was low, mainly due to low usability of the telemonitoring television channel. Adherence to the telemonitoring measurements was good, although participants needed more help from nurses than anticipated. Participants increased compliance to several Dutch dietary guidelines and no effects on nutritional status, physical functioning, and quality of life were found.

Discussion and Implications: Successful telemonitoring of nutritional parameters in community-dwelling older adults starts with optimal usability and acceptability by older adults and their health care professionals. This pilot study provides insight into how to optimize telemonitoring interventions for older adults for maximum impact on behaviour and health.

Keywords: Nutrition and Feeding issues, Information Technology, Preventive medicine/ care/ services

BACKGROUND AND OBJECTIVES

Undernutrition can be defined as "a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease" [1]. It has unfavourable consequences for the health and quality of life of older adults including falls, fractures, infections, immune dysfunctions, prolonged hospitalization, and death [2, 3]. Furthermore, the estimated annual medical costs related to undernutrition among older adults are € 1,5 billion in the Netherlands [4]. It is estimated that 11 to 35% of Dutch community-dwelling older adults are undernourished, with the highest prevalence observed among home care clients [5]. Despite the serious consequences and high prevalence, older adults and health care professionals lack awareness of the problem, and it is still unclear how the nutritional status of community-dwelling older adults can be monitored [6]. Feasible and effective approaches are necessary to signal undernutrition and diminish its risks.

To monitor nutritional status among community-dwelling older adults, eHealth can be used. eHealth is defined as "health services and information delivered or enhanced through the internet and related technologies" [7]. EHealth may contribute to high-quality, efficient, and accessible health care [7, 8]. The benefits of eHealth for older adults include preventing or delaying the onset of disability, improving communication, and enhancing self-management [9]. About 70% of Dutch older adults are willing to adopt eHealth if it enables them to live independently [10]. Older adults are more willing to adopt eHealth if they are convinced of the benefits such as increased safety, perceived usefulness, or a reduced burden on family caregivers [11, 12].

Despite its potential, eHealth is still not widely implemented within health care [8]. There is no evidence for the effective use of eHealth to prevent undernutrition among older adults, although Kraft and colleagues (2012) used a telemonitoring system to measure body weight and adherence to oral nutritional supplements among undernourished older adults. They found no significant effects, which was probably due to the small sample size. The study did not include a structured process evaluation, so insight into feasibility of the telemonitoring intervention is lacking. More research is needed to investigate whether eHealth is a feasible and effective approach to prevent undernutrition in community-dwelling older adults.

Before conducting a large-scale effectiveness study, we performed a pilot study in which we implemented the PhysioDom Home Dietary Intake Monitoring (HDIM) intervention among 20 home care clients. The intervention lasted three months and consisted of telemonitoring nutritional status, appetite, diet quality, and physical activity. The study included a process and effect evaluation. The process evaluation was guided by the theories of Saunders, Evans, and Joshi (2005) and Steckler and Linnan [13, 14]. While Saunders provides a practical framework on how to develop a process evaluation plan, Steckler and Linnan present a framework of relevant process indicators. We chose to study the process indicators of reach, fidelity, and dose, as these are regarded as the minimum set of indicators to consider [13]. We also included the indicator acceptability, because this is important for understanding whether older adults will adopt eHealth and for how implementation might be scaled [15]. We aimed to study the feasibility of this eHealth intervention, to test its potential impact on nutritional and health outcomes, and to further refine the intervention and/or study procedures.

RESEARCH DESIGN AND METHODS

Study design

The three-month pilot study ran from August 2015 until November 2015 and followed a one group pre-test post-test design, complemented by a qualitative study. We measured process and effect outcomes and telemonitoring measurements were carried out as part of the intervention. The study received approval from the Medical Ethical Committee of Wageningen University & Research and is registered at Clinical-Trials.gov (identifier NCT03211845).

Participants

The study included 20 home care clients. To qualify for participation, individuals needed to be 65 years or older, receive home care from care organization Zorggroep Noordwest-Veluwe (ZNWV), and live in the municipality of Nunspeet in the Netherlands. Individuals were excluded from participation if they were cognitively impaired (Mini Mental State Examination (MMSE) < 20), received terminal care, would receive home care for less than three months, had a visual impairment which made them unable to watch the television screen, and/or had a physical impairment that prevented them to use the telemonitoring system properly. Three nurses from ZNWV handed out invitation brochures to eligible home care clients. Home care clients who were interested to participate were visited by researchers to receive more information, ask questions, sign the informed consent and be screened on eligibility criteria.

Intervention

Telemonitoring and feedback

Participants measured their body weight weekly and kept track of their steps one week per month. Five participants also measured their blood pressure bi-weekly or monthly, depending on the advice of their nurse. For these telemonitoring measurements, participants received a weighing scale (A&D, type UC-411PBT-C), a pedometer (A&D, type UW-101), and a sphygmomanometer (A&D, type UA-767PBT-CI), respectively. Participants were instructed to weigh themselves without heavy clothes and shoes and after voiding. Participants had to measure their blood pressure at a fixed time during the day while being silent and sitting up straight and still in a chair with their left arm resting on the table. Participants also filled out the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) about diet quality according to the Dutch dietary guidelines for a healthy diet [16], the Simplified Nutritional Appetite Questionnaire (SNAQ) about appetite [17], and the Mini Nutritional Assessment Short Form (MNA-SF) about nutritional status [18]. These questionnaires were filled out at the start of the intervention during an interview with a researcher and two months later. To improve the fit with the intervention, participants could choose before the start of the study how to fill out these questionnaires this second time: 10 participants chose to do this during a telephone interview with a researcher, six chose for a project tablet, and four chose to use their own PC. Participants could view the measurements results on their television. Their television contained an additional channel that included menus for an agenda, messages, measurement results, and dietary and physical activity advice. This channel was created through a set-top box connected to the participant's television and the internet (either Ethernet or 3G connection). In this way, participants also received one to three non-tailored and computer-tailored television messages per day about nutrition and physical activity. The non-tailored messages were underpinned by behaviour change techniques such as belief selection and consciousness raising [19]. The computer-tailored messages contained the results of the DHD-FFQ and advice on how to improve diet quality and physical activity. The results of the telemonitoring measurements were also sent via the television set-top box to a website for health care professionals and were checked weekly by three nurses. Alerts were activated if a participant was undernourished or risked undernutrition, had lost more than five percent of baseline body weight, and/or had a body mass index (BMI) below 20 kg/m^2 (21 kg/m^2 for participants with chronic obstructive pulmonary disease). Alerts were also activated by a BMI above 30 kg/m^2 and by a new blood pressure measurement if applicable. When the nurse received an alert, she contacted the participant to investigate the causes and to provide appropriate guidance. If the participant was at risk for undernutrition, she advised on how to improve protein and energy intake and gave a brochure with advice. If the participant was undernourished, she referred the participant to a GP or dietician. Nurses were aided in this decision making process by decision trees and could consult a dietician from the care organization about nutritional advice for participants.

Implementation

Researchers ensured optimal implementation of the intervention by ten preparatory meetings with the involved health care professionals and/or a board member of ZNWV. In these meetings, the researchers discussed with the health care professionals how the intervention could connect to their needs, how it could fit within their working procedures, and which target group would benefit most from the intervention. The researchers also provided training sessions for health care professionals and participants. In a four-hour training session, the researchers taught the health care professionals how to use the project website and the decision trees. The dietician gave a workshop for the nurses on how to provide nutritional advice to participants. The 45-minute training for participants took place at their homes after the television channel and devices had been installed. The training followed the guided practice method [19], in which participants were prompted to rehearse with the intervention materials and received feedback from the researchers. Finally, a telephone helpdesk was available for the health care professionals and participants. If needed, researchers paid additional visits to participants to provide extra training.

Measurements

Process measures

Reach was defined as 'The proportion of intended target audience that participates in the intervention' [13]. Reach was studied by collecting socio-demographic characteristics of participants during a structured interview at the beginning of the study (see effect measures section), by keeping a logbook of reasons for drop-out, and by keeping a logbook during the recruitment period.

Fidelity was defined as 'The extent to which the intervention was delivered as planned' [14], and was assessed by keeping a logbook of intervention activities.

Dose received was defined as 'The extent to which participants actively engage with, interact with, are receptive to, and/or use materials or recommended resources. It is a characteristic of the target audience and it assesses the extent of engagement of participants with the intervention' [14]. Dose received was measured by a logbook of the data traffic of the television channel and a paper questionnaire including the question 'How often do you watch the television channel ('daily', 'often', 'sometimes', 'occasionally', or 'never').

Acceptability was defined as 'Participant's satisfaction with the program and interactions with staff and/or investigators' [13], and was measured with paper questionnaires for participants and health care professionals, in interviews with participants, and in an evaluation meeting with the nurses and board member. The questionnaire for participants contained statements about satisfaction ('I am satisfied with the project in general/with the nutrition component/with the physical activity component'), usability ('Weighing/Using the pedometer/Using the sphygmomanometer/Using the tablet is easy'), the television channel

('The TV channel is attractive', 'The TV channel is clear'; 'It is easy to get an overview on the TV channel/to navigate on the TV channel'), the training ('The training was clear', 'The project has been explained sufficiently to me'), and the helpdesk ('The helpdesk was accessible', 'I am satisfied with the helpdesk'). The questionnaire for health care professionals contained the statements 'I am satisfied with the project in general', 'I felt involved in the project', 'The project is useful to monitor nutritional status of clients/to monitor physical activity of clients', 'I am satisfied with the project website', 'I am satisfied with how the alerts worked', 'The project is a good addition to the care for clients', and 'The project fits well with my daily tasks'. The statements were answered on a five point Likert scale ranging from 'totally disagree' to 'totally agree'. Semi-structured interviews with participants were conducted face-to-face at the end of the study and guided by a topic list (Appendix 3.1). The evaluative meeting with the nurses and board member took place at the end of the study.

Effect measures

Effect measurements included dietary and physical activity behaviour, diet quality, appetite, nutritional status, body weight, physical functioning, and quality of life. They were performed at the beginning and at the end of the study, unless stated otherwise. The baseline characteristics age, sex, body weight, current diagnoses, education level, living situation, civil status, cognitive function (measured by the MMSE [20]) and type of received home care were recorded at the beginning of the study during an interview. *Behavioural determinants of healthy eating and physical activity* were measured with a self-developed paper questionnaire. The questionnaire contained statements about self-monitoring, goalsetting, social support, knowledge, awareness, outcome expectations, attitude, social norms, self-efficacy, and intention, to be answered on a five-point Likert scale ranging from totally disagree to totally agree, except for the knowledge statements which were answered with true, false, or unsure. Statements were derived from validated questionnaires [21-23] or were based on previous research [24, 25]. *Diet quality* was assessed with the DHD-FFQ [16]. This questionnaire contains 28 items and has an outcome score from zero to 80, with a higher score meaning better compliance to the Dutch dietary guidelines [26]. Eight sub scores indicate compliance to the Dutch dietary guidelines for the intake of vegetables, fruit, fish, alcohol, saturated fat, trans-fat, salt, and dietary fibre. An additional score indicates compliance to the Dutch guidelines for physical activity. For this study, we added scores for compliance to guidelines for protein and vitamin D intake as well [26, 27]. The DHD-FFQ was administered at the beginning and two months after the start of the intervention. *Appetite* and *nutritional status* were measured with the SNAQ and Mini Nutritional Assessment (MNA), respectively, during a face-to-face interview at the beginning and end of the study [17, 28]. *Body weight* was measured by researchers to the nearest 0.1 kg, whereby participants were asked to take off their shoes and heavy clothes such as jackets. *Level of independence of activities of daily living* and *physical functioning* were assessed with the Katz-15 paper questionnaire and Short Physical Performance Battery test (SPPB), respectively [29, 30]. Finally, *quality of life* was measured with the Short Form 36 paper questionnaire (SF36) [31, 32].

Data analysis

Quantitative data were analysed with SPSS version 22. Process outcomes were analysed using descriptive statistics by showing percentages or frequency of the response categories. Effect outcomes were analysed with Paired T-tests or, in case of non-normality, a Wilcoxon Signed-Rank Test. Qualitative data were analysed with ATLAS.ti (version 7.0). Interview recordings were transcribed verbatim. Three researchers coded the first two interviews together to reach consensus on how to code the interviews consistently. The remaining interviews were coded separately by two researchers after which the assigned codes were checked for agreement. In case of disagreements in coding, the researchers discussed until agreement about a final coding scheme was reached. Finally, codes were reviewed and main themes were identified.

RESULTS

Reach

Thirty-six home care clients were invited to participate in the study, of whom 20 agreed to participate. Reasons to decline participation included being deterred by the intervention's technology, perceiving the study as time consuming or too burdensome, and not fitting the local culture. Reasons to participate included the extra attention for nutrition and health and the reassurance that nurses would be present for support during the study. Participants were, on average, 81 years old. The majority was female (75%), had an intermediate education level (65%), and lived alone (60%) (Table 3.1). Nine participants dropped out of the study because of physical or mental health problems (*n* = 4), dislike of the project (*n* = 2), or difficulties with the television channel and measurement devices (*n* = 3). Four participants dropped out before the start of the intervention, two directly after the at-home training, and the remaining three after three, four, and eight weeks of intervention, respectively. One drop-out was already very concerned about his health, expecting that the project would reinforce this in a negative way. Another drop-out felt burdened to watch the television channel daily, "did not want to feel bound by anything at her age", and did not want to change dietary habits. Two other drop-outs mentioned becoming "nervous" of the technology, one indicating that she was also too impatient for it. Drop-outs were significantly lower educated and slightly, but not significantly, older than participants who completed the study (Table 3.1)

Fidelity

Researchers implemented the intervention as intended, although there were some small deviations from the intervention protocol. For example, participants should have done the telemonitoring measurements themselves, but nurses had to assist some of them as participants had difficulties using the television channel. As reasons for this, participants mentioned having health or mental problems, being of old age, and having a lack of technical skills. Although the nurses implemented the intervention according to the protocol, they also mentioned implementation barriers such as a high workload, lack of support from colleagues, understaffing, and changes within the care organization.

Table 3.1. Baseline characteristics of all participants of the PhysioDom HDIM pilot study (N = 20), participants who completed the study (n = 11), and participants who dropped out (n = 9).

	All participants (N = 20)	Completers (n = 11)	Drop-outs (n = 9)
Age (years), mean ± SD	80.6 ± 8.4	77.4 ± 9.3	80.9 ± 12.5
Gender (male), n (%)	5 (25.0)	3 (27.3)	2 (22.2)
BMI (kg/m2), mean ± SD	28.1 ± 3.9	28.8 ± 4.4	27.1 ± 3.1
No. of illnesses, mean ± SD	2.2 ± 1.3	2.1 ± 1.4	2.2 ± 1.3
MMSE score, mean ± SD	28.2 ± 2.2	28.3 ± 2.6	28.1 ± 1.6
Education level, n (%) [a]			
Low	2 (10.0)	0 (0.0)	2 (22.2)
Intermediate	13 (65.0)	6 (54.5)	7 (77.8)
High	5 (25.0)	5 (45.5)	0 (0.0) *
Living alone, n (%)	12 (60.0)	5 (45.5)	7 (77.8)
Civil status, n (%)			
Married	8 (40.0)	6 (54.5)	2 (20.0)
Unmarried	1 (5.0)	0 (0.0)	1 (11.1)
Divorced	1 (5.0)	1 (9.1)	0 (0.0)
Widow(er)	10 (50.0)	4 (36.4)	6 (60.0)
Care type, n (%)			
Domestic care	16 (80.0)	9 (81.8)	7 (77.8)
Personal care	10 (50.0)	5 (45.5)	5 (55.6)
Nursing care	1 (5.0)	1 (9.1)	0 (0.0)
Individual support	1 (5.0)	1 (9.1)	0 (0.0)

BMI: Body Mass Index; MMSE: Mini Mental State Examination; SD: standard deviation. Significant differences ($p < 0.05$) are indicated with an asterisk (*). [a] Low education level: primary school or less; Intermediate level of education: secondary professional education or vocational school; High education level: higher vocational education, university.

Dose received

Participants who completed the study adhered to 80% of the required weight measurements, 53% of the step count measurements, 84% of blood pressure measurements, and read 43% of the television messages. Two of the 11 respondents watched the television channel 'daily', four did this 'often', and the rest did this 'sometimes', 'occasionally', or 'never'.

Acceptability

Half of the participants agreed that they were satisfied with the project and one third was neutral about this statement (Figure 3.1). The interviews showed that participants were pleased with insight into their health status, the emphasis on the importance of a healthy lifestyle, and the attention that they received throughout the project (theme *positive aspects of the intervention*). On the other hand, some participants perceived the project as a heavy burden on their daily lives, were puzzled by the message that they risked undernutrition, and found the dietary advice not personal enough or sounding 'unfriendly' (themes *experience with dietary advice* and *risk of undernutrition*). Furthermore, most participants agreed that they received sufficient explanation, training, and help throughout the project (Figure 3.1). The majority of participants found it easy to weigh themselves (89%), to use the pedometer (70%), to use the sphygmomanometer (100%), and to use the tablet (67%) (Figure 3.1). The positive evaluation of the usability of these devices was also confirmed by the interviews, although some participants found the pedometer not sensitive enough and mentioned that the weighing scale did not connect well to the television channel (theme *user-friendliness of devices*). The usability of the television channel was rated lower in terms of attractiveness, clarity, ease to navigate, and ease to obtain overview (Figure 3.1). The interviews showed that participants experienced stress and frustration when the channel did not work properly, and that some participants became insecure about their own capabilities (themes *TV channel* and *stress and frustration*).

The nurses and dieticians were generally satisfied with the project and felt involved. They found the project useful to monitor physical activity and nutritional status, but they were less satisfied about the project website and how the alerts worked. Opinions were divided about whether the project was a good addition to care for their clients and about whether it fit with their daily tasks.

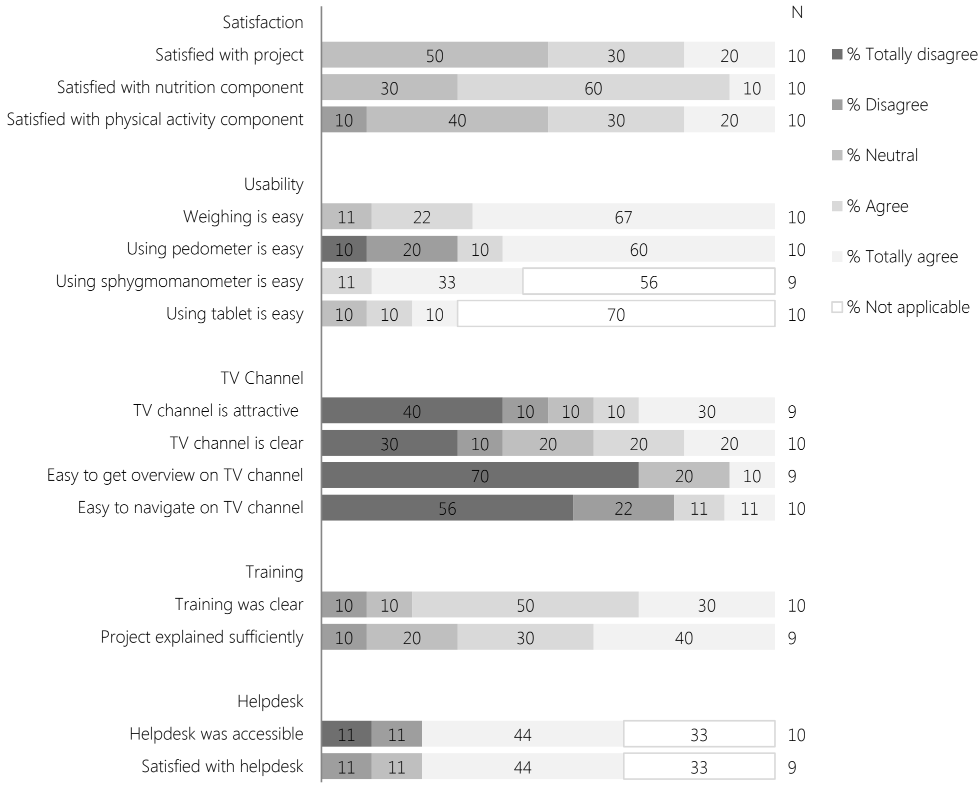

Figure 3.1. Acceptability aspects of the PhysioDom HDIM pilot study as rated by participants. Two participants filled out the questionnaire together and were considered as n = 1.

Effect outcomes

Although the main goal of the effect measurements was to test the study procedures and not to show impact, we found significant improvements in scores for compliance to dietary guidelines for fish (M1-M0 = 2.8 (1.3, 4.3)), dietary fibre (M1-M0 = 1.2, (0.01, 2.4)), protein (M1-M0 = 5.2, (2.6, 7.7)), and vitamin D (M1-M0 = 0.6, (0.1, 1.1). We found a significant decrease in the score for compliance to the guideline for saturated fatty acids (M1-M0 = -3.3, (-5.9, -0.6) (Table 3.2)). We did not find significant changes in most of the behavioural determinants, body weight, SNAQ score, MNA score, Katz-15 score, SPPB score, and SF-36 scores. In fact, significant negative changes were found for the following determinants of physical activity behaviour: goalsetting, expectations, and social norms (Appendix 3.2).

Table 3.2. Means at baseline and at follow-up of effect outcomes of the PhysioDom HDIM pilot study (N=11).

	Mean M0±SD	Mean M1±SD	Mean change (CI) [a]	Z (p-value) [b]
Diet quality (DHD score)				
Total score (0-80)	62.0 ± 5.9	61.1 ±8.9	-0.9 (-8.8, 7.0)	
Sub scores (0-10)				
Vegetables	5.7 ± 1.8	7.3 ± 2.5	1.5 (-0.1, 3.2)	
Fruit	8.2 ± 2.3	8.3 ± 2.8	0.2 (-1.7, 2.1)	
Fish*	5.6 ± 2.8	8.4 ± 2.2	2.8 (1.3, 4.3)	
Alcoholic drinks	9.6 ± 1.5	9.6 ± 1.5	0	
Dietary fibre*	6.8 ± 2.0	8.0 ± 2.1	1.2 (0.01, 2.4)	
Saturated fatty acids*	8.0 ± 3.0	4.7 ± 4.3	-3.3 (-5.9, -0.6)	
Trans-fatty acids	10.0 ± 0.0	7.3 ± 1.4		0.25 [c]
Sodium (Mdn ± IQR)	8.5 ± 0.7	8.5 ± 3.2		-0.3 (0.75)
Additional scores (0-10)				
Physical activity (Mdn ± IQR)	4.0 ± 8.0	6.7 ± 10.0		-0.7 (0.50)
Protein*	2.2 ± 2.3	7.4 ± 3.4	5.2 (2.6, 7.7)	
Vitamin D*	1.8 ± 0.6	2.4 ±0.8	0.6 (0.1, 1.1)	
Nutritional status				
SNAQ score (0-20) (Mdn ± IQR)	16.0 ±2.0	16.0 ± 1.0		-0.4 (0.71)
MNA score (0-30)	26.0 ± 2.4	26.3 ± 2.6	0.3 (-1.2, 1.8)	
Body weight (kg)	79.6 ± 13.1	80.0 ± 13.5	0.4 (-0.6, 4.5)	
Physical functioning				
Katz-15 sum score (0-15) [d] (Mdn ± IQR)	3.0 ± 5.0	2.0 ± 6.5		-1.0 (0.33)
SPPB score (0-10) (Mdn ± IQR)	6.0 ± 4.0	6.0 ± 5.0		-1.9 (0.06)
Quality of life				
SF36 PCS (0-100) [d]	37.4 ± 12.5	36.3 ± 12.3	-1.1 (-4.6, 2.5)	
SF36 MCS (0-100) [d] (Mdn ± IQR)	41.6 ± 12.9	44.9 ± 29.9		-1.9 (0.06)

[a] Analysed with Paired T-Test. [b] Analysed with Wilcoxon Signed-Rank Test. [c] Only a p-value is reported as this outcome was analysed with McNemar's Test. [d] 1 missing value. *p < 0.05. BMI: Body Mass Index; CI: confidence interval; DHD: Dutch Healthy Diet; IQR: interquartile range; SD: standard deviation; MCS: Mental Component Score; Mdn: median; MNA: Mini Nutritional Assessment; PCS: Physical Component Score; SF36: Short Form 36; SNAQ: Simplified Nutritional Assessment Score; SPPB: Short Physical Performance Battery.

DISCUSSION AND IMPLICATIONS

The main aim of this study was to evaluate the feasibility of a telemonitoring intervention that aimed to improve nutritional status of community-dwelling older adults. Researchers and health care professionals implemented the intervention as intended. However, almost half of the participants dropped out of the study and participants were only moderately satisfied with the intervention. Participants significantly increased their compliance to the Dutch dietary guidelines for dietary fibre, fish, protein, and vitamin D, but these findings should be confirmed in a larger scale study given the study design and the high drop-out rate.

We found one other pilot study that focused on telemonitoring of nutritional status of community-dwelling older adults [33]. The drop-out rate in this study was even higher than in our study. Drop-out in our study was due to poor usability of the intervention, dislike of the intervention, and mental and physical health problems. Furthermore, participants who completed the study were moderately satisfied with the intervention. Participants mentioned that the intervention put a burden on their daily lives, that the dietary advice was not sufficiently customized despite the computer-tailoring, and that the usability of the television channel was poor. Perceived system complexity and compatibility have previously been identified as determinants of adoption of eHealth [34-36]. Also other determinants encountered in this study are known as barriers for eHealth adoption, such as a low education level, lack of technological skills, and old age [37]. This implies that intervention developers should take these determinants into account to ensure that their intervention fits with the needs and capabilities of the end-user. One way of doing this is participatory design in which the end-user and other stakeholders are involved, preferably in continuous evaluation cycles so that technology is shaped through its usage [38, 39]. Although time and resource consuming, this contributes to effective eHealth applications that are better adopted by their end-users [39, 40].

Health care professionals were more positive about the intervention than participants and agreed that it was a good tool to monitor nutritional status of home care clients. They felt involved and were enthusiastic about the project. Regionally based, motivated intervention staff is a facilitating factor for implementing eHealth [37]. However, health care professionals also mentioned implementation barriers such as poor usability of the project website, poor fit with their daily tasks, a high workload, lack of support from colleagues, and understaffing. This is in line with literature [37, 41] and shows the need for a well thought-out implementation strategy for telemonitoring interventions that takes these factors into account. This can be done by, for example, involving health care professionals in designing eHealth, a priori assessment of required and available resources, and integrating eHealth applications into usual care workflows [42].

The effect evaluation showed that participants significantly increased their compliance to guidelines for the intake of fish, dietary fibre, protein, and vitamin D. These results suggest that a telemonitoring intervention with computer-tailored dietary advice can possibly improve diet quality. This is confirmed by other studies in older populations [43] and in younger and/or chronically diseased populations [44, 45]. Given the study design and the high drop-out rate, a larger-scale effectiveness study should confirm whether nutritional telemonitoring combined with tailored nutrition education can improve diet quality and nutritional status. However, this study indicates that the current intervention is not suitable for large-scale implementation and should first be improved to enhance acceptability by the intended end-users.

Based on this study, we have suggestions for improvement of this intervention and for future research on this topic in general. Firstly, easy-to-use and appealing technology is a prerequisite, and even more important in case of older adults who may have little computer experience. In this study, participants could become anxious and frustrated when having difficulties with the technology, sometimes even blaming themselves. A friendly and reliable helpdesk is imperative to keep participants motivated and to report any issue to improve usability. Secondly, attention should be paid to proper communication before and during the study. Literature shows that providing sufficient information and discussing expectations contributes to the decision to participate in a study about telehealth [46]. For example, we learned to avoid emphasising the 'technology side' of the study during recruitment as this could deter individuals to participate. Instead, we emphasised the goal of the study, namely improving nutrition and physical activity, and we used easy terms for the intervention technology. Furthermore, in case of a prototype or a pilot intervention like in this study, communication that the technology may still need improvement helps to create the right expectations among participants. Thirdly, the telemonitoring intervention should be less intensive. Although we hypothesised that one to three television messages per day would keep participants engaged, they felt rather burdened to watch the television channel daily. It should be kept in mind that older adults without computer experience may feel more easily burdened by technology than older adults with computer experience or younger adults. Fourthly, drop-out mainly occurred before and shortly after the start of the intervention. The time between signing the informed consent and the start of the intervention could be up to three months. To minimise drop-out, the time between application and start of the study should preferably be short so that changing circumstances, such as health, do not interfere with willingness to participate. Furthermore, it could be helpful to have additional helpdesk resources available at the start of the intervention to support participants in their learning curve to use the telemonitoring technology. Finally, it is necessary to improve communication about undernutrition. Some participants were distressed to hear that they risked undernutrition and were not able to deal well with this message. This may have to do with low awareness of this problem among older adults and requires communication that is sensitive to this [47].

In conclusion, successful telemonitoring of nutritional parameters in community-dwelling older adults starts with optimal acceptability by the intended users and their health care professionals. Considering the low acceptability and high drop-out rate, this telemonitoring intervention needs to be more user-friendly and less intensive to have an impact on behaviour and health.

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CONFLICT OF INTEREST

We have no conflict of interest to declare.

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Appendix 3.1. Interview topics and questions for interviews with participants of the PhysioDom HDIM pilot study.

Topics and questions
General
How do you look back on the PhysioDom HDIM project?
Positive aspects
What do you think was good about the project?
Negative aspects
What do you think was less good about the project?
Fits with needs
Do you think the project suited your needs?
Problems
What problems did you encounter during the PhysioDom HDIM project?
Manual and training
Did you miss information in the training or manual?
Devices
How did you experience the use of the weighing scale/pedometer/remote control/sphygmomanometer/tablet?
Do you think these devices were helpful in improving your health?
What problems did you encounter with the devices?
Effects of participation
Did you change something in your eating habits because of the project?
Did you change something in your physical activity pattern because of the project?
Did you notice changes in your health because of the PhysioDom HDIM project?
Improvements
What would you change about the PhysioDom HDIM project to improve it?
Do you have any remarks/ideas/tips or questions about the PhysioDom HDIM project?

Appendix 3.2. Changes in determinants of dietary and physical activity (PA) behaviour of participants of the PhysioDom HDIM pilot study.

Determinant	Question topic	Scale	Baseline, mean (*SD*) (*N*=11)	Mean change ± *SE* (*N*=10)	p
Self-monitoring	Frequency monitoring healthiness diet	Never – always	4.0 (1.0)	0.2 ± 0.2	0.32[b]
	Frequency monitoring quantity diet	Never – always	4.0 (1.0)	0.0 ± 0.2	1.00[b]
	Frequency monitoring weight	Never – always	4.1 (1.0)	0.0 ± 0.2	1.00[b]
	Frequency monitoring PA	Never – always	3.3 (1.5)	0.1 ± 0.3	0.76
Goalsetting	Frequency setting goals to improve diet	Never – always	3.3 (1.3)	-0.6 ± 0.3	0.13[c]
	Frequency setting goals for weight	Never – always	3.5 (1.3)	-0.2 ± 0.4	0.64
	Frequency setting goals for PA	Never – always	3.8 (1.2)	-0.1 ± 0.4	0.02
Expectations	More PA will improve daily activities	Totally disagree – totally agree	4.0 (0.8)	-0.7 ± 0.5[e]	0.20
	More PA will make me feel better	Totally disagree – totally agree	4.1 (0.9)	-0.4 ± 0.4[e]	0.27
	More PA will improve my social life	Totally disagree – totally agree	3.7 (1.3)	-0.7 ± 0.2[e]	0.02
	Eating healthier will improve daily activities	Totally disagree – totally agree	3.5 (1.4)	0.1 ± 0.1	-[c d]
	Eating healthier will make me feel better	Totally disagree – totally agree	3.9 (0.8)	-0.4 ± 0.5	0.44
Awareness	I know to what extend I follow the guidelines for a healthy diet	Totally disagree – totally agree	3.7 (1.2)	0.5 ± 0.3	0.10
	I know to what extend I follow the guidelines for PA	Totally disagree – totally agree	3.6 (1.6)	0.6 ± 0.4	0.19
Intention	I intend to eat healthier	Totally disagree – totally agree	3.6 (1.1)	-0.4 ± 0.3	0.26[b]
	I intend to increase PA	Totally disagree – totally agree	3.9 (0.7)	- 0.7 ± 0.4	0.13
Social norms	People find it important that I eat healthy	Totally disagree – totally agree	4.5 (0.7)	0.1 ± 0.3	0.76
	People eat healthy themselves	Totally disagree – totally agree	3.8 (1.2)	-0.1 ± 0.3[e]	0.73
	People find it important I get sufficient nutrients	Totally disagree – totally agree	4.0 (0.9)	0.1 ± 0.3	0.76
	People get sufficient nutrients themselves	Totally disagree – totally agree	4.0 (0.8)	-0.5 ± 0.8	0.21
	People find it important that I have sufficient PA	Totally disagree – totally agree	4.2 (0.8)	-0.1 ± 0.2	0.66[b]
	People have sufficient PA themselves	Totally disagree – totally agree	3.8 (1.2)	-0.9 ± 0.6	0.03

Appendix 3.2. Continued.

Determinant	Question topic	Scale	Baseline, mean (*SD*) (*N*=11)	Mean change ± *SE* (*N*=10)	p
Social support	People support me to eat healthy	Totally disagree – totally agree	3.9 (1.4)[e]	0.1 ± 0.3	0.69[c]
	People support me to get sufficient nutrients	Totally disagree – totally agree	3.6 (1.2)	0.2 ± 0.4	0.66
	People support me to get sufficient PA	Totally disagree – totally agree	4.3 (0.8)	-0.2 ± 0.2	- [c d]
Attitude	Eating healthy - scale sensibleness	Very sensible – very insensible	4.8 (0.4)	0.0 ± 0.2	1.00[b]
	Eating healthy - scale easiness	Very difficult – very easy	4.0 (1.3)	0.0 ± 0.4	1.00
	Eating healthy - scale pleasantness	Very pleasant – very unpleasant	3.8 (1.1)	-0.2 ± 0.3	0.58[b]
	Eating healthy - scale price	Very expensive – very cheap	3.3 (1.1)	-0.3 ± 0.4	0.45[b]
	Eating healthy - scale taste	Very disgusting – very delicious	4.7 (0.5)	-0.5 ± 0.3	0.14
	Eating healthy - scale importance	Very important – very unimportant	4.7 (0.5)	0.2 ± 0.3	0.66[b]
	Sufficient PA - scale sensibleness	Very sensible – very insensible	4.6 (0.5)	-0.2 ± 0.2	0.32[b]
	Sufficient PA - scale easiness	Very difficult – very easy	2.5 (1.5)	-0.2 ± 0.3	0.51
	Sufficient PA - scale pleasantness	Very pleasant – very unpleasant	3.4 (1.1)	-0.4 ± 0.3	0.30
	Sufficient PA - scale goodness	Very bad – very good	4.7 (0.6)	-0.1 ± 0.3	0.71[b]
	Sufficient PA - scale realism	Very realistic – very unrealistic	3.2 (1.3)	-0.2 ± 0.3	0.46[b]
	Sufficient PA - scale importance	Very important – very unimportant	4.9 (0.3)	0.0 ± 0.2	1.00[b]
Faith	Faith - 30 minutes per day PA	No faith at all – plenty of faith	3.1 (1.2)	0.6 ± 0.4	0.13
	Faith - 2x a week strength exercise	No faith at all – plenty of faith	2.8 (1.3)	0.2 ± 0.3	0.51
	Faith - eating healthy according the guidelines	No faith at all – plenty of faith	3.9 (0.9)	0.2 ± 0.3	0.43[b]
Knowledge [a]	11 question score	0-11 [a]	7.7 (1.8)	0.1 ± 0.8	0.90
	I know where to go for PA	Totally disagree – totally agree	4.5 (0.7)	-0.4 ± 0.4	0.41[b]
	I know where to go for meal	Totally disagree – totally agree	4.0 (1.6)	0.1 ± 0.5	0.71[b]

[a] These eleven questions were not based on a 5-point Likert scale, but were true/false questions. A score has been calculated by counting and adding up all correct answers. [b] Analysed with a Wilcoxon signed-rank test. [c] Analysed with a sign test. [d] Not enough valid cases to perform sign test. [e] One missing value.

Chapter 4

Effects of a multi-component nutritional telemonitoring intervention on nutritional status, diet quality, physical functioning, and quality of life of community-dwelling older adults

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ABSTRACT

This study aimed to evaluate the effects of an intervention including nutritional telemonitoring, nutrition education, and follow-up by a nurse on nutritional status, diet quality, appetite, physical functioning, and quality of life of Dutch community-dwelling elderly. We used a parallel arm pre-test post-test design with 204 older adults (average age 80 years) who were allocated to the intervention group (*N*=97) or control group (*N*=107), based on municipality. The intervention group received a six-month intervention including telemonitoring measurements, nutrition education, and follow-up by a nurse. Effect measurements took place at baseline, after 4.5 months, and at the end of the study. The intervention improved nutritional status of participants at risk of undernutrition (β (T1)=2.55, 95% CI (1.41, 3.68)), β (T2)=1.77, 95% CI (0.60, 2.94)) and scores for compliance to Dutch guidelines for the intake of vegetables (β=1.27, 95% CI (0.49, 2.05)), fruit (β=1.24, 95% CI (0.60, 1.88)), dietary fibre (β=1.13, 95% CI (0.70, 1.57)), protein (β=1.20, 95% CI (0.15, 2.24)), and physical activity (β=2.13, 95% CI (0.98, 3.29)). The intervention did not have an effect on body weight, appetite, physical functioning, and quality of life. In conclusion, this intervention leads to improved nutritional status in older adults at risk of undernutrition, and to improved diet quality and physical activity levels of community-dwelling elderly. Future studies with a longer duration should focus on older adults at higher risk of undernutrition than this study population to investigate whether impact of the intervention on nutritional and functional outcomes can be improved.

INTRODUCTION

Undernutrition adversely affects older adults' health and quality of life and can be caused by a variety of physiologic, pathologic, psychologic and social factors [1-3]. Undernutrition is prevalent across the continuum of care, with the highest prevalence observed in the rehabilitation setting (50.5%), followed by the hospital (38.7%), the nursing home (13.8%), and the community (5.8%) [4]. In absolute numbers, however, most undernutrition is encountered in the community as the majority of older adults lives independently [5]. Treatment of undernutrition with oral nutritional supplements increases body weight in older adults, but functional benefit from supplementation has not yet been assessed [6]. As it appears to be difficult to reverse the adverse effects of undernutrition, attention should be paid to the prevention of it [7].

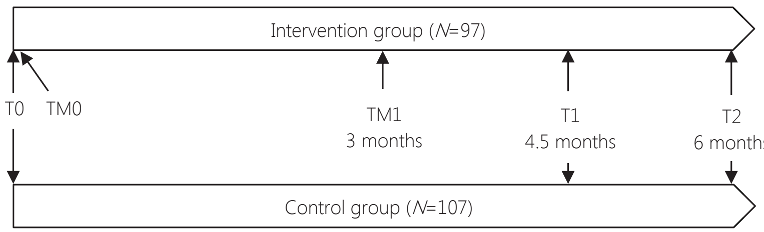
Undernutrition may be addressed by screening practices and nutrition education. Screening allows a targeted effort of time and resources on individuals at the greatest risk, resulting in a widespread demand for nutritional screening in at-risk populations [8]. In the Netherlands, only one quarter of home care clients is structurally screened for undernutrition and health care professionals and older adults seem unaware of the problem [9, 10]. Awareness of the importance of an optimal nutritional status for healthful ageing may be addressed by nutrition education or counselling. Moreover, during counselling, health care professionals identify and address risk factors for malnutrition including health, social, economic, and geographical factors [11, 12]. However, the value of nutrition education for elderly remains under recognised and nutrition education research among older adults is scarce [13, 14].

Nutritional screening and nutrition education might be addressed using eHealth, which is defined as 'health services and information delivered or enhanced through the internet and related technologies' [15]. eHealth is expected to contribute to more efficient ways of providing high-quality health care in an ageing population with increased pressure on health care resources [16]. To our knowledge, eHealth has not yet been used for nutritional screening and nutrition education in a community-dwelling elderly population. We present an intervention that combines nutritional screening in the form of telemonitoring with computer-tailored nutrition education. The aim of this study was to evaluate the effects of this intervention on the primary outcome nutritional status and secondary outcomes diet quality, appetite, physical functioning, and quality of life.

METHODS

Study design

The study followed a parallel arm pre-test post-test design and took place from April 2016 until June 2017. The intervention had a duration of six months and effect measurements took place during screening, at baseline (T0), after 4.5 months (T1), and at the end of the study (T2). Additionally, telemonitoring measurements of nutritional status, appetite, and diet quality took place in the intervention group as part of the intervention at the beginning of the study (TM0) and three months after the start of the study (TM1). The first measurements of nutritional status, appetite, and diet quality were used for both effect evaluation and telemonitoring purposes (T0/TM0) (Figure 4.1). The study was registered at ClinicalTrials.gov (identifier NCT03240094), URL http://bit.ly/2zFTs3P.



Nutritional status	X	X	X	X
Diet quality	X	X	X	X
Appetite	X	X	X	X
Physical functioning	X			X
Quality of life	X		X	X

Figure 4.1. Study design of the PhysioDom HDIM intervention in the Netherlands including effect measurements (T0, T1, and T2) and telemonitoring measurements (TM0 and TM1).

Ethical approval

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving participants were approved by the Medical Ethical Committee of Wageningen University, number NL53619.081.1. Written informed consent was obtained from all participants.

Participants

Recruitment took place from February 2016 until September 2016. Allocation of participants to the treatment group took place on the level of municipality. The involved care organisations appointed five municipalities where nurses and dieticians were available to implement the intervention. Four other municipalities were allocated to the control group. As a result, participants in the intervention group were recruited from the municipalities of Ermelo, Harderwijk, Nunspeet, Putten, and Renkum in the Netherlands. Participants in the control group were recruited from the municipalities of Ede, Rhenen, Veenendaal, and Wageningen in the Netherlands. Participants were recruited via invitation letters from care organizations Zorggroep Noordwest-Veluwe and Opella, via advertisements in local newspapers and public spaces, and via invitation per post. Persons could participate when they were 65 years or older and received home care and/or lived in a sheltered accommodation or service flat. Persons who showed interest to participate were visited by a researcher to receive more information about the study, to ask questions, to sign the informed consent, and to be screened on the exclusion criteria. Individuals were excluded from participation if they were cognitively impaired (Mini Mental State Examination (MMSE) < 20), had diagnosed cancer, received terminal care, were bedridden or bound to a wheelchair, or were unable to watch television. In total, 215 persons were screened for eligibility, of whom 97 were assigned to the intervention group and 107 to the control group, based on municipality. In the intervention group, 21 participants were lost to follow-up, mainly due to health problems or perceived difficulties with the telemonitoring technology. In the control group, six participants were lost to follow-up due to various reasons (Figure 4.2).

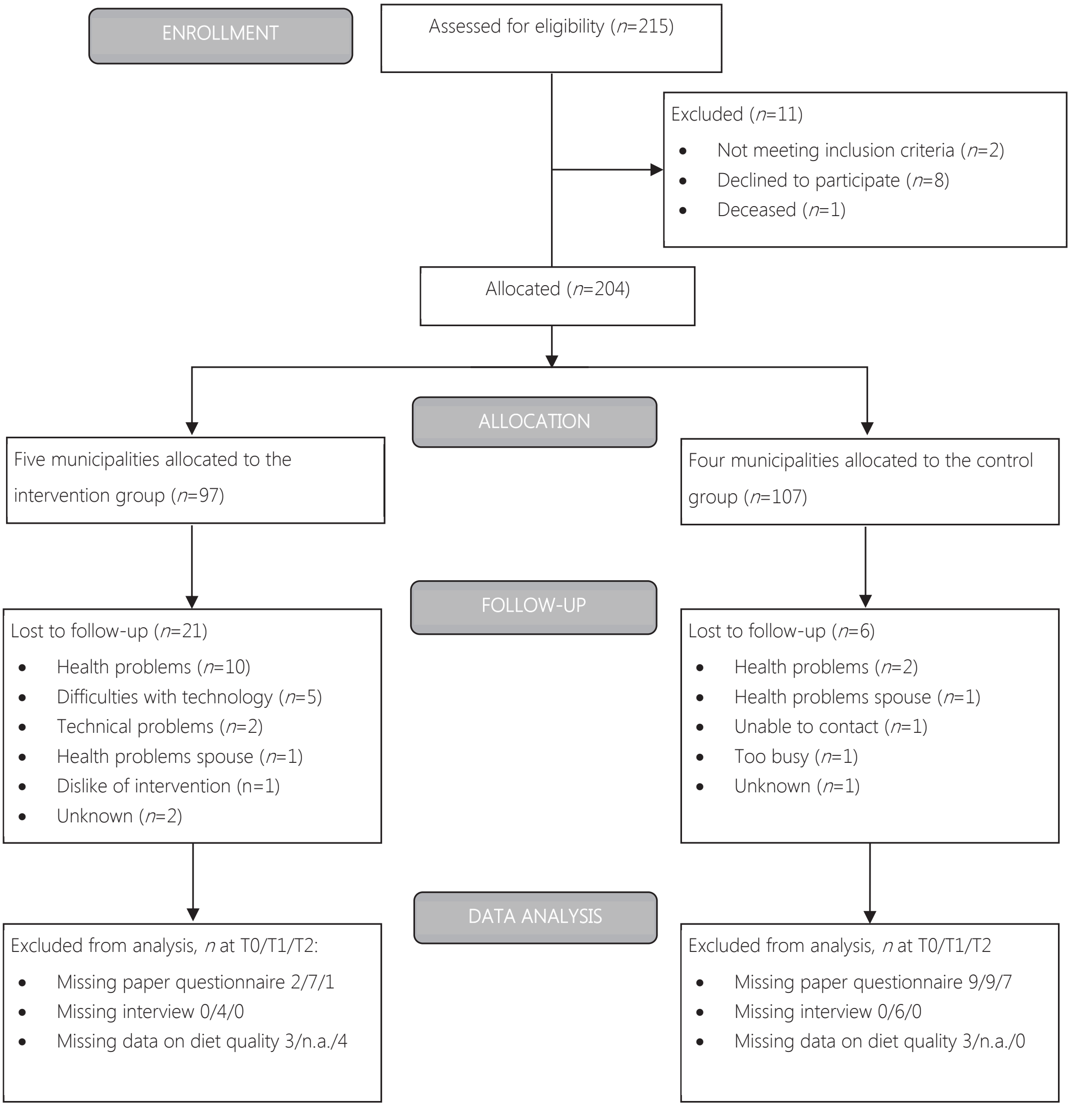


Figure 4.2. Flow diagram of participants of the PhysioDom Home Dietary Intake Monitoring intervention in the Netherlands.

Intervention

The PhysioDom Home Dietary Intake Monitoring (HDIM) intervention consisted of the following components: telemonitoring, nutrition education, and follow-up by a nurse. These components are described in more detail below.

Telemonitoring

Participants were asked to perform self-measurements of body weight (weekly), steps (one week per month), and blood pressure (monthly or bi-monthly, and only for a subsample of participants upon indication of a nurse). For these measurements, participants received a weighing scale (A&D, type UC-411PBT-C), a pedometer (A&D, type UW-101), and a sphygmomanometer (A&D, type UA-767PBT-CI), respectively. The weighing scale and sphygmomanometer were connected via Bluetooth to a set-top box. This box was connected to the participant's television. In this way, the telemonitoring results were automatically displayed on the participant's television. Furthermore, telemonitoring results were sent from the set-top box to the nurses via a secured internet connection. Furthermore, participants filled out questionnaires about nutritional status with the Mini Nutritional Assessment Short-Form (MNA-SF) [17], appetite with the Simplified Nutritional Appetite Questionnaire (SNAQ) [18], and diet quality with the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) [19]. These questionnaires were administered at the start of the study by means of an interview with a researcher (T0/TM0) and three months after the start of the study during a telephone interview with a researcher, or using their own computer or tablet received from the researchers (TM1) (Figure 4.1). The TM1 measurement of some participants was performed during the T1 measurement with researchers due to difficulties with filling out the questionnaires on a computer or tablet. Participants could view the results of these telemonitoring measurements on their television and received feedback on the results (see below).

Nutrition education

Participants received computer-tailored and non-tailored information about nutrition. The computer-tailored information contained two letters with the results of the DHD-FFQ that were sent after the administration of the DHD-FFQ at T0/TM0 and TM1. The results included scores (0-10) for compliance to Dutch guidelines for several nutrients and food groups and physical activity (see Outcomes section) and computer-tailored advice on how to improve compliance. These computer-tailored advices appeared automatically after filling out the DHD-FFQ on a website. Per nutrient or food group, two (for trans fatty acids) or five (for the other nutrients and food groups) different advices could be given, according to the score for that specific nutrient or food group. For example, participants with low scores for vegetable intake received suggestions that were easily accessible and that should fit with various reasons for not consuming vegetables (e.g. not liking vegetables), whereas participants with high scores for vegetable intake received suggestions that aimed at maintaining this behaviour and at having sufficient variation in vegetables. The non-tailored information consisted of three short and general television messages (<500 characters) that were sent weekly to the participants and that targeted determinants of dietary and physical activity behaviour such as awareness, knowledge, and attitude. For example, topics included dental health, eating alone versus eating with others, and how to enhance taste of the meal in case of impaired taste perception.

Follow-up by a nurse

In total, seven nurses and three dieticians were involved in the study. Each participant was assigned to a nurse who worked in the same municipality as where the participant lived. Nurses received the telemonitoring results and interpreted these with help of alerts that were activated in case of undernutrition or the risk of undernutrition, obesity or new blood pressure measurements. Thresholds for activation of alerts are described elsewhere [20]. Nurses decided about follow-up of alerts with the help of decision trees [20]. In case of risk of undernutrition, the nurse investigated on the causes by looking into the questionnaire results and by contacting the participants to ask more in-depth questions about the personal situation of the participant and possible risk factors. The nurse also advised participants on how to improve protein and energy intake and gave a brochure with advice on this. Studies have indicated the potential of nutrition counselling by a health care professional to impact nutritional outcomes in older adults [21-24]. In case of undernutrition and obesity, the nurse discussed with the participant whether referral to a general practitioner (GP) or dietician was desired for professional treatment. In case of undernutrition or risk of undernutrition, the health care professionals' advice had priority over the advice from the DHD-FFQ, although health care professionals could use the results from the DHD-FFQ to prioritise in the individual advice that was given to participants. In case of abnormal blood pressure measurements, the nurses followed their regular care pathways.

Implementation

To guide the quality of implementation, the researchers held four preparatory meetings with the involved health care professionals (HCPs), held monthly to bi-monthly evaluation meetings with HCPs during the study, provided individual at-home training to participants, and provided manuals and a support desk to the HCPs and participants. The preparatory meetings for the HCP's lasted one and a half hour each. During these meetings, the HCPs received all the information, materials, and training needed to provide proper follow-up of telemonitoring measurements to participants. The nurses also received a workshop from a dietician with the aim to improve knowledge about nutrition and undernutrition in older adults. The individual at-home training for participants took approximately 45 minutes and covered the use of the television channel, the weighing scale, the pedometer, and, if applicable, the sphygmomanometer and/or tablet. Researchers stimulated compliance to the intervention by giving participants a paper calendar with the telemonitoring measurements, illustrated cards with cues to use the television channel and to perform the telemonitoring measurements, and three newsletters. Participants in the control group received usual care. Domestic care was received by 80% of the control group participants, personal care and nursing care by 30% and 3%, respectively.

The intervention including its theoretical framework is described in more detail elsewhere [20].

Outcomes

Measurements took place during the screening visit, at T0, T1, and T2. Additionally, telemonitoring measurements took place at TM0 and TM1 as part of the telemonitoring intervention in the intervention group only (Figure 4.1). Data were collected with paper questionnaires and through structured interviews at the participants' homes performed by trained researchers or research assistants. *Baseline characteristics* were recorded during the screening visit in the intervention group and at T0 in the control group. Baseline characteristics included age, sex, height, body mass index (BMI, kg/m^2), education level, birth country, marital status, living situation (alone or with partner or relatives), and current diagnoses. These items were derived from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS) [25]. Furthermore, cognitive functioning was measured with the MMSE [26] and dental problems, swallowing problems, type and amount of care or informal care, presence of a diet, and wish for weight reduction were recorded. The primary outcome *nutritional status* was assessed with the Mini Nutritional Assessment at T0/TM0, T1, and T2 [27]. A higher MNA score means a better nutritional status, with a score from 0-16 indicating undernutrition, a score from 17-23.5 risk of undernutrition, and a score from 24-30 a normal nutritional status. Additionally, nutritional status was assessed at T0/TM0 and TM1 in the intervention group as part of the telemonitoring intervention, using the MNA-SF [17]. *Body weight* was measured at T0, T1, and T2 by researchers to the nearest 0.1 kg using a scale of the brand A&D, type UC-411PBT-C. Participants were asked to take off their shoes and heavy clothes before the measurement. Additionally, participants in the intervention group measured their body weight weekly as part of the telemonitoring intervention. *Diet quality* was measured with the DHD-FFQ at T0/TM0, TM1 and T2 [19]. The DHD-FFQ has 28 items and evaluates the compliance to Dutch dietary guidelines. These guidelines are formulated for the general population of two years and older and include vegetables, fruit, fish, alcohol, saturated fatty acids, trans-fatty acids, sodium, and dietary fibre [28]. Additionally, the DHD-FFQ assesses compliance to Dutch guidelines for physical activity [28]. For this study, compliance to guidelines for protein and vitamin D was also assessed, taking into account that older adults require a higher intake of vitamin D and protein than a younger population [28, 29]. The intake of these nutrients could be assessed by the DHD-FFQ as this questionnaire includes questions on all relevant protein and vitamin D rich food groups consumed by a Dutch elderly population [30]. Based on the level of compliance to a guideline, a score between 0 and 10 was composed with higher scores indicating better compliance to the guideline. Furthermore, a total score ranging from 0 to 80 indicates overall diet quality and is calculated by summing the scores for vegetables, fruit, fish, alcohol, saturated fatty acids, trans-fatty acids, sodium, and dietary fibre. *Appetite* was measured with the SNAQ questionnaire at T0/TM0, TM1, and T2 [31]. *Level of independence of activities of daily living* and *physical functioning* were measured at T0 and T2 with the Katz-15 questionnaire and Short Physical Performance Battery (SPPB), respectively [32, 33]. *Quality of life* was measured with the Short Form 36 questionnaire (SF36) at T0, T1, and T2 [34, 35].

Statistics

Sample size calculation

We aimed to detect a difference in MNA change of three and assumed a standard deviation of 6.1, based on previous research [36]. Furthermore, we took into account a two-sided significance level of 0.05 and a power of 80%. Based on the formula $2 * \frac{[(Z\alpha/2 + Z\beta)^2 * \sigma^2]}{\delta^2}$, with α = 0.05, β = 0.80, σ = 6.1, and δ = 3, we needed a sample size of 65 participants per group. Allowing for a drop-out rate of 30% at maximum, we needed a sample size of 93 participants in each group.

Data were analysed with SPSS version 22. Descriptive data were presented as means ± standard deviation or as percentages. Statistical analysis were carried out according to the intention-to-treat principle. Baseline differences between the intervention and control group were analysed with an independent *t* test or a chi-square test. Differences in changes between the intervention and control group were analysed using linear mixed models. Therefore, we first specified a model as large as possible for the fixed and random part, e.g. a saturated model with all main effects and interactions and an unstructured covariance matrix. Then we simplified the covariance model by specifying simpler covariance structures and testing them with (REML) LR test, until a model was obtained that was as parsimonious as possible. Finally, we simplified the fixed part of the model by including dummy's for T1, T2, treatment group, the interaction terms of the dummy's for T1 and T2 and treatment group, age, sex, and if necessary also other covariates that influenced the effect estimates. The analysis of the primary outcome nutritional status also included investigation of a possible interaction of the intervention with baseline nutritional status, categorised into normal nutritional status (MNA ≥ 24) or having undernutrition or risk of undernutrition (MNA ≤ 23.5). Furthermore, for the study outcome body weight we investigated a possible interaction of the intervention with desire to lose weight as about half of the participants in the intervention group desired to lose weight. Finally, we used logistic regression to analyse the effects of the intervention on the score for compliance to the dietary guideline for trans-fatty acids, as this score could be either 0 or 10.

RESULTS

Table 4.1 shows the baseline characteristics of the study population. Participants in the intervention group were slightly younger and had a higher BMI than participants in the control group. Furthermore, participants in the intervention group lived less often alone, were less often on a diet, and received more often informal care than participants in the control group.

Participants who dropped out of the study were significantly older and had a lower MMSE score. They were also significantly more likely to have swallowing problems and to receive personal care and/or nursing care at home. Furthermore, participants who dropped out had a worse physical functioning and were less physically active than participants who completed the study.

Table 4.1. Baseline characteristics of participants of the PhysioDom HDIM study.

	Intervention group (n=97)		Control group (n=107)		p-value [a]
	Mean	SD	Mean	SD	
Age (years)	78.4	7.2	81.0	7.9	0.02
BMI (kg/m2)	29.2	4.5	27.7	5.4	0.04
Number of diagnoses	1.5	1.5	1.3	1.3	0.26
MMSE score	28.6	1.5	25.8	1.9	0.69
	Percentage		Percentage		
Sex (male)	34		23.4		0.09
Education level [b]					0.08
Low	17.5		10.3		
Moderate	55.7		49.5		
High	26.8		40.2		
Civil status					0.11
Married	42.3		27.1		
Single	7.2		13.1		
Divorced	7.2		10.3		
Widowed	43.3		49.5		
Living alone	55.7		74.8		0.004
Born in the Netherlands	96.9		90.7		0.07
Dental problems	18.6		15.0		0.49
Swallowing problems	17.5		13.1		0.38
Desire to lose weight	52.7		39.4		0.07
Currently on a diet	9.7		23.2		0.01
Nutritional status					0.45
Normal nutritional status	79.2		83.8		
At risk of undernutrition	19.8		16.2		
Undernourished	1.0		0.0		
Type of care					
Domestic care	78.4		80.4		0.72
Personal care	32.0		29.9		0.75
Nursing care	9.3		2.8		0.05
Individual support	3.1		0.9		0.27
Informal care	32.0		11.2		<0.001
Service flat or sheltered housing	12.4		20.6		0.12

SD, Standard Deviation; BMI, Body Mass Index; MMSE, Mini-Mental State Examination. [a] Independent *t*-test or chi-square test. [b] Low education level: primary school or less; Intermediate level of education: secondary professional education or vocational school; High education level: higher vocational education, university.

Table 4.2 shows the crude means of the study outcomes. At T0, participants in the intervention group had a significantly lower compliance with guidelines for the intake of vegetables and fibre (t (197) = 2.15, p = 0.03), t (197) = 2.64, p = 0.009, respectively), and a lower compliance with guidelines for physical activity ((t (197) = 3.31, p = 0.001), than participants in the control group. The intervention group had a significantly better compliance to guidelines for intake of trans-fatty acids than the control group at T0 ((X^2 (1, N = 199) = 4.63, p = 0.03).

Participants in the intervention and control group did not significantly differ in changes over time in the primary outcome nutritional status. However, we observed a significant interaction of the intervention with baseline nutritional status. Intervention group participants with a poor nutritional status at baseline improved significantly more in MNA score than control group participants with a poor nutritional status at baseline (β (T1) = 2.55, 95% CI (1.41, 3.68), β (T2) = 1.77, 95% CI (0.60, 2.94)). Participants in the intervention and control group with a normal nutritional status at baseline did not significantly differ in changes over time in MNA score (Table 4.2). Furthermore, we did not find a significant effect of the intervention on body weight. Intervention group participants without a desire to lose weight increased more in body weight than control group participants without a desire to lose weight, although this was not statistically significant (Table 4.2).

The intervention did not have an effect on the total score for diet quality, but participants in the intervention group significantly increased their compliance with several Dutch dietary guidelines, compared to the control group. They significantly increased their compliance with the guidelines for vegetables (β = 1.27, 95% CI (0.49, 2.05)), fruit (β = 1.24, 95% CI (0.60, 1.88)), dietary fibre (β = 1.13, 95% CI (0.70, 1.57)), and protein (β = 1.20, 95% CI (0.15, 2.24)). Furthermore, participants in the intervention group slightly decreased their compliance with the guideline for the intake of sodium, whereas participants in the control group increased their compliance with this guideline. This difference in change over time was significant (β = -0.97, 95% CI (-1.77, -0.17)). The intervention did not have an effect on the remaining Dutch dietary guidelines for the intake of fish, saturated fatty acids, trans-fatty acids, alcohol, and vitamin D. Participants in the intervention group significantly improved their compliance with the Dutch guidelines for physical activity, compared to the control group (β = 2.13, 95% CI (0.98, 3.29)).

Finally, participants in the intervention and control group did not significantly differ in changes over time in appetite, physical functioning, and quality of life (Table 4.2).

Table 4.2. Crude means and standard deviations of study outcomes on T0, T1, and T2, and the beta's of the interaction terms treatment and time points T1 and T2.

	Intervention group						Control group						Linear mixed models		
	T0/TM0		T1/TM1		T2		T0		T1		T2		β T1 (95% CI)	β T2 (95% CI)	N
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Nutritional status															
MNA score (0-30)[a]	25.9	2.6	26.2	2.6	26.1	2.6	26.0	2.4	25.8	2.5	25.8	2.6	0.62 (-0.07, 1.32)	0.22 (-0.48, 0.92)	188
Normal	26.9	1.7	27.0	2.0	26.7	2.6	26.8	1.6	26.3	2.4	26.4	2.1	0.09 (-0.62, 0.81)	-0.17 (-0.90, 0.56)	153
At risk	22.2	1.9	24.7	2.0	24.2	2.3	21.9	1.5	23.4	2.6	22.5	3.0	2.55 (1.41, 3.68)***	1.77 (0.60, 2.94)**	35
Body weightt (kg)[b]	80.1	14.0	79.7	13.6	80.2	13.2	74.0	16.5	74.2	16.0	73.9	16.0	0.30 (-0.37, 0.98)	0.32 (-0.54, 1.17)	187
No desire for wt loss	72.9	12.0	73.5	12.7	74.8	12.9	68.0	12.8	68.7	12.7	67.9	12.8	0.72 (-0.13, 1.57)	0.97 (-0.11, 2.04)	101
Desire for wt loss	86.0	12.9	85.3	12.1	84.9	11.9	84.4	16.5	83.4	15.6	83.8	15.2	-0.06 (-0.87, 0.76)	-0.38 (-0.42, 0.65)	86
Diet quality (DHD score)															203
Total score (0-80)	57.3	10.0	60.8	9.4	59.8	10.4	56.5	10.2	n.a.		57.1	9.9	n.a	1.42 (-1.42, 4.26)	
Sub scores (0-10)															
Vegetables	6.3	2.7	7.0	2.7	7.9	2.6	7.2	2.7	n.a.		7.2	2.9	n.a	1.27 (0.49, 2.05)*	
Fruits	8.2	2.4	9.1	1.9	9.1	2.0	8.7	2.5	n.a.		8.4	2.9	n.a	1.24 (0.60, 1.88)***	
Dietary fibres	7.4	1.8	8.2	1.7	8.4	1.5	8.1	1.8	n.a.		7.9	2.1	n.a	1.13 (0.70, 1.57)***	
Fish	5.4	3.2	6.2	3.3	5.4	3.0	5.3	3.4	n.a.		5.2	3.7	n.a	-0.13 (-0.98, 0.72)	
Saturated fatty acids	5.0	4.3	5.0	4.1	4.5	4.1	4.5	4.0	n.a.		4.5	4.0	n.a	-0.54 (-1.72, 0.64)	
Trans-fatty acids															
(% compliant [c])	83.2		88.6		80.8		70.2		n.a.		73.3		n.a	OR: 0.77 (0.35, 1.72)	
Sodium	7.0	2.6	6.9	2.9	6.6	2.9	6.3	2.7	n.a.		6.9	2.5	n.a	-0.97 (-1.77, -0.17)*	
Alcohol	9.5	1.4	9.5	1.6	9.8	0.9	9.3	2.1	n.a.		9.5	1.7	n.a	0.09 (-0.30, 0.48)	
Extra scores (0-10)															
Protein	4.9	3.6	5.7	3.5	6.0	3.6	5.3	3.6	n.a.		5.1	3.8	n.a	1.20 (0.15, 2.24)*	
Vitamin D	2.5	1.5	2.9	1.6	2.7	1.7	2.2	1.1	n.a.		2.2	1.3	n.a	0.20 (-0.11, 0.52)	
Physical activity	5.0	4.1	6.2	4.0	6.3	3.8	6.9	3.8	n.a.		6.0	4.2	n.a	2.13 (0.98, 3.29)***	
Appetite															
SNAQ score (0-20)	15.6	1.8	15.4	1.8	15.5	1.9	15.6	1.7	n.a.		15.6	1.9	n.a	-0.19 (-0.65, 0.27)	204

Table 4.2. Continued.

	Intervention group						Control group						Linear mixed models		
	T0/TM0		T1/TM1		T2		T0		T1		T2		β T1 (95% CI)	β T2 (95% CI)	N
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Physical functioning															
Katz-15 score (0-15)	2.1	2.7	n.a.		2.1	2.8	2.0	2.7	n.a.		2.0	2.7	n.a	0.17 (-0.30, 0.64)	199
SPPB score (0-12)	7.2	3.1	n.a.		7.2	2.9	7.2	3.3	n.a.		6.6	3.5	n.a	0.21 (-0.32, 0.74)	203
Quality of life															
SF36 MCS (0-100)	46.8	9.7	47.8	10.7	47.1	10.9	49.3	9.7	48.8	9.8	49	10.3	1.12(-1.08, 3.32)	0.76 (-1.42, 2.94)	199
SF36 PCS (0-100)	37.2	10.9	38	10.7	38.1	11.0	39.8	10.3	39.8	10.8	39.8	11.1	-0.44 (-2.08, 1.20)	-0.44 (-2.06, 1.18)	199

SD, standard deviation; CI, confidence interval, MNA, Mini Nutritional Assessment; DHD, Dutch Healthy Diet; OR, Odds Ratio; SNAQ, Simplified Nutritional Appetite Questionnaire; SPPB, Short Physical Performance Battery; SF36, Short Form 36; MCS, Mental Component Score; PCS, Physical Component Score. All results are adjusted for age and sex. [a] Adjusted for age, sex, swallowing problems, dental problems, cognitive functioning and desire to lose weight. [b] Adjusted for age, sex, and desire to lose weight. [c] Analysed using logistic regression. Adjusted for age, sex, and baseline compliance to guidelines for intake of trans-fatty acids. *p<0.05; **p<0.01; ***p<0.001.

4

DISCUSSION

The aim of this study was to evaluate the effects of the PhysioDom HDIM intervention on nutritional status, diet quality, appetite, physical functioning, and quality of life. The intervention was effective in improving nutritional status in participants at risk of undernutrition and in improving several items of diet quality and compliance with guidelines for physical activity. The intervention did not have an effect on body weight, appetite, physical functioning, and quality of life.

The intervention led to an improved nutritional status in participants at risk of undernutrition. These participants received a more intense intervention than participants who were not at risk, as they received additional advice by a nurse and a brochure with advice on how to improve protein and energy intake. If necessary, they were referred to their GP or a dietician. To our knowledge, this is one of the first studies that used eHealth for nutrition screening and nutrition education to improve nutritional status in community-dwelling elderly. Other similar non-eHealth studies consisted of nutrition screening with a validated screening tool, followed by a nutrition intervention such as printed nutrition education material [37], nutrition newsletters and dietary consultation [38], personalised evaluation and consultation [39, 40], or a combination of counselling, nutrition education, and meals on wheels [41, 42]. These studies found similar positive effects on nutritional status of older adults at risk of undernutrition, although many of these studies lack the presence of a control group or rely on self-report [43]. Our study adds to these findings by suggesting that eHealth can be used for nutrition screening, but that additional consultation of a health care professional remains necessary to achieve an effect on nutritional status.

The intervention group improved compliance with guidelines for the intake of fruit, vegetables, dietary fibre, and protein [28, 29]. An optimal diet quality is essential for older adults as a more nutrient-dense diet is required considering the declined energy requirements and food intake that often accompany ageing. Only one other pilot study was found that used eHealth to provide computer-tailored dietary advice to older adults, as part of a web-based platform concerning healthy eating, physical activity, and meaningful social roles. This eight-week intervention appeared to be feasible to implement, but it did not lead to significant effects on dietary intake and physical activity [44]. A review of non-eHealth studies that focus on dietary advice and nutrition counselling for older adults reported positive effects on dietary intake [24]. For example, a six-month home-based nutrition education intervention consisting of eight home visits, bi-weekly phone calls, and monthly letters resulted in increased fruits and vegetables intakes [45]. The review further concludes that comprehensive interventions involving active participation and collaborative elements such as group classes and follow-up meetings are most promising in affecting nutritional outcomes, in contrast to interventions with limited personal contact with study participants [24]. These type of interventions are costly to implement and expensive to scale up however, as they require a considerable amount of human resources. Contrary to what this review concluded, our intervention with limited contact between participants and researchers was successful in improving diet quality. This could be explained by the fact that our intervention included personalised dietary advice, which is suggested to be more effective in achieving behaviour change than non-personalised advice [46]. Furthermore, the control group unexpectedly improved compliance to guidelines for the intake of salt. This may be a chance finding or it may be attributed to the fact that more participants in the control group were on a diet, although adjusting for this in the analyses did not alter the results. To conclude, this study shows that using a personalised eHealth approach for nutrition education can be as effective as a non-eHealth approach in improving diet quality, with the additional benefits that eHealth is more scalable and sustainable, while keeping costs limited [46].

The intervention group significantly improved compliance with guidelines for physical activity. Participants were asked to wear a pedometer for one week per month during the intervention period. Additionally, they were encouraged to set goals for their daily number of steps. In studies among younger adults, pedometer use is associated with significant increases in physical activity [47]. Studies in older adults also suggest that pedometer use can be effective in increasing daily steps [48, 49]. Our study confirms that pedometer-based interventions appear to be an easy and cheap way to encourage physical activity in community-dwelling older adults, although more research is needed to establish long-term effects.

The intervention did not have effects on body weight, appetite, physical functioning, and quality of life. The lack of effects on these type of outcomes is in line with a review by Van den Berg et al, which suggest that eHealth interventions for older adults show better results for behavioural outcomes than for medical outcomes, quality of life, and economic outcomes [50]. The lack of effects in this study could possibly be attributed to several aspects. Firstly, a longer intervention duration, a more intense intervention, and a larger sample size might be needed to establish effects on these long-term outcomes. Secondly, it is suggested that nutritional interventions that are implemented among a wide range of patients with a smaller risk of undernutrition have not demonstrated clinical benefits [8]. It is argued that interventions could better target persons who are at higher risk to become malnourished to be able to intervene in a more targeted and specialised way [8]. Indeed, less than one fifth of our study population risked undernutrition. Future research might target a population at greater risk of undernutrition to demonstrate effectiveness in a more homogenous sample, for example through connecting the intervention to care pathways for frail or hospitalised elderly patients.

To our knowledge, this is the first study that used eHealth for a combination of nutritional screening and education among community-dwelling older adults. A strength of this study was that the intervention was embedded within health care organisations, reflecting a real-life setting and thus improving external validity. Other strengths are the use of a theoretical framework including behaviour change techniques and providing tailored dietary advice, making a sustainable behavioural change more probable [46]. Furthermore, the addition of scores for compliance with guidelines for protein and vitamin D to the DHD-FFQ can be regarded as a strength. These nutrients are of particular interest for older adults with regard to bone health and muscle functioning. Adding these components to the orginial DHD-FFQ resulted in a more relevant dietary advice for our participants. Limitations of the study include the non-randomised design. Randomisation was not desirable due to risk of contamination as nurses delivered a large part of the intervention. This led to baseline differences between the intervention and control group. Although we were able to adjust for many possible confounders, we cannot completely exclude residual confounding. Another limitation was the high drop-out rate in the intervention group. However, under the assumption of most missing data being missing at random, linear mixed models still yield unbiased effect estimates [51]. Nevertheless, future research should focus on ways to keep frail or diseased participants in a study, for example by optimising the usability of interventions.

In conclusion, the findings of this study suggest that an eHealth intervention for nutrition screening and education can lead to improved nutritional status in older adults at risk of undernutrition, and that it can lead to improved adherence to guidelines for a healthy diet and physical activity in community-dwelling older adults. More insight is needed into how such interventions yield more impact, for example by studying the intervention's delivery, acceptability, and applicability in more detail, and by unravelling the intervention's mechanism of impact.

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CONFLICT OF INTEREST

None.

AUTHORSHIP

MvD coordinated implementation of the study, analysed the data, and drafted the article. All other authors critically read and revised the manuscript. MvD, JdV, AH, LdG, MvB, and MFe participated in the study design. MFr contributed to the implementation of the intervention.

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Chapter 5

Implementation of a multi-component telemonitoring intervention to improve nutritional status of community-dwelling older adults: a process evaluation

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ABSTRACT

Objective: The objective of this study was to conduct a process evaluation of a multi-component nutritional telemonitoring intervention implemented among Dutch community-dwelling older adults.

Design: A mixed-methods approach was employed guided by the process evaluation framework of the Medical Research Council and the Unified Theory of Acceptance and Use of Technology. The process indicators reach, dose, fidelity, and acceptability were measured at several time-points within the six-month intervention among participants and/or nurses.

Setting: The intervention was implemented in the context of two care organisations in the Netherlands.

Subjects: In total, 97 participants (average age 78 years) participated in the intervention and eight nurses were involved in implementation.

Results: About 80% of the participants completed the intervention. Drop-outs were significantly older, had a worse cognitive and physical functioning, and were more care-dependent. The intervention was largely implemented as intended and received well by participants (satisfaction score 4.1, scale 1-5), but less well by nurses (satisfaction score 3.5, scale 1-5). Participants adhered better to weight telemonitoring than to telemonitoring by means of questionnaires, for which half of the participants needed help. Intention to use the intervention was predicted by performance expectancy (β=0.40, 95% CI 0.13,0.67) and social influence (β=0.17, 95% CI 0.00,0.34). No association between process indicators and intervention outcomes was found.

Conclusions: This process evaluation showed that nutritional telemonitoring among older adults is feasible and accepted by older adults, but nurses' satisfaction should be improved. The study provided relevant insights for future development and implementation of eHealth interventions among older adults.

Keywords: Telemonitoring, undernutrition, older adults, implementation research.

INTRODUCTION

Undernutrition impedes healthy ageing as it has been associated with increased morbidity and mortality [1]. It is estimated that 5.8% of community-dwelling older adults are undernourished and another 31.8% are at risk of undernutrition [2]. Among home care clients the estimated prevalence of undernutrition is 35% [3]. Nevertheless, it is stated that undernutrition is "under-recognized and under-treated" [4]. Nutrition education and nutritional monitoring may improve awareness among older adults and health care professionals (HCP's), and may lead to timely detection and prevention [1].

In previous research the effectiveness of the PhysioDom Home Dietary Intake Monitoring (HDIM) intervention was studied [5]. This intervention consisted of telemonitoring, nutrition education, and follow-up by a nurse and was implemented in a health care setting among Dutch community-dwelling older adults. The intervention improved nutritional status in participants at risk of undernutrition and improved diet quality. No effects on physical functioning and quality of life were found [5].

Besides effect evaluation of such a complex, multi-component intervention, process evaluation of PhysioDom HDIM is indispensable. Firstly, insights from a process evaluation guide implementation quality and ensure that the intervention is carried out as intended [6]. Secondly, research to the context, implementation, and mechanisms of impact of PhysioDom HDIM is crucial to interpret findings from the effect evaluation and to implement the intervention in another setting [7]. Thirdly, policy makers frequently highlight the role of technology in supporting ageing in place and effort is put in developing technology to improve health and self-management of diseases [8]. However, several barriers hinder successful implementation and widespread adoption of eHealth among older adults is lacking [9]. Research on eHealth adoption by older adults has mostly focussed on the pre-implementation stage and often comprised qualitative studies [10]. More research is needed to understand what factors contribute to sustained use of eHealth. Therefore, process evaluation of the PhysioDom HDIM intervention could provide insight into what contributes to successful eHealth adoption by older adults. The aims of this paper were to study how

PhysioDom HDIM was delivered and received by participants and nurses, and to study the intervention's mechanisms of impact.

METHODS

Theoretical framework

A mixed-methods approach was employed guided by the framework of the Medical Research Council [7, 11]. Based on this framework, we included the process indicators reach, dose, fidelity, and acceptability. Acceptability was studied in further detail by using the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT is a widely used framework that unifies several technology acceptance models into one model, explaining up to 70% of intention to use technology through four factors: performance expectancy, effort expectancy, social influence, and facilitating conditions [11]. UTAUT has been widely applied in research, also among older adults [11-14], and is helpful in understanding the drivers of acceptance and in designing interventions that will be optimally used [11].

Study design

This process evaluation was conducted as part of a six-month intervention study which followed a parallel arm pre-test post-test design and took place from April 2016 until June 2017 [15]. We used data from the intervention group only. Measurements were conducted at baseline (T0), 4.5 months after the start of the study (T1), and six months after the start of the study (T2). Furthermore, continuous implementation monitoring took place through log data and registration of study procedures by researchers and nurses. The study was registered at ClinicalTrials.gov (identifier NCT03240094), URL http://bit.ly/2zFTs3P.

Participants

Participants were recruited from the municipalities of Ermelo, Harderwijk, Nunspeet, Putten, and Renkum in the Netherlands. They were invited via advertisements in local newspapers and public spaces, post, and letters from care organisations Zorggroep Noordwest-Veluwe and Opella. Persons could respond when they were 65 years or older and received home care and/or lived in a service flat or sheltered accommodation. Interested persons were visited by a researcher to receive more information about the study, ask questions, sign the informed consent, and be screened on the exclusion criteria. Persons were excluded if they were cognitively impaired (Mini Mental State Examination (MMSE) < 20), had diagnosed cancer, received terminal care, were bedridden or bound to a wheelchair, or were unable to watch television. In total, 107 persons were screened on eligibility for participation in the intervention group, of whom 97 were allocated to the intervention group. During the intervention period, 21 participants were lost to follow-up. This was mainly due to health problems (n=10) or difficulties with the telemonitoring technology (n=5).

Intervention

The PhysioDom HDIM intervention consisted of three components: nutritional telemonitoring, nutrition education, and follow-up of telemonitoring measurements by a nurse. These components are briefly explained below, a full description can be found elsewhere [15]. Participants performed self-measurements of body weight (weekly), steps taken during a day (one week per month), and blood pressure (monthly or bi-monthly, only upon indication of a nurse). Participants also filled out questionnaires about nutritional status, appetite, and diet quality using the Mini Nutritional Assessment Short-Form (MNA-SF) [16], Simplified Nutritional Appetite Questionnaire (SNAQ) [17], and Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) [18], respectively (at T0 and three months later). Participants could do this on a tablet, on their own computer, or via a telephone interview with researchers and were trained for this during an individual at-home training at T0. A helpdesk was available to support participants if they encountered difficulties. Furthermore, participants received three television messages per week containing general information about nutrition and physical activity. These short text messages (<500 characters) were displayed on a special television channel. Participants also received two letters with tailored information about how to improve compliance with Dutch guidelines for diet and physical activity. Tailoring was based on an individual's DHD-FFQ results: for each guideline, one out of two to five available advices was given, according to the score for that specific guideline. Finally, a team of eight nurses and three dieticians assessed the telemonitoring results. Nurses viewed the results on a website and checked the alerts that were activated in case of undernutrition, risk of undernutrition, obesity, or new blood pressure measurements.

Nurses decided about proper follow-up with the help of decision trees [19]. In case of risk of undernutrition, nurses investigated on the causes and advised participants on how to improve protein and energy intake [20]. In case of undernutrition and obesity, nurses discussed with participants whether referral to a GP or dietician was desired. In case of deviating blood pressure measurements, nurses followed regular care pathways. Nurses were trained during four preparatory meetings of one and a half hours with the researchers. They also attended a workshop from a dietician to improve knowledge about nutrition in older adults. The researchers held monthly to bi-monthly telephone meetings with nurses to address questions and to ensure proper implementation.

Measurements

Reach

Reach is defined as 'proportion of the intended priority audience that participates in the intervention' [6]. Reach was investigated by keeping a log book of drop-out and by collecting background characteristics of participants. Sex, age, BMI, education level, civil status, living situation, number of diagnoses, cognitive functioning as measured by the MMSE [21], the presence of dental and/or swallowing problems, and type of care were recorded during a screening visit before T0. Other characteristics were measured at T0, including nutritional status, measured by the Mini Nutritional Assessment (MNA) [22] and physical functioning, measured by the Short Physical Performance Battery and the Katz-15 [23, 24].

Fidelity

Fidelity is defined as 'the extent to which an intervention was implemented as planned' and was assessed by keeping a logbook of study procedures and a paper questionnaire for nurses [6]. This questionnaire was filled out half-way during the project and contained questions on how much time the HCP spent on the project, and how often the HCP used the project website.

Dose received

Dose received is defined as 'the extent to which participants actively engage with, interact with, are receptive to, and/or use materials or recommended resources' [6]. Dose received was measured by log data from the television channel and project website, paper questionnaires for participants and nurses, and registration lists of nurses. With log data the proportion of requested weight and step count measurements that was actually performed by participants was measured. It should be noted that participants also wrote down their steps on paper, so log data only partially reveal dose received concerning step counts. The questionnaire for participants was filled out at T1 and T2 and contained questions on the frequency of reading television messages and telemonitoring of body weight. The questionnaire for nurses was filled out half-way during the project and included the question 'how long on average did the contact moments take with participants with risk of undernutrition?'.

Acceptability

Acceptability of the intervention was studied by using the UTAUT model [11]. UTAUT constructs were measured at T1 and T2 by paper questionnaires for participants. The questionnaires contained statements that were answered on a five point Likert scale ranging from 'completely disagree' to 'completely agree'. *Performance expectancy* is defined as 'the degree to which an individual believes that using the system will help him or her to attain gains in job performance', and was translated to 'gains in health behaviour or health' to fit in the context of this study. Performance expectancy was measured using the following statements: 'The project helps me to be more physically active', 'The project helps me to eat healthier', and 'The project improved my health'. *Effort expectancy* is defined as 'the degree of ease associated with the use of the system' and was measured using the following statement: 'Working with the TV channel is easy' and the statements: 'It is easy to weigh myself/use the pedometer/use the remote control/use the tablet/use the sphygmomanometer'. *Social influence* is defined as 'the degree to which important others believe he or she should use the new system' and was measured with the following statements: 'My partner/family/friends/others support me in participating in the project' and

'The support of my partner/family/friends/others is important to me'. *Facilitating conditions* are defined as 'the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system', and was studied by several statements concerning the satisfaction about the helpdesk and the training. *Behavioural intent* was measured at T2 with one statement 'I would like to use the intervention more often'. Furthermore, semi-structured interviews with 15 participants were performed to gain more in-depth insight into acceptability. The interviews took on average 30 minutes, took place during T2 at the participants' homes, and were guided by an interview guide (Table 5.1). After verbal consent, all interviews were recorded and transcribed verbatim.

Acceptability of nurses was also assessed with help of the UTAUT model. Nurses filled out a paper questionnaire half-way during the project with statements that were answered on a five point Likert scale ranging from 'completely disagree' to 'completely agree'. The construct performance expectancy was divided into two sub constructs, 'gains for job performance' and 'gains for client'. Gains for job performance contained six statements concerning the added value of the intervention for the job performance of the HCP, for example 'Through the intervention I can do my work more efficiently'. Effort expectancy consisted of 10 items concerning the ease of use of the project website. Social influence was assessed by two items concerning the support of colleagues. Behavioural intent contained the statement 'I would like to participate in a continuation of the project'. Furthermore, semi-structured interviews of 20-30 minutes were held with each of the nurses including acceptability topics (Table 5.2). After verbal consent, interviews were recorded and transcribed verbatim.

Table 5.1. Interview guide for interviews with participants (N=15) of the PhysioDom HDIM intervention in the Netherlands.

Topics and questions
General
What did you think about the project in general?
Performance Expectancy
Did the project give you more insight into your diet and physical activity levels? Why or why not?
Did the devices function according to your expectations?
Are the devices/Is the project a good way to monitor your diet and physical activity levels? Or improve them?
Effort expectancy
How easy was the use of the devices?
Have you used these devices before the start of this project?
Did you have an idea how to use the devices for the project? Did this influence your decision to participate?
What do you think of how you deal with the devices?
Has the way you dealt with the devices changed during the project? Why/why not?
Social influence
Through whom have you gotten acquainted with the project?
How was the project presented to you? Was this a reason for you to participate?
Have you talked with persons in your surroundings (partner, family, friends) about the project? How did they support you during the project?
Have you talked with nurses about the project? Have you received support from the nurses during the project?
How important is it for you to receive support of others during the project?
Facilitating conditions & Behavioural intent
To what extent did the project fit into your daily routines?
To what extent did you invest time in the project?
To what extent did the devices fit your life style? Did you have to adjust your daily routines?
Do you think you will continue to use the devices?
Would you prefer the devices were changed, so that they would function better?
Closing remarks
Is there anything else you would like to mention?

Table 5.2. Interview guide for interviews with nurses (N=8) implementing the PhysioDom HDIM intervention in the Netherlands.

Topics and questions
General
How satisfied are you about the project in general?
Collaboration and communication
How did you experience the collaboration and communication? - With colleagues? - With researchers?
Implementation barriers and facilitators
What problems did you encounter that hindered implementing the intervention?
What helped you in implementing the intervention?
Facilitating conditions
Did you have everything that you needed to implement the intervention? - Knowledge - Materials - Support
Do you have suggestions to improve the intervention?
E.g. concerning intervention procedures, planning, methods, intervention manual or project website?
Would you like to continue the intervention?
Why or why not?
Closing remarks
Is there anything else you would like to mention?

Explaining mechanisms of impact

To study the mechanisms of impact, the associations of participant characteristics and the process indicator acceptability with intention to use the intervention were examined. Furthermore, the association of the process indicators acceptability and dose received with changes in the outcomes that were significantly affected by the intervention was examined. These were nutritional status and compliance to Dutch dietary guidelines for the intake of fruit, vegetables, dietary fibre, protein, and compliance to guidelines for physical activity [5]. Nutritional status was measured using the MNA during a structured interview with participants at T0, T1, and T2 [22]. Body weight was measured at T0, T1, and T2 by researchers using a weighing scale of the brand A&D, type UC-411PBT-C. Participants were asked to take off their shoes and heavy clothes such as a jacket before weighing. Diet quality was assessed using the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) during a structured interview with participants at T0 and T2 [18]. The DHD-FFQ contains 28 items to evaluate compliance to Dutch dietary guidelines for vegetables, fruit, fish, alcohol, saturated fatty acids, trans-fatty acids, sodium, and dietary fibre, and compliance to Dutch guidelines for physical activity [25].

Statistics

Data were analysed using SPSS Statistics for Windows version 22 (IBM Corp., Armonk, N.Y., USA). Baseline characteristics were analysed using descriptive statistics. Differences in baseline characteristics between completers and drop-outs were analysed using independent *t* tests or chi-square tests. The process indicators dose received and acceptability were analysed using descriptive statistics, showing percentages or means with standard deviations. Cronbach's alpha was used to investigate whether acceptability items could be combined into the UTAUT constructs. If Cronbach's alpha was lower than 0.70, items were presented separately. The association of participant characteristics and acceptability with intention to use the intervention was analysed using a nested linear regression analysis, including participant characteristics into the first block, then adding the four UTAUT constructs block wise to the model. An F-test revealed whether adding these constructs significantly increased the explained variance. Associations of process indicators and changes in health and behavioural outcomes were analysed using linear regression. Qualitative data were analysed using Atlas.ti version 7 (Scientific Software Development GmbH, Berlin, Germany). Interview transcripts were coded deductively using codes from UTAUT constructs. New codes were generated for relevant sections that did not belong to any of the UTAUT constructs. Thematic analysis was used to study factors that influenced acceptance of the intervention. Interviews with the nurses were analysed by grouping relevant sections, phrases, sentences or words into themes.

RESULTS

Reach

Table 5.3 shows the baseline characteristics of the study population. Twenty-one of 97 participants dropped out of the study. They were significantly older, had a lower cognitive and physical functioning, and were more care-dependent than participants who had completed the study. Reasons for drop-out were health problems (*n*=10), difficulties with the technology (*n*=5), inability to install the telemonitoring technology properly due to technical problems (*n*=2), health problems of spouse (*n*=1), dislike of the intervention (*n*=1), or reason for drop-out was unknown (*n*=2).

Fidelity

Telemonitoring measurements – Adherence to telemonitoring measurements was high for body weight and lower for steps, nutritional status, appetite, and diet quality (see 'Dose'). Half of the participants omitted to perform at least one of the telemonitoring questionnaires, so that researchers had to assist them with filling these out at T1. Furthermore, some participants needed nurses assistance with telemonitoring measurements, while it was the intention that participants would be able to perform these measurements independently.

Nutrition education – According to the intervention plan, participants received three television messages per week and two letters with computer-tailored advice about diet quality and physical activity.

Follow-up by the nurse – Nurses provided follow-up on the telemonitoring alerts according to the intervention plan. It was planned that this would take 0.75 hours per week. However, the project took nurses on average 1.26 hours per week (range 0.5-3.0). It was not specified how this time was distributed over the different intervention tasks, but part of this time might have been spent on the additional help that was needed with telemonitoring measurements. Half of the nurses checked the project website less often than once a week as agreed upon with the researchers, mentioning a lack of time as reason for this.

Table 5.3. Reach of the PhysioDom HDIM intervention in terms of baseline characteristics of the total group of participants, participants who completed the study, and participants who dropped out.

	Total (*N*=97)		Completers (*n*=76)		Drop-outs (*n*=21)		*p*-value
	Mean	*SD*	Mean	*SD*	Mean	*SD*	
Age (years)	78.4	7.2	77.3	7.2	82.3	6.1	<0.01
BMI (kg/m2)	29.2	4.5	29.0	4.1	29.6	5.9	0.66
Number of diagnoses	1.5	1.5	1.7	1.6	1.0	1.1	0.06
MMSE score [a]	28.6	1.5	29.0	1.2	27.2	1.9	<0.001
SPPB score [a]	7.2	3.1	7.6	2.9	5.4	3.2	<0.01
Katz-15 score [b]	2.11	2.7	1.9	2.6	3.2	2.8	0.07
	%		%		%		
Sex (male)	34		31.6		42.9		0.33
Education level [c]							0.56
Low	17.5		18.4		14.3		
Moderate	55.7		52.6		66.7		
High	26.8		28.9		19.0		
Living alone	55.7		59.2		42.9		0.22
Desire to lose weight [b]	52.7		53.3		50.0		1.0
Currently on a diet [b]	9.7		9.3		11.1		1.0
Nutritional status [a]							0.81
Normal nutritional status	79.2		77.6		85.0		
At risk of undernutrition	19.8		21.1		15.0		
Undernourished	1.0		1.3		0.0		
Type of care (more than one type per participant possible)							
Domestic care	78.4		76.3		85.7		0.55
Personal care	32.0		25.0		57.1		<0.01
Nursing care	9.3		5.3		23.8		0.02
Individual support	3.1		2.6		4.8		0.52
Informal care	32.0		32.9		28.6		0.80

SD, Standard Deviation; BMI, Body Mass Index; MMSE, Mini-Mental State Examination; SPPB, Short Physical Performance Battery; SF36, Short Form 36; MCS, Mental Component Score; PCS, Physical Component Score. [a] 1 missing value. [b] 4 missing values. [c] Low education level: primary school or less; Intermediate level of education: secondary professional education or vocational school; High education level: higher vocational education, university.

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Dose

Table 5.4 shows participants' adherence to the telemonitoring measurements. Either with or without help from nurses or researchers, participants performed on average 70% of the body weight measurements, 37% of the step count measurements, and 100% of the measurements of nutritional status, appetite, and diet quality. A bit less than half of the participants indicated to have read the television messages on a weekly basis. Log data revealed that 37.2% of the television messages were opened by participants. With regard to follow-up of telemonitoring measurements by a nurse, 36% of the participants received on average 1.2 phone calls and 12% was visited on average 2.8 times at home. These contact moments took on average 27.5 minutes. Five participants were referred to a dietician and another five were referred to their GP.

Table 5.4. Dose of the PhysioDom HDIM intervention components received by the intervention group.

Intervention component	Dose delivered by researchers or health care professionals	Dose received by participant		
Nutritional telemonitoring				
Body weight	Weekly	Log data: Compliance 70% Questionnaire: Compliance T1: 85.5% (n=69) Compliance T2: 85.3% (n=75)		
Steps	One week per month	Compliance 37 %		
Appetite, nutritional status, diet quality	3 months after the start	Compliance 100 %		
Nutrition education				
Television messages	3 per week	Reading television messages:	T1 (N=69)	T2 (N=75)
		< once per week %	27.5	33.4
		Once per week %	44.9	48.0
		> once per week %	27.5	18.7
		Log data: 37.2% of messages was opened		
Dietary advice letters	2 in total	n.e.		
Newsletters	3 in total	n.e.		
Follow-up by nurse				
Number of phone calls to participants	Upon an alert from the telemonitoring measurement results.	44 (*n*=35, 36% of study population)		
Number of visits to participants	Upon an alert from the telemonitoring measurement results.	30 (*n*=12, 12% of study population)		
Average duration of phone call/visit to participant		27.5 minutes		
Referral dietician	In case of undernutrition/high BMI	5 (*n*=5)		
Referral GP	In case of undernutrition/high BMI/high blood pressure	9 (*n*=5)		

N.e., not evaluated.

Acceptability

Table 5.5 shows that participants were satisfied about the project with scores of 4.0 out of five and higher at T1 and slightly lower scores at T2. Almost all acceptability scores slightly decreased from T1 to T2, although these decreases were not statistically significant. Of the four UTAUT constructs, *effort expectancy* and *facilitating conditions* were rated highest with scores between 3.8 and 4.0 at T1 and T2, indicating that participants found that the intervention technology was easy to use and that the helpdesk supported the use of the technology. Interviews with participants revealed that they were generally positive about the technology. The intended use of it was understood well. Nevertheless, many interviewees struggled with some intervention tools, mainly the weighing scale and the television channel. Remarkably, nurses were more negative about the participant's ease of use of the technology than participants themselves. Nurses were often asked to help with the telemonitoring measurements. Nurses mentioned that 'this generation' is not used to technology, that participants needed a lot of help, and that they easily became frustrated or stressed when technology was not working properly. With regard to facilitating conditions, interviewed participants perceived the helpdesk as friendly and helpful. However, participants also noticed that it was not always accessible, and some felt apprehension to approach the helpdesk: "I don't want to be a nuisance to anyone". *Performance expectancy* was rated 3.4 and 3.3 at T1 and T2, respectively, indicating that participants were neutral to positive about the contribution of the intervention to gains in a healthy diet, levels of physical activity, or health. All interviewees indicated that at least one intervention component gave new insight into their behaviour or health (for example the pedometer). However, the extent to which these insights impacted behaviour and health was highly variable among interviewees. Some interviewees indicated that the intervention helped to improve diet and physical activity and called the intervention "stimulating", "increasing awareness of own habits", and "providing useful insights for improving one's diet". Other interviewees mentioned that the intervention had little to no effect on them or their health and called the telemonitoring results and advices "unnecessary", "not for me", or "just for fun, nothing more." They were already satisfied with their health, found that the supervision of a health

Table 5.5. Acceptability of the PhysioDom HDIM intervention as rated by participants and health care professionals.

	T1			T2			
	Mean (1-5)	*SD*	*N*	Mean (1-5)	*SD*	*N*	Cronbach's alpha T1/T2
Participants							
General							
I am satisfied about the project in general	4.1	0.8	70	3.9	0.9	75	
I am satisfied about the nutrition part of the project	4.0	0.8	70	3.8	0.8	75	
I am satisfied about the physical activity part of the project	4.1	0.8	70	3.8	0.8	75	
I am satisfied about the contact with the nurse	4.3	0.6	23	3.8	0.8	24	
Performance expectancy	3.4	0.7	70	3.3	0.7	75	0.71/0.76
Effort expectancy	3.9	0.7	70	3.8	0.7		0.73/0.79
Social influence	3.2	1.2	69	3.1	1.1	73	0.94/0.89
Facilitating conditions	4.0	0.7	70	4.0	0.7	75	0.91/0.85
Behavioural intent	-	-	-	3.3	0.8	66	
Health care professionals	Mean (1-5)	*SD*	*N*				
General			8				
I am satisfied about the project in general	3.5	0.8					
Performance expectancy			8				
Gains for job performance	2.6	0.6					0.71
Gains for client							-0.81
The project is useful to monitor nutritional status	4.1	0.4					
The project is useful to coach clients concerning physical activity	3.9	0.4					
The project is useful to coach clients concerning nutrition.	3.9	0.4					
The project can contribute to a better health for clients	4.1	0.4					
Effort expectancy	3.2	0.5	8				0.80
Social influence			8				0.26
I felt supported by colleagues in implementing the intervention	3.3	0.5					
The support of colleagues is important to me	4.4	0.5					
Behavioural intent	2.3	1.0	8				

care professional was sufficient for them, or they already knew what they needed. While interviewees with a positive perspective appeared to be a majority, the distinction between the two points of view was not absolute. Most interviewees expressed both positive and negative sentiments regarding the performance of the intervention. Participants were neutral about *social influence* with scores of 3.2 and 3.1 at T1 and T2, respectively. In the interviews, participants mentioned that they received positive feedback of their social environment about their participation, but that the social environment had little influence on the participant's experience with the intervention. Participation was seen as a personal undertaking and the decision to participate was their own. Finally, participants were neutral about their intent to use the intervention more often. In the interviews, participants mentioned that it would be "just more of the same", "too time/energy consuming", or "[I] have already gotten everything out of this experience". Only five interviewees preferred to continue participation, mentioning the stimulation to be physically active and the structure the intervention provided: "Yes, the project stimulates. Now, I'll have to continue with it myself" and "Like I said, it's about structure in your life (...). This [intervention] is just a part of that".

Acceptability scores of nurses were slightly lower than that of participants with an average satisfaction score of 3.5 (Table 5.5). With regard to *performance expectancy*, nurses were more positive about the gains of the intervention for their clients than gains for their own job performance. Nurses called the project an addition to care, promising for the future, enabling ageing in place, and possibly cost-saving. However, the intervention was difficult to fit in the nurses' schedules as it took them a lot of time next to their normal working hours. Nurses made time for this when possible, but primary care needs of their clients had priority, sometimes resulting in postponing intervention-related tasks. *Effort expectancy* was rated neutral with a 3.2. Nurses found the lay-out of the project website not clear and intuitive, and they could not report follow-up of telemonitoring measurements on it. As a result, they had to keep their own administration next to the website. Nurses also reported interferences of the website. Finally, nurses found it difficult to provide follow-up of telemonitoring measurements of participants who did not receive home care. Nurses did not know the background or medical history of these participants and found it therefore difficult to assess telemonitoring results properly. With regard to *social influence*, nurses were neutral to slightly positive about support of their colleagues, while they indicated that support of colleagues is important to them. The interviews revealed that cooperation with colleagues within the project team was good, but that support of other colleagues and the management of the health care organisation was lacking. Cooperation with researchers was experienced as pleasant, although some nurses preferred to have more personal meetings instead of telephone meetings. Finally, nurses were negative about participation in a possible continuation of the intervention, with lack of time as main reason. Some nurses only wanted to continue if the project website would be improved including notifications via e-mail and integration of the website with the clients' electronic health records.

Intervention's mechanisms of impact

Table 5.6 shows determinants of intention to use the intervention. The first model with the participant characteristics age, sex, education, cognitive functioning, and physical functioning explained only 9% of the variation in intention to use PhysioDom HDIM. None of these characteristics was significantly associated with intention to use PhysioDom HDIM. The percentage of explained variance increased to 45% after adding the UTAUT constructs to the model. Performance expectancy and social influence significantly increased explained variance with 26% and 5%, respectively. Effort expectancy increased explained variance with 4% (p=0.07). The final model showed that performance expectancy and social influence were significant predictors of intention to use PhysioDom HDIM.

Table 5.7 shows the influence of the process indicators acceptability and dose received on effects of the intervention on nutritional status and DHD-FFQ scores for fruit, vegetables, fibre, protein, and physical activity. No significant associations between acceptability and dose received with effects of the intervention were observed.

Table 5.6. Determinants of intention to use the PhysioDom HDIM intervention (N=63).

	Block 1		Block 2		Block 3		Block 4		Final model	
R2	0.09		0.35		0.39		0.44		0.45	
F change	1.18		22.29		3.51		5.13		0.60	
p-value	0.33		0.00		0.07		0.03		0.44	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Age	-0.16	-0.63, 0.30	-0.30	-0.70, 0.10	-0.27	-0.66, 0.13	-0.13	-0.53, 0.27	-0.11	-0.52, 0.29
Sex	0.02	-0.01, 0.05	0.01	-0.02, 0.04	0.00	-0.03, 0.03	0.01	-0.02, 0.04	0.01	-0.02, 0.04
Education	-0.22	-0.53, 0.09	-0.09	-0.36, 0.18	-0.09	-0.35, 0.18	-0.03	-0.29, 0.23	-0.03	-0.29, 0.23
Cognitive functioning [a]	0.20	-0.03, 0.43	0.15	-0.05, 0.34	0.11	-0.08, 0.31	0.10	-0.08, 0.29	0.10	-0.09, 0.29
Physical functioning [b]	0.02	-0.07, 0.11	-0.01	-0.08, 0.07	-0.04	-0.12, 0.04	-0.03	-0.11, 0.05	-0.03	-0.10, 0.05
Performance expectancy			0.59	0.34, 0.84***	0.50	0.23, 0.76***	0.40	0.13, 0.67**	0.40	0.13, 0.67**
Effort expectancy					0.30	-0.02, 0.61	0.34	0.03, 0.65*	0.29	-0.05, 0.62
Social influence							0.19	0.02, 0.35*	0.17	0.00, 0.34*
Facilitating conditions									0.11	-0.18, 0.40

Dependent variable: intention to use PhysioDom HDIM more often (1-5). [a] Measured by Mini Mental State Examination. [b] Measured by Short Physical Performance Battery. *p<0.05; **p<0.01; ***p<0.001.

Table 5.7. Influence of acceptability and dose received on effects of the intervention on nutritional status and diet quality.

	MNA score ΔT1-T0		MNA score ΔT2-T0		DHD vegetables ΔT2-T0		DHD fruits ΔT2-T0		DHD fibre ΔT2-T0		DHD protein ΔT2-T0		DHD Physical activity ΔT2-T0	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Acceptability [a]														
Performance expectancy	0.21	-0.65, 1.06	0.41	-0.58, 1.39	-0.03	-1.27, 1.22	0.42	-0.45, 1.29	0.17	-0.45, 0.78	0.17	-1.86, 1.32	-0.70	-2.39, 0.98
Effort expectancy	0.80	-0.10, 1.69	0.07	-0.96, 1.10	-0.06	-1.37, 1.25	-0.57	-1.49, 0.34	0.39	-0.26, 1.03	0.17	-1.50, 1.84	-0.21	-1.98, 1.57
Social influence	0.35	-0.27, 0.97	0.20	-0.51, 0.91	-0.28	-1.19, 0.64	-0.43	-1.06, 0.21	0.13	-0.32, 0.58	-0.84	-2.01, 0.32	-0.14	-1.38, 1.10
Facilitating conditions	-0.87	-1.87, 0.13	-0.34	-1.48, 0.81	0.03	-1.45, 1.51	0.72	-0.31, 1.75	- 0.57	-1.30, 0.16	0.87	-1.02, 2.75	-1.08	-3.08, 0.93
Dose received														
Adherence body weight measurements [b]	0.49	-0.92, 1.91	0.58	-1.07, 2.23	0.54	-1.18, 2.27	-0.42	-1.80, 0.96	0.15	-0.71, 1.01	1.38	-0.76, 3.52	-1.54	-3.80, 0.73
% of messages opened [b]	0.01	-1.93, 1.95	0.03	-2.13, 2.19	0.99	-1.34, 3.32	0.64	-1.24, 2.51	0.48	-0.68, 1.63	0.56	-2.37, 3.49	-0.82	-3.91, 2.28
Frequency of having contact with nurse from project	-0.02	-0.30, 0.25	0.00	-0.31, 0.32	-0.17	-0.50,0.17	0.10	-0.17, 0.37	-0.00	-0.17, 0.16	-0.15	-0.58, 0.28	-0.08	-0.53, 0.36

MNA, Mini Nutritional Assessment; DHD, Dutch Healthy Diet; CI, Confidence Interval. [a] UTAUT constructs are combined in one model and adjusted for age, sex, help from relatives, living situation, and number of diagnoses. [b] Adjusted for age and education. $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

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DISCUSSION

This process evaluation provided insight into how PhysioDom HDIM was implemented and received by participants and nurses. The intervention was largely implemented as intended with higher satisfaction rates among participants than among nurses. Both participants and nurses mentioned concerns with regard to performance and effort expectancy of the intervention. Furthermore, participants' intention to use the intervention was predicted by performance expectancy and social influence. Acceptability and dose received were not associated with intervention effects.

With regard to the reach of this intervention, about 20% of the participants dropped out. Drop-outs were older, less healthy, and more care-dependent than completers. This is similar to the experience of another eHealth study among older adults in which drop-outs were older and participants dropped out due to health deterioration [26]. In two other studies, having one or more chronic conditions was associated with lower adherence to an eHealth intervention [27, 28]. This has implications for the expectation that eHealth improves health care access and health equity, as this study and other studies show that older age and poorer health is related to higher drop-out or lower adherence. Therefore, health disparities may still remain for persons that are less able or willing to keep up with eHealth [29]. For future generations of older adults with higher computer literacy this issue might be less problematic. Nevertheless, research should focus on how the reach towards these groups can be improved or by considering other modalities than eHealth to promote health in non-adopters of eHealth [30].

In general, participants were satisfied about the intervention. When looking at the UTAUT constructs, we found that participants rated effort expectancy and facilitating conditions the highest. Participants were more neutral about performance expectancy and social influence. The results for effort expectancy and social influence seem contradictory to the nurses' views. They were more negative about the participant's ease of use of the intervention than participants themselves. Furthermore, nurses supported many participants in performing the telemonitoring measurements, but participants were neutral about the role of social influence. This could be partly due to the operationalisation of social influence, as participants might not see their nurses as 'important others', but rather think of relatives. Another explanation might be that the nurses especially observed participants who frequently needed help. All in all, taking into account the view of both participants and nurses is relevant as both have an essential role in successful implementation.

However, social influence was a predictor for intention to use the intervention, together with performance expectancy. Performance expectancy has been identified as an important predictor of use [10-12, 31, 32]. The literature is divided about the role of social influence in eHealth adoption. According UTAUT, social influence is a significant predictor in mandatory settings only and studies did not find an association between social influence and intention to use eHealth among older adults [11, 12, 14]. However, our study and others did find an association [10, 33-36]. This might be explained by the way how social influence is operationalised in studies, or by the suggestion that the role of social influence is dependent on the context [12, 14]. Many technology acceptance models have reduced social influence to the construct of subjective norm (i.e. perception that important others think he/she should or should not use technology), but social influence also encompasses the influence of technology suppliers, HCP's, and the help of relatives [10, 37]. Models concerning technology acceptance by older adults should pay attention to this more complex role of social influence.

Unexpectedly, no associations between the process indicators dose received and acceptability with effects of the intervention were found. Previous research suggests that intervention adherence is related to better outcomes [38-41]. However, other studies did not find such an association or presented mixed results [28, 42-44]. It could be that the process indicators in this study and the way how they were measured did not capture implementation sufficiently. For example, self-report could have introduced recall bias. Another explanation might be that the relationship between process indicators and outcomes is more complex, e.g. not following a linear relationship or influenced by sociodemographic factors or personality traits [42, 43]. Future studies should continue to include process measures to unravel interventions' mechanisms of impact and to unveil successful intervention elements.

This study made use of evaluation frameworks to underpin the evaluation strategy. The MRC and UTAUT framework have been widely used for process evaluation and technology acceptance, respectively. One of the objections concerning UTAUT, however, is that this model lacks important determinants of technology use that are specific to community-dwelling older adults, such as cognitive and physical functioning and several contextual factors [10]. This was taken into account by including cognitive and physical functioning in the analyses, together with the UTAUT constructs. Furthermore, both quantitative and qualitative data were used to capture an in-depth overview of how the intervention was implemented and received. Collecting data from both participants and nurses resulted in two complementary perspectives on the intervention. A limitation of the study might be recall bias among nurses concerning their implementation of the intervention. Nurses were asked about their frequency and duration of intervention activities half-way during the intervention, and were reminded at the end of the intervention to record the contact moments with participants. This might have obscured the association between intervention dose and effects.

Based on this study, some implications for future research and practice are presented. Firstly, nurses found it difficult to perform follow-up of telemonitoring results of participants who did not receive home care. This suggests that telemonitoring can better be implemented within a care context in which nurses know the telemonitoring recipients. Secondly, telemonitoring has the purpose to partly replace care from HCP's. However, some of our participants needed much guidance from nurses in performing telemonitoring measurements, suggesting that the current intervention, implemented among the current generation, requires more guidance from nurses than desired. Improved usability may reduce the need for guidance, as well as the expectation that future generations have better computer literacy. Thirdly, this study underlines the importance of user centred design in developing eHealth intervention for older adults. This process evaluation revealed several aspects that would hinder long-term use of the intervention, such as the usability and interoperability of the nurses website, the perceived need for the intervention, and the usability and attractiveness of the television channel. Although we have pre-tested the telemonitoring technology in a pilot study, it is recommended that end-users and other relevant stakeholders are even more involved in iterative development cycles of eHealth applications [45, 46].

To conclude, the PhysioDom HDIM intervention was feasible to implement with good satisfaction among participants, but lower satisfaction among nurses. Nutritional telemonitoring interventions should be user-friendly so that telemonitoring measurements can be performed without guidance from nurses, and should fit with working procedures from nurses for successful adoption and implementation. The perceived benefits of the intervention and social influence predicted the participant's intention to use the intervention, which can be used as strategies for future intervention design and implementation. Future research should focus on how to enlarge the reach of eHealth interventions to more frail older adults and on unravelling mechanisms of impact.

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CONFLICT OF INTEREST

None.

AUTHORSHIP

MvD coordinated implementation of the study, analysed the data, and drafted the article. SS and ACR contributed to the study design. LdG, JdV, AH, SS, and ACR critically read and revised the manuscript.

ETHICAL STANDARDS DISCLOSURE

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the ethics committee of Wageningen University. Written informed consent was obtained from all subjects.

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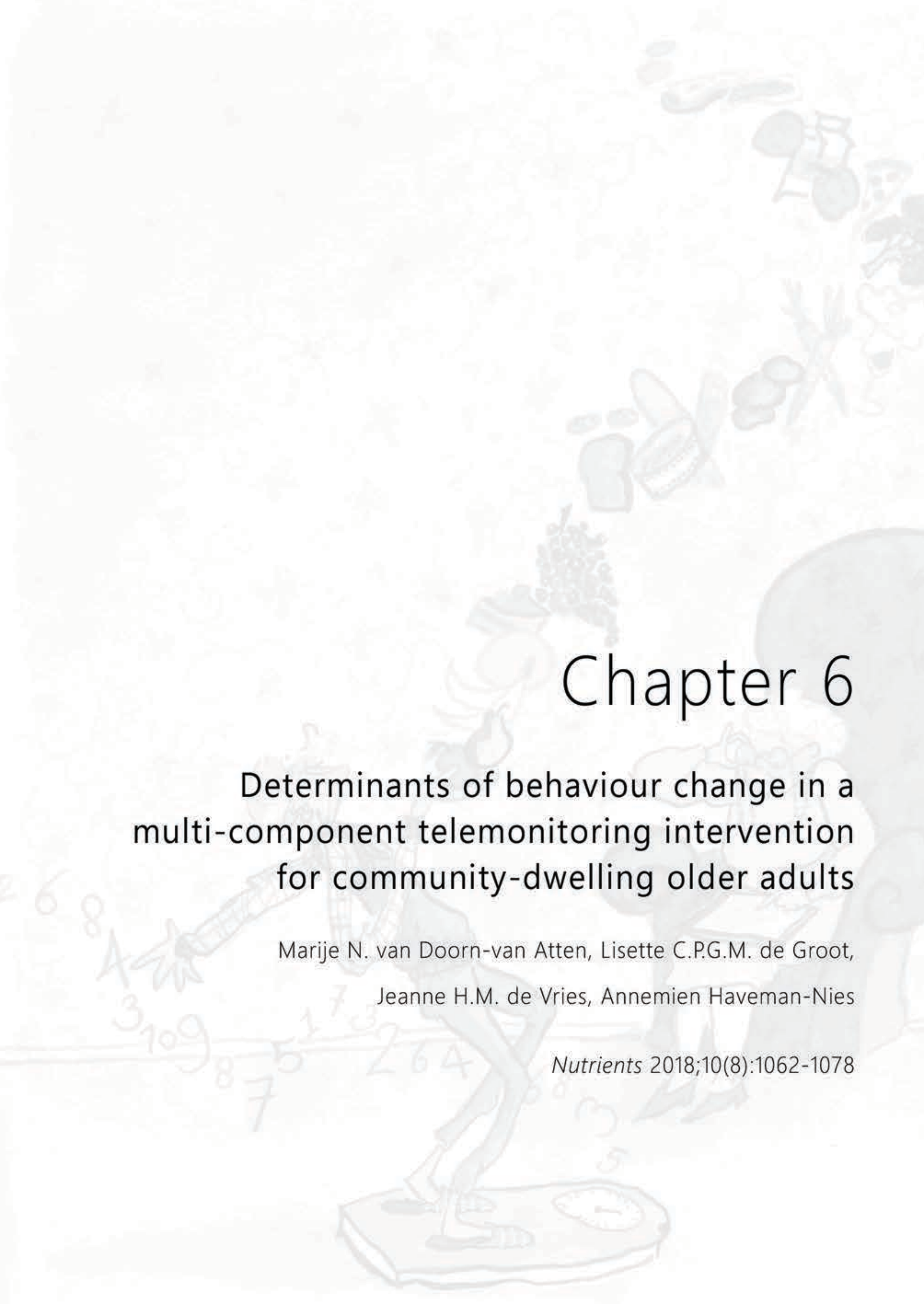

Chapter 6

Determinants of behaviour change in a multi-component telemonitoring intervention for community-dwelling older adults

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ABSTRACT

Optimal diet quality and physical activity levels are essential for healthy ageing. This study evaluated the effects of a multi-component telemonitoring intervention on behavioural determinants of diet quality and physical activity in older adults, and assessed the mediating role of these determinants and two behaviour change techniques in the intervention's effects. A non-randomised controlled design was used including 204 participants (average age 80 years) who were allocated to the intervention or control group based on municipality. The six-month intervention consisted of self-measurements of nutritional outcomes and physical activity, education, and follow-up by a nurse. The control group received regular care. Measurements took place at baseline, after 4.5 months and at the end of the study. The intervention increased self-monitoring and improved knowledge and perceived behavioural control for physical activity. Increased self-monitoring mediated the intervention's effect on diet quality, fruit intake, and saturated fatty acids intake. Improved knowledge mediated the effect on protein intake. Concluding, this intervention led to improvements in behavioural determinants of diet quality and physical activity. The role of the hypothesised mediators was limited. Insight into these mechanisms of impact provides directions for future development of nutritional eHealth interventions for older adults, in which self-monitoring may be a promising behaviour change technique. More research is necessary into how behaviour change is established in telemonitoring interventions for older adults.

Keywords: older adults; diet quality; physical activity; telemonitoring; lifestyle intervention; mechanisms of impact; mediation analyses

INTRODUCTION

An increasing number of older adults lives longer and healthier. An optimal nutritional status contributes to healthy ageing. Conversely, ageing poses nutritional risks as deteriorations in health, cognitive, and physical functioning, as well as changes in social circumstances, may impair nutritional status [1]. In the Netherlands, 11 to 35% of community-dwelling older adults are undernourished and diet quality of community-dwelling older adults is suboptimal [2, 3]. Furthermore, awareness concerning undernutrition is low among older adults [4, 5] and nutrition knowledge and attitude seem to be poorer among older adults than among younger adults [6-8]. Good access to appropriate nutrition care, such as meal programs, nutrition education, nutritional monitoring, counselling, and therapy, contributes to an optimal nutritional status [9]. Additionally, physical activity (PA) levels of older adults are suboptimal, with about one third of the 70–79-year-old and about half of the adults aged 80 years and over failing to meet the WHO guidelines for PA [10]. Barriers are mentioned such as health status, fear, and lack of interest [11, 12], with health status also acting as a facilitator (e.g., physical benefits of PA), together with enjoyment and social support [11]. Much is expected from eHealth as a way to improve nutrition and PA behaviour [13]. Advantages of eHealth include personalisation, scalability, accessibility, and reduced costs as compared to regular face-to-face care [13].

Reviews of eHealth interventions to improve nutrition behaviour in various settings show mixed results and mostly focus on younger populations [14-17]. eHealth interventions to improve nutritional outcomes in older adults are scarce. One pilot study focussed on providing computer-tailored dietary advice to older adults, in combination with improving physical activity and meaningful social roles. This appeared to be feasible, but effectiveness has yet to be affirmed in an RCT [18]. Another eHealth study focussed on nutritional counselling for older adults at increased cardiovascular risk, but effects on dietary intake were not evaluated [19]. The scarcity of nutritional eHealth interventions for older adults and mixed results of eHealth interventions to improve nutrition behaviour in a general population call for more research.

To explore the potential of nutritional eHealth interventions for older adults, it is not only necessary to know whether interventions are effective, but also how an intervention achieves its effects [14]. Ideally, interventions rely on a theoretical framework that specifies how an intervention results in effects on behavioural determinants and behaviour through behaviour change techniques (BCT's) [20]. Research shows that increased use of theory positively impacts effect sizes [21]. Testing a theoretical framework in order to verify the assumed relations deepens understanding of how interventions work and contributes to future intervention development. However, only a minority of nutritional eHealth studies that included a theoretical framework analysed the hypothesised mediators [14, 15], and more insight is needed into what contributes to effective eHealth interventions to improve nutrition behaviour in older populations.

The PhysioDom Home Dietary Intake Monitoring (HDIM) study focused on telemonitoring of nutritional parameters and physical activity. This intervention resulted in improved compliance with the Dutch dietary guidelines for the intake of vegetables, fruit, dietary fibre, and protein, and to guidelines for PA [22]. Concerning the content of the PhysioDom HDIM intervention, the three most important BCT's were self-monitoring, goalsetting, and feedback, reflecting an application of control theory [20, 23, 24]. Effectiveness of self-monitoring has been confirmed in non-eHealth studies [25], but eHealth studies including self-monitoring to promote behaviour change show less optimistic results [21, 26]. It has been shown that self-monitoring is more effective in combination with other BCT's such as goalsetting and tailored feedback [21, 26]. According to the control theory, self-monitoring, goalsetting and feedback are key in behavioural self-management [24], which is relevant nowadays with the increasing focus on self-management of health and health-related behaviours [27].

All in all, we hypothesized that the intervention would result in an increased frequency of self-monitoring and goalsetting, and in improved perceived behavioural control, attitude, and knowledge, in turn improving diet quality and PA. In this article, we aimed to shed light on these hypothesised mechanisms of impact by studying changes in frequency of self-monitoring and goalsetting, by studying the effects on perceived behavioural control, attitude, and knowledge, and by studying the mediating role of self-monitoring, goalsetting, perceived behavioural control, attitude, and knowledge in the effects of PhysioDom HDIM on diet quality and PA.

MATERIALS AND METHODS

Design

Measurements took place from April 2016 until June 2017, when the last participants finished the study. The study followed a non-randomised controlled design and had a duration of six months. Measurements took place at baseline (T0), after 4.5 months (T1), and after six months at the end of the study (T2). Telemonitoring measurements took place at the beginning of the study and three months after the start of the study, and only in the intervention group. The control group received regular care.

Ethics approval and consent to participate

Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki, and all study procedures involving participants were approved by the Medical Ethical Committee of Wageningen University on the 18th of February 2016, number NL53619.081.1.

Trial registration

The study was registered at ClinicalTrials.gov (identifier NCT03240094), URL http://bit.ly/2zFTs3P.

Participants

Participants were recruited from February 2016 until September 2016 and were recruited from nine small to middle-sized municipalities in the Netherlands. Allocation of participants to the intervention or control group took place on municipality level to prevent contamination between the intervention and control group as local HCP’s implemented the intervention. Five municipalities were non-randomly allocated to the intervention group and four other municipalities were allocated to the control group. Participants were recruited via letters from the two involved care organisations, via advertisements in local newspapers and public spaces, and invitation letters via post. Inclusion criteria were being 65 years or older and receiving home care and/or living in sheltered accommodation or a service flat. Exclusion criteria were cognitive impairment (Mini Mental State Examination (MMSE) <20), having cancer, receiving terminal care, being bedridden or bound to a wheelchair, or being unable to watch television. Persons who were interested to participate were visited by a researcher to receive more information, to have questions answered, to sign the informed consent, and to be screened on the exclusion criteria.

Intervention

The intervention consisted of telemonitoring measurements by participants, education concerning nutrition and PA, and follow-up by a nurse. These intervention components are further described below.

Telemonitoring measurements

Firstly, participants performed self-measurements of body weight (weekly, with an A&D weighing scale, type UC-411PBT-C), steps (one week per month using a pedometer of A&D, type UW-101), and blood pressure (monthly or bi-monthly, only upon indication of a nurse). They also filled out questionnaires about their nutritional status, appetite, and diet quality using the Mini Nutritional Assessment Short-Form (MNA-SF) [28], Simplified Nutritional Appetite Questionnaire (SNAQ) [29], and Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) [30], respectively. Participants filled out these questionnaires at T0 during an interview with a researcher and three months later by means of a computer, tablet, or during a telephone interview with a researcher. Participants could view their telemonitoring results on a special television channel and could thus become aware of their nutritional status and changes in nutritional status. On this television channel, participants also received short text messages in which they were asked to write down their goals for diet quality (two times) and steps (daily, during one week per month).

Education

Secondly, participants received computer-tailored and non-tailored information about nutrition and physical activity. The computer-tailored information consisted of advice sent per post on how to improve compliance with ten Dutch food-based dietary guidelines and the Dutch guideline for physical activity. This advice was tailored to the participant's current compliance with the guidelines as measured by the DHD-FFQ. For example, advice concerning vegetable intake contained more accessible suggestions for participants with low compliance than for participants who were already compliant, for which suggestions were more focussed on maintaining this behaviour and diversity of vegetable intake. The non-tailored information consisted of three short television messages per week containing general information about nutrition and physical activity.

Follow-up

Thirdly, a total of eight nurses was available to provide follow-up on the participants' self-measurements. On the project's website, they checked alerts that were activated in case of undernutrition, risk of undernutrition (based on MNA score, SNAQ score, weight loss of > five percent and/or body mass index (BMI) <20 kg/m^2), obesity (based on BMI >30 kg/m^2), or new blood pressure measurements. Nurses planned follow-up of these alerts with help of decision trees. In case of a good nutritional status, nurses kept monitoring without taking action. In case of risk of undernutrition, nurses contacted participants via telephone or a home visit. Nurses identified causes, provided suggestions on how to improve dietary intake, and gave a leaflet with advice to reverse the risk of undernutrition [31]. In case of undernutrition or obesity, nurses discussed with participants whether referral to a dietician or general practitioner was desirable.

Measurements

Measurements took place during a screening visit prior to the beginning of the study and at T0, T1, and T2. In the control group, the screening visit and T0 visit coincided. Data were collected by means of structured interviews at the participant's homes conducted by a trained researcher or research assistant. Furthermore, paper questionnaires were used to collect data.

Baseline characteristics

Baseline characteristics were recorded during the screening visit and at T0 and included sex, age, body weight, height, number of morbidities, education level, civil status, living situation, country of birth, cognitive functioning as measured by the Mini Mental State Examination (MMSE) [32], physical functioning as measured by the Katz-15 [33], nutritional status as measured by the Mini Nutritional Assessment (MNA) [34], desire to lose weight, and type of received care. Body weight was measured without shoes and heavy clothes (scale of type UC-411PBT-C, A&D).

Frequency of self-monitoring and goalsetting

Frequency of self-monitoring and goalsetting was measured at T0, T1, and T2 using a paper questionnaire with items derived from literature (Table 6.1). Self-monitoring was measured using four statements that were combined to form one scale for self-monitoring [35]. Goalsetting was measured using three statements that were combined to form one scale for goalsetting [36].

Behavioural determinants

Behavioural determinants were measured at T0, T1, and T2 using a paper questionnaire with items derived from literature (Table 6.1). Perceived behavioural control (PBC) was measured using two items for self-efficacy and two items for controllability for both physical activity (PA) and healthy eating (HE) behaviour [37]. These items were combined into two scales for PA and HE. Attitude concerning HE and PA were each measured by six semantic differential items [38]. Items were combined to form scales of attitude concerning PA and HE. Crohnbach's alpha's for the abovementioned questionnaire items ranged from 0.67 to 0.80. Knowledge was measured using 11 statements concerning a healthy diet and physical activity that were answered with 'true', 'false', or 'I don't know'. A knowledge score (0–11) was generated based on the number of correct answers.

Table 6.1. Items to measure self-monitoring, goalsetting, perceived behavioural control, and attitude in the PhysioDom HDIM study.

Construct	Questionnaire Items	Answering Options (1–5)	Crohnbach's Alpha T0
Self-monitoring	How often in the past month have you kept track in your head of the amount of food you have eaten? How often in the past month have you kept track in your head of the types of foods you have eaten during the course of the day? How often in the past month have you kept track in your head of how physically active you have been during a week? How often in the past month you have weighed yourself?	Never/a single time/a couple of times/every week/everyday	0.77
Goalsetting	How often in the past month did you set goals related to your weight? How often in the past month did you set goals related to your eating habits? How often in the past month did you set goals related to how much you exercise?	Never/a single time/a couple of times/every week/everyday	0.67
Perceived behavioural control healthy eating	I am confident that I can eat healthy in the coming month if I want to. Whether I eat healthy in the coming month is entirely up to me. Healthy eating in the coming month is for me… How much control do you have over healthy eating in the coming month?	Totally disagree–totally agree Totally disagree–totally agree Difficult–easy No control–complete control	0.70
Perceived behavioural control physical activity	I am confident that I can be sufficiently physically active in the coming month if I want to. Whether I am sufficiently physically active in the coming month is entirely up to me. Sufficient physical activity in the coming month is for me… How much control do you have over being sufficiently physically active in the coming month?	Totally disagree–totally agree Totally disagree–totally agree Difficult–easy No control–complete control	0.71
Attitude healthy eating	Healthy eating in the coming month is for me…	foolish–wise pleasant–unpleasant bad–good harmful–helpful unnecessary–necessary unenjoyable–enjoyable	0.70

Table 6.1. Continued.

Construct	Questionnaire Items	Answering Options (1–5)	Crohnbach's Alpha T0
Attitude physical activity	Physical activity in the coming month is for me…	foolish–wise pleasant–unpleasant bad–good harmful–helpful unnecessary–necessary boring–interesting	0.80

Compliance with Dutch dietary guidelines and guidelines for physical activity

Compliance with Dutch dietary guidelines and guidelines for physical activity were evaluated using the DHD-FFQ, which was administered during a structured interview at T0 and T2. The DHD-FFQ contains 28 items that evaluate compliance with Dutch dietary guidelines and compliance with PA guidelines [30, 39]. Additionally, for this study, compliance with guidelines for the intake of protein and vitamin D was evaluated as the DHD-FFQ contains questions on all relevant protein and vitamin D sources consumed by a Dutch elderly population [3, 40]. This resulted in sub scores for compliance with guidelines for the intake of fruit (≥200 g), vegetables (≥150–200 g), dietary fibre (≥14 g/4.2 MJ), fish (two times per week, from which at least one time fatty fish), saturated fatty acids (<10 en%), trans fatty acids (<1 en%), salt (<6 g), alcohol (≤2 glasses for men, ≤1 glass for women), protein (≥70 grams for men, ≥55 grams for women), vitamin D (≥20 mcg), and physical activity (moderate physical activity for at least 30 min a day on at least five days a week). These scores ranged from 0–10, with higher scores indicating better compliance. A total score for diet quality was constructed by summing scores for vegetables, fruit, dietary fibre, fish, alcohol, saturated fatty acids, trans-fatty acids, and sodium. More information can be found elsewhere [30].

Statistics

The sample size was based on the primary outcome of the main study: nutritional status [34]. Aiming to detect a difference in MNA change of three, assuming a standard deviation of 6.1 [41], and taking into account a two-sided significance level of 0.05 and power of 80%, a sample size of 65 participants per group was required based on the formula $2 \times \frac{[(Z\alpha/2 + Z\beta)^2 \times \sigma^2]}{\delta^2}$. We expected a drop-out rate of 30% at maximum, therefore we needed a sample size of at least 93 participants in each group.

Data were analysed using SPSS Statistics for Windows version 22 (IBM Corp., Armonk, NY, USA). Statistical analyses were carried out according to the intention-to-treat principle. Firstly, baseline characteristics of the intervention and control group were described using means (± standard deviations) or percentages. Differences between the groups were tested using independent *t*-tests, Mann-Whitney *U* tests in case of non-normality, or chi-square tests. Secondly, changes in self-monitoring and goalsetting and intervention effects on behavioural determinants were assessed using linear mixed models. Therefore, we first specified a model as large as possible including all main effects, possible interactions, and an unstructured covariance matrix. We then simplified the random part of the model by testing whether simpler covariance structures were allowed using the (REML) LR test, until a model was obtained that was as parsimonious as possible. Consequently, we simplified the fixed part of the model by including dummies for time points T1 and T2, treatment, the interaction terms of the time point dummies and treatment, age, sex, and also other covariates (e.g., BMI, education level, living situation, MNA, functional status, MMSE, municipality, diet, informal care) if they considerably (e.g., >10%) influenced the effect estimates. Thirdly, we performed mediation analyses to evaluate whether the effects of PhysioDom HDIM were mediated as hypothesised (Figure 6.1). The following outcomes were selected for mediation analyses as these were positively affected by the PhysioDom HDIM intervention: compliance with the Dutch dietary guidelines for the intake of fruit, vegetables, fibre, and protein, and compliance with Dutch guidelines for PA [22]. As mediation can also exist in absence of a significant intervention effect on the study's outcomes [42], also other components of the DHD-FFQ (alcohol, salt, saturated fatty acids, fish, and for this study vitamin D) and the total DHD-FFQ score were included as outcomes in the mediation analyses. To capture the longitudinal nature of the data, we used a multiple serial mediation model for each outcome and each hypothesised mediator in which the mediator at T1 and T2 was modelled in sequence (Figure 6.1). We regarded a parallel multiple mediator model less appropriate as the condition that no mediator causally influences another would probably not be fulfilled [42]. Using the PROCESS macro for SPSS version 2.16.3 we assessed whether indirect effects of the intervention on the selected outcomes through the hypothesised mediators were statistically significant [42]. Standard errors and confidence intervals of indirect effects were calculated using bootstrapping (10,000 samples). The analyses for diet quality and physical activity were adjusted for age, sex, and baseline values of the mediator.

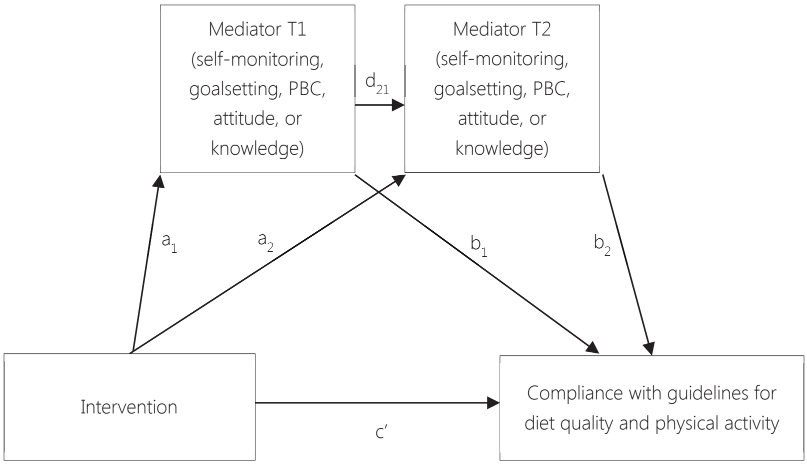

Figure 6.1. Hypothesised mediation pathways in the PhysioDom Home Dietary Intake Monitoring (HDIM) intervention. One model for each outcome and mediator.

RESULTS

Baseline characteristics

In total, 215 persons were screened, from which 97 were allocated to the intervention group and 107 to the control group. During the study, 21 intervention group participants and six control group participants were lost to follow-up. A flow chart with reasons for loss to follow-up can be found in Figure 6.2.

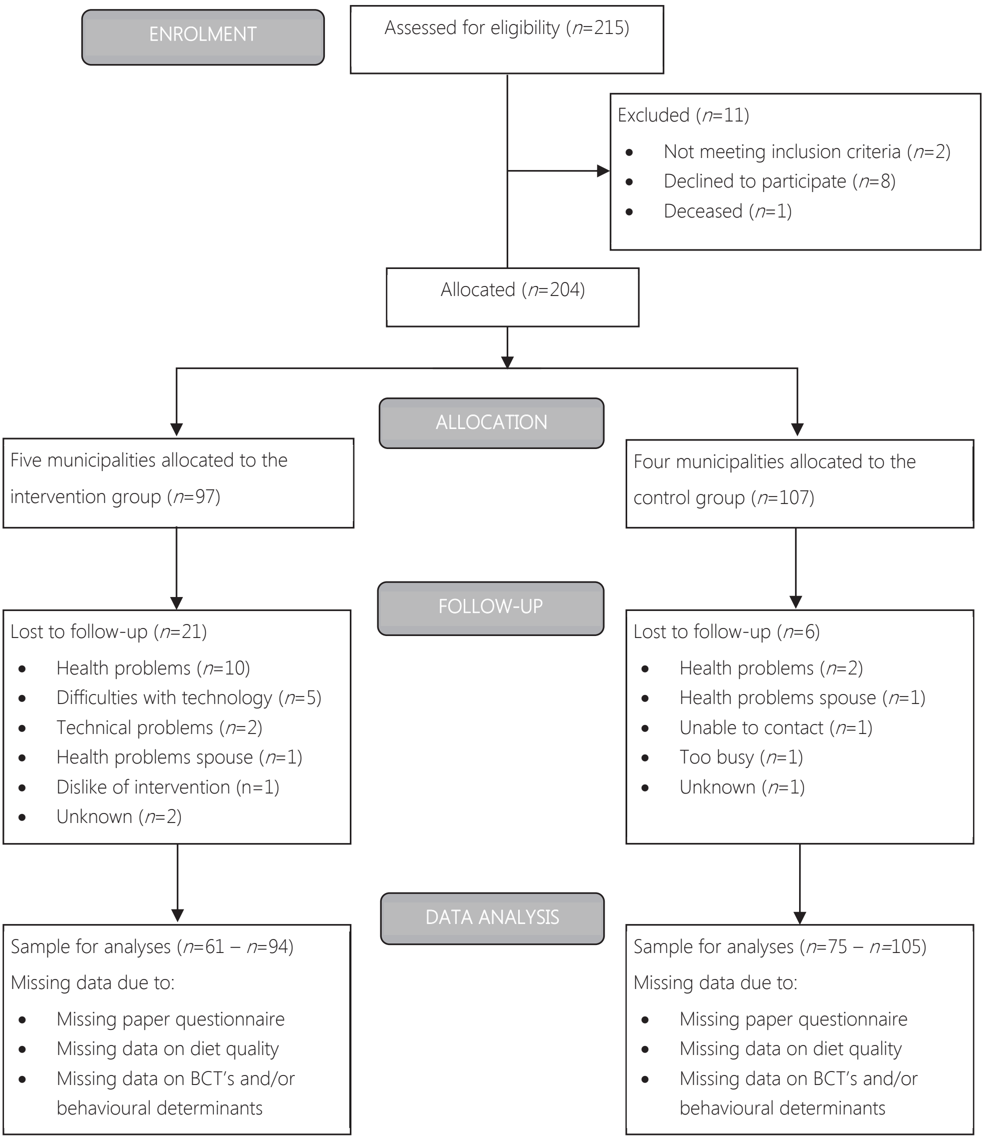

Figure 6.2. Flow diagram of participants of the PhysioDom HDIM study.

Table 6.2 shows the baseline characteristics of the intervention and control group. Participants in the intervention group were slightly younger and had a higher BMI than participants in the control group. Participants in the intervention group lived less often alone and received more often informal care than control group participants.

Table 6.2. Baseline characteristics of participants of the PhysioDom HDIM study.

	Intervention group (n=97)		Control group (n = 107)		p-value [a]
	Mean	SD	Mean	SD	
Age (years)	78.4	7.2	81.0	7.9	0.02
BMI (kg/m2)	29.2	4.5	27.7	5.4	0.04
Number of diagnoses	1.5	1.5	1.3	1.3	0.26
MMSE score	28.6	1.5	25.8	1.9	0.69
Katz-15 score	Mdn	IQR	Mdn	IQR	
	1.0	0–4	1.0	0–3	0.69
	Percentage		Percentage		
Sex (male)	35		23.4		0.09
Education level [b]					0.08
Low	17.5		10.3		
Moderate	55.7		49.5		
High	26.8		40.2		
Civil status					0.11
Married	42.3		27.1		
Single	7.2		13.1		
Divorced	7.2		10.3		
Widowed	43.3		49.5		
Living alone	55.7		74.8		0.004
Born in the Netherlands	96.9		90.7		0.07
Desire to lose weight	52.7		39.4		0.07
Nutritional status					0.45
Normal nutritional status	79.2		83.8		
At risk of undernutrition	19.8		16.2		
Undernourished	1.0		0.0		
Type of care					
Domestic care	78.4		80.4		0.72
Personal care	32.0		29.9		0.75
Nursing care	9.3		2.8		0.05
Individual support	3.1		0.9		0.27
Informal care	32.0		11.2		<0.001

SD, Standard Deviation; BMI, Body Mass Index; MMSE, Mini-Mental State Examination. [a] Independent *t*-test, Mann-Whitney test, or chi-square test. [b] Low education level: primary school or less; Intermediate level of education: secondary professional education or vocational school; High education level: higher vocational education, university.

Changes in self-monitoring and goalsetting and effects on behavioural determinants

Table 6.3 shows changes in self-monitoring and goalsetting and shows the effects of the intervention on behavioural determinants. At baseline, there were no significant differences between the intervention and control group. During the intervention, several significant changes were observed. Firstly, the intervention group significantly increased scores for self-monitoring at T1 and T2, compared to the control group (T1: $\beta = 0.49$, 95% CI 0.19, 0.80; T2: $\beta = 0.50$, 95% CI 0.20, 0.80). Secondly, intervention participants perceived an increased behavioural control for physical activity at T2 compared to the control group ($\beta = 0.26$, 95% CI 0.08, 0.45). Thirdly, participants in the intervention group improved their knowledge at T1 and T2 compared to the control group, with the improvement at T2 being significant ($\beta = 0.51$, 95% CI 0.04, 0.99).

Table 6.3. Changes in self-monitoring and goalsetting and effects of the PhysioDom HDIM intervention on knowledge, perceived behavioural control, and attitude.

	Intervention group						Control group						Linear mixed models		
	T0		T1		T2		T0		T1		T2		β T1 (95% CI)	β T2 (95% CI)	N
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Self-monitoring	2.9	1.2	3.5	0.9	3.3	1.1	3.1	1.2	3.1	1.2	3.0	1.3	0.49 (0.19, 0.80) **	0.50 (0.20, 0.80) **	199
Goalsetting	2.7	1.2	3.0	1.1	2.8	1.2	3.0	1.1	3.0	1.3	2.9	1.2	0.25 (−0.05, 0.55)	0.19 (−0.10, 0.48)	199
Knowledge [a]	7.3	2.1	8.2	1.9	8.3	1.8	7.5	2.0	7.5	2.1	7.6	2.2	0.51 (−0.09, 1.12)	0.51 (0.04, 0.99) *	198
PBC HE [b]	4.1	0.7	4.2	0.7	4.2	0.6	4.3	0.6	4.1	0.8	4.3	0.7	0.16 (−0.02, 0.33)	0.08 (−0.09, 0.25)	188
PBC PA	3.7	0.8	3.8	0.9	3.9	0.9	4.0	0.9	3.8	1.0	3.9	0.9	0.19 (−0.03, 0.41)	0.26 (0.08, 0.45) **	199
Attitude HE [c]	4.7	0.5	4.7	0.5	4.7	0.5	4.6	0.5	4.6	0.5	4.6	0.6	−0.01 (−0.18, 0.16)	0.00 (−0.17, 0.17)	188
Attitude PA [d]	4.5	0.6	4.4	0.8	4.5	0.7	4.5	0.7	4.4	0.8	4.5	0.7	−0.04 (−0.29, 0.22)	−0.05 (−0.26, 0.15)	190

SD, standard deviation; CI, confidence interval; PBC: perceived behavioural control; HE: healthy eating; PA: physical activity. All results are adjusted for age and sex. [a] Adjusted for age, sex, and Mini Mental State Examination score. [b] Adjusted for age, sex, BMI, living situation, nutritional status, and physical functioning. [c] Adjusted for age, sex, BMI, physical functioning and cognitive functioning. [d] Adjusted for age, sex, BMI, physical functioning. * $p < 0.05$; ** $p < 0.01$.

Effect mediation

Four significant mediation pathways were found. Firstly, the effect of the intervention on compliance with the guidelines for the intake of fruit was mediated by increased self-monitoring behaviour at T1. Secondly, the effect of the intervention on compliance with the guidelines for the intake of protein was mediated by improvements in knowledge at T1 and T2 (Table 6.4). Thirdly, even though a significant effect of the intervention on the total DHD-FFQ score was lacking, we found significant mediation by self-monitoring at T1 (Appendix 6.1). Likewise, increased self-monitoring mediated the intervention's effect on compliance with guidelines for the intake of saturated fat (Appendix 6.1).

Table 6.4. Mediation of the intervention's effect on diet quality and physical activity.

	Indirect effect 1 [a,b] ($a_1 \times b_1$)		Indirect effect 2 [a,c] ($a_1 \times d_{21} \times b_2$)		Indirect effect 3 [a,d] ($a_2 \times b_2$)		
	β (SE)	95% CI	β (SE)	(95% CI)	β (SE)	(95% CI)	*N*
T0–T2 Fruit							
Self-monit.	0.16 (0.10)	0.02, 0.45	0.02 (0.04)	−0.04, 0.13	0.04 (0.08)	−0.11, 0.24	141
Goalsetting	0.03 (0.08)	−0.08, 0.27	−0.00 (0.03)	−0.09, 0.03	−0.01 (0.04)	−0.15, 0.03	140
Knowledge	0.17 (0.14)	−0.01, 0.57	−0.02 (0.05)	−0.15, 0.05	−0.02 (0.06)	−0.21, 0.04	139
PBC HE	0.01 (0.05)	−0.05, 0.18	0.02 (0.03)	−0.01, 0.13	−0.02 (0.05)	−0.20, 0.04	136
Attitude HE	−0.00 (0.04)	−0.09, 0.07	0.00 (0.01)	−0.01, 0.03	−0.00 (0.05)	−0.12, 0.07	137
T0–T2 Vegetables							
Self–monit.	−0.07 (0.11)	−0.11, 0.35	−0.06 (0.05)	−0.22, 0.01	−0.12 (0.11)	−0.39, 0.04	141
Goalsetting	0.01 (0.06)	−0.05, 0.22	−0.00 (0.03)	−0.07, 0.05	−0.00 (0.05)	−0.12, 0.08	140
Knowledge	−0.07 (0.09)	−0.32, 0.06	−0.01 (0.05)	−0.11, 0.08	−0.01 (0.06)	−0.18, 0.08	139
PBC HE	−0.01 (0.07)	−0.25, 0.06	−0.01 (0.03)	−0.13, 0.02	0.02 (0.05)	−0.04, 0.21	136
Attitude HE	−0.01 (0.07)	−0.23, 0.07	0.00 (0.01)	−0.01, 0.04	−0.00 (0.05)	−0.13, 0.08	137
T0–T2 Dietary fibre							
Self-monit.	−0.07 (0.07)	−0.27, 0.03	0.03 (0.04)	−0.02. 0.14	0.07 (0.07)	−0.05, 0.26	141
Goalsetting	−0.00 (0.03)	−0.08, 0.05	0.01 (0.02)	−0.02, 0.09	0.02 (0.04)	−0.02, 0.15	140
Knowledge	0.02 (0.06)	−0.06, 0.22	0.01 (0.03)	−0.04, 0.10	0.1 (0.04)	−0.04, 0.14	139
PBC HE	0.05 (0.05)	−0.03, 0.20	−0.01 (0.02)	−0.08, 0.01	0.01 (0.03)	−0.02, 0.13	136
Attitude HE	0.00 (0.03)	−0.05, 0.06	0.00 (0.01)	−0.00, 0.03	−0.00 (0.02)	−0.09, 0.03	137
T0–T2 Protein							
Self-monit.	−0.25 (0.19)	−0.76, 0.00	0.00 (0.08)	−0.16, 0.18	0.00 (0.17)	−0.37, 0.34	141
Goalsetting	−0.04 (0.12)	−0.42, 0.12	0.01 (0.06)	−0.05, 0.23	0.04 (0.09)	−0.05, 0.37	140
Knowledge	−0.07 (0.12)	−0.44, 0.07	0.12 (0.09)	0.006, 0.41	0.12 (0.13)	−0.04, 0.52	139
PBC HE	0.06 (0.09)	−0.04, 0.40	−0.02 (0.04)	−0.17, 0.02	0.02 (0.07)	−0.05, 0.28	136
Attitude HE	0.01 (0.07)	−0.08, 0.23	0.00 (0.01)	−0.01, 0.06	−0.01 (0.06)	−0.20, 0.08	137
T0–T2 Physical activity							
Self-monit.	−0.02 (0.16)	−0.40, 0.29	−0.04 (0.08)	−0.27, 0.07	−0.10 (0.17)	−0.52, 0.18	141
Goalsetting	−0.02 (0.08)	−0.32, 0.07	−0.00 (0.05)	−0.51, 0.07	−0.01 (0.08)	−0.25, 0.10	140
Knowledge	−0.10 (0.13)	−0.49, 0.07	−0.04 (0.07)	−0.24, 0.05	−0.04 (0.09)	−0.35, 0.05	139
PBC PA	−0.04 (0.10)	−0.31, 0.10	0.07 (0.08)	−0.01, 0.34	0.16 (0.13)	−0.02, 0.51	137
Attitude PA	−0.003(0.05)	−0.14, 0.07	0.001 (0.02)	−0.04, 0.06	0.008 (0.05)	−0.06, 0.17	133

SE: standard error; Self-monit.: Self-monitoring; CI: confidence interval; PBC: perceived behavioural control; HE: healthy eating, PA: physical activity. All results were adjusted for age and sex. [a] Standard errors and confidence intervals for indirect effects were calculated with bootstrapping (10,000 samples). [b] Indirect effect of the intervention on the outcome Y through the mediator at T1. [c] Indirect effect of the intervention on the outcome Y through the mediators at T1 and T2 in serial. [d] Indirect effect of the intervention on the outcome Y through the mediator at T2.

DISCUSSION

This study aimed to evaluate the effects of a multi-component telemonitoring intervention on behavioural determinants of nutrition and physical activity behaviour in older adults, and to evaluate the role of mediators in the effects on behaviour. The intervention resulted in improvements in self-monitoring, perceived behavioural control for physical activity, and knowledge. Furthermore, self-monitoring mediated the effect of the intervention on total diet quality score and compliance with the guidelines for the intake of fruit and saturated fatty acids. Knowledge mediated the effect of the intervention on compliance with the guidelines for the intake of protein.

Intervention group participants increased their self-monitoring, which mediated the effect of the intervention on total DHD-FFQ score, and the intake of fruit and saturated fatty acids. Scores for self-monitoring improved from 2.9 at T0 to 3.5 at T1 and 3.3 at T2, meaning that the frequency of self-monitoring increased from on average a few times per month to somewhere between a few times per month and weekly, suggesting that this rather small change is already sufficient to partly mediate the intervention's effect. Self-monitoring of diet, physical activity, and weight has mainly been used in weight loss programs with more frequent self-monitoring resulting in more weight loss as compared to less frequent self-monitoring [43]. Another study focussing on the effects of self-monitoring by means of mobile devices showed positive outcomes on dietary intake [44]. In an intervention study, the effect of daily tailored messaging on weight loss was mediated by self-monitoring of diet and physical activity [45]. In our study, self-monitoring mediated the effect of the intervention on total diet quality score and the intake of fruit and saturated fatty acids, but not the effect on other diet quality components. A possible explanation is that self-monitoring of diet was not very intensive as participants filled out the DHD-FFQ twice during the six-month intervention, as opposed to more frequent dietary self-monitoring encountered in other studies [44]. Apparently, also other mechanisms besides self-monitoring have caused the intervention to result in positive changes in diet quality and physical activity. Increasing the frequency of self-monitoring of dietary intake may strengthen the effect of this intervention.

The intervention resulted in increased perceived behavioural control for PA, but this did not mediate the intervention's effect on physical activity. This seems contradictory to the theory of planned behaviour that poses that PBC precedes behavioural intention and behaviour [46]. Furthermore, PBC is seen as a predictor of the translation of intention into behaviour [47, 48]. With regard to older adults, PBC is considered as a consistent predictor of physical activity initiation and maintenance [49]. In contrast, an intervention study aiming to improve physical activity among participants with increased risk of type 2 diabetes shows that PBC did not predict physical activity or change in physical activity [50]. The authors argue that the TPB may be less accurate in explaining behaviour among clinical samples than among the often-used student samples, which could also explain the lack of mediation by PBC in this study [50]. All in all, other mechanisms besides the ones that we have measured may have been important in increasing physical activity levels of our study population, for example, awareness, enjoyment, or action planning [49].

The intervention had a positive effect on knowledge, and this mediated the intervention's effect on compliance with the guidelines for the intake of protein, but not the effects on compliance with other dietary guidelines. Knowledge score improved from 7.3 at T0 to 8.3 at T2, meaning that intervention group participants were able to answer one more knowledge statement correctly, from the eleven statements in total. This rather small effect size may explain why the intervention's effect was only limitedly mediated via knowledge. Nutrition education intervention studies among older adults have shown positive effects on knowledge [51-53], although in the study by Racine et al, this was not associated with better adherence to the DASH diet [51, 52]. A review examining the relationship between nutrition knowledge and dietary intake showed positive but weak correlations [54]. The general idea is that nutritional knowledge is necessary but not sufficient for changing dietary habits, and that the association of knowledge with diet quality is complex and influenced by many other demographic and environmental factors [54]. Furthermore, the knowledge questionnaire used in this study assessed declarative knowledge, while procedural knowledge of nutrition (e.g., knowing how to read food labels or how to cook a healthy meal) might be more relevant for making healthy food choices [55]. Nevertheless, improved knowledge did mediate the intervention's effect on the compliance with dietary guidelines for protein intake. This is a relevant finding, as sufficient protein intake in older adults is necessary to counteract age-related loss of muscle mass [56]. Furthermore, older adults seem unaware of the importance of sufficient intake of protein [4]. This study suggests that increasing nutritional knowledge might be an effective and relatively easy way to improve protein intake in older adults.

The intervention did not result in significant changes in goalsetting, attitude, and perceived behavioural control for healthy eating. Several possible explanations could be given. The emphasis of the intervention was on self-monitoring of nutritional outcomes and PA. Participants received training and instructions to do these self-measurements and were reminded via a paper calendar and television messages, resulting in increased self-monitoring behaviour. Participants were also prompted to set goals for diet quality and PA, but only via the intervention manual and via television messages, which were not always read. This could explain the lack of significant effects on goalsetting. Secondly, attitude and perceived behavioural control for healthy eating were also targeted through television messages. Again, too little messages might have been read to have an impact on these behavioural determinants. Furthermore, television messages to target PBC for healthy eating were mainly focussed on the individual. However, PBC might also be affected by characteristics that are not easily targeted, such as impaired physical functioning, limited mobility, limited cooking skills, or more environmental determinants such as distance to a supermarket. All in all, to target goalsetting, attitude, and perceived behavioural control for healthy eating, a higher intervention dose might be necessary to result in change.

To our knowledge, this is the first study that aimed to unravel mechanisms of impact of an intervention that focused on improving nutritional status in community-dwelling elderly through eHealth. Strengths of this study include the use of a theoretical framework and validated constructs to measure behavioural determinants. This study also has limitations that may have contributed to the limited significant findings from the mediation analyses. The population for analysis was smaller for the mediation analyses than for the mixed model analyses, as the method used for mediation analyses is less flexible concerning missing data. This could have resulted in a loss of power or have obscured mediation pathways. Secondly, using self-report measures of diet and physical activity instead of objective measures of behaviour may have led to weaker associations with the proposed behavioural determinants [57]. Furthermore, older adults might be less good in filling out TPB questionnaires than younger adults [50]. Thirdly, it is uncertain whether BCT's which have been proven successful in younger populations can be applied in older populations as well [58]. It may well be that some BCT's may be too complex for older adults with impaired physical functioning or in another way do not appeal to older adults, potentially explaining the limited results from the mediation analyses. Finally, it is uncertain whether effects on behavioural determinants and behaviour will sustain. Participants could keep the weighing scale and pedometer to keep track of their weight and daily steps. Employing BCT's enhances the chance that participants maintain their behaviour [13]. On the other hand, this study mainly focussed on individual determinants of health behaviour, while it is suggested that organisational and societal determinants are also important for achieving sustained change [59]. More research is necessary to assess the long-term effectiveness of nutritional eHealth interventions, and what exactly contributes to long-term impact.

Finally, this study showed that a multi-component telemonitoring intervention for community-dwelling older adults resulted in increased self-monitoring behaviour, and improved perceived behavioural control for physical activity and knowledge. The intervention's effect on total diet quality score, fruit intake, and saturated fatty acids intake was mediated by self-monitoring and the effect on protein intake was mediated by knowledge. Apparently, other unknown mediators have also played an important role in achieving the intervention's results on diet quality and physical activity. This calls for more research into which behaviour change techniques are effective in improving nutritional outcomes in older adults.

AUTHOR CONTRIBUTIONS

Conceptualization, C.P.G.M.d.G., J.H.M.d.V. and A.H.-N.; Data curation, M.N.v.D.-v.A.; Formal analysis, M.N.v.D.-v.A.; Investigation, M.N.v.D.-v.A.; Methodology, M.N.v.D.-v.A., C.P.G.M.d.G., J.H.M.d.V. and A.H.-N.; Writing—original draft, M.N.v.D.-v.A.; Writing—review & editing, C.P.G.M.d.G., J.H.M.d.V. and A.H.-N.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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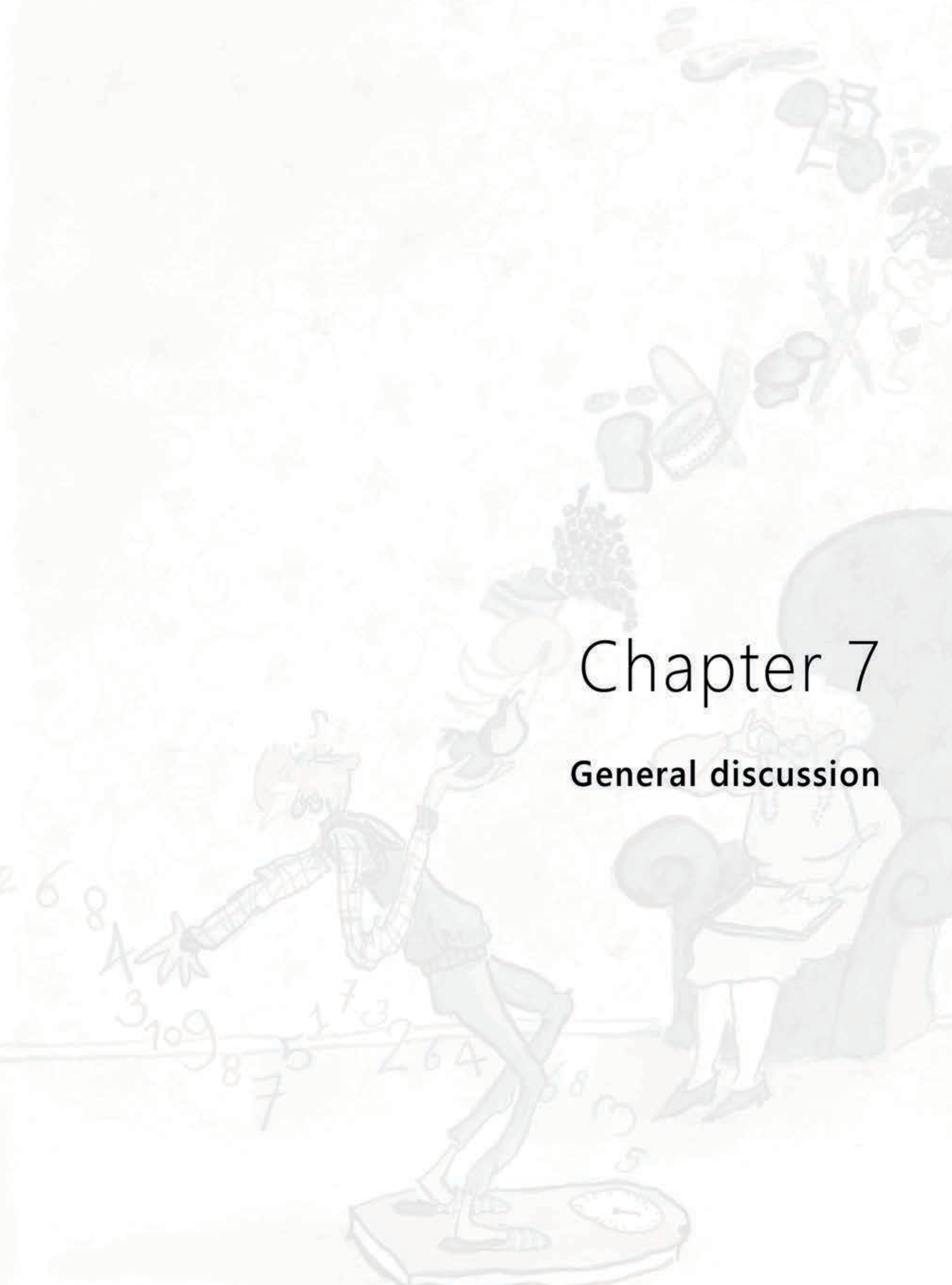
Appendix 6.1. Mediation of the intervention's effect on total diet quality score and other diet quality components.

	Indirect effect 1 [a, b] ($a_1 * b_1$)		Indirect effect 2 [a, c] ($a_1 * d_{21} * b_2$)		Indirect effect 3 [a, d] ($a_2 * b_2$)		
	β (SE)	95% CI	β (SE)	(95% CI)	β (SE)	(95% CI)	N
T0-T2 Total DHD-FFQ score							
Self-monit.	**0.79 (0.50)**	**0.09, 2.11**	0.07 (0.21)	-0.27, 0.65	0.16 (0.47)	-0.61, 1.35	141
Goalsetting	0.07 (0.30)	-0.24, 1.06	0.04 (0.16)	-0.15, 0.65	0.11 (0.26)	-0.15, 1.06	140
Knowledge	0.23 (0.37)	-0.28, 1.32	-0.17 (0.19)	-0.74, 0.07	-0.18 (0.27)	-1.10, 0.11	139
PBC HE	0.05 (0.23)	-0.28, 0.76	0.01 (0.11)	-0.20, 0.27	-0.01 (0.16)	-0.44, 0.28	136
Attitude HE	-0.03 (0.16)	-0.55, 0.19	-0.01 (0.06)	-0.19, 0.05	0.05 (0.24)	-0.30, 0.80	137
T0-T2 Fish							
Self-monit.	-0.07 (0.11)	-0.36, 0.10	0.01 (0.06)	-0.09, 0.14	0.02 (0.12)	-0.20, 0.30	141
Goalsetting	-0.01 (0.07)	-0.23, 0.07	-0.00 (0.03)	-0.08, 0.06	-0.00 (0.05)	-0.14, 0.09	140
Knowledge	0.09 (0.10)	-0.04, 0.38	-0.02 (0.06)	-0.17, 0.08	-0.02 (0.07)	-0.24, 0.08	139
PBC HE	0.05 (0.09)	-0.04, 0.35	-0.02 (0.04)	-0.18, 0.02	0.02 (0.06)	-0.04, 0.22	136
Attitude HE	0.00 (0.04)	-0.08, 0.09	-0.00 (0.01)	-0.04, 0.01	0.01 (0.05)	-0.06, 0.17	137
T0-T2 Saturated fatty acids							
Self-monit.	**0.31 (0.21)**	**0.02, 0.86**	0.06 (0.09)	-0.05, 0.32	0.14 (0.18)	-0.14, 0.59	141
Goalsetting	0.05 (0.16)	-0.17, 0.51	-0.00 (0.06)	-0.18, 0.10	-0.01 (0.10)	-0.30, 0.15	140
Knowledge	0.03 (0.15)	-0.22, 0.40	-0.03 (0.08)	-0.24, 0.09	-0.03 (0.10)	-0.35, 0.09	139
PBC HE	-0.01 (0.10)	-0.29, 0.16	0.04 (0.06)	-0.03, 0.27	-0.04 (0.10)	-0.39, 0.08	136
Attitude HE	-0.03 (0.12)	-0.46, 0.12	-0.01 (0.03)	-0.12, 0.02	0.03 (0.12)	-0.15, 0.37	137
T0-T2 Salt							
Self-monit.	0.05 (0.13)	-0.17, 0.37	0.02 (0.07)	-0.10, 0.20	0.04 (0.15)	-0.23, 0.40	141
Goalsetting	-0.00 (0.07)	-0.18, 0.12	0.01 (0.05)	-0.04, 0.19	0.03 (0.08)	-0.05, 0.34	140
Knowledge	0.00 (0.11)	-0.21, 0.27	-0.08 (0.07)	-0.32, 0.01	-0.08 (0.10)	-0.42, 0.03	139
PBC HE	-0.06 (0.09)	-0.37, 0.04	0.02 (0.04)	-0.02, 0.15	-0.02 (0.06)	-0.23, 0.04	136
Attitude HE	0.01 (0.05)	-0.05, 0.16	-0.00 (0.02)	-0.05, 0.02	0.01 (0.07)	-0.10, 0.20	137
T0-T2 Alcohol							
Self-monit.	0.04 (0.04)	-0.02, 0.17	0.01 (0.04)	-.0.05, 0.11	0.02 (0.08)	-0.13, 0.20	141
Goalsetting	-0.00 (0.03)	-0.10, 0.05	0.00 (0.02)	-0.01, 0.06	0.01 (0.02)	-0.01, 0.09	140
Knowledge	-0.00 (0.03)	-0.08, 0.05	0.01 (0.03)	-0.03, 0.11	0.01 (0.04)	-0.03, 0.15	139
PBC HE	0.01 (0.02)	-0.01, 0.07	0.01 (0.02)	-0.01, 0.11	-0.01 (0.04)	-0.18, 0.03	136
Attitude HE	0.00 (0.03)	-0.02, 0.10	-0.00 (0.02)	-0.08, 0.01	0.01 (0.08)	-0.07, 0.31	137
T0-T2 Vitamin D							
Self-monit.	0.00 (0.04)	-0.07, 0.08	-0.01 (0.03)	-0.06, 0.06	-0.01 (0.06)	-0.14, 0.11	141
Goalsetting	-0.00 (0.02)	-0.07, 0.03	-0.00 (0.01)	-0.05, 0.01	-0.01 (0.02)	-0.09, 0.01	140
Knowledge	0.01 (0.03)	-0.05, 0.08	0.03 (0.04)	-0.01, 0.16	0.04 (0.05)	-0.01, 0.24	139

Appendix 6.1. continued.

	Indirect effect 1 [a, b] ($a_1 * b_1$)		Indirect effect 2 [a, c] ($a_1 * d_{21} * b_2$)		Indirect effect 3 [a, d] ($a_2 * b_2$)		
	β (SE)	95% CI	β (SE)	(95% CI)	β (SE)	(95% CI)	N
PBC HE	0.02 (0.0.3)	-0.01, 0.12	-0.02 (0.03)	-0.12, 0.01	0.02 (0.05)	-0.03, 0.17	136
Attitude HE	0.00 (0.02)	-0.03, 0.08	-0.00 (0.00)	-0.02, 0.01	0.00 (0.02)	-0.03, 0.06	137

SE: standard error; Self-monit: Self-monitoring; CI: confidence interval; PBC: perceived behavioural control; HE: healthy eating, PA: physical activity. All results were adjusted for age and sex. [a] Standard errors and confidence intervals for indirect effects were calculated with bootstrapping (10.000 samples). [b] Indirect effect of the intervention on the outcome Y through the mediator at T1. [c] Indirect effect of the intervention on the outcome Y through the mediators at T1 and T2 in serial. [d] Indirect effect of the intervention on the outcome Y through the mediator at T2.



Chapter 7

General discussion

AIM AND SUMMARY OF MAIN FINDINGS

The aim of this thesis was to study the feasibility and the effectiveness of a multi-component intervention for community-dwelling older adults consisting of telemonitoring of nutritional outcomes and physical activity (PA), nutrition and PA education, and follow-up by a nurse. This was done by conducting a twelve-week pilot study and a six-month effect study that were guided by process and effect evaluations (Chapter 2). The pilot study, conducted among 20 Dutch home care clients, showed that the telemonitoring intervention was implemented as intended, but that acceptability among home care clients was low, leading to high levels of drop-out (Chapter 3). Insights from the pilot study were used to improve the intervention, after which it was implemented for six months among Dutch, Spanish, and British community-dwelling older adults. Results from the Dutch effect study showed that adherence to several components of the Dutch food based dietary guidelines and to PA recommendations improved in the intervention group, and that intervention group participants with risk of undernutrition improved their nutritional status, as compared to the control group (Chapter 4). A process evaluation of the Dutch effect study revealed that the telemonitoring intervention was feasible to implement and accepted well among participants. However, issues remain to be addressed that would hinder long-term implementation, for example suboptimal usability of the intervention technology and moderate satisfaction rates by nurses. The process evaluation further revealed that participants' intention to use the intervention was predicted by expected intervention benefits and social influence, and that process indicators were not associated with intervention effects (Chapter 5). Chapter 6 shows that the intervention positively influenced several behavioural determinants, from which knowledge mediated the intervention's effect on adherence to guidelines for protein intake. The behaviour change technique self-monitoring mediated the intervention's effect on diet quality and on adherence to guidelines for the intake of fruit and saturated fatty acids.

EFFECTIVENESS

The intervention resulted in positive effects on short-term outcomes (behavioural determinants), intermediate-term outcomes (health behaviours), and long-term outcomes (health). With regard to short-term outcomes, the intervention resulted in improved knowledge and improved perceived behavioural control for PA. Insight into modifiable determinants of nutrition and PA behaviours in older adults is valuable for intervention development, but research on this topic is still scarce [1]. The paragraph 'Mechanisms of impact' elaborates further on these findings.

With regard to intermediate-term outcomes, the intervention resulted in improved compliance with several Dutch dietary guidelines and Dutch guidelines for PA. Participants filled out the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) to assess compliance with these guidelines and to receive computer-tailored advice on how to improve compliance [2]. To our knowledge, this is one of the first studies that evaluated a short dietary screener as a tool to assess and improve diet quality among community-dwelling older adults, as part of a multi-component intervention. One other study evaluated a health promotion program among employees that included a screener to assess DASH diet adherence and to provide feedback, leading to improved fruit and vegetables intake [3, 4]. Another study implementing a similar approach in a general adult population concluded that personalised nutrition advice was more effective in improving dietary behaviour than 'one size fits all population-based advice' [5]. Another study described the development of a dietary screening tool for older adults, but did not evaluate implementation of this tool in practice [6]. Likewise, many studies focus on validation of short dietary screeners, but not on implementation in practice [7-11]. Furthermore, many existing dietary screeners focus on only one or a few dietary components, limiting the use to certain patient or at risk groups [12-16]. In contrast, the DHD-FFQ gives an overall picture of diet quality as it measures compliance to the national dietary guidelines, and has been further developed for implementation in various settings and population groups. Therefore, this short dietary screener with personalised feedback may be a promising and scalable approach for improving diet quality in older community-dwelling populations.

With regard to long-term outcomes, the intervention resulted in improved nutritional status in participants with risk of undernutrition, but not in participants with a normal nutritional status. The European PhysioDom study with pooled results from the British, Spanish and Dutch study sites adds to these findings by showing an improved appetite, nutritional status, and quality of life in participants with poor scores for appetite, nutritional status, and quality of life, respectively [17]. This diverging intervention response can be explained by varying degrees of intervention exposure, as participants at risk received a higher intervention dose including personal follow-up from a nurse. This follow-up consisted of nutrition counselling, which has been shown to improve nutritional status of older adults [18-20]. Two other studies also show better intervention responsiveness in participants with risk of undernutrition compared to participants without nutritional risk [21, 22]. Our results are also in line with a recent review concerning undernutrition-related eHealth interventions for community-dwelling older adults [23]. The review shows that eHealth interventions can result in improved dietary intake and quality of life, and a non-significant trend toward improved nutritional status was shown. A major difference with our research concerns the study population, with the reviewed studies mainly including participants at nutritional risk who were discharged from the hospital or rehabilitation ward. Our research adds to these findings by showing positive intervention effects on nutritional status in a more general community-dwelling older population at risk of undernutrition. Lastly, considering the effect sizes, other non-eHealth studies show similar [22] to slightly smaller [21] or slightly greater [24] effects on nutritional status compared to effects in our participants at risk of undernutrition, suggesting that an eHealth intervention may achieve more or less similar results compared to non-eHealth interventions.

The intervention did not lead to changes in physical functioning and quality of life. Physical functioning and quality of life might have been affected when the intervention would have been more intensive or the intervention duration would be longer, as healthy lifestyle behaviours may translate into compressed morbidity and decreased mortality risk [25]. However, with a longer intervention period 'the law of attrition' may become an issue, indicating the phenomenon that a substantial proportion of participants drops out or stops using an eHealth application over time [26]. The longer the study duration, the more effort should be undertaken to keep participants engaged. This could be done by, for example, introducing incentives or game elements [27]. Alternatively, a strengthened emphasis on habit formation can also be a strategy to maintain healthy behaviours that ultimately affect long-term outcomes such as functioning and quality of life.

FEASIBILITY

Apart from effectiveness, feasibility of an intervention should also be assessed to support implementation in public health practice [28]. After adjustment of the intervention in response to the pilot study, the intervention was accepted well among participants. Health care professionals, however, were neutral to positive about the intervention (Chapter 5). Several barriers and facilitators could be identified that influenced feasibility of this intervention.

Barriers that would hinder long-term implementation of this study include poor usability of the technology (for both participants and health care professionals), low perceived benefits of the intervention, poor adherence to digital telemonitoring questionnaires, and poor fit with working routine of health care professionals (Chapter 5). Much research concerning acceptability and feasibility has focused on potential users of eHealth [29] or existing eHealth services [30]. We found only two studies which focused on acceptability of nutrition-related eHealth interventions for older adults. In these studies, barriers are mentioned such as low perceived need for monitoring, limited awareness of undernutrition, low acceptability of the nutrition intervention [31], and frequent technological failure [32]. These barriers are in line with the major barriers encountered in our research, emphasising the need to improve undernutrition awareness among older adults, in turn influencing the perceived need for the intervention. This is crucial, as perceived need or benefit predicts intention to use an intervention, as shown in Chapter 5 and in literature [29, 33]. Furthermore, the identified barriers emphasize the importance of an optimal match between technology with the needs, wishes, and capabilities of its end-users. A mismatch and suboptimal usability may result from a technology-driven approach in which engineers do not engage with health care professionals and end-users [34]. This collaboration may be hindered by differences such as language and methodology [35]. User-centred, participatory design and a collaborative approach involving relevant stakeholders are appropriate strategies to develop eHealth interventions that connect well to the needs, wishes, and capabilities of the elderly end-users [36].

Major facilitators for implementation included the presence of a helpdesk, perceived benefits of the intervention, and support from health care professionals (Chapter 5). Other studies also mention the important role of nurses, relatives, or other human support in implementing a nutritional eHealth intervention and this could therefore be a successful strategy to enhance acceptability [31, 32, 37]. Other suggested facilitators for improving acceptability of nutritional eHealth interventions for older adults include cooperation with GPs, timely follow-up of telemonitoring measurements [31], and considering design features that are important for elderly end-users [38]. Researchers and eHealth developers should also keep in mind that older adults show considerable variety in for example health, health literacy, and computer literacy. One specific design will therefore not fit all and eHealth developers should take this diversity into account [39].

MECHANISMS OF IMPACT

So far, we have discussed implementation and outcomes of the PhysioDom HDIM intervention. Mechanisms of impact form the bridge between these two, explaining how an intervention leads to change [28]. Concerning this research, it would be interesting to have insight into the relative importance of the intervention components in establishing effects (e.g. telemonitoring, education, follow-up). However, we found no association between process indicators and intervention outcomes (Chapter 5), and we found only limited evidence for mechanisms of impact (Chapter 6). This may indicate that the association between intervention exposure and intervention outcome is more complicated than hypothesised. Insight into this so-called 'black box' is needed to reveal effective intervention elements and to inform intervention development [28]. Literature provides some insight into this. A review of home-based health behaviour interventions for frail community-dwelling elderly shows that elements such as 'education', 'enablement', 'adding objects to the environment' (e.g. a medicine dispenser), 'instructions on how to perform behaviour', and 'restructuring the physical environment' (e.g. removing objects for fall prevention) are associated with positive effects on physical functioning [40]. Concerning dietary interventions for older adults, behaviour change techniques (BCT's) such as 'barrier identification/problem solving', 'plan social support/social change', 'use of follow-up prompts' and 'goalsetting (outcome)' were associated with positive outcomes [41]. With regard to improving PA in older adults, 'feedback' was related to intervention effectiveness, often implemented in combination with other techniques such as self-monitoring or goalsetting [42]. However, in another review 'feedback' was associated with smaller effect sizes of PA change in older adults compared to studies not incorporating this BCT [43]. With regard to eHealth interventions to promote health behaviour change, the use of theory, especially the theory of planned behaviour, was associated with enhanced effectiveness, as well as the number of BCT's and additional modes of communicating with participants (e.g. SMS or text messages) [44]. The diversity of abovementioned results suggests that effective intervention elements vary by target population, target behaviour, intervention content, mode of delivery, and setting [45, 46]. A more narrow review focussing on undernutrition-related eHealth interventions in older adults shows that interventions with telephone consultation may be more successful than interventions with computerised devices, although only two studies with computerised devices were included [23]. Issues that hamper research concerning mechanisms of impact include insufficient reporting of BCT's [43, 47], uncertainty whether a BCT was implemented as planned [42], and the use of univariate statistical methods versus multivariate methods as BCT's are often combined and have a cumulative or synergistic effect [42, 46]. Future research should take these issues into account and researchers should be aware that intervention characteristics and context will probably affect the effectiveness of BCT's. This research informs future intervention development by showing that improved knowledge and increased self-monitoring mediated the intervention's effect on components of diet quality.

METHODOLOGICAL CONSIDERATIONS

Having reflected on the results of this research, some methodological considerations need to be highlighted. Firstly, eHealth is a rapidly developing field. Research findings may become outdated with technological advancement. By describing and testing the theory underpinning the intervention, however, we aimed to generate results that remain relevant for future technology based interventions [48]. Secondly, the PhysioDom HDIM intervention was initially developed in practice without reference to behavioural theory. We therefore identified theory and behaviour change techniques implicitly present in the intervention (Chapter 2) and tested these (Chapter 6). We found limited evidence for the hypothesized mediators and mechanisms of impact. This may indicate that a priori building on behaviour change theory remains preferable. For example, social support may be an important determinant of behavioural change in older adults [49, 50], which has not been explicitly incorporated during intervention development. On the other hand, practice constitutes a valuable source for intervention development with regard to maximising acceptability, feasibility, and external validity [51]. A combined effort of scientists and stakeholders from practice in developing interventions might therefore be most suitable [36]. Thirdly, the study populations in this research were quite heterogeneous, including participants with and without home care, with and without nutritional risk, and participants having a varying number of chronic conditions. We might have observed more effect when we would have included a more homogeneous study population [52]. On the other hand, a more diverse study population improves external validity, as opposed to other studies including only malnourished participants or patients discharged from a long-term care facility [23]. Neville et al pointed at the low external validity of computer-tailored dietary behaviour change interventions including populations that do not reflect a real-life setting [53]. The question remains which populations will benefit most of these types of interventions, also depending on whether the main focus of the intervention is preventative or curative. Novel approaches using big data or routine care data might be able to identify at-risk groups who may benefit from these types of interventions [54].

IMPLICATIONS FOR PRACTICE

Based on this thesis, a number of implications for practice are presented. This research shows that eHealth can be a promising approach in improving access to nutrition care. The Dutch "Care Module Nutrition" (Zorgmodule Voeding) is a norm that describes how nutrition care should take place, thereby distinguishing four levels: self-management, general nutritional counselling, individual dietetic treatment, and specialised dietetic treatment. Interventions such as PhysioDom HDIM connect well to the levels of self-management and nutrition counselling. This intervention supports self-management through encouraging self-monitoring and goalsetting. The intervention can also support nutrition counselling through providing tailored nutritional advice by means of the DHD-FFQ [55]. Currently, nutrition counselling is no routine practice for GPs or nurses. Health care professionals face several barriers in providing nutrition counselling such as a heavy workload/lack of time, no reimbursement [56], not being trained in nutrition, perceived lack of interest among patients [57], and a discrepancy with task perceptions [58]. Nevertheless, the GP is regarded as a source of authority and nutrition counselling by a GP may positively affect adoption of healthy dietary behaviours [59-62]. GPs or nurse practitioners can use the DHD-FFQ to gain insight into diet quality, and health care professionals can reinforce its benefits by explaining and stimulating its use and discussing the computer-tailored dietary advice. The same applies to screening for undernutrition. Despite guidelines, it is unclear in the Netherlands which health care professionals screen community-dwelling older adults for undernutrition and health care professionals lack awareness and time [63]. eHealth interventions such as PhysioDom HDIM can contribute to undernutrition screening as older adults themselves may receive a more prominent role in monitoring their nutritional status, fitting the current focus on self-management [64]. However, this research also points at several issues that should be taken into account for successful implementation in practice, such as social context and health equity, which are further elaborated below.

This research shows that the social context was of great importance for implementation. Perceived social influence was a significant predictor of intention to use the intervention (Chapter 5). Chapter 3 and Chapter 5 also describe that the nurses' support was necessary to keep participants motivated and engaged. Nurses themselves mentioned that the intervention was easier to implement if they already knew participants as home care clients compared to participants not receiving home care (Chapter 5). Literature also emphasises the importance of the social context in implementing eHealth among older adults [65-67]. Although eHealth may partly replace personal health care, the role of the social context seems crucial for successful implementation. This should be taken into account when developing and implementing eHealth interventions for this target population.

This research also implies that eHealth developers and implementers should be apprehensive about health equity. Our intervention mainly attracted participants from Dutch origin and attracted participants with a higher education level than the national average education level of people aged 65 and over [68]. Furthermore, drop-outs were significantly lower educated (Chapter 3), were older, had a worse physical and cognitive functioning, and were more care-dependent (Chapter 4) than study completers. Also literature confirms differential eHealth use among groups with varying levels of socio economic status, health, and age [69]. This challenges the expectation that eHealth will improve health care access and health equity [70]. Although future generations of older adults are expected to have more experience with computer technology, concerns remain that persons with low health or computer literacy will benefit less from eHealth [71, 72]. Related to that, self-management ability is associated with socio-economic status and social, cognitive, and physical functioning [73, 74]. eHealth developers should therefore be cautious not to exacerbate health disparities. Strategies to reduce health inequalities when using eHealth are therefore necessary, such as involving vulnerable groups during the design process so that needs of the intended end-users become clear and usability will be optimal, tailoring eHealth interventions to cultural background, socio-economic status or age, and increasing computer literacy [75].

IMPLICATIONS FOR POLICY

The role of eHealth within health care becomes increasingly prominent. Nevertheless, eHealth implementation proceeds at a slow pace, partly due to a lack of clarity concerning eHealth financing. To stimulate eHealth implementation, the Dutch government published a roadmap presenting extended possibilities to finance eHealth in 2019 [76]. The starting point is that eHealth should replace health care rather than being an addition to care. This means that already existing, reimbursed health care will also be reimbursed if it will be delivered by means of eHealth, given that the content of care and effectiveness will be unaffected. Conversely, health care that is currently not reimbursed, will neither be reimbursed as eHealth. The Dutch government leaves limited room for reimbursement of eHealth for the purposes of health promotion, prevention, and detection of at-risk groups, unfortunately [76]. Therefore, proving cost-effectiveness of interventions like PhysioDom HDIM is only a first step. For reimbursement, nutritional eHealth interventions should either be implemented as replacement of care that is already reimbursed, or better financial opportunities for prevention should be created. Several barriers to financing prevention exist however, such as lack of ownership or an unclear division of responsibilities among municipalities and insurance companies, more costs than benefits for the investor (benefits of prevention are usually spread out among several parties), and perverse incentives that make prevention of disease less rewarding [77]. On the other hand, increasing attention is being paid to prevention, for example by insurance companies and the National Prevention Agreement [78]. Furthermore, eHealth offers several advantages such as scalability, leading to lower costs per participant when scaled up to large numbers, and resulting in more realistic financing options [79].

FUTURE RESEARCH RECOMMENDATIONS

It is suggested that eHealth research for healthy ageing 'is still in an exploratory stage, exploring broad ranges of different technologies, interventions, and outcome measures in diverse populations but still at a small scale' [80]. Based on this research, several directions for future research can be given.

Firstly, future research should focus on how nutritional eHealth interventions achieve maximum impact on behaviour and longer-term health outcomes. This can partly be realised by studying mechanisms of impact. These could not be fully revealed in this research

(Chapter 5 and 6) and literature mentions a research gap concerning mechanisms of impact of nutritional eHealth interventions [40, 47]. Intervention development will therefore benefit from more insight into elements that are associated with positive intervention outcomes, such as behaviour change techniques, target behaviours, modes of delivery, or intervention dose [47]. A second way to increase impact on behaviour and health outcomes is gaining more insight into which target populations benefit most from these types of preventative nutritional eHealth interventions. For example, interventions can focus on selective prevention, targeting groups with increased undernutrition risk. Alternatively, a more individual approach can be taken, selecting individuals at risk to prevent undernutrition (indicated prevention) or selecting diseased individuals to prevent worsening of symptoms or adverse consequences (care-related prevention).

Secondly, cost-effectiveness of nutritional eHealth interventions for older adults should be studied. eHealth is expected to lead to cost containment through increased efficiency in health care [81]. eHealth interventions for preventing undernutrition among older adults are potentially cost effective as costs related to the treatment of undernutrition and its consequences are considerable [82]. However, research to this is scarce [23]. Some studies suggest that nutritional eHealth interventions are cost-effective, but this evidence concerns online weight management programs [83, 84]. Therefore, more studies are needed to assess this [47, 85].

The last direction for future research concerns the way how eHealth research is carried out. Ideally, stakeholders from policy, health care, insurance companies, and business are involved during intervention development to ensure that interventions have the potential to be scaled and integrated within health care [36]. Furthermore, future intervention development should, besides nutrition sciences, involve several (research) disciplines. Collaborating with social sciences is essential to develop theory-based interventions and to employ solid qualitative and quantitative research methods to gain insight into acceptability and mechanisms of impact. Also computer sciences and designers could be involved to gain insight into user-technology interactions and to maximise usability and adoption [38, 39, 86].

CONCLUSIONS

Our multi-component nutritional eHealth intervention led to improved diet quality and physical activity levels, and improved nutritional status in older adults with risk of undernutrition. This suggests that eHealth plays a valuable role in nutrition screening, prevention, and treatment of nutritional issues in community-dwelling older adults. The intervention was feasible to implement and was accepted by participants. Nevertheless, some issues need to be addressed to facilitate sustainable and scalable implementation, such as usability, perceived benefits of the intervention, and acceptability by health care professionals. Future research can address these issues by employing user-centred design and a collaborative approach involving all relevant stakeholders from research, practice, policy, and business. Directions for future research include unravelling mechanisms of impact, identifying groups of older adults that benefit most from nutritional eHealth interventions, improving accessibility of eHealth for vulnerable groups, establishing long-term effects on functioning and quality of life, and assessing economic impact.

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Summary

An optimal nutritional status contributes to healthy ageing. Conversely, ageing poses a nutritional risk as physiological, psychological, and social changes that may come with ageing influence appetite, food intake, and nutritional status. Undernutrition can be defined as "a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease". Although undernutrition is mostly prevalent among older adults living in long-term care facilities, in absolute numbers undernutrition is mostly encountered among older adults living in the community: 11 to 35% of community-dwelling older adults are affected. Undernutrition has unfavourable consequences for health, functioning, and quality of life. Therefore, prevention and early detection of nutritional risks are key for healthy ageing. Among many possible strategies and solutions that range from screening, prevention, and treatment, eHealth may be meaningful in signalling or preventing undernutrition at an early stage. The aim of this research was to provide insight into the feasibility and the effectiveness of a nutritional telemonitoring intervention for community-dwelling older adults. Chapters 2-6 present the results of this research and are summarised below.

The intervention consisted of self-measurements of nutritional outcomes and physical activity, nutrition education, and follow-up by a nurse. For this purpose, participants received measurement instruments (weighing scale, pedometer), and obtained an additional television channel and optionally a tablet computer to view their measurement results. The television channel was also used to display short messages concerning healthy eating and physical activity. Nurses received the results of the self-measurements and provided proper follow-up in case of nutritional risk. Although the intervention was practice-based, several theoretical strategies could be distinguished that underpinned the intervention, with the most important ones being self-monitoring, goalsetting, and feedback (Chapter 2).

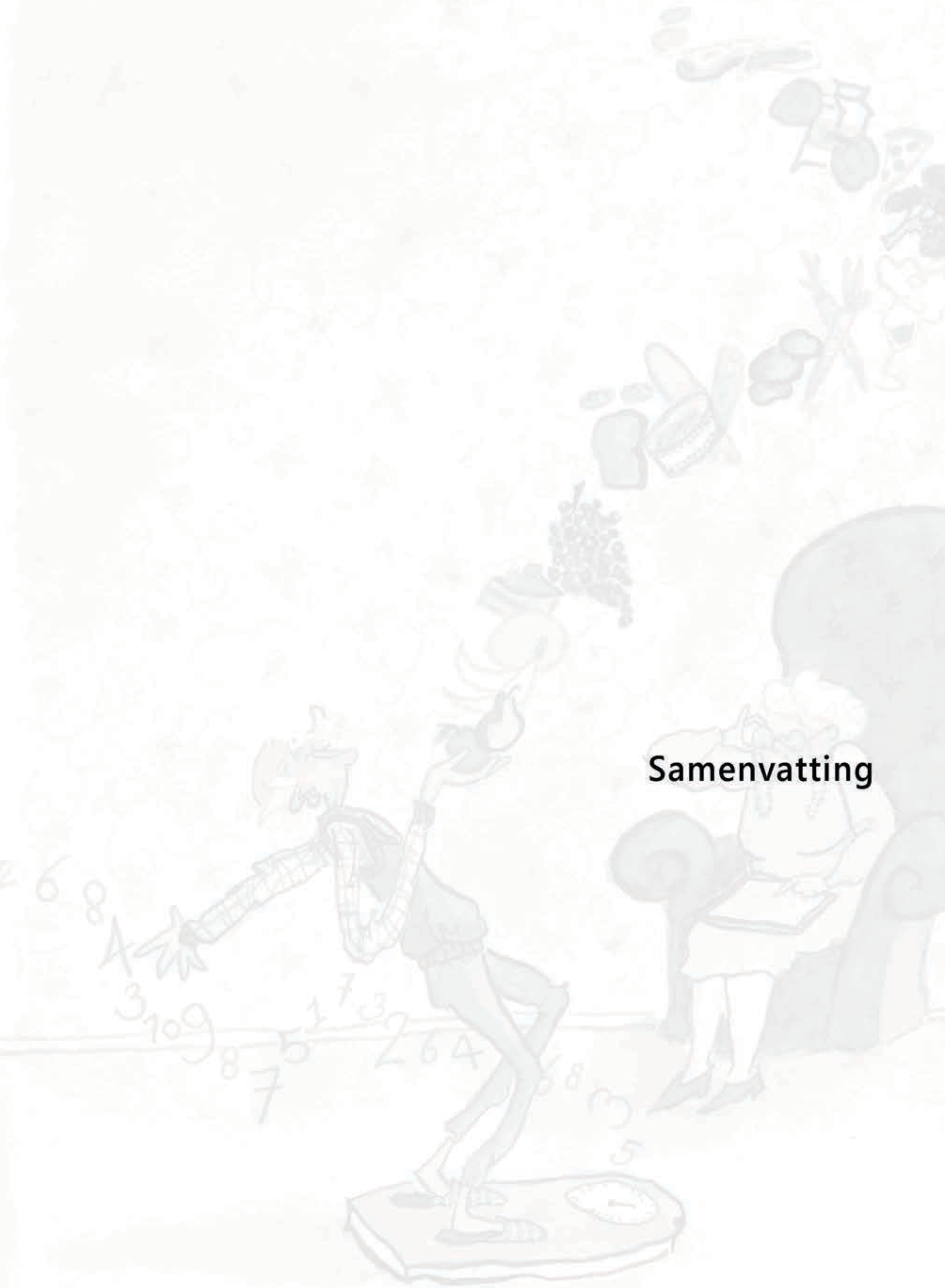
This intervention was tested during a three-month pilot study (*n*=20) (Chapter 3). This study showed that the intervention could be implemented as intended by researchers and health care professionals. However, participants' acceptance was low (only 50% was satisfied) and drop-out was high (*n*=9). Participants perceived the usability of the television channel as poor and needed more help than anticipated with the self-measurements. Based on these experiences, the intervention material was further developed with, among others, an improved television channel. The intervention was also made less intensive to further improve the fit with the target population.

Consequently, the intervention was evaluated during a six-month effect study (Chapter 4). Participants were allocated to the intervention group (*n*=97) or to the control group (*n*=107), based on municipality. Effect measurements were conducted at baseline, after 4.5 months, and at the end of the intervention and included measurements of diet quality, appetite, body weight, nutritional status, physical functioning, and quality of life. Participants at risk of undernutrition significantly improved their nutritional status (β (T1)=2.55, 95% CI (1.41, 3.68), β (T2)=1.77, 95% CI (0.60, 2.94)). Furthermore, intervention group participants increased scores for compliance with Dutch guidelines for the intake of vegetables (β=1.27, 95% CI (0.49, 2.05)), fruit (β=1.24, 95% CI (0.60, 1.88)), dietary fibre (β=1.13, 95% CI (0.70, 1.57)), protein (β=1.20, 95% CI (0.15, 2.24)), and physical activity (β=2.13, 95% CI (0.98, 3.29)). No effects on appetite, body weight, physical functioning, and quality of life were found.

Equally important as evaluating effectiveness, is investigating the feasibility and acceptability of an intervention. Therefore, a process evaluation was conducted in which a mixed method approach was used to study the process indicators reach, fidelity, dose, and acceptability (Chapter 5). A study of the reach of the intervention revealed that 80% of the participants completed the intervention and that participants who dropped out were older, had a worse cognitive and physical functioning, and were more care-dependent. With regard to fidelity, the intervention was implemented as intended. With regard to dose, participants' adherence to self-measurements of weight was better than adherence to self-measurements via questionnaires, for which half of the participants needed help. Concerning acceptability, the intervention was well received by participants (satisfaction score 4.1 on a scale from 1-5), but satisfaction rates of nurses were lower with an average score of 3.5 (scale 1-5). Two constructs of acceptability predicted the intention to use the intervention: performance expectancy (β=0.40, 95% CI 0.13,0.67) and social influence (β=0.17, 95% CI 0.00,0.34). None of the process indicators were associated with intervention outcomes.

Besides studying process and effect outcomes, testing the theoretical framework of an intervention deepens understanding of how an intervention achieves its effects, thereby contributing to future intervention development. For this purpose, measurements were conducted of compliance to the behaviour change techniques self-monitoring and goalsetting, and of the behavioural determinants perceived behavioural control, attitude, and knowledge. Mediation analyses were used to study the mechanisms of impact (Chapter 6). The intervention increased self-monitoring and improved knowledge and perceived behavioural control for physical activity. Increased self-monitoring mediated the intervention's effect on diet quality, fruit intake, and saturated fatty acids intake. Improved knowledge mediated the effect on protein intake. Nevertheless, the role of the hypothesised mediators was limited.

Concluding, our multi-component nutritional eHealth intervention led to improved diet quality and physical activity levels, and improved nutritional status in older adults with risk of undernutrition. The intervention was feasible to implement and was accepted by participants. This suggests that eHealth plays a valuable role in nutrition screening, prevention, and treatment of nutritional issues in community-dwelling older adults. Nevertheless, some issues need to be addressed to facilitate sustainable and scalable implementation, such as usability, perceived benefits of the intervention, and acceptability by health care professionals. Future research can address these issues by employing user-centred design and a collaborative approach involving all relevant stakeholders from research, practice, policy, and business. Directions for future research include unravelling mechanisms of impact, identifying groups of older adults that benefit most from nutritional eHealth interventions, improving accessibility of eHealth for vulnerable groups, establishing long-term effects on functioning and quality of life, and assessing economic impact.



Samenvatting

Een optimale voedingsstatus draagt bij aan gezond ouder worden. Tegelijkertijd kan het verouderingsproces van invloed zijn op de voedingsstatus. Lichamelijke, psychologische en sociale veranderingen kunnen de eetlust, de voedingsinname en de voedingsstatus negatief beïnvloeden. Ondervoeding kan omschreven worden als "een toestand waarbij sprake is van een tekort aan inname of opname van voeding dat leidt tot een veranderde lichaamssamenstelling, met nadelige effecten op lichamelijk en mentaal functioneren en klinische resultaten". Ondervoeding komt procentueel gezien het meest voor bij ouderen in woonzorgcentra, maar in absolute aantallen is het probleem het grootst onder ouderen die thuis wonen: geschat wordt dat 11 tot 35% van de ouderen die thuis wonen ondervoed zijn. Ondervoeding heeft nadelige effecten op de gezondheid, het functioneren en de kwaliteit van leven. Daarom is preventie en een vroegtijdige signalering van groot belang voor gezond ouder worden. Hiervoor zijn veel strategieën en mogelijkheden op het gebied van screening, preventie en behandeling. EHealth zou een mogelijkheid zijn voor het voorkomen of vroegtijdig signaleren van ondervoeding. Het doel van dit onderzoek was het verkrijgen van inzicht in de uitvoerbaarheid en effectiviteit van een telemonitoringsinterventie (de 'Eet & Beweegmonitor') rondom voeding bij thuiswonende ouderen. De hoofdstukken 2-6 beschrijven de resultaten van dit onderzoek en zijn hieronder samengevat.

De interventie bestond uit de volgende onderdelen: 1) zelfmetingen van gewicht, eetlust, voedingsstatus, kwaliteit van de voeding en lichamelijke activiteit, 2) voedingseducatie en 3) follow-up door een verpleegkundige. Hiervoor kregen deelnemers een weegschaal, een stappenteller, een extra televisiekanaal en optioneel een tablet. Op het televisiekanaal en de tablet konden deelnemers hun resultaten van de zelfmetingen bekijken. Op het televisiekanaal ontvingen deelnemers ook korte berichten over voeding en beweging. Verpleegkundigen ontvingen de resultaten van de zelfmetingen en gaven passende follow-up in geval van risico op ondervoeding. Alhoewel deze interventie in de praktijk is ontwikkeld, kunnen er verschillende gedragsveranderingstechnieken worden onderscheiden die ten grondslag liggen aan de interventie. Daarvan zijn de belangrijkste zelfmonitoring, doelen stellen en feedback (Hoofdstuk 2).

Deze interventie werd getest tijdens een drie maanden durende pilotstudie met 20 deelnemers (Hoofdstuk 3). Deze studie liet zien dat de interventie kon worden uitgevoerd zoals dat was bedoeld door onderzoekers en zorgprofessionals. De acceptatie onder deelnemers was echter laag (maar 50% was tevreden) en 9 van de 20 deelnemers stopten voortijdig met hun deelname. Deelnemers vonden de gebruiksvriendelijkheid van het televisiekanaal onvoldoende en hadden meer hulp nodig met de zelfmetingen dan vooraf gedacht. Op basis van deze ervaringen en inzichten werd het interventiemateriaal verder ontwikkeld met onder andere een gebruiksvriendelijker televisiekanaal. De interventie werd ook minder intensief gemaakt om beter aan te sluiten bij de doelgroep.

Vervolgens werd de interventie geëvalueerd tijdens een zes maanden durende effectstudie (Hoofdstuk 4). Deelnemers werden verdeeld over een interventiegroep (97 deelnemers) en een controlegroep (107 deelnemers), gebaseerd op de gemeente waar ze woonden. Effectmetingen werden uitgevoerd bij de start van de studie, na 4,5 maanden en aan het eind van de studie. Dit waren metingen van de kwaliteit van de voeding, eetlust, lichaamsgewicht, voedingsstatus, lichamelijk functioneren en kwaliteit van leven. Deelnemers met risico op ondervoeding verbeterden hun voedingsstatus significant (β (T1)=2,55, 95% CI (1,41, 3,68), β (T2)=1,77, 95% CI (0,60, 2,94)). Verder verbeterden deelnemers in de interventiegroep hun scores voor naleving van de Nederlandse richtlijnen voor de inname van groenten (β=1,27, 95% CI (0,49, 2,05)), fruit (β=1,24, 95% CI (0,60, 1,88)), voedingsvezel (β=1,13, 95% CI (0,70, 1,57)), eiwit (β=1,20, 95% CI (0,15, 2,24)) en lichamelijke activiteit (β=2,13, 95% CI (0,98, 3,29)). Er werden geen effecten gevonden op eetlust, lichaamsgewicht, lichamelijk functioneren en kwaliteit van leven.

Even belangrijk als het onderzoeken van de effectiviteit is het onderzoeken van de uitvoerbaarheid en acceptatie van een interventie. Daarom werd er een procesevaluatie gedaan waarbij zowel kwantitatieve als kwalitatieve methoden werden gebruikt. De procesindicatoren ‘reach’ (bereik), ‘fidelity’ (mate waarin een interventie is uitgevoerd zoals bedoeld), ‘dose’ (dosis) en ‘acceptability’ (acceptatie) werden bestudeerd (Hoofdstuk 5). Wat betreft het bereik van de interventie heeft 80% van de deelnemers de interventie afgemaakt.

Deelnemers die voortijdig stopten waren ouder, hadden een slechter cognitief en lichamelijk functioneren en hadden meer zorg nodig. Wat betreft 'fidelity' was de interventie uitgevoerd zoals bedoeld. Wat betreft 'dose' voldeden deelnemers beter aan de zelfmetingen van gewicht dan zelfmetingen via vragenlijsten over voedingsstatus, eetlust en kwaliteit van de voeding, waarvoor de helft van de deelnemers hulp nodig had. Wat betreft acceptatie werd de interventie goed ontvangen door deelnemers (tevredenheidsscore 4,1 op een schaal van 1-5), maar tevredenheidsscores van verpleegkundigen waren lager met een gemiddelde van 3,5 op een schaal van 1-5. Twee constructen van acceptatie voorspelden de intentie van deelnemers om met de interventie mee te doen: 'performance expectancy' (mate waarin men gelooft dat de technologie zal leiden tot gezond gedrag of gezondheid) (β=0,40, 95% CI 0,13, 0,67) en 'social influence' (mate waarin belangrijke anderen geloven dat men de technologie moet gebruiken) (β=0,17, 95% CI 0,00, 0,34). Geen van de procesindicatoren was geassocieerd met de effecten van de interventie.

Naast het bestuderen van het proces en de effecten is het onderzoeken van het theoretische kader van een interventie belangrijk om beter te begrijpen hoe een interventie werkt. Dit kan bijdragen aan het verder ontwikkelen van interventies. Voor dit doel werd gemeten in hoeverre de deelnemers zelfmetingen deden en doelen stelden. Ook werd een aantal gedragsdeterminanten gemeten, waaronder 'perceived behavioural control' (de mate waarin iemand verwacht controle te hebben over gedrag), houding en kennis. Impactmechanismen werden bestudeerd door middel van mediatie analyses (Hoofdstuk 6). De interventie leidde tot meer zelfmetingen, meer kennis, en meer ervaren controle over de mate waarin men lichamelijk actief is. Meer zelfmetingen medieerden het effect van de interventie op de totale score voor de kwaliteit van de voeding en scores voor de inname van fruit en verzadigd vet. Meer kennis medieerde het effect van de interventie op de score voor eiwit inname. Ondanks deze gevonden mediatie effecten was de rol van de veronderstelde mediatoren beperkt.

Concluderend, deze telemonitoringsinterventie rondom voeding bij thuiswonende ouderen heeft geleid tot een betere kwaliteit van de voeding en meer beweging, en een verbeterde voedingsstatus bij deelnemers met risico op ondervoeding. De interventie kon worden uitgevoerd zoals bedoeld en werd geaccepteerd door de deelnemers. Dit suggereert dat eHealth een waardevolle rol kan spelen in screening, preventie en behandeling van ondervoeding bij thuiswonende ouderen. Toch blijven er aspecten die aandacht vragen voordat dit soort interventies op grotere schaal en voor langere tijd kunnen worden ingezet. Hieronder vallen gebruiksvriendelijkheid, het waargenomen nut van de interventie door de doelgroep en acceptatie door zorgprofessionals. Toekomstig onderzoek kan inspelen op deze aspecten door de eindgebruiker centraal te stellen bij de ontwikkeling van de technologie en door een multidisciplinaire aanpak waarbij alle relevante stakeholders vanuit de wetenschap, praktijk, beleid en bedrijfsleven betrokken zijn. Aanbevelingen voor toekomstig onderzoek zijn onder andere het bestuderen van mechanismen van impact, het identificeren van groepen ouderen die het meeste baat hebben bij dit soort interventies, het verbeteren van de toegankelijkheid van eHealth interventies voor kwetsbare groepen, het behalen van effect op functioneren en kwaliteit van leven en het onderzoeken van kosteneffectiviteit.

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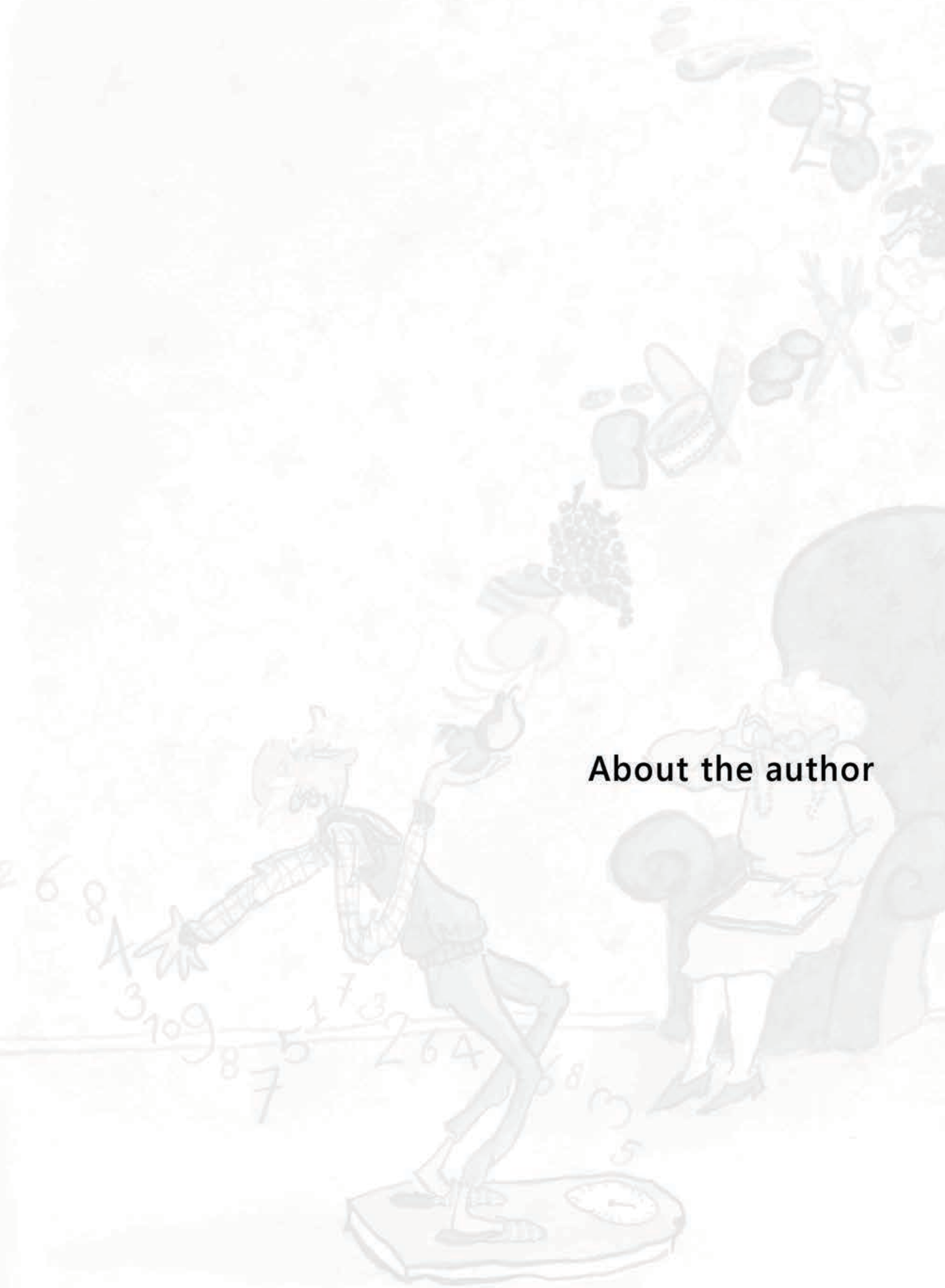

About the author

CURRICULUM VITAE

Marije Nadine van Atten was born on June 6, 1988 in Hendrik Ido Ambacht, the Netherlands. In 2006 she received her secondary school diploma from Johannes Fontanus College in Barneveld. Thereafter, she followed the EH-traject at the Evangelische Hogeschool in Amersfoort and continued her post-secondary education in Dentistry at Radboud University in Nijmegen. After achieving her BSc degree she continued her studies in Nutrition and Health at Wageningen University with a specialisation in Epidemiology and Public Health. She conducted her thesis at Wageningen Food & Biobased Research, entitled ´The effect of a multi-component intervention on meal enjoyment, appetite, nutritional status, weight and quality of life of Dutch nursing home residents'. After that, Marije completed her internship at the academic collaboration center AMPHI in Nijmegen, where she studied the adoption and implementation of community-based interventions to prevent overweight among children. Marije obtained her MSc degree cum laude in August 2013, after which she was appointed as junior researcher at Wageningen Food & Biobased Research. Here, she continued with her MSc thesis research and conducted a process and effect evaluation of an intervention to optimise meal enjoyment of Dutch nursing home residents. In March 2014, she started as a PhD fellow at the Division of Human Nutrition and Health at Wageningen University of which the results are described in this thesis. Her research focused on feasibility and effectiveness of nutritional telemonitoring for community-dwelling older adults. She joined the educational programme of the Graduate School VLAG, attended (international) conferences and courses, and was involved in teaching and supervising MSc students.

LIST OF PUBLICATIONS

Publications in peer-reviewed journals

van Doorn-van Atten, MN, Haveman-Nies, A, Pilichowski, P, Roca, R, de Vries, JHM, and de Groot, CPGM. Telemonitoring to improve nutritional status in community-dwelling elderly: design and methods for process and effect evaluation of a non-randomized controlled trial. BMC Geriatrics 2018;18(1):284-292.

van Doorn-van Atten, MN, Haveman-Nies, A, van Bakel, MM, Ferry, M, Franco, M, de Groot, CPGM, and de Vries, JHM. Effects of a multi-component nutritional telemonitoring intervention on nutritional status, diet quality, physical functioning and quality of life of community-dwelling older adults. British Journal of Nutrition 2018;119(10):1185-1194.

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van Doorn-van Atten, MN, Haveman-Nies, A, Heery, D, de Vries, JHM, and de Groot, CPGM. Feasibility and Effectiveness of Nutritional Telemonitoring for Home Care Clients: A Pilot Study. Gerontologist 2019;59(1):158-166.

Abstracts in scientific journals or proceedings

van Doorn-van Atten, MN, Haveman-Nies, A, de Vries, JHM, de Groot, CPGM. Telemonitoring voor vroegtijdige signalering en behandeling van ondervoeding bij ouderen: studieopzet en methoden voor evaluatie. Tijdschrift voor Gerontologie en Geriatrie 2015;46(4):216.

van Doorn-van Atten, MN, Haveman-Nies, A, de Vries, JHM, de Groot, CPGM. Telemonitoring to improve nutritional status and physical activity in older adults: a process and effect evaluation. European Geriatrics Medicine 2017;8(supp 1):213.

van Doorn-van Atten, MN, Haveman-Nies, A, de Vries, JHM, de Groot, CPGM, Telemonitoring om voedingsstatus en beweging bij thuiswonende ouderen te verbeteren: een proces- en effectevaluatie. Tijdschrift voor Gerontologie en Geriatrie 2017;48(5):223.

OVERVIEW OF COMPLETED TRAINING ACTIVITIES

Discipline specific activities	Institute and location	Year
Courses and workshops		
Masterclass 'Public health interventions in real-life settings'	AGORA/VLAG, Wageningen, NL	2013
Course 'Exposure Assessment in Nutrition Research'	VLAG, Wageningen, NL	2014
Seminar 'Social Context of Healthy Ageing'	RUG, Groningen, NL	2014
Meeting 'Early problem signalling in the community'	NPO, Utrecht, NL	2014
Conferences and meetings		
Symposium 'Designing Persuasive Technology to Improve eHealth Interventions'	Universiteit Twente, Enschede, NL	2014
European Union Geriatric Medicine Society Congress & National Gerontology Congress	EUGMS/NVG-knows, Rotterdam, NL	2014
Congress 'Ambition in Transition', *oral presentation*	AGORA/Caransscoop, Apeldoorn, NL	2014
Conference 'Harnessing digital technology for health behaviour change', *poster presentation*	UCL, London, UK	2015
National Gerontology Congress, *poster presentation*	NVG-knows, Ede, NL	2015
The Dutch Society for Research on Ageing meeting, *poster presentation*	DUSRA, Leiden, NL	2017
Conference 'Healthy Ageing', *oral presentation*	AGORA, Ermelo, NL	2017
European Union Geriatric Medicine Society Congress, *poster presentation, oral presentation*	EUGMS, Nice, FR	2017
National Gerontology Congress, *oral presentation*	NVG-knows, Ede, NL	2017
National Nutrition and Older Adults Congress, *oral presentation*	GerCare Consulting, Ede, NL	2018
General courses and workshops		
VLAG PhD week	VLAG, Baarlo, NL	2014
Project and Time management	WGS, Wageningen, NL	2015
Teaching and supervising thesis students	ESD, Wageningen, NL	2015
Multivariate analysis for food data/sciences	VLAG, Wageningen, NL	2016
ICH GCP WMO basic course	WUR, Wageningen, NL	2016
Mixed models	VLAG, Wageningen, NL	2017
Scientific writing	WGS, Wageningen, NL	2017
Optional courses and activities		
Preparing PhD research proposal	Wageningen, NL	2014
Paperclip meetings	Wageningen, NL	2014-2018
Lunch meetings nutrition and ageing research	Wageningen, NL	2014-2018
Newtrition committee	Wageningen, NL	2015-2016
PhysioDom HDIM consortium meetings	Wageningen (NL), Grenoble (FR), Paris (FR), Brussels (BE), Alston (UK)	2014-2018

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