



**Trial Title:**

*Pedagogy and enriched environment for rehabilitation in the home after stroke (PEERHOMECare): study protocol for a single-group feasibility study*

Approved: 16th February 2026

**Study Protocol and Statistical Analysis Plan (included)**

Date of document: 30th March 2026

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**Title:**

**Pedagogy and Enriched Environment for Rehabilitation in the HOME after stroke (PEER HOMEcare): study protocol for a single-group feasibility study**

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## Study protocol

### I. Summary/Abstract

Home-based rehabilitation after stroke is becoming increasingly important, as the pressure on hospital-based services are increasing and most spend their recovery in their homes. Therefore, most require opportunities to practice meaningful activities in their everyday environment. Enriching the home environment may represent a potential strategy to support rehabilitation by providing continuous task and context-specific stimulation that promotes recovery and functional independence. through frequent and exploratory use of the affected upper limb. Exploratory behaviour, characterised by varied, adaptive and self-initiated movements, is considered an important driver of motor learning and neuroplasticity. While strong evidence from animal research demonstrates benefits for functional recovery, the translation to post-stroke home-based rehabilitation has not been made previously. This study investigates the feasibility, acceptability, fidelity, adherence and preliminary clinical effects of the Pedagogy and Enriched Environment for Rehabilitation in the HOME after stroke (PEERHOMECare) intervention. PEERHOMECare is a theory-driven, person-centred intervention that introduces meaningful, targeted and progressive modifications to the home environment to promote exploratory use of the affected upper limb during daily activities. This prospective, single group, experimental study will recruit 45 stroke survivors  $\geq 18$  years of age, within 6 months post-stroke across Norway, Sweden and Latvia. The intervention consists of strategies for enriching the home environment to stimulate exploratory and functional movements, primarily through the use of utilising existing household materials and objects. Wearable sensors placed on the upper limbs will be used to capture activity patterns and provide objective insights into motor behaviour and engagement within the home, informing progressive adjustments to the environmental enrichments. Feasibility, acceptability and fidelity of the intervention will be assessed with questionnaires and interviews with participants and therapists. Preliminary clinical outcomes will be explored with reliable and valid assessments of upper limb- and ADL- function, as well as cognitive and emotional function. A dedicated website ([www.peerhomecare.com](http://www.peerhomecare.com)) provides study information and educational resources for all participants and project therapists. This feasibility study will provide important knowledge about the implementation and potential impact of the PEERHOMECare intervention and will inform the design of a future trial evaluating its clinical effectiveness in supporting home-based stroke rehabilitation.

### II. Keywords

Stroke, Rehabilitation, Home-based rehabilitation, Enriched Environment, Upper limb function, Activities of Daily Living, Motor learning, Motion sensors, Feasibility

### Statements and Declarations

All authors contributed to the study conception and design, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

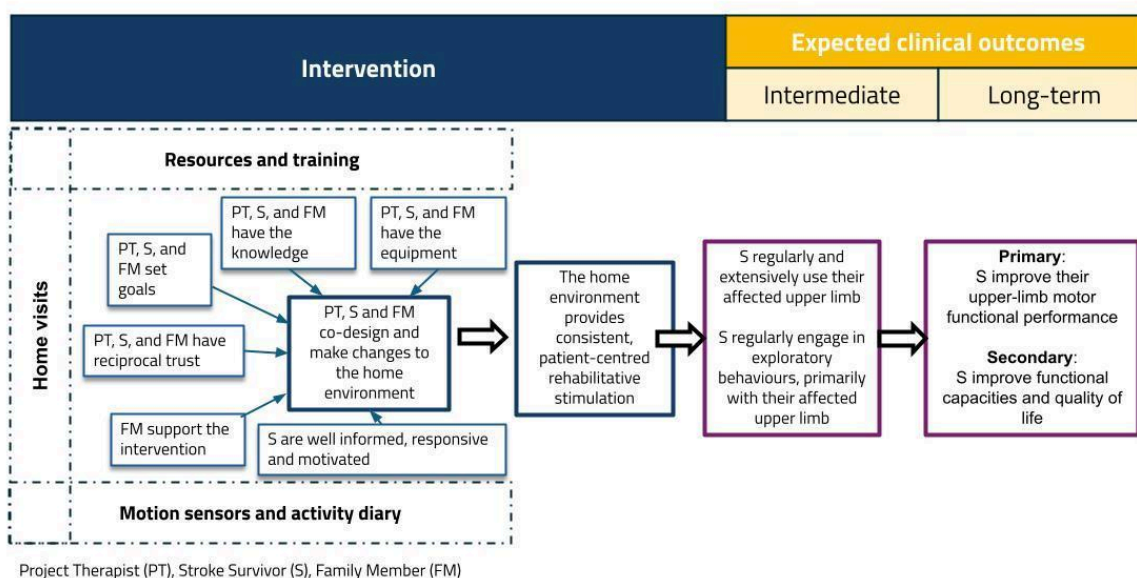
### III. Introduction

Stroke is the third leading cause of death and disability worldwide [1]. In 2021, there were 11.9 million new stroke cases and 93.8 million people living with stroke globally [2]. Despite age-adjusted declines in those over 70 years, overall numbers continue to rise due to population growth. Stroke imposes a substantial societal and healthcare burden, costing about €45 billion annually in Europe [3]. A majority of the stroke survivors are left with lasting impairments, for instance upper limb paresis occurs in approximately 70% of stroke survivors, and recovery of arm and hand function is a key priority in rehabilitation, as it is closely linked to independence in activities of daily living (ADL) [4]. The deliberate shift during the last decades of earlier hospital discharge and moving specialist rehabilitation services into patients' homes highlights the urgent need for more effective rehabilitation strategies [5].

Innovative strategies are needed for home-based rehabilitation, an increasingly central component of stroke care [6]. Home is where most stroke survivors spend most of their time in the post-acute phase, defined as the initial six months after stroke onset. The post-acute phase represents the most sensitive window for neuroplastic reparatory changes to occur and consequently movement functions to improve [7, 8]. While some neural repair occurs spontaneously, recovery is largely activity- and experience-dependent [9, 10], highlighting the importance of active, exploratory use of affected body parts in everyday contexts. Evidence from Early Supported Discharge demonstrates the potential of the home environment, where survivors are often more independent and active than in a hospital [11, 12]. However, the potential of home-based rehabilitation remains underused: only about 50% of survivors receive rehabilitation [13, 14], many feel unprepared for the transition home [15], and sedentary behaviour is common [16].

Environmental Enrichment (EE) is a promising strategy for improving home-based rehabilitation and transforming the home into a stimulating and supportive environment that actively engages patients to explore diverse motor, cognitive, sensory, and social activities, thereby promoting neuroplasticity and stroke rehabilitation outcomes [17]. Predominantly adopted in animal-based research, EE refers to housing conditions, such as enlarged spaces and the provision of equipment, that stimulate enhanced activities, exploration, and socialisation [9]. Evidence indicates that housing animal models of stroke in an EE improves the rehabilitation process through a series of nested plastic and reparatory mechanisms (for a detailed review of the mechanisms, see [18]), which underlie an enhancement of cognitive and motor functions [19] leading to an increased autonomy to perform daily functions. A handful of studies have translated EE to stroke rehabilitation in stroke units and hospital wards, showing increased physical, social, and cognitive activities [20-22], and reduction in depression, anxiety, and stress levels [23]. These initial translational efforts confirm the potential of EE to improve stroke rehabilitation.

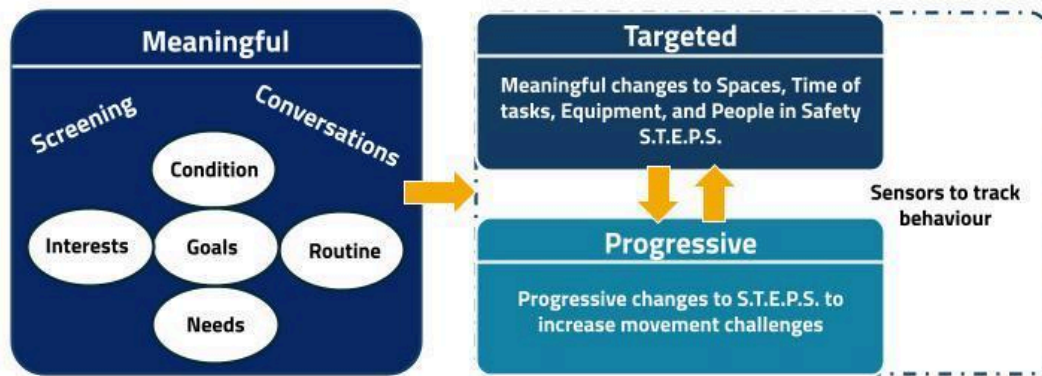
In response to the current challenges in rehabilitation and the potential of EE to improve current practice, we have developed the "Pedagogy and Enriched Environment for Rehabilitation in the HOME after stroke" (PEERHOMecare) intervention. PEERHOMecare is a translational, theory-driven, population-centred, complex intervention, developed in alignment with the framework for complex interventions of the Medical Research Council [MRC; 24, 25].



**Fig. 1** Diagram showing the intervention elements in the dotted boxes to promote the expected clinical outcomes. The process of developing the intervention will be described in detail elsewhere. Abbreviations: Project Therapists (PT), S: Stroke survivors, FM: Family Members. Google Sheets.

PEERHOMECare is a home-based intervention built upon a clear theoretical pathway of change and improvement (Fig. 1) to support a patient rehabilitation process. It utilises an innovative translation of EE, conceptualising it as a strategy that entails meaningful, targeted, and progressive changes to physical and social aspects of the home pertaining to everyday behaviours (for more details, see methods and [26]). These changes invite survivors to frequently use the affected upper extremity to carry out activities of daily living (ADLs) and to perform enhanced exploratory behaviours, promoting neuroplasticity and leading to improvement in upper limb functions. A recent scoping review of preclinical EE in stroke models [27] combined with rehabilitation and motor learning sciences informed the novel conceptualisation of the paradigm into meaningful (tailored to individuals' needs and routine), targeted (directed towards rehabilitation goals and capacity), and progressive (incremental manipulation of complexity, novelty, and variety) environmental modifications (Fig. 2).

To facilitate EE modifications, the intervention uses the S.T.E.P.S (space, time, equipment, people & safety) acronym to guide structured and systematic modifications to the environment (see methods). Through this new lens, EE involves simple and cost-free modifications that create numerous invitations, tailored to each survivor, to be active and repeatedly use their affected limb throughout the day [26]. It is population-centred, meaning it has been co-designed with stakeholders, and it is individualised to the conditions, goals, and needs of each stroke survivor and tailored to local contexts. Since many ADLs requiring adequate limb function limiting post-stroke independence, the main objective of the PEERHOMECare intervention is to enhance motor functional performance in the upper extremity. Being embedded in the individuals' living environment and targeting functions that support ADLs, this intervention fully aligns with Stroke Action Plan for Europe 2018-2030 [6] and the WHO definition of rehabilitation "a set of interventions designed to optimise functioning and reduce disability in individuals with health conditions in interaction with their environment" [28].



**Fig. 2** Conceptual framework of environmental modifications in PEERHOMECare intervention, comprising three components: meaningful (tailored to individuals' needs and routines), targeted (aligned with rehabilitation goals and capacity), and progressive (gradual increases in complexity, novelty, and variety).

The aim of the study is to investigate the feasibility, acceptability, fidelity, adherence and adverse events of the PEERHOMECare intervention in patient's homes. This is an important first step as set out in the MRC framework, as it is critical to investigate the feasibility prior to conducting a full scaled randomised controlled trial of an intervention [24]. The study will also investigate preliminary results of the clinical effectiveness. The feasibility trial will be carried out in three different countries, Norway, Sweden, and Latvia to evaluate feasibility in different healthcare systems and contexts. It is hypothesised that the delivery of the PEERHOMECare intervention will be found to be feasible and acceptable for people post-stroke, their family members, and the healthcare professionals.

## IV. Materials and Methods

### Design

This study uses a prospective, single group, experimental design and is conducted in accordance with the CONSORT checklist for feasibility studies [36] (Supplement 1.0). The study uses a combination of quantitative and qualitative methods to ensure a complete and person-centred approach on the investigation. The flow chart and design of the study is presented in Fig. 3.

### Study settings

The study will take place in the regions of Oslo in Norway, Gothenburg in Sweden and Riga in Latvia. The intervention will take place in the home of the participants.

### Participants

A total of 45 participants from Sweden, Latvia and Norway will be recruited, with approximately 15 individuals from each site to allow for variation in ages, living conditions and stroke type and severity. They will be adults of both sexes, diagnosed with stroke no more than 6 months prior to enrolment. They should either be about to be discharged or already have been discharged to their home following inpatient rehabilitation.

### PEERHOMECare Intervention

The intervention provides a progressive, home-based rehabilitation experience that integrates EE principles to stimulate motor learning through everyday activities. The intervention focuses on making meaningful, targeted, and progressive modifications to the home environment to promote frequent, varied, and exploratory use of the affected upper limb.

Meaningful refers to modifications centred on activities that matter to the stroke survivor, thus connected to their identity, independence, daily roles, or enjoyment. Targeted indicates that modifications are aligned with individualised rehabilitation goals and current capabilities to increase purposeful use of the affected limb. Progressive reflects the gradual adjustment of environmental demands over time, ensuring the survivor is safely challenged to engage in increasingly varied and exploratory movements, thereby supporting independence, skill acquisition, and confidence.

Environmental modifications focus on Spaces, Time, Equipment, and People involved in a task, within safe boundaries (S.T.E.P.S.). These are co-designed together with the participant and the project therapist (PT), implemented through (i) home visits from the project therapist that include structured screening and assessments to identify the participant's goals for the intervention, (ii) educational resources and materials (e.g. including a daily activity diary), and (iii) motion sensors to track movement behaviour.

*Meaningful* ADLs are here defined as activities that align with the survivor's rehabilitation goals, functional capacity, preferences, and daily routines [29]. Through home visits by the project therapist, goal identification begins with an inspired version of the Canadian Occupational Performance Measure (COPM), which is modified and used collaboratively with the survivor to prioritise personally meaningful activities and establish initial rehabilitation goals. Motor capacity, functional ADL performance and cognitive and psychological constructs are identified using the assessments as outlined in Table 4. These assessments are further considered to individualise the intervention to enable the identification of three meaningful goals and three routine ADLs.

*Targeted* EE modifications focus on the selected meaningful and routine ADLs, with the aim of increasing independence and task-specific engagement of the affected limb during task performance. Through collaborative discussions, the project therapist and survivor co-design changes according to S.T.E.P.S. Depending on current performance, modifications may facilitate the affected limb's contribution to bimanual tasks or encourage its use in unimanual activities.

*Progression* EE modifications are systematically progressed over time to increase task challenge through increasing complexity, variety, and novelty. This progression promotes diverse and exploratory task engagement while maintaining safety (see Table 1 for illustrative examples).

Table 1: Illustrative Case Examples: Operationalising S.T.E.P.S. within PEERHOMecare intervention.

<p><b>Participant profile.</b> A 62-year-old right-hand-dominant male presented with left hemiparesis and left hemi-spatial neglect. Visual acuity was intact; however, perceptual awareness of the left side was impaired, with a pronounced right-sided attentional bias. Deficits affected functional mobility, safety, and ADL performance, particularly tasks requiring bilateral coordination and environmental scanning. He lived at home with his wife and two adult sons (18 and 21 years). COPM goals included walking his dog, independent dressing (buttoning jeans), and playing chess with his sons. SAFE score for the left upper limb was 4 (shoulder abduction = 2, finger extension = 2). Rehabilitation priorities were upper-limb motor recovery, neglect management, functional independence, and home safety optimisation.</p>		
ADL Activity Identified	Dressing	Preparing breakfast (making coffee and toast)

<b>Meaningful</b>	<p>This activity was selected because it was personally meaningful identified in COPM, occurred daily, and required bilateral coordination, postural control, and visual attention to the left side.</p> <p>Independently being able to fasten and put on jeans or trousers represented dignity, privacy, and reduced reliance on his partner. The participant identified dressing without assistance as a key marker of recovery.</p>	<p>This task was selected because it occurred daily, required bimanual coordination, and when discussing previous daily routines with the participant it was found to be highly meaningful for morning routine and general happiness.</p> <p>Preparing coffee each morning represented independence and resumption of normal life roles. The participant reported that “starting the day myself” was emotionally important, making it a high-salience activity for practice.</p>
<b>Targeted</b>	<p>Initial observation, supported by survey data, showed minimal contribution of the affected limb, with reliance on the wife for balance and fastening. Modifications therefore aimed to increase active initiation and stabilisation by the affected limb while maintaining task success.</p> <p>The task was simplified by using the participant’s own trousers with a magnetic clip and Velcro fastening, preserving the meaningful goal while reducing fine motor demands.</p>	<p>Initial observation showed dominant use of the right arm and reduced attention to the left side. Modifications aimed to increase left-arm use for reaching and stabilising and to improve attention toward the left space.</p>
<b>Progressive using S.T.E.P.S</b>		
<b>Space</b>	<p>Practice was integrated into the daily routine in the bedroom and bathroom. Trousers were positioned on the left side of the bed to encourage attention to the affected side. As performance improved, the original button was reintroduced and practised repeatedly while watching TV to increase repetition.</p>	<p>Practice occurred in the kitchen during the morning routine. Items were initially placed on the left side and later returned to typical locations to increase independence.</p>
<b>Time</b>	<p>The task was practised at least five times per day as part of their normal routine (dressing, going to the toilet etc). Initially it was completed slowly to allow concentration, with speed increasing as performance improved.</p>	<p>The task was practised daily at breakfast. It was performed slowly at first to support attention, then progressed to normal speed.</p>
<b>Equipment</b>	<p>Practice began in sitting (bed, chair, or toilet). A mirror was added on the affected side for visual feedback, and later a table was introduced to support posture and task organisation.</p>	<p>Lightweight mugs, a non-slip mat, and an easy-pour kettle were used initially and gradually removed as ability improved.</p>
<b>Person</b>	<p>Initially, the wife provided physical assistance. Over time, the participant initiated the task independently, with the wife stepping back to standby support.</p>	<p>Verbal prompts and close support were provided at first. The participant progressed to initiating the task independently, with reduced input from his wife.</p>
<b>Safety</b>	<p>Assistance progressed from hands-on support to supervision from</p>	<p>Close supervision due to hot liquids progressed to occasional checking as safety awareness improved.</p>

	the doorway as balance and confidence improved.	
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### **Motion Sensor Monitoring and Use with the Activity Diary**

Participants will be asked to wear four CE-marked Inertial Measurement Unit (IMU) sensors (Xsens, Movella Inc., California, USA) for up to two hours per day. Sensors are worn over clothing using straps, and are positioned on the sternum, affected and non-affected forearms, and the affected upper arm. The number of sensors and their placement were determined based on pilot studies [30, 31] that provided the minimum number of sensors to capture movement information from stroke patients.

Project therapists will provide instruction on how to place the sensors and operate the receiver device, with additional guidance available in the training materials. The therapist and participant will decide together the most appropriate time of day for sensor use. The sensors will record acceleration and orientation of the body segments in three dimensions that will be captured by a custom-made application developed in Python (Version 3.9.24) (Python Software Foundation, python.org).

From these signals, quantitative metrics will be derived from another custom-made application developed in Matlab R2025b (Version 25.2.0.3150157) (Mathworks, Natick, MA). As stated, it is of primary importance to capture exploratory activity with the upper limb as to guarantee that manipulations in the home environment are effective and stimulating for recovery. For this reason, we derived measures of movement variability (entropy), smoothness, novelty of motor patterns, compensation (use of trunk when performing affected limb movements), use of the affected upper limb and proportion of time spent in moderate-to-vigorous physical activity. Variability and novelty are common aspects considered in the literature to capture exploratory behaviour [32]. We measure variability through entropy [33, 34] of the signal provided by the sensors in four different ways: 1) considering acceleration and orientation or 2) just orientation, 3) considering all sensors or 4) just the affected limb. These four types of variability allow interpretation from the project therapist on different aspects of the ADLs. Variation in ways to perform the same movement (changes in acceleration), varied movements (changes in joint orientations) emphasising, or not, the affected limb. Novelty was considered as to directly point when modifications of the environment led to new forms of acting, thus demonstrating whether exploration (entropy/ variability) lead to new movements. Compensation, use of the affected limb, and smoothness are measures directly related to how the participant performs the movements during ADL. The time spent in moderate-to-vigorous physical activity is an additional measure informing whether modifications lead to more active behaviours in the home.

To help interpret the information from the sensors, participants complete the activity diary on the same days as they wear the sensors. The diary provides an understanding of the stroke survivors' daily activity patterns. It provides context about what activities were being performed, where they took place, and how much assistance was needed. Combining sensor data with diary entries allows the therapy team to adjust S.T.E.P.S. modifications so the intervention remains appropriate, relevant, progressive and safe.

### **Educational resources**

The delivery and implementation of the intervention are supported by a fully functioning website ([www.peerhomecare.com](http://www.peerhomecare.com)) that serves as the program's digital companion. This intranet-style portal provides a centralised, secure access point for all individuals involved in the study, including project therapists, stroke survivors, and their support networks, including family members. Access is role-based, ensuring that users are presented with the specific training, information, and ongoing support materials relevant to their participation.

For participants with stroke and their family members, the educational content will focus on familiarisation with the intervention, including peer-led mentorship and motivational input from other stroke survivors, guidance on collecting and managing motion sensor data, and strategies to support active involvement in their own rehabilitation. PTs will utilise the portal as a standardised training-suite for administering and interpreting objective assessments, including sensor data, instructions on the intervention and application of PEERHOMECare Enriched Environment strategies.

To ensure the portal is accessible and user-friendly for survivors with post-stroke visual or cognitive impairments, the interface utilises adaptive accessibility features, such as high-contrast modes, scalable text, and a simplified, 'one-click' menu structure to minimise cognitive load. The resources primarily consist of short videos alongside clear, written content and illustrative images to ensure ease of understanding for all users. All digital resources are mirrored in a professional, print-ready format to be provided as physical manuals for participants who prefer or require paper-based materials ([35] <http://www.peerhomecare.com/>) Access to the learning materials and resources in the portal will be restricted to individuals involved in the study.

## Recruitment

Participants will be recruited from the stroke department at Sunnaas Rehabilitation Hospital and from specialised rehabilitation institutions and local municipalities in South-Eastern Norway, as well as from Sahlgrenska University Hospital (Gothenburg, Sweden) and Riga East University Hospital (Riga, Latvia).

Potentially eligible participants will be identified and screened by therapists experienced in stroke care and rehabilitation (see Table 2 for full eligibility criteria). Individuals will receive verbal and written information about the study, with accessible and adapted materials provided for those with communication or cognitive difficulties. Screening will include assessment of upper-limb motor function using the Shoulder Abduction and Finger Extension (SAFE) test (minimum score  $\geq 4$ ) and cognitive function using the Montreal Cognitive Assessment (MoCA). Because this is a feasibility study, we will explore how cognitive impairments influence participation; therefore, individuals with severe cognitive impairment (MoCA  $< 10$ ) will be excluded.

Table 2: Eligibility, inclusion and exclusion criteria

Inclusion criteria:	Exclusion criteria:
adults ( $\geq 18$ years old)	presence of other neurological conditions
diagnosed with first or second haemorrhagic or ischaemic stroke	reported limited life expectancy due to other medical conditions during the study period
stroke onset no more than six months before study enrolment	severe mental health disorders, including substance use disorders
discharged to their home following inpatient rehabilitation	a history of violence
reporting functional impairments in the upper extremity that affect functioning and participation in everyday life due to the latest stroke.	severe communication and/or cognition deficits (MoCA below 10 points) that prevent participants from being able to participate in the intervention, understand interview questions, or study-related instructions
score at least 4 points on the Shoulder Abduction + Finger Extension (SAFE) measure.	unwillingness of persons sharing the household to participate and accept the intervention
adequate language skills and cognitive functioning to be able to understand intervention material, perform outcome assessments and co-operate throughout the intervention	Uncontrolled medical issues such as unstable angina, severe hypertension, or severely limiting orthopaedic conditions

willing to participate and able to provide written consent	
consent for participation also by closest family members, if they live in the same household	

Once participants are screened and consented to participate in the study, descriptive characteristics will also be obtained to include stroke severity, location and type of stroke, date of stroke, dominant side, and modified Rankin Scale (mRS) score.

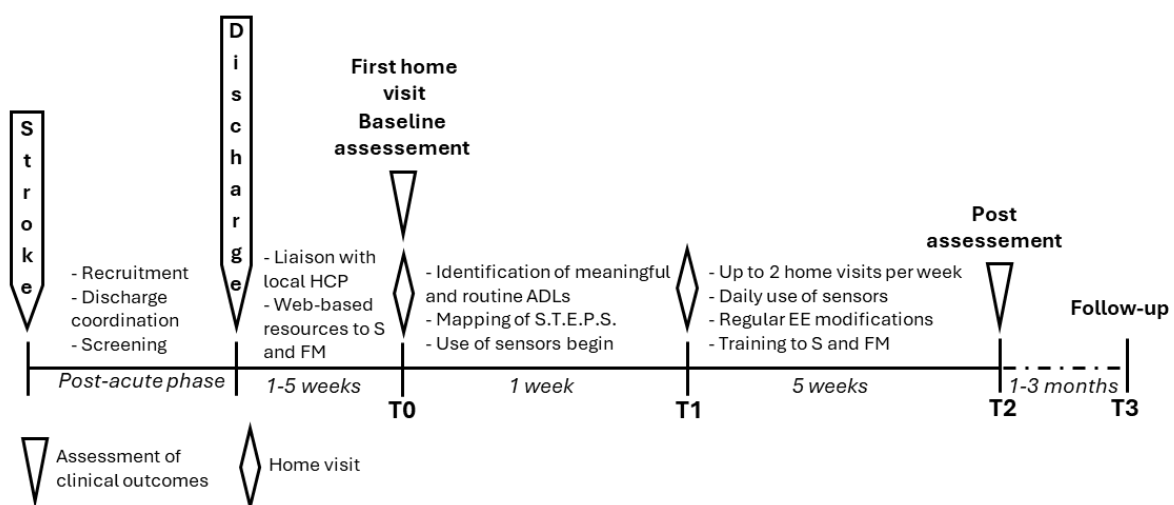
Information about the home environment will also be recorded, including type of residence (e.g., apartment or single house), number and types of rooms, presence of stairs, geographical setting (urban, semi-urban, rural), and cohabitants.

A cohabitant and/or healthcare professional clinically working with the participant, will also be invited to participate in the study.

### Timeline of the intervention

Once the participants have been recruited to the intervention, they and their family member (FM) will be given access to the web-based or paper-based information resources. One-to-five weeks after recruitment, the intervention will begin with a home visit by the project therapist. In week 1 (T0 -T1), the baseline testing of the clinical outcome measures will be made in the participant's home. The project therapist will identify and observe participants routines, daily and leisure activities, and goals, map the home environment, hand out and start using the motion sensors, and begin with the home modifications (Fig. 3).

Over the following 5 weeks (T1-T2), modifications to the home environment will be made and followed up (Table 1). The project therapist will perform 1-2 home visits per week with the addition of phone calls and/or videoconferences. The number and type of contacts with the project therapists will be tailored to the participants individual needs and preferences. The participants will keep an activity diary, recording the time and duration of the most important and relevant motor tasks. At T2, the primary clinical outcomes and the feasibility study outcomes will be assessed. These assessments will take around 1-2 hours and be carried out in the home. Three months after T2, the project therapist will conduct a follow-up call with the participants and FM to understand their thoughts about the intervention and to what extent they have continued to follow the EE principles afterwards (Fig. 3).



**Fig 3** Flow of the study design of the PEERHOMECare feasibility study

## Outcome measures

The primary outcomes of this study are the feasibility and acceptability of the intervention and study procedures. Secondary outcomes will explore preliminary changes in domains aligned with the intervention targets, including upper-limb motor recovery, real-world arm use, activity and participation, and psychosocial outcomes. These measures are exploratory and will inform outcome selection and sample size estimation for a future RCT.

## Primary outcomes

Feasibility and acceptability of the intervention and study procedures will be assessed across key domains, including recruitment processes, delivery of intervention components, use of technology and educational resources, and implementation of home modifications. Fidelity to the intervention by project therapists and participant adherence to intervention components will also be evaluated. Adverse events, including falls or injuries, will be documented.

Detailed definitions of feasibility variables, assessment tools, and outcome descriptions are provided in Table 3.

Table 3. Overview over the variables, the assessment tools and their descriptions in the feasibility trial of the PEER HOMEcare intervention.

Variable	Assessment tools	Description
<b>Feasibility</b>	Questionnaires; study logs; observational notes	Practical feasibility of delivering the intervention, including recruitment processes, resource requirements, time demands, and logistical considerations
<b>Acceptability</b>	Qualitative interviews; questionnaires	Participant and healthcare professional perceptions of the intervention, the training materials, and use of body-worn motion sensors
<b>Adherence</b>	Motion sensor data; activity diary; study logs; website analytics	Participant engagement with intervention components, including sensor use, diary completion and use of digital resources
<b>Fidelity</b>	Therapist questionnaires; protocol checklists	Extent to which the intervention is delivered as intended according to the protocol and training procedures
<b>Adverse events</b>	Study logs; interviews	Recording of any adverse events affecting participants or family members, such as falls, injuries, or other unexpected events

Semi-structured interviews will be conducted with a purposive sample of approximately 12–18 participants across the three participating countries (4–6 participants per country), to capture a range of experiences and perspectives. The interviews will explore participants experiences, perceived acceptability and self-reported effects of the intervention. The interviews will be guided by topics related to the intervention and analysed using thematic analysis. Data collection will take place shortly after completion of the intervention (T2).

In addition, the feasibility and relevance of collaboration with local healthcare professionals (HCPs) that also work with the participants will be explored. HCPs will be invited to share their perspectives and experiences of delivering or supporting the intervention within community services.

## Clinical outcomes

A complete list of the outcome measures of the intervention is provided in Table 4.

Action Research Arm Test (ARAT) [37, 38] will be used to assess functional motor activities in the upper limbs. ARAT is a valid and reliable outcome measure that has been used extensively in stroke research and rehabilitation ([Action Research Arm Test | RehabMeasures Database](#)).

Fugl Meyer Assessment Upper Extremity (FMA-UE) [39] will be used to assess sensorimotor impairments in the upper limbs. FMA-UE is both valid and reliable and widely used in stroke research and rehabilitation ([Fugl-Meyer Assessment | Institute of Neuroscience and Physiology, University of Gothenburg](#)).

Abilhand [40] is a self-report questionnaire about perceived difficulties with bimanual hand skills. Abilhand is found to be valid and reliable in stroke research ([ABILHAND | RehabMeasures Database](#)).

The Stroke Self-Efficacy Questionnaire (SSEQ) assesses stroke survivors' perceived confidence in performing functional and self-management activities. It provides a validated measure of self-efficacy relevant to poststroke rehabilitation and independence [41].

The Stroke Impact Scale (SIS) is a stroke specific patient-reported outcome measure capturing the multidimensional consequences of stroke across physical, emotional, cognitive, and participation domains. It is widely used to quantify recovery and quality of life [42].

Barthel Index (BI) [43], will be used to assess basic ADL and self care function. BI is considered valid and reliable to use in stroke research ([Barthel Index | RehabMeasures Database](#)).

The Patient Health Questionnaire (PHQ-9) is a short assessment of depressive symptom severity over the preceding two weeks. It is validated for screening and monitoring depression in clinical and research contexts [44].

The General Anxiety Disorder-7 (GAD-7) measures the severity of generalised anxiety symptoms and has strong psychometric properties and clinical utility [45].

## Secondary Outcomes- movement sensor measures

*Entropy* measures will be used to assess exploratory behaviour. *Entropy general* - considers all segments or the single affected limb and will demonstrate changes combining what and how movements were explored. *Entropy joints* - consider all segments or the single affected limb and will describe changes in how movements were explored. Entropy, as a measure of variability, have been used with success to demonstrate the necessary changes in movement behaviour anticipating improvements [46, 47].

*Novelty* is a direct measure of whether new segment orientations were observed when the sensors were used. In this current form, this measure has not been used before, but novelty has been proceduralised in other ways before in the field of motor control/ learning [48, 49].

*Smoothness* has been demonstrated as an important indicator of stroke recovery [50]. This will be used, therefore, as a day-to-day measure of motor function. Use of the affected limb is a direct measure of presence of movements with the affected limb. This is of relevance provided the goal of the participants.

*Compensation* has long been demonstrated to be one way that stroke survivors improve function over time [51]. A common way to compensate for the impaired limb is by moving the trunk while moving the affected limb. Thus, this measure captures whenever the trunk was moved simultaneously as the affected limb performed a movement.

*Use of the affected limb* is a simple measure estimating the amount of time (percentage), that the participant moved the affected limb. This measure verifies whether the manipulations require/afford

use of the affected limb to support goal achievement. In the long term, large values would hold learned non-use of the affected limb

Table 4. The clinical outcome measures and screening instruments that will be used in the PEER HOMEcare intervention.

Clinical outcome measures	Time of assessments	
	T0 Baseline	T2 End
Screening instruments		
Voluntary Muscle strength in shoulder abduction and finger extension (SAFE)	♦	
Cognitive functioning: Montreal cognitive assessment (MoCA)	♦	
Activities of daily living and dependence: Modified Rankin scale	♦	
CLINICAL OUTCOMES	♦	
Motor ability for upper limb		
Action Research Arm Test (ARAT)	♦	♦
Fugl-Meyer Assessment (FMA-UE)	♦	♦
Self-reported arm use: Abilhand	♦	♦
Self-efficacy and disability		
Stroke self-efficacy questionnaire (SSEQ)	♦	♦
Stroke impact scale (SIS)	♦	♦
Activities of daily living: Barthel Index	♦	♦
Depression and anxiety		
Patient health questionnaire-9 (PHQ-9)	♦	♦
Generalised anxiety disorder (GAD-7)	♦	♦

### Process evaluation – quantitative and qualitative data

A process evaluation will be conducted to understand how the intervention was implemented and experienced across the three participating countries. This will include examination of implementation fidelity, participant engagement, and contextual factors influencing delivery. Quantitative data from feasibility metrics, adherence measures, and study logs will be combined with qualitative findings from participant and healthcare professional interviews.

The process evaluation will explore how participants interacted with intervention components, including home modifications, educational resources, and motion sensors, and how these contributed to perceived benefits or challenges. Contextual influences such as home environment, support from family members, and differences in healthcare systems will also be considered. Findings will be used to refine the intervention and inform the design of a future definitive trial.

### Statistical analysis

All quantitative data will be analysed using IBM SPSS. Baseline characteristics and screening measures will be summarised using means and standard deviations or medians and interquartile ranges, as appropriate. Feasibility, acceptability, fidelity, and adherence outcomes will be summarised using descriptive statistics, including counts and percentages. The outcomes of the feasibility assessments will be interpreted as follows: A satisfaction rate of more than 80% will be regarded as a positive outcome and considered indicative of positive feasibility. The success criteria are described in Supplement 2.0.

Secondary outcome measures will be described with descriptive statistics. Exploratory analyses will examine changes between T0 and T2 using paired parametric or non-parametric tests, depending on

data distribution and variable type. As this is a feasibility study, these analyses will be interpreted cautiously and primarily used to estimate variability and inform the design of a future definitive trial. A p-value of <0.05 will be reported for completeness.

Sensor data will be analysed with a custom-made script in Matlab. Entropy measures will be calculated following [30, 31]. The data is first discretised in bins (with specific bin sizes for acceleration and orientation) and the frequency of the 6-dimensional time series bins is calculated. Then, using the probability of each bin occurrence, the entropy is calculated

$$(-\sum p_i \cdot \log(p_i)),$$

where  $p_i$  is the probability of the  $i$ th bin). Smoothness follows [52]. To have a single dimension of acceleration, we calculated the norm of the three dimensions. This was then integrated to have a peak speed and differentiated to identify jerk. The smoothness measure was the negative mean of absolute jerk divided by peak speed. Novelty considers the whole history of movements performed while wearing the sensors and calculates the percentage, from movements currently performed, that were novel. Use of affected upper limb delimits a threshold of acceleration at which moving of the arm is considered. From this, the percentage of time that movement occurred is calculated. Compensation considers the previous measure (use of the affected limb) and calculates whether the sternum was also moving at the time that the affected limb was moving. This cooccurrence of movement in trunk and affected limb is then divided by all motion of the affected limb to provide a percentage. Moderate to vigorous physical activity will be calculated following the general guidelines for wrist-worn accelerometers [53]. The Euclidean norm (minus one) of the acceleration provided by the forearm sensor will be calculated and summed over a period of 5 seconds. An epoch that shows values above a given threshold (to be validated in terms of the forearm) will be provided as an epoch of activity. Minutes that show more than 80% of activity will be considered a minute of moderate-to-vigorous physical activity.

## VI. Notes

### Patient and public involvement

Patients, family members and partner organisations with lived experience of stroke were involved in the development of the intervention and study procedures, with one recruited from one of the largest stroke organisations within Norway. Their input informed the selection of meaningful activities, the design of home-based components, and the format of educational materials to ensure relevance, usability, and acceptability. Feedback was also used to refine participant information, diary formats, and the timing of assessments to minimise burden.

During the feasibility study, participants will contribute further through qualitative interviews exploring their experiences of the intervention. The findings will inform refinement of the intervention and the design of a future definitive trial. Patients and the public will not be involved in recruitment or data collection beyond their role as study participants.

### Compliance with Ethical Standards and registrations

This study has been approved by The Regional Committee for Medical and Health Research Ethics for South-East of Norway in February 2026 (ID nr.816325). Latvia has also received approval from the Research Ethics Committee of Riga Stradiņš University (ID nr.2-PĒK-4/225/2026) and the Science Department of Riga East University Hospital (ID nr.AP/08-08.1/26/49) in February 2026. In Sweden the study was approved by the Authorities for Ethics in Research (ID nr. 2026-00409-01). The study will be performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

All participants will give written informed consent, which includes information about the study's purposes and consequences, participants' rights, confidentiality, data management, and emphasises the right to withdraw from the study at any time without giving any reason. Participants will not be asked to refrain from any ongoing treatment during the trial.

All authors declare no conflict of interest, neither of financial or non-financial nature.

### **Dissemination of results**

The results from the project will be published in peer-reviewed, scientific journals. The results will also be presented at conferences within the fields of physical medicine and rehabilitation, stroke and neurology, movement science as well as in motor learning and pedagogy. The project has established close cooperation with stakeholders in the patient organisations in all countries, and the results, experiences and knowledge gained in the project will be shared with them through joint meetings, newsletters and other information channels. The project has developed a specific web site where all relevant information and results from the project will be available for all.

### **Data management and data storage**

All data handling and storage will be confidential and be in line with Norwegian, Portuguese, Swedish, and Latvian privacy protection regulations and the General Data Protection Regulation (EU 2016/679). The main storage location will be the Services for Sensitive Data (TSD) at the University of Oslo, a highly secure platform for sensitive data with strict access control via two-factor authentication. All participant data will be pseudonymised using a unique project ID. The identification key, linking names and other personal identifiers to the project IDs, will be stored securely at each site responsible for recruitment of participants, accessible only to the PI and authorised data managers. A joint data controller agreement for the data on the TSD platform has been signed by all partners. Qualitative interviews will be recorded using a secure audio-recording service connected to TSD. Questionnaires, observations, and consent forms are accessed through Nettskjema into TSD. Some may initially be collected on paper and will be stored in fireproof, locked cabinets accessible only to the responsible PI at each site. All analyses will be conducted inside the TSD environment; raw or de-identified data will never be transferred out. Only fully anonymised results may be exported, subject to TSD approval. At project completion, anonymised datasets may be archived in the Open Science Framework (OSF) in compliance with GDPR and TSD rules. All project data will be retained for 5 years after completion, after which the PI will ensure secure destruction within TSD and any approved repositories.

### **Trial status**

In preparation

### **Project management**

The project will be managed by the Norwegian School of Sport Sciences, in close collaboration with Sunnaas Rehabilitation Hospital, University of Gothenburg and Riga Stradins University. The project team consists of a multidisciplinary group of researchers from these institutions with long experience in both clinical and research activities, with a various competence in motor learning, pedagogy, physical and occupational therapy, rehabilitation medicine, cognition, motion analysis and stroke rehabilitation.

### **Financing**

The project is financed with EU-funds through the Transforming Health Care Systems Joint National Call 2023 (THCS) programme (Agreement number 101195654) and is administered by the Norwegian Research Council and the Latvian Research Council. and the project for Norway and Latvia has been fully financed by THCS. The Swedish participation is financed through grants to the University of Gothenburg. There is no financial interest in the project by any of the partners or by their institutions.

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