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Identification of main characteristics influencing the suitability for telerehabilitation in stroke patients: Quantitative analyses of the REHA2030 Assessment

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Abstract

Background The Austria-Slovenian project REHA2030, with a broad spectrum of expertise, was focused on making the process of telerehabilitation (TR) possible as valuable user-centred post-clinical rehabilitation of stroke patients in rural areas. Health-related factors, impairments, and environmental and demographic factors influence the patients' suitability for stroke TR interventions and serve as possible risk factors for patients' non-adherence or drop-out. The REHA2030 Assessment aimed to identify barriers and resources that should be considered to enable people to participate in TR according to the REHA2030 approach. For that, a structured questionnaire, the "REHA Assessment", with 88 items, was developed and conducted by therapists about 160 stroke survivors in two rehabilitation clinics. The effect of the 87 characteristics on suitability was statistically analysed using parametric and non-parametric tests.

Results Twenty-five main personal and environmental characteristics significantly influencing TR's suitability in stroke patients were identified. Significant factors differences between participants ranked as suitable or not suitable for TR were short-term memory, motivation, visual and hearing abilities, and the ambulation scale. Furthermore, the ability to use technology (self-tech knowledge), daily phone or tablet use, and the general willingness to participate in the therapy were considered. The living situation (housing) and their independence in performing daily tasks such as eating (grooming, dressing, and use of toilet also influence the suitability of the participants. Another essential variable to indicate suitability is compliance.

Conclusions Analysis of the study results showed cognitive abilities, visual and hearing abilities, compliance and willingness to participate in the therapy, together with the knowledge of using technology, as the most enabling factors influencing the suitability for TR in stroke patients in chronic stage. Additionally, the patients' compliance depends on intrinsic motivation to participate in the REHA2030 TR system, which could be supported by increasing proficiency in digital technologies. In the deliberations of TR assessment, the acquired knowledge from the presented study should be considered with caution to limitations of the research data representing personal views of therapists on the patient's suitability for REHA2030 TR.

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Keywords Telerehabilitation, Stroke, Home care services, Assessment

Introduction

Stroke rehabilitation is a significant part of patient care since stroke is a common, chronic, severe and disabling healthcare issue globally and one of the leading causes of acquired adult disability [1]. Providing and delivering intensive, continuous, highly repetitive, task-oriented therapy is critical, especially when increased brain plasticity is presented [2]. Stroke may result in a variety of impaired functions. Examples of the need for multiple therapeutic interventions include moderate to severe motor deficits, cognitive deficits and communication deficits, with other common impairments being aphasia, executive dysfunction, memory loss, depression, dysarthria, and different types of sensory impairment such as loss of vision, touch, proprioception, hearing, and others [3]. In the assessment of disability level, measures of body functions, activity limitations and participation restrictions are used according to WHO's International Classification of Functioning, Disability, and Health [4], which provides a conceptual framework for the effect of stroke or other diseases on the individual [1, 3, 5]. Stroke survivors experience needs and participation restrictions in many domains, such as difficulty with autonomy, maintaining activities of daily living, or social reintegration [3]. Considering the numerous functional problems of people after stroke, rehabilitation requires a multidisciplinary team of skilled healthcare providers, including physiatrists, physiotherapists, speech therapists, occupational therapists, psychologists, psychiatrists and social workers [3, 6].

There is a growth of research in delivering rehabilitation interventions to stroke survivors also via telerehabilitation (TR), providing the opportunity for people to get access to rehabilitation services and therapists with the use of information and communication technologies, e.g., telephone, internet-based videoconferencing, robotic devices or wearable sensors [7]. By utilizing telerehabilitation methods, a continuation of individualized stroke rehabilitation programmes can be established aimed at the patient's functional needs and goals with remote feedback from therapists. TR is described as a feasible complementary or alternative method of providing rehabilitation services in stroke patients in a subacute or chronic stage [8]. Several randomized controlled trials have investigated the efficacy of TR in stroke patients compared to usual rehabilitation. TR appears to be as effective as usual rehabilitation methods for improving motor function, psychological status, independence and ADLs [9–11]. Nevertheless,

little is known about the leading health, disability and environmental factors influencing the recommendation of the stroke patient to participate in TR, which was the reason for designing the REHA2030 Assessment. According to Ciordea et al. (2021), there are no clear recommendations made for the most suitable ways to use TR because of the heterogeneity of existing data [11]. Current research suggests while implementing a home-based technology-driven program, it is needed to consider patient characteristics such as age, disability level, sensory impairments, technical proficiency and social context, as well as complex factors in the home environment [12, 13]. Regarding the complex home environment factors, technological equipment should be designed and applied to be operated by the patient him-/herself to motivate for an active participation and achievement of the rehabilitation goals [14].

The presented study was part of the REHA2030 project (01.2019–06.2022) which aimed to develop a comprehensive therapy platform for stroke patients and therapists and a service model that enables TR (in the participating countries Austria and Slovenia). The technology platform consists of an app (Android tablet) for patients with the possibility to connect a hand therapy device. The app's main features are the exercise conduction, activity monitoring, synchronous and asynchronous communication with the therapists, visual and auditive feedback and personal exercise diary. The therapists join the REHA2030 on a website where the whole therapy process is integrated – from patient data administration through therapy planning and exercises to activity monitoring and communication with the patients. The developed REHA2030 TR system provides a comprehensive approach to post-clinical care of stroke patients with a flexible structure and exercise sessions, offering synchronous or asynchronous training sessions with possible alternation of the exercise depending on individual needs [15]. REHA2030 offers therapy modules including physiotherapy, occupational therapy, speech therapy and clinical psychology. The platform and service model were developed, implemented and tested in a small-scale field trial with four patients and seven therapists. Another aspect of the REHA2030 project was to identify which prerequisites people after stroke should have to be suitable for a TR approach.

The REHA2030 Assessment aimed to identify barriers and resources that should be considered to enable people to participate in TR according to the REHA2030

approach. For this purpose, practice-relevant data should be evaluated with the help of a comprehensive assessment to identify factors that determine suitability.

Methodology

The REHA assessment was filled out in the two clinics URI Soca (Slovenia) and Private Clinic Laßnitzhöhe (Austria) between March 2021 and December 2021. The recruitment of the patients happened within their clinical stay by the therapists and clinical experts and was formally done by the signature of an informed consent. The questionnaire was filled out together with and about all patients who met the inclusion criteria (stroke patients in the age of 18 years old and above), agreed to participate (signature of the informed consent) and were not rejected by the exclusion criteria (severe cognitive or communication impairment restricting obtaining the consent or information needed).

In summary the structured questionnaire “REHA Assessment” with 88 items (Additional file 1; Appendix A) in eleven categories was filled by therapists and physicians together with 160 stroke patients at the end of their rehabilitation in-clinic stay.

Survey items were chosen based on two workshops and qualitative validation with a physiotherapist, an occupational therapist, and different medical professionals from the participating clinics. Already existing rehabilitation assessments, specifically Mini Mental State Examination for cognitive screening [16], the Box and Block test [17], and 9-Hole-Peg Test [18] to examine fine motor function, Timed Up and Go Test [19] and 6 Minute Walk Test [20] assessing mobility and distance walked, Modified Ashworth Scale [21] assessing spasticity, Functional Ambulation Categories [22] and Barthel Index [23] were included in the questionnaire. Besides the mentioned assessments, the developed questionnaire included rating of body functions, activities and participation categories, and environmental factors (housing situation, support and relationships, products, and technology). The indication of patients’ suitability for TR system was covered in the last category named “General recommendation for TR” with the question “Is the patient suitable for REHA2030?” and the following possible answers “not”, “rather no”, “rather yes” or “yes” and hereinafter described as not suitable, rather not suitable, rather suitable, and suitable. The suitability rating was a collective decision by all therapists involved.

All survey categories are listed below:

- Personal data
- Cognition
- Motor skills and sensitivity
- Senses

- Speech related issues
- Independence in activities of daily living
- Pain
- Other important consequence of stroke (optional)
- Care and social networks
- Technical products, framework, and knowledge (including ability and willingness to use REHA2030 technical system)
- General recommendation for TR

The structured questionnaire REHA Assessment consisted of closed and open-ended questions and scales together with the scores of the described existing rehabilitation assessments if available.

The majority of questions needed to be answered according to a 4-point Likert Scale (4_LS) which was applied for all questions on severity level of impairments: no – mild – moderate – severe (coded from 0–3). Exceptions were made for the Spasticity, where the Modified Ashworth Scale (MAS) was used, and the Ambulation, where the Functional Ambulation Categories were used due to its application in clinical practice. A 5-point Likert scale (5_LS) was used to assess the technical knowledge and the compliance: none – poor – fair- good – excellent (coded from 0–4). The suitability for TR was rated as yes – rather yes – rather no – no. A different 4-point Likert scale (4_LS_ADL) was also used to assess independence in activities of daily living but with different expressions: independent – supervision – assistance – dependent (coded from 0–3). Further scales used were a dichotomous (dt) scale (yes – no) for general information about, e.g., the impairment state (“Is the cognition impaired”) where all other questions in that section were only filled out if the questions were answered with “yes”. A dichotomous scale was also used when a finer scaling was not needed, e.g., if there was hemianopsia or if there was access to internet in the home available.

The rehabilitation clinics pseudonymized the patients’ data before transferred to the university. While selecting patients for the study, no preselection was made.

The study design as well as the questionnaire was cross-checked by the Ethics Committee of the Medical University of Graz (EK: 33–078 ex 20/21). All personal information of patients such as names or house address were excluded from the therapists and physicians before conducting the analysis.

Characteristics of enrolled patients

To get a feeling of the involved participant’s baseline, medical and nonmedical variables together with their distribution within the suitability groups were shown in Tables 1, 2 and 3. The variables were presented with the used scale, number of participants, means for the whole

Table 1 Baseline characteristics

Variable	Scale	N	mean	mean suitable ^b	mean not suitable ^b
sex	1=Male 2=Female	160	1=63% 2=37%	1=59% 2=41%	1=81% 2=19%
Age	numeric	160	59.41 ± 13.67	57 ± 13	65 ± 13
Affected Side	1=Left 2=right 3=both	156 ^a	1.56 ± 0.5	1.5 ± 0.51	1.6 ± 0.50
Date of stroke	date	159 ^a	2019.94 ± 1.23	2020 ± 1.2	2019 ± 0.77

^a missing data were omitted

^b patients ranked as suitable (YES) or not suitable (NO) for the REHA2030 TR system

sample and for the suitability groups. The selection of the presented variables was done based on iterative discussions with medical experts or show a significant difference between the groups.

A total of 160 patients were enrolled in the survey and their baseline characteristics were represented in Table 1- in summary 101 participants were identified as males (with age M=59, SD=13.8) and 59 as females (with age M=60.1, SD=13.3). Age ranged from 19 to 88 years (M=59.4, SD=13.6). All participants were diagnosed with a stroke of varying severity. Secondary diagnoses were dementia in three persons and epilepsy. Other secondary diagnoses were femoral neck fracture, obesity, COPD and acute psychological stress, which were each entered once. In 86 (55.1%) persons, only the left side,

and 64 (41.3%) persons, only the right side and one person had both sides affected by the infarction (stroke). At the time of the interview, 48 patients (28.7%) had an infarction less than a year ago (2021), 80 (47.9%) one year ago (2020), 12.6% two years ago (2019) and 10 (6%) more than two years ago.

In Table 2 are medical characteristics, which were included in the survey categories cognition, motors skills & sensitivity, senses and speech therapy issues, presented in detail.

In Table 3 are relevant parameters from the survey categories independence in activities of daily living, Care and social networks, Technical framework and miscellaneous and Compliance, REHA able and REHA want to presented in detail.

Table 2 Medical characteristics (stroke-related deficits)

Variable	Scale	N	mean	mean suitable ^b	mean not suitable ^b
MMSE	numeric	95 ^a	24.77 ± 5.72	25.75 ± 4.88	21.36 ± 7.02
Time Orientation deficit	dt	144 ^a	0.12 ± 0.33	0.08 ± 0.27	0.39 ± 0.50
Short-term memory deficit	4_LS	138 ^a	0.70 ± 0.72	0.63 ± 0.69	1.16 ± 0.90
Long-term memory deficit	4_LS	139 ^a	0.19 ± 0.46	0.13 ± 0.37	0.52 ± 0.75
Deficit in Attention	4_LS	136 ^a	0.92 ± 0.87	0.89 ± 0.85	1.20 ± 1.01
somatosensory Neglect syndrom	4_LS	138 ^a	0.10 ± 0.39	0.05 ± 0.29	0.37 ± 0.68
Spasticity in upper limb	Modified ashworth scale	150 ^a	1.12 ± 1.38	0.96 ± 1.27	1.74 ± 1.65
Deficit in Visuoconstruction	4_LS	135 ^a	0.53 ± 0.80	0.46 ± 0.73	1.06 ± 1.03
Ideational apraxia	4_LS	91 ^a	0.01 ± 0.11	0.00 ± 0.00	0.13 ± 0.35
6MinWalk	numeric	113	362.841 ± 147.02	365.23 ± 145.62	322.75 ± 161.43
Perceptual Disorder	4_LS	156 ^a	0.05 ± 0.27	0.01 ± 0.09	0.22 ± 0.55
Ambulation	Functional Ambulation Categories	160	3.53 ± 1.48	3.83 ± 1.16	2.31 ± 1.82
Visual impairment	4_LS	146 ^a	0.31 ± 0.61	0.22 ± 0.52	0.65 ± 0.75
Deficit in Verbal expression	4_LS	96 ^a	0.74 ± 0.92	0.71 ± 0.96	0.80 ± 0.77

4_LS 4 point likert scalem, dt Dichotom

^a missing data were omitted

^b patients ranked as suitable (YES) or not suitable (NO) for the REHA2030 TR system

Table 3 Non-medical characteristics related to person and home environment

Variable	Scale	N	mean	mean suitable ^b	mean not suitable ^b
Eating	4_LS_ADL	160	0.51 ± 0.74	0.37 ± 0.64	1.03 ± 0.90
Grooming	4_LS_ADL	160	0.73 ± 0.98	0.56 ± 0.85	1.41 ± 1.16
Dressing	4_LS_ADL	159 ^a	0.75 ± 1.02	0.56 ± 0.87	1.58 ± 1.18
Toilet use	4_LS_ADL	159 ^a	0.71 ± 1.07	0.47 ± 0.86	1.63 ± 1.26
Transfers	4_LS_ADL	160	0.63	0.41 ± 0.78	1.50 ± 1.22
Use of Aids (wheelchairs)	dt	160	0.29 ± 0.45	0.23 ± 0.42	0.53 ± 0.51
Use of phone	4_LS_ADL	160	0.58 ± 0.96	0.31 ± 0.67	1.63 ± 1.21
Living Situation—Housing	1 = private 2 = assisted living 3 = care home 4 = other	160	1.17 ± 0.56	1.09 ± 0.40	1.50 ± 0.88
caring needs	dt	160	0.33 ± 0.47	0.26 ± 0.44	0.63 ± 0.49
Formal caregiver	dt	160	0.21 ± 0.41	0.14 ± 0.35	0.47 ± 0.51
Self Assessment of technological knowledge	5_LS	152 ^a	1.86 ± 1.27	2.05 ± 1.20	0.89 ± 1.16
Compliance	5_LS	157 ^a	2.85 ± 0.94	3.07 ± 0.81	1.87 ± 0.82
Ability to use REHA2030 without support	dt	158 ^a	0.41 ± 0.45	0.47 ± 0.50	0.13 ± 0.35
Willingness to use REHA2030	dt	142 ^a	0.89 ± 0.31	0.94 ± 0.24	0.62 ± 0.50

4_LS_ADL 4 point likert scale_activities of daily living, dt dichotom, 5_LS 5 point likert scale

^a missing data were omitted

^b patients ranked as suitable (YES) or not suitable (NO) for the REHA2030 TR system

Statistical analysis

The data analysis process included an exploration of the data and correlation analysis between respondents marked as suitable and not suitable for TR according to the REHA2030 approach in general. In the second step, an in-depth analysis was carried out on the more finely defined groups. For that purpose, the software SPSS was used [16].

A descriptive analysis was performed for all variables, and the baseline characteristics were presented as mean values with standard deviation (M + SD). Normal distribution was checked with a Kolmogorov–Smirnov test (KS) for two samples. To check the significant differences between different samples, the t-test for independent samples and the Mann–Whitney-U Test (MWU) (asympt sig.) for not normally distributed variables, was used to identify which differences are given between participants who are ranked as suitable and not suitable. The effect size was calculated using the Pearson correlation coefficient, interpreted according to Cohan's d and reported as $r = .xx$. There were fewer variables in the study with normal distributed data, so variance analyses for more than two groups (e.g., ANOVA) between the fine-tuned suitability groups were excluded.

To get insights into how the self-initiative can be strengthened by the main variables based on the results to influence the suitability in TR, non-parametric bootstrapping analyses (with 5000 samples) were performed

with different combinations to identify mediation and moderation effects based on causal considerations. The PROCESS macro by Hayes [17] using square regression to exhibit a model's indirect, direct, and total effects and the significant results from computed confidence intervals that do not include zero was used for that purpose.

Results

The research methodology used in the study provided insights into the personal and environmental characteristics of in-clinic patients after stroke in Austria and Slovenia. In the case of ordinal scaled variables, it was explored how the respective variable differed in the suitability groups; in the case of dichotomous variables, the distribution of suitability was evaluated. These different representations of the variables and the description of each variable with significant differences between one of the groups as well as the results in detail and variables with significant differences ($p < 0.050$) and at least a medium effect size ($r > 0.3$), are shown in the Appendix (Additional file 2: Appendix B) in detail. From the presented details in the appendix (Additional file 2: Appendix B), it can be deduced how the evaluation of the variable affects the suitability and whether persons with a worse or better evaluation are more likely to be recommended for a TR. Described variables in this chapter refer to the main variables based on highly significant differences and effect sizes between the suitability groups.

Table 4 Distribution on suitability

Suitability groups in REHA2030				
(N)	(%)	Group code	Group name	General groups
60	37.5	3	Yes	suitable
64	40.0	2	Rather yes	
26	16.2	1	Rather not	not suitable
6	3.7	0	No	
4 missing	2.5	/		/

Suitability of enrolled patients

Only six patients were identified in the survey as “not suitable” for TR according to the REHA2030 approach, and 26 were marked as “Rather not suitable”. Generally speaking, 32 (20%) participants were identified as not suitable and 124 (77,5%) participants as suitable (Table 4).

Result description – group comparisons

To get an overview of the most relevant variables with a high significance ($p < 0,025$) and high effect size ($r > 0.5$) they were listed in Table 5. The results presented Table 5 already shows which prerequisites result in a recommendation for participation in a REHA2030 TR. The variables describe that a minimum of cognitive and visual abilities (short-term memory & visual impairment) are required. Furthermore, a technical understanding of smart devices (use of phone, technical assistance) as well as a certain independence (independents, housing, use of aids) and compliance (compliance, REHA want to) are necessary.

The differences between the general groups “suitable” and “not suitable” related to cognitive abilities show that the impairment of short-term memory and the motivation capability influences the suitability of the participants for REHA2030 TR system. Considering the results in detail (Additional file 2: Appendix B—Cognition), it can be observed that even mild impairments in short-term memory and the motivation capability are sufficient for a negative recommendation for a REHA2030 TR. Results related to physical abilities, including facial expressions and gestures, in addition to spasticity in the upper limb and limited visual abilities, and the Scale of ambulation [18], also serve as indicators of the suitability of the participants. Accordingly, those using aids such as crutches or especially wheelchairs were described as rather not suitable. From the detailed results (Additional file 2: Appendix B—Motor skills and sensitivity; senses, Speech therapy issues), it is shown that people with limited motor control or proprioception in the upper and lower extremities are more suitable for a personal therapy. Another factor for recommending REHA2030 TR is independence in daily living (Additional file 2: Appendix B—Independence in activities of daily living, care and social networks). Participants who live in a care home or have a formal caregiver are not recommended for REHA2030 TR. The abilities for independence in everyday life are also considered here, such as eating, grooming, dressing, use of toilet and the transfers. Likewise, the technical ability to use technology, respectively, and the daily

Table 5 Differences between the groupings of people who are and are not suitable for TR in detail and their categories regarding the REHA assessment

Categories	Variable	p	Effect size
Cognition	Short term memory	$p = 0.003^{**}$	$r = 0.7^{+++}$
Motor skills and sensitivity	Upper limb spasticity	$p = 0.018^{**}$	$r = 1.35^{+++}$
	Ambulation	$p = < 0.001^{**}$	$r = 1.32^{+++}$
Senses	Visual impairment	$p = 0.008^{**}$	$r = 0.57^{+++}$
Independence in activities of daily living	Use of phone	$p = 0.001^{**}$	$r = 0.50^{+++}$
Care and social networks	Housing	$p = 0.014^{**}$	$r = 0.53^{+++}$
	Technical assistance	$p = 0.006^{**}$	$r = 0.79^{+++}$
	Independents	$p = 0.003^{**}$	$r = 0.80^{+++}$
Technical framework and miscellaneous	Use of Aids (wheelchairs)	$p = 0.006^{**}$	$r = 0.80^{+++}$
Compliance, REHA able and REHA want to	Compliance	$p = < 0.001^{**}$	$r = 0.50^{+++}$
	REHA able	$p = < 0.001^{**}$	$r = 0.73^{+++}$
	REHA want to	$p = < 0.001^{**}$	$r = 0.70^{+++}$

** highly significant

+++ large effect size

use of smartphones or tablets is decisive for assessing suitability (Additional file 2: Appendix B—Technical framework and miscellaneous). Another essential point for the suitability classification was compliance and the willingness to participate in REHA2030 (Additional file 2: Appendix B—Compliance, REHA able and REHA want to).

In order to get a better understanding of the decision-making processes of the experts, the in-depth categories of suitability (not suitable, rather not suitable, rather suitable, suitable) were examined more closely.

For the differentiated groups “rather not suitable” and “rather yes suitable”, results show, in addition to the general groups “suitable” and “not suitable”, only four highly significant variables with a high effect size. Based on the details presented in the appendix (Additional file 2: Appendix B), short-term memory ($p=0.017$; $r=0.77$), grooming ($p=0.009$; $r=0.93$), self-tech knowledge ($p=0.003$; $r=1.20$) and compliance $p < 0.001$; $r=0.50$) are the most relevant factors for the professionals to distinct if a patient is rather suitable or rather not suitable.

In the case of the groups “suitable” or “rather yes suitable”, the differences were highly significant with a high effect size only at the lower limb proprioception ($p=0.009$; $r=0.80$). A closer look on the detailed results (Additional file 2: Appendix B) show that the ability to follow the instructions, the handling of smart devices and compliance are relevant factors for the medical experts to recommend people for a TR.

Mediation analysis

The performance of a mediation analysis resulted in a serial-parallel mediation model with two mediators (Fig. 1) tested by using model 6 with the PROCESS macro. In order to construct this model, causal considerations were made in the first step, and the corresponding

mediation and moderation analysis was carried out in the second step. For example, moderation effects of age and gender on the individual impact pathways could be excluded during this process. For increased clarity in this article, only significant results are presented, and a more in-depth analysis of the impact pathways of the results will be discussed separately. In summary, it can be shown that there is a direct effect ($B=0.609$ $p < 0.001$) from the variable REHA want to (intrinsic motivation) on the suitability as well as a positive mediation effect from the self-tech knowledge together with compliance on the suitability ($B=0.881$; $P < 0.001$).

The model shows that the initiative to participate (“REHA want to”) can be supported by increasing self-tech knowledge, which will lead to higher compliance and further positively influence suitability. The model also shows that there is no direct mediation effect from the variable “REHA want to” on compliance nor from the self-tech knowledge on the suitability for TR.

Discussion

In the presented study, 87 items related to person, health, disability, or environment were explored together with the possible suitability of patients to REHA2030 TR system. Both possible internal and external factors were considered. The analysis identified a total of 25 variables for which there were significant differences between the participants who were ranked as suitable and not suitable for TR.

Firstly, cognitive abilities were identified as suitability influencing factors. Cognitive deficit such as memory loss or demotivation is recognized as significant barrier to recommendations of TR based on the study results. However, cognitive impairment should be rather considered as a specific area for TR intervention since there is evidence of its efficacy [19]. Next, possible limited visual

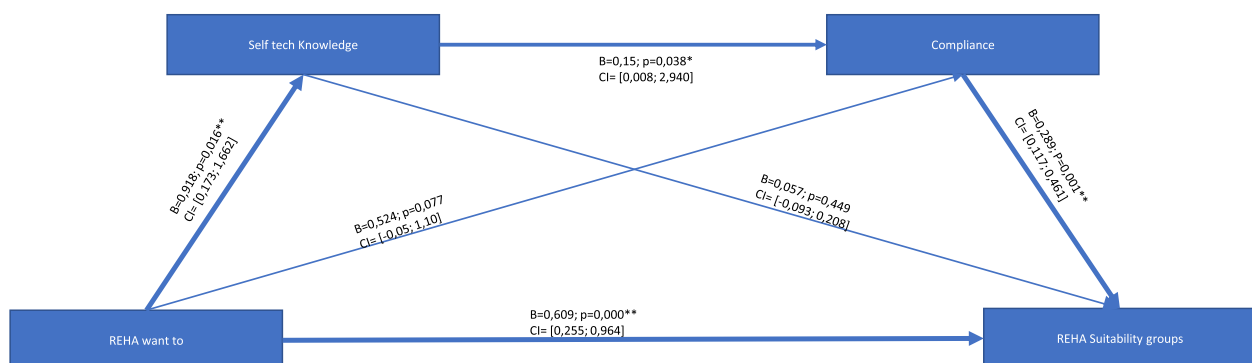


Fig. 1 Partial serial mediation model (Model 6_hayes PROCESS [ISBN 9781462549030]) to exhibit the relationship between interest in TR and eligibility for TR (n = 130). B = non-standardised coefficients; ** = highly significant ($p < 0.025$); direct effect C: $B=0.609$; $p=0.000$, $CI=[0.255; 0.964]$; indirect effect C: $B=0.881$; $p=0.000$, $CI=[0.544; 1.218]$

function or restriction in ambulation and activities of daily living serve as negative indicators of the suitability of the participants in the study. On the other hand, the technical knowledge and the ability to use smartphones or tablets refer to a substantial resource which could positively affect the process of TR recommendation. In rehabilitation, the virtual context is becoming increasingly essential. It refers to access and the ability to use technology such as cell or smartphones, computers or tablets to carry out daily routines and occupations and manage communication and social participation [20].

The added value of the presented study is the developed model based on the mediation analysis, which represents the relationship between the ability to use technology, patients' compliance and suitability for TR. Patient's willingness and initiative to participate in rehabilitation, in general, can be supported by an increase in technology knowledge, such as the ability to use a phone or tablet as well as knowledge of using apps. However, mediation analyses were performed ad hoc for a first insight into the impact pathways of the given variables. The model cannot be seen as definite because the used variables were all rated on a subjective perception of a therapist or by the participants themselves. Also, some variables cannot be included in a mediation analysis due to their dichotomous scale. In the interpretation of the model, it should be considered that compliance is about the general willingness for therapy and not exclusively about compliance for TR. At this point, a more in-depth analysis is also needed in order to understand the influencing factors in the background more deeply.

Our findings are in line with other studies regarding the barriers and resources for telerehabilitation [2, 10, 13, 21]. Furthermore, our findings within the mediation model can be compared to outcomes of other studies concerning to training and support [10, 22] as well as the medical characteristics of patients [2, 23]. What is different to the presented findings is for example that Tyagi et al. [13] describes the age as a barrier to use an iPad, which is not evident in the presented study. Although, the data in the presented study indicate that technical knowledge is lower among people of higher age. There is also a lack of studies dealing with medical characteristics of stroke patients affect participation in a TR. In agreement with previous research, it can be seen that the reported higher patient age is not a barrier for home-based TR [24, 25] or for virtual reality therapy [26]. More likely, it is necessary to consider disability level and local context [27], together with patient's motivation as well as ability and willingness to participate [2].

The investigation of personal and environmental characteristics influencing the TR is needed for healthcare providers to recognize possible risk factors of patients'

non-adherence or drop-out. Patients' selection for telehealth based on WFOT [28] should include therapists' clinical reasoning to determine the appropriateness of telehealth use, namely the client's diagnosis and impairments, nature of the interventions to be provided and ability to access technologies.. Poor awareness of technology and lack of motivation to understand or improve health are well recognized factors affecting digital health engagement and recruitment [29], whereas highly motivated patients and patients accustomed to the internet and technological devices benefit most from TR [11, 30]. However, patients' engagement can be supported with strategies tackling demotivation (such as reminders, weekly challenges, meaningful activities, and others) or with the provision of an adequate explanation and feedback [31]. To overcome technical barriers when recommending patients to TR, it is necessary to validate that technical requirements are ensured, and access to technical support and training is also provided [7]. The mediation analyses performed in the study support the concept of organizing practical workshops and training in the use of a TR system such as REHA2030 to strengthen digital literacy and technical skills after a stroke. Based on previous research, ensuring adequate training in used technology for patients and clinicians, and support provision is essential for adopting the TR service model [32].

A limiting factor of the study is, that the REHA2030 Assessment was designed with a high level of practical relevance and expertise to collect as many influencing factors as possible. The assessment of suitability, which has emerged from a practical approach, is a weakness in the study and as well a gap in the literature because no validated questionnaires can currently be found in the literature to assess the suitability for telerehabilitation in stroke patients. As a follow up, the results of this study will be used to structure a valid questionnaire on participation in a TR. Although the evaluation was carried out by a team of medical experts, bias cannot be completely avoided. Therefor should be noted that there are different factors behind the identified variables; for example, it is not entirely clear why the fact that people using aids and especially wheelchairs tend to be classified as unsuitable. Further research should focus on this background information in order to be able to make explicit statements. Certain variables could not be carried out with all participants (e.g., people using a wheelchair could not perform the 6 Minute Walking Test). As a result, 15% of the entire data set can be described as missing. In consideration of data collection, it must be emphasized that each therapist evaluated the patients' suitability for the REHA2030 TR system according to their opinion and experience. Therefore, it is necessary and planned to validate the technology-support therapy with the REHA2030 system

Table 6 Identified barriers and resources based on interpretation of study results

	Possible Barriers	Possible Resources
Person and Environment-Related Factors	Need of a caregiver (<i>could limit the access to TR without a presence of a caregiver</i>)	Ability to use a phone or tablet independently
	Slow Internet connection (<i>could limit the data transmission</i>)	Presence of a technical Assistance
	Restriction in ambulation (<i>could limit transfers and access to TR system without any assistance</i>)	Willingness to participate in REHA2030 TR system
	Restriction in activities of daily living (<i>could limit independency for TR access and readiness</i>)	Compliance
Medical-Related Factors	Cognitive impairment	Preserved memory functions, attention and time orientation
	Sensory impairment	Visuoconstructional skills
	Upper limb spasticity	Visual and hearing ability
	Neglect syndrome	perceptual ability
	Apraxia	

in cooperation with future users (interested parties, both patients and therapists) and to evaluate the suitability and effectiveness under real-life conditions.

Conclusions

A simplified insight into the possible barriers limiting participation in TR system and possible resources which enhance the process of recommendation a patient for TR system is presented in Table 6. Given factors are based on the interpretation of the most recurring study results presented in Table 5. Presented factors need to be considered individually taking into consideration patients' level of functioning, motivation and need for an assistance.

The process of recommending patients for a TR could be a clinical challenge because of the need to recognize possible barriers limiting the patients' engagement in TR. In this study, the results of REHA2030 Assessment were described, and the main factors influencing the suitability of patients for REHA2030 TR were introduced. For the further development and dissemination of a TR assessment and system, the study results show to consider as main characteristics influencing the suitability: cognition abilities, sensory functions, the scale of ambulation, independence, therapy compliance and technical skills (technical knowledge and ability to use phone or tablet). Based on the study results presented, it is further suggested that increasing the ability to use technology such as smartphones or tablets in patients positively affects patient's initiative to participate in TR. As presented, acquired technology knowledge directly increases suitability and possible recommendation of the patient for TR. Further research should aim at exploring the given areas' impact pathways and setting up a validated assessment of abilities and technical skills needed for REHA2030 or other TR systems based on the results presented.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s44247-023-00021-4>.

Additional file 1: Appendix A. Questionnaire to assess the eligibility of patients for REHA2030.

Additional file 2: Appendix B. Table B. Results in detail, including a description of the variables.

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Authors' contributions

All authors have read and approved the final manuscript. The study design, the development of the methodology, the realisation of the workshops and the conducting of the study were realised by DK and LW. The explorative data analysis and the in-depth statistical analysis were carried out by SF and he worked together with JBS in equal parts on the interpretation and writing of the article.

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Availability of data and materials

The data tables from the current study are available from S. Fink (s.fink@cuas.at) on reasonable request.

Declarations

Ethics approval and consent to participate

The project was approved by the Ethics Committee of the medical university of Graz and is listed under the index number: EK Nr: 1545/2020 Version 1 and were carried out in accordance with relevant guidelines and regulations. The consent to participate in the study was obtained from all patients and formally signed at the Informed consent.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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