The use of eHealth in rehabilitation after stroke

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General introduction

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Definition and epidemiology

Stroke, or a cerebrovascular accident (CVA), occurs when a clot in the blood vessel blocks the blood flow to the brain cells (ischemic stroke) or when a blood vessel in the brain breaks or ruptures (hemorrhagic stroke). Subsequently, brain cells are deprived of oxygen and glucose, causing damage to the brain tissues [1]. Abilities controlled by these brain tissues, such as memory and/or speech control, can be lost. As a consequence, persons who survive a stroke can face long-term disability with a considerable impact on their lives and those of their relatives [2].

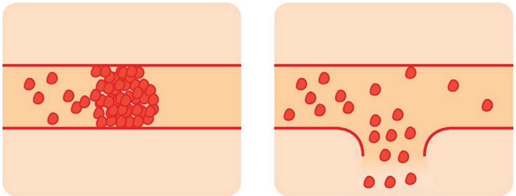

Figure 1. Images of the occurrence of an ischemic and hemorrhagic stroke [2].

After ischemic heart disease, stroke is the second leading cause of death in the world [3]. According to the World Stroke Organization (WSO), 1 in 6 people worldwide will have a stroke in their lifetime, 15 million people worldwide suffer a stroke each year and 5.8 million people die from it [4]. In the Netherlands, the incidence of stroke was estimated to be 42.300 in 2016 and the prevalence in that year was estimated to be 320.000 in the community based population [5].

Overall, stroke incidence has mainly shown either declining time trends or stable rates in high income countries [6]. On the other hand, the absolute number of stroke is expected to increase because of the ageing population and declining mortality rates, largely as a result of better control of high blood pressure and faster and better treatment (e.g. intravenous thrombolytic therapy and stroke services) [7;8]. Consequently, the overall stroke burden across the globe, in terms of the number of people affected by or who remain disabled from stroke, has increased [9]. Estimates from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD 2010) ranked stroke as the disease with the third-highest burden in disability, expressed in disability-adjusted life-years (DALY's), and the burden is projected to further rise from around 38 million DALYs globally in 1990 to 61 million DALYs in 2020 [10].

Consequences of stroke regarding functioning, disability and health

Stroke can have a broad and significant impact on a persons' physical, cognitive and social functioning. Especially cognitive impairment is common after stroke. A cohort study among 395 patients in the Netherlands showed that more than half of the stroke patients (66 percent) suffer from cognitive impairment two months post-stroke [12]. Although improvement is seen at six months post-stroke (prevalence of 50 percent), cognitive impairment still remains highly prevalent up to 6 months after stroke [12]. This often causes lifelong problems in activities of daily life and participation in society [11].

The International Classification of Functioning, Disability and Health (ICF) of the World Health Organization (WHO) is a helpful framework to classify a person's functioning and disability and plan delivery of care (Figure 1) [13]. The ICF is based on the biopsychosocial model and provides a coherent view of different perspectives of health: biological, individual and social. As the diagram indicates, in the ICF disability and functioning are viewed as outcomes of interactions between *health conditions* (diseases, disorders and injuries) *personal* [14;15] and *contextual factors* [13]. Because the ICF is very extensive, disease specific core sets (ICF Core Sets) have been developed for a number of chronic health conditions, including stroke, in order to provide an overview of categories of post-stroke disability [16]. The Brief ICF Core Set represents a selection of ICF domains or categories which can serve as a minimal standard for reporting of functioning and health in clinical studies and clinical encounters (Table 1-3) [17].

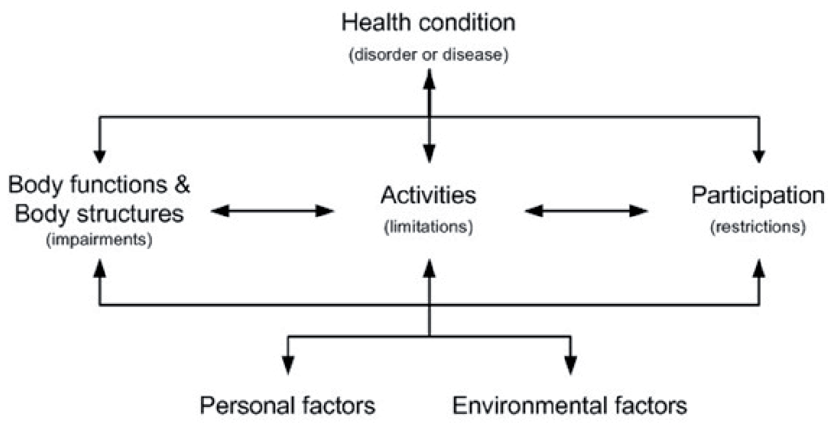

Figure 2. The model of the International Classification of Functioning, Disability and Health (ICF) shows the relationship between the different ICF components [18].

Table 1. International Classification of Functioning, Disability and Health (ICF) – categories of the components included in the Brief ICF Core Set for Stroke.

Body functions
b110 Consciousness functions b114 Orientation functions b140 Attention functions b144 Memory functions b167 Mental functions of language b730 Muscle power functions
Body structures
s110 Structure of brain s730 Structure of upper extremity
Activities and participation
d310 Communicating with – receiving – spoken messages d330 Speaking d450 Walking d510 Washing oneself d530 Toileting d540 Dressing d550 Eating
Environmental factors
e310 Immediate family e355 Health professionals e580 Health services, systems and policies

Medical management after stroke

Each year approximately 9.600 people in the Netherlands die because of stroke [19]. Those who survive a stroke are treated with acute care in a hospital (intensive care, medium care, stroke unit and/or neurology ward). The stay in the hospital is generally short and ends when the patient is medically stable [20]. Afterwards, about 60-65% is discharged to their homes. If needed, treatment can be provided by health professionals close to home (primary care) or in a rehabilitation center (outpatient care) [21]. For 25-30% of the patients, mostly older patients with multiple impairments, a nursing home for specialized geriatric rehabilitation or long stay is required. Ten percent, often young patients with potential for recovery and higher participation goals, are eligible for rehabilitation in a specialized rehabilitation center [22]. A flow of the patient journey after stroke is presented in Figure 3.

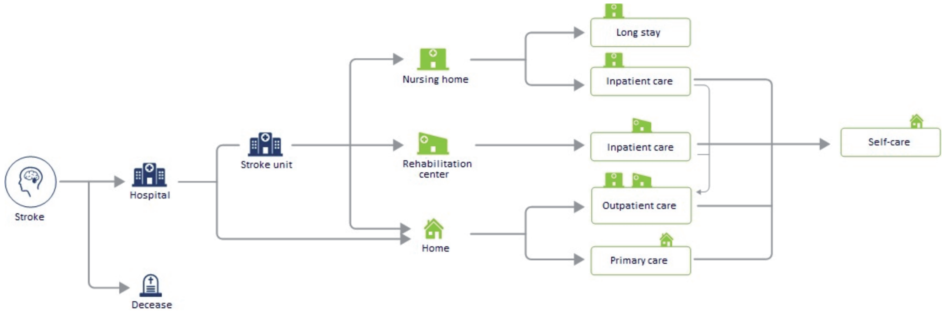

Figure 3. Patient journey after stroke describing the possible pathways of a stroke patient through the healthcare system in the Netherlands.

Specialized medical rehabilitation after stroke

Approximately 3.200 patients in the Netherlands use specialized medical rehabilitation stroke care yearly [22]. Medical specialist stroke rehabilitation is a comprehensive, multi-dimensional process including interventions that aim to facilitate restitution or substitution of limitations in impairment, activity or participation caused by stroke [23]. Rehabilitation typically follows a process of assessment of needs, goal setting, therapy and reassessment [24]. This process involves the patient, informal caregivers and various health care providers (e.g. physicians, physical and occupational therapists, speech-language therapists, psychologists and social worker). For each patient, a tailored treatment plan is defined, dependent on the type and severity of the impairments and the patients' goals. The length of these clinical pathways differs from 3 till 26 weeks [20]. After the rehabilitation period, about 90% of the patients are able to live independently [21]. The costs related to medical specialized rehabilitation were estimated at €147 million in 2015 [25]. The general health care costs for stroke were estimated at nearly €2.3 billion euros in 2011, 2.5% of the total healthcare costs [26]. As a result, stroke is one of ten most expensive diseases in the Netherlands.

eHealth in rehabilitation care (eRehabilitation)

Information and Communication Technology (ICT) is increasingly used in health care in general (eHealth) and in rehabilitation (eRehabilitation). eRehabilitation is applied for a number of (potential) purposes: 1) support of self-management and self-ownership [27], 2) improving access for (stroke) patients to health care services as well as bridging between services [28;29;30], 3) increasing the doses of treatment and more effective distribution in time [27], 4) monitoring compliance and progress [27], 5) structuring treatment and collecting treatment related data, 6) offering opportunities for more cost-effective interventions in the future and coping with ageing society [31;32] and 7) fulfilling a need in the digitizing society, patients and health care. With the different goals for eHealth, the nature of the technology employed in health care may vary largely, and there is a demand for their classification. An example of such a classification is published in the 'Co-creation eHealthbook' (Table 2) [33].

Table 2. Classification of eHealth applications for each technology [Wentzel, 2014; translated from Dutch].

Technology	Explanation
Web applications and portals	Applications that are offered to users via a web browser such as patient portals or educational portals for health professionals.
Mobile applications	Applications that are offered via a mobile device such as a smartphone or tablet.
Electronic patient records	Systems of a mostly medical-administrative nature in which healthcare providers register medical patient data within their own care organization.
Health-sensors and wearable devices	A category of devices that are often used in the home situation of patients to measure (vital body) functions, collect the results and possibly pass them on to a health professional.
Video communication (telecommunication)	Applications in which a visual dimension is added to the usual forms of telecommunication with the aim to strengthen contact between the care recipient and the care provider and to increase the communication possibilities.
Domotics	A general term for the application of electronics for home automation. It is often a combination of environment-aware sensors and actuators (devices that can influence the environment) with which the living environment in a home can be regulated or things in the home can be automatically operated.
Robotics	Machines that can perform and take over certain tasks such as offering structure in the day.
Medical integration networks	Electronic networks on which medical information is exchanged, such as medication data and prescriptions or radiological images.
General integration networks	Electronic networks of a more general nature for the exchange of data between cooperating (business) partners, for example about orders.
Business intelligence and big data	Business intelligence systems are focused on analyzing structured and unstructured data to provide information that can be used for decision support. If this is done within the field of care, this is called 'medical intelligence'. An analysis of very large amounts of data from different sources is called 'big data'.
Serious gaming	Use of game technology by applying a game element to 'serious matters', such as exercises in the context of psychological or physical treatment.

In addition, Krijgsman et al. 2012 describes three dimension to structure eHealth initiatives: 1) *the setting of the care process in which the eHealth application is used* (e.g. in the public health domain, as part of a care process, or in the support of a care process); 2) *the persons who use the eHealth application* (e.g. for health care professionals, for communication between patient and health care professional or patients between themselves; 3) *the technological basis of the eHealth application* (e.g. which platform or application type) [34].

Application of eRehabilitation after stroke

An established application of eHealth in stroke care management is *video communication*. Video patient-practitioner conferences are recommended in guidelines for acute stroke management in order to enroll a greater number of patients in therapies (e.g. correct diagnosis, promptly decide thrombolytic therapy and guide transfers to appropriate centers) [28;35]. More recently, video communication is applied for continuity of care [28]. Interactive patient-practitioner video consultations, as well as web portals, are used for both medical and educational services and stroke secondary prevention and monitoring [28].

In addition, 'off the shelve' *mobile and web applications* (e.g. exercises to train cognitive, speech and/or physical functioning) [36;37], *video games* (e.g. Nintendo Wii and Balance Board, Microsoft Kinect, etc.) [38] and *health sensors* (e.g. Fit-Bit, smartwatch, etc.) [39], developed for commercial purposes, are applied for stroke rehabilitation. Several applications have been developed for therapy purposes in general (e.g. Physitrack, Minddistrict, etc.) or for stroke specific (i.e. Care4Stroke, etc.). These technologies, mostly used on the initiative of patients and practitioners as a supplement to traditional care [28], are being applied in order to increase doses of treatment, monitor compliance and/or improve rehabilitation outcomes. *Robotics*, like exoskeleton types, also deliver high-intensity training for stimulation of motor disorders caused by stroke [40].

Furthermore, *electronic patient records* and *general/medical integration networks* have facilitated data-collection and data-analysis of aspects of stroke care in past years (e.g. team response time and time to other specific aspects of the care protocol, treatment outcomes, etc.). Registering accurate data and continue comparing data with other medical centers will further improve quality of stroke care and assist to identify patients who are eligible for clinical trials in the stroke population in the future [28].

Evidence for effectiveness of stroke eRehabilitation

This thesis concerns research on cognitive and comprehensive eRehabilitation interventions in patients with stroke. In general, in medical specialist rehabilitation, comprehensive multidisciplinary eRehabilitation that covers multiple aspects of stroke management (e.g. physical and cognitive functioning) is highly recommended and might become available in the future [28], but is not yet studied in clinical trials.

The effects of cognitive eHealth interventions on cognitive functioning in stroke patients are summarized in one meta-analyses of Laver et al. (2017) [41]. The aim of this meta-analyses was to determine the efficacy of virtual reality compared with an alternative intervention or no intervention on multiple outcome measures (i.e. upper limb function and activity, gait and balance, global motor function, activity limitation, participation restriction, quality of life and adverse events), including cognitive functioning. They searched different databases (e.g. Cochrane Stroke Group Trials Register (April 2017), CENTRAL, MEDLINE, Embase), trials registries and reference lists. A total of 72 studies (n=2470) were included, from which only three studies evaluated the effect of virtual reality interventions on cognition. These three trials [42;43;44] did not allow analysis, so that there are no results available on the effect of virtual reality on cognitive functioning. Other meta-analysis or systematic reviews of eHealth interventions on cognitive functioning in stroke patients are absent.

However, recently two RCTs addressing this question were performed [45;46]. Faria et al. (2016) studied the potential benefits of virtual reality based cognitive rehabilitation after stroke through simulated activities of daily living as compared to conventional therapy only [45]. The intervention involved a virtual simulation of a city where memory, attention, visuo-spatial abilities and executive functions tasks are integrated in the performance of several daily routines. A between groups analysis showed significantly greater improvements in global cognitive functioning, attention and executive functions in patients with stroke when comparing virtual reality to conventional therapy.

Van de Ven et al. (2017) investigated whether computer-based cognitive flexibility training improved subjective cognitive functioning and quality of life after stroke [46]. In the trial, adults (30±80 years old) who had suffered a stroke within the last 5 years were assigned to either an intervention group (n = 38), active control group (i.e., mock training; n=35), or waiting list control group (n=24). It was found both training groups improved on training tasks and all groups improved on executive functioning tasks, attention, reasoning, and psychomotor speed. However, the amount of improvement in executive and general cognitive functioning in the intervention group was similar to that of both control groups (active control and waiting list). Therefore, this improvement was likely due to training-unspecific effects. Overall, there is a lack of studies assessing the effect of eHealth intervention for cognitive functioning and quality of life after stroke.

Uptake of stroke eRehabilitation

Uptake of eRehabilitation can be described as a planned process and systematic introduction of eRehabilitation with the aim that it is given a structural place in rehabilitation care [47]. According to the theory of Grol and Wensing (2004), implementation can be influenced by several barriers and facilitators at different levels: Innovation, Individual health care professional, Individual Patient, Social context, Organizational context and Political and economic context [48]. For instance, for eRehabilitation a potential barrier at the level of the Innovation might be the variability in resources between different virtual rehabilitation networks [28]. Moreover, eHealth interventions often do not match with the requirements of intended users (e.g. patients and health care professionals), impairing the adoption of eHealth interventions [49;50]. At the level of the Individual health care professional, there are barriers to technology adoption related to the absence of a composite set of knowledge and skills among health care professionals regarding the use of eHealth [51]. Subsequently, there is a demand for new knowledge, skills and attributes among (future) health care professionals and new initiatives in education of health professions [52].

Outline of this thesis

Given the lack of knowledge the aims of this thesis are to:

I. Evaluate the outcome and process of an eHealth intervention for cognitive stroke rehabilitation.
II. Explore the (readiness for) use of eHealth among patients in rehabilitation.
III. Investigate the requirements of patients, informal caregivers, health professionals, teachers and students regarding the use of eHealth interventions in stroke rehabilitation.

Chapter 2 presents a randomized controlled trial (RCT) to determine the effect of an online serious brain training programme on multiple aspects of cognitive functioning in comparison to a control intervention in patients with self-perceived cognitive impairments 12–36 months after stroke (aim I).
Chapter 3 describes the adherence of patients with the online brain training programme by comparing two types of health professionals' supervision (aim I).
In *Chapter 4* the perspective of patients on use of eHealth in rehabilitation care is described by exploring their usage of common devices and investigating their preferences regarding usage of these devices in rehabilitation care (aim II).
Chapter 5 describes the results of a qualitative study, in which the requirements of patients with stroke, their informal caregivers and health professionals for the accessibility, usability

and content of comprehensive eRehabilitation after stroke were identified (aim III). The identified requirements were prioritized in *Chapter 6* by using a quantitative study design in order to assess which requirements found in the qualitative research are most important (aim III).

Chapter 7 provides an overview of the requirements (barriers and facilitators) according to students and teachers for the uptake of eHealth in curricula of two allied health professions, based on qualitative focus groups (aim III).

In *Chapter 8* a discussion is conducted on/elaborates the overall findings and recommendations are provided.

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