ORIGINAL REPORT

COMPLIANCE WITH UPPER LIMB HOME-BASED EXERGAMING INTERVENTIONS FOR STROKE PATIENTS: A NARRATIVE REVIEW

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Background: Telerehabilitation and follow-up techniques have been developed in recent years to assess the effectiveness of diverse intervention programmes that include exergaming technologies. For patients with upper limb impairment after stroke, motion-gaming technologies can provide effective and amusing training. Beyond efficiency, professionals must analyse patient compliance with the system for self-use at home, because patients may or may not independently perform the exercises prescribed by the therapist. Questions on the sustainable use of this type of home exercise also arise.
Objective: This review examines user compliance with exercise programmes, measured according to the training rate (percentage of prescribed sessions and minutes completed) and completion rate (number of drop-outs and discontinued interventions) reported or calculable according to the data collected.
Results and discussion: Rates of compliance with training were relatively high. No group effect on compliance was found. Drop-out and discontinued intervention rates were either due to external causes or directly related to the technologies. Some studies have reported the use of supervision, most of them through home visits and remote support. Few studies performed long-term follow-up, which could provide information to help broaden practices. This narrative review considers how this field of research may evolve in the future.

Key words: stroke; compliance; exergame; motion capture; virtual reality; technology; telerehabilitation; home.

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LAY ABSTRACT

The use of video games in hospitals as a rehabilitation tool in neurology is developing, particularly for stroke victims. For patients with arm problems, it can be effective and fun to use gamified systems. When the patient goes home, they must continue their rehabilitation in order to continue to progress or maintain their skills. However, performing exercises alone at home raises questions about patients' compliance with the exercises prescribed by their therapists. Do patients complete the prescribed sessions? Are there occasional or permanent interruptions? This narrative review attempts to address these questions. The review also examines the obstacles that might hinder the use of these technologies and the facilitators that may help compliance.

Telerehabilitation offers an alternative rehabilitation technique through the delivery of rehabilitation and habilitation services via information and communication technologies (ICTs) (1, 2). Telerehabilitation is a useful approach in outpatient rehabilitation, especially for post-stroke patients (3). Stroke was the second-leading cause of death and third-leading cause of death and disability combined worldwide in 2019 (4). Stroke is highly prevalent among older patients, many of whom have underlying health issues (e.g. diabetes, hypertension, and cardiovascular disease). Upper extremity paralysis is a predominant impairment after stroke, with a recovery rate of 10–20% (5), affecting independence and quality of life (6). This reflects the importance of post-hospital discharge support programmes. Telerehabilitation is one possible approach in outpatient stroke rehabilitation, with follow-up at home.

Exergaming, otherwise known as exercise-based games (e.g. virtual reality and interactive video-game interventions) is a relevant alternative home-based rehabilitation for persons with neurological diseases. The effectiveness of these interventions has been shown to be at least equivalent to conventional therapy or usual care (7). Most studies have focused on assessing the effectiveness of the technologies, but patient compliance with these technologies is under-explored. Even if the technology can be adapted technically or physiologically, it remains necessary for the patient to want to use it; therefore, effective implementation for self-use at home depends on patient compliance.

Medical compliance was defined in the late 1970s as "the extent to which the patient's behavior in terms of taking medications, following diets, or executing other lifestyle changes coincides with medical or health advice" (8). Exercise compliance is defined as "a person's compliance with a prescribed or self-prescribed fitness program" (9). The terms compliance, adherence, and concordance are often used interchangeably (10). The term compliance is used throughout this narrative review as an indication of positive patient behaviour in following an exercise programme. Many people do not feel motivated to engage in new habits, including exercise. In 2013, a meta-analysis showed that approximately 21% of people did not intend to take up physical activity, while 36% intended to, but found changing their sedentary behaviour difficult (11). Training is often limited by a lack of motivation, which can be the main reported reason for non-adherence with home exercise by individuals with chronic stroke (12). Designing optimal rehabilitation treatment programmes for stroke patients requires an understanding of "What" is the content of the treatment, "How much" treatment is required, and "When" treatment is best delivered (13).

This narrative review assesses patient compliance according to the type of upper limb technology used and the home implementation parameters.

GAME-BASED SYSTEMS IN THE HOME-BASED SETTING

Exergaming is defined as the integration of physical activity into a video-game environment that requires active body movements to control the game (14). The emergence of commercial video-game systems, coupled with handheld controllers and motion-capture devices, has facilitated the use of computer games for neurorehabilitation. These technologies have the potential to be effective for increasing upper limb capacities (15–18). Game-based systems may offer a motivational exercise environment that encourages continued use. Health professionals and participants have reported high levels of satisfaction and acceptance of telerehabilitation interventions (5). Piron et al. (2008) showed that post-stroke patients with arm motor impairments assigned to the home-based virtual reality group were able to engage in therapy at home through a user-friendly system, and the videoconferencing system ensured a good relationship between the patient and the remote therapist (19). Their study was based on the patient's degree of satisfaction, an important indicator of the efficacy of the therapeutic intervention, which improves the patient's motivation to engage in rehabilitation.

A range of commercial gaming systems are described in the literature for home use: Kinect™ (Microsoft Corporation; Redmond WA, USA) (30, 32, 34, 43), Wii™ (Nintendo, Japon) (25–28), Vive™ (HTC, Taïwan) (29), PlayStation® 3 Eye Move controller (Sony, Japon) (26), Leap Motion controller (Ultraleap, USA) (30) (Table I). These devices are mostly associated with custom games and other specific rehabilitation devices, such as robotic devices, specific controllers, and passive arm support (e.g. TheraBot system (Rehabilitation Robotics and Research and Design Lab, Milwaukee, WI, USA) (31), SaeboMAS (Saebo Inc., Charlotte NC, USA) with SCRIPT dynamic wrist and hand orthosis sensor (32), HandinMind (HiM) system (33) (Hocoma AG, Switzerland), P5 Glove (Essential Reality Inc; NY, USA) (24), Armeo®Senso (Hocoma AG, Switzerland) (34), BrightBrainer™ Grasp (Bright Cloud International, NJ, USA) (29), Myo Band (n.a) (26), MusicGlove (FlintRehab, CA, USA) (35), CyWee Z controller (CyWee Inc., Taiwan) (36) and passive arm support (30)) (Table I).

Some studies included real-time audio or video systems (30, 31, 39, 43, 47). The exergames used in the studies were specific or non-specific systems for upper-limb stroke rehabilitation. Devices can be used alone or in combination with other technologies (e.g. exoskeleton, robotics, exogenous stimulation, virtual reality headsets, and augmented reality), potentially further improving recovery. It is of interest to determine whether combinations can have a positive impact on compliance. For example, in the REINVENT platform (37), researchers combined the principles of action observation in head-mounted virtual reality with brain-computer interface (BCI) neurofeedback for stroke rehabilitation to try to elicit optimal rehabilitation gains. It would be of interest to assess the relevance of this on functional activities and in different settings (e.g. laboratory, clinic, home). As reported by Perrochon et al. (2019), future studies in the home should include the multiple observations reported in the literature to ensure an optimal exergaming design (7, 38).

HOME EXERCISE REGIMEN

Several systematic reviews have indicated that intensive treatment is favoured, but there is no consensus on the optimum amount, intensity, distribution, or duration of therapy (39). Across a large number of studies, the key elements of task-specific training are repeated, challenging the practice of functional, goal-oriented activities (40–42). Motion-tracking systems provide real-time feedback regarding execution of task-specific exercises, but it is unclear which is the most efficient training. To our knowledge, there are no guidelines regarding the appropriate maximum duration of research and clinical sessions to maintain

Table I. Characteristics of included studies

Author, year	Design Methods Data collection	Participants	Technology	Implementation parameters (number of sessions, frequency, and length)	Home training (min)	Drop out	Discontinued intervention
Brokaw et al. (43)	Pilot evaluation of the usability and utility in the home Qualitative Interview	1 stroke patient	Computer screen, Kinect™ (Microsoft Corporation; Redmond WA, USA), 5 custom games	19 sessions 30 min, 5 days/week, for 4 weeks	NR	No	1 session hardware not used final 3 training sessions
Burdea et al. (29)	Feasibility study Mixed Survey + training	7 chronic post-stroke patients 7 caregivers	BrightBrainer™ (Bright Cloud International, NJ, USA) computer, Vive™ (HTC, Taïwan) and BrightBrainer Grasp controllers, custom games, Automatic electrical meter	20 sessions wk 1 20 min wk 2 25 min wk 3 30 min wk 4 40 min 5 days/week, 4 weeks	605 min	1 screening failure (low MOCA score)	NR
Chen et al. (26)	Qualitative study in a randomized trial Qualitative semi-structured interviews	13 stroke patients	Computer, Myo Band, Wiimote™ (Nintendo, Japon) in a pistol-shaped holder, Power Mate, PlayStation® 3 Eye Move controller (Sony, Japon), Joystick, Logitech Trackpad, real-time video guidance	36 sessions 70 min at a fixed time every day 6 days per week, over 6–8 weeks	NR	No	NR
Dodakian et al. (35)	Pilot study Quantitative Survey	12 stroke patients	Laptop, wrist accelerometer sensor, MusicGlove (FlintRehab, CA, USA), 18 games, videoconference	1 structured hour + 1 h of free play, for 28 days (2 × 14-day separated by a 1–3-week break)	Active time (games+exercises): 60 ± 10 min/d, including a mean of 22 ± 24 min/d of free play. Total time (active time + education questions, measuring blood pressure, reading game instructions, donning devices, and taking breaks between tasks): 182 ± 61 min/d.	No	1 not completed 4 sessions (fatigue) 1 not completed 1 session (hardware malfunction) 1 missed 2 complete sessions (other medical appointments)
Fluet et al. (30)	A Feasibility and pilot study – comparison Mixed Survey + training	11 stroke patients: 5 enhanced motivation (EM) group + 6 unenhanced control (UC) group	Leap Motion controller (Ultraleap, USA) passive arm support, custom-designed simulations	As much as possible, but at least 20 min, daily for 12 weeks	> 400 sessions. Enhanced motivation group: 95±95 min per week (range 40–276 min) Unenhanced control group: 35 ± 31 min per week (range 3–93min)	NR	NR
King et al. (36)	Case series (after a trial of 10 sessions of bilateral therapy using VR) (Hijmans et al.2011) Mixed Survey + Training	3 patients with chronic stroke	Computer screen, CyWee Z controller (CyWee Inc., Taiwan) games	Chose when and for how long for in each session, for no longer than 90 min on any given day Each game at least once, after free to choose the proportion of time on any games for 8 weeks	≥ 35 min per session ≥ 4.5 times per week ≥ 33.5 hcontinued for between 55 and 61 days at home	No	Diary: mean number total of days missed: 11.66
McNulty et al. (25)	a randomized controlled trial Mixed Survey + structured interview + training	41 stroke patients (21 + 20)	Wiimote™ (Nintendo, Japon) Wii Sports™ games	10 sessions 60 min weekdays, progressively increasing, for 14 days follow-up 6 months	Wii-based Movement Therapy (WMT): 1,188 min modified constraint-induced movement therapy (mCIMT): 1,194 min. Completion rates 105.7 (93.6–114.7)% (WMT) and 101.0 (87.6–108.1)% (mCIMT)	2 EG (withdrew+death) 1 CG (unrelated medical condition)	NR
Nijenhuis et al. (32)	Pilot randomized controlled trial Mixed Survey + semi-structured interview + training	20 stroke patients (10 + 10)	Computer, SaeboMAS (Saebo Inc., Charlotte NC, USA) SCRIPT dynamic wrist and hand orthosis sensor, games	36 sessions at least 30 min per day, 6 days a week, for 6 weeks follow-up 2 months	CG: 189 (143–266) min per week EG: 118 (51–176) min per week ranging from 13 to 423 min per week	1 EG (shoulder pain due to external causes)	NR
Sivan et al (49)	Feasibility study Qualitative semi-structured interview	17 (9 prototype) patients + 7 therapists	Computer screen, powered joystick, controlled assistance, 8 games	8 weeks	NR	NR	NR
Standen et al. (27)	Prospective cohort study plus qualitative analysis Mixed Semi-structured interview + training	29 stroke patients, including 17 in the qualitative study	PC, Virtual glove, Wiimote™ (Nintendo, Japon), 3 custom games	3 times a day for periods of no more than 20 min, for 8 weeks	Percentage of the duration of use ranged from 1.46 to 70.6 percentage of days used ranged from 10% to 100%	Allocation: 4 EG (family issues, not interested, arm pain, severe aphasia) Follow-up: 1 CG (measures onerous) + 3 EG (illness, ill family member, going on holiday)	NR

(Continued)

Table I. (*contd.*)

Author, year	Design Methods Data collection	Participants	Technology	Implementation parameters (number of sessions, frequency, and length)	Home training (min)	Drop out	Discontinued intervention
Thielbar et al. (21)	Randomized trial - crossover, interventional study Mixed Survey + Training	20 chronic post-stroke patients (10 in the FSU group and 10 in the FMU group)	Computer, Kinect™ Microsoft Corporation; Redmond WA, USA) wireless mouse. 3 custom exercises, voice communication, remote central server, custom Google Cloud Virtual Machine	8 sessions 4 sessions of 1 h each week, for 4 weeks: 2 weeks with multi-user (MU) + 2 single-user (SU) version	For the SU mode, FSU group: 30.2±10.8 min and FMU: 39.9±12.8 min For the MU mode, the FSU and FMU groups had similar times	1 (medical reasons) 1 FMU group (declined participation)	MU mode: 18 of 20 subjects participated in all 8 sessions, and all 20 subjects participated in at least 7 sessions SU mode: only 15 of 20 subjects participated in all 8 sessions, and 16 of 20 participated in at least 7 sessions
Wingham et al. (28)	Pragmatic multi-centre RCT with a qualitative study and health economics analysis Qualitative semi-structured interview	19 stroke patients 10 caregivers	Television, Wii console, Wii games	For up to 45 min daily for 6 weeks followed up at 6 weeks and 6 months	EG: 37 min (range 4–108 min) CG: 32 min (range 4–63 min)	1 (timetable)	NR
Wittmann et al. (34)	Feasibility study Mixed Structured patient interview + training	11 stroke patients	Armeo®Senso (Hocoma, Switzerland) = wearable inertial measurement units (IMU)	As often as possible for 6 weeks	26.5±11.5 (min 8, max 41) days out of 42 days duration per week: 137±120 min (min 15, max 357) training sessions on 4.4 days per week training (gaming) duration per session: 30±16 min (min 11, max 56)	NR	NR

NR: non-recorded; EG: experimental group; CG: control group; EM: enhanced motivation group; UC: unenhanced control group; WMT: Wii-based movement therapy; mCIMT: modified constraint-induced movement therapy; SU: single user; MU: multi-user, wk: weeks; min: minimum; max: maximum; MoCA: montreal cognitive assessment.

compliance. Dose, frequency, and duration scheduling of home-based therapy are shown in Table I.

The overall dose ranged from 20 min (29) to 120 min per day (1 h structured activity and 1 h free play) (35). The recommended time increased stepwise each week for 1 study (29), whereas another progressively increased the time over 10 consecutive weekdays (25). Three studies did not give the number of expected min per day (30, 34, 36). Three studies indicated a time limit not to be exceeded; users played for as long as they wanted in a session and whenever they wanted, but for no longer than 90 min on any given day (36); 3 times per day for periods of no more than 20 min (27); or for up to 45 min daily (28). Conversely, another study indicated a minimum time limit requirement of 20 min daily (30). Time of day can be defined to accommodate the necessary appointments with therapists (21, 26). The current review observed variability in the prescriptions: studies proposing 30 min per day were considered as sub-therapeutic. In contrast, planning 1–2 h per day of task time and assessing repetitions and intensity accurately were recommended (13).

The number of sessions ranged from 8 (21) to 36 (26, 32). Six studies did not specify the number of expected sessions ((27, 28, 30, 34–36). The number of days per week were set at 5 (29, 43), 6 (26, 32) or 7 (28, 35). Hence, the sessions were discontinuous or continuous, depending on the study.

The most often used training duration in the studies was 6 weeks (26, 28, 32, 34, 36). Other studies had a total intervention duration ranging from 14 days (25) to 12 weeks (30). Only 1 study planned an interruption after 14 days of 1–3 weeks halfway through the intervention (35). They explained that 14 days was selected based on the success of the EXCITE trial of constraint-induced therapy, which showed benefits when making daily demands on patients for 14 days (44). Only 3 studies proposed follow-up to assess the persistence of improvements in motor function. They did not indicate any information on long-term engagement.

COMPLIANCE ASSESSMENT

Training compliance rate

Some authors referred to the training rate to assess compliance quantitatively. The ratio of the quantity of training performed by the patient to the quantity prescribed by the therapist was reported or calculated. Some authors considered the total training time, in minutes, performed by the study subject, the mean number of sessions per week, and the mean minutes per session for home-based interventions. These data can be compared with the authors' recommendations.

Certain studies calculated high compliance rate of approximately 96% (29). Other authors compared groups, for example, compliance was very high (99%) for the multi-user mode and 89% for the simple-user mode, suggesting that the training mode can affect the compliance (21). More, the change in the difficulty and complexity showed a greater increase in training time per session than the control group (30). Some other studies have a compliance rate of over 100, taking 100% as the time prescribed by the therapist. Indeed, some studies allow patients to do more exercises if they wish following their prescribed time (30, 32). For example, the completion rate was 105.7% (93.6–114.7%) for the Wii-based movement therapy and 101.0% (87.6–108.1%) for the control group (median, interquartile range) (25). Conversely, a high compliance rate was found for the control group (105%), but not for the experimental group using computerized gaming exercises (65.6%) (32).

A few studies reported the number of repetitions performed during the intervention (29, 34, 35). However, with few comparative data, we chose not to report the data in this review.

Participants in the study by Nijenhuis et al. (32) recorded the frequency and duration of training in a diary to assess user compliance with training duration and motivation. King et al. (36) used the same methods to assess patient engagement quantitatively, using diaries to record the occurrence and duration of the intervention.

Attrition rate

The attrition rate is calculated as the number of drop-outs and discontinued interventions. Within eHealth interventions, the exponential decrease in adherence has been described as the "Law of Attrition" (45). It is essential to consider the main causes of the rate and to set up tools to reduce the level of attrition as much as possible. Dropping out of therapy is an implicit marker of dissatisfaction or unacceptability. Variability in acceptable discontinued intervention/drop-out rates was found in the literature, ranging from 5%, to 20%, and 30% for follow-up of more than 1 year (46).

Literature results showed a high attrition rate for the home-based setting, although the drop-out rate was higher for the experimental group than for the control group (25, 27, 32). The completion rate was not described in all studies. However, among the studies that evaluated the completion rate, variable results were found. For example, a 94.7% rate for intervention completion was reported by Brokaw et al. (43), with only 1 missed session and a 97.9% rate was described by Dodakian et al. (35) with 3 patients not completing or missing sessions. King et al. (36) provided the number of days of intervention over the total intervention period for each subject, recorded by the participants in diaries, and reported a rate of 79.9%. Thielbar et al. (21) compared the training attrition rate between groups: in the multi-user (MU) mode, 90% of subjects participated in all 8 sessions, and 100% participated in at least 7 sessions. However, in the single-user (SU) mode, only 75% of subjects participated in all 8 sessions and 80% participated in at least 7 sessions (21).

BARRIERS TO COMPLIANCE

Non-compliance was intentional or non-intentional. Some factors were due to internal factors (no interest, pain, fatigue, severe aphasia, seizure, illness, death, etc.) and others to external factors (family issues, ill family member, holidays, schedule). This led to limited compliance, and patients either dropped out or discontinued the interventions. Some non-compliance factors were correlated with technical issues: Brokaw et al. (43) reported that participants completed 18 of the planned 19 sessions, but hardware issues prevented participants from using the system for the final 3 training sessions; Some studies reported technical issues with the hardware (26, 29, 35, 43, 49), the software (35), communication reliability causing storage data problems (29), the home setting (26, 29, 49), unsuitability for use with spastic hands (29), and time constraints (26). These aspects did not necessarily stop the patients from participating in the study. As reported by Perrochon et al. (2019), the rate of drop-out and discontinued interventions were due either to external causes or directly related to the technologies (7). Dodakian et al. (35) produced a summary document of the issues, solutions, and lessons learned for future telerehabilitation studies. This initiative is relevant for future perspectives. As Ong et al. (2018) stated, identifying manipulable aspects of treatment that reduce the probability of drop-out can guide the development of more acceptable interventions (47).

FACILITATORS OF COMPLIANCE

Some authors proposed a familiarization stage with the device before home use. Some studies provided laboratory familiarization before home use: 1 session (43), a brief 2- or 3-day orientation (21), and 10 sessions (36). Familiarization directly at home was also prescribed: 1 session (29) and 2 sessions (43). Other studies established an initial visit for training purposes (27, 30). These sessions equipped participants with the skills to continue the programme safely and independently at home.

Other means were established to carry out the intervention. One study supplied an instruction manual at the beginning (frequently asked questions and tips) (27), whereas another used a transfer package in each session including different forms to emphasize patient safety, monitor home practice, improve handling and compliance, and provide a forum for patient-centred goal-setting and problem-solving (25). This allows for self-care before calling in the therapists.

However, remote assistance was necessary in most of the studies for which it was made available. Technical issues were expected during studies with this type of technology. Some systems can be used as remotely monitored telerehabilitation; for example, some studies used only telephone calls while others used videoconferencing, education videos, web-based chats, or virtual reality systems (48). Clinicians can propose appropriate responses by adapting and personalizing the planned rehabilitation activities and offering technical assistance when needed. It is important to verify whether the use of telerehabilitation systems can improve patient engagement by conducting their rehabilitation training at home in a safe environment.

Four studies supervised the interventions by combining home visits and remote support via phone calls (27, 29, 30, 43), whereas 1 study relied only on home visits (32). Two studies used videoconferencing and remote support (26, 35) and 1 study scheduled remote appointments using the remote therapist-patient systems and telephone support (21). Remote access to data on participants' playing performance can be used to verify compliance with the protocol (29). It can be a way to automatically inform the researcher if the data has not been uploaded for three consecutive days (29). The first home visits included a time dedicated to installation and explanations with patients and possibly caregivers. Some studies did not offer supervision (34, 36, 49).

Furthermore, some authors requested patient feedback. Participants in the study by Chen et al. (26) specified having received support following minor technical issues. Participants and caregivers in the study by Wingham et al. (28) said they felt reassured and supported by the weekly phone call, but also appreciated the social connection.

Dodakian et al. (35) measured the assistance given by phone during the study. The authors supposed that the decrease in assistance required over time might be due to patient familiarity with the system and improved performance of the study team.

Videoconferencing allowed therapists to observe patient performance, answer questions, review the treatment plan, and, on select days, perform brief study assessments (26). In the same study, daily 30-min half-therapy sessions were supervised by videoconference, followed by 40 min during which the patient was alone. Dodakian et al. (2017) proposed 3 videoconferences per week, focusing on the prior week's activities, followed by a structured interview including specific inquiries on pain, adverse events, and the telerehabilitation system performance. The authors explained that providing feedback and encouragement could increase motivation, according to the standard of care (35). Johnson et al. (2011) described simple encouragement provided through video and audio feedback via a robot assistant (31). In addition to the aspects of communication with the user and monitoring of progress, it could also allow for remote monitoring of the the user's position when using the device (49).

Fluet et al. (30) described modest motivational enhancements and discussed areas for increasing the training time per session. One suggestion was that supervision in the form of email and text message reminders of weekly tasks could increase the number of training sessions.

It is important to make the games interesting and stimulating to increase the use of the device (49). Integration of the multi-player mode within a game-based task could also be a factor in increasing compliance (21, 49).

DISCUSSION

Compliance behaviour is complex, requiring an analysis based on theoretical models. Over the years, specific theoretical models for studying compliance have been described. In the Health Belief Model (HBM), compliance is determined by the knowledge and attitudes of the patient (50). There are 4 essential areas in the development of compliant behaviour: perceived susceptibility; perceived severity; perceived benefits; and perceived barriers. More recent forms of the HBM emphasized 2 other factors in the decision to engage in a behaviour: *(i)* self-efficacy, which is the patient's belief that he or she is capable of taking the recommended action; and *(ii)* action cues, which are aids that teach or remind the patient of the recommended action (51). Designing a novel technology for stroke patients involves a deep understanding of the persons who use the system and perform the activity, and the context in which that activity takes place. User expectations and needs must be understood, as must their motivations, and previous experiences (52). The context of use is also a key element to explore at this pre-implementation stage and to evaluate at the post-implementation stage. The architectural, material, and human environment must be considered with regard to use of the system in the patient's home. Evaluating user experience with interactions and the use of the system is relevant to obtain patient reactions in post-task

Table II. Summary of the current literature on compliance

Topics	Definitions	Major findings
Game-based systems in home settings	Exergaming: the integration of physical activity into a video game environment that requires active body movements to control the game	Most researchers used an off-the-shelf system (i.e. commercial system) as a primary tool with added elements or games adapted to neuro-rehabilitation
Home exercise regimen	Amount, intensity, distribution, or duration of treatment recommended by therapists	Variability in current prescriptions. 30 min per day is considered sub-therapeutic. Recommended to plan 1–2 h per day of task time and to assess repetitions and intensity accurately
Training compliance rate	Ratio between quantity of training completed by the patient and quantity previously prescribed by the therapist	Patients generally follow the prescription and some even go further by continuing to train if allowed. There is no group effect on compliance (it may be greater for the experimental group than the control group, or vice versa)
Attrition rate	Drop-out: percentage of subjects failing to complete a study Discontinued intervention: percentage of sessions failing to complete	High attrition rate for the home-based setting, although the drop-out rate was higher for the experimental group than for the control group The rate of discontinuation of intervention is lower for the multi-user (MU) mode than the single-user (SU) mode
Compliance barriers	Causes of non-compliance	Internal factors: no interest, pain, fatigue, severe aphasia, seizure, illness, death External factors: family issues, ill family member, holidays, timetable Technical adverse events: hardware, software, communication reliability causing storage data problems, home environment, unsuitability to use with spastic hands, time constraints
Compliance facilitators	Options for promoting exercise compliance	Explanations given by the therapist before the intervention Familiarization stage Notices/instructions available Remote or in-person assistance Remote or in-person monitoring Forum for patient-centred goal-setting and problem-solving Logbooks and diaries Multi-player mode

interview questions (53), and in particular, in terms of compliance with use and engagement.

Most researchers used an off-the-shelf system (i.e. a commercial system) as a primary tool and combined it with elements or games adapted to neuro-rehabilitation. According to Tamayo-Serrano et al. (2018), low-cost solutions are expected to promote the adoption of in-home rehabilitation systems by patients and health organizations (54). To be able to assess cost-effectiveness, quantified cost and time data must be considered. For example, Lloréns et al. (55) reported the cost of telerehabilitation and in-clinic programmes. Costs were reported in terms of human resources (time spent on assistance and guidance during the intervention, progress monitoring, and troubleshooting), round trips to the neurorehabilitation unit, and instrumentation (laptop, Kinect™, and internet access) (55). The cost of the clinical instrumentation was not considered, but this would have provided additional information for comparison. More transparency on the costs incurred would be useful for future studies. Table II summarizes the current literature on compliance.

CONCLUSION AND PERSPECTIVES

This narrative review identified current practices for user involvement in the development of stroke-patient decisions on home-based gaming technology. This review studied compliance with technologies adapted to post-stroke rehabilitation. The literature on the subject is recent. Heterogeneity is found on the type of technologies, the intervention regime, and the supervision, making it difficult to draw conclusions on compliance. More robust studies are needed to provide additional data.

In general, home-based gaming therapies are well received by patients and no significant problems occur. Additional experimental studies are required to understand which determinants, intrinsic to devices, impact the user's compliance. Further research into the conditions for the personalized specification of the technological devices, developed in co-construction with the user, would be useful. Current studies focus on short-term evaluations; however, a long-term view is necessary to assess user compliance for high-ecological validity. Future studies should investigate how emerging technologies enable long-term use and the transfer of the acquired knowledge to everyday life, and should identify resources and assess the suitability of the system's settings based on the best situation for home use.

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Authors' declaration of authorship contribution

All those designated as authors meet the International Committee of Medical Journal Editors (ICMJE) requirements for authorship.

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Conflicts of interest

The authors have no conflicts of interest to declare.

REFERENCES

1. Cramer SC, Dodakian L, Le V, See J, Augsburger R, McKenzie A, et al. Efficacy of home-based telerehabilitation vs in-clinic therapy for adults after stroke: a randomized clinical trial. JAMA Neurol 2019; 76: 1079. DOI: 10.1001/jamaneurol.2019.1604.
2. Richmond T, Peterson C, Cason J, Billings M, Terrell EA, Lee ACW, et al. American Telemedicine Association's principles for delivering telerehabilitation services. Int J Telerehab 2017; 9: 63–68. DOI: 10.5195/ijt.2017.6232.
3. Chang MC, Boudier-Revéret M. Usefulness of Telerehabilitation for Stroke Patients During the COVID-19 Pandemic. Am J Phys Med Rehabil 2020; 99(7): 582. DOI: 10.1097/PHM.0000000000001468.
4. Feigin VL, Stark BA, Johnson CO, Roth GA, Bisignano C, Abady GG, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol 2021; 20: 795–820. DOI: 10.1016/S1474-4422(21)00252-0.
5. Johansson T, Wild C. Telerehabilitation in stroke care – a systematic review. J Telemed Telecare 2011; 17: 1–6. DOI:10.1258/jtt.2010.100105.
6. Mayo NE, Wood-Dauphinee S, Côté R, Durcan L, Carlton J. Activity, participation, and quality of life 6 months poststroke. Arch Phys Med Rehabil 2002; 83: 1035–1042. DOI: 10.1053/apmr.2002.33984.
7. Perrochon A, Borel B, Istrate D, Compagnat M, Daviet J-C. Exercise-based games interventions at home in individuals with a neurological disease: a systematic review and meta-analysis. Ann Phys Rehabil Med 2019; 62: 366–378. DOI: 10.1016/j.rehab.2019.04.004.
8. Haynes RB, Taylor DW, Sackett DL. Compliance in health care. Baltimore, MD: Johns Hopkins University Press, 1979. 516 p.
9. The Free Dictionary [Internet]. "exercise compliance". Medical Dictionary for the Health Professions and Nursing, Farlex, 2012 [cited 24 Aug. 2022]. Available from: https://medical-dictionary.thefreedictionary.com/exercise+compliance
10. Fawcett J. Thoughts about meanings of compliance, adherence, and concordance. Nurs Sci Q 2020; 33: 358–360. DOI: 10.1177/0894318420943136.
11. Rhodes RE, de Bruijn G-J. How big is the physical activity intention-behaviour gap? A meta-analysis using the action control framework. Br J Health Psychol 2013; 18: 296–309. DOI: 10.1111/bjhp.12032.
12. Jurkiewicz MT, Marzolini S, Oh P. Adherence to a home-based exercise program for individuals after stroke. Top Stroke Rehabil 2011; 18: 277–284. DOI: 10.1310/tsr1803-277.
13. Bernhardt J, Hayward KS, Dancause N, Lannin NA, Ward NS, Nudo RJ, et al. A Stroke Recovery Trial Development Framework: consensus-based core recommendations from the second stroke recovery and rehabilitation roundtable. Neurorehabil Neural Repair 2019: 11. DOI: 10.1177/1747493019879657.
14. Mat Rosly M, Mat Rosly H, Davis OAM GM, Husain R, Hasnan N. Exergaming for individuals with neurological disability: a systematic review. Disabil Rehabil 2017; 39: 727–735. DOI: 10.3109/09638288.2016.1161086.
15. Alankus G. Motion-Based Video Games for Stroke Rehabilitation with Reduced Compensatory Motions 2011. All Theses and Dissertations (ETDs). 547. DOI: 10.7936/K7ZG6Q9R.
16. Fan W. An interactive motion-tracking system for home-based assessing and training reach-to-target tasks in stroke survivors – a preliminary study. Med Biol Eng Comput 2020: 19. DOI: 10.1007/s11517-020-02173-1.
17. Henderson A, Korner-Bitensky N, Levin M. Virtual reality in stroke rehabilitation: a systematic review of its effectiveness for upper limb motor recovery. Top Stroke Rehabil 2007; 14: 52–61. DOI: 10.1310/tsr1402-52.
18. Maier M, Rubio Ballester B, Duff A, Duarte Oller E, Verschure PFMJ. Effect of specific over nonspecific vr-based rehabilitation on poststroke motor recovery: a systematic meta-analysis. Neurorehabil Neural Repair 2019; 33: 112–129. DOI: 10.1177/1545968318820169.
19. Piron L, Turolla A, Tonin P, Piccione F, Lain L, Dam M. Satisfaction with care in post-stroke patients undergoing a telerehabilitation programme at home. J Telemed Telecare 2008; 14: 257–260. DOI: 10.1258/jtt.2008.080304.
20. Cameirão MS, Smailagic A, Miao G, Siewiorek DP. Coaching or gaming? Implications of strategy choice for home based stroke rehabilitation. J Neuroeng Rehabil 2016; 13: 1–15. DOI: 10.1186/s12984-016-0127-8.
21. Thielbar KO, Triandafilou KM, Barry AJ, Yuan N, Nishimoto A, Johnson J, et al. Home-based upper extremity stroke therapy using a multiuser virtual reality environment: a randomized trial. Arch Phys Med Rehabil 2020; 101: 196–203. DOI: 10.1016/j.apmr.2019.10.182.
22. Lin S, Mann J, Mansfield A, Wang RH, Harris JE, Taati B. Investigating the feasibility and acceptability of real-time visual feedback in reducing compensatory motions during self-administered stroke rehabilitation exercises: a pilot study with chronic stroke survivors. J Rehabil Assist Technol Eng 2019; 6: 1–16. DOI: 10.1177/2055668319831631.
23. Triandafilou KM, Tsoupikova D, Barry AJ, Thielbar KN, Stoykov N, Kamper DG. Development of a 3D, networked multi-user virtual reality environment for home therapy after stroke. J Neuroeng Rehabil 2018; 15: 2–13. DOI: 10.1186/s12984-018-0429-0.
24. Seo NJ, Arun Kumar J, Hur P, Crocher V, Motawar B, Lakshminarayanan K. Usability evaluation of low-cost virtual reality hand and arm rehabilitation games. J Rehabil Res Dev 2016; 53: 321–334. DOI: 10.1682/JRRD.2015.03.0045.
25. McNulty P, Thompson-Butel A, Faux S, Lin G, Katrak P, Harris L, et al. The efficacy of Wii-based movement therapy for upper limb rehabilitation in the chronic poststroke period: a randomized controlled trial. Int J Stroke 2015; 10: 1253–1260. DOI: 10.1111/ijs.12594.
26. Chen Y, Chen Y, Zheng K, Dodakian L, See J, Zhou R, et al. A qualitative study on user acceptance of a home-based stroke telerehabilitation system. Top Stroke Rehabil 2019; 27: 81–92. DOI: 10.1080/10749357.2019.1683792.
27. Standen PJ, Threapleton K, Connell L, Richardson A, Brown DJ, Battersby S, et al. Patients' use of a home-based virtual reality system to provide rehabilitation of the upper limb following stroke. Phys Ther 2015; 95: 350–359. DOI: 10.2522/ptj.20130564.

28. Wingham J, Adie K, Turner D, Schofield C, Pritchard C. Participant and caregiver experience of the Nintendo Wii SportsTM after stroke: qualitative study of the trial of WiiTM in stroke (TWIST). Clin Rehabil 2015; 29: 295–305. DOI: 10.1177/0269215514542638.
29. Burdea GC, Grampurohit N, Kim N, Polistico K, Kadaru A, Pollack S, et al. Feasibility of integrative games and novel therapeutic game controller for telerehabilitation of individuals chronic post-stroke living in the community. Top Stroke Rehabil 2020; 27: 321–336. DOI: 10.1080/10749357.2019.1701178.
30. Fluet GG, Qiu Q, Patel J, Cronce A, Merians AS, Adamovich SV. Autonomous use of the home virtual rehabilitation system: a feasibility and pilot study. Games Health J 2019; 8: 432–438. DOI: 10.1089/g4h.2019.0012.
31. Johnson MJ, Shakya Y, Strachota E, Ahamed SI. Low-cost monitoring of patients during unsupervised robot/computer assisted motivating stroke rehabilitation. Biomed Tech (Berl) 2011; 56: 5–9. DOI: 10.1515/BMT.2010.050.
32. Nijenhuis SM, Prange-Lasonder GB, Stienen AHA, Rietman JS, Buurke JH. Effects of training with a passive hand orthosis and games at home in chronic stroke: a pilot randomised controlled trial. Clin Rehabil 2017; 31: 207–216. DOI: 10.1177/0269215516629722.
33. Radder B, Prange-Lasonder G, Kottink AIR, Melendez-Calderon A, Buurke JH, Rietman JS. Feasibility of a wearable soft-robotic glove to support impaired hand function in stroke patients. J Rehabil Med 2018; 50: 598–606. DOI: 10.2340/16501977-2357.
34. Wittmann F, Held JP, Lambercy O, Starkey ML, Curt A, Höver R, et al. Self-directed arm therapy at home after stroke with a sensor-based virtual reality training system. J Neuroeng Rehabil 2016; 13: 1–10. DOI: 10.1186/s12984-016-0182-1.
35. Dodakian L, McKenzie AL, Le V, See J, Pearson-Fuhrhop K, Burke Quinlan E, et al. A home-based telerehabilitation program for patients with stroke. Neurorehabil Neural Repair 2017; 31: 923–933. DOI: 10.1177/1545968317733818.
36. King M, Hijmans JM, Sampson M, Satherley J, Hale L. Home-based stroke rehabilitation using computer gaming. NZ J Physiother 2012; 40: 128–134.
37. Vourvopoulos A, Marin-Pardo O, Neureither M, Saldana D, Jahng E, Liew S-L. Multimodal head-mounted virtual-reality brain-computer interface for stroke rehabilitation: a clinical case study with REINVENT. In: Chen JYC, Fragomeni G, editors. Virtual, augmented and mixed reality. Multimodal Interaction, vol. 11574, Cham: Springer International Publishing; 2019, p. 165–179. DOI: 10.1007/978-3-030-21607-8_13.
38. Wiemeyer J, Deutsch J, Malone LA, Rowland JL, Swartz MC, Xiong J, et al. Recommendations for the optimal design of exergame interventions for persons with disabilities: challenges, best practices, and future research. Games Health J 2015; 4: 58–62. DOI: 10.1089/g4h.2014.0078.
39. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. Lancet Neurol 2009; 8: 741–754. DOI: 10.1016/S1474-4422(09)70150-4.
40. Han C, Wang Q, Meng P, Qi M. Effects of intensity of arm training on hemiplegic upper extremity motor recovery in stroke patients: a randomized controlled trial. Clin Rehabil 2013; 27: 75–81. DOI: 10.1177/0269215512447223.
41. Kwakkel G, van Peppen R, Wagenaar RC, Wood Dauphinee S, Richards C, Ashburn A, et al. Effects of Augmented exercise therapy time after stroke: a meta-analysis. Stroke 2004; 35: 2529–2539. DOI: 10.1161/01.STR.0000143153.76460.7d.
42. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2016; 47. DOI: 10.1161/STR.0000000000000098.
43. Brokaw EB, Eckel E, Brewer BR. Usability evaluation of a kinematics focused Kinect therapy program for individuals with stroke. Technol Health Care 2015; 23: 143–151. DOI: 10.3233/THC-140880.
44. Wolf SL, Winstein CJ, Miller JP, Taub E, Uswatte G, Morris D, et al. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. JAMA 2006; 296: 2095. DOI: 10.1001/jama.296.17.2095.
45. Eysenbach G. The law of attrition. J Med Internet Res 2005; 7: e11. DOI: 10.2196/jmir.7.1.e11.
46. Hong QN, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, et al. The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. Education for Information 2018; 34: 285–291. DOI: 10.3233/EFI-180221.
47. Ong CW, Lee EB, Twohig MP. A meta-analysis of dropout rates in acceptance and commitment therapy. Behav Res Ther 2018; 104: 14–33. DOI: 10.1016/j.brat.2018.02.004.
48. Tchero H, Tabue Teguo M, Lannuzel A, Rusch E. Telerehabilitation for stroke survivors: systematic review and meta-analysis. J Med Internet Res 2018; 20: e10867. DOI: 10.2196/10867.
49. Sivan M, Gallagher J, Holt R, Weightman A, O'Connor R, Levesley M. Employing the International Classification of Functioning, Disability and Health framework to capture user feedback in the design and testing stage of development of home-based arm rehabilitation technology. Assist Technol 2016; 28: 175–82. DOI: 10.1080/10400435.2016.1140689.
50. Rosenstock IM. Historical origins of the health belief model. Health Educ Monogr 1974; 2: 328–335. DOI: 10.1177/109019817400200403.
51. Redding CA, Rossi JS, Rossi SR, Velicer WF, Prochaska JO. Health behavior models. Int Electron J Health Educ 2000; 3 (Special Issue): 180–193.
52. Prigatano GP. The importance of the patient's subjective experience in stroke rehabilitation. Top Stroke Rehabil 2011; 18: 30–34. DOI: 10.1310/tsr1801-30.
53. Rubin J, Chisnell D. Handbook of usability testing: how to plan, design, and conduct effective tests. 2nd edn. Indianapolis, IN: Wiley Pub; 2008.
54. Tamayo-Serrano P, Garbaya S, Blazevic P. Gamified in-home rehabilitation for stroke survivors: analytical review. Int J Serious Games 2018; 5. DOI: 10.17083/ijsg.v5i1.224.
55. Lloréns R, Noé E, Colomer C, Alcañiz M. Effectiveness, usability, and cost-benefit of a virtual reality–based telerehabilitation program for balance recovery after stroke: a randomized controlled trial. Arch Phys Med Rehabil 2015; 96: 418-425. DOI: 10.1016/j.apmr.2014.10.019.