Technology-based support for stroke caregiving: A rapid review of evidence

Elton H. Lobo[a*,b], Mohamed Abdelrazek[a], Finn Kensing[c], Lene J. Rasmussen[d,e], Patricia M. Livingston[f], John Grundy[g], Sheikh Mohammed Shariful Islam[h] and Anne Frølich[b,i]

[a]School of Information Technology, Deakin University, Geelong, VIC, Australia;
[b]Department of Public Health, University of Copenhagen, Copenhagen, Denmark;
[c]Department of Computer Science, University of Copenhagen, Copenhagen, Denmark;
[d]Department of Cellular and Molecular Medicine, University of Copenhagen, Copenhagen, Denmark;
[e]Center for Healthy Aging, University of Copenhagen, Copenhagen, Denmark;
[f]Faculty of Health, Deakin University, Geelong, VIC, Australia;
[g]Faculty of Information Technology, Monash University, VIC, Australia;
[h]Institute for Physical Activity and Nutrition (IPAN), Deakin University, Geelong, Australia; [i]Innovation and Research Centre for Multimorbidity, Slagelse Hospital, Region Zealand, Denmark;

Aim: This rapid review examines the technology-based interventions for caregivers of stroke proposed in the literature while also identifying the acceptability, effectiveness, and satisfaction of the implemented approaches.
Background: The increasing burden of supporting stroke survivors has resulted in caregivers searching for innovative solutions, such as technology-based interventions, to provide better care. Hence, its potential to support caregivers throughout the disease trajectory must be assessed**.**
Evaluation: Five electronic databases were systematically searched for articles related to stroke caregiving technologies based on well-defined inclusion and exclusion criteria.
Key issue(s): Fifteen articles met the inclusion criteria that focused on supporting caregivers through functionalities such as education, therapy and support, remote consultations, health assessments, and logs and reminders using different devices. The majority of interventions demonstrated positive conclusions for caregiving impact, acceptability, effectiveness, and satisfaction.
Conclusion: Findings highlight the influences of technology in improving stroke caregiving and the need to include user-centred design principles to create a meaningful, actionable, and feasible system for caregivers.
Implications for Nursing Management: Technology can educate and support stroke caregivers, thereby minimizing uncertainty and ensuring better care for the survivor.
Keywords: technology; stroke; caregiver; impact; preparedness; effectiveness, satisfaction; acceptance; usability

1. Introduction

Stroke is one of the leading causes of disability worldwide, resulting in physical, cognitive, and behavioural changes depending on the brain's affected area (Caro, Costa, & Da Cruz, 2018). After hospitalization and rehabilitation, most stroke survivors return to home with care primarily provided by an informal caregiver (i.e. family member or friend), who are unprepared to manage the needs of the survivor (Smith, Egbert, Dellman-Jenkins, Nanna, & Palmieri, 2012). As a result, leading to substantial personal cost to the caregiver (Denham et al., 2019).

Many caregivers often encounter emotional, physical, social, financial and other challenges when caring for the survivor (Hultman, Everson-Rose, Tracy, Lindquist, & Hadidi, 2019). Thus, several research groups have developed technology-based interventions to support stroke caregivers (Aldehaim, Alotaibi, Uphold, & Dang, 2016). These technology-based interventions often provide a convenient and low-cost method for delivering interventions to caregivers, such as information, monitoring and communication tools, and behaviour change support (Marcolino et al., 2018). Besides, previous studies have shown the benefits and capability of these interventions to provide information in different formats, improve decision-making, convenience, ability to promote health

information exchange and social interactions with peers or family members (Godwin, Mills, Anderson, & Kunik, 2013). Because of these functionalities and capabilities, technological-based interventions can support caregiving needs and activities, thereby improving caregiving impact and well-being (Lundberg, 2014).

While previous systematic reviews, for example, Aldehaim et al. (2016) had examined the impact of technological-based interventions on informal caregivers, and Mortenson et al. (2012) had reviewed the impact of assistive technology use by individuals with disabilities; to the best of our knowledge, no study has exclusively focused on both caregiving impact and the influence of technology to support caregiving activities. Hence, this rapid review aims to identify and appraise the technology's influence on caregiving impact while also identifying the acceptability, effectiveness, and satisfaction of implementing these technologies to their caregiving activities. Furthermore, this study highlights the interventions' content, such as functionalities, to create awareness of the tools available to support stroke caregiving.

2. Materials and methods

A rapid review methodology (Tricco, Langlois, & Straus, 2017) was adopted in this review. Rapid reviews are considered an emerging approach in health technology assessment to support informed decision-making in a timely manner (Khangura, Polisena, Clifford, Farrah, & Kamel, 2014). This methodology utilizes processes similar to a systematic literature review but limits its scope and various aspects of synthesis (Wu, Qian, Deng, & Yu, 2020).

2.1 Data sources and strategy

Peer-reviewed articles published up to May 2020 were systematically searched from five electronic databases (i.e. MEDLINE, Embase, CINAHL, PsycINFO, and Web of Science) and other electronic sources (i.e. Google Scholar and University Library). The search strategy included terms related to the PICOS framework, as shown in **Table 1** and **Supplementary Material A**, combined to produce optimal results. Database filters were included to eliminate articles that were not conducted on humans and not published in English.

Titles and abstracts were downloaded from the electronic databases into EndNote X9, and all duplicates were removed. The primary author initially screened titles and abstracts based on well-defined inclusion and exclusion criteria developed by all authors. Potentially relevant articles identified after screening were downloaded and subsequently reviewed by the primary author under the second author's supervision to determine eligibility. All authors discussed any discrepancies until a general consensus was achieved.

2.2 Inclusion and Exclusion criteria

We included articles if they; (i) were published in English, (ii) involved caregivers aged 18 years or older at different stages of study design and evaluation, (iii) included technologies (i.e. telehealth, mHealth, eHealth and Web) designed to support caregiving of stroke, (iv) identified the changes to caregivers' lives and the effectiveness of the technology in supporting their activities, and (v) stated the impact evaluation procedure. Articles were excluded from this review if they were available only as abstracts, opinions, letters to the editor, conceptual papers, protocols, and unpublished text, or excluded impact related to the intervention.

Table 1 Search terms defined based on the PICOS framework.

Criterion	Search terms
Population – Target participant group, i.e. caregiver of stroke, aged 18 years and above	"cerebrovascular disorders" OR "basal ganglia cerebrovascular disease" OR "brain ischemia" OR "carotid artery diseases" OR "intracranial arterial diseases" OR "intracranial embolism and thrombosis" OR "intracranial haemorrhage*" OR "stroke" OR "brain infarction" OR "cerebrovascular accident" OR vasospasm OR "vertebral artery dissection"
	caregiver OR caregivers OR "care givers" OR care-givers OR carer OR carers OR "family caregivers" OR "spouse caregivers" OR "informal caregiver" OR "formal caregiver" OR friends OR "family members" OR children OR spouse OR wife OR son OR daughter OR sibling OR brother OR sister OR mother OR father OR husband OR wife OR nurse
Intervention – Type of technology, i.e. telehealth, mHealth, eHealth, IoT and/or web	telehealth OR telemedicine OR telemonitoring OR telepractice OR telenursing OR telecare OR ehealth OR e-health OR mhealth OR "digital health" OR technology OR "mobile health" OR "mobile application" OR apps OR app OR "mobile apps" OR "mobile app" OR smartphone OR mobile OR telemonitor OR telerehabiliation OR "smart home" OR "assistive technology" OR "internet of things" OR internet-of-things OR iot OR "smart devices" OR "connected devices"
Setting – Intervention delivery mechanism	
Comparator – Study design leading to some form of comparison.	"qualitative research" OR "cohort studies" OR "observational study" OR "focus groups" OR semi-structured OR semistructured OR unstructured OR informal OR in-depth OR indepth OR face-to-face OR structure OR guide OR interview* OR discussion* OR question?aire* OR RCT OR "randomi?ed control trial*" OR "randomi?ed clinical trial*" OR pilot OR trial OR evaluation OR control OR feasibility OR acceptability OR usability
Outcomes – Health outcomes of the caregivers pre- and post- intervention use	burden OR stress OR fatigue OR burnout OR strain OR "emotional distress" OR "psychological distress" OR "physical support" OR "information support" OR "professional support" OR "involvement in care" OR support OR supporting OR aid OR assistance OR help OR guidance OR "supporting care"

2.3 Data extraction

The primary author extracted data from papers that met the inclusion criteria. Specifically, we extracted information related to the study population (size, age, range, and % female), intervention (type of intervention, functionalities, and implementation), design (control condition, follow-up period, and study methodology), setting, and outcomes (impact of technology, acceptability, effectiveness, and satisfaction). Data extracted were subsequently reviewed by the other authors to ensure accuracy. This review also included reference lists of systematic reviews identified through database searches.

2.4 Outcome measures

Outcome measures were evaluated based on (i) the impact of technology to support caregivers and (ii) the overall acceptability, effectiveness, and satisfaction of the technology implemented.

2.5 Risk of bias assessment

The risk of bias was assessed by the primary and secondary authors based on the Downs and Black (1998) instrument, where each author independently rated each article based on a 24 point criteria; scored either as 1 (Yes) or 0 (No). Any discrepancies were discussed with other authors until a general consensus was achieved.

3. Results

The combined search strategies identified 3100 potential articles, which were screened for eligibility (**Figure 1**). After removing duplicates and applying inclusion and exclusion criteria based on their titles and abstract, 53 full-text articles were reviewed, with 15 meeting the selection criteria, published from 2003 to 2020. The primary reasons for exclusion include; (i) articles not related to technology

(n=815), (ii) interventions not related to stroke (n=742), (iii) full-text articles unavailable (n=110), (iv) interventions were exclusively designed for survivors, and medical professionals (n=78), (v) studies did not evaluate the impact of technology implemented (n=11), and (vi) not available in English (n=5). **Table 2** summarises the characteristics of all of the included studies.

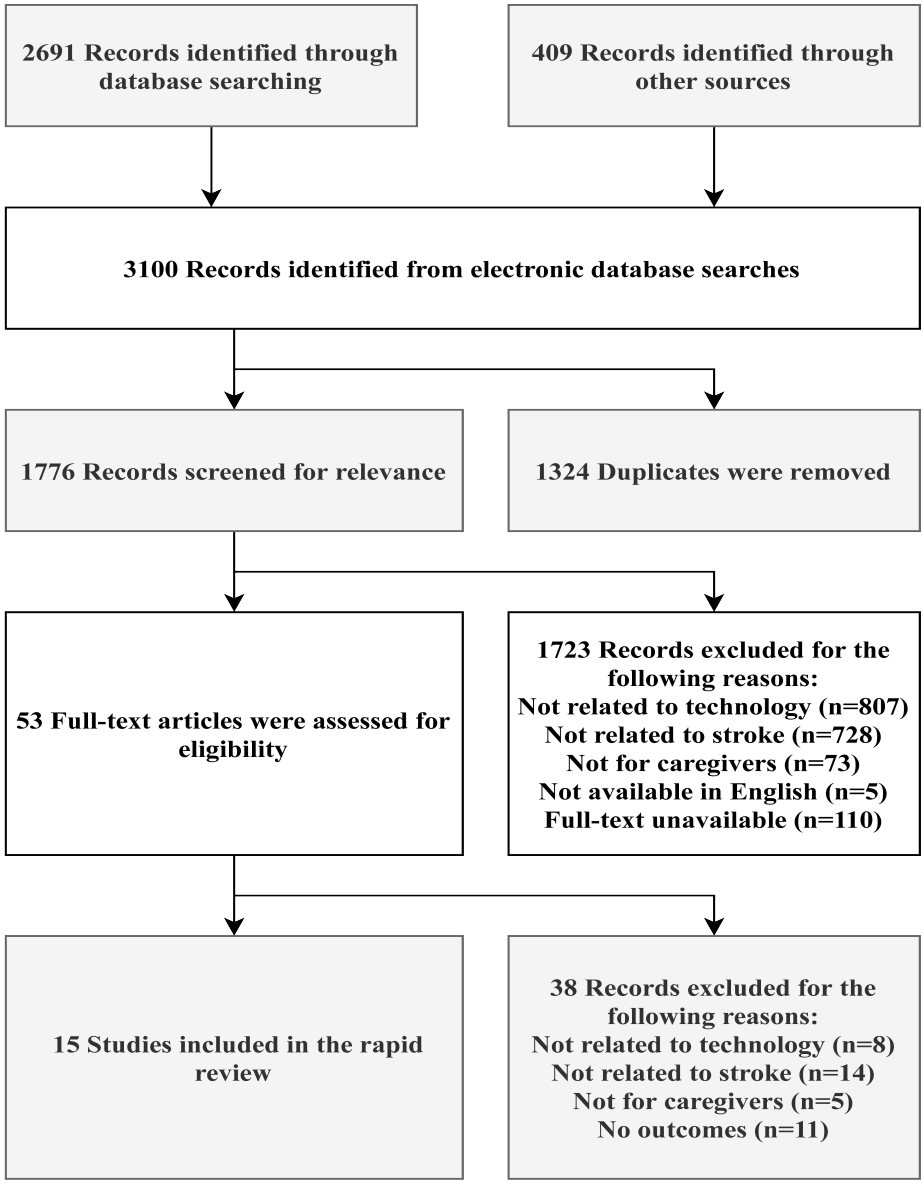

Figure 1. PRISMA flowchart for the synthesis of articles in this review.

Table 2 Summary of the included primary studies.

Author (Year), Country	Study Design	Demographics			Setting	Technology
		Age (SD)	No of Caregivers	Relationship to patient		
Caunca, Simonetto, Hartley, Wright, and Czaja (2020), USA	Iterative, user-centred approach	Phase I: 60 (9) Phase II: 57 (3) Phase III: 46 (17)	Phase I: 7 Phase II: 4 Phase III: 9	Spouse	Not given	mobile web platform
Mahmood et al. (2019), India	Cross-sectional questionnaire-based study	39 (12)	52	Not given	Home	mHealth app
Zhou et al. (2019), China	RCT	51.9 (12.5)	120	Not given	Hospital	mHealth app
Blanton, Dunbar, and Clark (2018), USA	Open-ended questionnaire-based study	> 21	6	Not given	Home	Web platform
Vloothuis et al. (2019), Netherlands	Observer-blinded, RCT	CG: 54.00 (12.26) IG:53.91 (14.90)	CG: 34 IG:32	Not given	Home	ehealth application and tele-rehabilitation
Sureshkumar et al. (2016), India	Mixed methods design	FT: 31.6 (7.66) PT: 39.5 (13.7)	30	Not given	Community	mHealth app
Van Den Berg et al. (2016), Netherlands	Pilot RCT	CG: 70.1 (12.4) IG: 64.5 (18.5) IGP: 64.7 (19.5)	Not given	Not given	Hospital and Home	ehealth application
Stone (2013), USA	Pre-Post test	18–34: 14/70 35–44: 14/70 45–54: 18/70 55–64: 4/70 65 over: 10/70	70	Spouse: 12/70 (17.1%) Child: 35/70 (50%) Parent: 3/70 (4.3%) Other 20/70(28.6%)	Community	Web platform
Smith et al. (2012), USA	Two-group, RCT	CG: 55.3 (6.9) IG: 54.9 (12.90)	32	Husband	Home	Telephone
Lutz, Chumbler, Lyles, Hoffman, and Kobb (2009), USA	Non-randomized open trial; mixed methods design	Not given	14	Twelve were spousal caregivers and two were daughters	Home	Telehealth

CG:	Pierce, Steiner, Khuder, Govoni, and Horn (2009), USA	Two-group, RCT	54 (12.2)	73	Wife	Home	Web platform
	Torp, Hanson, Hauge, Ulstein, and Magnusson (2008), Norway	Pilot Trial	Mean = 73 (median = 73, range 57–85)	19	Spouse	Home	Information and Communication Technology (or ICT)
	Marziali and Donahue (2006), Canada	Pilot RCT	67.8	66	Relatives	Home	Telehealth
	Marziali, Donahue, and Crossin (2005), Canada	Semi-structured Interviews	67.8	34	Wives, daughters and daughters-in law	Community	Telehealth
	Hartke and King (2003), USA	Two-group, RCT	69.72 (6)	88	Spouse	Community	Telephone

Control Group, IG: Intervention Group, IGP: Intervention Group per Protocol, PT: Pilot Testing, FT: Field Testing

3.1 Characteristics of studies

3.1.1 Study design and setting

The majority of the articles analyzed were Randomized Control Trials (Hartke & King, 2003; Marziali & Donahue, 2006; Pierce et al., 2009; Smith et al., 2012; Van Den Berg et al., 2016; Vloothuis et al., 2019; Zhou et al., 2019). The remaining articles were either pilot (Torp et al., 2008), feasibility (Blanton et al., 2018; Mahmood et al., 2019; Sureshkumar et al., 2016), iterative user-centred design (Caunca et al., 2020), pre- and post-test design (Stone, 2013), mixed-methods (Lutz et al., 2009) or evaluation (Marziali et al., 2005) based studies. These interventions were evaluated at home (n=9), community (n=4), or the hospital (n=2) settings in countries such as the USA (n=7), Canada (n=2), India (n=2), Netherlands (n=2), China (n=1) and Norway (n=1) as demonstrated in **Table**

3.1.2 Participant characteristics

A total sample of 1490 participants, including 934 caregivers, 552 survivors and 4 rehabilitation researchers were included in the primary studies. Across all articles, female caregivers accounted for more than 30% of participants over 18 years. These caregivers were either spouses (Caunca et al., 2020; Hartke & King, 2003; Lutz et al., 2009; Marziali et al., 2005; Pierce et al., 2009; Smith et al., 2012; Stone, 2013; Torp et al., 2008), children (Lutz et al., 2009; Marziali et al., 2005; Stone, 2013), parents (Stone, 2013) or other known stakeholders (Blanton et al., 2018; Mahmood et al., 2019; Marziali & Donahue, 2006; Marziali et al., 2005; Stone, 2013; Sureshkumar et al., 2016; Van Den Berg et al., 2016; Vloothuis et al., 2019; Zhou et al., 2019); who supported the stroke survivor.

3.2 Interventions and content

This review examined 15 studies comprising functionalities delivered using numerous devices (**Table 3**). These functionalities include (i) educational materials (Blanton et al., 2018; Caunca et al., 2020; Lutz et al., 2009; Mahmood et al., 2019; Pierce et al., 2009; Smith et al., 2012; Stone, 2013; Sureshkumar et al., 2016; Torp et al., 2008; Zhou et al., 2019), (ii) therapy and support (Hartke & King, 2003; Mahmood et al., 2019; Marziali & Donahue, 2006; Marziali et al., 2005; Van Den Berg et al., 2016; Vloothuis et al., 2019), (iii) remote consultations (Hartke & King, 2003; Lutz et al., 2009; Marziali & Donahue, 2006; Marziali et al., 2005; Pierce et al., 2009; Smith et al., 2012; Stone, 2013; Torp et al., 2008; Van Den Berg et al., 2016; Vloothuis et al., 2019), (iv) health assessments (Van Den Berg et al., 2016), and (v) logs and reminders (Vloothuis et al., 2019; Zhou et al., 2019), as demonstrated in **Table 3**.

Table 3. Intervention and content

Author (Year), Country	Devices Used	Functionality	Content
Hartke (2003), USA	Telephone	Therapy and support	• Psychoeducational Support
		Remote Consultations	• Telephone Consultations
Marziali (2005), Canada	Computer	Therapy and support	• Psychoeducational Support
		Remote Consultations	• Video Conferencing

Marziali (2006), Canada	Computer	Therapy and support	• Psychoeducational Support
		Remote Consultations	• Video Conferencing
Torp (2008), Norway	Computer	Education	• **Topics:** o Social Support, Nutrition and Caregiving Techniques
		Remote Consultations	• Online Discussions
Lutz (2009), USA	Telephone	Education	• **Topics:** o Disease, Emotional Support Practices, Physical Support Practices and Caregiving Techniques • **Delivery Format:** o Questionnaires
		Remote Consultations	• Telephone Consultations
Pierce (2009), USA	TV	Education	• **Topics:** o Disease, Emotional Support Practices and Caregiving Techniques • **Delivery Format:** o Text
		Remote Consultations	• Email Consultations
Smith (2012), USA	Computer	Education	• **Topics:** o Emotional Support Practices and Caregiving Techniques • **Delivery Formats:** o Text and Video
		Remote Consultations	• Email Consultations and Online Discussions
Stone (2013), USA	Computer	Education	• **Topic:** o Caregiving Techniques
		Remote Consultations	• Email Consultations
Sureshkumar (2016), India	Mobile	Education	• **Topic:** o Physical Support Practices • **Delivery Formats:** o Text and Video
van den Berg (2016), Netherlands	Mobile	Therapy and support	• Caregiver mediated exercises to support survivors
		Remote Consultations	• Video Conferencing
		Health Assessments	• Survivor activity monitoring using Fitbit Zip
Blanton (2018), USA	Computer Mobile	Education	• **Topics:** o Rehabilitation goal setting and Caregiving Techniques • **Delivery Formats:** o Text and Video
Vloothuis (2018), Netherlands	Mobile	Therapy and support	• Caregiver mediated exercises to support survivors
		Remote Consultations	• Email Consultations and Video Conferencing
		Logs and reminders	• Survivor Exercise Log
Mahmood (2019), India	Mobile	Education	• **Topic:** o Physical Support Practices • **Delivery Formats:** o Audio and Video
		Therapy and support	• Caregiver mediated exercises to support survivors
Zhou (2019), China	Mobile	Education	• **Topics:** o Physical Support Practices and Caregiving Techniques

			• **Delivery Formats:** o Text and Video
		Logs and reminders	• Exercise Reminders
Caunca (2020), USA	Mobile	Education	• **Topics:** o Disease, Emotional Support Practices, Physical Support Practices, Financial and Legal Management, Communication Practices, Nutrition and Caregiving Techniques • **Delivery Formats:** o Text and Video

Table 4. Caregiver Outcomes

Primary Author (Year) Study Design, Intervention	**Caregiver Activities of Daily Living**	**Caregiver Burden**	**Caregiver Health Status**	**Caregiver Preparedness**	**Caregiver Healthcare Utilization**	**Caregiver Self-Efficacy**	**Caregiver Self-Esteem**	**Caregiver Quality-of-Life**	**Caregiver Social Support**
Hartke (2003) Two-group, RCT, Telephone		No	No	No				No	
Marziali (2005) Semi-structured Interviews, Telehealth		Yes	Yes						
Marziali (2006) Pilot RCT, Telehealth	No	No	Yes						No
Torp (2008) Pilot Trial, ICT		No	No	Yes					Yes
Lutz (2009) Non-randomized open trial; mixed methods design, Telehealth		No							
Pierce (2009) Two-group, RCT, Web			No		Yes			No	
Smith (2012) Two-group, RCT, Telephone			Yes			Yes	Yes		No
Stone (2013) Pre-Post test, Web				Yes					
Sureshkumar (2016) Mixed methods design, mHealth									
van den Berg (2016) Pilot RCT, eHealth		Yes	Yes			Yes			

Blanton (2018) Open-ended questionnaire-based study, Web									
Vloothuis (2018) RCT, mHealth		No	Yes			No		No	
Mahmood (2019) Cross-sectional questionnaire-based study, mHealth									
Zhou (2019) RCT, mHealth		No							
Caunca (2020) Iterative, user-centred approach, mHealth	Yes	No	No	Partial		Yes			Partial

3.3 Impact of Technology on Stroke Caregiving

The technological impact (**Table 4**) of the included articles were identified using validated instruments, as demonstrated in **Table 5**. These instruments assessed the influence of the intervention on caregivers through factors such as;

(1) *Caregiver Activities of daily living (ADL):* The caregivers' ability to support the survivor in their daily living was assessed in two articles (Caunca et al., 2020; Marziali & Donahue, 2006). No statistical difference was identified between the intervention and control group of one article involving the use of communication-based technology (Marziali & Donahue, 2006). In contrast, the other article involving web-based education resources demonstrated caregivers' ability to support instrumental ADL rather than just ADL (Caunca et al., 2020).

(2) *Caregiver burden:* Nine articles (Caunca et al., 2020; Hartke & King, 2003; Lutz et al., 2009; Marziali & Donahue, 2006; Marziali et al., 2005; Van Den Berg et al., 2016; Vloothuis et al., 2019; Zhou et al., 2019) identified the ability of the intervention to support caregiving burden. Of these articles, only two (Marziali et al., 2005; Van Den Berg et al., 2016) identified statistical differences in the interventions' ability to reduce the caregiving burden. This involved telehealth (Marziali et al., 2005) and eHealth (Van Den Berg et al., 2016) based technologies. Furthermore, 95% of the caregivers involved in the telehealth technology group sessions reported lower stress levels, while those caregivers who used mHealth-based consultation and remote monitoring technology reported psychological benefits (Van Den Berg et al., 2016).

(3) *Caregiver health status:* Caregiver health status was reported in nine articles (Caunca et al., 2020; Hartke & King, 2003; Marziali & Donahue, 2006; Marziali et al., 2005; Pierce et al., 2009; Smith et al., 2012; Torp et al., 2008; Van Den Berg et al., 2016; Vloothuis et al., 2019), of which five articles (Marziali & Donahue, 2006; Marziali et al., 2005; Smith et al., 2012; Van Den Berg et al., 2016; Vloothuis et al., 2019) demonstrated positive health outcomes in factors such as depression (Smith et al., 2012; Van Den Berg et al., 2016), stress (Marziali & Donahue, 2006; Marziali et al., 2005), fatigue (Van Den Berg et al., 2016) and anxiety (Van Den Berg et al., 2016; Vloothuis et al., 2019). This included the use of communication (Marziali & Donahue, 2006; Marziali et al., 2005), web (Smith et al., 2012), and mHealth (Van Den Berg et al., 2016; Vloothuis et al., 2019) based technologies that delivered remote consultations (Marziali & Donahue, 2006; Marziali et al., 2005; Smith et al., 2012; Van Den

Berg et al., 2016; Vloothuis et al., 2019), education (Smith et al., 2012; Vloothuis et al., 2019) and remote patient monitoring (Van Den Berg et al., 2016) based functionalities.

(4) *Caregiver preparedness:* Four articles (Caunca et al., 2020; Hartke & King, 2003; Stone, 2013; Torp et al., 2008) assessed caregivers preparedness post-intervention use, of which two reported significant caregiver preparedness using web-based consultation technology (Stone, 2013; Torp et al., 2008), while another article reported adequate preparedness, which included the use of web-based education technology (Caunca et al., 2020).

(5) *Caregiver quality-of-life:* Four articles (Hartke & King, 2003; Pierce et al., 2009; Van Den Berg et al., 2016; Vloothuis et al., 2019) assessed caregivers quality-of-life using interventions such as education (Vloothuis et al., 2019), physical activity monitoring (Van Den Berg et al., 2016) and communication (Hartke & King, 2003; Pierce et al., 2009; Van Den Berg et al., 2016; Vloothuis et al., 2019) based resources. These resources were delivered through telephone (Hartke & King, 2003), web application (Pierce et al., 2009), and mobile applications (Van Den Berg et al., 2016; Vloothuis et al., 2019). Of the four articles, one article (Van Den Berg et al., 2016) did not present any statistical findings; while the remaining three articles (Hartke & King, 2003; Pierce et al., 2009; Vloothuis et al., 2019) demonstrated no statistical differences post-intervention use in all participant groups.

(6) *Caregiver self-esteem:* One article (Smith et al., 2012) demonstrated the influence of survivor depression on caregiver self-esteem. This article focused on delivering a web-based intervention that presents caregivers with education and communication resources. Reduced depression of the survivor was shown to increase caregiver self-esteem significantly.

(7) *Caregiver self-efficacy:* Four articles (Caunca et al., 2020; Smith et al., 2012; Van Den Berg et al., 2016; Vloothuis et al., 2019) reported the self-efficacy of caregivers post-intervention. Most of these interventions (Caunca et al., 2020; Smith et al., 2012; Van Den Berg et al., 2016) reported had higher self-efficacy. This involved the use of mobile (Van Den Berg et al., 2016) and web (Caunca et al., 2020; Smith et al., 2012) applications for education (Caunca et al., 2020; Smith et al., 2012), physical activity monitoring (Van Den Berg et al., 2016), therapy and consultations (Smith et al., 2012; Van Den Berg et al., 2016). One intervention demonstrated no significant change in self-efficacy when delivering education, communication, therapy, reminders, and log resources (Vloothuis et al., 2019).

(8) *Caregiver Healthcare utilization:* Only one article (Pierce et al., 2009) assessed caregivers' healthcare utilization, which focused on unspecified follow-ups with the medical professional or primary care after receiving online consultations using web applications. Findings from this study demonstrated no statistical differences between the number of medical professional or provider visits, but significant differences (i.e., 33% fewer visits for web application users) between the web and non-web application users in the emergency department visits. Furthermore, this study also demonstrated significant differences in hospital readmissions between the two groups (66% fewer hospital readmissions).

(9) *Caregiver Social support:* Of the 12 articles, four (Caunca et al., 2020; Marziali & Donahue, 2006; Smith et al., 2012; Torp et al., 2008) evaluated social support of caregivers using web applications. One intervention provided caregivers with education-based resources (Caunca et al., 2020), two interventions (Marziali & Donahue, 2006; Torp et al., 2008) provided caregivers with communication-based resources, and one (Smith et al., 2012) included both education and communication resources. The findings from these studies demonstrated no significant difference in the two articles (Marziali & Donahue, 2006; Smith et al., 2012), while the other two articles had adequate differences (Caunca et al., 2020) and a significant positive change (Torp et al., 2008).

Table 5. Instruments to determine study outcomes.

Outcome Measures	**Instruments**

Activities of daily living	Activities of daily living metrics (Finch et al., 1995)
	ADL Index (Katz, 1963)
Caregiver Burden	15-item Relative Stress Scale (Greene et al., 1982)
	Burden Index (Liu et al., 2015)
	Strain Index (Al-Janabi et al., 2010; Kruithof et al., 2015; Robinson, 1983; Visser-Meily et al., 2004)
	12-Item Zarit Burden Interview (Bédard et al., 2001)
	Revised Memory and Behavior Problems Checklist (Teri et al., 1992)
	22-Item Zarit Burden Interview (Zarit & Zarit, 1990)
Caregiver Health Status	Health Status Questionnaire (Kroenke et al., 2001; Pettit et al., 2001)
	Center for Epidemiologic Studies– Depression Scale (CES-D) (Radloff, 1977)
	20-item version of the General Health Questionnaire (GHQ-20) (D. Goldberg, 1985; D. P. Goldberg & Williams, 1988; Malt, 1989)
	Hospital Anxiety and Depression Scale (HADS) (Bjelland et al., 2002; Zigmond & Snaith, 1983)
	Fatigue Severity Scale (Valko et al., 2008)
Caregiver Preparedness	Caregiver Competence Scale (Pearlin et al., 1990)
	Self-administered carer questionnaire based on Morgan et al. (1998) guidelines
	Preparedness Scale (Archbold et al., 1990; Zwicker, 2010)
Healthcare Utilization	National Health Interview Survey (National Center for Health Statistics (NCHS), 1987)
Self-Efficacy	Mastery Scale (Pearlin & Schooler, 1978)
	General Self-Efficacy Scale (Johnston et al., 1995; Luszczynska et al., 2005; Steffen et al., 2002)
Self-Esteem	10-item Self-Esteem Scale (Rosenberg, 2015)
Caregiver Quality of Life	UCLA Loneliness Scale
	Carer Quality of Life Scale (Brouwer et al., 2006; Hoefman et al., 2013)
	Satisfaction with Life Scale (Diener et al., 1985)
Social Support	MOS Social Support Survey (Sherbourne & Stewart, 1991)
	12-Item Multidimensional Scale of Perceived Social Support (Zimet et al., 1988)
	Family and Friendship Contacts Scale (Andersson, 1984)
	Social Support Scale (Barrera Jr et al., 1981; Krause, 1995; Krause & Markides, 1990; Russell et al., 1980)

3.4 Acceptance, Effectiveness, and Satisfaction

Ten articles focused on evaluating the acceptability, effectiveness, and satisfaction of technological-based interventions (**Table 6**). The findings from these studies include:

(1) *Acceptance:* Acceptance of the technological-based intervention was evaluated in seven articles (Blanton et al., 2018; Caunca et al., 2020; Hartke & King, 2003; Mahmood et al., 2019; Marziali & Donahue, 2006; Marziali et al., 2005; Sureshkumar et al., 2016). In these articles, caregivers reported positive benefits when using the intervention. The benefits of the intervention included improvement in knowledge (Blanton et al., 2018), communication (Hartke & King, 2003; Mahmood et al., 2019; Marziali & Donahue, 2006; Marziali et al., 2005), awareness (Mahmood et al., 2019) and information delivery (Mahmood et al., 2019). Moreover, caregivers preferred the flexibility of accessing resources at any given time beneficial for their acceptance (Caunca et al., 2020). One study also described the technology's ability to reduce recovery time and cost of recovery (Mahmood et al., 2019).

(2) *Effectiveness:* Four articles (Mahmood et al., 2019; Smith et al., 2012; Sureshkumar et al., 2016; Van Den Berg et al., 2016) assessed the system's effectiveness in supporting the individual needs of caregivers. Of the four articles, three (Mahmood et al., 2019; Smith et al., 2012; Sureshkumar et al., 2016) demonstrated effectiveness, which was shown in the caregivers' level of confidence during recovery. One study (Smith et al., 2012) reported caregivers' need to share and continue using the app during survivors' recovery. In another study, caregivers' found that information delivery through video resources motivated them to provide better care to survivors (Sureshkumar et al., 2016). Further, one study demonstrated caregivers' willingness to use mobile-based home exercise programmes even if it required them to pay a nominal fee during registration (Mahmood et al., 2019).

(3) *Satisfaction:* Satisfaction was reported in seven articles (Blanton et al., 2018; Caunca et al., 2020; Hartke & King, 2003; Marziali & Donahue, 2006; Marziali et al., 2005; Stone, 2013; Sureshkumar et al., 2016), with six articles (Blanton et al., 2018; Caunca et al., 2020; Hartke & King, 2003; Marziali & Donahue, 2006; Marziali et al., 2005; Sureshkumar et al., 2016) demonstrating high caregiver satisfaction. Caregivers demonstrated satisfaction in the quality of the content (Blanton et al., 2018; Hartke & King, 2003; Marziali et al., 2005), ease of use (Blanton et al., 2018; Caunca et al., 2020; Marziali & Donahue, 2006; Sureshkumar et al., 2016), number of sessions (Hartke & King, 2003), and overall experience of the technology (Hartke & King, 2003). Some caregivers also reported the benefits of face-to-face communication with people living with similar experiences to promote better emotional support (Hartke & King, 2003; Marziali & Donahue, 2006; Marziali et al., 2005).

Table 6. Acceptance, effectiveness and satisfaction

Primary Author (Year) **Study Design, Intervention**	**Acceptance**	**Effectiveness**	**Satisfaction**
Hartke (2003) **Two-group, RCT, Telephone**	Yes		Yes
Marziali (2005) **Semi-structured Interviews, Telehealth**	Yes		Yes
Marziali (2006) **Pilot RCT, Telehealth**	Yes		Yes
Torp (2008) **Pilot Trial, ICT**			
Lutz (2009) **Non-randomized open trial; mixed methods design, Telehealth**			
Pierce (2009) **Two-group, RCT, Web**			
Smith (2012) **Two-group, RCT, Telephone**		Yes	
Stone (2013) **Pre-Post test, Web**			No
Sureshkumar (2016) **Mixed methods design, mHealth**	Yes	Yes	Yes
van den Berg (2016) **Pilot RCT, eHealth**		No	

Blanton (2018) **Open-ended questionnaire-based study, Web**	Yes		Yes
Vloothuis (2018) **RCT, mHealth**			
Mahmood (2019) **Cross-sectional questionnaire-based study, mHealth**	Yes	Yes	
Zhou (2019) **RCT, mHealth**			
Caunca (2020) **Iterative, user-centred approach, mHealth**	Yes		Yes

4. Discussion

The limited support available to caregivers in the stroke recovery process presents a potential opportunity for technology-based interventions to support these individuals in their daily activities. This rapid review attends to key factors that may contribute to impact, effectiveness, acceptance and satisfaction of the intervention during the disease trajectory. Specifically, highlighting the delivery process and ability to meet the needs of the caregiver, as compared towards only understanding its impact in care. For example, the systematic review conducted by Aldehaim et al. (2016) examined the impact of technology on several primary (i.e. depression) and secondary (i.e. burden, problem-solving abilities, health status, social support, preparedness and healthcare utilization) outcomes but did not consider its effectiveness, acceptance and satisfaction based on the individual needs of the caregiver. Hence, this review uncovers 15 eligible studies, and provides indications of promise towards technology use in stroke caregiving, and future perspectives to consider in its development.

Over the years, technology-based interventions have evolved from telephone to mHealth/eHealth systems (Mermelstein, Guzman, Rabinowitz, Krupinski, & Hilty, 2017). The purpose of these systems is to promote person-centred care (Dyb, Berntsen, & Kvam, 2021) and transform current healthcare practices through the promotion of information delivery, expansion of care and empowerment of individuals to manage their own health (Mermelstein et al., 2017). As a consequence, its implementation and evolution is evident in the research literature of stroke caregiving. For example, initially technology in stroke caregiving focused on telephone or telehealth systems (Hartke & King, 2003; Lutz et al., 2009; Marziali & Donahue, 2006; Marziali et al., 2005; Smith et al., 2012), which provided remote consultations, therapy and education support. Post-telephone and telehealth systems, researchers adopted web or ICT -based systems (Blanton et al., 2018; Pierce et al., 2009; Stone, 2013; Torp et al., 2008) to enable education and online discussions. Currently, mHealth technology (Caunca et al., 2020; Mahmood et al., 2019; Sureshkumar et al., 2016; Van Den Berg et al., 2016; Vloothuis et al., 2019; Zhou et al., 2019) has been considered by most researchers to educate, communicate, monitor, deliver and support care.

The technology implemented in stroke caregiving irrespective of the type of technology presents numerous advantages to support caregiver needs. A caregiver mentioned learning much about managing feelings and not being stressed as much in a web-based remote consultations' study. Moreover, caregivers felt prepared to manage the survivor's future condition (Marziali et al., 2005). Caregivers also discussed the importance of communication with nurses (Lutz et al., 2009) and people managing similar conditions (Marziali & Donahue, 2006; Marziali et al., 2005) using remote communication technology as it would allow them to ask questions or call at any given time (Lutz et al., 2009). Hence, receiving more practical advice (Marziali et al., 2005; Torp et al., 2008); thereby allowing the caregiver to feel less isolated and frustrated (Marziali et al., 2005). In addition to

supporting the needs of the caregiver, these technologies supported caregivers by improving their health status, preparedness, healthcare utilization, and self-esteem while influencing caregivers' activities of daily living and burden.

Despite the potential of technology in supporting caregiver needs, the research in these caregivers is limited and underrepresented compared to the technologies implemented for caregivers of other chronic diseases. The limitations in this studies is predominately methodological and impact related. Currently, most technologies implemented are based on credible research or best-practice guidelines (Hartke & King, 2003; Marziali & Donahue, 2006; Marziali et al., 2005; Torp et al., 2008; Zhou et al., 2019). While the use of theoretical models can form a strong foundation to design stroke caregiving technology as highlighted in the review, there is a lack of understanding and ability to support specific issues faced by the caregiver during recovery. As a result, it may affect its adherence over the course of recovery.

Lobo et al. (2021) suggests the use of user-centred design principles in stroke caregiving to limit these methodological issues and enable the researcher to understand a range of characteristics required to support stroke caregivers during recovery. However, only a few studies (Blanton et al., 2018; Caunca et al., 2020; Lutz et al., 2009; Sureshkumar et al., 2016) have considered user-centred design principles to understand the daily activities of caregivers and develop technologies to provide support. The lack of understanding of user needs may contribute to the limited impact current stroke caregiving technologies have on caregivers. A clear example of the potential of user-centred design in stroke caregiving technology is highlighted by the study conducted by Caunca et al. (2020), which shows improvement in caregiver activities of daily living, self-efficacy, and partial improvement in preparedness and social support. Moreover, caregivers demonstrated positive acceptance and satisfaction for the technology implemented. Hence, providing a case for future technologies in stroke caregiving to enable person-centred care.

4.1 Future Directions

The rapid review findings present two potential opportunities in stroke caregiving technology; the potential of technology interventions to support stroke caregiving and the need to consider usability and user experience in its design. Both opportunities have a common goal; to ensure the design of a system that provides caregivers with a meaningful, actionable, and feasible intervention.

Several human-computer interaction (HCI) studies have explored the possibilities of achieving these aspects through computer-supported cooperative work (Fitzpatrick & Ellingsen, 2013) and participatory design (Andersen et al., 2019). These include users' involvement as co-designers throughout the design and implementation considering a mixed-methods approach (i.e., a combination of surveys, interviews, observations, workshops, thinking-aloud sessions, and focus groups) (Kensing & Blomberg, 1998). These techniques allow the researcher to clearly define the project's scope and complexity (Andersen et al., 2019), thereby creating long-term acceptability, adoptability, and accessibility interventions (Liu, Fels, West, & Görges, 2019) that can have an impact on stroke caregiving.

4.2 Strengths and limitations

This rapid review is not without its limitations. Firstly, the review only considered studies available in English; therefore, it would be essential to note that this study does not cover all relevant literature available in technologies to support stroke caregiving, which could be a reason for the small number of articles included in this study. Furthermore, it may limit a comprehensive analysis of the potential of technology to support stroke caregiving. Secondly, there is a possibility for the exclusion of studies based on the limitation of search engines and terms since the definition of stroke caregiving technology is new and still evolving. Therefore, the definitions considered in this review may have not considered all the relevant studies. Thirdly, the review filtration and extraction process was

conducted by a single author under the supervision of another author. The filtration and extraction process considered a single author due to the time constraints, which was acceptable under the WHO methodology for rapid reviews. However, it may account for bias in the review. Finally, the review included articles comprising both survivors and caregivers in the evaluation process. This was due to the lack of technology-based interventions that explicitly supported stroke caregiving. Moreover, some studies also included a combination of survivor and caregiver outcomes. This would make it difficult to understand and classify the individual stakeholder's needs in these papers.

Despite the limitations, this review was designed and followed the guidelines based on the WHO methodology for rapid reviews including a rigorous review, extraction and bias assessment (i.e. to determine article eligibility). The review also revealed the impact of technology's to support caregiving, while showing methodological gaps to consider for future research. Moreover, it also demonstrated the need for user-centred design to ensure improved satisfaction and consideration for user-centred aspects related to intervention usability, content, and delivery to improve user experience and acceptability.

5. Conclusions

The rapid review shows that there is a potential to utilize technology to support caregivers of people with stroke. Technological-based interventions assisted caregivers by providing them tools to educate, support, communicate, assess and manage the stroke survivor while also collaborating with other stakeholders. Findings also highlight the impact of technology in stroke caregiving for systems that were developed through an understanding of caregiver needs. Hence, considerations need to be made to include users throughout the design process using user-centred design techniques, thereby possibly acceptance, satisfaction, and effectiveness throughout the disease trajectory.

6. Implications for Nursing Management

Stroke caregivers are often faced with uncertainty during recovery when responding to the survivors' needs for support due to the lack of preparation. Technological interventions can educate and support these caregivers, thereby improving the planning and management of care of a patient with stroke. While there have been technological-based interventions researched in the literature to support these caregivers, their potential has still not been realized as a means to ensure better caregiving outcomes. Hence, we propose the need to design stroke caregiving technology by including different stakeholders to create more usable and efficient technology to better support the caregiver during the recovery process.

7. References

Aldehaim, A. Y., Alotaibi, F. F., Uphold, C. R., & Dang, S. (2016). The impact of technology-based interventions on informal caregivers of stroke survivors: a systematic review. *Telemed J E Health, 22*(3), 223-231.

Andersen, T. O., Bansler, J. P., Kensing, F., Moll, J., Mønsted, T., Nielsen, K. D., . . . Svendsen, J. H. (2019). Aligning Concerns in Telecare: Three Concepts to Guide the Design of Patient-Centred E-Health. *Computer Supported Cooperative Work (CSCW), 28*(6), 1039-1072. doi:10.1007/s10606-018-9309-1

Blanton, S., Dunbar, S., & Clark, P. C. (2018). Content validity and satisfaction with a caregiver-integrated web-based rehabilitation intervention for persons with stroke. *Top Stroke Rehabil, 25*(3), 168-173.

Caro, C. C., Costa, J. D., & Da Cruz, D. M. C. (2018). Burden and Quality of Life of Family Caregivers of Stroke Patients. *Occup Ther Health Care, 32*(2), 154-171. doi:10.1080/07380577.2018.1449046

Caunca, M. R., Simonetto, M., Hartley, G., Wright, C. B., & Czaja, S. J. (2020). Design and Usability Testing of the Stroke Caregiver Support System: A Mobile-Friendly Website to Reduce Stroke Caregiver Burden. *Rehabil Nurs, 45*(3), 166-177.

Denham, A. M., Wynne, O., Baker, A. L., Spratt, N. J., Turner, A., Magin, P., . . . Bonevski, B. (2019). "This is our life now. Our new normal": A qualitative study of the unmet needs of carers of stroke survivors. *PLoS One, 14*(5), e0216682.

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health, 52*(6), 377-384.

Dyb, K., Berntsen, G. R., & Kvam, L. (2021). Adopt, adapt, or abandon technology-supported person-centred care initiatives: healthcare providers' beliefs matter. *BMC Health Services Research, 21*(1), 240. doi:10.1186/s12913-021-06262-1

Fitzpatrick, G., & Ellingsen, G. (2013). A review of 25 years of CSCW research in healthcare: contributions, challenges and future agendas. *Computer Supported Cooperative Work, 22*(4-6), 609-665.

Godwin, K. M., Mills, W. L., Anderson, J. A., & Kunik, M. E. (2013). Technology-driven interventions for caregivers of persons with dementia: a systematic review. *Am J Alzheimers Dis Other Demen, 28*(3), 216-222.

Hartke, R. J., & King, R. B. (2003). Telephone group intervention for older stroke caregivers. *Top Stroke Rehabil, 9*(4), 65-81.

Hultman, M. T., Everson-Rose, S. A., Tracy, M. F., Lindquist, R., & Hadidi, N. N. (2019). Associations between characteristics of stroke survivors and caregiver depressive symptoms: a critical review. *Top Stroke Rehabil, 26*(7), 528-537. doi:10.1080/10749357.2019.1641010

Kensing, F., & Blomberg, J. (1998). Participatory Design: Issues and Concerns. *Computer Supported Cooperative Work (CSCW), 7*(3), 167-185. doi:10.1023/A:1008689307411

Khangura, S., Polisena, J., Clifford, T. J., Farrah, K., & Kamel, C. (2014). Rapid review: an emerging approach to evidence synthesis in health technology assessment. *Int J Technol Assess Health Care, 30*(1), 20.

Liu, P., Fels, S., West, N., & Görges, M. (2019). Human Computer Interaction Design for Mobile Devices Based on a Smart Healthcare Architecture. *arXiv*, 1902.03541.

Lobo, E. H., Frølich, A., Rasmussen, L. J., Livingston, P. M., Grundy, J., Abdelrazek, M., & Kensing, F. (2021). Understanding the Methodological Issues and Solutions in the Research Design of Stroke Caregiving Technology. *Front Public Health, 9*, 647249. doi:10.3389/fpubh.2021.647249

Lundberg, S. (2014). The results from a two-year case study of an information and communication technology support system for family caregivers. *Disabil Rehabil Assist Technol, 9*(4), 353-358.

Lutz, B. J., Chumbler, N. R., Lyles, T., Hoffman, N., & Kobb, R. (2009). Testing a home-telehealth programme for US veterans recovering from stroke and their family caregivers. *Disabil Rehabil, 31*(5), 402-409.

Mahmood, A., Blaizy, V., Verma, A., Stephen Sequeira, J., Saha, D., Ramachandran, S., . . . Solomon, J. M. (2019). Acceptability and attitude towards a mobile-based home exercise program among stroke survivors and caregivers: A cross-sectional study. *Int J Telemed Appl, 2019*, 5903106.

Marcolino, M. S., Oliveira, J. A. Q., D'Agostino, M., Ribeiro, A. L., Alkmim, M. B. M., & Novillo-Ortiz, D. (2018). The impact of mHealth interventions: systematic review of systematic reviews. *JMIR Mhealth Uhealth, 6*(1), e23.

Marziali, E., & Donahue, P. (2006). Caring for others: Internet video-conferencing group intervention for family caregivers of older adults with neurodegenerative disease. *Gerontologist, 46*(3), 398-403.

Marziali, E., Donahue, P., & Crossin, G. (2005). Caring for others: Internet health care support intervention for family caregivers of persons with Alzheimer's, stroke, or Parkinson's disease. *Fam Soc, 86*(3), 375-383.

Mermelstein, H., Guzman, E., Rabinowitz, T., Krupinski, E., & Hilty, D. (2017). The Application of Technology to Health: The Evolution of Telephone to Telemedicine and Telepsychiatry: A Historical Review and Look at Human Factors. *J. technol. behav. sci, 2*(1), 5-20. doi:10.1007/s41347-017-0010-x

Mortenson, W. B., Demers, L., Fuhrer, M. J., Jutai, J. W., Lenker, J., & DeRuyter, F. (2012). How assistive technology use by individuals with disabilities impacts their caregivers: a systematic review of the research evidence. *American journal of physical medicine & rehabilitation, 91*(11), 984-998. doi:10.1097/PHM.0b013e318269eceb

Pierce, L. L., Steiner, V. L., Khuder, S. A., Govoni, A. L., & Horn, L. J. (2009). The effect of a Web-based stroke intervention on carers' well-being and survivors' use of healthcare services. *Disabil Rehabil, 31*(20), 1676-1684.

Smith, G. C., Egbert, N., Dellman-Jenkins, M., Nanna, K., & Palmieri, P. A. (2012). Reducing depression in stroke survivors and their informal caregivers: a randomized clinical trial of a Web-based intervention. *Rehabil Psychol, 57*(3), 196.

Stone, K. (2013). Enhancing preparedness and satisfaction of caregivers of patients discharged from an inpatient rehabilitation facility using an interactive website. *Rehabil Nurs, 39*(2), 76-85.

Sureshkumar, K., Murthy, G., Natarajan, S., Naveen, C., Goenka, S., & Kuper, H. (2016). Evaluation of the feasibility and acceptability of the 'Care for Stroke'intervention in India, a smartphone-enabled, carer-supported, educational intervention for management of disability following stroke. *BMJ Open, 6*(2), e009243.

Torp, S., Hanson, E., Hauge, S., Ulstein, I., & Magnusson, L. (2008). A pilot study of how information and communication technology may contribute to health promotion among elderly spousal carers in Norway. *Health Soc Care Community, 16*(1), 75-85.

Tricco, A. C., Langlois, E., & Straus, S. E. (2017). *Rapid reviews to strengthen health policy and systems: a practical guide*: World Health Organization.

Van Den Berg, M., Crotty, M., Liu, E., Killington, M., Kwakkel, G., & Van Wegen, E. (2016). Early supported discharge by caregiver-mediated exercises and e-health support after stroke: a proof-of-concept trial. *Stroke, 47*(7), 1885-1892.

Vloothuis, J. D., Mulder, M., Nijland, R. H., Goedhart, Q. S., Konijnenbelt, M., Mulder, H., . . . Kwakkel, G. (2019). Caregiver-mediated exercises with e-health support for early supported discharge after stroke (CARE4STROKE): A randomized controlled trial. *PLoS One, 14*(4), e0214241.

Wu, Q., Qian, S., Deng, C., & Yu, P. (2020). Understanding Interactions Between Caregivers and Care Recipients in Person-Centered Dementia Care: A Rapid Review. *Clinical interventions in aging, 15*, 1637-1647. doi:10.2147/CIA.S255454

Zhou, B., Zhang, J., Zhao, Y., Li, X., Anderson, C. S., Xie, B., . . . Prvu Bettger, J. (2019). Caregiver-Delivered Stroke Rehabilitation in Rural China: The RECOVER Randomized Controlled Trial. *Stroke, 50*(7), 1825-1830.